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Object-Oriented Programming
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Using Object-Oriented Design in MATLAB

- “Why Use Object-Oriented Design” on page 1-2
- “Handle Object Behavior” on page 1-7
Why Use Object-Oriented Design

In this section...

“Approaches to Writing MATLAB Programs” on page 1-2
“When Should You Create Object-Oriented Programs” on page 1-2

Approaches to Writing MATLAB Programs

Creating software applications typically involves designing the application data and implementing operations performed on that data. Procedural programs pass data to functions, which perform the necessary operations on the data. Object-oriented software encapsulates data and operations in objects that interact with each other via the object's interface.

The MATLAB language enables you to create programs using both procedural and object-oriented techniques and to use objects and ordinary functions together in your programs.

Procedural Program Design

In procedural programming, your design focuses on the steps that must execute to achieve a desired state. Typically, you represent data as individual variables or fields of a structure. You implement operations as functions that take the variables as arguments. Programs usually call a sequence of functions, each one of which is passed data, and then returns modified data. Each function performs an operation or many operations on the data.

Object-Oriented Program Design

The object-oriented program design involves:

- Identifying the components of the system or application that you want to build
- Analyzing and identifying patterns to determine what components are used repeatedly or share characteristics
- Classifying components based on similarities and differences

After performing this analysis, you define classes that describe the objects your application uses.

Classes and Objects

A class describes a set of objects with common characteristics. Objects are specific instances of a class. The values contained in an object’s properties are what make an object different from other objects of the same class. The functions defined by the class (called methods) are what implement object behaviors that are common to all objects of a class.

When Should You Create Object-Oriented Programs

You can implement simple programming tasks as simple functions. However, as the magnitude and complexity of your tasks increase, functions become more complex and difficult to manage.

As functions become too large, you can break them into smaller functions and pass data from one to function to another. However, as the number of functions becomes large, designing, and managing the data passed to functions becomes difficult and error prone. At this point, consider moving your MATLAB programming tasks to object-oriented designs.
Understand a Problem in Terms of Its Objects

Thinking in terms of objects is simpler and more natural for some problems. Think of the nouns in your problem statement as the objects to define and the verbs as the operations to perform.

Consider the design of classes to represent money lending institutions (banks, mortgage companies, individual money lenders, and so on). It is difficult to represent the various types of lenders as procedures. However, you can represent each one as an object that performs certain actions and contains certain data. The process of designing the objects involves identifying the characteristics of a lender that are important to your application.

Identify Commonalities

What do all money lenders have in common? All MoneyLender objects can have a loan method and an InterestRate property, for example.

Identify Differences

How does each money lender differ? One can provide loans to businesses while another provides loans only to individuals. Therefore, the loan operation might need to be different for different types of lending institutions. Subclasses of a base MoneyLender class can specialize the subclass versions of the loan method. Each lender can have a different value for its InterestRate property.

Factor out commonalities into a superclass and implement what is specific to each type of lender in the subclass.

Add Only What Is Necessary

These institutions might engage in activities that are not of interest to your application. During the design phase, determine what operations and data an object must contain based on your problem definition.

Objects Manage Internal State

Objects provide several useful features not available from structures and cell arrays. For example, objects can:

• Constrain the data values assigned to any given property
• Calculate the value of a property only when it is queried
• Broadcast notices when any property value is queried or changed
• Restrict access to properties and methods

Reducing Redundancy

As the complexity of your program increases, the benefits of an object-oriented design become more apparent. For example, suppose that you implement the following procedure as part of your application:

1. Check inputs
2. Perform computation on the first input argument
3. Transform the result of step 2 based on the second input argument
4. Check validity of outputs and return values

You can implement this procedure as an ordinary function. But suppose that you use this procedure again somewhere in your application, except that step 2 must perform a different computation. You
could copy and paste the first implementation, and then rewrite step 2. Or you could create a function that accepted an option indicating which computation to make, and so on. However, these options lead to more complicated code.

An object-oriented design can factor out the common code into what is called a base class. The base class would define the algorithm used and implement whatever is common to all cases that use this code. Step 2 could be defined syntactically, but not implemented, leaving the specialized implementation to the classes that you then derive from this base class.

Step 1
function checkInputs()
    % actual implementation
end

Step 2
function results = computeOnFirstArg()
    % specify syntax only
end

Step 3
function transformResults()
    % actual implementation
end

Step 4
function out = checkOutputs()
    % actual implementation
end

The code in the base class is not copied or modified. Classes you derive from the base class inherit this code. Inheritance reduces the amount of code to be tested, and isolates your program from changes to the basic procedure.

**Defining Consistent Interfaces**

The use of a class as the basis for similar, but more specialized classes is a useful technique in object-oriented programming. This class defines a common interface. Incorporating this kind of class into your program design enables you to:

- Identify the requirements of a particular objective
- Encode requirements into your program as an interface class

**Reducing Complexity**

Objects reduce complexity by reducing what you must know to use a component or system:

- Objects provide an interface that hides implementation details.
- Objects enforce rules that control how objects interact.

To illustrate these advantages, consider the implementation of a data structure called a doubly linked list. See “Implementing Linked Lists with Classes” on page 3-23 for the actual implementation.

Here is a diagram of a three-element list:
To add a node to the list, disconnect the existing nodes in the list, insert the new node, and reconnect the nodes appropriately. Here are the basic steps:

First disconnect the nodes:

1. Unlink \( n2.\text{Prev} \) from \( n1 \)
2. Unlink \( n1.\text{Next} \) from \( n2 \)

Now create the new node, connect it, and renumber the original nodes:

1. Link \( \text{new}.\text{Prev} \) to \( n1 \)
2. Link \( \text{new}.\text{Next} \) to \( n3 \) (was \( n2 \))
3. Link \( n1.\text{Next} \) to \( \text{new} \) (will be \( n2 \))
4. Link \( n3.\text{Prev} \) to \( \text{new} \) (will be \( n2 \))

The details of how methods perform these steps are encapsulated in the class design. Each node object contains the functionality to insert itself into or remove itself from the list.

For example, in this class, every node object has an `insertAfter` method. To add a node to a list, create the node object and then call its `insertAfter` method:

```python
nnew = NodeConstructor;
nnew.insertAfter(n1)
```

Because the node class defines the code that implements these operations, this code is:

- Implemented in an optimal way by the class author
- Always up to date with the current version of the class
- Properly tested
- Can automatically update old-versions of the objects when they are loaded from MAT-files.

The object methods enforce the rules for how the nodes interact. This design removes the responsibility for enforcing rules from the applications that use the objects. It also means that the application is less likely to generate errors in its own implementation of the process.
Fostering Modularity

As you decompose a system into objects (car -> engine -> fuel system -> oxygen sensor), you form modules around natural boundaries. Classes provide three levels of control over code modularity:

- Public — Any code can access this particular property or call this method.
- Protected — Only this object's methods and methods of objects derived from this object's class can access this property or call this method.
- Private — Only the object's own methods can access this property or call this method.

Overloaded Functions and Operators

When you define a class, you can overload existing MATLAB functions to work with your new object. For example, the MATLAB serial port class overloads the `fread` function to read data from the device connected to the port represented by this object. You can define various operations, such as equality (`eq`) or addition (`plus`), for a class you have defined to represent your data.

See Also

More About

- “Role of Classes in MATLAB“ on page 3-2
More than one variable can refer to the same handle object. Therefore, users interact with instances of handle classes differently than instances of value classes. Understanding how handle objects behave can help you determine whether to implement a handle or a value class. This topic illustrates some of those interactions.

For more information on handle classes, see “Handle Classes”.

**What Is a Handle?**

Certain kinds of MATLAB objects are handles. When a variable holds a handle, it actually holds a reference to the object.

Handle objects enable more than one variable to refer to the same object. Handle-object behavior affects what happens when you copy handle objects and when you pass them to functions.

**Copies of Handles**

All copies of a handle object variable refer to the same underlying object. This reference behavior means that if \( h \) identifies a handle object, then,

\[ h2 = h; \]

Creates another variable, \( h2 \), that refers to the same object as \( h \).

For example, the MATLAB `audioplayer` function creates a handle object that contains the audio source data to reproduce a specific sound segment. The variable returned by the `audioplayer` function identifies the audio data and enables you to access object functions to play the audio.

MATLAB software includes audio data that you can load and use to create an `audioplayer` object. This sample load audio data, creates the audio player, and plays the audio:

```matlab
load gong Fs y
gongSound = audioplayer(y,Fs);
play(gongSound)
```

Suppose that you copy the `gongSound` object handle to another variable (`gongSound2`):

```matlab
gongSound2 = gongSound;
```

The variables `gongSound` and `gongSound2` are copies of the same handle and, therefore, refer to the same audio source. Access the `audioplayer` information using either variable.
For example, set the sample rate for the gong audio source by assigning a new value to the `SampleRate` property. First get the current sample rate and then set a new sample rate:

```matlab
sr = gongSound.SampleRate;
disp(sr)
8192
```

```matlab
gongSound.SampleRate = sr*2;
```

You can use `gongSound2` to access the same audio source:

```matlab
disp(gongSound2.SampleRate)
16384
```

Play the gong sound with the new sample rate:

```matlab
play(gongSound2)
```

### Handle Objects Modified in Functions

When you pass an argument to a function, the function copies the variable from the workspace in which you call the function into the parameter variable in the function’s workspace.

Passing a nonhandle variable to a function does not affect the original variable that is in the caller’s workspace. For example, `myFunc` modifies a local variable called `var`, but when the function ends, the local variable `var` no longer exists:

```matlab
function myFunc(var)
    var = var + 1;
end
```

Define a variable and pass it to `myfunc`:

```matlab
x = 12;
myFunc(x)
```

The value of `x` has not changed after executing `myFunc(x)`:  

```matlab
disp(x)
12
```

The `myFunc` function can return the modified value, which you could assign to the same variable name (`x`) or another variable.

```matlab
function out = myFunc(var)
    out = var + 1;
end
```

Modify a value in `myfunc`:

```matlab
x = 12;
x = myFunc(x);
disp(x)
13
```
When the argument is a handle variable, the function copies only the handle, not the object identified by that handle. Both handles (original and local copy) refer to the same object.

When the function modifies the data referred to by the object handle, those changes are accessible from the handle variable in the calling workspace without the need to return the modified object.

For example, the `modifySampleRate` function changes the `audioplayer` sample rate:

```matlab
function modifySampleRate(audioObj,sr)
    audioObj.SampleRate = sr;
end
```

Create an `audioplayer` object and pass it to the `modifySampleRate` function:

```matlab
load gong Fs y
gongSound = audioplayer(y,Fs);
disp(gongSound.SampleRate)
8192
modifySampleRate(gongSound,16384)
disp(gongSound.SampleRate)
16384
```

The `modifySampleRate` function does not need to return a modified `gongSound` object because `audioplayer` objects are handle objects.

### Determine If an Object Is a Handle

Handle objects are members of the `handle` class. Therefore, you can always identify an object as a handle using the `isa` function. `isa` returns logical `true` (1) when testing for a handle variable:

```matlab
load gong Fs y
gongSound = audioplayer(y,Fs);
isa(gongSound,'handle')
```

To determine if a variable is a valid handle object, use `isa` and `isvalid`:

```matlab
if isa(gongSound,'handle') && isvalid(gongSound)
    ...
end
```

### Deleted Handle Objects

When a handle object has been deleted, the handle variables that referenced the object can still exist. These variables become invalid because the object they referred to no longer exists. Calling `delete` on the object removes the object, but does not clear handle variables.

For example, create an `audioplayer` object:

```matlab
load gong Fs y
gongSound = audioplayer(y,Fs);
```

The output argument, `gongSound`, is a handle variable. Calling `delete` deletes the object along with the audio source information it contains:
delete(gongSound)

However, the handle variable still exists:

disp(gongSound)

handle to deleted audioplayer

The `whos` command shows `gongSound` as an `audioplayer` object:

```
whos

    Name       Size             Bytes  Class          Attributes
    ---------  -----------  --------  -----------  ---------------
    Fs        1x1          8        double
    gongSound 1x1          0        audioplayer
    y         42028x1      336224   double
```

**Note** The value for Bytes returned by the `whos` command does not include the data referenced by a handle because many variables can reference the same data.

The handle `gongSound` no longer refers to a valid object, as shown by the `isvalid` handle method:

```
isvalid(gongSound)

ans =
    logical
        0
```

Calling `delete` on a deleted handle does nothing and does not cause an error. You can pass an array containing both valid and invalid handles to `delete`. MATLAB deletes the valid handles, but does not issue an error when encountering handles that are already invalid.

You cannot access properties with the invalid handle variable:

```
gongSound.SampleRate

Invalid or deleted object.
```

Functions and methods that access object properties cause an error:

```
play(gongSound)

Invalid or deleted object.
```

To remove the variable, `gongSound`, use `clear`:

```
clear gongSound

whos

    Name       Size             Bytes  Class          Attributes
    ---------  -----------  --------  -----------  ---------------
    Fs        1x1          8        double
    y         42028x1      336224   double
```
See Also

More About

- “Handle Class Destructor” on page 7-13
- “Comparison of Handle and Value Classes” on page 7-2
Basic Example
Create a Simple Class

In this section...

“Design Class” on page 2-2
“Create Object” on page 2-3
“Access Properties” on page 2-3
“Call Methods” on page 2-3
“Add Constructor” on page 2-4
“Vectorize Methods” on page 2-4
“Overload Functions” on page 2-5
“BasicClass Code Listing” on page 2-6

Design Class

The basic purpose of a class is to define an object that encapsulates data and the operations performed on that data. For example, BasicClass defines a property and two methods that operate on the data in that property:

- **Value** — Property that contains the numeric data stored in an object of the class
- **roundOff** — Method that rounds the value of the property to two decimal places
- **multiplyBy** — Method that multiplies the value of the property by the specified number

Here is the definition of BasicClass:

```matlab
classdef BasicClass
    properties
        Value {mustBeNumeric}
    end
    methods
        function r = roundOff(obj)
            r = round([obj.Value],2);
        end
        function r = multiplyBy(obj,n)
            r = [obj.Value] * n;
        end
    end
end
```

For a summary of class syntax, see classdef.

To use the class:

- Save the class definition in a .m file with the same name as the class.
- Create an object of the class.
- Access the properties to assign data.
- Call methods to perform operation on the data.
Create Object

Create an object of the class using the class name:

\[ a = \text{BasicClass} \]

\[ a = \]

BasicClass with properties:

Value: []

Initially, the property value is empty.

Access Properties

Assign a value to the Value property using the object variable and a dot before the property name:

\[ a.\text{Value} = \pi/3; \]

To return a property value, use dot notation without the assignment:

\[ a.\text{Value} \]

\[ \text{ans} = \]

1.0472

For information on class properties, see “Class Properties” on page 5-10.

Call Methods

Call the roundOff method on object \( a \):

\[ \text{roundOff}(a) \]

\[ \text{ans} = \]

1.0500

Pass the object as the first argument to a method that takes multiple arguments, as in this call to the multiplyBy method:

\[ \text{multiplyBy}(a,3) \]

\[ \text{ans} = \]

3.1416

You can also call a method using dot notation:

\[ a.\text{multiplyBy}(3) \]

It is not necessary to pass the object explicitly as an argument when using dot notation. The notation uses the object to the left of the dot and method name.

For information on class methods, see “Methods and Functions” on page 5-13.
Add Constructor

Classes can define a special method to create objects of the class, called a constructor. Constructor methods enable you to pass arguments to the constructor, which you can assign as property values. The BasicClass Value property restricts its possible values using the mustBeNumeric function.

Here is a constructor for the BasicClass class. When you call the constructor with an input argument, it is assigned to the Value property. If you call the constructor without an input argument, the Value property has a default value of empty ([ ]).

```matlab
methods
    function obj = BasicClass(val)
        if nargin == 1
            obj.Value = val;
        end
    end
end
```

By adding this constructor to the class definition, you can create an object and set the property value in one step:

```matlab
a = BasicClass(pi/3)
a =
    BasicClass with properties:
        Value: 1.0472
```

The constructor can perform other operations related to creating objects of the class.

For information on constructors, see “Class Constructor Methods” on page 9-16

Vectorize Methods

MATLAB enables you to vectorize operations. For example, you can add a number to a vector:

```matlab
[1 2 3] + 2
ans =
    3 4 5
```

MATLAB adds the number 2 to each of the elements in the array [1 2 3]. To vectorize the arithmetic operator methods, enclose the obj.Value property reference in brackets.

```matlab
[obj.Value] + 2
```

This syntax enables the method to work with arrays of object. For example, create an object array using indexed assignment.

```matlab
obj(1) = BasicClass(2.7984);
obj(2) = BasicClass(sin(pi/3));
obj(3) = BasicClass(7);
```

Then this expression:
[obj.Value] + 2

Is equivalent to this expression:


Because the `roundOff` method is vectorized, it can operate on arrays:

```matlab
roundOff(obj)
ans =
   2.8000   0.8700   7.0000
```

### Overload Functions

Classes can implement existing functionality, such as addition, by defining a method with the same name as the existing MATLAB function. For example, suppose that you want to add two `BasicClass` objects. It makes sense to add the values of the `Value` properties of each object.

Here is an overloaded version of the MATLAB `plus` function. It defines addition for the `BasicClass` class as adding the property values:

```matlab
method
    function r = plus(o1,o2)
        r = [o1.Value] + [o2.Value];
    end
end
```

By implementing a method called `plus`, you can use the “+” operator with objects of `BasicClass`.

```matlab
a = BasicClass(pi/3);
b = BasicClass(pi/4);
a + b
ans =
   1.8326
```

By vectorizing the `plus` method, you can operate on object arrays.

```matlab
a = BasicClass(pi/3);
b = BasicClass(pi/4);
c = BasicClass(pi/2);
ar = [a b];
ar + c
ans =
   2.6180   2.3562
```

### Related Information

For information on overloading functions, see “Overload Functions in Class Definitions” on page 9-26.

For information on overloading operators, see “Operator Overloading” on page 17-38.
**BasicClass Code Listing**

Here is the BasicClass definition after adding the features discussed in this topic:

```plaintext
classdef BasicClass
     properties
       Value {mustBeNumeric}
     end
     methods
       function obj = BasicClass(val)
         if nargin == 1
           obj.Value = val;
         end
       end
       function r = roundOff(obj)
         r = round([obj.Value],2);
       end
       function r = multiplyBy(obj,n)
         r = [obj.Value] * n;
       end
       function r = plus(o1,o2)
         r = [o1.Value] + [o2.Value];
       end
     end
end
```

**See Also**

**Related Examples**

- “Class Syntax Guide”
- “Validate Property Values” on page 8-20
MATLAB Classes Overview

- “Role of Classes in MATLAB” on page 3-2
- “Developing Classes — Typical Workflow” on page 3-6
- “Representing Structured Data with Classes” on page 3-14
- “Implementing Linked Lists with Classes” on page 3-23
Role of Classes in MATLAB

Classes

In the MATLAB language, every value is assigned to a class. For example, creating a variable with an assignment statement constructs a variable of the appropriate class:

```matlab
a = 7;
b = 'some text';
s.Name = 'Nancy';
s.Age = 64;
whos
```

```
Name      Size            Bytes  Class     Attributes
a         1x1                 8  double
b         1x9                18  char
s         1x1               370  struct
```

Basic commands like `whos` display the class of each value in the workspace. This information helps MATLAB users recognize that some values are characters and display as text while other values are double precision numbers, and so on. Some variables can contain different classes of values like structures.

Predefined Classes

MATLAB defines fundamental classes that comprise the basic types used by the language. These classes include numeric, logical, char, cell, struct, and function handle.

User-Defined Classes

You can create your own MATLAB classes. For example, you could define a class to represent polynomials. This class could define the operations typically associated with MATLAB classes, like addition, subtraction, indexing, displaying in the command window, and so on. These operations would need to perform the equivalent of polynomial addition, polynomial subtraction, and so on. For example, when you add two polynomial objects:

```matlab
p1 + p2
```

the `plus` operation must be able to add polynomial objects because the polynomial class defines this operation.

When you define a class, you can overload special MATLAB functions (such as `plus.m` for the addition operator). MATLAB calls these methods when users apply those operations to objects of your class.

See “Representing Polynomials with Classes” on page 19-2 for an example that creates just such a class.
MATLAB Classes — Key Terms

MATLAB classes use the following words to describe different parts of a class definition and related concepts.

- **Class definition** — Description of what is common to every instance of a class.
- **Properties** — Data storage for class instances
- **Methods** — Special functions that implement operations that are usually performed only on instances of the class
- **Events** — Messages defined by classes and broadcast by class instances when some specific action occurs
- **Attributes** — Values that modify the behavior of properties, methods, events, and classes
- **Listeners** — Objects that respond to a specific event by executing a callback function when the event notice is broadcast
- **Objects** — Instances of classes, which contain actual data values stored in the objects' properties
- **Subclasses** — Classes that are derived from other classes and that inherit the methods, properties, and events from those classes (subclasses facilitate the reuse of code defined in the superclass from which they are derived).
- **Superclasses** — Classes that are used as a basis for the creation of more specifically defined classes (that is, subclasses).
- **Packages** — Folders that define a scope for class and function naming

Some Basic Relationships

This section discusses some of the basic concepts used by MATLAB classes.

**Classes**

A class is a definition that specifies certain characteristics that all instances of the class share. These characteristics are determined by the properties, methods, and events that define the class and the values of attributes that modify the behavior of each of these class components. Class definitions describe how objects of the class are created and destroyed, what data the objects contain, and how you can manipulate this data.

**Class Hierarchies**

It sometimes makes sense to define a new class in terms of existing classes. This approach enables you to reuse the designs and techniques in a new class that represents a similar entity. You accomplish this reuse by creating a subclass. A subclass defines objects that are a subset of those objects defined by the superclass. A subclass is more specific than its superclass and might add new properties, methods, and events to those components inherited from the superclass.

Mathematical sets can help illustrate the relationships among classes. In the following diagram, the set of Positive Integers is a subset of the set of Integers and a subset of Positives. All three sets are subsets of Reals, which is a subset of All Numbers.

The definition of Positive Integers requires the additional specification that members of the set be greater than zero. Positive Integers combine the definitions from both Integers and Positives. The resulting subset is more specific, and therefore more narrowly defined, than the supersets, but still shares all the characteristics that define the supersets.
The “is a” relationship is a good way to determine if it is appropriate to define a particular subset in terms of existing supersets. For example, each of the following statements makes sense:

- A Positive Integer is an Integer
- A Positive Integer is a Positive number

If the “is a” relationship holds, then it is likely you can define a new class from a class or classes that represent some more general case.

**Reusing Solutions**

Classes are usually organized into taxonomies to foster code reuse. For example, if you define a class to implement an interface to the serial port of a computer, it would probably be similar to a class designed to implement an interface to the parallel port. To reuse code, you could define a superclass that contains everything that is common to the two types of ports, and then derive subclasses from the superclass in which you implement only what is unique to each specific port. Then the subclasses would inherit all the common functionality from the superclass.

**Objects**

A class is like a template for the creation of a specific instance of the class. This instance or object contains actual data for a particular entity that is represented by the class. For example, an instance of a bank account class is an object that represents a specific bank account, with an actual account number and an actual balance. This object has built into it the ability to perform operations defined by the class, such as making deposits to and withdrawals from the account balance.

Objects are not just passive data containers. Objects actively manage the data contained by allowing only certain operations to be performed, by hiding data that does not need to be public, and by preventing external clients from misusing data by performing operations for which the object was not designed. Objects even control what happens when they are destroyed.
**Encapsulating Information**

An important aspect of objects is that you can write software that accesses the information stored in the object via its properties and methods without knowing anything about how that information is stored, or even whether it is stored or calculated when queried. The object isolates code that accesses the object from the internal implementation of methods and properties. You can define classes that hide both data and operations from any methods that are not part of the class. You can then implement whatever interface is most appropriate for the intended use.

**References**


**See Also**

**Related Examples**

- “Create a Simple Class” on page 2-2
- “Developing Classes — Typical Workflow” on page 3-6
- “Representing Structured Data with Classes” on page 3-14
- “Implementing Linked Lists with Classes” on page 3-23
Developing Classes — Typical Workflow

In this section...

“Formulating a Class” on page 3-6
“Specifying Class Components” on page 3-7
“BankAccount Class Implementation” on page 3-7
“Formulating the AccountManager Class” on page 3-10
“Implementing the AccountManager Class” on page 3-11
“AccountManager Class Synopsis” on page 3-11
“Using BankAccount Objects” on page 3-12

Formulating a Class

This example discusses how to approach the design and implementation of a class. The objective of this class is to represent a familiar concept (a bank account). However, you can apply the same approach to most class designs.

To design a class that represents a bank account, first determine the elements of data and the operations that form your abstraction of a bank account. For example, a bank account has:

- An account number
- An account balance
- A status (open, closed, etc.)

You must perform certain operations on a bank account:

- Create an object for each bank account
- Deposit money
- Withdraw money
- Generate a statement
- Save and load the BankAccount object

If the balance is too low and you attempt to withdraw money, the bank account broadcasts a notice. When this event occurs, the bank account broadcasts a notice to other entities that are designed to listen for these notices. In this example, a simplified version of an account manager program performs this task.

In this example, an account manager program determines the status of all bank accounts. This program monitors the account balance and assigns one of three values:

- open — Account balance is a positive value
- overdrawn — Account balance is overdrawn, but by $200 or less.
- closed — Account balance is overdrawn by more than $200.

These features define the requirements of the BankAccount and AccountManager classes. Include only what functionality is required to meet your specific objectives. Support special types of accounts by subclassing BankAccount and adding more specific features to the subclasses. Extend the AccountManager as required to support new account types.
Specifying Class Components

Classes store data in properties, implement operations with methods, and support notifications with events and listeners. Here is how the BankAccount and AccountManager classes define these components.

Class Data

The class defines these properties to store the account number, account balance, and the account status:

- **AccountNumber** — A property to store the number identifying the specific account. MATLAB assigns a value to this property when you create an instance of the class. Only BankAccount class methods can set this property. The SetAccess attribute is private.
- **AccountBalance** — A property to store the current balance of the account. The class operation of depositing and withdrawing money assigns values to this property. Only BankAccount class methods can set this property. The SetAccess attribute is private.
- **AccountStatus** — The BankAccount class defines a default value for this property. The AccountManager class methods change this value whenever the value of the AccountBalance falls below 0. The Access attribute specifies that only the AccountManager and BankAccount classes have access to this property.
- **AccountListener** — Storage for the InsufficentFunds event listener. Saving a BankAccount object does not save this property because you must recreate the listener when loading the object.

Class Operations

These methods implement the operations defined in the class formulation:

- **BankAccount** — Accepts an account number and an initial balance to create an object that represents an account.
- **deposit** — Updates the AccountBalance property when a deposit transaction occurs.
- **withdraw** — Updates the AccountBalance property when a withdrawal transaction occurs.
- **getStatement** — Displays information about the account.
- **loadobj** — Recreates the account manager listener when you load the object from a MAT-file.

Class Events

The account manager program changes the status of bank accounts that have negative balances. To implement this action, the BankAccount class triggers an event when a withdrawal results in a negative balance. Therefore, the triggering of the InsufficientFunds event occurs from within the withdraw method.

To define an event, specify a name within an events block. Trigger the event by a call to the notify handle class method. Because InsufficientFunds is not a predefined event, you can name it with any char vector and trigger it with any action.

BankAccount Class Implementation

It is important to ensure that there is only one set of data associated with any object of a BankAccount class. You would not want independent copies of the object that could have, for
example, different values for the account balance. Therefore, implement the BankAccount class as a handle class. All copies of a given handle object refer to the same data.

BankAccount Class Synopsis

<table>
<thead>
<tr>
<th>BankAccount Class</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>classdef BankAccount &lt; handle</code></td>
<td>Handle class because there should be only one copy of any instance of BankAccount.</td>
</tr>
<tr>
<td></td>
<td>“Comparison of Handle and Value Classes” on page 7-2</td>
</tr>
<tr>
<td>properties (Access = ?AccountManager)</td>
<td>AccountStatus contains the status of the account determined by the current balance. Access is limited to the BankAccount and AccountManager classes. “Class Members Access” on page 12-23</td>
</tr>
<tr>
<td>AccountStatus = 'open'</td>
<td>AccountStatus property access by AccountManager class methods.</td>
</tr>
<tr>
<td></td>
<td>AccountNumber and AccountBalance properties have private set access.</td>
</tr>
<tr>
<td></td>
<td>AccountListener property is transient so the listener handle is not saved.</td>
</tr>
<tr>
<td></td>
<td>See “Specify Property Attributes” on page 8-5.</td>
</tr>
<tr>
<td></td>
<td>Class defines event called InsufficientFunds. withdraw method triggers event when account balance becomes negative.</td>
</tr>
<tr>
<td></td>
<td>For information on events and listeners, see “Events”.</td>
</tr>
<tr>
<td>events</td>
<td>Block of ordinary methods. See “Methods and Functions” on page 5-13 for syntax.</td>
</tr>
<tr>
<td>InsufficientFunds</td>
<td>Constructor initializes property values with input arguments.</td>
</tr>
<tr>
<td></td>
<td>AccountManager.addAccount is static method of AccountManager class. Creates listener for InsufficientFunds event and stores listener handle in AccountListener property.</td>
</tr>
<tr>
<td>methods</td>
<td>deposit adjusts value of AccountBalance property.</td>
</tr>
<tr>
<td><code>function BA = BankAccount(AccountNumber,InitialBalance)</code></td>
<td>If AccountStatus is closed and subsequent deposit brings AccountBalance into positive range, then AccountStatus is reset to open.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><code>function deposit(BA,amt)</code></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
BankAccount Class

function withdraw(BA, amt)
    if strcmp(BA.AccountStatus, 'closed') && BA.AccountBalance < 0
        disp(['Account ', num2str(BA.AccountNumber), ' has been closed.'])
        return
    end
    newbal = BA.AccountBalance - amt;
    BA.AccountBalance = newbal;
    if newbal < 0
        notify(BA, 'InsufficientFunds')
    end
end

function getStatement(BA)
    disp('-------------------------')
    disp(['Account: ', num2str(BA.AccountNumber)])
    ab = sprintf('%0.2f', BA.AccountBalance);
    disp(['CurrentBalance: ', ab])
    disp(['Account Status: ', BA.AccountStatus])
    disp('-------------------------')
end

function obj = loadobj(s)
    if isstruct(s)
        accNum = s.AccountNumber;
        initBal = s.AccountBalance;
        obj = BankAccount(accNum, initBal);
    else
        obj.AccountListener = AccountManager.addAccount(s);
    end
end

function BA = BankAccount(accNum, initBal)
    BA.AccountNumber = accNum;
    BA.AccountBalance = initBal;
    BA.AccountListener = AccountManager.addAccount(BA);
end

Discusson

Updates AccountBalance property. If value of account balance is negative as a result of the withdrawal, notify triggers InsufficientFunds event.

For more information on listeners, see “Events and Listeners Syntax” on page 11-18.

Display selected information about the account.

End of ordinary methods block.

Beginning of static methods block. See “Static Methods” on page 9-24

loadobj method:

• If the load operation fails, create the object from a struct.
• Recreates the listener using the newly created BankAccount object as the source.

For more information on saving and loading objects, see “Save and Load Process for Objects” on page 13-2

End of static methods block

End of classdef

Expand for Class Code

classdef BankAccount < handle
    properties (Access = AccountManager)
        AccountStatus = 'open'
    end
    properties (SetAccess = private)
        AccountNumber
        AccountBalance
    end
    properties (Transient)
        AccountListener
    end
    events
        InsufficientFunds
    end
    methods
        function BA = BankAccount(accNum, initBal)
            BA.AccountNumber = accNum;
            BA.AccountBalance = initBal;
            BA.AccountListener = AccountManager.addAccount(BA);
        end
    end

End of classdef
function deposit(BA, amt)
    BA.AccountBalance = BA.AccountBalance + amt;
    if BA.AccountBalance > 0
        BA.AccountStatus = 'open';
    end
end

function withdraw(BA, amt)
    if (strcmp(BA.AccountStatus, 'closed') && BA.AccountBalance <= 0)
        disp(['Account ', num2str(BA.AccountNumber), ' has been closed.'])
        return
    end
    newbal = BA.AccountBalance - amt;
    BA.AccountBalance = newbal;
    if newbal < 0
        notify(BA, 'InsufficientFunds')
    end
end

function getStatement(BA)
    disp('-------------------------
    disp(['Account: ', num2str(BA.AccountNumber)]))
    ab = sprintf('%0.2f', BA.AccountBalance);
    disp(['CurrentBalance: ', ab])
    disp(['Account Status: ', BA.AccountStatus])
    disp('-------------------------')
end

methods (Static)
    function obj = loadobj(s)
        if isstruct(s)
            accNum = s.AccountNumber;
            initBal = s.AccountBalance;
            obj = BankAccount(accNum, initBal);
        else
            obj.AccountListener = AccountManager.addAccount(s);
        end
    end
end
end

### Formulating the AccountManager Class

The purpose of the AccountManager class is to provide services to accounts. For the BankAccount class, the AccountManager class listens for withdrawals that cause the balance to drop into the negative range. When the BankAccount object triggers the InsufficientFunds event, the AccountManager resets the account status.

The AccountManager class stores no data so it does not need properties. The BankAccount object stores the handle of the listener object.

The AccountManager performs two operations:

- Assign a status to each account as a result of a withdrawal
- Adds an account to the system by monitoring account balances.

### Class Components

The AccountManager class implements two methods:

- `assignStatus` — Method that assigns a status to a BankAccount object. Serves as the listener callback.
- `addAccount` — Method that creates the InsufficientFunds listener.
Implementing the AccountManager Class

The AccountManager class implements both methods as static because there is no need for an AccountManager object. These methods operate on BankAccount objects.

The AccountManager is not intended to be instantiated. Separating the functionality of the AccountManager class from the BankAccount class provides greater flexibility and extensibility. For example, doing so enables you to:

- Extend the AccountManager class to support other types of accounts while keeping the individual account classes simple and specialized.
- Change the criteria for the account status without affecting the compatibility of saved and loaded BankAccount objects.
- Develop an Account superclass that factors out what is common to all accounts without requiring each subclass to implement the account management functionality.

AccountManager Class Synopsis

<table>
<thead>
<tr>
<th>AccountManager Class</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>classdef AccountManager</td>
<td>This class defines the InsufficientFunds event listener and the listener callback.</td>
</tr>
<tr>
<td>methods (Static)</td>
<td>There is no need to create an instance of this class so the methods defined are static. See “Static Methods” on page 9-24.</td>
</tr>
<tr>
<td>function assignStatus(BA)</td>
<td>The assignStatus method is the callback for the InsufficientFunds event listener. It determines the value of a BankAccount object AccountStatus property based on the value of the AccountBalance property.</td>
</tr>
<tr>
<td>function lh = addAccount(BA)</td>
<td>addAccount creates the listener for the InsufficientFunds event that the BankAccount class defines.</td>
</tr>
<tr>
<td>end</td>
<td>See “Control Listener Lifecycle” on page 11-23</td>
</tr>
<tr>
<td>end</td>
<td>end statements for methods and for classdef.</td>
</tr>
</tbody>
</table>

Expand for Class Code

classdef AccountManager
methods (Static)
function assignStatus(BA)
    if BA.AccountBalance < 0
        if BA.AccountBalance < -200
            BA.AccountStatus = 'closed';
        else
            BA.AccountStatus = 'overdrawn';
        end
    end
end

function lh = addAccount(BA)
    lh = addlistener(BA, 'InsufficientFunds', ...
    @(src, ~)AccountManager.assignStatus(src));
end
end
end
function lh = addAccount(BA)
    lh = addlistener(BA, 'InsufficientFunds', @(src, ~)AccountManager.assignStatus(src));
end
end

Using BankAccount Objects

The BankAccount class, while overly simple, demonstrates how MATLAB classes behave. For example, create a BankAccount object with an account number and an initial deposit of $500:

BA = BankAccount(1234567,500)

BA =

    BankAccount with properties:
        AccountNumber: 1234567
        AccountBalance: 500
        AccountListener: [1x1 event.listener]

Use the getStatement method to check the status:

getStatement(BA)

-------------------------------
Account: 1234567
CurrentBalance: 500.00
Account Status: open
-------------------------------

Make a withdrawal of $600, which results in a negative account balance:

withdraw(BA,600)
getStatement(BA)

-------------------------------
Account: 1234567
CurrentBalance: -100.00
Account Status: overdrawn
-------------------------------

The $600 withdrawal triggered the InsufficientFunds event. The current criteria defined by the AccountManager class results in a status of overdrawn.

Make another withdrawal of $200:

withdraw(BA,200)
getStatement(BA)

-------------------------------
Account: 1234567
CurrentBalance: -300.00
-------------------------------
Now the AccountStatus has been set to closed by the listener and further attempts to make withdrawals are blocked without triggering the event:

```plaintext
withdraw(BA,100)
```

Account 1234567 has been closed.

If the AccountBalance is returned to a positive value by a deposit, then the AccountStatus is returned to open and withdrawals are allowed again:

```plaintext
deposit(BA,700)
getStatement(BA)
```

---

**Account: 1234567**
**CurrentBalance: 400.00**
**Account Status: open**

---
Representing Structured Data with Classes

This example defines a class for storing data with a specific structure. Using a consistent structure for data storage makes it easier to create functions that operate on the data. A MATLAB struct with field names describing the particular data element is a useful way to organize data. However, a class can define both the data storage (properties) and operations that you can perform on that data (methods). This example illustrates these advantages.

Background for the Example

For this example, the data represents tensile stress/strain measurements. These data are used to calculate the elastic modulus of various materials. In simple terms, stress is the force applied to a material and strain is the resulting deformation. Their ratio defines a characteristic of the material. While this approach is an over simplification of the process, it suffices for this example.

Structure of the Data

This table describes the structure of the data.

<table>
<thead>
<tr>
<th>Data</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>char vector identifying the type of material tested</td>
</tr>
<tr>
<td>SampleNumber</td>
<td>Number of a particular test sample</td>
</tr>
<tr>
<td>Stress</td>
<td>Vector of numbers representing the stress applied to the sample during the test.</td>
</tr>
<tr>
<td>Strain</td>
<td>Vector of numbers representing the strain at the corresponding values of the applied stress.</td>
</tr>
<tr>
<td>Modulus</td>
<td>Number defining an elastic modulus of the material under test, which is calculated from the stress and strain data</td>
</tr>
</tbody>
</table>
The TensileData Class

This example begins with a simple implementation of the class and builds on this implementation to illustrate how features enhance the usefulness of the class.

The first version of the class provides only data storage. The class defines a property for each of the required data elements.

```matlab
classdef TensileData
    properties
        Material
        SampleNumber
        Stress
        Strain
        Modulus
    end
end
```

Create an Instance and Assign Data

The following statements create a TensileData object and assign data to it:

```matlab
td = TensileData;
td.Material = 'Carbon Steel';
td.SampleNumber = 001;
td.Stress = [2e4 4e4 6e4 8e4];
td.Strain = [.12 .20 .31 .40];
td.Modulus = mean(td.Stress./td.Strain);
```

Advantages of a Class vs. a Structure

Treat the TensileData object (td in the previous statements) much as you would any MATLAB structure. However, defining a specialized data structure as a class has advantages over using a general-purpose data structure, like a MATLAB struct:

- Users cannot accidentally misspell a field name without getting an error. For example, typing the following:

  ```matlab
td.Modulis = ...  
```

  would simply add a field to a structure. However, it returns an error when td is an instance of the TensileData class.
- A class is easy to reuse. Once you have defined the class, you can easily extend it with subclasses that add new properties.
- A class is easy to identify. A class has a name so that you can identify objects with the whos and class functions and the Workspace browser. The class name makes it easy to refer to records with a meaningful name.
- A class can validate individual field values when assigned, including class or value.
- A class can restrict access to fields, for example, allowing a particular field to be read, but not changed.
Restrict Properties to Specific Values

Restrict properties to specific values by defining a property set access method. MATLAB calls the set access method whenever setting a value for a property.

Material Property Set Function

The Material property set method restricts the assignment of the property to one of the following strings: aluminum, stainless steel, or carbon steel.

Add this function definition to the methods block.

```matlab
classdef TensileData
    properties
        Material
        SampleNumber
        Stress
        Strain
        Modulus
    end
    methods
        function obj = set.Material(obj,material)
            if (strcmpi(material,'aluminum') ||
                strcmpi(material,'stainless steel') ||
                strcmpi(material,'carbon steel'))
                obj.Material = material;
            else
                error('Invalid Material')
            end
        end
    end
end
```

When there is an attempt to set the Material property, MATLAB calls the `set.Material` method before setting the property value.

If the value matches the acceptable values, the function sets the property to that value. The code within the `set` method can access the property directly to avoid calling the property set method recursively.

For example:

```matlab
td = TensileData;
td.Material = 'brass';
```

Error using TensileData/set.Material
Invalid Material

Simplifying the Interface with a Constructor

Simplify the interface to the `TensileData` class by adding a constructor that:

- Enables you to pass the data as arguments to the constructor
- Assigns values to properties

The constructor is a method having the same name as the class.
methods
    function td = TensileData(material,samplenum,stress,strain)
        if nargin > 0
            td.Material = material;
            td.SampleNumber = samplenum;
            td.Stress = stress;
            td.Strain = strain;
        end
    end
end

Create a TensileData object fully populated with data using the following statement:

\[
\text{td} = \text{TensileData('carbon steel',1,...}
\begin{array}{c}
[2e4 \text{ } 4e4 \text{ } 6e4 \text{ } 8e4],...
\end{array}
\begin{array}{c}
[.12 \text{ } .20 \text{ } .31 \text{ } .40])
\end{array}
\]

**Calculate Data on Demand**

If the value of a property depends on the values of other properties, define that property using the Dependent attribute. MATLAB does not store the values of dependent properties. The dependent property get method determines the property value when the property is accessed. Access can occur when displaying object properties or as the result of an explicit query.

**Calculating Modulus**

TensileData objects do not store the value of the Modulus property. The constructor does not have an input argument for the value of the Modulus property. The value of the Modulus:

- Is calculated from the Stress and Strain property values
- Must change if the value of the Stress or Strain property changes

Therefore, it is better to calculate the value of the Modulus property only when its value is requested. Use a property get access method to calculate the value of the Modulus.

**Modulus Property Get Method**

The Modulus property depends on Stress and Strain, so its Dependent attribute is true. Place the Modulus property in a separate properties block and set the Dependent attribute.

The get.Modulus method calculates and returns the value of the Modulus property.

\[
\begin{align*}
\text{properties (Dependent)} \\
\text{    Modulus} \\
\end{align*}
\]

Define the property get method in a methods block using only default attributes.

\[
\begin{align*}
\text{methods} \\
\text{    function modulus = get.Modulus(obj)} \\
\text{        ind = find(obj.Strain > 0);} \\
\text{        modulus = mean(obj.Stress(ind)./obj.Strain(ind));} \\
\text{    end} \\
\end{align*}
\]

This method calculates the average ratio of stress to strain data after eliminating zeros in the denominator data.
MATLAB calls the get.Modulus method when the property is queried. For example,

```matlab
td = TensileData('carbon steel',1,
    [2e4 4e4 6e4 8e4],
    [.12 .20 .31 .40]);
td.Modulus
```

ans = 
  1.9005e+005

**Modulus Property Set Method**

To set the value of a Dependent property, the class must implement a property set method. There is no need to allow explicit setting of the Modulus property. However, a set method enables you to provide a customized error message. The Modulus set method references the current property value and then returns an error:

```matlab
methods
    function obj = set.Modulus(obj,-)
        fprintf('%s%d
','Modulus is: ',obj.Modulus)
        error('You cannot set the Modulus property');
    end
end
```

**Displaying TensileData Objects**

The TensileData class overloads the disp method. This method controls object display in the command window.

The disp method displays the value of the Material, SampleNumber, and Modulus properties. It does not display the Stress and Strain property data. These properties contain raw data that is not easily viewed in the command window.

The disp method uses fprintf to display formatted text in the command window:

```matlab
methods
    function disp(td)
        fprintf(1,...
            'Material: %s\nSample Number: %g\nModulus: %1.5g\n','
            td.Material,td.SampleNumber,td.Modulus);
    end
end
```

**Method to Plot Stress vs. Strain**

It is useful to view a graph of the stress/strain data to determine the behavior of the material over a range of applied tension. The TensileData class overloads the MATLAB plot function.

The plot method creates a linear graph of the stress versus strain data and adds a title and axis labels to produce a standardized graph for the tensile data records:

```matlab
methods
    function plot(td,varargin)
        plot(td.Strain,td.Stress,varargin{:})
        title(['Stress/Strain plot for Sample',,...
            num2str(td.SampleNumber)])
        ylabel('Stress (psi)')
    end
end
```
The first argument to this method is a TensileData object, which contains the data.

The method passes a variable list of arguments (varargin) directly to the built-in plot function. The TensileData plot method allows you to pass line specifier arguments or property name-value pairs.

For example:

```matlab
td = TensileData('carbon steel',1,...
    [2e4 4e4 6e4 8e4],[.12 .20 .31 .40]);
plot(td,'-+b','LineWidth',2)
```

**TensileData Class Synopsis**

<table>
<thead>
<tr>
<th>Example Code</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td>classdef TensileData</td>
<td>Value class enables independent copies of object. For more information, see “Comparison of Handle and Value Classes” on page 7-2</td>
</tr>
</tbody>
</table>
Example Code

```matlab
properties
    Material
    SampleNumber
    Stress
    Strain
end

properties (Dependent)
    Modulus
end

methods

function td = TensileData(material,samplenum,...
    stress,strain)
    if nargin > 0
        td.Material = material;
        td.SampleNumber = samplenum;
        td.Stress = stress;
        td.Strain = strain;
    end
end

function obj = set.Material(obj,material)
    if (strcmpi(material,'aluminum') ||...
        strcmpi(material,'stainless steel') ||...
        strcmpi(material,'carbon steel'))
        obj.Material = material;
    else
        error('Invalid Material')
    end
end

function m = get.Modulus(obj)
    ind = find(obj.Strain > 0);
    m = mean(obj.Stress(ind)./obj.Strain(ind));
end

function obj = set.Modulus(obj,~)
    fprintf('%s%d
','Modulus is: ',obj.Modulus)
    error('You cannot set Modulus property');
end
```

Discussion

See “Structure of the Data” on page 3-14

Calculate Modulus when queried. For information about this code, see “Calculate Data on Demand” on page 3-17.

For general information, see “Set and Get Methods for Dependent Properties” on page 3-16.

For general information about methods, see “Ordinary Methods” on page 9-6

For information about this code, see “Simplifying the Interface with a Constructor” on page 3-16.

For general information about constructors, see “Class Constructor Methods” on page 9-16

Restrict possible values for Material property.

For information about this code, see “Restrict Properties to Specific Values” on page 3-16.

For general information about property set methods, see “Property Set Methods” on page 8-44.

Calculate Modulus property when queried.

For information about this code, see “Modulus Property Get Method” on page 3-17.

For general information about property get methods, see “Property Get Methods” on page 8-47.

Add set method for Dependent Modulus property. For information about this code, see “Modulus Property Set Method” on page 3-18.

For general information about property set methods, see “Property Set Methods” on page 8-44.
### Example Code

```matlab
function disp(td)
    fprintf(1,'Material: %s
Sample Number: %g
Modulus: %1.5g
',
    td.Material,td.SampleNumber,td.Modulus)
end
```

```matlab
function plot(td,varargin)
    plot(td.Strain,td.Stress,varargin{:})
title([\'Stress/Strain plot for Sample'
        num2str(td.SampleNumber)])
ylabel('Stress (psi)')
xlabel('Strain %')
end
end
```

### Discussion

Overload `disp` method to display certain properties:

For information about this code, see “Displaying TensileData Objects” on page 3-18.

For general information about overloading `disp`, see “Overloading the disp Function” on page 18-34.

Overload `plot` function to accept TensileData objects and graph stress vs. strain.

“Method to Plot Stress vs. Strain” on page 3-18

end statements for methods and for classdef.

---

### Expand for Class Code

```matlab
classdef TensileData
    properties
        Material
        SampleNumber
        Stress
        Strain
    end

    properties (Dependent)
        Modulus
    end

    methods
        function td = TensileData(material,samplenum,stress,strain)
            if nargin > 0
                td.Material = material;
                td.SampleNumber = samplenum;
                td.Stress = stress;
                td.Strain = strain;
            end
        end

        function obj = set.Material(obj,material)
            if (strcmpi(material,'aluminum') ||
                strcmpi(material,'stainless steel') ||
                strcmpi(material,'carbon steel'))
                obj.Material = material;
            else
                error('Invalid Material')
            end
        end

        function m = get.Modulus(obj)
            ind = find(obj.Strain > 0);
            m = mean(obj.Stress(ind)./obj.Strain(ind));
        end
    end
end
```
function obj = set.Modulus(obj,~)
    fprintf('%s%d
', 'Modulus is: ', obj.Modulus)
    error('You cannot set Modulus property');
end

function disp(td)
    sprintf('Material: %s
Sample Number: %g
Modulus: %1.5g
',
    td.Material, td.SampleNumber, td.Modulus)
end

function plot(td,varargin)
    plot(td.Strain, td.Stress, varargin{:})
    title(['Stress/Strain plot for Sample ',
    num2str(td.SampleNumber)])
    xlabel('Strain %')
    ylabel('Stress (psi)')
end
end

See Also

More About
• “Class Components” on page 5-4
Implementing Linked Lists with Classes

In this section...

“Class Definition Code” on page 3-23
“dlnode Class Design” on page 3-23
“Create Doubly Linked List” on page 3-24
“Why a Handle Class for Linked Lists?” on page 3-25
“dlnode Class Synopsis” on page 3-25
“Specialize the dlnode Class” on page 3-34

Class Definition Code

For the class definition code listing, see “dlnode Class Synopsis” on page 3-25.

To use the class, create a folder named @dlnode and save dlnode.m to this folder. The parent folder of @dlnode must be on the MATLAB path. Alternatively, save dlnode.m to a path folder.

dlnode Class Design

dlnode is a class for creating doubly linked lists in which each node contains:

• Data array
• Handle to the next node
• Handle to the previous node

Each node has methods that enable the node to be:

• Inserted before a specified node in a linked list
• Inserted after a specific node in a linked list
• Removed from a list

Class Properties

The dlnode class implements each node as a handle object with three properties:

• Data — Contains the data for this node
• Next — Contains the handle of the next node in the list (SetAccess = private)
• Prev — Contains the handle of the previous node in the list (SetAccess = private)

This diagram shows a list with three-nodes n1, n2, and n3. It also shows how the nodes reference the next and previous nodes.
Class Methods

The dlnode class implements the following methods:

- `dlnode` — Construct a node and assign the value passed as an input to the Data property
- `insertAfter` — Insert this node after the specified node
- `insertBefore` — Insert this node before the specified node
- `removeNode` — Remove this node from the list and reconnect the remaining nodes
- `clearList` — Remove large lists efficiently
- `delete` — Private method called by MATLAB when deleting the list.

Create Doubly Linked List

Create a node by passing the node’s data to the dlnode class constructor. For example, these statements create three nodes with data values 1, 2, and 3:

```matlab
n1 = dlnode(1);
n2 = dlnode(2);
n3 = dlnode(3);
```

Build these nodes into a doubly linked list using the class methods designed for this purpose:

```matlab
n2.insertAfter(n1) % Insert n2 after n1
n3.insertAfter(n2) % Insert n3 after n2
```

Now the three nodes are linked:

```matlab
n1.Next % Points to n2
ans =
  dlnode with properties:
    Data: 2
    Next: [1x1 dlnode]
    Prev: [1x1 dlnode]

n2.Next.Prev % Points back to n2
ans =
  dlnode with properties:
    Data: 2
    Next: [1x1 dlnode]
    Prev: [1x1 dlnode]

n1.Next.Next % Points to n3
ans =
  dlnode with properties:
    Data: 3
    Next: []
    Prev: [1x1 dlnode]
```
n3.Prev.Prev % Points to n1
ans =
dlnode with properties:
    Data: 1
    Next: [1x1 dlnode]
    Prev: []

**Why a Handle Class for Linked Lists?**

Each node is unique in that no two nodes can be previous to or next to the same node.

For example, a node object, `node`, contains in its `Next` property the handle of the next node object, `node.Next`. Similarly, the `Prev` property contains the handle of the previous node, `node.Prev`. Using the three-node linked list defined in the previous section, you can demonstrate that the following statements are true:

```
n1.Next == n2
n2.Prev == n1
```

Now suppose that you assign `n2` to `x`:

```
x = n2;
```

The following two equalities are then true:

```
x == n1.Next
x.Prev == n1
```

But each instance of a node is unique so there is only one node in the list that can satisfy the conditions of being equal to `n1.Next` and having a `Prev` property that contains a handle to `n1`. Therefore, `x` must point to the same node as `n2`.

There has to be a way for multiple variables to refer to the same object. The MATLAB `handle` class provides a means for both `x` and `n2` to refer to the same node.

The handle class defines the `eq` method (use `methods('handle')` to list the handle class methods), which enables the use of the `==` operator with all handle objects.

**Related Information**

For more information on handle classes, see “Comparison of Handle and Value Classes” on page 7-2.

**dlnode Class Synopsis**

This section describes the implementation of the `dlnode` class.
<table>
<thead>
<tr>
<th>Example Code</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>classdef dlnode &lt; handle</code></td>
<td>“dlnode Class Design” on page 3-23</td>
</tr>
<tr>
<td><code>&quot;dlnode Class Design&quot; on page 3-23</code></td>
<td></td>
</tr>
<tr>
<td><code>Why a Handle Class for Linked Lists?” on page 3-25</code></td>
<td></td>
</tr>
<tr>
<td><code>&quot;Comparison of Handle and Value Classes” on page 7-2</code></td>
<td></td>
</tr>
<tr>
<td><code>properties Data</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>&quot;dlnode Class Design” on page 3-23</code></td>
<td></td>
</tr>
<tr>
<td><code>properties (SetAccess = private)</code></td>
<td></td>
</tr>
<tr>
<td><code>Next = dlnode.empty</code></td>
<td></td>
</tr>
<tr>
<td><code>Prev = dlnode.empty</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>&quot;Property Attributes” on page 8-7: SetAccess.</code></td>
<td></td>
</tr>
<tr>
<td><code>Initialize these properties to empty dlnode objects.</code></td>
<td></td>
</tr>
<tr>
<td><code>For general information about properties, see “Property Syntax” on page 8-4</code></td>
<td></td>
</tr>
<tr>
<td><code>methods</code></td>
<td></td>
</tr>
<tr>
<td><code>function node = dlnode(Data)</code></td>
<td></td>
</tr>
<tr>
<td><code>if (nargin &gt; 0)</code></td>
<td></td>
</tr>
<tr>
<td><code>node.Data = Data;</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>Creating an individual node (not connected) requires only the data.</code></td>
<td></td>
</tr>
<tr>
<td><code>For general information about constructors, see “Guidelines for Constructors” on page 9-17</code></td>
<td></td>
</tr>
<tr>
<td><code>function insertAfter(newNode, nodeBefore)</code></td>
<td></td>
</tr>
<tr>
<td><code>removeNode(newNode);</code></td>
<td></td>
</tr>
<tr>
<td><code>newNode.Next = nodeBefore.Next;</code></td>
<td></td>
</tr>
<tr>
<td><code>newNode.Prev = nodeBefore;</code></td>
<td></td>
</tr>
<tr>
<td><code>if ~isempty(nodeBefore.Next)</code></td>
<td></td>
</tr>
<tr>
<td><code>nodeBefore.Next.Prev = newNode;</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>nodeBefore.Next = newNode;</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>Insert node into a doubly linked list after specified node, or link the two specified nodes if there is not already a list. Assigns the correct values for Next and Prev properties.</code></td>
<td></td>
</tr>
<tr>
<td><code>“Insert Nodes” on page 3-29</code></td>
<td></td>
</tr>
<tr>
<td><code>function insertBefore(newNode, nodeAfter)</code></td>
<td></td>
</tr>
<tr>
<td><code>removeNode(newNode);</code></td>
<td></td>
</tr>
<tr>
<td><code>newNode.Next = nodeAfter;</code></td>
<td></td>
</tr>
<tr>
<td><code>newNode.Prev = nodeAfter.Prev;</code></td>
<td></td>
</tr>
<tr>
<td><code>if ~isempty(nodeAfter.Prev)</code></td>
<td></td>
</tr>
<tr>
<td><code>nodeAfter.Prev.Next = newNode;</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>nodeAfter.Prev = newNode;</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>Insert node into doubly linked list before specified node, or link the two specified nodes if there is not already a list. This method assigns correct values for Next and Prev properties. See “Insert Nodes” on page 3-29</code></td>
<td></td>
</tr>
<tr>
<td><code>function removeNode(node)</code></td>
<td></td>
</tr>
<tr>
<td><code>if ~isscalar(node)</code></td>
<td></td>
</tr>
<tr>
<td><code>error('Nodes must be scalar')</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>prevNode = node.Prev;</code></td>
<td></td>
</tr>
<tr>
<td><code>nextNode = node.Next;</code></td>
<td></td>
</tr>
<tr>
<td><code>if ~isempty(prevNode)</code></td>
<td></td>
</tr>
<tr>
<td><code>prevNode.Next = nextNode;</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>if ~isempty(nextNode)</code></td>
<td></td>
</tr>
<tr>
<td><code>nextNode.Prev = prevNode;</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>node.Next = = dlnode.empty;</code></td>
<td></td>
</tr>
<tr>
<td><code>node.Prev = = dlnode.empty;</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>Remove node and fix the list so that remaining nodes are properly connected. node argument must be scalar.</code></td>
<td></td>
</tr>
<tr>
<td><code>Once there are no references to node, MATLAB deletes it.</code></td>
<td></td>
</tr>
<tr>
<td><code>“Remove a Node” on page 3-30</code></td>
<td></td>
</tr>
</tbody>
</table>
Avoid recursive calls to destructor as a result of clearing the list variable. Loop through list to disconnect each node. When there are no references to a node, MATLAB calls the class destructor (see the `delete` method) before deleting it.

Class destructor method. MATLAB calls the `delete` method you delete a node that is still connected to the list.

End of private methods and end of class definition.

Implementing Linked Lists with Classes

classdef dlnode < handle
    % dlnode A class to represent a doubly-linked node.
    % Link multiple dlnode objects together to create linked lists.
    properties
        Data
    end

    properties(SetAccess = private)
        Next = dlnode.empty
        Prev = dlnode.empty
    end

    methods
        function node = dlnode(Data)
            % Construct a dlnode object
            if nargin > 0
                node.Data = Data;
            end
        end

        function insertAfter(newNode, nodeBefore)
            % Insert newNode after nodeBefore.
            removeNode(newNode);
            newNode.Next = nodeBefore.Next;
            newNode.Prev = nodeBefore;
            if ~isempty(nodeBefore.Next)
                nodeBefore.Next.Prev = newNode;
            end
            nodeBefore.Next = newNode;
        end

        function insertBefore(newNode, nodeAfter)
            % Insert newNode before nodeAfter.
            removeNode(newNode);
            newNode.Next = nodeAfter;
            newNode.Prev = nodeAfter.Prev;
        end
    end
end
end

Expand for Class Code
if ~isempty(nodeAfter.Prev)
    nodeAfter.Prev.Next = newNode;
end
nodeAfter.Prev = newNode;
end

function removeNode(node)
    % Remove a node from a linked list.
    if ~isscalar(node)
        error('Input must be scalar')
    end
    prevNode = node.Prev;
    nextNode = node.Next;
    if ~isempty(prevNode)
        prevNode.Next = nextNode;
    end
    if ~isempty(nextNode)
        nextNode.Prev = prevNode;
    end
    node.Next = dlnode.empty;
    node.Prev = dlnode.empty;
end

function clearList(node)
    % Clear the list before clearing list variable
    prev = node.Prev;
    next = node.Next;
    removeNode(node)
    while ~isempty(next)
        node = next;
        next = node.Next;
        removeNode(node);
    end
    while ~isempty(prev)
        node = prev;
        prev = node.Prev;
        removeNode(node)
    end
end

methods (Access = private)
    function delete(node)
        clearList(node)
    end
end

Class Properties

Only dlnode class methods can set the Next and Prev properties because these properties have private set access (SetAccess = private). Using private set access prevents client code from performing any incorrect operation with these properties. The dlnode class methods perform all the operations that are allowed on these nodes.

The Data property has public set and get access, allowing you to query and modify the value of Data as required.
Here is how the dlnode class defines the properties:

```matlab
properties
    Data
end
properties(SetAccess = private)
    Next = dlnode.empty;
    Prev = dlnode.empty;
end
```

**Construct a Node Object**

To create a node object, specify the node's data as an argument to the constructor:

```matlab
function node = dlnode(Data)
    if nargin > 0
        node.Data = Data;
    end
end
```

**Insert Nodes**

There are two methods for inserting nodes into the list — `insertAfter` and `insertBefore`. These methods perform similar operations, so this section describes only `insertAfter` in detail.

```matlab
function insertAfter(newNode, nodeBefore)
    removeNode(newNode);
    newNode.Next = nodeBefore.Next;
    newNode.Prev = nodeBefore;
    if ~isempty(nodeBefore.Next)
        nodeBefore.Next.Prev = newNode;
    end
    nodeBefore.Next = newNode;
end
```

**How `insertAfter` Works**

First, `insertAfter` calls the `removeNode` method to ensure that the new node is not connected to any other nodes. Then, `insertAfter` assigns the `newNode` Next and Prev properties to the handles of the nodes that are after and before the `newNode` location in the list.

For example, suppose that you want to insert a new node, nnew, after an existing node, n1, in a list containing n1–n2–n3.

First, create nnew:

```matlab
nnew = dlnode(rand(3));
```

Next, call `insertAfter` to insert nnew into the list after n1:

```matlab
nnew.insertAfter(n1)
```

The `insertAfter` method performs the following steps to insert nnew in the list between n1 and n2:

- Set nnew.Next to n1.Next (n1.Next is n2):
  ```matlab
  nnew.Next = n1.Next;
  ```
• Set nnew.Prev to n1
  
nnew.Prev = n1;
• If n1.Next is not empty, then n1.Next is still n2, so n1.Next.Prev is n2.Prev, which is set to nnew
  
n1.Next.Prev = nnew;
• n1.Next is now set to nnew
  
n1.Next = nnew;

Remove a Node

The removeNode method removes a node from a list and reconnects the remaining nodes. The insertBefore and insertAfter methods always call removeNode on the node to insert before attempting to connect it to a linked list.

Calling removeNode ensures that the node is in a known state before assigning it to the Next or Prev property:

```matlab
function removeNode(node)
    if ~isscalar(node)
        error('Input must be scalar')
    end
    prevNode = node.Prev;
    nextNode = node.Next;
    if ~isempty(prevNode)
        prevNode.Next = nextNode;
    end
    if ~isempty(nextNode)
        nextNode.Prev = prevNode;
    end
    node.Next = dlnode.empty;
    node.Prev = dlnode.empty;
end
```

For example, suppose that you remove n2 from a three-node list (n1–n2–n3):

n2.removeNode;
removeNode removes n2 from the list and reconnects the remaining nodes with the following steps:

\[
\begin{align*}
    n1 &= n2.\text{Prev}; \\
    n3 &= n2.\text{Next}; \\
    \text{if } n1 \text{ exists, then} & \quad n1.\text{Next} = n3; \\
    \text{if } n3 \text{ exists, then} & \quad n3.\text{Prev} = n1
\end{align*}
\]

The list is rejoined because \( n1 \) connects to \( n3 \) and \( n3 \) connects to \( n1 \). The final step is to ensure that \( n2.\text{Next} \) and \( n2.\text{Prev} \) are both empty (that is, \( n2 \) is not connected):

\[
\begin{align*}
    n2.\text{Next} &= \text{dlnode.empty}; \\
    n2.\text{Prev} &= \text{dlnode.empty};
\end{align*}
\]

**Removing a Node from a List**

Suppose that you create a list with 10 nodes and save the handle to the head of the list:

\[
\begin{align*}
    \text{head} &= \text{dlnode(1)}; \\
    \text{for } i &= 10:-1:2 \\
        & \quad \text{new} = \text{dlnode}(i); \\
        & \quad \text{insertAfter(new, head);} \\
    \text{end}
\end{align*}
\]

Now remove the third node (Data property assigned the value 3):

removeNode(head.Next.Next)

Now the third node in the list has a data value of 4:

head.Next.Next

\[
\begin{align*}
    \text{ans} &= \\
        \text{dlnode with properties:}
\end{align*}
\]

\[
\begin{align*}
    \text{Data: } 4 \\
    \text{Next: } [1x1 \text{ dlnode}] \\
    \text{Prev: } [1x1 \text{ dlnode}]
\end{align*}
\]

And the previous node has a Data value of 2:

head.Next
ans =

dlnode with properties:
    Data: 2
    Next: [1x1 dlnode]
    Prev: [1x1 dlnode]

Delete a Node

To delete a node, call the `removeNode` method on that node. The `removeNode` method disconnects the node and reconnects the list before allowing MATLAB to destroy the removed node. MATLAB destroys the node once references to it by other nodes are removed and the list is reconnected.

```
>> removeNode(n2)
```

MATLAB calls `delete(n2)`

Delete the List

When you create a linked list and assign a variable that contains, for example, the head or tail of the list, clearing that variable causes the destructor to recurse through the entire list. With large enough list, clearing the list variable can result in MATLAB exceeding its recursion limit.

The `clearList` method avoids recursion and improves the performance of deleting large lists by looping over the list and disconnecting each node. `clearList` accepts the handle of any node in the list and removes the remaining nodes.

```
function clearList(node)
    if ~isscalar(node)
        error('Input must be scalar')
    end
    prev = node.Prev;
    next = node.Next;
    removeNode(node)
    while ~isempty(next)
        node = next;
        next = node.Next;
    end
```

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removeNode(node);
end
while ~isempty(prev)
    node = prev;
    prev = node.Prev;
    removeNode(node)
end
end

For example, suppose that you create a list with many nodes:

head = dlnode(1);
for k = 100000:-1:2
    nextNode = dlnode(k);
    insertAfter(nextNode,head)
end

The variable head contains the handle to the node at the head of the list:

head

head =

dlnode with properties:

    Data: 1
    Next: [1x1 dlnode]
    Prev: []

head.Next

ans =

dlnode with properties:

    Data: 2
    Next: [1x1 dlnode]
    Prev: [1x1 dlnode]

You can call clearList to remove the whole list:

clearList(head)

The only nodes that have not been deleted by MATLAB are those nodes for which there exists an explicit reference. In this case, those references are head and nextNode:

head

head =

dlnode with properties:

    Data: 1
    Next: []
    Prev: []

nextNode

nextNode =
dlnode with properties:

Data: 2
Next: []
Prev: []

You can remove these nodes by clearing the variables:

clear head nextNode

The delete Method

The delete method simply calls the clearList method:

methods (Access = private)
    function delete(node)
        clearList(node)
    end
end

The delete method has private access to prevent users from calling delete when intending to delete a single node. MATLAB calls delete implicitly when the list is destroyed.

To delete a single node from the list, use the removeNode method.

Specialize the dlnode Class

The dlnode class implements a doubly linked list and provides a convenient starting point for creating more specialized types of linked lists. For example, suppose that you want to create a list in which each node has a name.

Rather than copying the code used to implement the dlnode class, and then expanding upon it, you can derive a new class from dlnode (that is, subclass dlnode). You can create a class that has all the features of dlnode and also defines its own additional features. And because dlnode is a handle class, this new class is a handle class too.

NamedNode Class Definition

To use the class, create a folder named @NamedNode and save NamedNode.m to this folder. The parent folder of @NamedNode must be on the MATLAB path. Alternatively, save NamedNode.m to a path folder.

The following class definition shows how to derive the NamedNode class from the dlnode class:

```
classdef NamedNode < dlnode
    properties
        Name = '';
    end
    methods
        function n = NamedNode (name,data)
            if nargin == 0
                name = '';
                data = [];
            end
            n = n@dlnode(data);
            n.Name = name;
```
The **NamedNode** class adds a **Name** property to store the node name.

The constructor calls the class constructor for the **dlnode** class, and then assigns a value to the **Name** property.

**Use NamedNode to Create a Doubly Linked List**

Use the **NamedNode** class like the **dlnode** class, except that you specify a name for each node object. For example:

```matlab
n(1) = NamedNode('First Node',100);
n(2) = NamedNode('Second Node',200);
n(3) = NamedNode('Third Node',300);
```

Now use the insert methods inherited from **dlnode** to build the list:

```matlab
n(2).insertAfter(n(1))
n(3).insertAfter(n(2))
```

A single node displays its name and data when you query its properties:

```matlab
n(1).Next
ans =
    NamedNode with properties:
        Name: 'Second Node'
        Data: 200
        Next: [1x1 NamedNode]
        Prev: [1x1 NamedNode]
```

```matlab
n(1).Next.Next
ans =
    NamedNode with properties:
        Name: 'Third Node'
        Data: 300
        Next: []
        Prev: [1x1 NamedNode]
```

```matlab
n(3).Prev.Prev
ans =
    NamedNode with properties:
        Name: 'First Node'
        Data: 100
        Next: [1x1 NamedNode]
        Prev: []
```
See Also

More About
• “The Handle Superclass” on page 7-11
Static Data
Static Data

What Is Static Data

Static data refers to data that all objects of the class share and that you can modify after creation.

Use static data to define counters used by class instances or other data that is shared among all objects of a class. Unlike instance data, static data does not vary from one object to another. MATLAB provides several ways to define static data, depending on your requirements.

Static Variable

Classes can use a persistent variable to store static data. Define a static method or local function in which you create a persistent variable. The method or function provides access to this variable. Use this technique when you want to store one or two variables.

Saving an object of the class defining the persistent variable does not save the static data associated with the class. To save your static data in an object, or define more extensive data, use the static data object technique “Static Data Object” on page 4-3

Implementation

The StoreData class defines a static method that declares a persistent variable Var. The setgetVar method provides set and get access to the data in the persistent variable. Because the setgetVar method has public access, you can set and get the data stored in the persistent variable globally. Control the scope of access by setting the method Access attribute.

classdef StoreData
    methods (Static)
    function out = setgetVar(data)
        persistent Var;
        if nargin
            Var = data;
        end
        out = Var;
    end
end

Set the value of the variable by calling setgetVar with an input argument. The method assigns the input value to the persistent variable:

StoreData.setgetVar(10);

Get the value of the variable by calling setgetVar with no input argument:
a = StoreData.setgetVar
a =
   10
Clear the persistent variable by calling clear on the StoreData class:
clear StoreData
a = StoreData.setgetVar
a =
   []
Add a method like setgetVar to any class in which you want the behavior of a static property.

**Static Data Object**

To store more extensive data, define a handle class with public properties. Assign an object of the class to a constant property of the class that uses the static data. This technique is useful when you want to:

- Add more properties or methods that modify the data.
- Save objects of the data class and reload the static data.

**Implementation**

The SharedData class is a handle class, which enables you to reference the same object data from multiple handle variables:

classdef SharedData < handle
    properties
        Data1
        Data2
    end
end

The UseData class is the stub of a class that uses the data stored in the SharedData class. The UseData class stores the handle to a SharedData object in a constant property.

classdef UseData
    properties (Constant)
        Data = SharedData
    end
    % Class code here
end

The Data property contains the handle of the SharedData object. MATLAB constructs the SharedData object when loading the UseData class. All subsequently created instances of the UseData class refer to the same SharedData object.

To initialize the SharedData object properties, load the UseData class by referencing the constant property.

h = UseData.Data
h = 

    SharedData with properties:
        Data1: []
        Data2: []

Use the handle to the SharedData object to assign data to property values:

    h.Data1 = 'MyData1';
    h.Data2 = 'MyData2';

Each instance of the UseData class refers to the same handle object:

    a1 = UseData;
    a2 = UseData;

Reference the data using the object variable:

    a1.Data.Data1

ans =

    MyData1

Assign a new value to the properties in the SharedData object:

    a1.Data.Data1 = rand(3);

All new and existing objects of the UseData class share the same SharedData object. a2 now has the rand(3) data that was assigned to a1 in the previous step:

    a2.Data.Data1

ans =

    0.8147    0.9134    0.2785
    0.9058    0.6324    0.5469
    0.1270    0.0975    0.9575

To reinitialize the constant property, clear all instances of the UseData class and then clear the class:

    clear a1 a2
    clear UseData

**Constant Data**

To store constant values that do not change, assign the data to a constant property. All instances of the class share the same value for that property. Control the scope of access to constant properties by setting the property Access attribute.

The only way to change the value of a constant property is to change the class definition. Use constant properties like public final static fields in Java®.

**See Also**
clear | persistent
Related Examples
• “Define Class Properties with Constant Values” on page 15-2
• “Static Methods” on page 9-24

More About
• “Method Attributes” on page 9-4
• “Property Attributes” on page 8-7
• “Static Properties” on page 5-52
Class Definition—Syntax Reference

- “Class Files and Folders” on page 5-2
- “Class Components” on page 5-4
- “Classdef Block” on page 5-8
- “Class Properties” on page 5-10
- “Methods and Functions” on page 5-13
- “Events and Listeners” on page 5-17
- “Attribute Specification” on page 5-18
- “Call Superclass Methods on Subclass Objects” on page 5-20
- “Representative Class Code” on page 5-22
- “MATLAB Code Analyzer Warnings” on page 5-27
- “Objects In Conditional Statements” on page 5-29
- “Operations on Objects” on page 5-34
- “Use of Editor and Debugger with Classes” on page 5-37
- “Automatic Updates for Modified Classes” on page 5-39
- “Compatibility with Previous Versions” on page 5-45
- “Comparison of MATLAB and Other OO Languages” on page 5-48
Class Files and Folders

In this section...

"Class Definition Files" on page 5-2
"Options for Class Folders“ on page 5-2
"Options for Class Files“ on page 5-2
"Group Classes with Package Folders“ on page 5-3

Class Definition Files

Put class definition code in files that have the .m extension. The name of the file must be the same as the name of the class followed by the .m extension.

For information on the code that defines a class, see “Class Components” on page 5-4.

Options for Class Folders

There are two ways to create folders that contain class-definition files:

• Path folder — a folder that is on the MATLAB path.
• Class folder — a folder that is in a path folder and is named with the @ character and the class name. For example:

@MyClass

Class folders are not directly on the MATLAB path. The path folder that contains the class folder is on the MATLAB path.

Options for Class Files

There are two ways to specify classes with respect to files and folders:

• Create a single, self-contained class definition file in a path folder or a class folder
• Define a class in multiple files, which requires you to use a class folder inside a path folder

Create a Single, Self-Contained Class Definition File

Create a single, self-contained class definition file in a folder on the MATLAB® path. The name of the file must match the class (and constructor) name and must have the .m extension. Define the class entirely in this file. You can put other single-file classes in this folder.

The following diagram shows an example of this folder organization. pathfolder is a folder on the MATLAB path.
**Distribute the Class Definition to Multiple Files**

If you use multiple files to define a class, put all the class-definition files (the file containing the `classdef` and all class method files) in a single `@ClassName` folder. That class folder must be inside a folder that is on the MATLAB path. You can define only one class in a class folder:

```
pathfolder
  @ClassNameA
    ClassNameA.m       Contains classdef
    classMethod.m      Class method in separate file
    ClassNameB.m       Contains entire class definition
```

A path folder can contain classes defined in both class folders and single files without a class folder.

**Group Classes with Package Folders**

The parent folder to a package folder is on the MATLAB path, but the package folder is not. Package folders (which always begin with a `+` character) can contain multiple class definitions, package-scoped functions, and other packages. A package folder defines a new name space in which you can reuse class names. Use the package name to refer to classes and functions defined in package folders (for example, `packagefld1.ClassNameA()`, `packagefld2.packageFunction()`).

```
pathfolder
  +packagefld1
    @ClassNameA
      ClassNameA.m       Contains classdef
      classMethod.m      Class method in separate file
      ClassNameB.m       Contains entire class definition
  +packagefld2
    packageFunction.m
    ClassNameA.m
    ClassNameB.m
```

**See Also**

**More About**

- "Folders Containing Class Definitions" on page 6-13
- "Packages Create Namespaces" on page 6-20
- "Methods in Separate Files" on page 9-8
Class Components

Class Building Blocks

MATLAB organizes class definition code into modular blocks, delimited by keywords. All keywords have an associated end statement:

- `classdef...end` — Definition of all class components
- `properties...end` — Declaration of property names, specification of property attributes, assignment of default values
- `methods...end` — Declaration of method signatures, method attributes, and function code
- `events...end` — Declaration of event name and attributes
- `enumeration...end` — Declaration of enumeration members and enumeration values for enumeration classes.

`properties`, `methods`, `events`, and `enumeration` are keywords only within a `classdef` block.

Class Definition Block

The `classdef` block contains the class definition within a file that starts with the `classdef` keyword and terminates with the `end` keyword.

```
classdef (ClassAttributes) ClassName < SuperClass
    ...
end
```

For example, this `classdef` defines a class called `MyClass` that subclasses the `handle` class, but cannot be used to derive subclasses:

```
classdef (Sealed) MyClass < handle
    ...
end
```

See, “Classdef Block” on page 5-8 for more syntax information.
Properties Block

The properties block (one for each unique set of attribute specifications) contains property definitions, including optional initial values. The properties block starts with the properties keyword and terminates with the end keyword.

```matlab
classdef ClassName
    properties (PropertyAttributes)
        end
    end
end
```

For example, this class defines a property called Prop1 that has private access and has a default value equal to the output of the date function.

```matlab
classdef MyClass
    properties (SetAccess = private)
        Prop1 = date
    end
end
```

See “Property Definition” on page 8-13 for more information.

Methods Block

The methods block (one for each unique set of attribute specifications) contains function definitions for the class methods. The methods block starts with the methods keyword and terminates with the end keyword.

```matlab
classdef ClassName
    methods (MethodAttributes)
        end
    end
end
```

For example:

```matlab
classdef MyClass
    methods (Access = private)
        function obj = myMethod(obj)
            ...
        end
    end
end
```

See “Methods and Functions” on page 5-13 for more information.

Events Block

The events block (one for each unique set of attribute specifications) contains the names of events that this class declares. The events block starts with the events keyword and terminates with the end keyword.

```matlab
```

5-5
classdef ClassName
    events (EventAttributes)
        EventName
    end
    ...
end

For example, this class defined an event called StateChange with a ListenAccess set to protected:

classdef EventSource
    events (ListenAccess = protected)
       StateChanged
    end
    ...
end

See “Events and Listeners” on page 5-17 for more information.

A Complete Class

A complete class definition contains any combination of properties, methods, and events code blocks.

classdef (Sealed) MyClass < handle
    properties (SetAccess = private)
        Prop1 = datenum(date)
    end
    properties
        Prop2
    end
    methods
        function obj = MyClass(x)
            obj.Prop2 = x;
        end
    end
    methods (Access = {?MyOtherClass})
        function d = myMethod(obj)
            d = obj.Prop1 + x;
        end
    end
    events (ListenAccess = protected)
       StateChanged
    end
end

Enumeration Classes

Enumeration classes are specialized classes that define a fixed set of names representing a single type of value. Enumeration classes use an enumeration block that contains the enumeration members defined by the class.

The enumeration block starts with the enumeration keyword and terminates with the end keyword.

classdef ClassName < SuperClass
    enumeration
        EnumerationMember
    end
end
For example, this class defines two enumeration members that represent logical false and true:

```matlab
classdef Boolean < logical
    enumeration
    No (0)
    Yes (1)
end
end
```

See, “Define Enumeration Classes” on page 14-4 for more information.

**Related Information**

“Folders Containing Class Definitions” on page 6-13
Classdef Block

In this section...

“How to Specify Attributes and Superclasses” on page 5-8
“Class Attribute Syntax” on page 5-8
“Superclass Syntax” on page 5-8
“Local Functions in Class File” on page 5-9

How to Specify Attributes and Superclasses

The classdef block contains the class definition. The classdef line is where you specify:

• Class attributes
• Superclasses

The classdef block contains the properties, methods, and events subblocks.

Class Attribute Syntax

Class attributes modify class behavior in some way. Assign values to class attributes only when you want to change their default value.

No change to default attribute values:

classdef ClassName
end

One or more attribute values assigned:

classdef (attribute1 = value,...)
end

For example, the TextString class specifies that it cannot be used to derive subclasses:

classdef TextString (Sealed)
end

See “Class Attributes” on page 6-5 for a list of attributes and a discussion of the behaviors they control.

Superclass Syntax

Derive a class from one or more other classes by specifying the superclasses on the classdef line:

classdef ClassName < SuperclassName
end

For example, the LinkedList class inherits from classes called Array and handle:
classdef LinkedList < Array & handle
    ...
end

**Local Functions in Class File**

You can define only one class per file. However, you can add local functions to a file containing the classdef block. Local functions are scoped to the classdef file and have access to private and protected class members.

classdef ClassName
    ...
end
function localFunction
    ...
end

**See Also**

**Related Examples**
- “User-Defined Classes” on page 6-2
- “Design Subclass Constructors” on page 12-7
- “Local Functions”
Class Properties

In this section...

- "The Properties Block" on page 5-10
- "Access to Property Values" on page 5-11

The Properties Block

Define class properties within a properties block:

```matlab
classdef ClassName
    properties (PropertyAttributes)
        PropertyName size class {validation functions} = DefaultValue
    end
end
```

Property attributes apply to all properties defined within the block. To define properties with different attributes, use multiple properties blocks. All property attributes have default values. For a list of property attributes, see "Property Attributes" on page 8-7.

Restrict the size, class, and other aspects of values assigned to properties in the property definition. For more information, see “Validate Property Values” on page 8-20.

Optionally assign default values to the property in the properties block. MATLAB evaluates the assignment statement when the class is first referenced or when loading a saved object. For more information, see “Property Definition” on page 8-13.

**Note** Evaluation of property default values occurs only when the value is first needed, and only once when MATLAB first initializes the class. MATLAB does not reevaluate the expression each time you create an instance of the class.

For more information on the evaluation of expressions that you assign as property default values, see “When MATLAB Evaluates Expressions” on page 6-10.

Properties with Different Attributes

The following class defines three properties. Model and Color use default attribute values, resulting in public read and write access. SerialNumber has read-only access by object users. Assign the SerialNumber property value from a class member function, such as the constructor or other class method.

```matlab
classdef NewCar
    properties
        Model
        Color
    end
    properties (SetAccess = private)
        SerialNumber
    end
end
```

```matlab```
```
Access to Property Values

Use dot notation to access property value.

A = NewCar

A =

NewCar with properties:

    Model: []
    Color: []
    SerialNumber: []

Set the Model and Color properties:

A.Model = 'XGT7000';
A.Color = 'Red';

Add a constructor to the NewCar class to set property values:

classdef NewCar
    properties
        Model
        Color
    end
    properties (SetAccess = private)
        SerialNumber
    end
    methods
        function obj = NewCar(model,color)
            obj.Model = model;
            obj.Color = color;
            obj.SerialNumber = datenum(datetime('now'));
        end
    end
end

A = NewCar('XGT7000','Red')

A =

NewCar with properties:

    Model: 'XGT7000'
    Color: 'Red'
    SerialNumber: 7.362456078531134e+05

See Also

Related Examples

• “Ways to Use Properties” on page 8-2
• “Validate Property Values” on page 8-20
Methods and Functions

In this section...

“The Methods Block” on page 5-13
“Method Calling Syntax” on page 5-13
“Private Methods” on page 5-14
“More Detailed Information on Methods” on page 5-14
“Class-Related Functions” on page 5-14
“How to Overload Functions and Operators” on page 5-15
“Rules for Defining Methods in Separate Files” on page 5-15

The Methods Block

Define methods as MATLAB functions within a methods block, inside the classdef block. The constructor method has the same name as the class and returns an initialized object of the class. To create an object with property values that are unique to that instance, assign values to properties in the class constructor. Terminate all method functions with an end statement.

```matlab
classdef ClassName
    properties
        PropertyName
    end
    methods
        function obj = ClassName(arg1,...)
            obj.PropertyName = arg1;
            ...
        end
        function ordinaryMethod(obj, arg1,...)
            ...
        end
    end
    methods (Static)
        function staticMethod(arg1,...)
            ...
        end
    end
end
```

Method Calling Syntax

MATLAB differs from languages like C++ and Java in that there is no special hidden class object passed to all methods. You must pass an object of the class explicitly to the method. The leftmost argument does not need to be the class object, and the argument list can have multiple objects. MATLAB dispatches to the method defined by the class of the dominant argument. For more information, see “Method Invocation” on page 9-11.

Methods must be on the MATLAB path when called. For example, if you create an object and then change your current folder to a folder from which the method file is not visible, an error occurs when you call that method.

Always use case-sensitive method names in your MATLAB code.
Ordinary Methods

Call ordinary methods using MATLAB function syntax or dot notation. For example, suppose that you have a class that defines ordinaryMethod. Pass an object of the defining class and whatever arguments are required.

```matlab
classdef MyClass
    methods
        function out = ordinaryMethod(obj,arg1)
            ...
        end
    end
end
```

Call `ordinaryMethod` using the object `obj` of the class and either syntax:

```matlab
obj = MyClass;
r = ordinaryMethod(obj,arg1);
r = obj.ordinaryMethod(arg1);
```

Static Methods

Static methods do not require an object of the class. To call a static method, prefix the method name with the class name so that MATLAB can determine what class defines the method.

```matlab
classdef MyClass
    methods (Static)
        function out = staticMethod(arg1)
            ...
        end
    end
end
```

Call `staticMethod` using the syntax `classname.methodname`:

```matlab
r = MyClass.staticMethod(arg1);
```

See “Static Methods” on page 9-24 for information on methods that do not require objects of their class.

Private Methods

Use the Access method attribute to create a private method. You do not need to use a private folder.

See “Method Attributes” on page 9-4 for a list of method attributes.

More Detailed Information on Methods

“Methods”

Class-Related Functions

You can define functions that are not class methods in the file that contains the class definition (classdef). Define local functions outside of the classdef - end block, but in the same file as the class definition. Functions defined in classdef files work like local functions. You can call these
functions from anywhere in the same file, but they are not visible outside of the file in which you define them.

Local functions in classdef files are useful for utility functions that you use only within that file. These functions can take or return arguments that are instances of the class but, it is not necessary, as in the case of ordinary methods. For example, the following code defines myUtilityFcn outside the classdef block:

```matlab
classdef MyClass
    properties
        PropName
    end
    methods
        function obj = MyClass(arg1)
            obj.PropName = arg1;
        end
    end % End of classdef

function myUtilityFcn
    ...
end
```

You also can create package functions, which require the use of the package name when calling these functions.

How to Overload Functions and Operators

Overload MATLAB functions for your class by defining a class method with the same name as the function that you want to overload. MATLAB dispatches to the class method when the function is called with an instance of the class.

You can overload MATLAB arithmetic, logical, relational, and indexing operators by defining class methods with the appropriate names.

See the handle class for a list of operations defined for that class. All classes deriving from handle inherit these methods.

Rules for Defining Methods in Separate Files

The following rules apply to methods defined in separate files:

- To specify attributes for a method defined in a separate file, declare this method in a methods block in the classdef file. Specify the attribute values with the methods block.
- Match the syntax declared in the methods block (if used) to the method's function line.
- The separate file must be in the class (@) folder.
- The class constructor method must be defined in the classdef file. The constructor cannot be in a separate file.
- Handle class delete methods must be defined in the classdef file. The delete method cannot be in a separate file.

All functions that use dots in their names must be defined in the classdef file, including:

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• Converter methods that must use the package name as part of the class name because the class is contained in packages
• Property set and get access methods

For more information on defining methods in separate files, see “Methods in Separate Files” on page 9-8

See Also

More About
• “Methods in Class Design” on page 9-2
Define and Trigger Events

To define an event, declare a name for the event in an events block. Trigger the event using the handle class notify method. Only classes derived from the handle class can define events.

For example, MyClass class:

- Subclasses handle
- Defines an event named StateChange
- Triggers the event using the inherited notify method in its updateUI method.

```matlab
classdef MyClass < handle
    events StateChange
    end
    methods
        function updateUI(obj)
            ... notify(obj,'StateChange');
        end
    end
end
```

Listen for Events

Any number of objects can listen to the StateChange event. When notify executes, MATLAB calls all registered listener callbacks. MATLAB passes the handle of the object generating the event and event data to the callback functions. To create a listener, use the addlistener method of the handle class.

```matlab
addlistener(event_obj,'StateChange',@myCallback)
```

To control the lifecycle of the listener, use the event.listener constructor to create the listener object.

See Also
- event.hasMoreListeners | event.listener | event.proplisteener

Related Examples
- “Overview Events and Listeners” on page 11-2
- “Events and Listeners Syntax” on page 11-18

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Attribute Syntax

Attributes modify the behavior of classes and class components (properties, methods, and events). Attributes enable you to define useful behaviors without writing complicated code. For example, you can create a read-only property by setting its SetAccess attribute to private, but leaving its GetAccess attribute set to public:

```matlab
properties (SetAccess = private)
    ScreenSize = getScreenSize
end
```

All class definition blocks (classdef, properties, methods, and events) support specific attributes. All attributes have default values. Specify attribute values only in cases where you want to change from the default value to another predefined value.

**Note** Specify the value of a particular attribute only once in any component block.

Attribute Descriptions

For lists of supported attributes, see:

- “Class Attributes” on page 6-5
- “Property Attributes” on page 8-7
- “Method Attributes” on page 9-4
- “Event Attributes” on page 11-16

Attribute Values

When you specify attribute values, those values affect all the components defined within the defining block. For example, the following property definition blocks set the:

- AccountBalance property SetObservable attribute to true
- SSNumber and CreditCardNumber properties' Hidden attribute to true and SetAccess attribute to private.

Defining properties with different attribute settings requires multiple properties blocks.

```matlab
properties (SetObservable = true)
    AccountBalance
end
properties (SetAccess = private, Hidden = true)
```
Specified multiple attributes in a comma-separated list, as shown in the previous example.

When specifying class attributes, place the attribute list directly after the `classdef` keyword:
```
classdef (AttributeName = attributeValue) ClassName
    ...
end
```

**Simpler Syntax for true/false Attributes**

You can use a simpler syntax for attributes whose values are `true` or `false` — the attribute name alone implies `true` and adding the `not` operator (`~`) to the name implies `false`. For example:
```
methods (Static)
    ...
end
```

Is the same as:
```
methods (Static = true)
    ...
end
```

Use the `not` operator before an attribute name to define it as `false`:
```
methods (~Static)
    ...
end
```

Is the same as:
```
methods (Static = false)
    ...
end
```

All attributes that take a logical value (that is, `true` or `false`) have a default value of `false`. Therefore, specify an attribute only if you want to set it to `true`.

**See Also**

**Related Examples**

- "Evaluation of Expressions in Class Definitions" on page 6-8
Call Superclass Methods on Subclass Objects

In this section...

“Superclass Relation to Subclass” on page 5-20
“How to Call Superclass Methods” on page 5-20
“How to Call Superclass Constructor” on page 5-20

Superclass Relation to Subclass

Subclasses can override superclass methods to support the greater specialization defined by the subclass. Because of the relationship that a subclass object is a superclass object, it is often useful to call the superclass version of the method before executing the specialized subclass code.

How to Call Superclass Methods

Subclass methods can call superclass methods if both methods have the same name. From the subclass, reference the method name and superclass name with the @ symbol.

This diagram illustrates how to call the superMethod defined by MySuperClass.

For example, a subclass can call a superclass disp method to implement the display of the superclass part of the object. Then the subclass adds code to display the subclass part of the object:

```matlab
classdef MySub < MySuperClass
    methods
        function disp(obj)
            disp@MySuperClass(obj)
            disp@MySuperClass(obj)
            ...
        end
    end
end
```

How to Call Superclass Constructor

If you create a subclass object, MATLAB calls the superclass constructor to initialize the superclass part of the subclass object. By default, MATLAB calls the superclass constructor without arguments. If you want the superclass constructor called with specific arguments, explicitly call the superclass
constructor from the subclass constructor. The call to the superclass constructor must come before any other references to the object.

The syntax for calling the superclass constructor uses an @ symbol:

```matlab
obj = obj@MySuperClass(SuperClassArguments);
```

In the following class, the `MySub` object is initialized by the `MySuperClass` constructor. The superclass constructor constructs the `MySuperClass` part of the object using the specified arguments.

```matlab
classdef MySub < MySuperClass
    methods
        function obj = MySub(arg1,arg2, ...)
            obj = obj@MySuperClass(SuperClassArguments);
        end
    end
end
```

See “Subclass Constructors” on page 9-19 for more information.

**See Also**

**Related Examples**

- “Modify Inherited Methods” on page 12-13
Class Calculates Area

The CircleArea class shows the syntax of a typical class definition. This class stores a value for the radius of a circle and calculates the area of the circle when you request this information. CircleArea also implements methods to graph, display, and create objects of the class.

To use the CircleArea class, copy this code into a file named CircleArea.m and save this file in a folder that is on the MATLAB path.

```matlab
classdef CircleArea
    properties
        Radius
    end
    properties (Constant)
        P = pi
    end
    properties (Dependent)
        Area
    end
    methods
        function obj = CircleArea(r)
            if nargin > 0
                obj.Radius = r;
            end
        end
        function val = get.Area(obj)
            val = obj.P*obj.Radius^2;
        end
        function obj = set.Radius(obj,val)
            if val < 0
                error('Radius must be positive')
            end
            obj.Radius = val;
        end
        function plot(obj)
            r = obj.Radius;
            d = r*2;
            pos = [0 0 d d];
            curv = [1 1];
            rectangle('Position',pos,'Curvature',curv,...
                'FaceColor',[.9 .9 .9])
            line([0,r],[r,r])
            text(r/2,r+.5,['r = ',num2str(r)])
            title(['Area = ',num2str(obj.Area)])
            axis equal
        end
        function disp(obj)
            rad = obj.Radius;
            disp(['Circle with radius: ',num2str(rad)])
    end
end
```
methods (Static)
    function obj = createObj
        prompt = {'Enter the Radius'};
        dlgTitle = 'Radius';
        rad = inputdlg(prompt,dlgTitle);
        r = str2double(rad{:});
        obj = CircleArea(r);
    end
end
end

Use the CircleArea Class

Create an object using the dialog box:
ca = CircleArea.createObj

Add a value for radius and click OK.

Query the area of the defined circle:
ca.Area

ans =
    164.2202

Call the overloaded plot method:
plot(ca)
Description of Class Definition

Class definition code begins with the `classdef` keyword followed by the class name:
```
classdef CircleArea
```
Define the `Radius` property within the `properties-end` keywords. Use default attributes:
```
    properties
        Radius
    end
```
Define the `P` property as `Constant` ("Define Class Properties with Constant Values" on page 15-2). Call the `pi` function only once when class is initialized.
```
    properties (Constant)
        P = pi
    end
```
Define the `Area` property as `Dependent` because its value depends on the `Radius` property.
```
    properties (Dependent)
        Area
    end
```
```
methods % Begin defining methods
The `CircleArea` class constructor method has the same name as the class and accepts the value of the circle radius as an argument. This method also allows no input arguments. ("Class Constructor Methods" on page 9-16)
function obj = CircleArea(r)
    if nargin > 0
        obj.Radius = r;
    else
        obj.Radius = 0;
    end
end

Because the Area property is Dependent, it does not store its value. The get.Area method calculates the value of the Area property whenever it is queried. ("Set and Get Methods for Dependent Properties" on page 8-49)

function val = get.Area(obj)
    val = obj.P*obj.Radius^2;
end

The set.Radius method tests the value assigned to the Radius property to ensure that the value is not less than zero. MATLAB calls set.Radius to assign a value to Radius. ("Property Set Methods" on page 8-44.

function obj = set.Radius(obj,val)
    if val < 0
        error('Radius must be positive')
    end
    obj.Radius = val;
end

The CircleArea class overloads the plot function. The plot method uses the rectangle function to create a circle and draws the radius. ("Overload Functions in Class Definitions" on page 9-26

function plot(obj)
    r = obj.Radius;
    d = r*2;
    pos = [0 0 d d];
    curv = [1 1];
    rectangle('Position',pos,'Curvature',curv)
    line([0,r],[r,r])
    text(r/2,r+.5,['r = ',num2str(r)])
    axis equal
end

The CircleArea class overloads the disp function to change the way MATLAB displays objects in the command window.

function disp(obj)
    rad = obj.Radius;
    disp(['Circle with radius: ',num2str(rad)])
end

methods (Static)

The CircleArea class defines a Static method that uses a dialog box to create an object. ("Static Methods" on page 9-24

function obj = createObj
    prompt = {'Enter the Radius'};
    dlgTitle = 'Radius';
    rad = inputdlg(prompt,dlgTitle);
    r = str2double(rad{:});
    obj = CircleArea(r);
end
End of Static methods block and end of classdef block.

end
end
MATLAB Code Analyzer Warnings

Syntax Warnings and Property Names

The MATLAB Code Analyzer helps you optimize your code and avoid syntax errors while you write code. It is useful to understand some of the rules that the Code Analyzer applies in its analysis of class definition code. This understanding helps you avoid situations in which MATLAB allows code that is undesirable.

Variable/Property Name Conflict Warnings

The Code Analyzer warns about the use of variable names in methods that match the names of properties. For example, suppose that a class defines a property called EmployeeName and in this class, there is a method that uses EmployeeName as a variable:

```matlab
properties
    EmployeeName
end
methods
    function someMethod(obj,n)
        EmployeeName = n;
    end
end
```

While the previous function is legal MATLAB code, it results in Code Analyzer warnings for two reasons:

- The value of EmployeeName is never used
- EmployeeName is the name of a property that is used as a variable

If the function someMethod contained the following statement instead:

```matlab
obj.EmployeeName = n;
```

The Code Analyzer generates no warnings.

If you change someMethod to:

```matlab
function EN = someMethod(obj)
    EN = EmployeeName;
end
```

The Code Analyzer returns only one warning, suggesting that you might actually want to refer to the EmployeeName property.

While this version of someMethod is legal MATLAB code, it is confusing to give a property the same name as a function. Therefore, the Code Analyzer provides a warning suggesting that you might have intended the statement to be:
EN = obj.EmployeeName;

**Exception to Variable/Property Name Rule**

Suppose that you define a method that returns a value of a property and uses the name of the property for the output variable name. For example:

```matlab
function EmployeeName = someMethod(obj)
    EmployeeName = obj.EmployeeName;
end
```

The Code Analyzer does not warn when a variable name is the same as a property name when the variable is:

- An input or output variable
- A global or persistent variable

In these particular cases, the Code Analyzer does not warn you that you are using a variable name that is also a property name. Therefore, a coding error like the following:

```matlab
function EmployeeName = someMethod(obj)
    EmployeeName = EmployeeName; % Forgot to include obj.
end
```

does not trigger a warning from the Code Analyzer.

**See Also**

**Related Examples**

- “Use of Editor and Debugger with Classes” on page 5-37
Enable Use of Objects in Conditional Statements

Enable the use of objects in conditional statements by defining relational operators for the class of the object. Classes that derive from the `handle` class inherit relational operators. Value classes can implement operators to support the use of conditional statements involving objects. For information on defining operators for your class, see “Operator Overloading” on page 17-38.

How MATLAB Evaluates Switch Statements

MATLAB enables you to use objects in `switch` statements when the object’s class defines an `eq` method. The `eq` method implements the `==` operation on objects of that class.

For objects, `case_expression == switch_expression` defines how MATLAB evaluates `switch` and `cases` statements.

The values returned by the `eq` method must be of type `logical` or convertible to `logical`. MATLAB attempts to convert the output of `eq` to a logical value if the output of the `eq` method is a nonlogical value.

**Note** You do not need to define `eq` methods for enumeration classes. See “Enumerations in Switch Statements” on page 5-32.

Handle Objects in Switch Statements

All classes derived from the `handle` class inherit an `eq` method. The expression, `h1 == h2` is true if `h1` and `h2` are handles for the same object.

For example, the `BasicHandle` class derives from `handle`:

```matlab
classdef BasicHandle < handle
    properties
        Prop1
    end
    methods
        function obj = BasicHandle(val)
            if nargin > 0
                obj.Prop1 = val;
            end
        end
end
```
Create a `BasicHandle` object and use it in a `switch` statement:

```matlab
h1 = BasicHandle('Handle Object');
h2 = h1;
```

Here is the `switch` statement code:

```matlab
switch h1
  case h2
    disp('h2 is selected')
  otherwise
    disp('h2 not selected')
end
```

The result is:

```
h2 is selected
```

**Object Must Be Scalar**

The `switch` statements work only with scalar objects. For example:

```matlab
h1(1) = BasicHandle('Handle Object');
h1(2) = BasicHandle('Handle Object');
h1(3) = BasicHandle('Handle Object');
h2 = h1;
```

```matlab
switch h1
  case h2
    disp('h2 is selected')
  otherwise
    disp('h2 not selected')
end
```

The result is:

```
SWITCH expression must be a scalar or string constant.
```

In this case, `h1` is not scalar. Use `isscalar` to determine if an object is scalar before entering a `switch` statement.

**How to Define the eq Method**

To enable the use of value-class objects in `switch` statements, implement an `eq` method for the class. Use the `eq` method to determine what constitutes equality of two objects of the class.

**Behave like a Built-in Type**

Some MATLAB functions also use the built-in `==` operator in their implementation. Therefore, your implementation of `eq` should be replaceable with the built-in `eq` to enable objects of your class work like built-in types in MATLAB code.

**Design of eq**

Implement the `eq` method to return a logical array representing the result of the `==` comparison.
For example, the `SwitchOnVer` class implements an `eq` method that returns `true` for the `==` operation if the value of the `Version` property is the same for both objects. In addition, `eq` works with arrays the same way as the built-in `eq`. For the following expression:

```plaintext
obj1 == obj2
```

The `eq` method works as follows:

- If both `obj1` and `obj2` are scalar, `eq` returns a scalar value.
- If both `obj1` and `obj2` are nonscalar arrays, then these arrays must have the same dimensions, and `eq` returns an array of the same size.
- If one input argument is scalar and the other is a nonscalar array, then `eq` treats the scalar object as if it is an array having the same dimensions as the nonscalar array.

**Implementation of `eq`**

Here is a class that implements an `eq` method. Ensure that your implementation contains appropriate error checking for the intended use.

```matlab
classdef SwitchOnVer
    properties
        Version
    end
    methods
        function obj = SwitchOnVer(ver)
            if nargin > 0
                obj.Version = ver;
            end
        end
        function bol = eq(obj1,obj2)
            if ~strcmp(class(obj1),class(obj2))
                error('Objects are not of the same class')
            end
            s1 = numel(obj1);
            s2 = numel(obj2);
            if s1 == s2
                bol = false(size(obj1));
                for k=1:s1
                    if obj1(k).Version == obj2(k).Version
                        bol(k) = true;
                    else
                        bol(k) = false;
                    end
                end
            elseif s1 == 1
                bol = scalarExpEq(obj2,obj1);
            elseif s2 == 1
                bol = scalarExpEq(obj1,obj2);
            else
                error('Dimension mismatch')
            end
        end
        function ret = scalarExpEq(ns,s)
            % ns is nonscalar array
            % s is scalar array
            ret = false(size(ns));
            n = numel(ns);
            for kk=1:n
```
if ns(kk).Version == s.Version
    ret(kk) = true;
else
    ret(kk) = false;
end
end
end
end

Use SwitchOnVer objects in switch statements:

% Create known versions of objects
ov1 = SwitchOnVer(1.0);
ov2 = SwitchOnVer(2.0);
ov3 = SwitchOnVer(3.0);
...

if isscalar(objIn)
    switch(objIn)
        case ov1
            disp('This is version 1.0')
        case ov2
            disp('This is version 2.0')
        case ov3
            disp('This is version 3.0')
        otherwise
            disp('There is no version')
    end
else
    error('Input object must be scalar')
end

Enumerations in Switch Statements

MATLAB enables you to use enumerations in switch statements without requiring an explicitly defined eq method for the enumeration class.

For example, the WeeklyPlanner class defines enumerations for five days of the week. The switch/case statements in the todaySchedule static method dispatch on the enumeration member corresponding to the current day of the week. The date and datestr functions return a char vector with the name of the current day.

classdef WeeklyPlanner
    enumeration
        Monday, Tuesday, Wednesday, Thursday, Friday
    end
    methods (Static)
        function todaySchedule
dayName = datestr(date,'dddd');
dayEnum = WeeklyPlanner.(dayName);
switch dayEnum
            case WeeklyPlanner.Monday
                disp('Monday schedule')
            case WeeklyPlanner.Tuesday

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disp('Tuesday schedule')
case WeeklyPlanner.Wednesday
disp('Wednesday schedule')
case WeeklyPlanner.Thursday
disp('Thursday schedule')
case WeeklyPlanner.Friday
disp('Friday schedule')
end
end
end
Call todaySchedule to display today's schedule:
WeeklyPlanner.todaySchedule

**Enumerations Derived from Built-In Types**

Enumeration classes that derived from built-in types inherit the superclass `eq` method. For example, the `FlowRate` class derives from `int32`:

```matlab
classdef FlowRate < int32
    enumeration
        Low    (10)
        Medium (50)
        High   (100)
    end
end
```

The `switchEnum` function switches on the input argument, which can be a `FlowRate` enumeration value.

```matlab
function switchEnum(inpt)
    switch inpt
        case 10
            disp('Flow = 10 cfm')
        case 50
            disp('Flow = 50 cfm')
        case 100
            disp('Flow = 100 cfm')
    end
end
```

Call `switchEnum` with an enumerated value:

```matlab
switchEnum(FlowRate.Medium)
Flow = 50 cfm
```
Operations on Objects

Object Operations

A fundamental purpose of objects is to contain data and facilitate ways to manipulate that data. Objects often define their own version of ordinary MATLAB functions that work with the object. For example, you can create a `timeseries` object and pass the object to `plot`:

```matlab
ts = timeseries(rand(100,1),.01:.01:1,'Name','Data1');
plot(ts)
```

However, MATLAB does not call the standard `plot` function. MATLAB calls the `timeseries` `plot` method, which can extract the data from the `timeseries` object and create a customized graph.
**Help on Objects**

Suppose that you use an audioplayer object to play audio with MATLAB. To play audio, load audio data into MATLAB and create an audioplayer:

```
load('handel','Fs','y')
chorus = audioplayer(y,Fs);
```

The audioplayer function creates an object that you access using the object variable chorus. MATLAB stores the audio source and other information in the object properties.

Here are the properties and values for the chorus instance of the audioplayer:

```
chorus =
```

Click the link to get the documentation on audioplayer objects.

The object’s documentation discusses the purpose of the object and describes the properties and methods that you use when working with objects of that class.

You can also list the methods to see what operations you can perform. Pass the object to the methods function to see the list:

```
methods(chorus)
```

Methods for class audioplayer:

```
audioplayer  getdisp   pause   resume   stop
delete       horzcat   play     set       vertcat
get           isplaying playblocking setdisp
```

To play the audio, use the play method:

```
play(chorus)
```
Functions to Test Objects
These functions provide logical tests, which are useful when using objects in ordinary functions.

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<tr>
<td>a == b (eq)</td>
<td>Determine if handle variable a refers to the same object as handle variable b.</td>
</tr>
<tr>
<td>isobject</td>
<td>Determine whether input is a MATLAB object</td>
</tr>
</tbody>
</table>

Functions to Query Class Components
These functions provide information about object class components.

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>class</td>
<td>Return class of object.</td>
</tr>
<tr>
<td>enumeration</td>
<td>Display class enumeration members and names.</td>
</tr>
<tr>
<td>events</td>
<td>List event names defined by the class.</td>
</tr>
<tr>
<td>methods</td>
<td>List methods implemented by the class.</td>
</tr>
<tr>
<td>methodsview</td>
<td>List methods in separate window.</td>
</tr>
<tr>
<td>properties</td>
<td>List class property names.</td>
</tr>
</tbody>
</table>

See Also

Related Examples
- “Class Syntax Guide”
Use of Editor and Debugger with Classes

In this section...

“Write Class Code in the Editor” on page 5-37
“How to Refer to Class Files” on page 5-37
“How to Debug Class Files” on page 5-37

Write Class Code in the Editor

The MATLAB code editor provides an effective environment for class development. The Code Analyzer, which is built into the editor, check code for problems and provides information on fixing these problems. For information on editor use and features, see edit.

How to Refer to Class Files

Define classes in files just like scripts and functions. To use the editor or debugger with a class file, use the full class name. For example, suppose the file for a class, myclass.m is in the following location:

+PackFld1/+PackFld2/@myclass/myclass.m

To open myclass.m in the MATLAB editor, you could reference the file using dot-separated package names:

edit PackFld1.PackFld2.myclass

You could also use path notation:

edit +PackFld1/+PackFld2/@myclass/myclass

If myclass.m is not in a class folder, then enter:

edit +PackFld1/+PackFld2/myclass

To refer to functions inside a package folder, use dot or path separators:

edit PackFld1.PackFld2.packFunction
edit +PackFld1/+PackFld2/packFunction

To refer to a method defined in its own file inside a class folder, use:

edit +PackFld1/+PackFld2/@myclass/myMethod

How to Debug Class Files

For debugging, dbstop enables you to set breakpoints in the class constructor by specifying the fully qualified class file name. To set a breakpoint at a method defined in the class file, specify the line number of the method with the dbstop command. For example, if the method begins on line 14 in the classdef file, myclass.m, use this command to put a breakpoint on the first executable line of the method.

dbstop in myclass at 14
See “Automatic Updates for Modified Classes” on page 5-39 for information about clearing class after modification.

See Also
dbstop

Related Examples
• “MATLAB Code Analyzer Warnings” on page 5-27
• “Debug a MATLAB Program”
Automatic Updates for Modified Classes

In this section...

<table>
<thead>
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<th>Link</th>
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<tr>
<td>“Consequences of Automatic Update” on page 5-39</td>
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<tr>
<td>“What Happens When Class Definitions Change” on page 5-39</td>
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<td>“Actions That Do Not Trigger Updates” on page 5-40</td>
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<tr>
<td>“Multiple Updates to Class Definitions” on page 5-40</td>
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<td>“Updates to Method Definitions” on page 5-42</td>
</tr>
<tr>
<td>“Updates to Event Definitions” on page 5-43</td>
</tr>
</tbody>
</table>

When MATLAB Loads Class Definitions

MATLAB loads a class definition:

- The first time the class is referenced, such as creating an instance, accessing a constant property, or calling a static method of the class.
- Whenever the definition of a loaded class changes and MATLAB returns to the command prompt.
- When you change the MATLAB path and cause a different definition of the class to be used. The change takes effect after MATLAB returns to the command prompt.
- Whenever you access the class metadata.

MATLAB allows only one definition for a class to exist at any time. Therefore, MATLAB attempts to update all existing objects of a class automatically to conform to the new class definition. You do not need to call `clear classes` to remove existing objects when you change their defining class.

**Note** Using an editor other than the MATLAB editor or using MATLAB Online™ can result in delays to automatic updating.

Consequences of Automatic Update

MATLAB follows a set of basic rules when updating existing objects. An automatic update can result in:

- Existing objects being updated to the new class definition.
- An error if MATLAB cannot convert the objects to the new class definition or if there is an error in the class definition itself.

Here is an example of what happens when you create an instance of a concrete class edit the class definition to make the class abstract.
a = MyClass;
% Edit MyClass to make it Abstract
a

Error using MyClass/display
Cannot update object because the class 'MyClass' is now abstract.

Note MATLAB does not update metaclass instances when you change the definition of a class. You must get new metaclass data after updating a class definition.

What Happens When Class Definitions Change

MATLAB updates existing objects when a class definition changes, including the following situations:

- Value change to handle — Existing objects become independent handles referring to different objects.
- Enumeration member added — Existing objects preserve the enumeration members they had previously, even if the underlying values have changed.
- Enumeration member removed — Existing objects that are not using the removed member have the same enumeration members that they had previously. Existing objects that use the removed member replace the removed member with the default member of the enumeration.
- Enumeration block removed — Enumeration members are taken out of use.
- Superclass definition changed — Changes applied to all subclasses in the hierarchy of that superclass.
- Superclass added or removed — Change of superclass applied to all existing objects.

Actions That Do Not Trigger Updates

These actions do not update existing objects:

- Calling the class function on an out-of-date object
- Assigning an out-of-date object to a variable
- Calling a method that does not access class data
- Changing property validation in the class definition (“Validate Property Values” on page 8-20)

Objects do not update until referenced in a way that exposes the change, such as invoking the object display or assigning to a property.

Multiple Updates to Class Definitions

Updates do not occur incrementally. Updates conform to the latest version of the class.

Object Validity with Deleted Class File

Deleting a class definition file does not make instances of that class invalid. However, you cannot call methods on existing objects of that class.
When Updates Are Not Possible

Some class updates result in an invalid class definition. In these cases, objects do not update until the error is resolved:

- Adding a superclass can result in a property or method being defined twice.
- Changing a superclass to be Sealed when objects of one of its subclasses exists results in an invalid subclass definition.

Some class updates cause situations in which MATLAB cannot update existing objects to conform to a modified class definition. These cases result in errors until you delete the objects:

- Adding an enumeration block to a non-enumeration class
- Redefining a class to be abstract
- Removing a class from a heterogeneous hierarchy that results in there being no default object to replace existing objects in a heterogeneous array
- Updating a class to restrict array formation behavior, such as overloading array indexing and concatenation.
- Inheriting a subsref, subsasgn, cat, vertcat, or horzcat method
- Redefining a handle class to be a value class.

Potential Consequences of Class Updates

- Following an update, existing objects can be incompatible with the new class definition. For example, a newly added property can require execution of the constructor to be valid.
- Removing or renaming properties can lose the data held in the property. For example, if a property holds the only reference to another object and you remove that property from the class, the MATLAB deletes the object because there are no longer any references to it.
- Removing a class from a heterogeneous class hierarchy can result in invalid heterogeneous array elements. In this case, the default object for the heterogeneous hierarchy replaces these array elements.

Updates to Class Attributes

Changing class attributes can change existing object behavior or make the objects invalid. MATLAB returns an error when you access the invalid objects.

<table>
<thead>
<tr>
<th>Change</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Make Abstract = true</td>
<td>Accessing existing objects returns an error.</td>
</tr>
<tr>
<td>Change AllowedSubclasses</td>
<td>Newly created objects can inherit from different superclasses than existing objects.</td>
</tr>
<tr>
<td>Change ConstructOnLoad</td>
<td>Loading classes obeys the current value of ConstructOnLoad.</td>
</tr>
<tr>
<td>Change HandleCompatible</td>
<td>Newly created objects can have different class hierarchy than existing objects.</td>
</tr>
<tr>
<td>Change Hidden</td>
<td>Appearance of class in list of superclasses and access by help function can change</td>
</tr>
</tbody>
</table>
### Updates to Property Definitions

When you change the definition of class properties, MATLAB applies the changes to existing objects of the class.

<table>
<thead>
<tr>
<th>Change</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change InferiorClasses</td>
<td>Method dispatching for existing objects can change.</td>
</tr>
<tr>
<td>Make Sealed = true</td>
<td>Existing subclass objects return errors when accessed.</td>
</tr>
</tbody>
</table>

**Add property**
- Adds the new property to existing objects of the class. Sets the property values to the default value (which is [ ] if the class definition does not specify a default).

**Remove property**
- Removes the property from existing objects of the class. Attempts to access the removed property fail.

**Change property default value**
- Does not apply the new default value to existing objects of the class.

**Move property between subclass and superclass**
- Does not apply different default value when property definition moves between superclass and subclass.

**Change property attribute value**
- Applies changes to existing objects of the class.

Some cases require transitional steps:
- **Abstract** — Existing objects of a class that becomes abstract cannot be updated. Delete these objects.
- **Access** — Changes to the public, protected, or private property access settings affect access to existing objects. Changes to the access lists do not change existing objects. However, if you add classes to the access list, instances of those classes have access to this property. If you remove classes from the access list, objects of those classes no longer have access to this property.
- **Dependent** — If changed to true, existing objects no longer store property values. If you want to query the property value, add a property get method for the property.
- **Transient** — If changed to true, objects already saved, reload this property value. If changed to false, objects already saved reload this property using the default value.

### Updates to Method Definitions

When you change the definition of class methods, MATLAB changes the affected class member in existing objects as follows.

<table>
<thead>
<tr>
<th>Change</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add method</td>
<td>You can call the new method on existing objects of the class.</td>
</tr>
</tbody>
</table>
### Updates to Event Definitions

<table>
<thead>
<tr>
<th>Change</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add event</td>
<td>Existing objects of the class support the new event.</td>
</tr>
<tr>
<td>Change event name</td>
<td>New event name is visible to existing objects of the class. MATLAB:</td>
</tr>
<tr>
<td></td>
<td>• Does not update existing metaclass objects</td>
</tr>
<tr>
<td></td>
<td>• Does update newly acquired metaclass objects</td>
</tr>
<tr>
<td></td>
<td>• Does not update listeners to use new event name</td>
</tr>
<tr>
<td>Remove event</td>
<td>Existing objects no longer support deleted event.</td>
</tr>
<tr>
<td>Change</td>
<td>Effect</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Change event attribute value</td>
<td>Apply changes to existing objects of the class.</td>
</tr>
<tr>
<td></td>
<td>Some cases require transitional steps:</td>
</tr>
<tr>
<td></td>
<td>• <strong>ListenAccess</strong> — Changes to event <em>public, protected</em>, or <em>private</em> listen access settings affect access to existing objects.</td>
</tr>
<tr>
<td></td>
<td>Changes to the access list do not change existing objects. However, if you add classes to the access list, objects of those classes can create listeners for this event. If you remove classes from the access list, objects of those classes are not allowed to create listeners for this event.</td>
</tr>
<tr>
<td></td>
<td>• <strong>NotifyAccess</strong> — Changes to event <em>public, protected</em>, or <em>private</em> notify access settings affect access to existing objects.</td>
</tr>
<tr>
<td></td>
<td>Changes to the access list do not change existing objects. However, if you add classes to the access list, instances of those classes can trigger this event. If you remove classes, objects of those classes are not able to trigger this event.</td>
</tr>
</tbody>
</table>

**See Also**

**Related Examples**

- “Use of Editor and Debugger with Classes” on page 5-37
Compatibility with Previous Versions

New Class-Definition Syntax Introduced with MATLAB Software Version 7.6

MATLAB software Version 7.6 introduces a new syntax for defining classes. This new syntax includes:

- The `classdef` keyword begins a block of class-definitions code. An `end` statement terminates the class definition.
- Within the `classdef` code block, `properties`, `methods`, and `events` are also keywords delineating where you define the respective class members.

Cannot Mix Class Hierarchy

It is not possible to create class hierarchies that mix classes defined before Version 7.6 and current class definitions that use `classdef`. Therefore, you cannot subclass an old class to create a version of the new class.

Only One “@” Class Folder Per Class

For classes defined using the new `classdef` keyword, a class folder shadows all class folders that occur after it on the MATLAB path. Classes defined in class folders must locate all class files in that single folder. However, classes defined in class folders continue to take precedence over functions and scripts having the same name, even those functions and scripts that come before them on the path.

Private Methods

You do not need to define private folders in class folders in Version 7.6. You can set the method’s `Access` attribute to `private` instead.

Changes to Class Constructors

Class constructor methods have two major differences. Class constructors:

- Do not use the `class` function.
- Must call the superclass constructor only if you want to pass arguments to its constructor. Otherwise, no call to the superclass constructor is necessary.

Example of Old and New Syntax

Compare the following two `Stock` constructor methods. The `Stock` class is a subclass of the `Asset` class, which requires arguments passed to its constructor.

Constructor Function Before Version 7.6
function s = Stock(description, num_shares, share_price)
    s.NumShares = num_shares;
    s.SharePrice = share_price;
    % Construct Asset object
    a = Asset(description, 'stock', share_price*num_shares);
    % Use the class function to define the stock object
    s = class(s, 'Stock', a);
end % End of function

Write the same Stock class constructor as shown here. Define the inheritance on the classdef line
and define the constructor within a methods block.

Constructor Function for Version 7.6

classdef Stock < Asset
    ...
    methods
        function s = Stock(description, num_shares, share_price)
            % Call superclass constructor to pass arguments
            s = s@Asset(description, 'stock', share_price*num_shares);
            s.NumShares = num_shares;
            s.SharePrice = share_price;
            end % End of function
    end % End of methods block
    end % End of classdef block

New Features Introduced with Version 7.6

- Properties: “Ways to Use Properties” on page 8-2
- Handle classes: “Comparison of Handle and Value Classes” on page 7-2
- Events and listeners: “Event and Listener Concepts” on page 11-12
- Class member attributes: “Attribute Specification” on page 5-18
- Abstract classes: “Abstract Classes and Class Members” on page 12-72
- Dynamic properties: “Dynamic Properties — Adding Properties to an Instance” on page 8-54
- Ability to subclass MATLAB built-in classes: “Design Subclass Constructors” on page 12-7
- Packages for scoping functions and classes: “Packages Create Namespaces” on page 6-20.
  MATLAB does not support packages for classes created before MATLAB Version 7.6 (that is, classes that do not use classdef).
- The JIT/Accelerator supports objects defined only by classes using classdef.

Examples of Old and New

The MATLAB Version 7.6 implementation of classes uses different syntax from previous releases. However, classes written in previous versions continue to work. Most of the code you use to implement the methods is likely to remain the same, except where you take advantage of new features.

The following sections reimplement examples using the latest syntax. The original MATLAB Classes and Objects documentation implemented these same examples and provide a comparison of old and new syntax.
“Representing Polynomials with Classes” on page 19-2

“A Class Hierarchy for Heterogeneous Arrays” on page 20-2
Comparison of MATLAB and Other OO Languages

In this section...

<table>
<thead>
<tr>
<th>Some Differences from C++ and Java Code on page 5-48</th>
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<tr>
<td>Object Modification on page 5-49</td>
</tr>
<tr>
<td>Static Properties on page 5-52</td>
</tr>
<tr>
<td>Common Object-Oriented Techniques on page 5-52</td>
</tr>
</tbody>
</table>

Some Differences from C++ and Java Code

The MATLAB programming language differs from other object-oriented languages, such as C++ or Java in some important ways.

Public Properties

Unlike fields in C++ or the Java language, you can use MATLAB properties to define a public interface separate from the implementation of data storage. You can provide public access to properties because you can define set and get access methods that execute automatically when assigning or querying property values. For example, the following statement:

```matlab
myobj.Material = 'plastic';
```

assigns the char vector plastic to the Material property of myobj. Before making the actual assignment, myobj executes a method called set.Material (assuming the class of myobj defines this method), which can perform any necessary operations. See “Property Access Methods” on page 8-39 for more information on property access methods.

You can also control access to properties by setting attributes, which enable public, protected, or private access. See “Property Attributes” on page 8-7 for a full list of property attributes.

No Implicit Parameters

In some languages, one object parameter to a method is always implicit. In MATLAB, objects are explicit parameters to the methods that act on them.

Dispatching

In MATLAB classes, method dispatching is not based on method signature, as it is in C++ and Java code. When the argument list contains objects of equal precedence, MATLAB uses the leftmost object to select the method to call.

However, if the class of an argument is superior to the class of the other arguments, MATLAB dispatches to the method of the superior argument, regardless of its position within the argument list.

See “Class Precedence” on page 6-18 for more information.

Calling Superclass Method

- In C++, you call a superclass method using the scoping operator: `superclass::method`
- In Java code, you use: `superclass.method`
The equivalent MATLAB operation is `method@superclass`.

**Other Differences**

In MATLAB classes, there is no equivalent to C++ templates or Java generics. However, MATLAB is weakly typed and it is possible to write functions and classes that work with different types of data.

MATLAB classes do not support overloading functions using different signatures for the same function name.

**Object Modification**

MATLAB classes can define public properties, which you can modify by explicitly assigning values to those properties on a given instance of the class. However, only classes derived from the `handle` class exhibit reference behavior. Modifying a property value on an instance of a value class (classes not derived from `handle`), changes the value only within the context in which the modification is made.

The sections that follow describe this behavior in more detail.

**Objects Passed to Functions**

MATLAB passes all variables by value. When you pass an object to a function, MATLAB copies the value from the caller into the parameter variable in the called function.

However, MATLAB supports two kinds of classes that behave differently when copied:

- Handle classes — a handle class instance variable refers to an object. A copy of a handle class instance variable refers to the same object as the original variable. If a function modifies a handle object passed as an input argument, the modification affects the object referenced by both the original and copied handles.

- Value classes — the property data in an instance of a value class are independent of the property data in copies of that instance (although, a value class property could contain a handle). A function can modify a value object that is passed as an input argument, but this modification does not affect the original object.

See “Comparison of Handle and Value Classes” on page 7-2 for more information on the behavior and use of both kinds of classes.

**Passing Value Objects**

When you pass a value object to a function, the function creates a local copy of the argument variable. The function can modify only the copy. If you want to modify the original object, return the modified object and assign it to the original variable name. For example, consider the value class, `SimpleClass`:

```matlab
classdef SimpleClass
    properties
        Color
    end
    methods
        function obj = SimpleClass(c)
            if nargin > 0
                obj.Color = c;
            end
```
Create an instance of SimpleClass, assigning a value of red to its Color property:

\[
\text{obj} = \text{SimpleClass('red');}
\]

Pass the object to the function \( g \), which assigns blue to the Color property:

\[
\text{function } y = g(x) \\
\quad x.\text{Color} = '\text{blue}'; \\
\quad y = x; \\
\end{function}
\]

\[
\text{y} = g(\text{obj});
\]

The function \( g \) modifies its copy of the input object and returns that copy, but does not change the original object.

\[
\text{y.Color}
\]
\[
\text{ans} =
\]
\[
\text{blue}
\]

\[
\text{obj.Color}
\]
\[
\text{ans} =
\]
\[
\text{red}
\]

If the function \( g \) did not return a value, the modification of the object Color property would have occurred only on the copy of \( \text{obj} \) within the function workspace. This copy would have gone out of scope when the function execution ended.

Overwriting the original variable actually replaces it with a new object:

\[
\text{obj} = g(\text{obj});
\]

**Passing Handle Objects**

When you pass a handle to a function, the function makes a copy of the handle variable, just like when passing a value object. However, because a copy of a handle object refers to the same object as the original handle, the function can modify the object without having to return the modified object.

For example, suppose that you modify the SimpleClass class definition to make a class derived from the handle class:

\[
\text{classdef SimpleHandleClass < handle}
\]
\[
\quad \text{properties}
\]
\[
\quad \quad \text{Color}
\]
\[
\quad \end{function}
\]
\[
\quad \text{methods}
\]
\[
\quad \quad \text{function } \text{obj} = \text{SimpleHandleClass}(c)
\]
\[
\quad \quad \quad \text{if } \text{nargin} > 0
\]
\[
\quad \quad \quad \quad \text{obj.Color} = c;
\]
\[
\quad \quad \end{function}
\]

\[
\text{obj} = \text{SimpleHandleClass}('\text{red}');
\]

\[
\text{Pass the object to the function } g, \text{ which assigns blue to the Color property:}
\]

\[
\text{function } y = g(x)
\]
\[
\quad x.\text{Color} = '\text{blue}';
\]
\[
\quad y = x;
\]
\[
\end{function}
\]

\[
\text{y} = g(\text{obj});
\]

The function \( g \) modifies its copy of the input object and returns that copy, but does not change the original object.

\[
\text{y.Color}
\]
\[
\text{ans} =
\]
\[
\text{blue}
\]

\[
\text{obj.Color}
\]
\[
\text{ans} =
\]
\[
\text{red}
\]

If the function \( g \) did not return a value, the modification of the object Color property would have occurred only on the copy of \( \text{obj} \) within the function workspace. This copy would have gone out of scope when the function execution ended.

Overwriting the original variable actually replaces it with a new object:

\[
\text{obj} = g(\text{obj});
\]
Create an instance of `SimpleHandleClass`, assigning a value of `red` to its `Color` property:

```matlab
obj = SimpleHandleClass('red');
```

Pass the object to the function `g`, which assigns `blue` to the `Color` property:

```matlab
y = g(obj);
```

The function `g` sets the `Color` property of the object referred to by both the returned handle and the original handle:

```matlab
y.Color
ans =
blue

obj.Color
ans =
blue
```

The variables `y` and `obj` refer to the same object:

```matlab
y.Color = 'yellow';
obj.Color
ans =
yellow
```

The function `g` modified the object referred to by the input argument (`obj`) and returned a handle to that object in `y`.

**MATLAB Passes Handles by Value**

A handle variable is a reference to an object. MATLAB passes this reference by value.

Handles do not behave like references in C++. If you pass an object handle to a function and that function assigns a different object to that handle variable, the variable in the caller is not affected. For example, suppose you define a function `g2`:

```matlab
function y = g2(x)
    x = SimpleHandleClass('green');
    y = x;
end
```

Pass a handle object to `g2`:

```matlab
obj = SimpleHandleClass('red');
y = g2(obj);
y.Color
ans =
green
```
obj.Color  
an = red

The function overwrites the handle passed in as an argument, but does not overwrite the object referred to by the handle. The original handle obj still references the original object.

**Static Properties**

In MATLAB, classes can define constant properties, but not "static" properties in the sense of other languages like C++. You cannot change constant properties from the initial value specified in the class definition.

MATLAB has long-standing rules that variables always take precedence over the names of functions and classes. Assignment statements introduce a variable if one does not exist.

Expressions of this form

A.B = C

Introduce a new variable, A, that is a struct containing a field B whose value is C. If A.B = C could refer to a static property of class A, then class A would take precedence over variable A.

This behavior would be a significant incompatibility with prior releases of MATLAB. For example, the introduction of a class named A on the MATLAB path could change the meaning of an assignment statement like A.B = C inside a .m code file.

In other languages, classes rarely use static data, except as private data within the class or as public constants. In MATLAB, you can use constant properties the same way you use public final static fields in Java. To use data that is internal to a class in MATLAB, create persistent variables in private or protected methods or local functions used privately by the class.

Avoid static data in MATLAB. If a class has static data, using the same class in multiple applications causes conflicts among applications. Conflicts are less of an issue in some other languages. These languages compile applications into executables that run in different processes. Each process has its own copy of the class static data. MATLAB, frequently runs many different applications in the same process and environment with a single copy of each class.

For ways to define and use static data in MATLAB, see “Static Data” on page 4-2.

**Common Object-Oriented Techniques**

This table provides links to sections that discuss object-oriented techniques commonly used by other object-oriented languages.

<table>
<thead>
<tr>
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User-Defined Classes

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What Is a Class Definition

A MATLAB class definition is a template whose purpose is to provide a description of all the elements that are common to all instances of the class. Class members are the properties, methods, and events that define the class.

Define MATLAB classes in code blocks, with subblocks delineating the definitions of various class members. For syntax information on these blocks, see “Class Components” on page 5-4.

Attributes for Class Members

Attributes modify the behavior of classes and the members defined in the class-definition block. For example, you can specify that methods are static or that properties are private. The following sections describe these attributes:

- “Class Attributes” on page 6-5
- “Method Attributes” on page 9-4
- “Property Attributes” on page 8-7
- “Event Attributes” on page 11-16

Class definitions can provide information, such as inheritance relationships or the names of class members without actually constructing the class. See “Class Metadata” on page 16-2.

See “Specifying Attributes” on page 6-7 for more on attribute syntax.

Kinds of Classes

There are two kinds of MATLAB classes—handle classes and value classes.

- Value classes represent independent values. Value objects contain the object data and do not share this data with copies of the object. MATLAB numeric types are value classes. Values objects passed to and modified by functions must return a modified object to the caller.
- Handle classes create objects that reference the object data. Copies of the instance variable refer to the same object. Handle objects passed to and modified by functions affect the object in the caller’s workspace without returning the object.

For more information, see “Comparison of Handle and Value Classes” on page 7-2.
Constructing Objects

For information on class constructors, see “Class Constructor Methods” on page 9-16.

For information on creating arrays of objects, see “Construct Object Arrays” on page 10-2.

Class Hierarchies

For more information on how to define class hierarchies, see “Hierarchies of Classes — Concepts” on page 12-2.

classdef Syntax

Class definitions are blocks of code that are delineated by the classdef keyword at the beginning and the end keyword at the end. Files can contain only one class definition.

The following diagram shows the syntax of a classdef block. Only comments and blank lines can precede the classdef keyword.

classdef keyword begins definition block.

classdef (ConstructOnLoad = true) PositiveIntegers < Integers & Positives

end keyword terminates definition block.

Class Code

Here is a simple class definition with one property and a constructor method that sets the value of the property when there is an input argument supplied.

classdef MyClass
    properties
        Prop
    end
    methods
        function obj = MyClass(val)
            if nargin > 0
                obj.Prop = val;
            end
        end
end
To create an object of `MyClass`, save the class definition in a `.m` file having the same name as the class and call the constructor with any necessary arguments:

```matlab
d = datestr(now);
o = MyClass(d);
```

Use dot notation to access the property value:

```matlab
o.Prop
```

```
ans =
10-Nov-2005 10:38:14
```

The constructor should support a no argument syntax so MATLAB can create default objects. For more information, see “No Input Argument Constructor Requirement” on page 9-19.

For more information on the components of a class definition, see “Class Components” on page 5-4

**See Also**

**Related Examples**

- “Create a Simple Class” on page 2-2
- “Developing Classes — Typical Workflow” on page 3-6
- “Representing Structured Data with Classes” on page 3-14
Class Attributes

In this section...

“Specifying Class Attributes” on page 6-5
“Specifying Attributes” on page 6-7
“Class-Specific Attributes” on page 6-7

Specifying Class Attributes

All classes support the attributes listed in the following table. Attributes enable you to modify the behavior of class. Attribute values apply to the class defined within the classdef block.

```matlab
classdef (Attribute1 = value1, Attribute2 = value2,...) ClassName
    ...
end
```

For more information on attribute syntax, see “Attribute Specification” on page 5-18.
## Class Attributes

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>logical</td>
<td>If specified as <code>true</code>, this class is an abstract class (cannot be instantiated). See “Abstract Classes and Class Members” on page 12-72 for more information.</td>
</tr>
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</table>
| AllowedSubclasses| meta.class object or cell array of meta.class objects | List classes that can subclass this class. Specify subclasses as meta.class objects in the form:  
  • A single meta.class object  
  • A cell array of meta.class objects. An empty cell array, {}, is the same as a Sealed class (no subclasses).  
  Specify meta.class objects using the `?ClassName` syntax only. See “Specify Allowed Subclasses” on page 12-20 for more information. |
| ConstructOnLoad  | logical                    | If `true`, MATLAB calls the class constructor when loading an object from a MAT-file. Therefore, implement the constructor so it can be called with no arguments without producing an error. See “Initialize Objects When Loading” on page 13-22 for more information. |
| HandleCompatible | logical                    | If specified as `true`, this class can be used as a superclass for handle classes. All handle classes are HandleCompatible by definition. See “Handle Compatible Classes” on page 12-32 for more information. |
| Hidden           | logical                    | If `true`, this class does not appear in the output of the superclasses or help functions. |
| InferiorClasses  | meta.class object or cell array of meta.class objects | Use this attribute to establish a precedence relationship among classes. Specify a cell array of meta.class objects using the `?` operator.  
  The fundamental classes are always inferior to user-defined classes and do not show up in this list. See “Class Precedence” on page 6-18 and “Dominant Argument in Overloaded Graphics Functions” on page 9-38. |
| Sealed           | logical                    | If `true`, this class cannot be subclassed. |
| Framework attributes | Classes that use certain framework base classes have framework-specific attributes. See the documentation for the specific base class you are using for information on these attributes. |
Specifying Attributes

Attributes are specified for class members in the `classdef`, `properties`, `methods`, and `events` definition blocks. The particular attribute setting applies to all members defined within that particular block. You can use multiple `properties`, `methods`, and `events` definition blocks to apply different attribute setting to different class members.

Superclass Attribute Values Are Not Inherited

Class attributes settings are not inherited, so superclass attribute values do not affect subclasses.

Attribute Syntax

Specify class attribute values in parentheses, separating each attribute name/attribute value pair with a comma. The attribute list always follows the `classdef` or class member keyword, as shown:

```matlab
classdef (attribute-name = expression, ...) ClassName
    properties (attribute-name = expression, ...) ...
    end
    methods (attribute-name = expression, ...) ...
    end
    events (attribute-name = expression, ...) ...
    end
end
```

Class-Specific Attributes

Some MATLAB classes define additional attributes that you can use only with the class hierarchies that define these attributes. See the specific documentation for the classes you are using for information on any additional attributes supported by those classes.

See Also

More About
- “Expressions in Attribute Specifications” on page 6-9
Evaluation of Expressions in Class Definitions

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<tr>
<td>“Expression Evaluation in Handle and Value Classes” on page 6-10</td>
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</table>

Why Use Expressions

An expression used in a class definition can be any valid MATLAB statement that evaluates to a single array. Use expressions to define property default values and in attribute specifications. Expressions are useful to derive values in terms of other values. For example, suppose that you want to define a constant property with the full precision value of \( 2 \pi \). You can assign the property the value returned by the expression \( 2 \pi \). MATLAB evaluates the function when first loading the class.

For information on assign property default values and attribute values, see the following topics:

- “Property Definition” on page 8-13
- “Attribute Specification” on page 5-18

Where to Use Expressions in Class Definitions

Here are some examples of expressions used in a class definition:

```matlab
classdef MyClass
    % Some attributes are set to logical values
    properties (Constant = true)
        CnstProp = 2*pi
    end
    properties
        % Static method of this class
        Prop1 = MyClass.setupAccount
        % Constant property from this class
        Prop2 = MyClass.CnstProp
        % Function that returns a value
        Prop3 = datestr(now)
        % A class constructor
        Prop4 = AccountManager
    end
    methods (Static)
        function accNum = setupAccount
            accNum = randi(9,[1,12]);
        end
    end
end
```

MATLAB does not call property set methods when assigning the result of default value expressions to properties. (See “Property Access Methods” on page 8-39 for information about these special methods.)
Enumerations that derived from MATLAB types can use expression to assign a value:

```matlab
classdef FlowRate < int32
    enumeration
        Low    (10)
        Medium (FlowRate.Low*5)
        High   (FlowRate.Low*10)
    end
end
```

MATLAB evaluates these expressions only once when enumeration members are first accessed.

**Expressions in Attribute Specifications**

For attributes values that are logical true or false, class definitions can specify attribute values using expressions. For example, this assignment makes MyClass sealed (cannot be subclassed) for versions of MATLAB before R2014b (verLessThan)

```matlab
classdef MyClass
    inherits (Sealed = verLessThan('matlab','8.4'))
end
```

The expression on the right side of the equal sign (=) must evaluate to true or false. You cannot use any definitions from the class file in this expression, including any constant properties, static methods, and local functions.

While you can use conditional expression to set attribute values, doing so can cause the class definition to change based on external conditions. Ensure that this behavior is consistent with your class design.

**Note** The AllowedSubclasses and the InferiorClasses attributes require an explicit specification of a cell array of meta.class objects as their values. You cannot use expressions to return these values.

See “Attribute Specification” on page 5-18 for more information on attribute syntax.

**Expressions That Specify Default Property Values**

Property definitions allow you to specify default values for properties using any expression that has no reference to variables. For example, VectorAngle defines a constant property (Rad2Deg) and uses it in an expression that defines the default value of another property (Angle). The default value expression also uses a static method (getAngle) defined by the class:

```matlab
classdef VectorAngle
    properties (Constant)
        Rad2Deg = 180/pi
    end
    properties
        Angle = VectorAngle.Rad2Deg*VectorAngle.getAngle([1 0],[0 1])
    end
    methods
        function obj = VectorAngle(vx,vy)
            obj.Angle = VectorAngle.getAngle(vx,vy);
        end
    methods (Static)
        function r = getAngle(vx,vy)
```
% Calculate angle between 2D vectors
cr = vx(1)*vy(1) + vx(2)*vy(2)/sqrt(vx(1)^2 + vx(2)^2) * ...
sqrt(vy(1)^2 + vy(2)^2);
r = acos(cr);
end
end
end

You cannot use the input variables to the constructor to define the default value of the Angle property. For example, this definition for the Angle property is not valid:

```matlab
properties
    Angle = VectorAngle.Rad2Deg*VectorAngle.getAngle(vx,vy)
end
```

Attempting to create an instance causes an error:

```matlab
a = VectorAngle([1,0],[0,1])
```

Error using `VectorAngle`
Unable to update the class 'VectorAngle' because the new definition contains an error:
Undefined function or variable 'vx'.

**Expressions in Class Methods**

Expression in class methods execute like expressions in any function. MATLAB evaluates an expression within the function workspace when the method executes. Therefore, expressions used in class methods are not considered part of the class definition and are not discussed in this section.

**How MATLAB Evaluates Expressions**

MATLAB evaluates the expressions used in the class definition without any workspace. Therefore, these expressions cannot reference variables of any kind.

MATLAB evaluates expressions in the context of the class file, so these expressions can access any functions, static methods, and constant properties of other classes that are on your path at the time MATLAB initializes the class. Expressions defining property default values can access constant properties defined in their own class.

**When MATLAB Evaluates Expressions**

MATLAB evaluates the expressions in class definitions only when initializing the class. Initialization occurs before the first use of the class.

After initialization, the values returned by these expressions are part of the class definition and are constant for all instances of the class. Each instance of the class uses the results of the initial evaluation of the expressions without re-evaluation.

If you clear a class, then MATLAB reinitializes the class by reevaluating the expressions that are part of the class definition. (see “Automatic Updates for Modified Classes” on page 5-39)

**Expression Evaluation in Handle and Value Classes**

The following example shows how value and handle object behave when assigned to properties as default values. Suppose that you have the following classes.
Expressions in Value Classes

The `ClassExp` class has a property that contains a `ContClass` object:

```matlab
classdef ContClass
    properties
        % Assign current date and time
        TimeProp = datestr(now)
    end
end

classdef ClassExp
    properties
        ObjProp = ContClass
    end
end
```

When you first use the `ClassExp` class, MATLAB creates an instance of the `ContClass` class. MATLAB initializes both classes at this time. All instances of `ClassExp` include a copy of this same instance of `ContClass`.

```matlab
a = ClassExp;
a.ObjProp.TimeProp
```

```matlab
ans = 08-Oct-2003 17:16:08
```

The `TimeProp` property of the `ContClass` object contains the date and time when MATLAB initialized the class. Creating additional instances of the `ClassExp` class shows that the date string has not changed:

```matlab
b = ClassExp;
b.ObjProp.TimeProp
```

```matlab
ans = 08-Oct-2003 17:16:08
```

Because this example uses a value class for the contained object, each instance of the `ClassExp` has its own copy of the object. For example, suppose that you change the value of the `TimeProp` property on the object contained by `ClassExp` object `b`:

```matlab
b.ObjProp.TimeProp = datestr(now)
```

```matlab
ans = 08-Oct-2003 17:22:49
```

The copy of the object contained by object `a` is unchanged:

```matlab
a.ObjProp.TimeProp
```

```matlab
ans = 08-Oct-2003 17:16:08
```
Expressions in Handle Classes

Now consider the behavior if the contained object is a handle object:

```matlab
classdef ContClass < handle
    properties
        TimeProp = datestr(now)
    end
end
```

Creating two instances of the `ClassExp` class shows that MATLAB created an object when it initialized the `ContClass`. MATLAB used a copy of the object’s handle for each instance of the `ClassExp` class. Therefore, there is one `ContClass` object and the `ObjProp` property of each `ClassExp` object contains a copy of its handle.

Create an instance of the `ClassExp` class and note the time of creation:

```matlab
a = ClassExp;
a.ObjProp.TimeProp
ans = 
08-Oct-2003 17:46:01
```

Create a second instance of the `ClassExp` class. The `ObjProp` contains the handle of the same object:

```matlab
b = ClassExp;
b.ObjProp.TimeProp
ans = 
08-Oct-2003 17:46:01
```

Reassign the value of the contained object `TimeProp` property:

```matlab
b.ObjProp.TimeProp = datestr(now);
b.ObjProp.TimeProp
ans = 
08-Oct-2003 17:47:34
```

The `ObjProp` property of object `b` contains a handle to the same object as the `ObjProp` property of object `a`. The value of the `TimeProp` property has changed on this object as well:

```matlab
a.ObjProp.TimeProp
ans =
08-Oct-2003 17:47:34
```

See Also

More About
- “Comparison of Handle and Value Classes” on page 7-2
Folders Containing Class Definitions

Class Definitions on the Path

To call a class method, the class definition must be on the MATLAB path, as described in the next sections.

Class and Path Folders

There are two types of folders that can contain class definition files.

- Path folders — The folder is on the MATLAB path and the folder name does not begin with an @ character. Use this type of folder when you want multiple classes in one folder. However, the entire class definition must be contained in one file.
- Class folders — The folder name begins with an @ character followed by the class name. The folder is not on the MATLAB path, but its parent folder is on the path. Use this type of folder when you want to use multiple files for one class definition.

See the path function for information about the MATLAB path.

Using Path Folders

The class definition files in the folders are on the MATLAB path. Therefore, class definitions placed in path folders behave like any ordinary function with respect to precedence—the first occurrence of a name on the MATLAB path takes precedence over all subsequent occurrences of the same name.

The name of each class definition file must match the name of the class that is specified with the classdef keyword. Using a path folder eliminates the need to create a separate class folder for each class. However, the entire class definition, including all methods, must be contained within a single file.

Suppose that you have three classes defined in a single folder:

.../path_folder/MyClass1.m
.../path_folder/MyClass2.m
.../path_folder/MyClass3.m

To use these classes, add path_folder to your MATLAB path:

addpath path_folder
Using Class Folders

A class folder name always begins with the @ character followed by the class name for the folder name. A class folder must be contained in a path folder, but the class folder is not on the MATLAB path. Place the class definition file inside the class folder, which also can contain separate method files. The class definition file must have the same name as the class folder (without the @ character). The class definition (beginning with the `classdef` keyword) must appear in the file before any other code (white space and comments do not constitute code).

```
.../parent_folder/@MyClass/MyClass.m
.../parent_folder/@MyClass/myMethod1.m
.../parent_folder/@MyClass/myMethod2.m
```

Define only one class per folder. All files have a `.m` extension or, for MATLAB versions R2018a and later, standalone methods can be live functions with a `.mlx` extension.

Use a class folder when you want to use more than one file for your class definition. MATLAB treats any function file in the class folder as a method of the class. Function files can be MATLAB code (.m), Live Code file format (.mlx), MEX functions (platform dependent extensions), and P-code files (.p).

Class files provide the advantage that MATLAB can explicitly identify any file in the folder as a method of that class. For more information, see “Changing Path to Update Class Definition” on page 6-16.

The base name of each file must be a valid MATLAB function name. Valid function names begin with an alphabetic character and can contain letters, numbers, or underscores. For more information, see “Methods in Separate Files” on page 9-8.

Functions in Private Folders Within Class Folders

Private folders contain functions that are accessible only from functions defined in folders immediately above the private folder. Any functions defined in a private folder inside a class folder become methods of the class that have private access.

If a class folder contains a private folder, only the class defined in that folder can access functions defined in the private folder. Subclasses do not have access to superclass private functions. For more information on private folders, see “Private Functions”.

If you want a subclass to have access to the private functions of the superclass, define the functions as protected methods of the superclass. Specify the methods with the `Access` attribute set to `protected`.

Dispatching to Methods in Private Folders

If a class defines functions in a private folder that is in a class folder, then MATLAB follows these precedence rules when dispatching to the private functions vs. a local function defined in the classdef file:

- Using dot notation (`obj.methodName`), a function in a private folder takes precedence over a local function defined in the classdef file.
- Using function notation (`methodName(obj)`), a local function defined in the classdef file takes precedence over the function in the private folder.
No Class Definitions in Private Folders

You cannot put class definitions (classdef file) in private folders because doing so would not meet the requirements for class or path folders.

Class Precedence and MATLAB Path

When there are multiple class definition files with the same name, the file location on the MATLAB path determines the file precedence. All class definition files before a class on the path take precedence, whether or not the definitions are contained in a class folder. The class takes precedence over all class definition files occurring later on the path.

For example, consider a path with the following folders, containing the files indicated.

<table>
<thead>
<tr>
<th>Order in Path</th>
<th>Folder and File</th>
<th>File Defines</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>fldr1/Foo.m</td>
<td>Class Foo</td>
</tr>
<tr>
<td>2</td>
<td>fldr2/Foo.m</td>
<td>Function Foo</td>
</tr>
<tr>
<td>3</td>
<td>fldr3/@Foo/Foo.m</td>
<td>Class Foo</td>
</tr>
<tr>
<td>4</td>
<td>fldr4/@Foo/bar.m</td>
<td>Method bar</td>
</tr>
<tr>
<td>5</td>
<td>fldr5/Foo.m</td>
<td>Class Foo</td>
</tr>
</tbody>
</table>

Here is the logic that MATLAB applies to determine which version of Foo to call:

Class fldr1/Foo.m takes precedence over the class fldr3/@Foo because:

- fldr1/Foo.m is before fldr3/@Foo on the path

Class fldr3/@Foo takes precedence over function fldr2/Foo.m because:

- fldr3/@Foo is a class in a class folder
- fldr2/Foo.m is not a class
- Classes in class folders take precedence over functions

Function fldr2/Foo.m takes precedence over class fldr5/Foo.m because:

- fldr2/Foo.m comes before class fldr5/Foo.m on the path
- fldr5/Foo.m is not in a class folder
- Classes that are not defined in class folders obey the path order with respect to functions.

Class fldr3/@Foo takes precedence over class fldr4/@Foo because:

- The method bar is not recognized as part of the Foo class defined in fldr3/@Foo.

If fldr3/@Foo/Foo.m does not contain a classdef keyword (that is, it is a MATLAB class created before Version 7.6), then fldr4/@Foo/bar.m becomes a method of the Foo class defined in fldr3/@Foo.

Previous Behavior of Classes Defined in Class Folders

In MATLAB Versions 5 through 7, class folders do not shadow other class folders having the same name, but residing in later path folders. Instead, the class uses the combination of methods from all class folders having the same name to define the class. This behavior is no longer supported.
For backward compatibility, classes defined in class folders always take precedence over functions and scripts having the same name. This precedence applies to functions and scripts that come before these classes on the path.

**Changing Path to Update Class Definition**

Changing your MATLAB path can change the class definition file for a class (see path). However, for classes that are defined in path folders (that is, not in class @ folders), you must clear the class before MATLAB recognizes the new folder as the current class definition.

**Class Definitions in Class Folders**

Suppose that you define two versions of a class named Foo in two folders, fldA and fldB.

```matlab
fldA/+FooPkg/@Foo/Foo.m
fldB/+FooPkg/@Foo/Foo.m
```

Add folder fldA to the top of the path.

```matlab
addpath fldA
```

Create an instance of class FooPkg.Foo. MATLAB uses fldA/+FooPkg/@Foo/Foo.m as the class definition.

```matlab
a = FooPkg.Foo;
```

Change the current folder to fldB.

```matlab
cd fldB
```

The current folder is always first on the path. Therefore, MATLAB finds fldB/+FooPkg/@Foo/Foo.m as the definition for class FooPkg.Foo.

```matlab
b = FooPkg.Foo;
```

MATLAB automatically updates the existing instance, a, to use the new class definition in fldB.

**Class Definitions in Path Folders**

Suppose that you define two versions of a class named Foo in two folders, fldA and fldB, but do not use a class folder.

```matlab
fldA/+FooPkg/Foo.m
fldB/+FooPkg/Foo.m
```

Add folder fldA to the top of the path.

```matlab
addpath fldA
```

Create an instance of class FooPkg.Foo. MATLAB uses fldA/+FooPkg/@Foo/Foo.m as the class definition.

```matlab
a = FooPkg.Foo;
```

Change the current folder to fldB.

```matlab
cd fldB
```
The current folder is effectively the top of the path. However, MATLAB does not identify `fldB/FooPkg/Foo.m` as the definition for class `FooPkg.Foo`. MATLAB continues to use the original class definition until you clear the class.

To use the definition of `FooPkg.Foo` in `fldB`, clear `FooPkg.Foo`.

```
clear FooPkg.Foo
```

MATLAB automatically updates the existing objects to conform to the class definition in `fldB`. Usually, clearing instance variables is unnecessary.

See Also

More About
- “Packages Create Namespaces” on page 6-20
- “Automatic Updates for Modified Classes” on page 5-39
- “Live Code File Format (.mlx)”
- “MEX File Functions”
- “Protect Your Source Code”
Class Precedence

Use of Class Precedence

MATLAB uses class precedence to determine which method to call when multiple classes have the same method. You can specify the relative precedence of user-defined classes with the class InferiorClasses attribute.

The material presented in this topic builds on an understanding of the following information:

• “Class Metadata” on page 16-2
• “Attribute Specification” on page 5-18

Why Mark Classes as Inferior

When more than one class defines methods with the same name or when classes overload functions, MATLAB determines which method or function to call based on the dominant argument. Here is how MATLAB determines the dominant argument:

1  Determine the dominant argument based on the class of arguments.
2  If there is a dominant argument, call the method of the dominant class.
3  If arguments are of equal precedence, use the leftmost argument as the dominant argument.
4  If the class of the dominant argument does not define a method with the name of the called function, call the first function on the path with that name.

InferiorClasses Attribute

Specify the relative precedence of user-defined classes using the class InferiorClasses attribute. To specify classes that are inferior to the class you are defining, assign a cell array of class meta.class objects to this attribute.

For example, the following classdef declares that MyClass is dominant over ClassName1 and ClassName2.

classdef (InferiorClasses = {?ClassName1,?ClassName2}) MyClass
    ...
end

The ? operator combined with a class name creates a meta.class object. See metaclass.

The following MATLAB classes are always inferior to classes defined using the classdef syntax and cannot be used in this list.

double, single, int64, uint64, int32, uint32, int16, uint16, int8, uint8, char, string, logical, cell, struct, and function_handle.
Dominant Class

MATLAB uses class dominance when evaluating expressions involving objects of more than one class. The dominant class determines:

- Which class method to call when more than one class defines methods with the same names.
- The class of arrays that are formed by combining objects of different classes, assuming MATLAB can convert the inferior objects to the dominant class.

No Attribute Inheritance

Subclasses do not inherit a superclass InferiorClasses attribute. Only classes specified in the subclass InferiorClasses attribute are inferior to subclass objects.

See Also

More About

- “Class Precedence and MATLAB Path” on page 6-15
- “Dominant Argument in Overloaded Graphics Functions” on page 9-38
Packages Create Namespaces

In this section...

“Package Folders” on page 6-20
“Internal Packages” on page 6-20
“Referencing Package Members Within Packages” on page 6-21
“Referencing Package Members from Outside the Package” on page 6-21
“Packages and the MATLAB Path” on page 6-22

Package Folders

Packages are special folders that can contain class folders, function, and class definition files, and other packages. The names of classes and functions are scoped to the package folder. A package is a namespace within which names must be unique. Function and class names must be unique only within the package. Using a package provides a means to organize classes and functions. Packages also enable you to reuse the names of classes and functions in different packages.

Note Packages are not supported for classes created before MATLAB Version 7.6 (that is, classes that do not use classdef).

Package folders always begin with the + character. For example,

+mypack
+mypack/pkfcn.m  % a package function
+mypack/@myClass % class folder in a package

The parent of the top-level package folder must be on the MATLAB path.

Listing the Contents of a Package

List the contents of a package using the help command:

help event

Contents of event:

EventData                      - event.EVENTDATA    Base class for event data
PropertyEvent                  - event.PROPERTYEVENT    Event data for object property events
listener                       - event.LISTENER    Listener object
proplistener                   - event.PROPLISTENER    Listener object for property events

You can also use the what command:

what event

Classes in directory Y:xxx\matlab\toolbox\matlab\lang\+event
EventData PropertyEvent listener proplistener

Internal Packages

MathWorks® reserves the use of packages named internal for utility functions used by internal MATLAB code. Functions that belong to an internal package are intended for MathWorks use only.
Using functions or classes that belong to an internal package is discouraged. These functions and classes are not guaranteed to work in a consistent manner from one release to the next. Any of these functions and classes might be removed from the MATLAB software in any subsequent release without notice and without documentation in the product release notes.

**Referencing Package Members Within Packages**

All references to packages, functions, and classes in the package must use the package name prefix, unless you import the package. (See “Import Classes” on page 6-24.) For example, call this package function:

```plaintext
+mypack/pkfcn.m
```

With this syntax:

```plaintext
z = mypack.pkfcn(x,y);
```

Definitions do not use the package prefix. For example, the function definition line of the pkfcn.m function would include only the function name:

```plaintext
function z = pkfcn(x,y)
```

Define a package class with only the class name:

```plaintext
classdef myClass
```

but call it with the package prefix:

```plaintext
obj = mypack.myClass(arg1,arg2,...);
```

Calling class methods does not require the package name because you have an object of the class. You can use dot or function notation:

```plaintext
obj.myMethod(arg)
myMethod(obj,arg)
```

A static method requires the full class name, which includes the package name:

```plaintext
mypack.myClass.stMethod(arg)
```

**Referencing Package Members from Outside the Package**

Functions, classes, and other packages contained in a package are scoped to that package. To reference any of the package members, prefix the package name to the member name, separated by a dot. For example, the following statement creates an instance of MyClass, which is contained in mypack package.

```plaintext
obj = mypack.MyClass;
```

**Accessing Class Members — Various Scenarios**

This section shows you how to access various package members from outside a package. Suppose that you have a package mypack with the following contents:

```plaintext
+mypack
+mypack/myfcn.m
```
Invoke the myFcn function in mypack:

```matlab
mypack.myFcn(arg)
```

Create an instance of each class in mypack:

```matlab
obj1 = mypack.MyFirstClass;
obj2 = mypack.MySecondClass(arg);
```

Invoke the myFcn function that is in the package mysubpack:

```matlab
mypack.mysubpack.myFcn(arg1,arg2);
```

If mypack.MyFirstClass has a method called myFcn, call it like any method call on an object:

```matlab
obj = mypack.MyFirstClass;
myFcn(obj,arg);
```

If mypack.MyFirstClass has a property called MyProp, assign it using dot notation and the object:

```matlab
obj = mypack.MyFirstClass;
obj.MyProp = x;
```

### Packages and the MATLAB Path

You cannot add package folders to the MATLAB path, but you must add the package parent folder to the MATLAB path. Package members are not accessible if the package parent folder is not on the MATLAB path, even if the package folder is the current folder. Making the package folder the current folder is not sufficient to add the package parent folder to the path.

Package members remain scoped to the package. Always refer to the package members using the package name. Alternatively, import the package into the function in which you call the package member, see “Import Classes” on page 6-24.

Package folders do not shadow other package folders that are positioned later on the path, unlike classes, which do shadow other classes. If two or more packages have the same name, MATLAB treats them all as one package. If redundantly named packages in different path folders define the same function name, then MATLAB finds only one of these functions.

### Resolving Redundant Names

Suppose a package and a class have the same name. For example:

```matlab
fldr_1/+foo
fldr_2/@foo/foo.m
```

A call to which foo returns the path to the executable class constructor:
A function and a package can have the same name. However, a package name by itself is not an identifier. Therefore, if a redundant name occurs alone, it identifies the function. Executing a package name alone returns an error.

**Package Functions vs. Static Methods**

In cases where a package and a class have the same name, a package function takes precedence over a static method. For example, path folder `fldrA` contains a package function and path folder `fldrB` contains a class static method:

```plaintext
fldrA/+foo/bar.m % bar is a function in package foo
fldrB/@foo/bar.m % bar is a static method of class foo
```

A call to `which foo.bar` returns the path to the package function:

```plaintext
which foo.bar
fldrA/+foo//bar.m  % package function
```

In cases where the same path folder contains both package and class folders with the same name, the package function takes precedence over the static method.

```plaintext
fldr/@foo/bar.m % bar is a static method of class foo
fldr/+foo/bar.m % bar is a function in package foo
```

A call to `which foo.bar` returns the path to the package function:

```plaintext
which foo.bar
fldr/+foo/bar.m
```

If a path folder `fldr` contains a `classdef` file `foo` that defines a static method `bar` and the same folder contains a package `+foo` that contains a package function `bar`.

```plaintext
fldr/foo.m      % bar is a static method of class foo
fldr/+foo/bar.m % bar is a function in package foo
```

A call to `which foo.bar` returns the path to the package function:

```plaintext
which foo.bar
fldr/+foo/bar.m
```

**See Also**

**More About**

- “Folders Containing Class Definitions” on page 6-13
- “Class Precedence” on page 6-18
Import Classes

Syntax for Importing Classes

Import classes into a function to simplify access to class members. For example, suppose that there is a package that contains several classes and you will use only one of these classes or a static method in your function. Use the `import` command to simplify code. Once you have imported the class, you do not need to reference the package name:

```matlab
function myFunc
    import pkg.MyClass
    obj = MyClass(arg,...); % call MyClass constructor
    obj.Prop = MyClass.staticMethod(arg,...); % call MyClass static method
end
```

Import all classes in a package using the syntax `pkg.*`:

```matlab
function myFunc
    import pkg.*
    obj1 = MyClass1(arg,...); % call pkg.MyClass1 constructor
    obj2 = MyClass2(arg,...); % call pkg.MyClass2 constructor
    a = pkgFunction();  % call package function named pkgFunction
end
```

Import Static Methods

Use `import` to import a static method so that you can call this method without using the class name. Call `import` with the full class name, including any packages, and the static method name:

```matlab
function myFunc
    import pkg.MyClass.MyStaticMethod
    MyStaticMethod(arg,...); % call static method
end
```

Import Package Functions

Use `import` to import package functions so that you can call these functions without using the package name. Call `import` with the package and function name:

```matlab
function myFunc
    import pkg.pkgFunction
    pkgFunction(arg,...); % call imported package function
end
```
Package Function and Class Method Name Conflict

Avoid importing an entire package using the * wildcard syntax. Doing so imports an unspecified set of names into the local scope. For example, suppose that you have the following folder organization:

+pkg/timedata.m % package function
+pkg/@MyClass/MyClass.m % class definition file
+pkg/@MyClass/timedata.m % class method

Import the package and call timedata on an instance of MyClass:

import pkg.*
myobj = pkg.MyClass;
timedata(myobj)

A call to timedata finds the package function, not the class method because MATLAB applies the import and finds pkg.timedata first. Do not use a package in cases where you have name conflicts and plan to import the package.

Clearing Import List

You cannot clear the import list from a function workspace. To clear the base workspace only, use:

clear import

See Also
import

More About
• “Packages Create Namespaces” on page 6-20
Value or Handle Class — Which to Use

• “Comparison of Handle and Value Classes” on page 7-2
• “Which Kind of Class to Use” on page 7-9
• “The Handle Superclass” on page 7-11
• “Handle Class Destructor” on page 7-13
• “Find Handle Objects and Properties” on page 7-21
• “Implement Set/Get Interface for Properties” on page 7-22
• “Implement Copy for Handle Classes” on page 7-30
Comparison of Handle and Value Classes

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**Basic Difference**

A value class constructor returns an object that is associated with the variable to which it is assigned. If you reassign this variable, MATLAB creates an independent copy of the original object. If you pass this variable to a function to modify it, the function must return the modified object as an output argument. For information on value-class behavior, see “Avoid Unnecessary Copies of Data”.

A handle class constructor returns a handle object that is a reference to the object created. You can assign the handle object to multiple variables or pass it to functions without causing MATLAB to make a copy of the original object. A function that modifies a handle object passed as an input argument does not need to return the object.

All handle classes are derived from the abstract `handle` class.

**Create a Value Class**

By default, MATLAB classes are value classes. The following definition creates a value class named `MyValueClass`:

```matlab
classdef MyValueClass
    ...
end
```

**Create a Handle Class**

To create a handle class, derive the class from the `handle` class.

```matlab
classdef MyHandleClass < handle
    ...
end
```

**Behavior of MATLAB Built-In Classes**

MATLAB fundamental classes are value classes (numeric, `logical`, `char`, `cell`, `struct`, and function handle). For example, if you create an object of the class `int32` and make a copy of this object, the result is two independent objects. When you change the value of `a`, the value of `b` does not change. This behavior is typical of classes that represent values.

```matlab
a = int32(7);
b = a;
a = a^4;
```
MATLAB graphics objects are implemented as handle objects because they represent visual elements. For example, create a graphics line object and copy its handle to another variable. Both variables refer to the same line object.

```matlab
x = 1:10; y = sin(x);
l1 = line(x,y);
l2 = l1;
```

Set the properties of the line object using either copy of the handle.

```matlab
set(l2,'Color','red')
set(l1,'Color','green')
get(l2,'Color')
ans =
     0     1     0
```

Calling the `delete` function on the `l2` handle destroys the line object. If you attempt to set the `Color` property on the line `l1`, the `set` function returns an error.

```matlab
delete(l2)
set(l1,'Color','blue')
```

Error using `matlab.graphics.primitive.Line/set`
Invalid or deleted object.

If you delete the object by deleting any one of the existing handles, all copies are now invalid because you deleted the single object to which all handles refer.

Deleting a handle object is not the same as clearing the handle variable. In the graphics object hierarchy, the parent of the object holds a reference to the object. For example, the parent axes hold a reference to the line object referred to by `l1` and `l2`. If you clear both variables from the workspace, the object still exists.

For more information on the behavior of handle objects, see “Handle Object Behavior” on page 1-7.

**User-Defined Value Classes**

MATLAB associates objects of value classes with the variables to which you assign the object. When you copy a value object to another variable or pass a value object to a function, MATLAB creates an independent copy of the object and all the data contained by the object. The new object is independent of changes to the original object. Value objects behave like MATLAB numeric and `struct` classes. Each property behaves essentially like a MATLAB array.

Value objects are always associated with one workspace or temporary variable. Value objects go out of scope when their variable goes out of scope or is cleared. There are no references to value objects, only copies that are independent objects.

**Value Object Behavior**

Here is a value class that stores a value in its `Number` property. The default property value is the number 1.
Create a NumValue object assigned to the variable a.

```matlab
a = NumValue
```

```
NumValue with properties:
  Number: 1
```

Assign the value of a to another variable, b.

```matlab
b = a
```

```
NumValue with properties:
  Number: 1
```

The variables a and b are independent. Changing the value of the Number property of a does not affect the Number property of b.

```matlab
a.Number = 7
```

```
NumValue with properties:
  Number: 7
```

```matlab
b
```

```
NumValue with properties:
  Number: 1
```

**Modifying Value Objects in Functions**

When you pass a value object to a function, MATLAB creates a copy of that object in the function workspace. Because copies of value objects are independent, the function does not modify the object in the caller's workspace. Therefore, functions that modify value objects must return the modified object to be reassigned in the caller's workspace.

For more information, see “Object Modification” on page 5-49.

**User-Defined Handle Classes**

Instances of classes that derive from the handle class are references to the underlying object data. When you copy a handle object, MATLAB copies the handle, but does not copy the data stored in the
object properties. The copy refers to the same object as the original handle. If you change a property value on the original object, the copied handle references the same change.

**Handle Object Behavior**

Here is a handle class that stores a value in its `Number` property. The default property value is the number 1.

```matlab
classdef NumHandle < handle
    properties
        Number = 1
    end
end
```

Create a `NumHandle` object assigned to the variable `a`.

```matlab
a = NumHandle
```

```matlab
a = NumHandle with properties:
    Number: 1
```

Assign the value of `a` to another variable, `b`.

```matlab
b = a
```

```matlab
b = NumHandle with properties:
    Number: 1
```

The variables `a` and `b` refer to the same underlying object. Changing the value of the `Number` property of `a` also changes the `Number` property of `b`. That is, `a` and `b` refer to the same object.

```matlab
a.Number = 7
```

```matlab
a = NumHandle with properties:
    Number: 7
```

```matlab
b = NumHandle with properties:
    Number: 7
```

**Modifying Handle Objects in Functions**

When you pass a handle object to a function, MATLAB creates a copy of the handle in the function workspace. Because copies of handles reference the same underlying object, functions that modify the handle object effectively modify the object in the caller’s workspace as well. Therefore, it is not
necessary for functions that modify handle objects passed as input arguments to return the modified object to the caller.

For more information, see “Object Modification” on page 5-49.

**Deleting Handles**

You can destroy handle objects by explicitly calling the handle `delete` method. Deleting the handle of a handle class object makes all handles invalid. For example:

```plaintext
a = NumHandle;
b = a;
delete(a)
b.Number
```

Invalid or deleted object.

Calling `delete` on a handle object invokes the destructor function or functions for that object. See “Handle Class Destructor” on page 7-13 for more information.

**Initialize Properties to Contain Handle Objects**

For information on the differences between initializing properties to default values in the properties block and initializing properties from within the constructor, see “Initialize Property Values” on page 8-13 and “Initialize Arrays of Handle Objects” on page 10-9.

**Determining Equality of Objects**

Equality for value objects means that the objects are of the same class and have the same state.

Equality for handle objects means that the handle variables refer to the same object. You also can identify handle variables that refer to different objects of the same class that have the same state.

**Equality of Value Objects**

To determine if value objects are the same size and their contents are of equal value, use `isequal`. For example, use the previously defined `NumValue` class to create two instances and test for equality:

```plaintext
a = NumValue;
b = NumValue;
isequal(a,b)
an=
1
```

`a` and `b` are independent and therefore are not the same object. However each represents the same value.

If you change the value represented by a value object, the objects are no longer equal.

```plaintext
a = NumValue;
b = NumValue;
b.Number = 7;
isequal(a,b)
an=
false
```
Value classes do not have a default eq method to implement the == operation.

**Equality of Handle Objects**

Handle objects inherit an eq method from the handle base class. You can use == and isequal to test for two different relationships among handle objects:

- The handles refer to the same object: == and isequal return true.
- The handles refer to objects of the same class that have the same values, but are not the same objects — only isequal returns true.

Use the previously defined NumHandle class to create an object and copy the handle.

```matlab
a = NumHandle;
b = a;
```

Test for equality using == and isequal.

```matlab
a == b
ans =
1
isequal(a,b)
ans =
1
```

Create two instances of the NumHandle class using the default values.

```matlab
a = NumHandle;
b = NumHandle;
```

Determine if a and b refer to the same object.

```matlab
a == b
ans =
0
```

Determine if a and b have the same values.

```matlab
isequal(a,b)
ans =
1
```

**Functionality Supported by Handle Classes**

Deriving from the handle class enables your class to:
• Inherit several useful methods ("Handle Class Methods" on page 7-11)
• Define events and listeners ("Events and Listeners Syntax" on page 11-18)
• Define dynamic properties ("Dynamic Properties — Adding Properties to an Instance" on page 8-54)
• Implement set and get methods ("Implement Set/Get Interface for Properties" on page 7-22)
• Customize copy behavior ("Implement Copy for Handle Classes" on page 7-30)

See "The Handle Superclass" on page 7-11 for more information on the handle class and its methods.

**See Also**

**Related Examples**

• "Which Kind of Class to Use" on page 7-9
• "Implement Copy for Handle Classes" on page 7-30
• "Handle Object Behavior" on page 1-7
Which Kind of Class to Use

Examples of Value and Handle Classes

Handle and value classes are useful in different situations. For example, value classes enable you to create array classes that have the same behavior as MATLAB numeric classes.

“Representing Polynomials with Classes” on page 19-2 and “Representing Structured Data with Classes” on page 3-14 provides examples of value classes.

Handle classes enable you to create objects that more than one function or object can share. Handle objects allow more complex interactions among objects because they allow objects to reference each other.

“Implementing Linked Lists with Classes” on page 3-23 and “Developing Classes — Typical Workflow” on page 3-6 provides examples of a handle class.

When to Use Value Classes

Value class objects behave like normal MATLAB variables. A typical use of value classes is to define data structures. For example, suppose that you want to define a class to represent polynomials. This class can define a property to contain a list of coefficients for the polynomial. It can implement methods that enable you to perform various operations on the polynomial object. For example, implement addition and multiplication without converting the object to another class.

A value class is suitable because you can copy a polynomial object and have two objects that are identical representations of the same polynomial. For an example of value classes, see “Subclasses of MATLAB Built-In Types” on page 12-41.

For information on MATLAB pass-by-value semantics, see “Avoid Unnecessary Copies of Data”.

When to Use Handle Classes

Handle objects are useful in specialized circumstances where an object represents a physical object such as a graph or an external device rather than a mathematical object like a number or matrix. Handle objects are derivations of the handle class, which provides functionality such as events and listeners, destructor method, and support for dynamic properties.

Use a handle class when:

- No two instances of a class can have the same state, making it impossible to have exact copies. For example:
  - A copy of a graphics object (such as a line) has a different position in its parents list of children than the object from which it was copied. Therefore, the two objects are not identical.
• Nodes in lists or trees having specific connectivity to other nodes — no two nodes can have the same connectivity.
• The class represents physical and unique objects like serial ports and printers.
• The class represents visible objects like graphics components.
• The class defines events and notifies listeners when an event occurs (notify is a handle class method).
• The class creates listeners by calling the handle class addlistener method.
• The class subclasses the dynamicprops class (a subclass of handle) so that instances can define dynamic properties.
• The class subclasses the matlab.mixin.SetGet class (a subclass of handle) so that it can implement a graphics object style set/get interface to access property values.
• You want to create a singleton class or a class in which you track the number of instances from within the constructor.
• Instances of a class cannot share state, such as nodes in a linked list.

See Also

Related Examples
• “Handle Compatible Classes” on page 12-32
The Handle Superclass

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Building on the Handle Class

The `handle` class is an abstract class. Therefore, you cannot create objects of this class directly. Use the `handle` class as a superclass to implement subclasses that inherit handle behavior. MATLAB defines several classes that derive from the `handle` class. These classes provide specialized functionality to subclasses.

Specialized Handle Base Classes

To add both handle behavior and specific functionality to your class, derive your class from these `handle` classes:

- `matlab.mixin.SetGet` — Provides `set` and `get` methods to access property values.
- `dynamicprops` — Enables you to define properties that are associated with an object, but not the class in general.
- `matlab.mixin.Copyable` Provides a copy method that you can customize for your class.

For information on how to define subclasses, see “Design Subclass Constructors” on page 12-7.

Handle Class Methods

When you derive a class from the `handle` class, the subclass inherits methods that enable you to work more effectively with handle objects.

List the methods of a class by passing the class name to the `methods` function:

```matlab
methods('handle')
```

Methods for class handle:

```plaintext
addlistener  findobj  gt  lt
delete      findprop  isvalid  ne
eq          ge        le  notify
```

Event and Listener Methods

For information on how to use the `notify` and `addlistener` methods, see “Events and Listeners Syntax” on page 11-18.
Relational Methods

TF = eq(H1,H2)
TF = ne(H1,H2)
TF = lt(H1,H2)
TF = le(H1,H2)
TF = gt(H1,H2)
TF = ge(H1,H2)

The handle class overloads these functions to support equality tests and sorting on handles. For each pair of input arrays, these functions return a logical array of the same size. Each element is an element-wise equality or comparison test result. The input arrays must be the same size or one (or both) can be scalar. The method performs scalar expansion as required. For more information on handle class relational methods, see relational operators.

Test Handle Validity

Use the isvalid handle class method to determine if a variable is a valid handle object. For example, in the statement:

B = isvalid(H)

B is a logical array in which each element is true if, and only if, the corresponding element of H is a valid handle. B is always the same size as H.

When MATLAB Destroys Objects

MATLAB destroys objects in the workspace of a function when the function:

• Reassigns an object variable to a new value
• Does not use an object variable for the remainder of a function
• Function execution ends

When MATLAB destroys an object, it also destroys values stored in the properties of the object. MATLAB frees computer memory associated with the object for use by MATLAB or the operating system.

You do not need to free memory in handle classes. However, there can be other operations that you want to perform when destroying an object. For example, closing a file or shutting down an external program that the object constructor started. Define a delete method in your handle subclass for these purposes.

See “Handle Class Destructor” on page 7-13 for more information.

See Also

Related Examples

• “Comparison of Handle and Value Classes” on page 7-2
Handle Class Destructor

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### Basic Knowledge

Class destructor – a method named `delete` that MATLAB calls implicitly before destroying an object of a handle class. Also, user-defined code can call `delete` explicitly to destroy an object.

Nondestructor – a method named `delete` that does not meet the syntax requirements of a valid destructor. Therefore, MATLAB does not call this method implicitly when destroying handle objects. A method named `delete` in a value class is not a destructor. A method named `delete` in a value class that sets the `HandleCompatible` attribute to `true` is not a destructor.

### Syntax of Handle Class Destructor Method

MATLAB calls the destructor of a handle class when destroying objects of the class. MATLAB recognizes a method named `delete` as the class destructor only if you define `delete` as an ordinary method with the appropriate syntax.

To be a valid class destructor, the `delete` method:

- Must define one, scalar input argument, which is an object of the class.
- Must not define output arguments
- Cannot be `Sealed`, `Static`, or `Abstract`
- Cannot use arguments blocks for input argument validation.

In addition, the `delete` method should not:

- Throw errors, even if the object is invalid.
- Create new handles to the object being destroyed
- Call methods or access properties of subclasses
MATLAB does not call a noncompliant `delete` method when destroying objects of the class. A noncompliant `delete` method can prevent the destruction of the object by shadowing the handle class `delete` method.

A `delete` method defined by a value class that is handle compatible is not a destructor, even if the `delete` method is inherited by a handle subclass. For information on handle compatible classes, see “Handle Compatible Classes” on page 12-32.

Declare `delete` as an ordinary method:

```matlab
methods
  function delete(obj)
    % obj is always scalar
    ...
  end
end
```

**delete Called Element-Wise on Array**

MATLAB calls the `delete` method separately for each element in an array. Therefore, a `delete` method is passed only one scalar argument with each invocation.

Calling `delete` on a deleted handle should not error and can take no action. This design enables `delete` to work on object arrays containing a mix of valid and invalid objects.

**Handle Object During delete Method Execution**

Calling the `delete` method on an object always results in the destruction of the object. The object is destroyed when the call to `delete` is made explicitly in MATLAB code or when called by MATLAB because an object is no longer reachable from any workspace. Once called, a `delete` method cannot abort or prevent object destruction.

A `delete` method can access properties of the object being deleted. MATLAB does not destroy these properties until after the `delete` methods for the class of the object and all superclasses finish executing.

If a `delete` method creates new variables that contain a handle to the object being deleted, those handles are invalid. After the `delete` method finishes execution, handles to the deleted object in any variables in any workspace are invalid.

The `isvalid` method returns `false` for the handle object within the `delete` method because object destruction begins when the method is called.

MATLAB calls `delete` methods in the inverse of the construction order. That is, MATLAB invokes subclass `delete` methods before superclass `delete` methods.

If a superclass expects a property to be managed by subclasses, then the superclass should not access that property in its `delete` method. For example, if a subclass uses an inherited abstract property to store an object handle, then the subclass should destroy this object in its `delete` method, but the superclass should not access that property in its `delete` method.
Support Destruction of Partially Constructed Objects

Errors that occur while constructing an object can result in a call to `delete` before the object is fully created. Therefore, class `delete` methods must be able to work with partially constructed objects.

For example, the `PartialObject` class `delete` method determines if the `Data` property is empty before accessing the data this property contains. If an error occurs while assigning the constructor argument to the `Name` property, MATLAB passes the partially constructed object to `delete`.

```matlab
classdef PartialObject < handle
    properties
        % Restrict the Name property
        % to a cell array
        Name cell
        Data
    end
    methods
        function h = PartialObject(name)
            if nargin > 0
                h.Name = name;
                h.Data.a = rand(10,1);
            end
        end
        function delete(h)
            % Protect against accessing properties
            % of partially constructed objects
            if ~isempty(h.Data)
                t = h.Data.a;
                disp(t)
            else
                disp('Data is empty')
            end
        end
    end
end
```

An error occurs if you call the constructor with a char vector, instead of the required cell array:

```matlab
obj = PartialObject('Test')
```

MATLAB passes the partially constructed object to the `delete` method. The constructor did not set the value of the `Data` property because the error occurred when setting the `Name` property.

```
Data is empty
Error setting 'Name' property of 'PartialObject' class:
```

When to Define a Destructor Method

Use a `delete` method to perform cleanup operations before MATLAB destroys the object. MATLAB calls the `delete` method reliably, even if execution is interrupted with Ctrl-c or an error.

If an error occurs during the construction of a handle class, MATLAB calls the class destructor on the object along with the destructors for any objects contained in properties and any initialized base classes.
For example, suppose that a method opens a file for writing and you want to close the file in your delete method. The delete method can call fclose on a file identifier that the object stores in its FileID property:

```
function delete(obj)
    fclose(obj.FileID);
end
```

**Destructors in Class Hierarchies**

If you create a hierarchy of classes, each class can define its own delete method. When destroying an object, MATLAB calls the delete method of each class in the hierarchy. Defining a delete method in a handle subclass does not override the handle class delete method. Subclass delete methods augment the superclass delete methods.

**Inheriting a Sealed Delete Method**

Classes cannot define a valid destructor that is Sealed. MATLAB returns an error when you attempt to instantiate a class that defines a Sealed delete method.

Normally, declaring a method as Sealed prevents subclasses from overriding that method. However, a Sealed method named delete that is not a valid destructor does not prevent a subclass from defining its own destructor.

For example, if a superclass defines a method named delete that is not a valid destructor, but is Sealed, then subclasses:

- Can define valid destructors (which are always named delete).
- Cannot define methods named delete that are not valid destructors.

**Destructors in Heterogeneous Hierarchies**

Heterogeneous class hierarchies require that all methods to which heterogeneous arrays are passed must be sealed. However, the rule does not apply to class destructor methods. Because destructor methods cannot be sealed, you can define a valid destructor in a heterogeneous hierarchy that is not sealed, but does function as a destructor.

For information on heterogeneous hierarchies, see “Designing Heterogeneous Class Hierarchies” on page 10-20

**Object Lifecycle**

MATLAB invokes the delete method when the lifecycle of an object ends. The lifecycle of an object ends when the object is:

- No longer referenced anywhere
- Explicitly deleted by calling delete on the handle

**Inside a Function**

The lifecycle of an object referenced by a local variable or input argument exists from the time the variable is assigned until the time it is reassigned, cleared, or no longer referenced within that function or in any handle array.
A variable goes out of scope when you explicitly clear it or when its function ends. When a variable goes out of scope and its value belongs to a handle class that defines a `delete` method, MATLAB calls that method. MATLAB defines no ordering among variables in a function. Do not assume that MATLAB destroys one value before another value when the same function contains multiple values.

**Sequence During Handle Object Destruction**

MATLAB invokes the `delete` methods in the following sequence when destroying an object:

1. The `delete` method for the class of the object
2. The `delete` method of each superclass class, starting with the immediate superclasses and working up the hierarchy to the most general superclasses

MATLAB invokes the `delete` methods of superclasses at the same level in the hierarchy in the order specified in the class definition. For example, the following class definition specifies `supclass1` before `supclass2`. MATLAB calls the `delete` method of `supclass1` before the `delete` method of `supclass2`.

```matlab
classdef myClass < supclass1 & supclass2
```

After calling each `delete` method, MATLAB destroys the property values belonging exclusively to the class whose method was called. The destruction of property values that contain other handle objects can cause a call the `delete` methods for those objects when there are no other references to those objects.

Superclass `delete` methods cannot call methods or access properties belonging to a subclass.

**Destruction of Objects with Cyclic References**

Consider a set of objects that reference other objects of the set such that the references form a cyclic graph. In this case, MATLAB:

- Destroys the objects if they are referenced only within the cycle
- Does not destroy the objects as long as there is an external reference to any of the objects from a MATLAB variable outside the cycle

MATLAB destroys the objects in the reverse of the order of construction. For more information, see “Handle Object During delete Method Execution” on page 7-14.

**Restrict Access to Object Delete Method**

Destroy handle objects by explicitly calling `delete` on the object:

```matlab
delete(obj)
```

A class can prevent explicit destruction of an object by setting its `delete` method Access attribute to `private`. However, a method of the class can call the `private delete` method.

If the class `delete` method Access attribute is `protected`, only methods of the class and of subclasses can explicitly delete objects of that class.

However, when an object lifecycle ends, MATLAB calls the object’s `delete` method when destroying the object regardless of the method’s Access attribute.
Inherited Private Delete Methods

Class destructor behavior differs from the normal behavior of an overridden method. MATLAB executes each delete method of each superclass upon destruction, even if that delete method is not public.

When you explicitly call an object's delete method, MATLAB checks the delete method Access attribute in the class defining the object, but not in the superclasses of the object. A superclass with a private delete method cannot prevent the destruction of subclass objects.

Declaring a private delete method makes most sense for sealed classes. In the case where classes are not sealed, subclasses can define their own delete methods with public access. MATLAB calls a private superclass delete method as a result of an explicit call to a public subclass delete method.

Nondestructor Delete Methods

A class can implement a method named delete that is not a valid class destructor. MATLAB does not call this method implicitly when destroying an object. In this case, delete behaves like an ordinary method.

For example, if the superclass implements a Sealed method named delete that is not a valid destructor, then MATLAB does not allow subclasses to override this method.

A delete method defined by a value class cannot be a class destructor.

Java Objects Referencing MATLAB Objects

Java does not support the object destructors that MATLAB objects use. Therefore, it is important to manage the lifecycle of all objects used in applications that include both Java and MATLAB objects.

References Can Prevent Destructor Execution

Java objects that hold references to MATLAB objects can prevent deletion of the MATLAB objects. In these cases, MATLAB does not call the handle object delete method even when there is no handle variable referring to that object. To ensure your delete method executes, call delete on the object explicitly before the handle variable goes out of scope.

Problems can occur when you define callbacks for Java objects that reference MATLAB objects.

For example, the CallbackWithJava class creates a Java com.mathworks.jmi.Callback object and assigns a class method as the callback function. The result is a Java object that has a reference to a handle object via the function-handle callback.

```matlab
classdef CallbackWithJava < handle
    methods
        function obj = CallbackWithJava
            jo = com.mathworks.jmi.Callback;
            set(jo,'DelayedCallback',@obj.cbFunc); % Assign method as callback
            jo.postCallback
        end
        function cbFunc(obj,varargin)
            c = class(obj);
            disp(['Java object callback on class ',c])
        end
        function delete(obj)
            c = class(obj);
            disp(['ML object destructor called for class ',c])
    end
end
```
Suppose that you create a `CallbackWithJava` object from within a function:

```matlab
function testDestructor
cwj = CallbackWithJava
...
end
```

Creating an instance of the `CallbackWithJava` class creates the `com.mathworks.jmi.Callback` object and executes the callback function:

```matlab
testDestructor

cwj =

    CallbackWithJava with no properties.
```

Java object callback on class CallbackWithJava

The handle variable, `cwj`, exists only in the function workspace. However, MATLAB does not call the class `delete` method when the function ends. The `com.mathworks.jmi.Callback` object still exists and holds a reference to the object of the `CallbackWithJava` class, which prevents destruction of the MATLAB object.

```matlab
clear classes
```

Warning: Objects of `CallbackWithJava` class exist. Cannot clear this class or any of its superclasses.

To avoid causing inaccessible objects, call `delete` explicitly before losing the handle to the MATLAB object.

```matlab
function testDestructor
cwj = CallbackWithJava
...
delete(cwj)
end
```

**Manage Object Lifecycle in Applications**

MATLAB applications that use Java objects should manage the lifecycle of the objects involved. A typical user interface application references Java objects from MATLAB objects and creates callbacks on Java objects that reference MATLAB objects.

You can break these cyclic references in various ways:

- Explicitly call `delete` on the MATLAB objects when they are no longer needed
- Unregister the Java object callbacks that reference MATLAB objects
- Use intermediate handle objects that reference both the Java callbacks and the MATLAB objects.
See Also

More About
• "Handle Object Behavior" on page 1-7
Find Handle Objects and Properties

In this section...

“Find Handle Objects” on page 7-21
“Find Handle Object Properties” on page 7-21

Find Handle Objects

The `findobj` method enables you to locate handle objects that meet certain conditions.

```
function HM = findobj(H,<conditions>)
```

The `findobj` method returns an array of handles matching the conditions specified. You can use regular expressions with `findobj`. For more information, see `regexp`.

Find Handle Object Properties

The `findprop` method returns the `meta.property` object for the specified object and property.

```
function mp = findprop(h,'PropertyName')
```

The property can also be a dynamic property created by the `addprop` method of the `dynamicprops` class.

Use the returned `meta.property` object to obtain information about the property, such as the settings of any of its attributes. For example, the following statements determine that the setting of the `AccountStatus` property `Dependent` attribute is `false`.

```
ba = BankAccount(007,50,'open');
mp = findprop(ba,'AccountStatus');
mp.Dependent
ans =
   0
```

See Also
handle

Related Examples

• “Class Metadata” on page 16-2
Implement Set/Get Interface for Properties

The Standard Set/Get Interface

Some MATLAB objects, such as graphics objects, implement an interface based on `set` and `get` functions. These functions enable access to multiple properties on arrays of objects in a single function call.

You can add `set` and `get` functionality to your class by deriving from one of these classes:

- `matlab.mixin.SetGet` — use when you want support for case-insensitive, partial property name matching. Deriving from `matlab.mixin.SetGet` does not affect the exact property name required by the use of dot notation reference to properties.
- `matlab.mixin.SetGetExactNames` — use when you want to support only case-sensitive full property name matching.

Note The `set` and `get` methods referred to in this section are different from property set access and property get access methods. See “Property Access Methods” on page 8-39 for information on property access methods.

Subclass Syntax

Use the abstract class `matlab.mixin.SetGet` or `matlab.mixin.SetGetExactNames` as a superclass:

```matlab
classdef MyClass < matlab.mixin.SetGet
    ...
end
```

Because `matlab.mixin.SetGet` and `matlab.mixin.SetGetExactNames` derive from the handle class, your subclass is also a handle class.

Get Method Syntax

The `get` method returns the value of an object property using the object handle and the property name. For example, assume `H` is the handle to an object:

```matlab
v = get(H,'PropertyName');
```

If you specify an array of handles with a single property name, `get` returns the property value for each object as a cell array of values:
CV = get(H,'PropertyName');

The CV array is always a column regardless of the shape of H.

If you specify a cell array of char vector property names and an array of handles, get returns a cell array of property values. Each row in the cell corresponds to an object in the handle array. Each column in the cell corresponds to a property name.

```plaintext
props = {'PropertyName1','PropertyName2'};
CV = get(H,props);
```

get returns an m-by-n cell array, where \( m = \text{length}(H) \) and \( n = \text{length(props)} \).

If you specify a handle array, but no property names, get returns an array of type struct in which each structure in the array corresponds to an object in H. Each field in each structure corresponds to a property defined by the class of H. The value of each field is the value of the corresponding property.

SV = get(H);

If you do not assign an output variable, then H must be scalar.

For an example, see “Using get with Arrays of Handles” on page 7-25.

**Set Method Syntax**

The set method assigns the specified value to the specified property for the object with handle H. If H is an array of handles, MATLAB assigns the value to the property for each object in the array H.

```plaintext
set(H,'PropertyName',PropertyValue)
```

You can pass a cell array of property names and a cell array of property values to set:

```plaintext
props = {'PropertyName1','PropertyName2'};
vals = {Property1Value,Property2Value};
set(H,props,vals)
```

If \( \text{length}(H) \) is greater than one, then the property value cell array (vals) can have values for each property in each object. For example, suppose \( \text{length}(H) \) is 2 (two object handles). You want to assign two property values on each object:

```plaintext
props = {'PropertyName1','PropertyName2'};
vals = {Property11Value,Property12Value;Property21Value,Property22Value};
set(H,props,vals)
```

The preceding statement is equivalent to the follow two statements:

```plaintext
set(H(1),'PropertyName1',Property11Value,'PropertyName2',Property12Value)
set(H(2),'PropertyName1',Property21Value,'PropertyName2',Property22Value)
```

If you specify a scalar handle, but no property names, set returns a struct with one field for each property in the class of H. Each field contains an empty cell array.

SV = set(h);

**Class Derived from matlab.mixin.SetGet**

This sample class defines a set/get interface and illustrates the behavior of the inherited methods:
classdef LineType < matlab.mixin.SetGet
  properties
    Style = ' -'
    Marker = 'o'
  end
  properties (SetAccess = protected)
    Units = 'points'
  end
  methods
    function obj = LineType(s,m)
      if nargin > 0
        obj.Style = s;
        obj.Marker = m;
      end
    end
    function obj = set.Style(obj,val)
      if ~(strcmpi(val,'-') ||...
           strcmpi(val,'--') ||...
           strcmpi(val,':'))
        error('Invalid line style ')
      end
      obj.Style = val;
    end
    function obj = set.Marker(obj,val)
      if ~isstrprop(val,'graphic')
        error('Marker must be a visible character')
      end
      obj.Marker = val;
    end
  end
end

Create an instance of the class and save its handle:

h = LineType('--','*');

Query the value of any object property using the inherited get method:

geth('Marker')

ans = *

Set the value of any property using the inherited set method:

set(h,'Marker','Q')

**Property Access Methods Called with set and get**

MATLAB calls property access methods (set.Style or set.Marker in the LineType class) when you use the set and get methods.

set(h,'Style','-.')

Error using LineType>LineType.set.Style
Invalid line style

For more information on property access methods, see “Property Access Methods” on page 8-39
**List All Properties**

Return a struct containing object properties and their current values using `get`:

```matlab
h = LineType('--','*');
SV = get(h)
SV =
    Style: '--'
    Marker: '*'
    Units: 'points'
```

Return a struct containing the properties that have public `SetAccess` using `set`:

```matlab
S = set(h)
S =
    Style: {}
    Marker: {}
```

The `LineType` class defines the `Units` property with `SetAccess = protected`. Therefore, `S = set(h)` does not create a field for `Units` in `S`.

`set` cannot return possible values for properties that have nonpublic set access.

**Using get with Arrays of Handles**

Suppose that you create an array of `LineType` objects:

```matlab
H = [LineType('..','z'),LineType('--','q')]
H =
1x2 LineType with properties:
    Style
    Marker
    Units
```

When `H` is an array of handles, `get` returns a `(length(H)-by-1) cell array of property values:

```matlab
CV = get(H,'Style')
CV =
    '..'
    '--'
```

When `H` is an array of handles and you do not specify a property name, `get` returns a struct array containing fields with names corresponding to property-names. Assign the output of `get` to a variable when `H` is not scalar:

```matlab
SV = get(H)
SV =
2x1 struct array with fields:
Get the value of the `Marker` property from the second array element in the `SV` array of structures:

```matlab
SV(2).Marker
```

```matlab
ans =
q
```

### Arrays of Handles, Names, and Values

You can pass an array of handles, a cell array of property names, and a cell array of property values to `set`. The property value cell array must have one row of property values for each object in `H`. Each row must have a value for each property in the property name array:

```matlab
H = [LineType('..','z'), LineType('--','q')];
set(H, {'Style', 'Marker'}, {'..', 'o'; '--', 'x'})
```

The result of this call to `set` is:

```matlab
H(1)
```

```matlab
ans =

    LineType with properties:
        Style: '..'
        Marker: 'o'
        Units: 'points'
```

```matlab
H(2)
```

```matlab
ans =

    LineType with properties:
        Style: '--'
        Marker: 'x'
        Units: 'points'
```

### Customize the Property List

Customize the way property lists display by redefining the following methods in your subclass:

- `setdisp` — When you call `set` with no output argument and a single scalar handle input, `set` calls `setdisp` to determine how to display the property list.
- `getdisp` — When you call `get` with no output argument and a single scalar handle input, `get` calls `getdisp` to determine how to display the property list.

### Set Priority for Matching Partial Property Names

Classes that derive from `matlab.mixin.SetGet` can use the `PartialMatchPriority` property attribute to specify a relative priority for partial name matching. MATLAB applies this attribute when resolving incomplete and case-insensitive text strings that match more than one property name.
The inherited set and get methods can resolve inexact property names when there are no ambiguities resulting from inexact name strings. When a partial property name is ambiguous because the name matches more than one property, the PartialMatchPriority attribute value can determine which property MATLAB matches.

The default priority is equivalent to PartialMatchPriority = 1. To reduce the relative priority of a property, set PartialMatchPriority to a positive integer value of 2 or greater. The priority of a property decreases as the value of PartialMatchPriority increases.

For example, in this class the Verbosity property has a higher priority for name matching than the Version property.

```matlab
classdef MyClass < matlab.mixin.SetGet
    properties
        Verbosity
    end
    properties (PartialMatchPriority = 2)
        Version
    end
end
```

Calling the set method with the potentially ambiguous inexact name Ver sets the Verbosity property because of its higher relative priority. Without setting the PartialMatchPriority attribute, the ambiguous name would cause an error.

```matlab
a = MyClass;
set(a,"Ver",10)
disp(a)
```

```matlab
MyClass with properties:

    Verbosity: 10
    Version: []
```

The same name selection applies to the get method.

```matlab
v = get(a,"Ver")
v =
```

```matlab
10
```

**Case and Name Matching**

A full name match with nonmatching case takes precedence over a partial match with a higher priority property. For example, this class defines the BaseLine property with a priority of 1 (the default) and a Base property with a priority of 2 (lower than 1).

```matlab
classdef MyClass < matlab.mixin.SetGet
    properties
        BaseLine
    end
    properties (PartialMatchPriority = 2)
        Base
    end
end
```
Calling the `set` method with the string `base` sets the `Base` property. `Baseline` has a higher priority, but the full name match with incorrect case takes precedence.

```matlab
a = MyClass;
set(a,"base",-2)
disp(a)
```

```
MyClass with properties:

    Baseline: []
    Base: -2
```

### Reduce Incompatibilities When Adding New Properties

You can use the `PartialMatchPriority` attribute to avoid introducing code incompatibilities when adding a new property. For example, this class enables the `set` and `get` methods to refer to the `Distance` property with the string `Dis` because the `DiscreteSamples` property has a lower priority.

```matlab
classdef Planet < matlab.mixin.SetGet
    % Version 1.0
    properties
        Distance
    end
    properties(PartialMatchPriority = 2)
        DiscreteSamples
    end
end
```

Version 2.0 of the class introduces a property named `Discontinuities`. To prevent the possibility of causing an ambiguous partial property name in existing code, use `PartialMatchPriority` to set the priority of `Discontinuities` lower than that of previously existing properties.

```matlab
classdef Planet < matlab.mixin.SetGet
    % Version 2.0
    properties
        Diameter;
        NumMoons = 0
        ApparentMagnitude;
        DistanceFromSun;
    end
    properties(PartialMatchPriority = 2)
        DiscreteSamples;
    end
    properties(PartialMatchPriority = 3)
        Discontinuities = false;
    end
end
```

For version 1.0 of the `Planet` class, this call to the `set` method was not ambiguous.

```matlab
p = Planet;
set(p,"Disc",true)
```

However, with the introduction of the `Discontinuities` property, the string `Disc` becomes ambiguous. By giving the `Discontinuities` property a lower priority, the string `Disc` continues to match the `DiscreteSamples` property.
**Note** When writing reusable code, using complete, case-sensitive property names avoids ambiguities, prevents incompatibilities with subsequent software releases, and produces more readable code.

**See Also**
get | matlab.mixin.SetGet | matlab.mixin.SetGetExactNames | set

**More About**
- "Ways to Use Properties" on page 8-2
Implement Copy for Handle Classes

Copy Method for Handle Classes

Copying a handle variable results in another handle variable that refers to the same object. You can add copy functionality to your handle class by subclassing `matlab.mixin.Copyable`. The inherited copy method enables you to make shallow copies of objects of the class. The `CopyObj` class shows the behavior of copy operations.

```matlab
classdef CopyObj < matlab.mixin.Copyable
    properties
        Prop
    end
end
```

Create an object of the `CopyObj` class and assign the handle of a `line` object to the property `Prop`.

```matlab
a = CopyObj;
a.Prop = line;
```

Copy the object.

```matlab
b = copy(a);
```

Confirm that the handle variables `a` and `b` refer to different objects.

```matlab
a == b
ans =
    logical
    0
```

However, the `line` object referred to by `a.Prop` has not been copied. The handle contained in `a.Prop` refers to the same object as the handle contained in `b.Prop`.

```matlab
a.Prop == b.Prop
ans =
    logical
    1
```

For more detailed information on the behavior of the copy operation, see `copy`.
Customize Copy Operation

Customize handle object copy behavior by deriving your class from `matlab.mixin.Copyable`. The `matlab.mixin.Copyable` class is an abstract base class that derives from the handle class. `matlab.mixin.Copyable` provides a template for customizing object copy operations by defining:

- `copy` — Sealed method that defines the interface for copying objects
- `copyElement` — Protected method that subclasses can override to customize object copy operations for the subclass

The `matlab.mixin.Copyable.copy` method, calls the `copyElement` method. Your subclass customizes the copy operation by defining its own version of `copyElement`.

The default implementation of `copyElement` makes shallow copies of all the nondependent properties. `copyElement` copies each property value and assigns it to the new (copied) property. If a property value is a handle object, `copyElement` copies the handle, but not the underlying data.

To implement different copy behavior for different properties, override `copyElement`. For example, the `copyElement` method of the `SpecializedCopy` class:

- Creates a new class object
- Copies the value of Prop1 to the new object
- Reinitializes the default value of Prop2 by adding a timestamp when the copy is made

```matlab
classdef SpecializedCopy < matlab.mixin.Copyable
    properties
        Prop1
        Prop2 = datestr(now)
    end
    methods(Access = protected)
        function cp = copyElement(obj)
            cp = SpecializedCopy;
            cp.Prop1 = obj.Prop1;
            cp.Prop2 = datestr(now);
        end
    end
end
```

Create an object of the class and assign a value to `Prop1`:

```matlab
a = SpecializedCopy;
a.Prop1 = 7
```

```
SpecializedCopy with properties:

    Prop1: 7
    Prop2: '17-Feb-2015 17:51:23'
```

Use the inherited `copy` method to create a copy of `a`:

```matlab
b = copy(a)
```
The copy (object b) has the same value for Prop1, but the subclass copyElement method assigned a new value to Prop2. Notice the different timestamp.

Copy Properties That Contain Handles

Copying an object also copies the values of object properties. Object properties can contain other objects, including handle objects. If you simply copy the value of a property that contains a handle object, you are actually copying the handle, not the object itself. Therefore, your copy references the same object as the original object. Classes that derive from the matlab.mixin.Copyable class can customize the way the copy method copies objects of the class.

Class to Support Handle Copying

Suppose that you define a class that stores a handle in an object property. You want to be able to copy objects of the class and want each copy of an object to refer to a new handle object. Customize the class copy behavior using these steps:

• Create a subclass of matlab.mixin.Copyable.
• Override copyElement to control how the property containing the handle is copied.
• Because the property value is a handle, create a new default object of the same class.
• Copy property values from the original handle object to the new handle object.

The “HandleCopy” on page 7-32 class customizes copy operations for the property that contains a handle object. The “ColorProp” on page 7-33 class defines the handle object to assign to Prop2:

Create an object and assign property values:

a = HandleCopy;
    a.Prop1 = 7;
    a.Prop2 = ColorProp;

Make a copy of the object using the copy method inherited from matlab.mixin.Copyable:

b = copy(a);

Demonstrate that the handle objects contained by objects a and b are independent. Changing the value on object a does not affect object b:

a.Prop2.Color = 'red';
b.Prop2.Color

ans =
blue

HandleCopy

The HandleCopy class customizes the copy operation for objects of this class.

classdef HandleCopy < matlab.mixin.Copyable
    properties
Prop1 % Shallow copy
Prop2 % Handle copy
end
methods (Access = protected)
 function cp = copyElement(obj)
   % Shallow copy object
   cp = copyElement@matlab.mixin.Copyable(obj);
   % Get handle from Prop2
   hobj = obj.Prop2;
   % Create default object
   new_hobj = eval(class(hobj));
   % Add public property values from orig object
   HandleCopy.propValues(new_hobj,hobj);
   % Assign the new object to property
   cp.Prop2 = new_hobj;
 end
end
methods (Static)
 function propValues(newObj,orgObj)
   pl = properties(orgObj);
   for k = 1:length(pl)
     if isprop(newObj,pl{k})
       newObj.(pl{k}) = orgObj.(pl{k});
     end
   end
 end
end

ColorProp

The ColorProp class defines a color by assigning an RGB value to its Color property.

classdef ColorProp < handle
   properties
     Color = 'blue';
   end
end

Exclude Properties from Copy

Use the NonCopyable property attribute to indicate that you do not want a copy operation to copy a particular property value. By default, NonCopyable is false, indicating that the property value is copyable. You can set NonCopyable to true only on properties of handle classes.

For classes that derive from matlab.mixin.Copyable, the default implementation of copyElement honors the NonCopyable attribute. Therefore, if a property has its NonCopyable attribute set to true, then copyElement does not copy the value of that property. If you override copyElement in your subclass, you can choose how to use the NonCopyable attribute.

Set the Attribute to Not Copy

Set NonCopyable to true in a property block:

properties (NonCopyable)
   Prop1
end
Default Values

If a property that is not copyable has a default value assigned in the class definition, the copy operation assigns the default value to the property. For example, the CopiedClass assigns a default value to Prop2.

```matlab
classdefCopiedClass < matlab.mixin.Copyable
    properties (NonCopyable)
    Prop1
    Prop2 = datestr(now) % Assign current time
    end
end
```

Create an object to copy and assign a value to Prop1:

```matlab
a = CopiedClass;
a.Prop1 = 7
```

```matlab
a = CopiedClass with properties:
    Prop1: 7
    Prop2: '17-Feb-2015 15:19:34'
```

Copy a to b using the copy method inherited from matlab.mixin.Copyable:

```matlab
b = copy(a)
```

```matlab
b = CopiedClass with properties:
    Prop1: []
    Prop2: '17-Feb-2015 15:19:34'
```

In the copy b, the value of Prop1 is not copied. The value of Prop2 is set to its default value, which MATLAB determined when first loading the class. The timestamp does not change.

Objects with Dynamic Properties

Subclasses of the dynamicprops class allow you to add properties to an object of the class. When a class derived from dynamicprops is also a subclass of matlab.mixin.Copyable, the default implementation of copyElement does not copy dynamic properties. The default value of NonCopyable is true for dynamic properties.

The default implementation of copyElement honors the value of a dynamic property NonCopyable attribute. If you want to allow copying of a dynamic property, set its NonCopyable attribute to false. Copying a dynamic property copies the property value and the values of the property attributes.

For example, this copy operation copies the dynamic property, DynoProp, because its NonCopyable attribute is set to false. The object obj must be an instance of a class that derives from both dynamicprops and matlab.mixin.Copyable:

```matlab
obj = MyDynamicClass;
p = addprop(obj,'DynoProp');
```
p.NonCopyable = false;
obj2 = copy(obj);

See Also
matlab.mixin.Copyable

Related Examples
• “Dynamic Properties — Adding Properties to an Instance” on page 8-54
Properties — Storing Class Data

- “Ways to Use Properties” on page 8-2
- “Property Syntax” on page 8-4
- “Property Attributes” on page 8-7
- “Property Definition” on page 8-13
- “Mutable and Immutable Properties” on page 8-18
- “Validate Property Values” on page 8-20
- “Property Class and Size Validation” on page 8-25
- “Property Validation Functions” on page 8-31
- “Metadata Interface to Property Validation” on page 8-37
- “Property Access Methods” on page 8-39
- “Property Set Methods” on page 8-44
- “Property Get Methods” on page 8-47
- “Set and Get Methods for Dependent Properties” on page 8-49
- “Properties Containing Objects” on page 8-52
- “Dynamic Properties — Adding Properties to an Instance” on page 8-54
- “Set and Get Methods for Dynamic Properties” on page 8-57
- “Dynamic Property Events” on page 8-59
- “Dynamic Properties and ConstructOnLoad” on page 8-63
Ways to Use Properties

What Are Properties

Properties encapsulate the data that belongs to instances of classes. Data contained in properties can be public, protected, or private. This data can be a fixed set of constant values, or it can depend on other values and calculated only when queried. You control these aspects of property behaviors by setting property attributes and by defining property-specific access methods.

Flexibility of Object Properties

In some ways, properties are like fields of a struct object. However, storing data in an object property provides more flexibility. Properties can:

- Define a constant value that you cannot change outside the class definition. See “Define Class Properties with Constant Values” on page 15-2.
- Calculate its value based on the current value of other data. See “Property Get Methods” on page 8-47.
- Execute a function to determine if an attempt to assign a value meets a certain criteria. See “Property Set Methods” on page 8-44.
- Trigger an event notification when any attempt is made to get or set its value. See “Property-Set and Query Events” on page 11-14.
- Control access by code to the property values. See the SetAccess and GetAccess attributes “Property Attributes” on page 8-7.
- Control whether its value is saved with the object in a MAT-file. See “Save and Load Objects” on page 13-2.

For an example of a class that defines and uses a class, see “Create a Simple Class” on page 2-2.

Types of Properties

There are two types of properties:

- Stored properties — Use memory and are part of the object
- Dependent properties — No allocated memory and the get access method calculates the value when queried

Features of Stored Properties

- Property value is stored when you save the object to a MAT-file
- Can assign a default value in the class definition
- Can restrict property value to a specific class and size
- Can execute validation functions to control allowed property value (default and assigned)
• Can use a set access method to control possible values when set

**When to Use Stored Properties**

• You want to be able to save the property value in a MAT-file
• The property value is not dependent on other property values

**Features of Dependent Properties**

Dependent properties save memory because property values that depend on other values are calculated only when needed.

**When to Use Dependent Properties**

Define properties as dependent when you want to:

• Compute the value of a property from other values (for example, you can compute area from Width and Height properties).
• Provide a value in different formats depending on other values. For example, the size of a push button in values determined by the current setting of its Units property.
• Provide a standard interface where a particular property is or is not used, depending on other values. For example, different computer platforms can have different components on a toolbar).

For examples of classes that use dependent properties, see “Calculate Data on Demand” on page 3-17 and “A Class Hierarchy for Heterogeneous Arrays” on page 20-2.

**See Also**

**Related Examples**

• “Property Attributes” on page 8-7
• “Validate Property Values” on page 8-20
• “Property Access Methods” on page 8-39
• “Static Properties” on page 5-52
Property Syntax

In this section...

“Property Definition Block” on page 8-4
“Access Property Values” on page 8-5
“Inheritance of Properties” on page 8-5
“Specify Property Attributes” on page 8-5

Property Definition Block

The following illustration shows a typical property specification. The properties and end keywords delineate a block of code that defines properties having the same attribute settings.

Note Properties cannot have the same name as the class.

For an example, see “Create a Simple Class” on page 2-2.

Assigning a Default Value

The preceding example shows the Coefficients property specified as having a default value of [0 0 1].

You can initialize property values with MATLAB expressions. However, these expressions cannot refer to the class that you are defining in any way, except to call class static methods. MATLAB executes expressions that create initial property values only when initializing the class, which occurs just before first using the class. See “Property Default Values” on page 8-14 for more information about how MATLAB evaluates default value expressions.
Define One Property Per Line

Property names must be listed on separate lines. MATLAB interprets a name following a property name as the name of a class.

Restrict Property Values

You can restrict property values by associating a class with the property in the property definition. For example, the definition of MyData requires that values assigned to this property must be of type int32 or types that are compatible with int32.

```matlab
properties
    MyData int32
end
```

For more information, see “Validate Property Values” on page 8-20.

Access Property Values

Property access syntax is like MATLAB structure field syntax. For example, if obj is an object of a class, then you can get the value of a property by referencing the property name:

```matlab
val = obj.PropertyName
```

Assign values to properties by putting the property reference on the left side of the equal sign:

```matlab
obj.PropertyName = val
```

When you access a property, MATLAB executes any property set or get access method and triggering any enabled property events.

Inheritance of Properties

When you derive one class from another class, the derived (subclass) class inherits all the properties of the superclass. In general, subclasses define only properties that are unique to that particular class. Superclasses define properties that are used by more than one subclass.

Specify Property Attributes

Attributes specified with the properties keyword apply to all property definitions that follow in that block. If you want to apply attribute settings to certain properties only, reuse the properties keyword and create another property block for those properties.

For example, the following code shows the SetAccess attribute set to private for the IndependentVar and Order properties, but not for the Coefficients property:
For information about the properties of a specific class, use the `properties` function.

### See Also

### Related Examples

- “Validate Property Values” on page 8-20
- “Property Definition” on page 8-13
- “Property Attributes” on page 8-7
**Property Attributes**

In this section...
- “Purpose of Property Attributes” on page 8-7
- “Specifying Property Attributes” on page 8-7
- “Table of Property Attributes” on page 8-7

**Purpose of Property Attributes**

Specifying attributes in the class definition enables you to customize the behavior of properties for specific purposes. Control characteristics like access, data storage, and visibility of properties by setting attributes. Subclasses do not inherit superclass member attributes.

**Specifying Property Attributes**

Assign property attributes on the same line as the `properties` keyword:

```plaintext
properties (Attribute1 = value1, Attribute2 = value2, ...)
end
```

For example, give the `Data` property `private` access:

```plaintext
properties (Access = private)
  Data
end
```

For more information on attribute syntax, see “Attribute Specification” on page 5-18.

**Table of Property Attributes**

All properties support the attributes listed in the following table. Attribute values apply to all properties defined within the `properties...end` code block that specifies the nondefault values.
## Property Attributes

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AbortSet</td>
<td>logical</td>
<td>If true, MATLAB does not set the property value if the new value is the same as the current value. MATLAB does not call the property set method, if one exists. For handle classes, setting AbortSet to true also prevent the triggering of property PreSet and PostSet events.</td>
</tr>
<tr>
<td>Abstract</td>
<td>logical</td>
<td>If true, the property has no implementation, but a concrete subclass must redefine this property without Abstract being set to true.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Abstract properties cannot define set or get access methods. See “Property Access Methods” on page 8-39.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Abstract properties cannot define initial values. See “Assigning a Default Value” on page 8-4.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• All subclasses must specify the same values as the superclass for the property SetAccess and GetAccess attributes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Abstract=true use with the class attribute Sealed=false (the default).</td>
</tr>
<tr>
<td>Access</td>
<td></td>
<td>Use Access to set both SetAccess and GetAccess to the same value. Query the values of SetAccess and GetAccess directly (not Access).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>public – unrestricted access</td>
</tr>
<tr>
<td></td>
<td></td>
<td>protected – access from class or subclasses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>private – access by class members only (not subclasses)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>List of classes that have get and set access to this property. Specify classes as meta.class objects in the form:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A single meta.class object</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A cell array of meta.class objects. An empty cell array, {}, is the same as private access.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See “Class Members Access” on page 12-23</td>
</tr>
<tr>
<td>Attribute Name</td>
<td>Class</td>
<td>Description</td>
</tr>
<tr>
<td>---------------</td>
<td>-------</td>
<td>-------------</td>
</tr>
</tbody>
</table>
| Constant      | logical | Set to true if you want only one value for this property in all instances of the class:  
  • Subclasses inherit constant properties, but cannot change them.  
  • Constant properties cannot be Dependent.  
  • SetAccess is ignored.  
  See “Define Class Properties with Constant Values” on page 15-2 for more information. |
|               |       |             |
| Dependent     | logical | If false, property value is stored in object. If true, property value is not stored in object.  
  The set and get functions cannot access the property by indexing into the object using the property name.  
  MATLAB does not display in the command window the names and values of Dependent properties that do not define a get method (scalar object display only).  
  Values returned by dependent property get methods are not considered when testing for object equality using isequal.  
  • “Calculate Data on Demand” on page 3-17  
  • “Property Get Methods” on page 8-47  
  • “Avoid Property Initialization Order Dependency” on page 13-9 |
<p>| | | |
|               |       |             |</p>
<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GetAccess</td>
<td>enumeration</td>
<td>public — unrestricted access</td>
</tr>
<tr>
<td></td>
<td></td>
<td>protected — access from class or subclasses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>private — access by class members only (not from subclasses)</td>
</tr>
<tr>
<td></td>
<td>default = public</td>
<td>List classes that have get access to this property. Specify classes as <code>meta.class</code> objects in the form:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A single <code>meta.class</code> object</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A cell array of <code>meta.class</code> objects. An empty cell array, <code>{}</code>, is the same as private access.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See “Class Members Access” on page 12-23</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MATLAB does not display in the command window the names and values of properties having protected or private GetAccess or properties whose Hidden attribute is true.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>The <code>struct</code> function defines fields for all properties when converting objects to structs.</td>
</tr>
<tr>
<td>GetObservable</td>
<td>logical</td>
<td>If true, and it is a handle class property, then you can create listeners for access to this property. The listeners are called whenever property values are queried. See “Property-Set and Query Events” on page 11-14</td>
</tr>
<tr>
<td></td>
<td>default = false</td>
<td></td>
</tr>
<tr>
<td>Hidden</td>
<td>logical</td>
<td>Determines if the property can be shown in a property list (e.g., Property Inspector, call to <code>set</code> or <code>get</code>, etc.).</td>
</tr>
<tr>
<td></td>
<td>default = false</td>
<td></td>
</tr>
<tr>
<td>NonCopyable</td>
<td>logical</td>
<td>Determine if property value can be copied when object is copied.</td>
</tr>
<tr>
<td></td>
<td>default = false</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>You can set NonCopyable to true only in handle classes.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>For more information, see “Exclude Properties from Copy” on page 7-33</td>
</tr>
<tr>
<td>Attribute Name</td>
<td>Class</td>
<td>Description</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PartialMatchPriority</td>
<td>Positive integer</td>
<td>Use only with subclasses of <code>matlab.mixin.SetGet</code>. Define the relative priority of partial property name matches used in <code>set</code> and <code>get</code> methods. For more information, see “Set Priority for Matching Partial Property Names” on page 7-26.</td>
</tr>
<tr>
<td>SetAccess</td>
<td>enumeration</td>
<td>public — unrestricted access</td>
</tr>
<tr>
<td></td>
<td></td>
<td>protected — access from class or subclasses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>private — access by class members only (not from subclasses)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>immutable — property can be set only in the constructor.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>List classes that have set access to this property. Specify classes as <code>meta.class</code> objects in the form:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A single <code>meta.class</code> object</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• A cell array of <code>meta.class</code> objects. An empty cell array, <code>{}</code>, is the same as <code>private</code> access.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>See “Class Members Access” on page 12-23</td>
</tr>
<tr>
<td>SetObservable</td>
<td>logical</td>
<td>If <code>true</code>, and it is a handle class property, then you can create listeners for access to this property. The listeners are called whenever property values are modified. See “Property-Set and Query Events” on page 11-14</td>
</tr>
<tr>
<td>Transient</td>
<td>logical</td>
<td>If <code>true</code>, property value is not saved when object is saved to a file. See “Save and Load Process for Objects” on page 13-2 for more about saving objects.</td>
</tr>
<tr>
<td>Framework attributes</td>
<td>Classes that use certain framework base classes have framework-specific attributes. See the documentation for the specific base class you are using for information on these attributes.</td>
<td></td>
</tr>
</tbody>
</table>
See Also

Related Examples
• “Property Definition” on page 8-13
Property Definition

What You Can Define

Control aspects of property definitions in the following ways:

• Specify a default value for each property individually, see “Property Default Values” on page 8-14.
• Assign property values in a class constructor, see “Assign Property Values in Constructor” on page 8-15.
• Define properties with constant values, see “Named Values” on page 14-2.
• Assign property attribute values on a per block basis, see “Property Attributes” on page 8-16.
• Define methods that execute when the property is set or queried, see “Methods to Set and Get Property Values” on page 8-16.
• Define the class and size of property values, see “Validate Property Values” on page 8-20.
• Define properties that do not store values, but whose values depend on other properties, see “Types of Properties” on page 8-2.

Note Properties cannot have the same name as the class.

Note Always use case-sensitive property names in your MATLAB code.

Initialize Property Values

There are two basic approaches to initializing property values:

• In the property definition — MATLAB evaluates the expression only once and assigns the same value to the property of every instance.
• In a class constructor — MATLAB evaluates the assignment expression for each instance, which ensures that each instance has a unique value.

For more information on the evaluation of expressions that you assign as property default values, see “When MATLAB Evaluates Expressions” on page 6-10.
Property Default Values

Within a properties block, you can control an individual property’s default value. Assign default values as a value or MATLAB expressions. Expressions cannot reference variables. For example:

- Prop1 — No assignment results in empty [] default value
- Prop2 — Assign character array as default value
- Prop3 — Assign result of expression as default value
- Prop4 — Assign the same instance of a handle class to Prop4 for all instances of this class
- Prop5 — Assign a default value that satisfies the specified restrictions of scalar positive double.

```matlab
classdef ClassName
    properties
        Prop1
        Prop2 = 'some text'
        Prop3 = sin(pi/12)
        Prop4 = containers.Map
        Prop5 (1,1) double {mustBePositive} = 1
    end
end
```

If the class definition does not specify a default property value, MATLAB initializes the property value to empty double ([]). If the class specifies any class, size, or validation function restrictions on the property value, then the class must ensure that the default value satisfies those restrictions by assigning a valid value when an empty value is invalid.

**Note** Evaluation of property default values occurs only when the value is first needed, and only once when MATLAB first initializes the class. MATLAB does not reevaluate the expression each time you create an instance of the class.

For more information on the evaluation of expressions that you assign as property default values, see “Evaluation of Expressions in Class Definitions” on page 6-8 and “Properties Containing Objects” on page 8-52.

For information on class, size, and validation functions used in property definitions, see “Validate Property Values” on page 8-20.

**Initializing Properties to Handle Objects**

MATLAB assigns the specified default values to properties only once when MATLAB loads the class definition. If you use a handle class constructor to create a property default value, MATLAB calls the constructor only when the class is first used, and then uses the same object handle as the default for the property in all objects created. Because all of the object handles reference the same object, any changes you make to the handle object in one instance are made to the handle object in all instances.

If you want a property value to be initialized to a new instance of a handle object each time you create an object of your class, assign the property value in the constructor.
Assign Property Values in Constructor

To assign values to a property from within the class constructor, refer to the object that the constructor returns (the output variable obj) and the property name using dot notation:

```matlab
classdef MyClass
    properties
        Prop1
    end
    methods
        function obj = MyClass(intval)
            % Initialize Prop1 for each instance
            obj.Prop1 = intval;
        end
    end
end
```

When you assign a property in the class constructor, MATLAB evaluates the assignment statement for each object you create. Assign property values in the constructor if you want each object to contain a unique value for that property.

For example, suppose that you want to assign a unique handle object to the property of another object each time you create one of the other objects. Assign the handle object to the property in the constructor. Call the handle object constructor to create a unique handle object with each instance of your class.

```matlab
classdef ContainsHandle
    properties
        Prop1
    end
    methods
        function obj = ContainsHandle(keySet,valueSet)
            obj.Prop1 = MyHandleClass(keySet,valueSet);
        end
    end
end
```

For more information on constructor methods, see “Referencing the Object in a Constructor” on page 9-19.

Default Values Evaluated Before Constructing Object

MATLAB validates property default values before the assignment of values in the constructor. It is necessary for the default value assigned in the properties block and the property value set in a class constructor to satisfy the specified validation. For example, this class restricts Prop to a scalar positive double, but does not assign a valid default value. By default, MATLAB assigns a default value of empty double, which causes a run-time error.

```matlab
classdef PropInit
    properties
        % Error without valid default value
        Prop (1,1) double {mustBePositive}
        % Empty default fails mustBePositive
    end
    methods
        function obj = PropInit(positiveInput)
            obj.Prop = positiveInput;
        end
    end
end
```
Calling the class constructor with a valid value for Prop results in an error from the validation function mustBePositive.

```
obj = PropInit(2);
```

Error using implicit default value of property 'Prop' of class 'PropInit': Value must be positive.

**Property Attributes**

All properties have attributes that modify certain aspects of the property's behavior. Specified attributes apply to all properties in a particular properties block. For example:

```
classdef ClassName
    properties (PropertyAttribute = value)
        Prop1
        Prop2
    end
end
```

For example, only methods in the same class definition can modify and query the Salary and Password properties.

```
classdef EmployeeInfo
    properties (Access = private)
        Salary
        Password
    end
end
```

This restriction exists because the class defines these properties in a properties block with the Access attribute set to private.

**Property Attributes**

For a description of property attributes you can specify, see, “Property Attributes” on page 8-7.

**Methods to Set and Get Property Values**

MATLAB calls whenever setting or querying a property value. Define property set access or get access methods in methods blocks that specify no attributes and have the following syntax:

```
methods
    function obj = set.PropertyName(obj, value)
        ...
    end

    function value = get.PropertyName(obj)
        ...
    end
end
```

For specific information on access method syntax, see “Property Get Methods” on page 8-47 and “Property Set Methods” on page 8-44.
MATLAB does not call the property set access method when assigning the default value specified in the property's definition block.

For example, the `set.Password` method tests the length of the character array assigned to a property named `Password`. If there are fewer than seven characters in the value assigned to the property, MATLAB returns the error. Otherwise, MATLAB assigns the specified value to the property.

```matlab
function obj = set.Password(obj,pw)
    if numel(pw) < 7
        error('Password must have at least 7 characters')
    else
        obj.Password = pw;
    end
end
```

For more information on property access methods, see “Property Access Methods” on page 8-39.

**Reference Object Properties Using Variables**

MATLAB can resolve a property name from a `char` variable using an expression of the form:

```matlab
object.(PropertyNameVar)
```

where `PropertyNameVar` is a variable containing the name of a valid object property. Use this syntax when passing property names as arguments. For example, the `getPropValue` function returns the value of the `KeyType` property:

```matlab
PropName = 'KeyType';
function o = getPropValue(obj,PropName)
    o = obj.(PropName);
end
```

**See Also**

**Related Examples**

- “Evaluation of Expressions in Class Definitions” on page 6-8
- “Ways to Use Properties” on page 8-2
- “Validate Property Values” on page 8-20
Mutable and Immutable Properties

In this section...

"Set Access to Property Values" on page 8-18
"Define Immutable Property" on page 8-18

Set Access to Property Values

The property SetAccess attribute enables you to determine under what conditions code can modify object property values. There are four levels of set access that provide varying degrees of access to object property values:

- **SetAccess = public** — Any code with access to an object can set public property values. There are differences between the behavior of handle and value classes with respect to modifying object properties.

- **SetAccess = protected** — Only code executing from within class methods or methods of subclasses can set property values. You cannot change the value of an object property unless the class or any of its subclasses defines a method to do so.

- **SetAccess = private** — Only the defining class can set property values. You can change the value of an object property only if the class defines a method that sets the property.

- **SetAccess = immutable** — Property value is set during construction. You cannot change the value of an immutable property after the object is created. Set the value of the property as a default or in the class constructor. You cannot define a property set method (`set.PropertyName`) for an immutable property.

For related information, see “Properties Containing Objects” on page 8-52.

Define Immutable Property

In this class definition, only the Immutable class constructor can set the value of the CurrentDate property:

```matlab
classdef Immutable
    properties (SetAccess = immutable)
        CurrentDate
    end
    methods
        function obj = Immutable
            obj.CurrentDate = date;
        end
    end
end

a = Immutable
a =

Immutable with properties:
    CurrentDate: '19-Oct-2005'
```
See Also

Related Examples
• “Property Attributes” on page 8-7
• “Object Modification” on page 5-49
Validate Property Values

Property Validation in Class Definitions

MATLAB property validation enables you to place specific restrictions on property values. You can use validation to constrain the class and size of property values. Also, you can use functions to establish criteria that the property value must conform to. MATLAB defines a set of validation functions and you can write your own validation functions.

The use of property validation is optional in class definitions.

Additional Information on Property Validation

For more information on property validation, see “Property Class and Size Validation” on page 8-25, “Property Validation Functions” on page 8-31, and “Metadata Interface to Property Validation” on page 8-37.

Validation Syntax

The highlighted area in the following code shows the syntax for property validation.

```matlab
classdef MyClass
    properties
        Prop(dim1,dim2,...) ClassName {fcn1,fcn2,...} = defaultValue
    end
end
```

Property validation includes any of the following:

- **Size** — The length of each dimension, specified as a positive integer or a colon. A colon indicates that any length is allowed in that dimension. The value assigned to the property must conform to the specified size or be compatible with the specified size. For more information, see “Property Size Validation” on page 8-25.
- **Class** — The name of a single MATLAB class. The value assigned to the property must be of the specified class or convertible to the specified class. Use any MATLAB class or externally defined class that is supported by MATLAB, except for Java and COM classes. For more information, see “Property Class Validation” on page 8-26.
• Functions — A comma-separated list of validation function names. MATLAB passes the value assigned to the property to each the validation functions after applying any possible class and size conversions. Validator functions throw errors if the validation fails, but do not return values. For more information, see “Property Validation Functions” on page 8-31.

For a list of MATLAB validation functions, see “MATLAB Validation Functions” on page 8-33.

Using Property Validation

Use property validation for public properties to control the values user code assigns to the properties.

If you want to restrict property values to a fixed set of identifiers, create an enumeration class for these identifiers and constrain the property to this class. For information on enumeration classes, see “Define Enumeration Classes” on page 14-4.

MATLAB type conversion rules apply to property validation. For example, MATLAB can coerce from one to another numeric type. Therefore, restricting a property value to a specific numeric type, such as double does not prevent the assignment of other numeric types to the property.

To ensure that a property can be assigned only a specific type of value, restrict the property to a type that supports only the desired type conversions or use a validation function to specify the exact class allowed for the property instead of specifying the property type. MATLAB evaluates the type specification before executing any validation functions. For more information, see “Order of Validation” on page 8-22.

Specify Valid Default

Ensure that any default value assigned to the property meets the restrictions imposed by the specified validation. If you do not specify a default value, MATLAB creates a default value by assigning an empty object of the specified class or by calling the default constructor if size restriction does not allow the use of an empty default value. The default constructor must return an object of the correct size.

Sample Class Using Property Validation

The ValidateProps class defines three properties with validation.

classdef ValidateProps
  properties
    Location(1,3) double {mustBeReal, mustBeFinite}
    Label(1,:) char {mustBeMember(Label,{'High','Medium','Low'})} = 'Low'
    State(1,1) matlab.lang.OnOffSwitchState
  end
end

• Location must be a 1-by-3 array of class double whose values are real, finite numbers.
• Label must be a char vector that is either 'High', 'Medium', or 'Low'.
• State must be an enumeration member of the matlab.lang.OnOffSwitchState class (off or on).

Validation at Instantiation

Creating an object of the ValidateProps class performs the validation on implicit and explicit default values:

a = ValidateProps
When creating the object, MATLAB:

- Initializes the Location property value to [0 0 0] to satisfy the size and class requirements.
- Sets the Label property to its default value, 'Low'. The default value must be a member of the allowed set of values. The empty char implicit default value would cause an error.
- Sets the State property to the off enumeration member defined by the matlab.lang.OnOffSwitchState class.

For information on how MATLAB selects default values, see “Default Values Per Size and Class” on page 8-30.

### Order of Validation

When a value is assigned to the property, including default values that are specified in the class definition, MATLAB performs validation in this order:

- Class validation — This validation can cause conversion to a different class, such as conversion of a char to string. Assignment to properties follows MATLAB coercion rules for arrays.
- Size validation — This validation can cause size conversion, such as scalar expansion or conversion of a column vector to a row vector. Assignment to a property that specifies a size validation behaves the same as assignment to any MATLAB array. For information on indexed assignment, see “Array Indexing”.
- Validator functions — MATLAB passes the result of the class and size validation to each validation function, in left to right order. An error can occur before all validation functions have been called, which ends the validation process.
- Set method — MATLAB performs property validation before calling a property set method, if one is defined for that property. Assignment to the property within a property set or get method does not apply the validation again. Often, you can replace property set methods using property validation.

### Property Validation Errors

The ValueProp class uses size, class, and function validation to ensure that an assignment to the Value property is a double scalar that is not negative.

```matlab
classdef ValueProp
    properties
        Value(1,1) double {mustBeNonnegative} = 0
    end
end
```

This statement attempts to assign a cell array to the property. This assignment violates the class validation.

```matlab
a.Value = {10,20};
```
Error setting property 'Value' of class 'ValueProp':
Invalid data type. Value must be double or be convertible to double.

This statement attempts to assign a 1-by-2 double array to the property. This assignment violates the size validation.

```
a.Value = [10 20];
```

Error setting property 'Value' of class 'ValueProp':
Size of value must be scalar.

This statement attempts to assign a scalar double to the property. This assignment fails the function validation, which requires a nonnegative number.

```
a.Value = -10;
```

Error setting property 'Value' of class 'ValueProp':
Value must be nonnegative.

The validation process ends with the first error encountered.

**Abstract Property Validation**

You can define property validation for abstract properties. The validation applies to all subclasses that implement the property. However, subclasses cannot use any validation on their implementation of the property. When inheriting validation for a property from multiple classes, only a single Abstract property in one superclass can define the validation. None of the superclasses can define the property as nonAbstract.

**Objects Not Updated When Changing Validation**

If you change the property validation while objects of the class exist, MATLAB does not attempt to apply the new validation to existing property values. However, MATLAB does apply the new validation when you make assignments to the properties of existing objects.

**Validation During Load Operation**

When saving an object to a MAT file, MATLAB saves all nondefault property values with the object. When loading the object, MATLAB restores these property values in the newly created object.

If a class definition changes the property validation such that the loaded property value is no longer valid, MATLAB substitutes the currently defined default value for that property. However, the `load` function suppresses the validation errors that occur before assigning the default value from the current class definition. Therefore, validation errors are silently ignored during load operations.

To illustrate this behavior, this example creates, saves, and loads an object of the `MonthTemp` class. This class restricts the `AveTemp` property to a cell array.

```
classdef MonthTemp
    properties
        AveTemp cell
    end
end
```

Create a `MonthTemp` object and assign a value to the `AveTemp` property.
a = MonthTemp;
a.AveTemp = {'May',70};

Save the object using save.

save TemperatureFile a

Edit the property definition to change the validation class for the AveTemp property from cell array to containers.Map.

classdef MonthTemp
    properties
        AveTemp containers.Map
    end
end

Load the saved object with the new class definition on the MATLAB path. MATLAB cannot assign the saved value to the AveTemp property because the cell array, {'May',70}, is not compatible with the current requirement that the property value be a containers.Map object. MATLAB cannot convert a cell array to a containers.Map.

To address the incompatibility, MATLAB sets the AveTemp property of the loaded object to the current default value, which is an empty containers.Map object.

load TemperatureFile a
a.AveTemp

ans =

Map with properties:
    Count: 0
    KeyType: char
    ValueType: any

The loaded object has a different value assigned to the AveTemp property because the saved value is now invalid. However, the load process suppresses the validation error.

To prevent loss of data when changing class definitions and reloading objects, implement a loadobj method or class converter method that enables the saved values to satisfy the current property validation.

For more information on saving and loading objects, see “Save and Load Process for Objects” on page 13-2.

See Also

Related Examples

- “Property Class and Size Validation” on page 8-25
- “Property Validation Functions” on page 8-31
Property Class and Size Validation

In this section...

“Property Class and Size” on page 8-25
“Property Size Validation” on page 8-25
“Property Class Validation” on page 8-26
“Default Values Per Size and Class” on page 8-30

Property Class and Size

MATLAB applies any class and size validation defined for a property before calling validation functions. Assignment to a property that defines size or class validation is analogous to assignment to a MATLAB object array. MATLAB can apply class and size conversions to the right side of the assignment to satisfy class and size validation.

For more information, see “Order of Validation” on page 8-22 and “Property Validation Functions” on page 8-31.

Property Size Validation

Specify the property size as the row, column, and additional dimension following the property name.

classdef MyClass
    properties
        Prop(dim1,dim2,...) = defaultValue
    end
end

Assignment and Size Validation

This class defines the size of the Location property as 1-by-3. Any value assigned to this property must conform to that size or must be convertible to that size.

classdef ValidateProps
    properties
        Location(1,3)
    end
end

The implicit default value assigned by MATLAB, [0 0 0], conforms to the specified size:

a = ValidateProps

a =
    ValidateProps with properties:
        Location: [0 0 0]

MATLAB applies scalar expansion when you assign a scalar the Location property.

a = ValidateProps;
a.Location = 1
a =

    ValidateProps with properties:
        Location: [1 1 1]

MATLAB converts columns to rows to match the size specification:

col = [1;1;1]

col =

    1
    1
    1

a.Location = col

a =

    ValidateProps with properties:
        Location: [1 1 1]

Colon in Size Specification

A colon in the size specification indicates that the corresponding dimension can have any length. For example, you can assign a value of any length to the Label property in this class.

classdef ValidateProps
    properties
    Label(1,:)
    end
end

a = ValidateProps;
a.Label = 'Click to Start'
a =

    ValidateProps with properties:
        Label: 'Click to Start'

Assignment to a property that defines size validation follows the same rules as the equivalent indexed array assignment. For information on indexing behavior of multidimensional arrays, see “Compatible Array Sizes for Basic Operations”.

Property Class Validation

Defining the class of a property can reduce the need to test the values assigned to the property in your code. Any value assigned to the property must be of the specified class or convertible to the specified class.

You can specify only one class per property. Use validation functions like mustBeNumeric or mustBeInteger to restrict properties to a broader category of classes. For more information on validation functions, see “Property Validation Functions” on page 8-31.
You can use any MATLAB class or externally defined class that is supported by MATLAB, except Java and COM classes.

Place the name of the class in the property definition block following the property name and optional size specification.

classdef MyClass
    properties
        Prop ClassName = defaultValue
    end
end

If you do not specify a default value, MATLAB assigns an empty object of the specified class to the property. If you define a size and a class, MATLAB attempts to create a default value for the property that satisfies both the size and class requirement.

MATLAB creates the default value by calling the class constructor with no arguments. The class must have a constructor that returns an object of the specified size when called with no input arguments or you must specify a default value for the property that satisfies the property size restriction. For more information, see “Default Values Per Size and Class” on page 8-30.

**Using Class Validation**

The PropsWithClass class defines two properties with class definitions:

- **Number** — Values must be of class double or convertible to double.
- **Today** — Values must be of class char or convertible to char. The default value is the char vector returned by the date function.

```matlab
classdef PropsWithClass
    properties
        Number double
        Today char = date
    end
end
```

Create an object of the PropsWithClass class.

```matlab
p = PropsWithClass
```

```matlab
p =

    PropsWithClass with properties:

        Number: []
        Today: '10-Sep-2016'
```

MATLAB performs conversions from any compatible class to the property class. For example, assign a datetime array to the Today property.

```matlab
p.Today = [datetime('now'),datetime('tomorrow')];
disp(class(p.Today))
```

```matlab
ans =

    char
```
Because the `datetime` class has a `char` converter, you can assign a `datetime` array to the `Today` property.

Assigning an incompatible value to a property that uses class validation causes an error:

```matlab
p.Number = datetime('now');
```

Error setting property 'Number' of class 'PropsWithClass':
Invalid data type. Value must be double or be convertible to double.

**User-Defined Class for Validation**

You can define a class to control the values assigned to a property. Enumeration classes enable users to set property values to character vectors or string scalars with inexact name matching.

For example, suppose that there is a class that represents a three-speed mechanical pump. You can define an enumeration class to represent the three flow rates.

```matlab
classdef FlowRate < int32
    enumeration
        Low    (10)
        Medium (50)
        High   (100)
    end
end
```

The `Pump` class has a method to return the current flow rate in gallons per minute. Define the `Speed` property as a `FlowRate` class.

```matlab
classdef Pump
    properties
        Speed FlowRate
    end
    methods
        function getGPM(p)
            if isempty(p.Speed)
                gpm = 0;
            else
                gpm = int32(p.Speed); % Convert to double
            end
            fprintf('Flow rate is: %i GPM\n',gpm);
        end
    end
end
```

Users can set the `Speed` property using inexact text.

```matlab
p = Pump;
p.Speed = 'm'
p =

     Pump with properties:
         Speed: Medium
```

The numerical value is available from the property.

```matlab
getGPM(p)
```
Flow rate is: 50 GPM

For information about enumeration classes, see “Define Enumeration Classes” on page 14-4.

**Integer Class Validation**

MATLAB supports several integer classes (see “Integers”). However, restricting a property to an integer class can result in integer overflow. The resulting value can saturate at the maximum or minimum value in the integer’s range.

When integer overflow occurs, the value that is assigned to a property can be a value that is different from the value from the right side of the assignment statement.

For example, suppose that you want to restrict a property value to a scalar `uint8`.

```matlab
classdef IntProperty
    properties
        Value(1,1) uint8
    end
end
```

Assigning a numeric value to the `Value` property effectively casts the numeric value to `uint8`, but does not result in an error for out-of-range values.

```matlab
a = IntProperty;
a.Value = -10;
disp(a.Value)
```

Assignment to the `Value` property is equivalent to indexed assignment of an array. If the assigned value is out of the range of values that `uint8` can represent, MATLAB sets the value to the closest value that it can represent using `uint8`.

```matlab
a = uint8.empty;
a(1) = -10
```  

To avoid the potential for integer overflow, use a combination of validation functions that restrict the value to the intended range instead of an integer class.

```matlab
classdef IntProperty
    properties
        Value(1,1) {mustBeInteger, mustBeNonnegative,...
                    mustBeLessThan(Value,256)}
    end
end
```

Because there is no conversion of the assigned value by the `uint8` class, the validators catch out of range values and throw an appropriate error:

```matlab
a = IntProperty;
a.Value = -10;
```
Error setting property 'Value' of class 'IntProperty': Value must be nonnegative.

Default Values Per Size and Class

Any default property value that you assign in the class definition must conform to the specified validation.

Implicit Default Values

MATLAB defines a default value implicitly if you do not specify a default value in the class definition. This table shows how size and class determine the implicit default value of MATLAB classes.

<table>
<thead>
<tr>
<th>Size</th>
<th>Class</th>
<th>Implicit Default Assigned by MATLAB</th>
</tr>
</thead>
<tbody>
<tr>
<td>(m,n)</td>
<td>Any numeric</td>
<td>m-by-n array of zeros of specified class.</td>
</tr>
<tr>
<td>(m,:) or (:n)</td>
<td>Any class</td>
<td>m-by-0 or 0-by-n of specified class.</td>
</tr>
<tr>
<td>(m,n)</td>
<td>char</td>
<td>m-by-n char array of spaces.</td>
</tr>
<tr>
<td>(m,n)</td>
<td>cell</td>
<td>m-by-n cell array with each cell containing a 0-by-0 double.</td>
</tr>
<tr>
<td>(m,n)</td>
<td>struct</td>
<td>m-by-n struct</td>
</tr>
<tr>
<td>(m,n)</td>
<td>string</td>
<td>m-by-n string</td>
</tr>
<tr>
<td>(m,n)</td>
<td>enumeration class</td>
<td>First enumeration member defined in the class.</td>
</tr>
<tr>
<td>(1,1)</td>
<td>function_handle</td>
<td>Runtime error — define a default value in the class.</td>
</tr>
</tbody>
</table>

To determine the implicit default value for nonzero and explicit size specifications, MATLAB calls the default class constructor and builds an array of the specified size using the instance returned by the constructor call. If the class does not support a default constructor (that is, a constructor called with no arguments), then MATLAB throws an error when instantiating the class containing the validation.

If the specified size has any zero or unrestricted (:) dimensions, MATLAB creates a default value that is an empty array with the unrestricted dimension set to zero.

For heterogeneous arrays, MATLAB calls the getDefaultScalarElement method to get the default object.

See Also

Related Examples

- “Validate Property Values” on page 8-20
- “Property Validation Functions” on page 8-31
- “Enumerations for Property Values” on page 14-14
Validate Property Using Functions

Use property validation functions in class definitions to impose specific restrictions on property values. A validation function accepts a potential property value as an argument and issues an error if the value does not meet the specific requirement imposed by the function.

During the validation process, MATLAB passes the value to each validation function listed in the class definition. MATLAB calls each function from left to right and throws the first error encountered. The value passed to the validation functions is the result of any conversion applied by the class and size specifications. For more information on class and size validation, see “Property Class and Size Validation” on page 8-25.

For a list of MATLAB validation functions, see “MATLAB Validation Functions” on page 8-33

Validation Function Syntax

Specify validation functions as a comma-separated list of function names or function calls with arguments, enclosed in braces.

```matlab
classdef MyClass
    properties
        Prop {fcn1,fcn2,...} = defaultValue
    end
end
```

MATLAB passes the potential property value to the validation function implicitly. However, if the validation function requires input arguments in addition to the potential property value, then you must include both the property and the additional arguments. Additional arguments must be literal values and cannot reference variables. Literal values are nonsymbolic representations, such as numbers and text.

For example, consider the function `mustBeGreaterThan`. It requires a limiting value as an input parameter. This validation function requires that a property value must be greater than this limiting value.

```matlab
properties
    Prop {mustBeGreaterThan(Prop,10)}
end
```

Using Validation Functions

The following class specifies validation functions for each property.
• **Data** must be numeric and finite.
• **Interp** must be one of the three options listed. Specify a default value for this property to satisfy this requirement.

```matlab
classdef ValidatorFunction
    properties
        Data {mustBeNumeric, mustBeFinite}
        Interp {mustBeMember(Interp,{'linear','cubic','spline'})} = 'linear'
    end
end
```

Creating a default object of the class shows the initial values.

```matlab
a = ValidatorFunction
```

```
ValidatorFunction with properties:
    Data: []
    Interp: 'linear'
```

Assigning values to properties calls the validation functions.

```matlab
a.Data = 'cubic'
```

Error setting property 'Data' of class 'ValidatorFunction':
Value must be numeric.

Because the **Data** property validation does not include a numeric class, there is no conversion of the char vector to a numeric value. If you change the validation of the **Data** property to specify the class as **double**, MATLAB converts the char vector to a double array.

```matlab
properties
    Data double {mustBeNumeric, mustBeFinite}
end
```

The assignment to the char vector does not produce an error because MATLAB converts the char vector to class double.

```matlab
a.Data = 'cubic'
a = 
```

```
ValidatorFunction with properties:
    Data: [99 117 98 105 99]
    Interp: 'linear'
```

Assignment to the **Interp** property requires an exact match.

```matlab
a = ValidatorFunction;
a.Interp = 'cu'
```

Error setting property 'Interp' of class 'ValidatorFunction':
Value must be a member of this set
linear
  cubic
  spline
Using an enumeration class provides inexact matching and case insensitivity.

**Enumeration Class for Inexact Matching**

Property validation using an enumeration class provides these advantages:

- Inexact, case-insensitive matching for unambiguous char vectors or string scalars
- Conversion of inexact matches to correct values

For example, suppose that you define the `InterpMethod` enumeration class for the `Interp` property validation.

```matlab
classdef InterpMethod
    enumeration
        linear
        cubic
        spline
    end
end
```

Change the `Interp` property validation to use the `InterpMethod` class.

```matlab
classdef ValidatorFunction
    properties
        Data {mustBeNumeric, mustBeFinite}
        Interp InterpMethod
    end
end
```

Assign a value matching the first few letters of 'cubic'.

```matlab
a = ValidatorFunction;
a.Interp = 'cu'
```

```matlab
a = ValidatorFunction with properties:
    Data: []
    Interp: cubic
```

**MATLAB Validation Functions**

MATLAB defines functions for use in property validation. These functions support common use patterns for validation and provide descriptive error messages. This table lists the MATLAB validation functions, their meanings, and the MATLAB functions used by the validation functions.

<table>
<thead>
<tr>
<th>Name</th>
<th>Meaning</th>
<th>Functions Called on Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>mustBePositive(value)</code></td>
<td>value &gt; 0</td>
<td><code>gt, isreal, isnumeric, islogical</code></td>
</tr>
<tr>
<td>Name</td>
<td>Meaning</td>
<td>Functions Called on Inputs</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------</td>
</tr>
<tr>
<td><code>mustBeNonpositive(value)</code></td>
<td>value &lt;= 0</td>
<td><code>ge, isreal, isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeFinite(value)</code></td>
<td>value has no NaN and no Inf elements.</td>
<td><code>isfinite</code></td>
</tr>
<tr>
<td><code>mustBeNonNan(value)</code></td>
<td>value has no NaN elements.</td>
<td><code>isnan</code></td>
</tr>
<tr>
<td><code>mustBeNonnegative(value)</code></td>
<td>value &gt;= 0</td>
<td><code>ge, isreal, isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeNegative(value)</code></td>
<td>value &lt; 0</td>
<td><code>lt, isreal, isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeNonzero(value)</code></td>
<td>value ~= 0</td>
<td><code>eq, isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeGreaterThan(value, c)</code></td>
<td>value &gt; c</td>
<td><code>gt, isscalar, isreal, isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeLessThan(value, c)</code></td>
<td>value &lt; c</td>
<td><code>lt, isreal, isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeGreaterThanOrEqual(value, c)</code></td>
<td>value &gt;= c</td>
<td><code>ge, isreal, isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeLessThanOrEqual(value, c)</code></td>
<td>value &lt;= c</td>
<td><code>le, isreal, isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeNonempty(value)</code></td>
<td>value is not empty.</td>
<td><code>isempty</code></td>
</tr>
<tr>
<td><code>mustBeNonsparse(value)</code></td>
<td>value has no sparse elements.</td>
<td><code>issparse</code></td>
</tr>
<tr>
<td><code>mustBeNumeric(value)</code></td>
<td>value is numeric.</td>
<td><code>isnumeric</code></td>
</tr>
<tr>
<td><code>mustBeNumericOrLogical(value)</code></td>
<td>value is numeric or logical.</td>
<td><code>isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeReal(value)</code></td>
<td>value has no imaginary part.</td>
<td><code>isreal</code></td>
</tr>
<tr>
<td><code>mustBeInteger(value)</code></td>
<td>value == floor(value)</td>
<td><code>isreal, isfinite, floor, isnumeric, islogical</code></td>
</tr>
<tr>
<td><code>mustBeMember(value, S)</code></td>
<td>value is an exact match for a member of S.</td>
<td><code>ismember</code></td>
</tr>
</tbody>
</table>
Define Validation Functions

Validator functions are ordinary MATLAB functions that are designed for the specific purpose of validating property values. Functions used as property validators:

- Accept the potential property value as an input argument
- Do not return values
- Throw errors if the validation fails

Creating your own validation function is useful when you want to provide specific validation that is not available using the MATLAB validation functions. You can create local functions within the class file or place the function on the MATLAB path to be available for use in any class.

For example, the `ImData` class uses a local function to define a validator that restricts the `Data` property to a specific range of numeric values.

classdef ImData
    properties
        Data {mustBeNumeric, mustBeInRange(Data,[0,255])} = 0
    end
end
function mustBeInRange(a,b)
    if any(a(:) < b(1)) || any(a(:) > b(2))
        error(['Value assigned to Data property is not in range ',...
            num2str(b(1)),'...',num2str(b(2))])
    end
end

When you create an instance of the `ImData` class, MATLAB validates that the default value is numeric, in the range 0...255, and not empty.

a = ImData

a =

    ImData with properties:

          Data: 0

Property assignment invokes the validators in left-to-right order. Assigning a char vector to the `Data` property causes an error thrown by `mustBeNumeric`.

a.Data = 'red'

Error setting property 'Data' of class 'ImData':
Value must be numeric.

Assigning a numeric value that is out of range causes an error thrown by `mustBeInRange`.

a.Data = -1

Error setting property 'Data' of class 'ImData':
Value assigned to Data property is not in range 0...255

Add Support for Validation Functions

Support MATLAB validation functions for objects of your class by implementing the dependent functions as methods of your class. To determine which methods to implement for each function, see
the validation function reference pages listed in this table “MATLAB Validation Functions” on page 8-33.

For example, suppose that you want your class to support the `mustBeGreaterThan` validation function. Overload these MATLAB functions as methods in your class:

- `isreal` — Always return logical `true` because `mustBeGreaterThan` does not support complex numbers.
- `gt` — The second object in the comparison must be scalar, as required by `mustBeGreaterThan`.

The `SupportmBGT` class implements support for `mustBeGreaterThan`.

```matlab
classdef SupportmBGT
    properties
        Prop(1,1) double {mustBeReal}
    end
    methods
        function obj = SupportmBGT(data)
            if nargin > 0
                obj.Prop = data;
            end
        end
        function tf = isreal(obj)
            tf = true;
        end
        function tf = gt(obj1, obj2)
            tf = [obj1(:).Prop] > obj2.Prop;
        end
    end
end
```

Use `mustBeGreaterThan` with objects of this class:

```matlab
a = SupportmBGT(10);
b = SupportmBGT(12);
mustBeGreaterThan(a,b)
```

Error using `mustBeGreaterThan` (line 19)
Value must be greater than the comparison value.

See Also

Related Examples

- “Validate Property Values” on page 8-20
- “Property Class and Size Validation” on page 8-25
Metadata Interface to Property Validation

For information on property validation, see “Validate Property Values” on page 8-20.

You can determine what validation applies to a property by accessing the validation metadata. Instances of the meta.Validation class provide the following information about property validation.

- Class requirement of the property specified as a meta.class object
- Size requirements of the property value specified as an array of meta.FixedDimension and meta.UnrestrictedDimension objects
- Function handles referencing validation functions applied to property values specified as a cell array of function handles.

For example, the ValidationExample class defines a property that must be an array of doubles that is 1-by-any number of elements and must be a real number that is greater than 10.

classdef ValidationExample
    properties
        Prop (1,:) double {mustBeReal, mustBeGreaterThan(Prop, 10)} = 200;
    end
end

Access the meta.Validation object from the property's meta.property object. Get the validation information from the meta.Validation object properties. Collection this information into a cell array.

- Get the size information from the Size property
- Get the class name from the Class property
- Get a cell array of function handles for the validation functions from the ValidatorFunctions property.

mc = ValidationExample;
mp = findobj(mc.PropertyList,'Name','Prop');
sz = mp.Validation.Size;
len = length(sz);
dim = cell(1:len);
for k = 1:len
    switch class(sz(k))
        case 'meta.FixedDimension'
            dim(k) = sz(k).Length;
        case 'meta.UnrestrictedDimension'
            dim(k) = ':';
    end
end
dim{end+1} = mp.Validation.Class.Name;
dim{end+1} = mp.Validation.ValidatorFunctions;

See Also
meta.Validation | meta.property
Related Examples

- “Validate Property Values” on page 8-20
- “Property Class and Size Validation” on page 8-25
- “Property Validation Functions” on page 8-31
Properties Provide Access to Class Data

In MATLAB, properties can have public access. Therefore, properties can provide access to data that the class design exposes to users.

Use property access methods to provide error checking or to implement side effects resulting from property access. Examples of access methods include functions that update other property values when setting the property or translate the format of a property value before returning the value.

For specific information on access method syntax, see “Property Get Methods” on page 8-47 and “Property Set Methods” on page 8-44.

You can use property validation to restrict the size, class, and other aspects of property values. For information on property validation, see “Validate Property Values” on page 8-20.

Performance Considerations with Access Methods

Property access methods do add the overhead of a function call whenever accessing property values. If performance-critical access to properties occurs inside methods of the class, define private properties to store values. Use these values inside methods without any error checking. For less frequent access from outside the class, define public Dependent properties that use access methods for error checking.

For information on access methods used with Dependent properties, see “Set and Get Methods for Dependent Properties” on page 8-49.

Property Set and Get Methods

Property access methods execute specific code whenever the property value is queried or assigned a value. These methods enable you to perform various operations:

- Execute code before assigning property values to perform actions such as:
  - Impose value range restrictions (“Validate Property Values” on page 8-20)
  - Check for proper types and dimensions
  - Provide error handling
- Execute code before returning the current values of properties to perform actions such as:
  - Calculate the value of properties that do not store values (see “Calculate Data on Demand” on page 3-17)
• Change the value of other properties
• Trigger events (see “Overview Events and Listeners” on page 11-2)

To control what code can access properties, see “Property Attributes” on page 8-7.

MATLAB Calls Access Methods

**Note** You cannot call property access methods directly. MATLAB calls these methods when you access property values.

Property access methods execute automatically whenever you set or query the corresponding property values from outside the access method. MATLAB does not call access methods recursively. That is, MATLAB does not call the set method when setting the property from within its set method. Similarly, MATLAB does not call the get method when querying the property value from within its get method.

Obtain the function handle for the set and get access methods from the property `meta.property` object. The `meta.property SetMethod` and `GetMethod` properties contain the function handles that refer to these methods.

Restrictions on Access Methods

Define property access methods only:

• For concrete properties (that is, properties that are not abstract)
• Within the class that defines the property (unless the property is abstract in that class, in which case the concrete subclass must define the access method).

MATLAB has no default set or get property access methods. Therefore, if you do not define property access methods, MATLAB software does not invoke any methods before assigning or returning property values.

Once defined, only the set and get methods can set and query the actual property values. See “When Set Method Is Called” on page 8-45 for information on cases where MATLAB does not call property set methods.

**Note** Property set and get access methods are not equivalent to user-callable set and get methods used to set and query property values from an instance of the class. See “Implement Set/Get Interface for Properties” on page 7-22 for information on user-callable set and get methods.

Access Methods Cannot Call Functions to Access Properties

You can set and get property values only from within your property set or get access method. You cannot call another function from the set or get method and attempt to access the property value from that function.

For example, an anonymous function that calls another function to do the actual work cannot access the property value. Similarly, an access function cannot call another function to access the property value.
Defining Access Methods

Access methods have special names that include the property name. Therefore, `get.PropertyName` executes whenever `PropertyName` is referenced and `set.PropertyName` executes whenever `PropertyName` is assigned a value.

Define property access methods in a methods block that specifies no attributes. You cannot call these methods directly. MATLAB calls these methods when any code accesses the properties.

Property access methods do not appear in the list of class methods returned by the `methods` command and are not included in the `meta.class` object `Methods` property.

Access Method Function Handles

The property `meta.property` object contains function handles to the property set and get methods. `SetMethod` contains a function handle to the set method. `GetMethod` contains a function handle to the get method.

Obtain these handles from the `meta.property` object:

```matlab
mc = ClassName;
mp = findobj(mc.PropertyList,'Name','PropertyName');
fh = mp.GetMethod;
```

For example, if the class `MyClass` defines a get method for its `Text` property, you can obtain a function handle to this function from the `meta.class` object:

```matlab
mc = MyClass;
mp = findobj(mc.PropertyList,'Name','Text');
fh = mp.GetMethod;
```

The returned value, `fh`, contains a function handle to the get method defined for the specified property name for the specified class.

For information on defining function handles, see “Create Function Handle”

Set and Get Method Execution and Property Events

MATLAB software generates events before and after set and get operations. You can use these events to inform listeners that property values have been referenced or assigned. The timing of event generation is as follows:

- **PreGet** — Triggered before calling the property get method
- **PostGet** — Triggered after the property get method has returned its value

If a class computes a property value (`Dependent = true`), then the behaviors of its set events are like the get events:

- **PreSet** — Triggered before calling the property set method
- **PostSet** — Triggered after calling the property set method

If a property is not computed (`Dependent = false`, the default), then the assignment statement with the set method generates the events:

- **PreSet** — Triggered before assigning the new property value within the set method
• **PostSet** — Triggered after assigning the new property value within the set method

For information about using property events, see “Create Property Listeners” on page 11-32.

**Access Methods and Properties Containing Arrays**

You can use array indexing with properties that contain arrays without interfering with property set and get methods.

For indexed reference:

```matlab
val = obj.PropName(n);
```

MATLAB calls the get method to get the referenced value.

For indexed assignment:

```matlab
obj.PropName(n) = val;
```

MATLAB:

• Invokes the get method to get the property value
• Performs the indexed assignment on the returned property
• Passes the new property value to the set method

**Access Methods and Arrays of Objects**

When reference or assignment occurs on an object array, MATLAB calls the set and get methods in a loop. In this loop, MATLAB always passes scalar objects to set and get methods.

**Modify Property Values with Access Methods**

Property access methods are useful in cases where you want to perform some additional steps before assigning or returning a property value. For example, the `Testpoint` class uses a property set method to check the range of a value. It then applies scaling if it is within a particular range, and set it to `NaN` if it is not.

The property get methods applies a scale factor before returning its current value:

```matlab
classdef Testpoint
    properties
        expectedResult = []
    end
    properties(Constant)
        scalingFactor = 0.001
    end
    methods
        function obj = set.expectedResult(obj,erIn)
            if erIn >= 0 && erIn <= 100
                erIn = erIn.*obj.scalingFactor;
                obj.expectedResult = erIn;
            else
                obj.expectedResult = NaN;
            end
    end
```
function er = get.expectedResult(obj)
er = obj.expectedResult/obj.scalingFactor;
end
end

See Also

More About

- “Property Set Methods” on page 8-44
- “Property Get Methods” on page 8-47
- “Properties Containing Objects” on page 8-52
Property Set Methods

In this section...
"Overview of Property Access Methods" on page 8-44
"Property Set Method Syntax" on page 8-44
"Validate Property Set Value" on page 8-44
"When Set Method Is Called" on page 8-45

Overview of Property Access Methods
For an overview of property access methods, see “Property Access Methods” on page 8-39

Property Set Method Syntax
MATLAB calls a property's set method whenever a value is assigned to the property.

Note You cannot call property access methods directly. MATLAB calls these methods when you access property values.

Property set methods have the following syntax, where PropertyName is the name of the property.

For a value class:

    methods
    function obj = set.PropertyName(obj,value)
        ...
    end

    • obj — Object whose property is being assigned a value
    • value — The new value that is assigned to the property

Value class set functions must return the modified object to the calling function. Handle classes do not need to return the modified object.

For a handle class:

    methods
    function set.PropertyName(obj,value)
        ...
    end

Use default method attributes for property set methods. The methods block defining the set method cannot specify attributes.

Validate Property Set Value

Use the property set method to validate the value being assigned to the property. The property set method can perform actions like error checking on the input value before taking whatever action is necessary to store the new property value.
classdef MyClass
    properties
        Prop1
    end
    methods
        function obj = set.Prop1(obj,value)
            if (value > 0)
                obj.Prop1 = value;
            else
                error('Property value must be positive')
            end
        end
    end
end

For an example of a property set method, see “Restrict Properties to Specific Values” on page 3-16.

**When Set Method Is Called**

If a property set method exists, MATLAB calls it whenever a value is assigned to that property. However, MATLAB does NOT call property set methods in the following cases:

- A value is assigned to a property from within its own property set method, to prevent recursive calling of the set method. However, property assignments made from functions called by a set method do call the set method.
- MATLAB assigns a default value to the property during initialization of an object before calling object constructor functions.
- When MATLAB copies a value object (any object that is not a handle), MATLAB does not call the set or get method when copying property values from one object to another.
- Any assignment made to a property value that is the same as the current value when the property’s AbortSet attribute is true. See “Assignment When Property Value Is Unchanged” on page 11-35 for more information on this attribute.

**Setting Property Value in Constructor**

Setting a property value in the constructor causes the property set method to be called. For example, the PropertySetMethod class defines a property set method for the Prop1 property.

classdef PropertySetMethod
    properties
        Prop1 = "Default String"
    end
    methods
        function obj = PropertySetMethod( str )
            if nargin > 0
                obj.Prop1 = str;
            end
        end

        function obj = set.Prop1(obj,str)
            obj.Prop1 = str;
            fprintf( 'set.Prop1 method called. Prop1 = %s\n', obj.Prop1 );
        end
    end
end
If you call the class constructor with no input arguments, MATLAB does not call the `set.Prop1` method.

```matlab
>> o = PropertySetMethod
o =
    PropertySetMethod with properties:
        Prop1: "Default String"
```

Setting the property value in the constructor results in a call to the property set method.

```matlab
>> o = PropertySetMethod("New string")
set.Prop1 method called. Prop1 = New string
```

```matlab
o =
    PropertySetMethod with properties:
        Prop1: "New string"
```

If you copy the object to another variable, MATLAB does not call the property set method even though the right side object in the assignment uses a nondefault value for the property:

```matlab
a = o;
```

```matlab
a.Prop1
```

```matlab
ans =
    "New string"
```

### See Also

### Related Examples

- “Property Get Methods” on page 8-47
- “Methods to Set and Get Property Values” on page 8-16
- “Validate Property Values” on page 8-20
Property Get Methods

Overview of Property Access Methods

For an overview of property access methods, see “Property Access Methods” on page 8-39.

Property Get Method Syntax

MATLAB calls a property's get method whenever the property value is queried.

Note You cannot call property access methods directly. MATLAB calls these methods when you access property values.

Property get methods have the following syntax, where PropertyName is the name of the property. The function must return the property value.

methods
    function value = get.PropertyName(obj)
    ...
end

Calculate Value for Dependent Property

The SquareArea class defines a dependent property Area. MATLAB does not store a value for the dependent Area property. When you query the value of the Area property, MATLAB calls the get.Area method calculates the value based on the Width and Height properties.

classdef SquareArea
    properties
        Width
        Height
    end
    properties (Dependent)
        Area
    end
    methods
        function a = get.Area(obj)
            a = obj.Width * obj.Height;
        end
    end
end
Errors Not Returned from Get Method

The MATLAB default object display suppresses error messages returned from property get methods. MATLAB does not allow an error issued by a property get method to prevent the display of the entire object.

Use the property set method to validate the property value. Validating the value when setting a property ensures that the object is in a valid state. Use the property get method only to return the value that the set method has validated.

Get Method Behavior

MATLAB does NOT call property get methods in the following cases:

- Getting a property value from within its own property get method, which prevents recursive calling of the get method
- Copying a value object (that is, not derived from the handle class). The set or get method is not called when copying property values from one object to another.

See Also

Related Examples

- “Set and Get Methods for Dependent Properties” on page 8-49
Set and Get Methods for Dependent Properties

Dependent properties do not store data. The value of a dependent property depends on some other value, such as the value of a nondependent property.

Dependent properties must define get-access methods (`get.PropertyName`) to determine a value for the property when the property is queried.

The values returned by dependent property get methods are not considered when testing for object equality using `isequal` and `isequaln`.

To be able to set the value of a dependent property, the property must define a set access method (`set.PropertyName`). The property set access method usually assigns the value to another, nondependent property for storage of the value.

For example, the `Account` class returns a value for the dependent `Balance` property that depends on the value of the `Currency` property. The `get.Balance` method queries the `Currency` property before calculating a value for the `Balance` property.

MATLAB calls the `get.Balance` method when the `Balance` property is queried. You cannot call `get.Balance` explicitly.

Here is a partial listing of the class showing a dependent property and its get method:

```matlab
classdef Account
    properties
        Currency
        DollarAmount
    end
    properties (Dependent)
        Balance
    end
    ... methods
        function value = get.Balance(obj)
            c = obj.Currency;
            switch c
                case 'E'
                    v = obj.DollarAmount / 1.1;
                case 'P'
                    v = obj.DollarAmount / 1.5;
                otherwise
                    v = obj.DollarAmount;
            end
            format bank
            value = v;
        end
    end
end
```
Calculate Dependent Property Value

One application of a property get method is to determine the value of a property only when you need it, and avoid storing the value. To use this approach, set the property Dependent attribute to true:

```matlab
properties (Dependent = true)
    Prop
end
```

The get method for the Prop property determines the value of that property and assigns it to the object from within the method:

```matlab
function value = get.Prop(obj)
    value = calculateValue;
    ...
end
```

This get method calls a function or static method called `calculateValue` to calculate the property value and returns `value` as a result. The property get method can take whatever action is necessary within the method to produce the output value.

For an example of a property get method, see “Calculate Data on Demand” on page 3-17.

When to Use Set Methods with Dependent Properties

Although a dependent property does not store its value, you can define a set method for a dependent property to enable code to set the property.

For example, suppose that you have a class that changes the name of a property from `OldPropName` to `NewPropName`. You can continue to allow the use of the old name without exposing it to new users. To support the old property name, define `OldPropName` a dependent property with set and get methods:

```matlab
properties
   NewPropName
end
properties (Dependent, Hidden)
   OldPropName
end
methods
    function obj = set.OldPropName(obj,val)
        objNewPropName = val;
    end
    function value = get.OldPropName(obj)
        value = objNewPropName;
    end
end
```

There is no memory wasted by storing both old and new property values. Code that accesses `OldPropName` continues to work as expected. Setting the Hidden attribute of `OldPropName` prevents new users from seeing the property.

Assignments made from property set methods cause the execution of any set methods defined for properties being set. See “Calculate Data on Demand” on page 3-17 for an example.
**Private Set Access with Dependent Properties**

If you use a dependent property only to return a value, then do not define a set access method for the dependent property. Instead, set the `SetAccess` attribute of the dependent property to `private`. For example, consider the following get method for the `MaxValue` property:

```matlab
methods
    function mval = get.MaxValue(obj)
        mval = max(obj.BigArray(:));
    end
end
```

This example uses the `MaxValue` property to return a value that it calculates only when queried. For this application, define the `MaxValue` property as dependent and private:

```matlab
properties (Dependent, SetAccess = private)
    MaxValue
end
```

**See Also**

**Related Examples**

- “Property Attributes” on page 8-7
Properties Containing Objects

In this section...

“Assigning Objects as Default Property Values” on page 8-52
“Assigning to Read-Only Properties Containing Objects” on page 8-52
“Assignment Behavior” on page 8-52

Assigning Objects as Default Property Values

MATLAB evaluates property default values only once when loading the class. MATLAB does not reevaluate the assignment each time you create an object of that class. If you assign an object as a default property value in the class definition, MATLAB calls the constructor for that object only once when loading the class.

Note  Evaluation of property default values occurs only when the value is first needed, and only once when MATLAB first initializes the class. MATLAB does not reevaluate the expression each time you create an instance of the class.

For more information on the evaluation of expressions that you assign as property default values, see “When MATLAB Evaluates Expressions” on page 6-10.

Assigning to Read-Only Properties Containing Objects

When a class defines a property with private or protected SetAccess, and that property contains an object which itself has properties, assignment behavior depends on whether the property contains a handle or a value object:

- Handle object – you can set properties on handle objects contained in read-only properties
- Value object – you cannot set properties on value object contained in read-only properties.

Assignment Behavior

These classes illustrate the assignment behavior:

- **ReadOnlyProps** - class with two read-only properties. The class constructor assigns a handle object of type HanClass to the PropHandle property and a value object of type ValClass to the PropValue property.
- **HanClass** - handle class with public property
- **ValClass** - value class with public property

```matlab
classdef ReadOnlyProps
    properties(SetAccess = private)
        PropHandle
        PropValue
    end
    methods
        function obj = ReadOnlyProps
            obj.PropHandle = HanClass;
```
obj.PropValue = ValClass;
end
end
end
classdef HanClass < handle
    properties
        Hprop
    end
end
classdef ValClass
    properties
        Vprop
    end
end

Create an instance of the ReadOnlyProps class:

a = ReadOnlyProps

a =

ReadOnlyProps with properties:

    PropHandle: [1x1 HanClass]
    PropValue: [1x1 ValClass]

Use the private PropHandle property to set the property of the HanClass object it contains:

class(a.PropHandle.Hprop)

ans =

double

a.PropHandle.Hprop = 7;

Attempting to make an assignment to the value class object property is not allowed:

a.PropValue.Vprop = 11;

You cannot set the read-only property 'PropValue' of ReadOnlyProps.

See Also

More About
- “Mutable and Immutable Properties” on page 8-18
Dynamic Properties — Adding Properties to an Instance

What Are Dynamic Properties

You can add properties to instances of classes that derive from the `dynamicprops` class. These dynamic properties are sometimes referred to as instance properties. Use dynamic properties to attach temporary data to objects or to assign data that you want to associate with an instance of a class, but not all objects of that class.

It is possible for more than one program to define dynamic properties on the same object. In these cases, avoid name conflicts. Dynamic property names must be valid MATLAB identifiers (see “Variable Names”) and cannot be the same name as a method of the class.

Characteristics of Dynamic Properties

Once defined, dynamic properties behave much like class-defined properties:

- Set and query the values of dynamic properties using dot notation. (See “Assign Data to the Dynamic Property” on page 8-55.)
- MATLAB saves and loads dynamic properties when you save and load the objects to which they are attached. (See “Dynamic Properties and ConstructOnLoad” on page 8-63.)
- Define attributes for dynamic property. (See “Set Dynamic Property Attributes” on page 8-55).
- By default, dynamic properties have their `NonCopyable` attribute set to `true`. If you copy an object containing a dynamic property, the dynamic property is not copied. (See “Objects with Dynamic Properties” on page 7-34)
- Add property set and get access methods. (See “Set and Get Methods for Dependent Properties” on page 8-49.)
- Listen for dynamic property events. (See “Dynamic Property Events” on page 8-59.)
- Access dynamic property values from object arrays, with restricted syntax. (See “Accessing Dynamic Properties in Arrays” on page 10-11.)
- The `isequal` function always returns `false` when comparing objects that have dynamic properties, even if the properties have the same name and value. To compare objects that contain dynamic properties, overload `isequal` for your class.

Define Dynamic Properties

Any class that is a subclass of the `dynamicprops` class (which is itself a subclass of the `handle` class) can define dynamic properties using the `addprop` method. The syntax is:

```
P = addprop(H,'PropertyName')
```

where:

P is an array of `meta.DynamicProperty` objects
H is an array of handles

*PropertyName* is the name of the dynamic property you are adding to each object

**Naming Dynamic Properties**

Use only valid names when naming dynamic properties (see “Variable Names”). In addition, *do not* use names that:

- Are the same as the name of a class method
- Are the same as the name of a class event
- Contain a period (.)
- Are the names of function that support array functionality: empty, transpose, ctranspose, permute, reshape, display, disp, details, or sort.

**Set Dynamic Property Attributes**

To set property attributes, use the `meta.DynamicProperty` object associated with the dynamic property. For example, if `P` is the object returned by `addprop`, this statement sets the property’s `Hidden` attribute to true:

```matlab
P.Hidden = true;
```

The property attributes `Constant` and `Abstract` have no meaning for dynamic properties. Setting the value of these attributes to `true` has no effect.

**Remove a Dynamic Property**

Remove the dynamic property by deleting its `meta.DynamicProperty` object:

```matlab
delete(P);
```

**Assign Data to the Dynamic Property**

Suppose, you are using a predefined set of user interface widget classes (buttons, sliders, check boxes, etc.). You want to store the location of each instance of the widget class. Assume that the widget classes are not designed to store location data for your particular layout scheme. You want to avoid creating a map or hash table to maintain this information separately.

Assuming the `button` class is a subclass of `dynamicprops`, add a dynamic property to store your layout data. Here is a simple class to create a `uicontrol` button:

```matlab
classdef button < dynamicprops
    properties
        UiHandle
    end
    methods
        function obj = button(pos)
            if nargin > 0
                if length(pos) == 4
                    obj.UiHandle = uicontrol('Position',pos,'Style','pushbutton');
                else
                    error('Improper position')
                end
            end
    end
```

8-55
Create an instance of the `button` class, add a dynamic property, and set its value:

```matlab
b1 = button([20 40 80 20]);
b1.addprop('myCoord');
b1.myCoord = [2,3];
```

Access the dynamic property just like any other property, but only on the object on which you defined it:

```matlab
b1.myCoord
```

**ans =**

```
2   3
```

**Access Attribute for Dynamic Properties**

Using nonpublic Access with dynamic properties is not recommended because these properties belong to specific instances that are often created outside of class methods. The Access attribute of a dynamic property applies to the class of the instance that contains the dynamic property. The dynamic property Access attribute does not necessarily apply to the class whose method adds the dynamic property.

For example, if a base class method adds a dynamic property with private access to an instance, the private access applies only to the class of the instance.

For more information on dynamic property attributes, see `meta.DynamicProperty`. Use the handle `findprop` method to get the `meta.DynamicProperty` object.

**See Also**

**Related Examples**

- “Set and Get Methods for Dynamic Properties” on page 8-57
- “Dynamic Property Events” on page 8-59
- “Dynamic Properties and ConstructOnLoad” on page 8-63
Set and Get Methods for Dynamic Properties

You can define property set access or get access methods for dynamic properties without creating additional class methods. For general information on the use of access methods, see “Property Access Methods” on page 8-39.

Create Access Methods for Dynamic Properties

Use these steps to create a property access method:

• Define a function that implements the operations you want to perform before the property set or get occurs. These methods must have the following signatures: `mySet(obj,val)` or `val = myGet(obj)`
• Obtain the dynamic property's corresponding `meta.DynamicProperty` object.
• Assign a function handle referencing your set or get property function to the `meta.DynamicProperty` object's `GetMethod` or `SetMethod` property. This function does not need to be a method of the class. You cannot use a naming scheme like `set.PropertyName`. Instead, use any other valid function name.

Suppose that you want to create a property set function for the `myCoord` dynamic property of the `button` class created in “Define Dynamic Properties” on page 8-54.

Write the function as follows.

```matlab
function set_myCoord(obj,val)
    if ~(length(val) == 2)
        error('myCoords require two values')
    end
    obj.myCoord = val;
end
```

Because `button` is a handle class, the property set function does not need to return the object as an output argument.

To get the `meta.DynamicProperty` object, use the `handle` class `findprop` method:

```matlab
mb1 = b1.findprop('myCoord');
mb1.SetMethod = @set_myCoord;
```

MATLAB calls the property set function whenever you set this property:

```matlab
b1.myCoord = [1 2 3] % length must be two
```

Error using `button.set_myCoord`
myCoords require two values

You can set and get the property values only from within your property access methods. You cannot call another function from the set or get method, and then attempt to access the property value from that function.
Shared Set and Get Methods

You can assign the same function handle for the set or get method of multiple dynamic properties. MATLAB passes only the object and the value to the assigned set function.

Reference or assignment to a property from within its set or get method does not invoke the set or get method again. Therefore, if you use a handle to the same function for multiple dynamic properties, that function is not invoked when accessing any of those properties from within that function.

See Also

Related Examples

- “Dynamic Properties — Adding Properties to an Instance” on page 8-54
Dynamic Property Events

Dynamic Properties and Ordinary Property Events

Dynamic properties support property set and get events so you can define listeners for these properties. Listeners are bound to the particular dynamic property for which they are defined.

If you delete a dynamic property, and then create another dynamic property with the same name, the listeners do not respond to events generated by the new property. A listener defined for a dynamic property that has been deleted does not cause an error, but the listener callback is never executed.

“Property-Set and Query Events” on page 11-14 provides more information on how to define listeners for these events.

Dynamic-Property Events

To respond to the addition and removal of dynamic properties, attach listeners to objects containing the dynamic properties. The dynamicprops class defines events for this purpose:

- **PropertyAdded** — Triggered when you add a dynamic property to an object derived from the dynamicprops class.
- **PropertyRemoved** — Triggered when you delete the object or the meta.DynamicProperty object associated with a dynamic property.
- **ObjectBeingDestroyed** — Triggered when the object is destroyed. This event is inherited from the handle class.

These events have public listen access (ListenAccess attribute) and private notify access (NotifyAccess attribute).

The PropertyAdded and PropertyRemoved events pass an event.DynamicPropertyEvent object to listener callbacks. The event data object has three properties:

- **PropertyName** — Name of the dynamic property that is added or removed
- **Source** — Handle to the object that is the source of the event
- **EventName** — Name of the event (PropertyAdded, PropertyRemoved, or ObjectBeingDestroyed)
Listen for a Specific Property Name

Suppose that you have an application that creates a dynamic property under certain conditions. You want to:

- Set the value of a hidden property to true when a property named SpecialProp is added.
- Set the value of the hidden property to false when SpecialProp is removed.

Use the event.DynamicPropertyEvent event data to determine the name of the property and whether it is added or deleted.

The DynamTest class derives from dynamicprops. It defines a hidden property, HiddenProp.

classdef DynamTest < dynamicprops
    properties (Hidden)
        HiddenProp
    end
end

Define a callback function that uses the EventName property of the event data to determine if a property is added or removed. Obtain the name of the property from the PropertyName property of the event data. If a dynamic property is named SpecialProp, change the value of the hidden property.

function DyPropEvtCb(src,evt)
    switch evt.EventName
    case 'PropertyAdded'
        switch evt.PropertyName
        case 'SpecialProp'
            % Take action based on the addition of this property
            %...
            %...
            src.HiddenProp = true;
            disp('SpecialProp added')
        otherwise
            % Other property added
            %...
            disp([evt.PropertyName,' added'])
        end
    case 'PropertyRemoved'
        switch evt.PropertyName
        case 'SpecialProp'
            % Take action based on the removal of this property
            %...
            %...
            src.HiddenProp = false;
            disp('SpecialProp removed')
        otherwise
            % Other property removed
            %...
            disp([evt.PropertyName,' removed'])
        end
    end
end

Create an object of the DynamTest class.
dt = DynamTest;

Add a listener for both PropertyAdded and PropertyRemoved events.

lad = addlistener(dt,'PropertyAdded',@DyPropEvtCb);
lrm = addlistener(dt,'PropertyRemoved',@DyPropEvtCb);

**PropertyAdded Event Callback Execution**

Adding a dynamic property triggers the PropertyAdded event. This statement adds a dynamic property to the object and saves the returned meta.DynamicProperty object.

ad = addprop(dt,'SpecialProp');

The addition of the dynamic property causes the listener to execute its callback function, DyPropEvtCb. The callback function assigns a value of true to the HiddenProp property.

dt.HiddenProp
ans =
    1

**PropertyRemoved Event Callback Execution**

Remove a dynamic property by calling delete on the meta.DynamicProperty object that is returned by the addprop method. Removing the meta.DynamicProperty object triggers the PropertyRemoved event.

Delete the meta.DynamicProperty object returned when adding the dynamic property SpecialProp.

delete(ad)

The callback executes:

SpecialProp removed

The value of HiddenProp is now false.

dt.HiddenProp
ans =
    0

**How to Find meta.DynamicProperty Objects**

You can obtain the meta.DynamicProperty object for a dynamic property using findprop. Use findprop if you do not have the object returned by addprop.

ad = findprop(dt,'SpecialProp');
See Also

Related Examples

- “Dynamic Properties — Adding Properties to an Instance” on page 8-54
Dynamic Properties and ConstructOnLoad

Setting the class ConstructOnLoad attribute to true causes MATLAB to call the class constructor when loading the class. MATLAB saves and restores dynamic properties when loading an object.

If you create dynamic properties from the class constructor, you can cause a conflict if you also set the class ConstructOnLoad attribute to true. Here is the sequence:

- A saved object saves the names and values of properties, including dynamic properties
- When loaded, a new object is created and all properties are restored to the values at the time the object was saved
- Then, the ConstructOnLoad attribute causes a call to the class constructor, which would create another dynamic property with the same name as the loaded property. See “Save and Load Objects” on page 13-2 for more on the load sequence.
- MATLAB prevents a conflict by loading the saved dynamic property, and does not execute addprop when calling the constructor.

If you use ConstructOnLoad, add dynamic properties from the class constructor, and want the constructor to call addprop at load time, then set the dynamic property Transient attribute to true. This setting prevents the property from being saved. For example:

```matlab
classdef (ConstructOnLoad) MyClass < dynamicprops
    function obj = MyClass
        P = addprop(obj,'DynProp');
        P.Transient = true;
        ...
    end
end
```

See Also

Related Examples

- “Dynamic Properties — Adding Properties to an Instance” on page 8-54
Methods — Defining Class Operations

- “Methods in Class Design” on page 9-2
- “Method Attributes” on page 9-4
- “Ordinary Methods” on page 9-6
- “Methods in Separate Files” on page 9-8
- “Method Invocation” on page 9-11
- “Class Constructor Methods” on page 9-16
- “Static Methods” on page 9-24
- “Overload Functions in Class Definitions” on page 9-26
- “Class Support for Array-Creation Functions” on page 9-29
- “Object Precedence in Method Invocation” on page 9-36
- “Dominant Argument in Overloaded Graphics Functions” on page 9-38
- “Class Methods for Graphics Callbacks” on page 9-41
Methods in Class Design

Class Methods

Methods are functions that implement the operations performed on objects of a class. Methods, along with other class members support the concept of encapsulation—class instances contain data in properties and class methods operate on that data. This design allows the internal workings of classes to be hidden from code outside of the class, and thereby enabling the class implementation to change without affecting code that is external to the class.

Methods have access to private members of their class including other methods and properties. This encapsulation enables you to hide data and create special interfaces that must be used to access the data stored in objects.

Examples and Syntax

For an example to get started writing classes, see “Create a Simple Class” on page 2-2

For sample code and syntax, see “Methods and Functions” on page 5-13

For a discussion of how to create classes that modify standard MATLAB behavior, see “Methods That Modify Default Behavior” on page 17-2.

For information on the use of @ and path directors and packages to organize your class files, see “Class Files and Folders” on page 5-2

For the syntax to use when defining classes in more than one file, see “Methods in Separate Files” on page 9-8

Kinds of Methods

There are specialized kinds of methods that perform certain functions or behave in particular ways:

- Ordinary methods are functions that act on one or more objects and return some new object or some computed value. These methods are like ordinary MATLAB functions that cannot modify input arguments. Ordinary methods enable classes to implement arithmetic operators and computational functions. These methods require an object of the class on which to operate. See “Ordinary Methods” on page 9-6.

- Constructor methods are specialized methods that create objects of the class. A constructor method must have the same name as the class and typically initializes property values with data obtained from input arguments. The class constructor method must declare at least one output argument, which is the object being constructed. The first output is always the object being constructed. See “Class Constructor Methods” on page 9-16
• Destructor methods are called automatically when the object is destroyed, for example if you call `delete(object)` or there are no longer any references to the object. See “Handle Class Destructor” on page 7-13

• Property access methods enable a class to define code to execute whenever a property value is queried or set. See “Property Access Methods” on page 8-39

• Static methods are functions that are associated with a class, but do not necessarily operate on class objects. These methods do not require an instance of the class to be referenced during invocation of the method, but typically perform operations in a way specific to the class. See “Static Methods” on page 9-24

• Conversion methods are overloaded constructor methods from other classes that enable your class to convert its own objects to the class of the overloaded constructor. For example, if your class implements a `double` method, then this method is called instead of the double class constructor to convert your class object to a MATLAB double object. See “Object Converters” on page 17-10 for more information.

• Abstract methods define a class that cannot be instantiated itself, but serves as a way to define a common interface used by numerous subclasses. Classes that contain abstract methods are often referred to as interfaces. See “Abstract Classes and Class Members” on page 12-72 for more information and examples.

Method Naming

The name of a function that implements a method can contain dots (for example, `set.PropertyName`) only if the method is one of the following:

• Property set/get access method (see “Property Access Methods” on page 8-39)
• Conversion method that converts to a package-qualified class, which requires the use of the package name (see “Packages Create Namespaces” on page 6-20)

You cannot define property access or conversion methods as local functions, nested functions, or separately in their own files. Class constructors and package-scoped functions must use the unqualified name in the function definition; do not include the package name in the function definition statement.

See Also

Related Examples

• “Method Attributes” on page 9-4
• “Rules for Naming to Avoid Conflicts” on page 9-28
Method Attributes

Purpose of Method Attributes

Specifying attributes in the class definition enables you to customize the behavior of methods for specific purposes. Control characteristics like access, visibility, and implementation by setting method attributes. Subclasses do not inherit superclass member attributes.

Specifying Method Attributes

Assign method attributes on the same line as the methods keyword:

```plaintext
methods (Attribute1 = value1, Attribute2 = value2,...) end
```

For more information on attribute syntax, see “Attribute Specification” on page 5-18.

Table of Method Attributes

Attributes enable you to modify the behavior of methods. All methods support the attributes listed in the following table.

Attribute values apply to all methods defined within the methods...end code block that specifies the nondefault values.
Method Attributes

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Class</th>
<th>Description</th>
</tr>
</thead>
</table>
| Abstract       | logical Default = false | If true, the method has no implementation. The method has a syntax line that can include arguments that subclasses use when implementing the method:  
  - Subclasses are not required to define the same number of input and output arguments. However, subclasses generally use the same signature when implementing their version of the method.  
  - The method can have comments after the function line.  
  - The method does not contain function or end keywords, only the function syntax (e.g., [a,b] = myMethod(x,y)) |
| Access         | • enumeration, default = public  
  • meta.class object  
  • cell array of meta.class objects | Determines what code can call this method:  
  - public — Unrestricted access  
  - protected — Access from methods in class or subclasses  
  - private — Access by class methods only (not from subclasses)  
  - List classes that have access to this method. Specify classes as meta.class objects in the form:  
    - A single meta.class object  
    - A cell array of meta.class objects. An empty cell array, {}, is the same as private access.  

  See “Class Members Access” on page 12-23 |
| Hidden         | logical Default = false | When false, the method name shows in the list of methods displayed using the methods or methodsview commands. If set to true, the method name is not included in these listings and ismethod does not return true for this method name. |
| Sealed         | logical Default = false | If true, the method cannot be redefined in a subclass. Attempting to define a method with the same name in a subclass causes an error. |
| Static         | logical Default = false | Specify as true to define a method that does not depend on an object of the class and does not require an object argument. Use the class name to call the method: classname.methodname or an instance of the class: obj.methodname  

  “Static Methods” on page 9-24 provides more information. |
| Framework attributes | Classes that use certain framework base classes have framework-specific attributes. See the documentation for the specific base class you are using for information on these attributes. |
Ordinary Methods

Ordinary Methods Operate on Objects

Ordinary methods define functions that operate on objects of the class. Therefore, one of the input arguments must be an object or array of objects of the defining class. These methods can compute values based on object data, can overload MATLAB built-in functions, and can call other methods and functions. Ordinary methods can return modified objects.

Methods Inside classdef Block

This example shows the definition of a method (methodName) within the classdef and methods blocks:

```matlab
classdef ClassName
    methods (AttributeName = value,...)
        function methodName(obj,args)
            % method code
            ...
        end
    end % end of method block
    end
end
```

Method attributes apply only to that particular methods block, which is terminated by the `end` statement.

**Note** Nonstatic methods must include an explicit object variable as a function argument. The MATLAB language does not support an implicit reference in the method function definition.

Example of a Method

The `addData` method adds a value to the `Data` property of `MyData` objects. The `mustBeNumeric` function restricts the value of the `Data` property to numeric values. The property has a default value of `0`.

The `addData` method returns the modified object, which you can reassign to the same variable.

```matlab
classdef MyData
    properties
        Data {mustBeNumeric} = 0
    end
    methods
        function obj = addData(obj,val)
            if isnumeric(val)
newData = obj.Data + val;
obj.Data = newData;
end
end
end

a = MyData;
a = addData(a,75)

a =

MyData with properties:

Data: 75

Calling Methods

Either of the following statements is correct syntax for calling a method, where obj is an object of the class defining the methodName method:

obj.methodName(arg)
methodName(obj,arg)

Method Files

You can define methods:

• Inside the class definition block
• In a separate file in the class folder (that is, @ClassName folder)

For more information on class folders, see “Folders Containing Class Definitions” on page 6-13.

See Also

More About

• “Methods in Separate Files” on page 9-8
• “Determining Which Method Is Invoked” on page 9-11
• “Operator Overloading” on page 17-38
Methods in Separate Files

In this section...

"Class Folders” on page 9-8
"Define Method in Function File” on page 9-8
"Specify Method Attributes in classdef File” on page 9-9
"Methods You Must Define in the classdef File” on page 9-10

Class Folders

You can define class methods in files that are separate from the class definition file, with certain exceptions (see “Methods You Must Define in the classdef File” on page 9-10).

To use multiple files for class definitions, put the class files in a folder having a name beginning with the @ character followed by the name of the class (this is called a class folder). Ensure that the parent folder of the class folder is on the MATLAB path.

If the class folder is contained in one or more package folders, then the top-level package folder must be on the MATLAB path.

For example, the folder @MyClass must contain the file MyClass.m (which contains the classdef block) and can contain other methods and function defined in files having a .m extension. The folder @MyClass can contain a number of files:

@MyClass/MyClass.m
@MyClass/subsref.m
@MyClass/subsasgn.m
@MyClass/horzcat.m
@MyClass/vertcat.m
@MyClass/myFunc.m

Types of Method Files

MATLAB treats any function file in the class folder as a method of the class. Function files can be MATLAB code (.m), Live Code file format (.mlx), MEX functions (platform dependent extensions), and P-code files (.p). The base name of the file must be a valid MATLAB function name. Valid function names begin with an alphabetic character, and can contain letters, numbers, or underscores.

Define Method in Function File

To define a method in a separate file in the class folder, create the function in a file. Do not use the method-end keywords in that file. Name the file with the function name, as with any function.

In the myFunc.m file, implement the method:

```matlab
function output = myFunc(obj, arg1, arg2)
    % code here
end
```

It is a good practice to declare the function signature in the classdef file in a methods block:

```matlab
classdef MyClass
    methods
```

Methods in Separate Files

Specify Method Attributes in classdef File

If you specify method attributes for a method that you define in a separate function file, include the method signature in a methods block in the classdef file. This methods block specifies the attributes that apply to the method.

For example, the following code shows a method with Access set to private in the methods block. The method implementation resides in a separate file. Do not include the function or end keywords in the methods block. Include only the function signature showing input and output arguments.

```matlab
classdef MyClass
    methods (Access = private)
        output = myFunc(obj,arg1,arg2)
    end
end
```

In a file named `myFunc.m`, in the `@MyClass` folder, define the function:

```matlab
function output = myFunc(obj,arg1,arg2)
    ...
end
```

Static Methods in Separate Files

To create a static method, set the method Static attribute to true and list the function signature in a static methods block in the classdef file. Include the input and output arguments with the function name. For example:

```matlab
classdef MyClass
    methods (Static)
        output = staticFunc1(arg1,arg2)
        staticFunc2
    end
end
```

Define the functions in separate files using the same function signature. For example, in the file `@MyClass/staticFunc1.m`:

```matlab
function output = staticFunc1(arg1,arg2)
    ...
end
```

and in `@MyClass/staticFunc2.m`:

```matlab
function staticFunc2
    ...
end
```
Methods You Must Define in the classdef File

Define the following methods in the classdef file. You cannot define these methods in separate files:

- Class constructor
- All functions that use dots in their names, including:
  - Converter methods that must use the package name as part of the class name because the class is contained in packages
  - Property set and get access methods

Related Information

- “Converters for Package Classes” on page 17-10
- “Property Access Methods” on page 8-39

See Also

Related Examples

- “Folders Containing Class Definitions” on page 6-13
- “Live Code File Format (.mlx)”
- “MEX File Functions”
- “Protect Your Source Code”
Method Invocation

Determining Which Method Is Invoked

When MATLAB invokes an ordinary method that has an argument list, it uses the following criteria to determine which method to call:

- The class of the leftmost argument whose class is not specified as inferior to any other argument's class is chosen as the dominant class and its method is invoked.
- If this class does not define the called method, then a function with that name that is on the MATLAB path is invoked.
- If no such function exists, MATLAB issues an error indicating that the dominant class does not define the named method.

Dominant Argument

MATLAB uses dominant argument dispatching to determine which version of a method to call. During method dispatching, MATLAB determines the dominant class from among the arguments in the call. In general, all MATLAB classes defined using the classdef syntax have equal precedence for purposes of method dispatching.

Classes defined using the classdef syntax take precedence over these MATLAB classes:

double, single, int64, uint64, int32, uint32, int16, uint16, int8, uint8, char, string, logical, cell, struct, and function_handle.

In general, when two or more objects are part of the argument list, the method defined for the class of the left-most object is invoked. However, user-defined classes can specify the relative dominance of specific classes. For information, see "Class Precedence" on page 6-18.

For example, suppose classA defines classB as inferior and suppose that both classes define a method called combine.

Calling the method with an object of classB and classA:

combine(B,A)

actually calls the combine method of classA because A is the dominant argument.
Dot Notation vs. Function Notation

MATLAB classes support both function and dot notation syntax for calling methods. For example, if `setColor` is a method of the class of object `X`, then calling `setColor` with function notation would be:

```matlab
X = setColor(X,'red');
```

The equivalent method call using dot notation is:

```matlab
X = X.setColor('red')
```

However, in certain cases, the results for dot notation can differ with respect to how MATLAB dispatching works:

- If there is an overloaded `subsref`, it is invoked whenever using dot notation. That is, the statement is first tested to see if it is subscripted assignment.
- If there is no overloaded `subsref`, then `setColor` must be a method of `X`. An ordinary function or a class constructor is never called using this notation.
- Only the argument `X` (to the left of the dot) is used for dispatching. No other arguments, even if dominant, are considered. Therefore dot notation can call only methods of `X`; methods of other arguments are never called.

Case Where Result Is Different

Here is an example of a case where dot and function notation can give different results. Suppose that you have the following classes:

- `classA` defines a method called `methodA` that requires an object of `classB` as one of its arguments
- `classB` defines `classA` as inferior to `classB`

```matlab
classdef (InferiorClasses = {?classA}) classB
    ...
end
```

The `methodA` method is defined with two input arguments, one of which is an object of `classB`:

```matlab
classdef classA
    methods
        function methodA(obj,obj_classB)
            ...
        end
    end
end
```

`classB` does not define a method with the same name as `methodA`. Therefore, the following syntax causes MATLAB to search the path for a function with the same name as `methodA` because the second argument is an object of a dominant class. If a function with that name exists on the path, then MATLAB attempts to call this function instead of the method of `classA` and most likely returns a syntax error.

```matlab
obj = classA(...);
methodA(obj,obj_classB)
```

Dot notation is stricter in its behavior. For example, this call to `methodA`: 
obj = classA(...);
obj.methodA(obj_classB)

can call only methodA of the class of obj.

**Referencing Names with Expressions—Dynamic Reference**

You can reference an object's properties or methods using an expression in dot-parentheses syntax:

```matlab
obj.(expression)
```

The expression must evaluate to a char vector that is the name of a property or a method. For example, the following statements are equivalent:

```matlab
obj.Property1
obj.("Property1")
```

In this case, obj is an object of a class that defines a property called Property1. Therefore, you can pass a char variable in the parentheses to reference to property:

```matlab
propName = 'Property1';
obj.(propName)
```

You can call a method and pass input arguments to the method using another set of parentheses:

```matlab
obj.(expression)(arg1,arg2,...)
```

Using this notation, you can make dynamic references to properties and methods in the same way you can create dynamic references to the fields of structs.

As an example, suppose that an object has methods corresponding to each day of the week. These methods have the same names as the days of the week (Monday, Tuesday, and so on). Also, the methods take as char vector input arguments, the current day of the month (the date). Now suppose that you write a function in which you want to call the correct method for the current day.

Use an expression created with the `date` and `datestr` functions:

```matlab
obj.(datestr(date,'dddd'))(datestr(date,'dd'))
```

The expression `datestr(date,'dddd')` returns the current day as a char vector. For example:

```matlab
datestr(date,'dddd')
ans =
Tuesday
```

The expression `datestr(date,'dd')` returns the current date as a char vector. For example:

```matlab
datestr(date,'dd')
ans =
11
```

Therefore, the expression using dot-parentheses (called on Tuesday the 11th) is the equivalent of:

```matlab
obj.Tuesday('11')
```
Index into Result of Method Call

You can use dot indexing into the result of a method call to obtain a value. For example, this class defines a property and a constructor method. The constructor sets the property value after evaluating an expression using the input argument.

```matlab
classdef polyEval
    properties
        Result
    end
    methods
        function obj = polyEval(x)
            if nargin
                obj.Result = 2*x.^3 + 7*x.^2 + 2*x + 7;
            end
        end
    end
end
```

You can index into the result of a method call to access the value of the property. For example, this call to `polyEval()` returns the value that is assigned to the property. The instance of the `polyEval` class is created as a temporary variable and is not saved in the workspace.

```matlab
polyEval(-3.5).Result
ans =
0
```

In this case, the expression, `polyEval(-3.5).Result` represents the value 0 (the value -3.5 is a root of the polynomial). You can assign the result of evaluating this expression to a variable or use it in other expressions.

You can dot index into the result of any method that returns a result for which dot indexing is defined, such as an object or structure which can be indexed using a property or field name. You must include the parentheses in all indexing expressions even if there are no arguments. For example, to index into the result of a call to the `polyEval()` constructor with no inputs, use this expression.

```matlab
polyEval().Result
```

For more information on indexing into the result of function calls, see “Indexing into Function Call Results”.

Controlling Access to Methods

There can be situations where you want to create methods for internal computation within the class, but do not want to publish these methods as part of the public interface to the class. In these cases, you can use the `Access` attribute to set the access to one of the following options:

- **public** — Any code having access to an object of the class can access this method (the default).
- **private** — Restricts method access to the defining class, excluding subclasses. Subclasses do not inherit private methods.
- **protected** — Restricts method access to the defining class and subclasses derived from the defining class. Subclasses inherit this method.
• Access list — Restricts method access to classes in access list. For more information, see “Class Members Access” on page 12-23

Local and nested functions inside the method files have the same access as the method. Local functions inside a class-definition file have private access to the class defined in the same file.

**Invoking Superclass Methods in Subclass Methods**

A subclass can override the implementation of a method defined in a superclass. If the subclass method needs to execute additional code instead of completely replacing the superclass method. MATLAB classes can use a special syntax for invocation of superclass methods from a subclass implementation for the same-named method.

The syntax to call a superclass method in a subclass class uses the @ symbol:

```
MethodName@SuperclassName
```

For example, the following disp method is defined for a Stock class that is derived from an Asset class. The method first calls the Asset class disp method, passing the Stock object so that the Asset components of the Stock object can be displayed. After the Asset disp method returns, the Stock disp method displays the two Stock properties:

```matlab
classdef Stock < Asset
  methods
    function disp(s)
      disp@Asset(s) % Call base class disp method first
      fprintf(1,'Number of shares: %g
Share price: %3.2f
',s.NumShares,s.SharePrice);
    end % disp
  end
end
```

**Limitations of Use**

The following restrictions apply to calling superclass methods. You can use this notation only within:

- A method having the same name as the superclass method you are invoking
- A class that is a subclass of the superclass whose method you are invoking

**Invoking Built-In Functions**

The MATLAB `builtin` function enables you to call the built-in version of a function that has been overloaded by a method.

**See Also**

**More About**

- “Object Precedence in Method Invocation” on page 9-36
- “Class Precedence” on page 6-18
Class Constructor Methods

In this section...

“Purpose of Class Constructor Methods” on page 9-16
“Basic Structure of Constructor Methods” on page 9-16
“Guidelines for Constructors” on page 9-17
“Default Constructor” on page 9-17
“When to Define Constructors” on page 9-18
“Related Information” on page 9-18
“Initializing Objects in Constructor” on page 9-18
“No Input Argument Constructor Requirement” on page 9-19
“Subclass Constructors” on page 9-19
“Implicit Call to Inherited Constructor” on page 9-21
“Errors During Class Construction” on page 9-22
“Output Object Suppressed” on page 9-22

Purpose of Class Constructor Methods

A constructor method is a special function that creates an instance of the class. Typically, constructor methods accept input arguments to assign the data stored in properties and return an initialized object.

For a basic example, see “Create a Simple Class” on page 2-2.

All MATLAB classes have a default constructor method. This method returns an object of the class that is created with no input arguments. A class can define a constructor method that overrides the default constructor. An explicitly defined constructor can accept input arguments, initialize property values, call other methods, and perform other operations necessary to create objects of the class.

Basic Structure of Constructor Methods

Constructor methods can be structured into three basic sections:

- Pre-initialization — Compute arguments for superclass constructors.
- Object initialization — Call superclass constructors.
- Post initialization — Perform any operations related to the subclass, including referencing and assigning to the object, call class methods, passing the object to functions, and so on.

This code illustrates the basic operations performed in each section:

classdef ConstructorDesign < BaseClass1
    properties
        ComputedValue
    end
    methods
        function obj = ConstructorDesign(a,b,c)
            % Pre Initialization %
        end
end
% Any code not using output argument (obj)
if nargin == 0
    % Provide values for superclass constructor
    % and initialize other inputs
    a = someDefaultValue;
    args{1} = someDefaultValue;
    args{2} = someDefaultValue;
else
    % When nargin != 0, assign to cell array, 
    % which is passed to supclass constructor
    args{1} = b;
    args{2} = c;
end
compvalue = myClass.staticMethod(a);

%% Object Initialization %%
% Call superclass constructor before accessing object
% You cannot conditionalize this statement
obj = obj@BaseClass1(args{:});

%% Post Initialization %%
% Any code, including access to object
obj.classMethod(arg);
obj.ComputedValue = compvalue;
...
end
...
end
...
end

Call the constructor like any function, passing arguments and returning an object of the class.

obj = ConstructorDesign(a,b,c);

Guidelines for Constructors

- The constructor has the same name as the class.
- The constructor can return multiple arguments, but the first output must be the object created.
- If you do not want to assign the output argument, you can clear the object variable in the constructor (see “Output Object Suppressed” on page 9-22).
- If you create a class constructor, ensure it can be called with no input arguments. See “No Input Argument Constructor Requirement” on page 9-19.
- If your constructor makes an explicit call to a superclass constructor, this call must occur before any other reference to the constructed object and cannot occur after a return statement.
- Calls to superclass constructors cannot be conditional. You cannot place superclass construction calls in loops, conditions, switches, try/catch, or nested functions. See “No Conditional Calls to Superclass Constructors” on page 9-20 for more information.

Default Constructor

If a class does not define a constructor, MATLAB supplies a default constructor that takes no arguments and returns a scalar object whose properties are initialized to property default values. The
default constructor supplied by MATLAB also calls all superclass constructors with no arguments or with any argument passed to the default subclass constructor.

When a subclass does not define a constructor, the default constructor passes its inputs to the direct superclass constructor. This behavior is useful when there is no need for a subclass to define a constructor, but the superclass constructor does require input arguments.

**When to Define Constructors**

Define a constructor method to perform object initialization that a default constructor cannot perform. For example, when creating an object of the class requires:

- Input arguments
- Initializing object state, such as property values, for each instance of the class
- Calling the superclass constructor with values that are determined by the subclass constructor

**Related Information**

For information specific to constructing enumerations, see “Enumeration Class Constructor Calling Sequence” on page 14-6.

For information on creating object arrays in the constructor, see “Construct Object Arrays” on page 10-2.

If the class being created is a subclass, MATLAB calls the constructor of each superclass class to initialize the object. Implicit calls to the superclass constructor are made with no arguments. If superclass constructors require arguments, call them from the subclass constructor explicitly. See “Control Sequence of Constructor Calls” on page 12-11

**Initializing Objects in Constructor**

Constructor methods return an initialized object as an output argument. The output argument is created when the constructor executes, before executing the first line of code.

For example, the following constructor can assign the value of the object's property A as the first statement because the object obj has already been assigned to an instance of MyClass.

```matlab
function obj = MyClass(a,b,c)
    obj.A = a;
    ...
end
```

You can call other class methods from the constructor because the object is already initialized.

The constructor also creates an object whose properties have their default values — either empty ([]) or the default value specified in the property definition block.

For example, this constructor operates on the input arguments to assign the value of the Value property.

```matlab
function obj = MyClass(a,b,c)
    obj.Value = (a + b) / c;
```
Referencing the Object in a Constructor

When initializing the object, for example, by assigning values to properties, use the name of the output argument to refer to the object within the constructor. For example, in the following code the output argument is `obj` and the object is reference as `obj`:

```
% obj is the object being constructed
function obj = MyClass(arg)
    obj.property1 = arg*10;
    obj.method1;
    ...
end
```

For more information on defining default property values, see “Property Default Values” on page 8-14.

No Input Argument Constructor Requirement

There are cases where the constructor must be able to be called with no input argument:

• When loading objects into the workspace, if the class `ConstructOnLoad` attribute is set to `true`, the `load` function calls the class constructor with no arguments.

• When creating or expanding an object array such that not all elements are given specific values, the class constructor is called with no arguments to fill in unspecified elements (for example, `x(10,1) = MyClass(a,b,c);`). In this case, the constructor is called once with no arguments to populate the empty array elements `(x(1:9,1))` with copies of this one object.

If there are no input arguments, the constructor creates an object using only default properties values. A good practice is to add a check for zero arguments to the class constructor to prevent an error if either of these two cases occur:

```
function obj = MyClass(a,b,c)
    if nargin > 0
        obj.A = a;
        obj.B = b;
        obj.C = c;
        ...
    end
end
```

For ways to handle superclass constructors, see “Basic Structure of Constructor Methods” on page 9-16.

Subclass Constructors

Subclass constructors can call superclass constructors explicitly to pass arguments to the superclass constructor. The subclass constructor must specify these arguments in the call to the superclass constructor and must use the constructor output argument to form the call. Here is the syntax:

```
classdef MyClass < SuperClass
    methods
        function obj = MyClass(a,b,c)
```
The subclass constructor must make all calls to superclass constructors before any other references to the object (obj). This restriction includes assigning property values or calling ordinary class methods. Also, a subclass constructor can call a superclass constructor only once.

**Reference Only Specified Superclasses**

If the classdef does not specify the class as a superclass, the constructor cannot call a superclass constructor with this syntax. That is, subclass constructor can call only direct superclass constructors listed in the classdef line.

```matlab
classdef MyClass < SuperClass1 & SuperClass2
```

MATLAB calls any uncalled constructors in the left-to-right order in which they are specified in the classdef line. MATLAB passes no arguments with these calls.

**No Conditional Calls to Superclass Constructors**

Calls to superclass constructors must be unconditional. There can be only one call for a given superclass. Initialize the superclass portion of the object by calling the superclass constructors before using the object (for example, to assign property values or call class methods).

To call a superclass constructor with different arguments that depend on some condition, build a cell array of arguments and provide one call to the constructor.

For example, the `Cube` class constructor calls the superclass `Shape` constructor using default values when the `Cube` constructor is called with no arguments. If the `Cube` constructor is called with four input arguments, then pass `upvector` and `viewangle` to the superclass constructor:

```matlab
classdef Cube < Shape
    properties
        SideLength = 0
        Color = [0 0 0]
    end
    methods
        function cubeObj = Cube(length,color,upvector,viewangle)
            % Assemble superclass constructor arguments
            if nargin == 0
                super_args{1} = [0 0 1];
                super_args{2} = 10;
            elseif nargin == 4
                super_args{1} = upvector;
                super_args{2} = viewangle;
            else
                error('Wrong number of input arguments')
            end

            % Call superclass constructor
            cubeObj@Shape(super_args{:});

            % Assign property values if provided
            if nargin > 0
```
function cubeObj = Cube(length,color,upvector,viewangle)
    % Assemble superclass constructor arguments
    if nargin == 0
        super_args = {};
    elseif nargin == 4
        super_args{1} = upvector;
        super_args{2} = viewangle;
    else
        error('Wrong number of input arguments')
    end

    % Call superclass constructor
    cubeObj@Shape(super_args{:});

    % Assign property values if provided
    if nargin > 0
        cubeObj.SideLength = length;
        cubeObj.Color = color;
    end
end

Zero or More Superclass Arguments

To support a syntax that calls the superclass constructor with no arguments, provide this syntax explicitly.

Suppose in the case of the Cube class example, all property values in the Shape superclass and the Cube subclass have default values specified in the class definitions. Then you can create an instance of Cube without specifying any arguments for the superclass or subclass constructors.

Here is how you can implement this behavior in the Cube constructor:

More on Subclasses

See “Design Subclass Constructors” on page 12-7 for information on creating subclasses.

Implicit Call to Inherited Constructor

MATLAB passes arguments implicitly from a default subclass constructor to the superclass constructor. This behavior eliminates the need to implement a constructor method for a subclass only to pass arguments to the superclass constructor.

For example, the following class constructor requires one input argument (a datetime object), which the constructor assigns to the CurrentDate property.
classdef BaseClassWithConstr
    properties
        CurrentDate datetime
    end
    methods
        function obj = BaseClassWithConstr(dt)
            obj.CurrentDate = dt;
        end
    end
end

Suppose that you create a subclass of BaseClassWithConstr, but your subclass does not require an explicit constructor method.

classdef SubclassDefaultConstr < BaseClassWithConstr
    ...
end

You can construct an object of the SubclassDefaultConstr by calling its default constructor with the superclass argument:

obj = SubclassDefaultConstr(datetime);

For information on subclass constructors, see “Subclass Constructors” on page 9-19 and “Default Constructor” on page 9-17.

Errors During Class Construction

For handle classes, MATLAB calls the delete method when an error occurs under the following conditions:

- A reference to the object is present in the code prior to the error.
- An early return statement is present in the code before the error.

MATLAB calls the delete method on the object, the delete methods for any objects contained in properties, and the delete methods for any initialized base classes.

Depending on when the error occurs, MATLAB can call the class destructor before the object is fully constructed. Therefore class delete methods must be able to operate on partially constructed objects that might not have values for all properties. For more information, see “Support Destruction of Partially Constructed Objects” on page 7-15.

For information on how objects are destroyed, see “Handle Class Destructor” on page 7-13.

Output Object Suppressed

You can suppress the assignment of the class instance to the ans variable when no output variable is assigned in a call to the constructor. This technique is useful for apps that creates graphical interface windows that hold onto the constructed objects. These apps do not need to return the object.

Use nargout to determine if the constructor has been called with an output argument. For example, the class constructor for the MyApp class clears the object variable, obj, if called with no output assigned:

classdef MyApp
    methods
function obj = MyApp
    ...
    if nargout == 0
        clear obj
    end
    ...
    end
end

When a class constructor does not return an object, MATLAB does not trigger the `meta.class.InstanceCreated` event.

See Also

Related Examples
- “Simplifying the Interface with a Constructor” on page 3-16
- “Subclass Constructor Implementation” on page 12-8
Static Methods

What Are Static Methods

Static methods are associated with a class, but not with specific instances of that class. These methods do not require an object of the class as an input argument. Therefore, you can call static methods without creating an object of the class.

Why Define Static Methods

Static methods are useful when you do not want to create an instance of the class before executing some code. For example, suppose you want to set up the MATLAB environment or use the static method to calculate data required to create class instances.

Suppose that a class needs a value for pi calculated to particular tolerances. The class could define its own version of the built-in pi function for use within the class. This approach maintains the encapsulation of the class's internal workings, but does not require an instance of the class to return a value.

Defining Static Methods

To define a method as static, set the methods block Static attribute to true. For example:

```matlab
classdef MyClass
methods(Static)
    function p = pi(tol)
        [n d] = rat(pi,tol);
        p = n/d;
    end
end
end
```

Calling Static Methods

Invoke static methods using the name of the class followed by dot (.), then the name of the method:

```matlab
classname.staticMethodName(args,...)
```

Calling the pi method of MyClass in the previous section would require this statement:

```matlab
value = MyClass.pi(.001);
```

You can also invoke static methods using an instance of the class, like any method:
obj = MyClass;
value = obj.pi(.001);

**Inheriting Static Methods**

Subclasses can redefine static methods unless the method's `Sealed` attribute is also set to `true` in the superclass.

**See Also**

**Related Examples**

- “Implementing the AccountManager Class” on page 3-11
Overload Functions in Class Definitions

In this section...

| “Why Overload Functions” on page 9-26 |
| “Implementing Overloaded MATLAB Functions” on page 9-26 |
| “Rules for Naming to Avoid Conflicts” on page 9-28 |

Why Overload Functions

Classes can redefine MATLAB functions by implementing methods having the same name. Overloading is useful when defining specialized types that you want to behave like existing MATLAB types. For example, you can implement relational operations, plotting functions, and other commonly used MATLAB functions to work with objects of your class.

You can also modify default behaviors by implementing specific functions that control these behaviors. For more information on functions that modify default behaviors, see “Methods That Modify Default Behavior” on page 17-2.

Implementing Overloaded MATLAB Functions

Class methods can provide implementations of MATLAB functions that operate only on instances of the class. This restriction is possible because MATLAB can always identify to which class an object belongs.

MATLAB uses the dominant argument to determine which version of a function to call. If the dominant argument is an object, then MATLAB calls the method defined by the object’s class, if one exists.

In cases where a class defines a method with the same name as a global function, the class’s implementation of the function is said to overload the original global implementation.

To overload a MATLAB function:

- Define a method with the same name as the function you want to overload.
- Ensure that the method argument list accepts an object of the class, which MATLAB uses to determine which version to call.
- Perform the necessary steps in the method to implement the function. For example, access the object properties to manipulate data.

Generally, the method that overloads a function produces results similar to the MATLAB function. However, there are no requirements regarding how you implement the overloading method. The overloading method does not need to match the signature of the overloaded function.

Note: MATLAB does not support overloading functions using different signatures for the same function name.
Overload the bar Function

It is convenient to overload commonly used functions to work with objects of your class. For example, suppose that a class defines a property that stores data that you often graph. The MyData class overrides the bar function and adds a title to the graph:

```
classdef MyData
    properties
        Data
    end
    methods
        function obj = MyData(d)
            if nargin > 0
                obj.Data = d;
            end
        end
        function bar(obj)
            y = obj.Data;
            bar(y,'EdgeColor','r');
            title('My Data Graph')
        end
    end
end
```

The MyData bar method has the same name as the MATLAB bar function. However, the MyData bar method requires a MyData object as input. Because the method is specialized for MyData objects, it can extract the data from the Data property and create a specialized graph.

To use the bar method, create an object:

```
y = rand(1,10);
md = MyData(y);
```

Call the method using the object:

```
bar(md)
```

You can also use dot notation:

```
md.bar
```

Implementing MATLAB Operators

Classes designed to implement new MATLAB data types typically define certain operators, such as addition, subtraction, or equality.

For example, standard MATLAB addition (+) cannot add two polynomials because this operation is not defined by simple addition. However, a polynomial class can define its own plus method that the MATLAB language calls to perform addition of polynomial objects when you use the + symbol:

```
p1 + p2
```

For information on overloading operators, see “Operator Overloading” on page 17-38.
Rules for Naming to Avoid Conflicts

The names of methods, properties, and events are scoped to the class. Therefore, adhere to the following rules to avoid naming conflicts:

- You can reuse names that you have used in unrelated classes.
- You can reuse names in subclasses if the member does not have public or protected access. These names then refer to entirely different methods, properties, and events without affecting the superclass definitions.
- Within a class, all names exist in the same name space and must be unique. A class cannot define two methods with the same name and a class cannot define a local function with the same name as a method.
- The name of a static method is considered without its class prefix. Thus, a static method name without its class prefix cannot match the name of any other method.

See Also

Related Examples

- “Dominant Argument in Overloaded Graphics Functions” on page 9-38
- “Class Support for Array-Creation Functions” on page 9-29
Class Support for Array-Creation Functions

In this section...

“Extend Array-Creation Functions for Your Class” on page 9-29
“Which Syntax to Use” on page 9-30
“Implement Support for Array-Creation Functions” on page 9-30

Extend Array-Creation Functions for Your Class

There are several MATLAB functions that create arrays of a specific size and type, such as `ones` and `zeros`. User-defined classes can add support for array-creation functions without requiring the use of overloaded method syntax.

Class support for any of the array-creation functions enables you to develop code that you can share with built-in and user-defined data types. For example, the class of the variable `x` in the following code can be a built-in type during initial development, and then be replaced by a user-defined class that transparently overloads `zeros`:

```matlab
cls = class(x);
zArray = zeros(m,n,cls);
```

Array-creation functions create arrays of a specific type in two ways:

- Class name syntax — Specify class name that determines the type of array elements.
- Prototype object syntax — Provide a prototype object that the function uses to determine the type and other characteristics of the array elements.

For example:

```matlab
zArray = zeros(2,3,'uint8');
p = uint8([1 3 5 ; 2 4 6]);
zArray = zeros(2,3,'like',p);
```

After adding support for these functions to a class named `MyClass`, you can use similar syntax with that class:

```matlab
zArray = zeros(2,3,'MyClass');
```

Or pass an object of your class:

```matlab
p = MyClass(...);
zArray = zeros(size(p),'like',p);
```

MATLAB uses these arguments to dispatch to the appropriate method in your class.

Array-Creation Functions That Support Overloading

The following functions support this kind of overloading.

<table>
<thead>
<tr>
<th>Array-Creation Functions</th>
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<tbody>
<tr>
<td><code>ones</code></td>
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</table>
### Array-Creation Functions

<table>
<thead>
<tr>
<th>Function</th>
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<tbody>
<tr>
<td>zeros</td>
</tr>
<tr>
<td>eye</td>
</tr>
<tr>
<td>nan (lowercase)</td>
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<tr>
<td>inf</td>
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<tr>
<td>true</td>
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<td>rand</td>
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<tr>
<td>randn</td>
</tr>
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<td>randi</td>
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</tbody>
</table>

### Which Syntax to Use

To create an array of default objects, which require no input arguments for the constructor, then use the class name syntax.

To create an array of objects with specific property values or if the constructor needs other inputs, use the prototype object to provide this information.

Classes can support both the class name and the prototype object syntax.

You can implement a class name syntax with the `true` and `false` functions even though these functions do not support that syntax by default.

#### Class Name Method Called If Prototype Method Does Not Exist

If your class implements a class name syntax, but does not implement a prototype object syntax for a particular function, you can still call both syntaxes. For example, if you implement a static `zeros` method only, you can call:

```matlab
zeros(...,'like',MyClass(...))
```

In the case in which you call the prototype object syntax, MATLAB first searches for a method named `zerosLike`. If MATLAB cannot find this method, it calls for the `zeros` static method.

This feature is useful if you only need the class name to create the array. You do not need to implement both methods to support the complete array-creation function syntax. When you implement only the class name syntax, a call to a prototype object syntax is the same as the call to the class name syntax.

### Implement Support for Array-Creation Functions

Use two separate methods to support an array-creation function. One method implements the class name syntax and the other implements the prototype object syntax.

For example, to support the `zeros` function:

- Implement the class name syntax:
zeros(...,'ClassName')

As a Static method:

methods (Static)
    function z = zeros(varargin)
        ...
    end
end

• Implement the prototype object syntax:

zeros(...,'like',obj)

As a Hidden method with the char vector 'Like' appended to the name.

methods (Hidden)
    function z = zerosLike(obj,varargin)
        ...
    end
end

**How MATLAB Interprets the Function Call**

The special support for array-creation functions results from the interpretation of the syntax.

• A call to the zeros function of this form:

zeros(...,'ClassName')

Calls the class static method with this syntax:

ClassName=zeros(varargin{1:end-1})

• A call to the zeros function of this form:

zeros(...,'like',obj)

Calls the class method with this syntax:

zerosLike(obj,varargin{1:end-2})

**Support All Function Inputs**

The input arguments to an array-creation function can include the dimensions of the array the function returns and possibly other arguments. In general, there are three cases that your methods must support:

• No dimension input arguments resulting in the return of a scalar. For example:

    z = zeros('MyClass');

• One or more dimensions equal to or less than zero, resulting in an empty array. For example:

    z = zeros(2,0,'MyClass');

• Any number of valid array dimensions specifying the size of the array. For example:

    z = zeros(2,3,5,'MyClass');
When the array-creation function calls your class method, it passes the input arguments, excluding the class name or the literal 'like' and the object variable to your method. You can implement your methods with these signatures:

- `zeros(varargin)` for “class name” methods
- `zeros(obj,varargin)` for “like prototype object” methods

**Sample Class**

The `Color` class represents a color in a specific color space, such as, RGB, HSV, and so on. The discussions in “Class Name Method Implementations” on page 9-32 and “Prototype Object Method Implementation” on page 9-33 use this class as a basis for the overloaded method implementations.

```matlab
classdef Color
    properties
        ColorValues = [0,0,0]
        ColorSpace = 'RGB'
    end
    methods
        function obj = Color(cSpace,values)
            if nargin > 0
                obj.ColorSpace = cSpace;
                obj.ColorValues = values;
            end
        end
    end
end
```

**Class Name Method Implementations**

The `zeros` function strips the final `ClassName` char vector and uses it to form the call to the static method in the `Color` class. The arguments passed to the static method are the array dimension arguments.

Here is an implementation of a `zeros` method for the `Color` class. This implementation:

- Defines the `zeros` method as `Static` (required)
- Returns a scalar `Color` object if the call to `zeros` has no dimension arguments
- Returns an empty array if the call to `zeros` has any dimensions arguments equal to 0.
- Returns an array of default `Color` objects. Use `repmat` to create an array of the dimensions specified by the call to `zeros`.

```matlab
classdef Color
    ... (Static)
    function z = zeros(varargin)
        if (nargin == 0)
            % For zeros('Color')
            z = Color;
        elseif any([varargin{:}] <= 0)
            % For zeros with any dimension <= 0
            z = Color.empty(varargin{:});
        else
            % For zeros(m,n,...,'Color')
            % Use property default values
        end
    end
end
```
The `zeros` method uses default values for the `ColorValues` property because these values are appropriate for this application. An implementation of a `ones` method can set the `ColorValues` property to `[1,1,1]`, for example.

Suppose that you want to overload the `randi` function to achieve the following objectives:

- Define each `ColorValue` property as a 1-by-3 array in the range of 1 to a specified maximum value (for example, 1-255).
- Accommodate scalar, empty, and multidimensional array sizes.
- Return an array of `Color` objects of the specified dimensions, each with random `ColorValues`.

```matlab
classdef Color
    ... (Static)
    methods (Static)
        function r = randi(varargin)
            if (nargin == 0)
                % For randi('ClassName')
                r = Color('RGB',randi(255,[1,3]));
            elseif any([varargin{2:end}] <= 0)
                % For randi with any dimension <= 0
                r = Color.empty(varargin{2:end});
            else
                % For randi(max,m,n,...,'ClassName')
                if numel([varargin{:}]) < 2
                    error('Not enough input arguments')
                end
                dims = [varargin{2:end}];
                r = zeros(dims,'Color');
                for k = 1:prod(dims)
                    r(k) = Color('RGB',randi(varargin{1},[1,3]));
                end
            end
        end
    end
end
```

**Prototype Object Method Implementation**

The objective of a method that returns an array of objects that are “like a prototype object” depends on the requirements of the class. For the `Color` class, the `zerosLike` method creates objects that have the `ColorSpace` property value of the prototype object, but the `ColorValues` are all zero.

Here is an implementation of a `zerosLike` method for the `Color` class. This implementation:

- Defines the `zerosLike` method as Hidden
- Returns a scalar `Color` object if the call to the `zeros` function has no dimension arguments
- Returns an empty array if the call to the `zeros` function has any dimension arguments that are negative or equal to 0.
- Returns an array of `Color` objects of the dimensions specified by the call to the `zeros` function.

```matlab
classdef Color
    ... (Static)
    methods (Static)
        function r = zerosLike(varargin)
            r = Color.empty(varargin{2:end});
        end
end
```
classdef Color
    ...
    methods (Hidden)
        function z = zerosLike(obj,varargin)
            if nargin == 1
                % For zeros('like',obj)
                cSpace = obj.ColorSpace;
                z = Color;
                z.ColorSpace = cSpace;
            elseif any(varargin{:} <= 0)
                % For zeros with any dimension <= 0
                z = Color.empty(varargin{:});
            else
                % For zeros(m,n,...,'like',obj)
                if ~isscalar(obj)
                    error('Prototype object must be scalar')
                end
                obj = Color(obj.ColorSpace,zeros(1,3,'like',obj.ColorValues));
                z = repmat(obj,varargin{:});
            end
        end
    end
end

Full Class Listing

Here is the Color class definition with the overloaded methods.

Note In actual practice, the Color class requires error checking, color space conversions, and so on. This overly simplified version illustrates the implementation of the overloaded methods.
error('Not enough input arguments')
end
dims = [varargin{2:end}];
r = zeros(dims,'Color');
for k = 1:prod(dims)
    r(k) = Color('RGB',randi(varargin{1},[1,3]));
end
end
end
methods (Hidden)
function z = zerosLike(obj,varargin)
    if nargin == 1
        % For zeros('like',obj)
        cSpace = obj.ColorSpace;
        z = Color;
        z.ColorSpace = cSpace;
    elseif any([varargin{:}] <= 0)
        % For zeros with any dimension <= 0
        z = Color.empty(varargin{:});
    else
        % For zeros(m,n,...,'like',obj)
        if ~isscalar(obj)
            error('Prototype object must be scalar')
        end
        obj = Color(obj.ColorSpace,zeros(1,3,'like',obj.ColorValues));
        z = repmat(obj,varargin{:});
    end
end
end
end

See Also

Related Examples
• "Construct Object Arrays" on page 10-2
Object Precedence in Method Invocation

**Object Precedence**

Establishing an object precedence enables MATLAB to determine which of possibly many versions of an operator or function to call in a given situation.

For example, consider the expression

\[ objectA + objectB \]

Ordinarily, objects have equal precedence and the method associated with the leftmost object is called. However, there are two exceptions:

- Classes defined with the `classdef` syntax have precedence over these MATLAB classes:
  
  ```
  double, single, int64, uint64, int32, uint32, int16, uint16, int8, uint8, char, string, logical, cell, struct, and function_handle.
  ```

- Classes defined with the `classdef` syntax can specify their relative precedence with respect to other classes using the `InferiorClasses` attribute.

Consider the example in “Representing Polynomials with Classes” on page 19-2. The `DocPolynom` class defines a `plus` method that enables the addition of `DocPolynom` objects. Given the object `p`:

```matlab
p = DocPolynom([1 0 -2 -5])
p =
x^3-2*x-5
```

the expression:

```matlab
1 + p
ans =
x^3-2*x-4
```

calls the `DocPolynom plus` method (which converts the `double`, 1, to a `DocPolynom` object and then implements the addition of two polynomials). The `DocPolynom` class has precedence over the built-in `double` class.

**Defining Precedence**

You can specify the relative precedence of classes defined with the `classdef` syntax by listing inferior classes in a class attribute. The `InferiorClasses` property places a class below other classes in the precedence hierarchy. Define the `InferiorClasses` property in the `classdef` statement:

```matlab
classdef (InferiorClasses = {?class1,?class2}) myClass
```

This attribute establishes a relative priority of the class being defined with the order of the classes listed.
Location in the Hierarchy

If \texttt{objectA} is above \texttt{objectB} in the precedence hierarchy, then the expression
\[
\texttt{objectA} + \texttt{objectB}
\]
calls \texttt{@classA/plus.m}. Conversely, if \texttt{objectB} is above \texttt{objectA} in the precedence hierarchy, then MATLAB calls \texttt{@classB/plus.m}.

See Also

More About

- “Dominant Argument in Overloaded Graphics Functions” on page 9-38
- “Class Precedence” on page 6-18
Dominant Argument in Overloaded Graphics Functions

Graphics Object Precedence

MATLAB graphics objects have the same precedence as objects of classes defined using the classdef syntax. If you want to implement a method that accepts a graphics object as its first argument (for example, an axes handle), but dispatches to the method of your class, define the MATLAB graphics class as inferior to your class.

Dominant Argument

When evaluating expression involving objects of more than one class, MATLAB uses the dominant argument to determine which method or function to call.

Here is how MATLAB dispatches in response to a function call:

- Determine the dominant argument based on the class of arguments.
- If there is a dominant argument, call the method of the dominant class.
- If arguments are of equal precedence, use the leftmost argument as the dominant argument.
- If the class of the dominant argument does not define a method with the name of the called function, call the first function on the path with that name.

Defining Class Precedence

Specify the relative precedence of MATLAB classes using the InferiorClasses class attribute. Here is the basic syntax:

classdef (InferiorClasses = {?class1,?class2}) ClassName

The following definition of the TemperatureData class implements a specialized version of plot to graph temperature data. The class plot method supports a variable number of input arguments to allow an axes handle as the first argument:

plot(obj)
plot(ax,obj)

obj is an instance of the TemperatureData class and ax is an axes handle.

MATLAB calls the plot method in both cases because the TemperatureData class specifies the matlab.graphics.axis.Axes as inferior.

classdef (InferiorClasses = {?matlab.graphics.axis.Axes}) TemperatureData
  properties
    Time
    Temperature
methods
function obj = TemperatureData(x,y)
    obj.Time = x;
    obj.Temperature = y;
end
function plot(varargin)
    if nargin == 1
        obj = varargin{1};
        plot(obj.Time,obj.Temperature)
    elseif nargin == 2
        ax = varargin{1};
        obj = varargin{2};
        plot(ax,obj.Time,obj.Temperature)
    elseif nargin > 2
        ax = varargin{1};
        obj = varargin{2};
        plot(ax,obj.Time,obj.Temperature,varargin{3:end})
    end
    datetick('x')
    xlabel('Time')
    ylabel('Temperature')
end
end

The following call to plot dispatches to the TemperatureData plot method, not the built-in plot function, because the TemperatureData object is dominant over the axes object.

```matlab
x = 1:10;
y = rand(1,10)*100;
ax = axes;
td = TemperatureData(x,y);
plot(ax,td)
```

**Calls to Inferior-Class Methods**

When you declare a class as inferior to your class, and both classes define a method with the same name, MATLAB dispatches to your class method regardless of argument order.

Suppose the TemperatureData class that is described in the previous section defines a set method. If you attempt to assign an object of the TemperatureData class to the UserData property of an axes object:

```matlab
td = TemperatureData(x,y);
set(gca,'UserData',td)
```

The results is a call to the TemperatureData set method. MATLAB does not call the built-in set function.

To support the use of a set function with inferior classes, implement a set method in your class that calls the built-in set function when the first argument is an object of the inferior class.

```matlab
function set(varargin)
    if isa(varargin{1},'matlab.graphics.axis.Axes')
        builtin('set',varargin{:})
    else
        ...
    end
end
```
See Also

More About
• “Object Precedence in Method Invocation” on page 9-36
Class Methods for Graphics Callbacks

Referencing the Method

To use an ordinary class method as callback for a graphics object, specify the callback property as a function handle referencing the method. For example,

```matlab
uicontrol('Style','slider','Callback',@obj.sliderCallback)
```

Where your class defines a method called `sliderCallback` and `obj` is an instance of your class.

To use a static method as a callback, specify the callback property as a function handle that includes the class name that is required to refer to a static method:

```matlab
uicontrol('Style','slider','Callback',@MyClass.sliderCallback)
```

Syntax for Method Callbacks

For ordinary methods, use dot notation to pass an instance of the class defining the callback as the first argument:

```matlab
@obj.methodName
```

Define the callback method with the following input arguments:

- An instance of the defining class as the first argument
- The event source handle
- The event data

The function signature would be of this form:

```matlab
function methodName(obj,src,eventData)
    ...
end
```

For static methods, the required class name ensures MATLAB dispatches to the method of the specified class:

```matlab
@MyClass.methodName
```

Define the static callback method with two input arguments — the event source handle and the event data

The function signature would be of this form:

```matlab
function methodName(src,eventData)
```
Passing Extra Arguments

If you want to pass arguments to your callback in addition to the source and event data arguments passed by MATLAB, you can use an anonymous function. The basic syntax for an anonymous function that you assign to the graphic object's Callback property includes the object as the first argument:

@\( (src, event) \) \text{callbackMethod}(object, src, eventData, arg1, \ldots, argn) \)

The function signature would be of this form:

function \text{methodName}(obj, src, eventData, varargin)
    ...
end

Use a Class Method for a Slider Callback

This example shows how to use a method of your class as a callback for an uicontrol slider.

The SeaLevelSlider class creates a slider that varies the color limits of an indexed image to give the illusion of varying the sea level.

Class Definition

Define SeaLevelSlider as a handle class with the following members:

- The class properties store figure and axes handles and the calculated color limits.
- The class constructor creates the graphics objects and assigns the slider callback.
- The callback function for the slider accepts the three required arguments — a class instance, the handle of the event source, and the event data. The event data argument is empty and not used.
- The uicontrol callback uses dot notation to reference the callback method: \ldots 'Callback', @obj.sliderCallback.

classdef SeaLevelSlider < handle
    properties
        Figure
        Axes
        CLimit
    end

    methods
        function obj = SeaLevelSlider(x, map)
            obj.Figure = figure('Colormap', map, ... 'Position', [100, 100, 560, 580], ... 'Resize', 'off');
            obj.Axes = axes('DataAspectRatio', [1, 1, 1], ... 'XLimMode', 'manual', 'YLimMode', 'manual', ... 'Parent', obj.Figure);
            image(x, 'CDataMapping', 'scaled', ... 'Parent', obj.Axes);
            obj.CLimit = get(obj.Axes, 'CLim');
            uicontrol('Style', 'slider', ... 'Parent', obj.Figure, ... 'Max', obj.CLimit(2) - 10, ... 'Min', obj.CLimit(1) - 1, ... 'Value', obj.CLimit(1), ...
Using the SeaLevelAdjuster Class

The class uses the cape image that is included with the MATLAB product. To obtain the image data, use the `load` command:

```matlab
load cape X map
```

After loading the data, create a `SeaLevelSlider` object for the image:

```matlab
slaObj = SeaLevelSlider(X,map);
```

Move the slider to change the color mapping and visualize a rise in sea level.
See Also

More About
• “Listener Callback Syntax” on page 11-24
Object Arrays

- “Construct Object Arrays” on page 10-2
- “Initialize Object Arrays” on page 10-5
- “Empty Arrays” on page 10-7
- “Initialize Arrays of Handle Objects” on page 10-9
- “Accessing Dynamic Properties in Arrays” on page 10-11
- “Implicit Class Conversion” on page 10-13
- “Concatenating Objects of Different Classes” on page 10-15
- “Designing Heterogeneous Class Hierarchies” on page 10-20
- “Heterogeneous Array Constructors” on page 10-27
Construct Object Arrays

In this section...

"Build Arrays in the Constructor" on page 10-2
"Referencing Property Values in Object Arrays" on page 10-2

Build Arrays in the Constructor

A class constructor can create an array by building the array and returning it as the output argument.

For example, the ObjectArray class creates an object array that is the same size as the input array. Then it initializes the Value property of each object to the corresponding input array value.

classdef ObjectArray
    properties
        Value
    end
    methods
        function obj = ObjectArray(F)
            if nargin ~= 0
                m = size(F,1);
                n = size(F,2);
                obj(m,n) = obj;
                for i = 1:m
                    for j = 1:n
                        obj(i,j).Value = F(i,j);
                    end
                end
            end
        end
    end
end

To preallocate the object array, assign the last element of the array first. MATLAB fills the first to penultimate array elements with the ObjectArray object.

After preallocating the array, assign each object Value property to the corresponding value in the input array F. To use the class:

- Create 5-by-5 array of magic square numbers
- Create a 5-by-5 object array

F = magic(5);
A = ObjectArray(F);
whos

<table>
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<tr>
<th>Name</th>
<th>Size</th>
<th>Bytes</th>
<th>Class</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
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<td>A</td>
<td>5x5</td>
<td>304</td>
<td>ObjectArray</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>5x5</td>
<td>200</td>
<td>double</td>
<td></td>
</tr>
</tbody>
</table>

Referencing Property Values in Object Arrays

Given an object array objArray in which each object has a property PropName:
• Reference the property values of specific objects using array indexing:
  
  `objArray(ix).PropName`

• Reference all values of the same property in an object array using dot notation. MATLAB returns a comma-separated list of property values.

  `objArray.PropName`

• To assign the comma-separated list to a variable, enclose the right-side expression in brackets:

  `values = [objArray.PropName]`

For example, given the ObjProp class:

```matlab
classdef ObjProp
    properties
        RegProp
    end
    methods
        function obj = ObjProp
            obj.RegProp = randi(100);
        end
    end
end
```

Create an array of ObjProp objects:

```matlab
for k = 1:5
    objArray(k) = ObjProp;
end
```

Access the RegProp property of the second element of the object array using array indexing:

```matlab
objArray(2).RegProp
```

ans =

```
91
```

Assign the values of all RegProp properties to a numeric array:

```matlab
propValues = [objArray.RegProp]
```

`propValues =
```
```
82  91  13  92  64
```

Use standard indexing operations to access the values of the numeric array. For more information on numeric arrays, see “Matrices and Arrays”.

**See Also**

**Related Examples**

• “Initialize Object Arrays” on page 10-5
• “Initialize Arrays of Handle Objects” on page 10-9
• “Class Constructor Methods” on page 9-16
Initialize Object Arrays

In this section...

“Calls to Constructor” on page 10-5
“Initial Value of Object Properties” on page 10-6

Calls to Constructor

During the creation of object arrays, MATLAB can call the class constructor with no arguments, even if the constructor does not build an object array. For example, suppose that you define the following class:

```matlab
classdef SimpleValue
    properties
        Value
    end
    methods
        function obj = SimpleValue(v)
            obj.Value = v;
        end
    end
end
```

Execute the following statement to create an array:

```matlab
a(1,7) = SimpleValue(7)
```

Error using SimpleValue (line 7)
Not enough input arguments.

This error occurs because MATLAB calls the constructor with no arguments to initialize elements 1 through 6 in the array.

Your class must support the no input argument constructor syntax. A simple solution is to test `nargin` and let the case when `nargin == 0` execute no code, but not error:

```matlab
classdef SimpleValue
    properties
        Value
    end
    methods
        function obj = SimpleValue(v)
            if nargin > 0
                obj.Value = v;
            end
        end
    end
end
```

Using the revised class definition, the previous array assignment statement executes without error:

```matlab
a(1,7) = SimpleValue(7)
```

a =
1x7 SimpleValue array with properties:
  Value

The object assigned to array element \( a(1,7) \) uses the input argument passed to the constructor as the value assigned to the property:

\[
a(1,7)
\]

\[
\text{ans} =
\text{SimpleValue with properties:}
  \text{Value: 7}
\]

MATLAB created the objects contained in elements \( a(1,1:6) \) with no input argument. The default value for properties empty \([\text{}]\). For example:

\[
a(1,1)
\]

\[
\text{ans} =
\text{SimpleValue with properties:}
  \text{Value: [\text{}]}
\]

MATLAB calls the SimpleValue constructor once and copies the returned object to each element of the array.

**Initial Value of Object Properties**

When MATLAB calls a constructor with no arguments to initialize an object array, one of the following assignments occurs:

- If property definitions specify default values, MATLAB assigns these values.
- If the constructor assigns values in the absence of input arguments, MATLAB assigns these values.
- If neither of the preceding situations apply, MATLAB assigns the value of empty double (that is, \([\text{}]) to the property.

**See Also**

**Related Examples**

- “Initialize Arrays of Handle Objects” on page 10-9
Empty Arrays

Creating Empty Arrays

Empty arrays have no elements, but are of a certain class. All nonabstract classes have a static method named `empty` that creates an empty array of the same class. The `empty` method enables you to specify the dimensions of the output array. However, at least one of the dimensions must be 0. For example, define the `SimpleValue` class:

```matlab
classdef SimpleValue
    properties
        Value
    end
    methods
        function obj = SimpleValue(v)
            if nargin > 0
                obj.Value = v;
            end
        end
    end
end
```

Create a 5-by-0 empty array of class `SimpleValue`.

```matlab
ary = SimpleValue.empty(5,0)
```

```matlab
ary =
    5x0 SimpleValue array with properties:
        Value
```

Calling `empty` with no arguments returns a 0-by-0 empty array.

Assigning Values to an Empty Array

An empty object defines the class of an array. To assign nonempty objects to an empty array, MATLAB calls the class constructor to create default instances of the class for every other array element. Once you assign a nonempty object to an array, all array elements must be nonempty objects.

**Note** A class constructor must avoid returning empty objects by default.

For example, using the `SimpleValue` defined in the “Initialize Object Arrays” on page 10-5 section, create an empty array:

```matlab
ary = SimpleValue.empty(5,0);
class(ary)
```
ans =
SimpleValue

ary is an array of class SimpleValue. However, it is an empty array:

ary(1)
Index exceeds matrix dimensions.

If you make an assignment to a property value, MATLAB calls the SimpleClass constructor to grow
the array to the require size:

ary(5).Value = 7;
ary(5).Value

ans =
    7

ary(1).Value

ans =
    []

MATLAB populates array elements one through five with SimpleValue objects created by calling the
class constructor with no arguments. Then MATLAB assigns the property value 7 to the object at
ary(5).

See Also

Related Examples

•  “Initialize Arrays of Handle Objects” on page 10-9
Initialize Arrays of Handle Objects

When initializing an array of handle objects, MATLAB fills in the empty elements of an array with a default object. To create the default object, MATLAB:

- Calls the class constructor once to obtain an object
- Creates unique handles for each element in the array
- Copies the property values from the constructed default object without calling the constructor again.

The `InitHandleArray` class illustrates this behavior:

```matlab
classdef InitHandleArray < handle
    properties
        RandNumb
    end
    methods
        function obj = InitHandleArray
            obj.RandNumb = randi(100);
        end
    end
end
```

The property `RandNumb` contains a random number that the `InitHandleArray` constructor assigns.

Consider what happens when MATLAB initialize an array created by assigning to the last element in the array. (The last element is the one with the highest index values). Suppose the value of the `RandNumb` property of the `InitHandleArray` object assigned to the element `A(4,5)` is 59:

```matlab
A(4,5) = InitHandleArray;
A(4,5).RandNumb
```

```
ans =
59
```

The element in the index location `A(4,5)` is an instance of the `InitHandleArray` class. The default object used for element `A(1,1)` is also an instance of the `InitHandleArray` class, but its `RandNumb` property is set to a different random number.

To fill in the preceding array elements, MATLAB calls the class constructor to create a single object. MATLAB copies this object to all the remaining array elements. Calling the constructor to create the default object resulted in another call to the `randi` function, which returns a new random number:

```matlab
A(1,1).RandNumb
```

```
ans =
10
```

MATLAB copies this second instance to all remaining array elements:

```matlab
A(2,2).RandNumb
```

```
ans =
10
```
A(2,3).RandNumb
ans =
   10

When initializing an object array, MATLAB assigns a copy of a single object to the empty elements in
the array. MATLAB gives each object a unique handle so that later you can assign different property
values to each object. The objects are not equivalent:

A(1,1) == A(2,2)

ans =
   0

That is, the handle A(1,1) does not refer to the same object as A(2,2). The creation of an array
with a statement such as:

A(4,5) = InitHandleArray;

results in two calls to the class constructor. The first creates the object for array element A(4,5).
The second creates a default object that MATLAB copies to all remaining empty array elements.

**Related Information**

For information on array manipulation, see “Multidimensional Arrays”

See “Initializing Properties to Handle Objects” on page 8-14 for information on assigning values to
properties.

See “Object Array Indexing” on page 17-12 for information on implementing `subsasgn` methods for
your class.
Accessing Dynamic Properties in Arrays

You cannot reference all the dynamic properties in an object array using a single statement, as you can with ordinary properties. For example, the `ObjectArrayDynamic` class subclasses the `dynamicprops` class.

```matlab
classdef ObjectArrayDynamic < dynamicprops
    properties
        RegProp
    end
    methods
        function obj = ObjectArrayDynamic
            obj.RegProp = randi(100);
        end
    end
end
```

You can add dynamic properties to objects of the `ObjectArrayDynamic` class. Create an object array and add dynamic properties to each member of the array. Define elements 1 and 2 as `ObjectArrayDynamic` objects:

```matlab
a(1) = ObjectArrayDynamic;
a(2) = ObjectArrayDynamic;
```

Add dynamic properties to each object and assign a value.

```matlab
a(1).addprop('DynoProp');
a(1).DynoProp = 1;
a(2).addprop('DynoProp');
a(2).DynoProp = 2;
```

Get the values of the ordinary properties, as with any array.

```matlab
a.RegProp
ans =
    4
ans =
    85
```

However, MATLAB returns an error if you try to access the dynamic properties of all array elements using this syntax.

```matlab
a.DynoProp
No appropriate method, property, or field 'DynoProp' for class 'ObjectArrayDynamic'.
```

Refer to each object individually to access dynamic property values:

```matlab
a(1).DynoProp
ans =
    1
```
a(2).DynoProp

ans =

2

For information about classes that can define dynamic properties, see “Dynamic Properties — Adding Properties to an Instance” on page 8-54.
Implicit Class Conversion

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Class Conversion Mechanism

When you create or modify object arrays using concatenation or subscripted assignment, MATLAB attempts to convert unlike types to conform to the class of the array. MATLAB performs this conversion implicitly.

To perform the conversion, MATLAB attempts to call a converter method defined by the class to be converted. A converter method has the same name as the destination class. For example, if a class defines a method named `double`, this method converts an object of the class to an object of class `double`.

If no converter exists in the source object's class, then this call resolves to a call to the constructor of the destination class.

Both concatenation and subscripted assignment can cause MATLAB to apply this class conversion mechanism. The conversion can be successful or can result in an error if the conversion is not possible.

Concatenation

In concatenation operations, the dominant object determines the class of the resulting array. MATLAB determines the dominant object as follows:

- User-defined classes are dominant over built-in classes such as `double`.
- If there is no defined dominance relationship between any two objects, then the leftmost object dominates

For example, in the statement `C = [A, B]`, if A is the dominant object, MATLAB attempts to convert B to the class of A.

Subscripted Assignment

In subscripted assignment, the left side of the assignment statement defines the class of the array. If you assign array elements when the right side is a different class than the left side, MATLAB attempts to convert to the class of the left side.

For example, assigning an object of `ClassB` to an element of array `A` requires conversion.

```matlab
A = ClassA;
B = ClassB;
A(2) = B;
```
MATLAB first looks for a converter method defined by the class of the source object B. This converter method must have the name `ClassA` in this case. The subscripted assignment is effectively a call to the converter defined by `ClassB`:

\[
A(2) = \text{ClassA}(B) \ % \text{Call method of ClassB}
\]

If no converter method exists, this call resolves to a call to the destination class constructor:

\[
A(2) = \text{ClassA}(B) \ % \text{Call ClassA constructor}
\]

**See Also**

**Related Examples**

- “Valid Combinations of Unlike Classes”
- “Concatenating Objects of Different Classes” on page 10-15
- “Object Converters” on page 17-10
- “Function Argument Validation”
Concatenating Objects of Different Classes

In this section...

“Basic Knowledge” on page 10-15
“MATLAB Concatenation Rules” on page 10-15
“Concatenating Objects” on page 10-15
“Calling the Dominant-Class Constructor” on page 10-16
“Converter Methods” on page 10-17

Basic Knowledge

The material presented in this section builds on an understanding of the information presented in the following sections.

• “Construct Object Arrays” on page 10-2
• “Valid Combinations of Unlike Classes”

MATLAB Concatenation Rules

MATLAB follows these rules for concatenating objects:

• MATLAB always attempts to convert all objects to the dominant class.
• User-defined classes take precedence over built-in classes like double.
• If there is no defined dominance relationship between any two objects, then the leftmost object dominates (see “Class Precedence” on page 6-18).

When converting to a dominant class during concatenation or subscripted assignment, MATLAB searches the non-dominant class for a conversion method that is the same name as the dominant class. If such a conversion method exists, MATLAB calls it. If a conversion method does not exist, MATLAB calls the dominant class constructor on the non-dominant object.

It is possible for the dominant class to define horzcat, vertcat, or cat methods that modify the default concatenation process.

Note MATLAB does not convert objects to a common superclass unless those objects are part of a heterogeneous hierarchy. For more information, see “Designing Heterogeneous Class Hierarchies” on page 10-20.

Concatenating Objects

Concatenation combines objects into arrays:

\[ \text{ary} = [\text{obj}_1, \text{obj}_2, \text{obj}_3, \ldots, \text{obj}_n]; \]

The size of \text{ary} is 1-by-n.

\[ \text{ary} = [\text{obj}_1; \text{obj}_2; \text{obj}_3; \ldots; \text{obj}_n]; \]

The size of \text{ary} is n-by-1.
The class of the arrays is the same as the class of the objects being concatenated. Concatenating objects of different classes is possible if MATLAB can convert objects to the dominant class. MATLAB attempts to convert unlike objects by:

- Calling the inferior object converter method, if one exists.
- Passing an inferior object to the dominant class constructor to create an object of the dominant class.

If conversion of the inferior object is successful, MATLAB returns an array that is of the dominant class. If conversion is not possible, MATLAB returns an error.

**Calling the Dominant-Class Constructor**

MATLAB calls the dominant class constructor to convert an object of an inferior class to the dominant class. MATLAB passes the inferior object to the constructor as an argument. If the class design enables the dominant class constructor to accept objects of inferior classes as input arguments, then concatenation is possible without implementing a separate converter method.

If the constructor simply assigns this argument to a property, the result is an object of the dominant class with an object of an inferior class stored in a property. If this assignment is not a desired result, then ensure that class constructors include adequate error checking.

For example, consider the class `ColorClass` and two subclasses, `RGBColor` and `HSVColor`:

```matlab
classdef ColorClass
    properties
        Color
    end
end
```

The class `RGBColor` inherits the `Color` property from `ColorClass`. `RGBColor` stores a color value defined as a three-element vector of red, green, and blue (RGB) values. The constructor does not restrict the value of the input argument. It assigns this value directly to the `Color` property.

```matlab
classdef RGBColor < ColorClass
    methods
        function obj = RGBColor(rgb)
            if nargin > 0
                obj.Color = rgb;
            end
        end
    end
end
```

The class `HSVColor` also inherits the `Color` property from `ColorClass`. `HSVColor` stores a color value defined as a three-element vector of hue, saturation, brightness value (HSV) values.

```matlab
classdef HSVColor < ColorClass
    methods
        function obj = HSVColor(hsv)
            if nargin > 0
                obj.Color = hsv;
            end
        end
    end
end
```
Create an instance of each class and concatenate them into an array. The `RGBColor` object is dominant because it is the leftmost object and neither class defines a dominance relationship:

```matlab
crgb = RGBColor([1 0 0]);
chsv = HSVColor([0 1 1]);
ary = [crgb, chsv];
class(ary)
```

```matlab
ans = RGBColor
```

You can combine these objects into an array because MATLAB can pass the inferior object of class `HSVColor` to the constructor of the dominant class. However, notice that the `Color` property of the second `RGBColor` object in the array actually contains an `HSVColor` object, not an RGB color specification:

```matlab
ary(2).Color
```

```matlab
ans =

HSVColor with properties:
   Color: [0 1 1]
```

Avoid this undesirable behavior by:

- Implementing converter methods
- Performing argument checking in class constructors before assigning values to properties

## Converter Methods

If your class design requires object conversion, implement converter methods for this purpose.

The `ColorClass` class defines converter methods for `RGBColor` and `HSVColor` objects:

```matlab
classdef ColorClass
    properties
        Color
    end
    methods
        function rgbObj = RGBColor(obj)
            if isa(obj, 'HSVColor')
                rgbObj = RGBColor(hsv2rgb(obj.Color));
            end
        end
        function hsvObj = HSVColor(obj)
            if isa(obj, 'RGBColor')
                hsvObj = HSVColor(rgb2hsv(obj.Color));
            end
        end
    end
end
```

Create an array of `RGBColor` and `HSVColor` objects with the revised superclass:

```matlab
crgb = RGBColor([1 0 0]);
chsv = HSVColor([0 1 1]);
```
ary = [crgb,chsv];
class(ary)
ans =
RGBColor

MATLAB calls the converter method for the HSVColor object, which it inherits from the superclass. The second array element is now an RGBColor object with an RGB color specification assigned to the Color property:

ary(2)
ans =
RGBColor with properties:
    Color: [1 0 0]
ary(2).Color
ans =
    1     0     0

If the leftmost object is of class HSVColor, the array ary is also of class HSVColor, and MATLAB converts the Color property data to HSV color specification.

ary = [chsv crgb]
ary =
1x2 HSVColor
Properties:
    Color
ary(2).Color
ans =
    0     1     1

Defining a converter method in the superclass and adding better argument checking in the subclass constructors produces more predictable results. Here is the RGBColor class constructor with argument checking:

classdef RGBColor < ColorClass
    methods
        function obj = RGBColor(rgb)
            if nargin == 0
                rgb = [0 0 0];
            else
                if ~(isa(rgb,'double')...  
                    && size(rgb,2) == 3 ...  
                    && max(rgb) <= 1 && min(rgb) >= 0)  
                    error('Specify color as RGB values')
                end
            end
        end
    end
end
obj.Color = rgb;
end
end
end

Your applications can require additional error checking and other coding techniques. The classes in these examples are designed only to demonstrate concepts.

See Also

More About

• “Implicit Class Conversion” on page 10-13
• “Object Converters” on page 17-10
• “Hierarchies of Classes — Concepts” on page 12-2
Creating Classes That Support Heterogeneous Arrays

This topic describes the concepts involved in defining classes that support the formation of heterogeneous arrays. For information on the concatenation of existing MATLAB objects, see these topics.

- “Concatenating Objects of Different Classes” on page 10-15
- “Valid Combinations of Unlike Classes”

For an example that uses heterogeneous arrays, see “A Class Hierarchy for Heterogeneous Arrays” on page 20-2.

MATLAB Arrays

MATLAB determines the class of an array by the class of the objects contained in the array. MATLAB is unlike some languages in which you define an array of object pointers or references. In these other languages, the type of the array is different from the type of an object in the array. You can access the elements of the array and dispatch to methods on those elements, but you cannot call an object method on the whole array, as you can in MATLAB.

Object arrays in MATLAB are homogeneous in class. Because of this homogeneity, you can perform operations on whole arrays, such as multiplying numeric matrices. You can form heterogeneous arrays by defining a hierarchy of classes that derive from a common superclass. Cell arrays provide option for an array type that can hold different kinds of unrelated objects.

Heterogeneous Hierarchies

You can form arrays of objects that are subclasses of a common superclass when these classes are part of a heterogeneous hierarchy. A MATLAB heterogeneous class hierarchy:

- Derives from `matlab.mixin.Heterogeneous`
- Defines a single root superclass that derives directly from `matlab.mixin.Heterogeneous`
• Seals methods that are inherited by subclasses.

For example, in the following diagram, Shape is the root of the heterogeneous hierarchy.

Heterogeneous Arrays

A heterogeneous array is an array of objects that differ in their specific class, but all objects derive from or are instances of a common superclass. The common superclass forms the root of the hierarchy of classes that you can combine into heterogeneous arrays.

The common superclass must derive from `matlab.mixin.Heterogeneous`. Methods that you can call on the array as a whole must have the same definitions for all subclasses.

Heterogeneous hierarchies are useful to:

• Create arrays of objects that are of different classes, but part of a related hierarchy.
• Call methods of the most specific common superclass on the array as a whole
• Access properties of the most specific common superclass using dot notation with the array
• Use common operators that are supported for object arrays
• Support array indexing (scalar or nonscalar) that returns arrays of the most specific class

Heterogeneous Array Concepts

• Heterogeneous array — An array in which two or more elements belong to different specific classes. All elements derive from the same root superclass.
• Root superclass — Class derived directly from `matlab.mixin.Heterogeneous`. The root superclass can be abstract or concrete. Only concrete subclasses of the root superclass can form heterogeneous arrays.
• Most specific common superclass — The most specific class in the inheritance hierarchy from which all the objects in a heterogeneous array derive. The most specific common superclass can be the root superclass or a more specific superclass shared by the objects currently in the array.
• Class of a heterogeneous array — The most specific common superclass from which all objects in the heterogeneous array derive. Adding and removing objects from a heterogeneous array can change the most specific superclass shared by the instances. This change results in a change in the class of a heterogeneous array. The most specific common superclass can be abstract.
**Nature of Heterogeneous Arrays**

The heterogeneous hierarchy in this diagram illustrates the characteristics of heterogeneous arrays concerning:

- Array class
- Property access
- Method invocation

![Diagram](image)

**Class of Heterogeneous Arrays**

The class of a heterogeneous array is that of the most specific superclass shared by the objects of the array.

If the following conditions are true, the concatenation and subscripted assignment operations return a heterogeneous array:

- The objects on the right side of the assignment statement are of different classes
- All objects on the right side of the assignment statement derive from a common subclass of `matlab.mixin.Heterogeneous`

For example, form an array by concatenating objects of these classes. The class of `a1` is `ClassA`:

```matlab
a1 = [SpecificA,SpecificB];
class(a1)
```
ans =
ClassA

If the array includes an object of the class SpecificC, the class of a2 is RootSuperclass:

a2 = [SpecificA,SpecificB,SpecificC];
class(a2)
ans =
RootSuperclass

If you assigned an object of the class SpecificC to array a1 using indexing, the class of a1 becomes RootSuperclass:

a1(3) = SpecificC;
class(a1)
ans =
RootSuperclass

If the array contains objects of only one class, then the array is not heterogeneous. For example, the class of a is SpecificA.

a = [SpecificA,SpecificA];
class(a)
ans =
SpecificA

**Property Access**

Access array properties with dot notation when the class of the array defines the properties. The class of the array is the most specific common superclass, which ensures all objects inherit the same properties.

For example, suppose ClassA defines a property called Prop1.

a1 = [SpecificA,SpecificB];
a1.Prop1

Referring to Prop1 using dot notation returns the value of Prop1 for each object in the array.

**Method Invocation**

To invoke a method on a heterogeneous array, the class of the array must define or inherit the method as Sealed. For example, suppose RootSuperclass defines a Sealed method called superMethod.

Call the method on all objects in the array a2:

a2 = [SpecificA,SpecificB,SpecificC];
a2.superMethod

Sealing the method (so that it cannot be overridden in a subclass) ensures that the same method definition exists for all elements of the array. Calling that method on a single element of the array invokes the same method implementation as calling the method on the whole array.
Unsupported Hierarchies

Heterogeneous hierarchies cannot have ambiguities when obtaining default objects, determining the class of the array, and converting class objects to other types. Members of the hierarchy can derive from only one root superclass (that is, from only one direct subclass of `matlab.mixin.Heterogeneous`).

This diagram shows a hierarchy that is not allowed:

```
matlab.mixin.Heterogeneous
  /       \
 OtherBaseClass   RootSuperclass
   /                     \
  ClassA                 ClassB
   /         \
  SpecificA   SpecificB
   \
  SpecificC
```

ClassA derives from two classes that are subclasses of `matlab.mixin.Heterogeneous`.

The next diagram shows two separate heterogeneous hierarchies. ClassA has only one root superclass (called `OtherBaseClass`). The heterogeneous hierarchy is no longer ambiguous:
Default Object

A default object is the object returned by calling the class constructor with no arguments. MATLAB uses default objects in these situations:

- Indexed assignment creates an array with gaps in array elements. For example, assign the first element of array h to index 5:

  \[
  h(5) = \text{ClassA}(\text{arg1}, \text{arg2});
  \]

  MATLAB fills the unassigned positions with default objects.

- Loading a heterogeneous array from a MAT-file when the class definition of a specific object in the array is not available. MATLAB replaces the object with the default object.

Heterogeneous hierarchies enable you to define the default object for that hierarchy. The \texttt{matlab.mixin.Heterogeneous} class provides a default implementation of a method called \texttt{getDefaultScalarElement}. This method returns an instance of the root class of the heterogeneous hierarchy, unless the root superclass is abstract.

If the root superclass is abstract or is not appropriate for a default object, override the \texttt{getDefaultScalarElement} method. Implement the \texttt{getDefaultScalarElement} override in the root superclass, which derives directly from \texttt{matlab.mixin.Heterogeneous}.

\texttt{getDefaultScalarElement} must return a scalar object that is derived from the root superclass. For specific information on how to implement this method, see \texttt{getDefaultScalarElement}.
Conversion During Assignment and Concatenation

If you create a heterogeneous array that contains objects that are not derived from the same root superclass, MATLAB attempts to call a method called convertObject. Implement convertObject to convert objects to the appropriate class. There is no default implementation of this method.

To support the formation of heterogeneous arrays using objects that are not part of the heterogeneous hierarchy, implement a convertObject method in the root superclass. The convertObject method must convert the nonmember object to a valid member of the heterogeneous hierarchy.

For details on implementing the convertObject method, see matlab.mixin.Heterogeneous.

Empty Arrays of Heterogeneous Abstract Classes

For homogeneous arrays, MATLAB does not allow you to initialize an empty array of an abstract class. However, if the class is part of a heterogeneous hierarchy, you can initialize empty arrays of an abstract class. Initializing an empty heterogeneous array is useful in cases in which you do not know the class of the concrete elements in advance.

For example, suppose RootSuperclass is an abstract class that is the root of a heterogeneous hierarchy. Initialize an array using the empty static method:

ary = RootSuperclass.empty;

See Also

Related Examples

- “A Class Hierarchy for Heterogeneous Arrays” on page 20-2
- “Handle-Compatible Classes and Heterogeneous Arrays” on page 12-39
Building Arrays in Superclass Constructors

When a subclass in a heterogeneous class hierarchy calls its superclass to construct an array of objects, you must ensure that the superclass constructor does not return a heterogeneous array to the subclass. The following programming patterns show how to avoid the errors caused by returning the wrong class to the subclass constructor.

When Errors Can Occur

Constructors must return objects that are the same class as the defining class. When working with objects from a heterogeneous class hierarchy, the class of an object array can change as you add array elements of different classes. As a result, heterogeneous superclass constructors can change the class of object arrays when the class design requires all the following techniques:

• Building object arrays in subclass constructors
• Calling superclass constructors from subclass constructors to pass arguments
• Creating object arrays in the superclass constructor

In addition, either of the following is true:

• The root superclass is not abstract and does not implement a getDefaultScalarElement method.
• The root superclass implements a getDefaultScalarElement method that returns an object that is not the same class as the subclass.

When assigning to object arrays, MATLAB uses the default object to fill in unassigned array elements. In a heterogeneous hierarchy, the default object can be the superclass that is called by the subclass constructor. Therefore, building an array in the superclass constructor can create a heterogeneous array.

If a superclass constructor returns a heterogeneous array to the subclass constructor, MATLAB generates an error (see “Potential Error” on page 10-30).

Initialize Array in Superclass Constructor

To avoid errors, initialize the object array explicitly in the superclass constructor. For example, use repelem in the superclass constructor to initialize the array before initializing the superclass part of the objects. Initializing the array ensures that all elements assigned into the array are of the same class as the obj argument.
In this code, the superclass constructor creates one object for each element in the input argument, arg:

```matlab
method
  function obj = SuperClass(arg)
    ...
    n = numel(arg);
    obj = repelem(obj,1,n);
    for k = 1:n
      obj(k).SuperProp = arg(k);
    end
    ...
  end
end
```

The subclass constructor calls the superclass constructor to pass the required argument array, a:

```matlab
method
  function obj = SubClass(a)
    obj = obj@SuperClass(a);
    for k = 1:numel(a)
      obj(k).SubProp = a(k);
    end
  end
end
```

**Sample Implementation**

The following class hierarchy defines a subclass that builds object arrays in its constructor. The root superclass of the hierarchy initializes the superclass part of the objects in the array.

This class hierarchy represents members of an engineering team. The classes in the hierarchy include:

- **TeamMembers** — Superclass for specific team member classes, like `ProjectEngineer`. TeamMembers defines the Name and PhoneX properties and derives from `matlab.mixin.Heterogeneous`.
- **ProjectEngineer** — Team members that are engineers. Each instance inherits a Name and PhoneX property and defines a billing Rate property.
- **Other members** — Other types of team members not implemented for this example for simplicity.
The `TeamMembers` class is the root of the heterogeneous hierarchy and is a concrete class. Before assigning values to the `Name` and `PhoneX` properties, the constructor initializes an array of subclass (`ProjectEngineer`) objects.

The `ProjectEngineer` constructor provides the `obj` argument for the call to `repelem` with this statement:

```matlab
obj = obj@TeamMembers(varargin{1:2});
```

Here is the `TeamMembers` class:

```matlab
classdef TeamMembers < matlab.mixin.Heterogeneous

    properties
        Name
        PhoneX
    end

dependent

    classdef ProjectEngineer < TeamMembers
        methods
            function obj = TeamMembers(nme,ext)
                if nargin > 0
                    n = numel(nme);
                    obj = repelem(obj,1,n);
                    for k = 1:n
                        obj(k).Name = nme{k};
                        obj(k).PhoneX = ext(k);
                    end
                else
                    obj.Name = '';
                end
            end
        end
end
end
```

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The ProjectEngineer class represents one type of team member. This class supports array inputs and returns an array of objects.

```matlab
classdef ProjectEngineer < TeamMembers
    % Inputs: {Name}, [PhoneX], {Rate}
    properties
        Rate
    end
    methods
        function obj = ProjectEngineer(varargin)
            obj = obj@TeamMembers(varargin{1:2});
            for k = 1:numel(varargin{1})
                obj(k).Rate = varargin{3}{k};
            end
        end
    end
end
```

The ProjectEngineer class requires a cell array of names, a numeric array of phone extensions, and a cell array of billing rates for each engineer in the team.

```matlab
nm = {'Fred','Nancy','Claudette'};
px = [8112,8113,8114];
rt = {'C2','B1','A2'};
tm = ProjectEngineer(nm,px,rt)
```

```matlab
tm =
    1x3 ProjectEngineer array with properties:
        Rate
        Name
        PhoneX
```

**Potential Error**

The TeamMembers constructor initializes the object array with this statement:

```matlab
obj = repelem(obj,1,n);
```

Because the obj argument to repelem is a ProjectEngineer object, the array returned is of the same class.

Without this statement, the TeamMembers constructor would create default objects to fill in array elements in the for loop. The resulting heterogeneous array would be of the class of the common superclass (TeamMembers in this case). If the superclass returns this heterogeneous array to the subclass constructor, it is a violation of the rule that class constructors must preserve the class of the returned object.

MATLAB issues this error:

```
When constructing an instance of class 'ProjectEngineer', the constructor must preserve the class of the returned object.
Error in ProjectEngineer (line 8)
    obj = obj@TeamMembers(varargin{1:2});
```
See Also

More About

- “Designing Heterogeneous Class Hierarchies” on page 10-20
Events — Sending and Responding to Messages

- “Overview Events and Listeners” on page 11-2
- “Define Custom Event Data” on page 11-5
- “Observe Changes to Property Values” on page 11-8
- “Implement Property Set Listener” on page 11-10
- “Event and Listener Concepts” on page 11-12
- “Event Attributes” on page 11-16
- “Events and Listeners Syntax” on page 11-18
- “Listener Lifecycle” on page 11-23
- “Listener Callback Syntax” on page 11-24
- “Callback Execution” on page 11-27
- “Determine If Event Has Listeners” on page 11-29
- “Listen for Changes to Property Values” on page 11-32
- “Assignment When Property Value Is Unchanged” on page 11-35
- “Techniques for Using Events and Listeners” on page 11-39
Overview Events and Listeners

Why Use Events and Listeners

Events are notices that objects broadcast in response to something that happens, such as a property value changing or a user interaction with an application program. Listeners execute functions when notified that the event of interest occurs. Use events to communicate changes to objects. Listeners respond by executing the callback function.

For more information, see “Event and Listener Concepts” on page 11-12.

Events and Listeners Basics

When using events and listeners:

• Only handle classes can define events and listeners.
• Define event names in the events block of a class definition (“Events and Listeners Syntax” on page 11-18).
• Use event attributes to specify access to the event (“Event Attributes” on page 11-16).
• Call the handle notify method to trigger the event. The event notification broadcasts the named event to all listeners registered for this event.
• Use the handle addlistener method to couple a listener to the event source object. MATLAB destroys the listener when the source of the event is destroyed.
• Use the handle listener method to create listeners that are not coupled to the lifecycle of the event source object. This approach is useful when the event source and the listeners are defined in different components that you want to be able to add, remove, or modify independently. Your application code controls the listener object lifecycle.
• Listener callback functions must define at least two input arguments — the event source object handle and the event data (See “Listener Callback Syntax” on page 11-24 for more information).
• Modify the data passed to each listener callback by subclassing the event.EventData class.

Predefined Events

MATLAB Defines events for listening to property sets and queries. For more information, see “Listen for Changes to Property Values” on page 11-32.

All handle objects define an event named ObjectBeingDestroyed. MATLAB triggers this event before calling the class destructor.

Event Syntax

Define an event name in the events code block:
classdef ClassName < handle
    ...
    events
        EventName
        end
    end
end

For example, MyClass defines an event named StateChange:

classdef MyClass < handle
    events
        StateChange
        end
    end

Trigger an event using the handle class notify method:

classdef ClassName < handle
    ...
    events
        EventName
        end
    ...
    methods
        function anyMethod(obj)
            ...
            notify(obj,'EventName');
        end
    end
end

Any function or method can trigger the event for a specific instance of the class defining the event. For example, the triggerEvent method calls notify to trigger the StateChange event:

classdef MyClass < handle
    events
        StateChange
        end
    methods
        function triggerEvent(obj)
            notify(obj,'StateChange')
        end
    end
end

Trigger the StateChange event with the triggerEvent method:

obj = MyClass;
obj.triggerEvent

For more information, see “Events and Listeners Syntax” on page 11-18.

Create Listener

Define a listener using the handle class addlistener or listener method. Pass a function handle for the listener callback function using one of these syntaxes:
• `addlistener(SourceOfEvent, 'EventName', @functionName)` — for an ordinary function.
• `addlistener(SourceOfEvent, 'EventName', @Obj.methodName)` — for a method of `Obj`.
• `addlistener(SourceOfEvent, 'EventName', @ClassName.methodName)` — for a static method of the class `ClassName`.

```
ListenerObject = addlistener(SourceOfEvent, 'EventName', @listenerCallback);
```

`addlistener` returns the listener object. The input arguments are:

• `SourceOfEvent` — An object of the class that defines the event. The event is triggered on this object.
• `EventName` — The name of the event defined in the class `events` code block.
• `@listenerCallback` — a function handle referencing the function that executes in response to the event.

For example, create a listener object for the `StateChange` event:

```
function lh = createListener(src)
    lh = addlistener(src, 'StateChange', @handleStateChange)
end
```

Define the callback function for the listener. The callback function must accept as the first two arguments the event source object and an event data object: Use the event source argument to access the object that triggered the event. Find information about the event using the event data object.

```
function handleStateChange(src, eventData)
    % src - handle to object that triggered the event
    % eventData - event.EventData object containing information about the event.
    ...
end
```

For more information, see “Listener Callback Syntax” on page 11-24.

**See Also**
`event.EventData` | `handle`

**Related Examples**
• “Listener Lifecycle” on page 11-23
• “Implement Property Set Listener” on page 11-10
Define Custom Event Data

In this section...

“Class Event Data Requirements” on page 11-5
“Define and Trigger Event” on page 11-5
“Define Event Data” on page 11-6
“Create Listener for Overflow Event” on page 11-6

Class Event Data Requirements

Suppose that you want to create a listener callback function that has access to specific information when the event occurs. This example shows how by creating custom event data.

Events provide information to listener callback functions by passing an event data argument to the specified function. By default, MATLAB passes an `event.EventData` object to the listener callback. This object has two properties:

- `EventName` — Name of the event triggered by this object.
- `Source` — Handle of the object triggering the event.

Provide additional information to the listener callback by subclassing the `event.EventData` class.

- Define properties in the subclass to contain the additional data.
- Define a constructor that accepts the additional data as arguments.
- Set the `ConstructOnLoad` class attribute.
- Use the subclass constructor as an argument to the `notify` method to trigger the event.

Define and Trigger Event

The `SimpleEventClass` defines a property set method (see “Property Set Methods” on page 8-44) from which it triggers an event if the property is set to a value exceeding a certain limit. The property set method performs these operations:

- Saves the original property value
- Sets the property to the specified value
- If the specified value is greater than 10, the set method triggers an `Overflow` event
- Passes the original property value, and other event data, in a `SpecialEventDataClass` object to the `notify` method.

```matlab
classdef SimpleEventClass < handle
    properties
        Prop1 = 0
    end
    events
        Overflow
    end
    methods
        function set.Prop1(obj, value)
            orgvalue = obj.Prop1;
```
obj.Prop1 = value;
if (obj.Prop1 > 10)
    % Trigger the event using custom event data
    notify(obj,'Overflow',SpecialEventDataClass(orgvalue));
end
end
end

define event data

Event data is always contained in an event.EventData object. The SpecialEventDataClass adds the original property value to the event data by subclassing event.EventData:

classdef (ConstructOnLoad) SpecialEventDataClass < event.EventData
    properties
        OrgValue = 0
    end
    methods
        function eventData = SpecialEventDataClass(value)
            eventData.OrgValue = value;
        end
    end
end

create listener for overflow event

To listen for the Overflow event, attach a listener to an instance of the SimpleEventClass class. Use the addlistener method to create the listener. Also, you must define a callback function for the listener to execute when the event is triggered.

The function setupSEC instantiates the SimpleEventClass class and adds a listener to the object. In this example, the listener callback function displays information that is contained in the eventData argument (which is a SpecialEventDataClass object).

function sec = setupSEC
    sec = SimpleEventClass;
    addlistener(sec,'Overflow',@overflowHandler)
    function overflowHandler(eventSrc,eventData)
        disp('The value of Prop1 is overflowing!')
        disp(['Its value was: ' num2str(eventData.OrgValue)])
        disp(['Its current value is: ' num2str(eventSrc.Prop1)])
    end
end

Create the SimpleEventClass object and add the listener:

sec = setupSEC;
sec.Prop1 = 5;
sec.Prop1 = 15; % listener triggers callback

The value of Prop1 is overflowing!
Its value was: 5
Its current value is: 15
See Also

Related Examples
• “Observe Changes to Property Values” on page 11-8
Observe Changes to Property Values

This example shows how to listen for changes to a property value. This example uses:

- **PostSet** event predefined by MATLAB
- **SetObservable** property attribute to enable triggering the property **PostSet** event.
- **addlistener** handle class method to create the listener

```matlab
classdef PropLis < handle
    % Define a property that is SetObservable
    properties (SetObservable)
        ObservedProp = 1
    end
    methods
        function attachListener(obj)
            % Attach a listener to a PropListener object
            addlistener(obj,'ObservedProp','PostSet',@PropLis.propChange);
        end
    end
    methods (Static)
        function propChange(metaProp,eventData)
            % Callback for PostSet event
            % Inputs: meta.property object, event.PropertyEvent
            h = eventData.AffectedObject;
            propName = metaProp.Name;
            disp(['The ',propName,' property has changed.'])
            disp(['The new value is: ',num2str(h.ObservedProp)])
            disp(['Its default value is: ',num2str(metaProp.DefaultValue)])
        end
    end
end
```

The **PropLis** class uses an ordinary method (**attachListener**) to add the listener for the **ObservedProp** property. If the **PropLis** class defines a constructor, the constructor can contain the call to **addlistener**.

The listener callback is a static method (**propChange**). MATLAB passes two arguments when calling this function:

- **metaProp** — a **meta.property** object for **ObservedProp**
- **eventData** — an **event.PropertyEvent** object contain event-specific data.

These arguments provide information about the property and the event.

Use the **PropLis** class by creating an instance and calling its **attachListener** method:

```matlab
plObj = PropLis;
plObj.ObservedProp
```

```matlab
ans =
    1
```

```matlab
plObj.attachListener
plObj.ObservedProp = 2;
```
The ObservedProp property has changed.
The new value is: 2
Its default value is: 1

See Also
addlistener | event.proplistener | listener

Related Examples
• “Listener Lifecycle” on page 11-23
• “Implement Property Set Listener” on page 11-10
Implement Property Set Listener

This example shows how to define a listener for a property set event. The listener callback triggers when the value of a specific property changes. The class defined for this example uses a method for a push-button callback and a static method for the listener callback. When the push-button callback changes the value of a property, the listener executes its callback on the PreSet event.

This example defines a class (PushButton) with these design elements:

- **ResultNumber** - Observable property
- uiicontrol pushbutton - Push-button object used to generate a new graph when its callback executes
- A listener that responds to a change in the observable property

**PushButton Class Design**

The PushButton class creates figure, uiicontrol, axes graphics objects, and a listener object in the class constructor.

The push button's callback is a class method (named pressed). When the push button is activated, the following sequence occurs:

1. MATLAB executes the pressed method, which graphs a new set of data and increments the ResultNumber property.
2. Attempting to set the value of the ResultNumber property triggers the PreSet event, which executes the listener callback before setting the property value.
3. The listener callback uses the event data to obtain the handle of the callback object (an instance of the PushButton class), which then provides the handle of the axes object that is stored in its AxHandle property.
4. The listener callback updates the axes Title property, after the callback completes execution, MATLAB sets the ResultsNumber property to its new value.

```matlab
classdef PushButton < handle
    properties (SetObservable)
        ResultNumber = 1
    end
    properties
        AxHandle
    end
    methods
        function buttonObj = PushButton
            myFig = figure;
            buttonObj.AxHandle = axes('Parent',myFig);
            uicontrol('Parent',myFig,...
                'Style','pushbutton','...
                'String','Plot Data','...
                'Callback',@(src,evnt)pressed(buttonObj));
            addlistener(buttonObj,'ResultNumber','PreSet',...
                @PushButton.updateTitle);
        end
    end
    methods
        function pressed(obj)
```

---
scatter(obj.AxHandle, randn(1,20), randn(1,20), 'p')
obj.ResultNumber = obj.ResultNumber + 1;
end
end
methods (Static)
    function updateTitle(~, eventData)
        h = eventData.AffectedObject;
        set(get(h.AxHandle, 'Title'), 'String', ['Result Number: ', ...
            num2str(h.ResultNumber)])
    end
end
end

The scatter graph looks similar to this graph after three push-button clicks.

buttonObj = PushButton;

See Also

Related Examples

• “Listen for Changes to Property Values” on page 11-32
Event and Listener Concepts

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The Event Model

Events represent changes or actions that occur within objects. For example,

- Modification of class data
- Execution of a method
- Querying or setting a property value
- Destruction of an object

Basically, any activity that you can detect programmatically can generate an event and communicate information to other objects.

MATLAB classes define a process that communicates the occurrence of events to other objects that respond to the events. The event model works this way:

- A handle class declares a name used to represent an event. “Name Events” on page 11-18
- After creating an object of the event-declaring class, attach listener to that object. “Control Listener Lifecycle” on page 11-23
- A call to the handle class notify method broadcasts a notice of the event to listeners. The class user determines when to trigger the event. “Trigger Events” on page 11-18
- Listeners execute a callback function when notified that the event has occurred. “Specifying Listener Callbacks” on page 11-24
- You can bind listeners to the lifecycle of the object that defines the event, or limit listeners to the existence and scope of the listener object. “Control Listener Lifecycle” on page 11-23

The following diagram illustrates the event model.
Limitations

There are certain limitations to the use of events:

- The event source cannot guarantee that listeners exist when triggering the event.
- A listener cannot prevent other listeners from being notified that the event occurred.
- The order in which listeners execute is not defined.
- Listeners should not modify the event data object passed to the listener callback, because other listeners are passed this same handle object.

Default Event Data

Events provide information to listener callbacks by passing an event data argument to the callback function. By default, MATLAB passes an `event.EventData` object to the listener callback. This object has two properties:

- **EventName** — The event name as defined in the class `event` block
- **Source** — The object that is the source of the event
MATLAB passes the source object to the listener callback in the required event data argument. Use the source object to access any of the object’s public properties from within your listener callback function.

**Customize Event Data**

You can create a subclass of the `event.EventData` class to provide additional information to listener callback functions. The subclass would define properties to contain the additional data and provide a method to construct the derived event data object so it can be passed to the `notify` method.

“Define Event-Specific Data” on page 11-21 provides an example showing how to customize this data.

**Events Only in Handle Classes**

You can define events only in handle classes. This restriction exists because a value class is visible only in a single MATLAB workspace so no callback or listener can have access to the object that triggered the event. The callback could have access to a copy of the object. However, accessing a copy is not useful because the callback cannot access the current state of the object that triggered the event or effect any changes in that object.

“Comparison of Handle and Value Classes” on page 7-2 provides general information on handle classes.

“Events and Listeners Syntax” on page 11-18 shows the syntax for defining a handle class and events.

**Property-Set and Query Events**

There are four predefined events related to properties:

- **PreSet** — Triggered just before the property value is set, before calling its set access method
- **PostSet** — Triggered just after the property value is set
- **PreGet** — Triggered just before a property value query is serviced, before calling its get access method
- **PostGet** — Triggered just after returning the property value to the query

These events are predefined and do not need to be listed in the class `events` block.

When a property event occurs, the callback is passed an `event.PropertyEvent` object. This object has three properties:

- **EventName** — The name of the event described by this data object
- **Source** — The source object whose class defines the event described by the data object
- **AffectedObject** — The object whose property is the source for this event (that is, `AffectedObject` contains the object whose property was either accessed or modified).

You can define your own property-change event data by subclassing the `event.EventData` class. The `event.PropertyEvent` class is a sealed subclass of `event.EventData`. 
See “Listen for Changes to Property Values” on page 11-32 for a description of the process for creating property listeners.

See “The PostSet Event Listener” on page 11-47 for an example.

See “Property Access Methods” on page 8-39 for information on methods that control access to property values.

**Listeners**

Listeners encapsulate the response to an event. Listener objects belong to the `event.listener` class, which is a handle class that defines the following properties:

- **Source** — Handle or array of handles of the object that generated the event
- **EventName** — Name of the event
- **Callback** — Function to execute when an enabled listener receives event notification
- **Enabled** — Callback function executes only when Enabled is true. See “Enable and Disable Listeners” on page 11-49 for an example.
- **Recursive** — Allow listener to trigger the same event that caused execution of the callback.

**Recursive** is false by default. If the callback triggers the event for which it is defined as the callback, the listener cannot execute recursively. Therefore, set **Recursive** to false if the callback must trigger its own event. Setting the **Recursive** property to true can create a situation where infinite recursion reaches the recursion limit and triggers an error.

“Control Listener Lifecycle” on page 11-23 provides more specific information.
Event Attributes

Specify Event Attributes

The following table lists the attributes you can set for events. To specify a value for an attribute, assign the attribute value on the same line as the event keyword. For example, all the events defined in the following events block have protected ListenAccess and private NotifyAccess.

```
events (ListenAccess = protected, NotifyAccess = private)
    EventName1
    EventName2
end
```

To define other events in the same class definition that have different attribute settings, create another events block.
### Event Attributes

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Class</th>
<th>Description</th>
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<tr>
<td>Hidden</td>
<td>logical</td>
<td>Default = false</td>
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<tr>
<td>ListenAccess</td>
<td>enumeration, default = public</td>
<td>Determines where you can create listeners for the event.</td>
</tr>
<tr>
<td>NotifyAccess</td>
<td>enumeration, default = public</td>
<td>Determines where code can trigger the event.</td>
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#### ListenAccess
- **public** — Unrestricted access
- **protected** — Access from methods in class or subclasses
- **private** — Access by class methods only (not from subclasses)

List classes that have listen access to this event. Specify classes as `meta.class` objects in the form:
- A single `meta.class` object
- A cell array of `meta.class` objects. An empty cell array, `{}`, is the same as `private` access.

See “Class Members Access” on page 12-23

#### NotifyAccess
- **public** — Any code can trigger event
- **protected** — Can trigger event from methods in class or derived classes
- **private** — Can trigger event by class methods only (not from derived classes)

List classes that have notify access to this event. Specify classes as `meta.class` objects in the form:
- A single `meta.class` object
- A cell array of `meta.class` objects. An empty cell array, `{}`, is the same as `private` access.

See “Class Members Access” on page 12-23

### Framework attributes
Classes that use certain framework base classes have framework-specific attributes. See the documentation for the specific base class you are using for information on these attributes.

### See Also

### Related Examples
- “Events and Listeners Syntax” on page 11-18
Events and Listeners Syntax

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Components to Implement

Implementation of events and listeners involves these components:

- Specification of the name of an event in a handle class — “Name Events” on page 11-18.
- A function or method to trigger the event when the action occurs — “Trigger Events” on page 11-18.
- Listener objects to execute callback functions in response to the triggered event — “Listen to Events” on page 11-19.
- Default or custom event data that the event passes to the callback functions — “Define Event-Specific Data” on page 11-21.

Name Events

Define an event by declaring an event name inside an events block. For example, this class creates an event called ToggledState:

```matlab
classdef ToggleButton < handle
    properties
        State = false
    end
    events
        ToggledState
    end
end
```

Trigger Events

The OnStateChange method calls notify to trigger the ToggledState event. Pass the handle of the object that is the source of the event and the name of the event to notify.

```matlab
classdef ToggleButton < handle
    properties
        State = false
    end
    events
        ToggledState
    end
    methods
        function OnStateChange(obj,newState)
            if newState ~= obj.State
```
Listen to Events

After the call to notify triggers an event, MATLAB broadcasts a message to all listeners that are defined for that event and source object. There are two ways to create listeners: using the handle class addlistener or listener method.

Use addlistener for Persistent Listeners

If you want the listener to persist beyond the normal variable scope, use addlistener to create it. The event source object holds a reference to the listener object. When the event source object is destroyed, MATLAB destroys the listener.

This code defines a listener for the ToggleState event:

```plaintext
lh = addlistener(obj,'ToggleState',@RespondToToggle.handleEvnt);
```

**addlistener** has these arguments:

- `obj` — The object that is the source of the event
- `ToggleState` — The event name passed as a char vector
- `@RespondToToggle.handleEvnt` — A function handle to the callback function (see the following definition “Define Listener” on page 11-20).

Use handle.listener to Decouple Listener and Source

Use the listener method to create listeners when you want to manage the lifecycle of the listener and do not want a coupling between the event source and listener object. MATLAB does not destroy listeners created with listener when the event source is destroyed. However, your code must keep the listener object handle in scope when creating listeners using listener.

The listener method requires the same arguments as addlistener: the event-naming object, the event name, and a function handle to the callback. listener returns the handle to the listener object.

```plaintext
lh = listener(obj,'EventName',@callbackFunction)
```

For example, this code uses the ToggleState event discussed previously:

```plaintext
lh = listener(obj,'ToggleState',@RespondToToggle.handleEvnt)
```

Callback Function

The listener callback function must accept a minimum of two arguments, which MATLAB automatically passes to the callback. Here are the required arguments:

- The source of the event — that is, obj in the call to addlistener or event.listener.
- An event.EventData object or a subclass of event.EventData, such as the ToggleEventData object described in, “Define Event-Specific Data” on page 11-21.
Define the callback function to accept the source object and event data arguments.

```matlab
function callbackFunction(src,evtdata)
    end...
```

For more information on callback syntax, see “Listener Callback Syntax” on page 11-24.

**Define Listener**

The *RespondToToggle* class defines objects that listen for the *ToggleState* event defined in the *ToggleButton* class.

```matlab
classdef RespondToToggle < handle
    methods
        function obj = RespondToToggle(toggle_button_obj)
            addlistener(toggle_button_obj,'ToggledState',@RespondToToggle.handleEvnt);
        end
    end
    methods (Static)
        function handleEvnt(src,~)
            if src.State
                disp('ToggledState is true')
            else
                disp('ToggledState is false')
            end
        end
    end
end
```

The class *RespondToToggle* adds the listener in its constructor. In this case, the class defines the callback (*handleEvnt*) as a static method that accepts the two required arguments:

- *src* — The handle of the object triggering the event (that is, a *ToggleButton* object)
- *evtdata* — An *event.EventData* object

For example, this code creates objects of both classes:

```matlab
tb = ToggleButton;
rtt = RespondToToggle(tb);
```

Whenever you call the *OnStateChange* method of the *ToggleButton* object, notify triggers the event. For this example, the callback displays the value of the *State* property:

```matlab
tb.OnStateChange(true)
ToggledState is true
```

```matlab
tb.OnStateChange(false)
ToggledState is false
```

**Remove Listeners**

Remove a listener object by calling *delete* on its handle. For example, if the class *RespondToToggle* saved the listener handle as a property, you could delete the listener.

```matlab
classdef RespondToToggle < handle
    properties
        ListenerHandle % Property for listener handle
    end
    methods
        function obj = RespondToToggle(toggle_button_obj)
```

11 Events — Sending and Responding to Messages

11-20
hl = addlistener(toggle_button_obj,'ToggledState',@RespondToToggle.handleEvnt);
obj.ListenerHandle = hl; % Save listener handle
end
end
methods (Static)
    function handleEvnt(src,~)
        if src.State
            disp('ToggledState is true')
        else
            disp('ToggledState is false')
        end
    end
end
end

With this code change, you can remove the listener from an instance of the RespondToToggle class. For example:

tb = ToggleButton;
rtt = RespondToToggle(tb);

The object rtt is listening for the ToggleState event triggered by object tb. To remove the listener, call delete on the property containing the listener handle.

delete(rtt.ListenerHandle)

To deactivate a listener temporarily, see “Temporarily Deactivate Listeners” on page 11-23.

**Define Event-Specific Data**

Suppose that you want to pass the state of the toggle button as a result of the event to the listener callback. You can add more data to the default event data by subclassing the event.EventData class and adding a property to contain this information. Then you can pass this object to the notify method.

**Note** To save and load objects that are subclasses of event.EventData, such as ToggleEventData, enable the ConstructOnLoad class attribute for the subclass.

classdef (ConstructOnLoad) ToggleEventData < event.EventData
    properties
        NewState
    end

    methods
        function data = ToggleEventData(newState)
            data.NewState = newState;
        end
    end
end

The call to notify can use the ToggleEventData constructor to create the necessary argument.

evtdata = ToggleEventData(newState);
notify(obj,'ToggledState',evtdata);
See Also

Related Examples

•  “Listener Callback Syntax” on page 11-24
•  “Listen for Changes to Property Values” on page 11-32
•  “Techniques for Using Events and Listeners” on page 11-39
## Listener Lifecycle

### In this section...

- “Control Listener Lifecycle” on page 11-23
- “Temporarily Deactivate Listeners” on page 11-23
- “Permanently Delete Listeners” on page 11-23

### Control Listener Lifecycle

There are two ways to create listeners:

- `addlistener` creates a coupling between the listener and event source object. The listener object persists until you delete it or until the event object is destroyed. When the event source object is destroyed, MATLAB automatically destroys the listener object.

- `listener` constructs listener objects that are not coupled to the lifecycle of the event source object. The listener is active as long as the listener object remains in scope and is not explicitly deleted. Therefore, your application must maintain a reference to the listener object by storing the listener handle. The advantage of uncoupling the listener and event objects is that you can define and destroy each independently.

For more information, see “Events and Listeners Syntax” on page 11-18.

### Temporarily Deactivate Listeners

The `addlistener` method returns the listener object so that you can set its properties. For example, you can temporarily disable a listener by setting its `Enabled` property to `false`:

```matlab
ListenerHandle.Enabled = false;
```

To reenable the listener, set `Enabled` to `true`.

```matlab
ListenerHandle.Enabled = true;
```

### Permanently Delete Listeners

Calling `delete` on a listener object destroys it and permanently removes the listener:

```matlab
delete(ListenerHandle)
```

**Note** Do not use the `pack` command with objects that define events and listeners. The `pack` command causes the destruction of any listeners defined for the objects in the workspace. For information on restoring listeners when saving objects, see “Restore Listeners” on page 13-26.

### See Also

### Related Examples

- "Enable and Disable Listeners" on page 11-49
Listener Callback Syntax

In this section...

“Specifying Listener Callbacks” on page 11-24
“Input Arguments for Callback Function” on page 11-24
“Additional Arguments for Callback Function” on page 11-25

Specifying Listener Callbacks

CallBacks are functions that execute when the listener receives notification of the event. Pass a function handle referencing the callback function to `addlistener` or `listener` when creating the listener.

All callback functions must accept at least two arguments:

- The handle of the object that is the source of the event
- An `event.EventData` object or an object that is derived from the `event.EventData` class.

Syntax to Reference Callback

For a function: `functionName`

```
lh = addlistener(eventSourceObj,'EventName',@functionName)
```

For an ordinary method called with an object of the class: `obj.methodName`

```
lh = addlistener(eventSourceObj,'EventName',@obj.methodName)
```

For a static method: `ClassName.methodName`

```
lh = addlistener(eventSourceObj,'EventName',@ClassName.methodName)
```

For a function in a package: `PackageName.functionName`

```
lh = addlistener(eventSourceObj,'EventName',@PackageName.functionName)
```

Input Arguments for Callback Function

Define the callback function to accept the required arguments:

```
function callbackFunction(src,evnt)
    ...
end
```

If you do not use the event source and event data arguments, you can define the function to ignore these inputs:

```
function callbackFunction(~,~)
    ...
end
```

For a method:

```
function callbackMethod(obj,src,evnt)
    ...
end
```
Additional Arguments for Callback Function

To pass arguments to your callback in addition to the source and event data arguments passed by MATLAB, use an anonymous function. Anonymous functions can use any variables that are available in the current workspace.

Syntax Using Anonymous Function

Here is the syntax for an ordinary method. The input arguments (arg1,...,argn) must be defined in the context in which you call addlistener.

\[
\text{lh} = \text{addlistener(src,'EventName',@(src,evnt)obj.callbackMethod(src,evnt,arg1,...,argn)}
\]

Use varargin to define the callback function.

\[
\text{function callbackMethod(src,evnt,varargin)}
\]

\[
\begin{align*}
\text{arg1} &= \text{varargin[1]}; \\
\text{...} \\
\text{argn} &= \text{varargin[n]}; \\
\text{...}
\end{align*}
\]

For general information on anonymous function, see “Anonymous Functions”.

Using Methods for Callbacks

The TestAnonyFcn class shows the use of an anonymous function with an additional argument. The listener callback displays the inputs arguments to show how MATLAB calls the callback method.

\[
\text{classdef TestAnonyFcn < handle}
\]

\[
\begin{align*}
\text{events} \\
\text{Update}
\end{align*}
\]

\[
\text{methods}
\]

\[
\begin{align*}
\text{function obj = TestAnonyFcn} \\
\text{t = datestr(now);} \\
\text{addlistener(obj,'Update',@(src,evnt)obj.evntCb(src,evnt,t));}
\end{align*}
\]

\[
\text{function triggerEvnt(obj)}
\]

\[
\begin{align*}
\text{notify(obj,'Update')} \\
\end{align*}
\]

\[
\text{methods (Access = private)}
\]

\[
\begin{align*}
\text{function evntCb~,~,event, varargin)} \\
\text{disp([》Number of inputs: ',num2str(nargin)])} \\
\text{disp(event.EventName)} \\
\text{disp(varargin{:})}
\end{align*}
\]

Create an object and trigger the event by calling the triggerEvt method:

\[
\begin{align*}
\text{obj = TestAnonyFcn;} \\
\text{obj.triggerEvnt;} \\
\text{Number of inputs: 4} \\
\text{Update} \\
\text{01-Jul-2008 17:19:36}
\end{align*}
\]
See Also

Related Examples
- “Callback Execution” on page 11-27
- “Create Function Handle”
Callback Execution

In this section...

“When Callbacks Execute” on page 11-27
“Listener Order of Execution” on page 11-27
“Callbacks That Call notify” on page 11-27
“Manage Callback Errors” on page 11-27
“Invoke Functions from Function Handles” on page 11-27

When Callbacks Execute

Listeners execute their callback function when notified that the event has occurred. Listeners are passive observers in the sense that errors in the execution of a listener callback do not prevent the execution of other listeners responding to the same event, or execution of the function that triggered the event.

Callback function execution continues until the function completes. If an error occurs in a callback function, execution stops and control returns to the calling function. Then any remaining listener callback functions execute.

Listener Order of Execution

The order in which listeners callback functions execute after the firing of an event is undefined. However, all listener callbacks execute synchronously with the event firing.

The handle class notify method calls all listeners before returning execution to the function that called notify.

Callbacks That Call notify

Do not modify and reuse or copy and reuse the event data object that you pass to notify, which is then passed to the listener callback.

Listener callbacks can call notify to trigger events, including the same event that invoked the callback. When a function calls notify, MATLAB sets the property values of the event data object that is passed to callback functions. To ensure that these properties have appropriate values for subsequently called callbacks, always create a new event data object if you call notify with custom event data.

Manage Callback Errors

If you want to control how your program responds to errors, use a try/catch statement in your listener callback function to handle errors.

Invoke Functions from Function Handles

When you create a function handle inside a class method, the context of the method determines the context in which the function executes. This context gives the function access to private and protected methods that are accessible to that class.
For example, the UpdateEvt class defines an event named Update and a listener for that event. The listener callback is the private method evtCb.

```matlab
classdef UpdateEvt < handle
    events
    Update
    end
    methods
        function obj = UpdateEvt
            addlistener(obj,'Update',@evtCb);
        end
    end
    methods (Access = private)
        function obj = evtCb(obj,varargin)
            disp('Updated Event Triggered')
        end
    end
end
```

Private methods are normally accessible only by class methods. However, because the function handle is created in a class method, notify can execute the callback from outside of the class:

```matlab
a = UpdateEvt;
a.notify('Update')
```

Updated Event Triggered

**See Also**

**Related Examples**

- “Listener Callback Syntax” on page 11-24
Determine If Event Has Listeners

Do Listeners Exist for This Event?

Use the `event.hasListener` function to determine if a specific event has listeners. `event.hasListener` accepts an array of event source objects and an event name as input arguments. It returns an array of logical values indicating if listeners exist for the specified event on each object in the array.

**Note** When called, `event.hasListener` must have `NotifyAccess` for the event. That is, call `event.hasListener` in a context in which you can call `notify` for the event in question.

Why Test for Listeners

Use `event.hasListener` to avoid sending event notifications when there are no listeners for the event. For example, if creating custom event data consumes significant resources, or if events are triggered repeatedly, use `event.hasListener` to test for listeners before performing these steps.

Coding Patterns

- Conditionalize the creation of event data and the call to `notify` using `event.hasListener`. For an object array `a`, determine if there are listeners before creating event data and triggering the event:

  ```java
  if any(event.hasListener(a,'NameOfEvent'))
      evt = MyCustomEventData(...);
      notify(a,'NameOfEvent',evt)
  end
  ```

- Trigger events selectively using logical indexing with the values returned by `event.hasListener`. Send event notifications only for array elements that have listeners:

  ```java
  ind = event.hasListeners(a,'NameOfEvent');
  notify(a(ind),'NameOfEvent',evt)
  ```

Listeners in Heterogeneous Arrays

If the input object array is heterogeneous, the class of the array must define the specified event. You can query the listeners only for events that all objects in the array define.

For example, in the following diagram, the class of a heterogeneous array formed with objects of classes `SpecificA`, `SpecificB`, and `SpecificC` is `RootSuperclass`. Therefore, `event.hasListener` can find listeners only for the `RootEvent` event, because it is the only event common to all array elements.
Create a heterogeneous array with the three most specific classes:

```matlab
ehet = [SpecificA,SpecificB,SpecificC];
class(het)
ans
RootSuperclass
events(het)
Events for class RootSuperclass
    RootEvent

event.hasListener cannot determine if there are listeners for events that are defined by some but not all objects in the array:

```matlab
event.hasListener(het,'ClassAEvent')
```
Error using event.hasListener
Event 'ClassAEvent' is not defined for class 'RootSuperclass'.
```

Determine if individual objects in the heterogeneous array have listeners defined for their specific events, by indexing into the array:

```matlab
event.hasListener(het(1),'ClassAEvent')
```

For more information about determining the class of heterogeneous arrays, see “Designing Heterogeneous Class Hierarchies” on page 10-20.
See Also

Related Examples
- “Listener Lifecycle” on page 11-23
Listen for Changes to Property Values

Create Property Listeners

For handle classes, you can define listeners for the predeclared property events (named: PreSet, PostSet, PreGet, and PostGet). To create listeners for those named events:

- Specify the SetObservable and/or GetObservable property attributes.
- Define callback functions
- Create the property listener by including the name of the property and the event in the call to addlistener or listener.
- If necessary, subclass event.data to create a specialized event data object to pass to the callback function.
- Prevent execution of the callback if the new value is the same as the current value (see “Assignment When Property Value Is Unchanged” on page 11-35).

Set Property Attributes to Enable Property Events

In the properties block, enable the SetObservable attribute. You can define PreSet and PostSet listeners for the properties defined in this block:

```
properties (SetObservable)
    PropOne
    PropTwo
...
end
```

Define Callback Function for Property Event

The listener executes the callback function when MATLAB triggers the property event. Define the callback function to have two specific arguments, which are passed to the function automatically when called by the listener:

- Event source — a meta.property object describing the object that is the source of the property event
- Event data — a event.PropertyEvent object containing information about the event

You can pass additional arguments if necessary. It is often simple to define this method as Static because these two arguments contain most necessary information in their properties.

For example, suppose the handlePropEvents function is a static method of the class creating listeners for two properties of an object of another class:

```
methods (Static)
    function handlePropEvents(src, evnt)
        switch src.Name
            case 'PropOne'
                % PropOne has triggered an event
                ...
```

Another possibility is to use the `event.PropertyEvent` object's `EventName` property in the `switch` statement to key off the event name (`PreSet` or `PostSet` in this case).

“Class Metadata” on page 16-2 provides more information about the `meta.property` class.

**Add Listener to Property**

The `addlistener` handle class method enables you to attach a listener to a property without storing the listener object as a persistent variable. For a property event, use the four-argument version of `addlistener`.

Here is a call to `addlistener`:

```matlab
addlistener(EventObject,'PropOne','PostSet',@ClassName.handlePropertyEvents);
```

The arguments are:

- `EventObject` — handle of the object generating the event
- `PropOne` — name of the property to which you want to listen
- `PostSet` — name of the event for which you want to listen
- `@ClassName.handlePropertyEvents` — function handle referencing a static method, which requires the use of the class name

If your listener callback is an ordinary method and not a static method, the syntax is:

```matlab
addlistener(EventObject,'PropOne','PostSet',@obj.handlePropertyEvents);
```

where `obj` is the handle of the object defining the callback method.

If the listener callback is a function that is not a class method, you pass a function handle to that function. Suppose that the callback function is a package function:

```matlab
addlistener(EventObject,'PropOne','PostSet',@package.handlePropertyEvents);
```

For more information on passing functions as arguments, see “Create Function Handle”.

**Property Event and Listener Classes**

The following two classes show how to create `PostSet` property listeners for two properties — `PropOne` and `PropTwo`.

**Class Generating the Event**

The `PropEvent` class enables property `PreSet` and `PostSet` event triggering by specifying the `SetObservable` property attribute. These properties also enable the `AbortSet` attribute, which prevents the triggering of the property events if the properties are set to a value that is the same as their current value (see “Assignment When Property Value Is Unchanged” on page 11-35).

```matlab
classdef PropEvent < handle
    properties (SetObservable, AbortSet)
```
PropOne
PropTwo
end
methods
    function obj = PropEvent(p1,p2)
        if nargin > 0
            obj.PropOne = p1;
            obj.PropTwo = p2;
        end
    end
end

Class Defining the Listeners

The PropListener class defines two listeners:

- Property PropOne PostSet event
- Property PropTwo PostSet event

You can define listeners for other events or other properties using a similar approach. It is not necessary to use the same callback function for each listener. See the meta.property and event.PropertyEvent reference pages for more on the information contained in the arguments passed to the listener callback function.

classdef PropListener < handle
    % Define property listeners
    methods
        function obj = PropListener(evtobj)
            if nargin > 0
                addlistener(evtobj,'PropOne','PostSet',@PropListener.handlePropEvents);
                addlistener(evtobj,'PropTwo','PostSet',@PropListener.handlePropEvents);
            end
        end
    end
    methods (Static)
        function handlePropEvents(src,evnt)
            switch src.Name
                case 'PropOne'
                    sprintf('PropOne is %s\n',num2str(evnt.AffectedObject.PropOne))
                case 'PropTwo'
                    sprintf('PropTwo is %s\n',num2str(evnt.AffectedObject.PropTwo))
            end
        end
    end
end

See Also

Related Examples

- "Assignment When Property Value Is Unchanged" on page 11-35
AbortSet When Value Does Not Change

When you set a property value, MATLAB triggers the property PreSet and PostSet events, invokes the property set method (if one is defined), and sets the property value. These actions occur even when the current value of the property is the same as the new value.

You can prevent these actions by setting the property's AbortSet attribute to true. When AbortSet is enabled, MATLAB compares the current property value to the new value being assigned to the property. If the new value is the same as the current value, MATLAB does not:

- Set the property value.
- Trigger the PreSet and PostSet events.
- Call the property set method, if one exists.

To compare values, MATLAB must get the current value of the property. Getting the current value causes the property get method (get.Property) to execute, if one exists. Any errors that occur when calling the property get method are visible to the user, even if MATLAB does not change the current value.

How MATLAB Compares Values

MATLAB uses the isequal function to determine if the current value of the property is the same as the new value. To determine if specific values evaluate as equal when using the AbortSet attribute, see the isequal function documentation or any isequal method overloaded for the class of the property value.

When to Use AbortSet

Use of the AbortSet attribute does incur some overhead in the comparison of the current and new property values. Using the AbortSet attribute can slow all property assignments because the current and assigned value are always compared before the assignment is made. The AbortSet attribute is most useful when:

- You want to prevent notification of the PreSet and PostSet events and execution of the listener callbacks when the property value does not change.
- The cost of setting a property value is greater than the cost of comparing the current property value with the value being assigned, and you are willing to incur the comparison cost with all assignments to the property.
Implement AbortSet

The following example shows how the AbortSet attribute works. The AbortTheSet class defines a property, PropOne, that has listeners for the PreGet, PreSet, PostGet, and PostSet events and enables the AbortSet attribute.

Note To use this class, save the AbortTheSet class in a file with the same name in a folder on your MATLAB path.

classdef AbortTheSet < handle
    properties (SetObservable, GetObservable, AbortSet)
        PropOne = 7
    end
    methods
        function obj = AbortTheSet
            addlistener(obj,'PropOne','PreGet',@obj.getPrePropEvt);
            addlistener(obj,'PropOne','PreSet',@obj.setPrePropEvt);
            addlistener(obj,'PropOne','PostGet',@obj.getPostPropEvt);
            addlistener(obj,'PropOne','PostSet',@obj.setPostPropEvt);
        end
        function propval = get.PropOne(obj)
            disp('get.PropOne called')
            propval = obj.PropOne;
        end
        function set.PropOne(obj,val)
            disp('set.PropOne called')
            obj.PropOne = val;
        end
        function getPrePropEvt(obj,src,evnt)
            disp ('Pre-get event triggered')
            % ...
        end
        function setPrePropEvt(obj,src,evnt)
            disp ('Pre-set event triggered')
            % ...
        end
        function getPostPropEvt(obj,src,evnt)
            disp ('Post-get event triggered')
            % ...
        end
        function setPostPropEvt(obj,src,evnt)
            disp ('Post-set event triggered')
            % ...
        end
        function disp(obj)
            disp (class(obj))
        end
    end
end

The class specifies an initial value of 7 for the PropOne property. Therefore, if you create an object and assign the property value of 7, there is no need to trigger the PreSet event. However, the getPropOne method is called to get the current value of the property to compare to the assigned value.
obj = AbortTheSet;
obj.PropOne = 7;

get.PropOne called

If you specify a value other than 7, then MATLAB performs these steps:

- Gets the current property value
- Triggers the PreSet event
- Sets the property to the assigned value
- Triggers the PostSet event

obj = AbortTheSet;
obj.PropOne = 9;

get.PropOne called
Pre-set event triggered
set.PropOne called
Post-set event triggered

If you query the property value, the PreGet and PostGet events are triggered.

obj.PropOne

Pre-get event triggered
get.PropOne called
Post-get event triggered

ans =

9

**Using AbortSet with Property Validation**

When classes use property validation and AbortSet in a property definition, MATLAB evaluates the
property validation before comparing the current value to the value being assigned. For example, revise the AbortTheSet class to add a size restriction of 1-by-3 to the PropOne property.

classdef AbortTheSet < handle
properties (SetObservable, GetObservable, Abort)
% Restrict size to 1-by-3
% ************************
PropOne (1,3) = [7 7 7]
% ************************
end
methods
function obj = AbortTheSet
  addlistener(obj,'PropOne','PreGet',@obj.getPrePropEvt);
  addlistener(obj,'PropOne','PreSet',@obj.setPrePropEvt);
  addlistener(obj,'PropOne','PostGet',@obj.getPostPropEvt);
  addlistener(obj,'PropOne','PostSet',@obj.setPostPropEvt);
end
function propval = get.PropOne(obj)
  disp('get.PropOne called')
  propval = obj.PropOne;
end
function set.PropOne(obj,val)
    disp('set.PropOne called')
    obj.PropOne = val;
end
function getPrePropEvt(obj,src,evnt)
    disp ('Pre-get event triggered')
    % ...
end
function setPrePropEvt(obj,src,evnt)
    disp ('Pre-set event triggered')
    % ...
end
function getPostPropEvt(obj,src,evnt)
    disp ('Post-get event triggered')
    % ...
end
function setPostPropEvt(obj,src,evnt)
    disp ('Post-set event triggered')
    % ...
end
function disp(obj)
    % Overload disp to avoid accessing property
    disp (class(obj))
end
end

Because MATLAB applies scalar expansion to satisfy the size restriction, the following assignment
does not trigger the PreSet or PostSet events.

obj = AbortTheSet;
obj.PropOne = 7;

get.PropOne called

obj.PropOne

Pre-get event triggered
get.PropOne called
Post-get event triggered

ans =

   7    7    7

For information on property validation, see “Validate Property Values” on page 8-20.

See Also

Related Examples

- “Property Access Methods” on page 8-39
- “Determine If Event Has Listeners” on page 11-29
Techniques for Using Events and Listeners

Example Overview

This example defines two classes:

- `fcneval` — The function evaluator class contains a MATLAB expression and evaluates this expression over a specified range.
- `fcnview` — The function viewer class contains a `fcneval` object and displays surface graphs of the evaluated expression using the data contained in `fcneval`.

This class defines two events:

- A class-defined event that occurs when a new value is specified for the MATLAB function
- A property event that occurs when the property containing the limits is changed

The following diagram shows the relationship between the two objects. The `fcnview` object contains a `fcneval` object and creates graphs from the data it contains. `fcnview` creates listeners to change the graphs if any of the data in the `fcneval` object change.
Techniques Demonstrated in This Example

- Naming an event in the class definition
- Triggering an event by calling `notify`
- Enabling a property event via the `SetObservable` attribute
- Creating listeners for class-defined events and property `PostSet` events
- Defining listener callback functions that accept additional arguments
- Enabling and disabling listeners

Summary of `fcneval` Class

The `fcneval` class evaluates a MATLAB expression over a specified range of two variables. The `fcneval` is the source of the data that objects of the `fcnview` class graph as a surface. `fcneval` is the source of the events used in this example. For a listing of the class definition, see “@fcneval/fcneval.m Class Code” on page 11-50

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>FofXY</code></td>
<td>function handle</td>
<td>MATLAB expression (function of two variables).</td>
</tr>
<tr>
<td><code>Lm</code></td>
<td>two-element vector</td>
<td>Limits over which function is evaluated in both variables. <code>SetObservable</code> attribute set to true to enable property event listeners.</td>
</tr>
<tr>
<td><code>Data</code></td>
<td>structure with x, y, and z matrices</td>
<td>Data resulting from evaluating the function. Used for surface graph. <code>Dependent</code> attribute set to true, which means the <code>get.Data</code> method is called to determine property value when queried and no data is stored.</td>
</tr>
</tbody>
</table>
### Event

<table>
<thead>
<tr>
<th>Event</th>
<th>When Triggered</th>
</tr>
</thead>
<tbody>
<tr>
<td>UpdateGraph</td>
<td>FofXY property set function (set.FofXY) calls the notify method when a new value is specified for the MATLAB expression on an object of this class.</td>
</tr>
</tbody>
</table>

### Method

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>fcneval</td>
<td>Class constructor. Inputs are function handle and two-element vector specifying the limits over which to evaluate the function.</td>
</tr>
<tr>
<td>set.FofXY</td>
<td>FofXY property set function. Called whenever property value is set, including during object construction.</td>
</tr>
<tr>
<td>set.Lm</td>
<td>Lm property set function. Used to test for valid limits.</td>
</tr>
<tr>
<td>get.Data</td>
<td>Data property get function. This method calculates the values for the Data property whenever that data is queried (by class members or externally).</td>
</tr>
<tr>
<td>grid</td>
<td>A static method (Static attribute set to true) used in the calculation of the data.</td>
</tr>
</tbody>
</table>

### Summary of fcnview Class

Objects of the fcnview class contain fcneval objects as the source of data for the four surface graphs created in a function view. fcnview creates the listeners and callback functions that respond to changes in the data contained in fcneval objects. For a listing of the class definition, see “@fcnview/fcnview.m Class Code” on page 11-51

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>FcnObject</td>
<td>fcneval object</td>
<td>This object contains the data that is used to create the function graphs.</td>
</tr>
<tr>
<td>HAxes</td>
<td>axes handle</td>
<td>Each instance of a fcnview object stores the handle of the axes containing its subplot.</td>
</tr>
<tr>
<td>HUpdateGraph</td>
<td>event.listener object for UpdateGraph event</td>
<td>Setting the event.listener object's Enabled property to true enables the listener; false disables listener.</td>
</tr>
<tr>
<td>HLLm</td>
<td>event.listener object for Lm property event</td>
<td>Setting the event.listener object's Enabled property to true enables the listener; false disables listener.</td>
</tr>
<tr>
<td>HEnableCm</td>
<td>uimenu handle</td>
<td>Item on context menu used to enable listeners (used to handle checked behavior)</td>
</tr>
<tr>
<td>HDisableCm</td>
<td>uimenu handle</td>
<td>Item on context menu used to disable listeners (used to manage checked behavior)</td>
</tr>
<tr>
<td>HSurface</td>
<td>surface handle</td>
<td>Used by event callbacks to update surface data.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>fcneval</td>
<td>Class constructor. Input is fcneval object.</td>
</tr>
<tr>
<td>createLisn</td>
<td>Calls addlistener to create listeners for UpdateGraph and Lm property PostSet listeners.</td>
</tr>
<tr>
<td>Method</td>
<td>Purpose</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------------------------------------------------</td>
</tr>
<tr>
<td>lims</td>
<td>Sets axes limits to current value of fcneval object's Lm property. Used by event handlers.</td>
</tr>
<tr>
<td>updateSurfaceData</td>
<td>Updates the surface data without creating a new object. Used by event handlers.</td>
</tr>
<tr>
<td>listenUpdateGraph</td>
<td>Callback for UpdateGraph event.</td>
</tr>
<tr>
<td>listenLm</td>
<td>Callback for Lm property PostSet event</td>
</tr>
<tr>
<td>delete</td>
<td>Delete method for fcnview class.</td>
</tr>
<tr>
<td>createViews</td>
<td>Static method that creates an instance of the fcnview class for each subplot, defines the context menus that enable/disable listeners, and creates the subplots</td>
</tr>
</tbody>
</table>

### Methods Inherited from Handle Class

Both the fcneval and fcnview classes inherit methods from the handle class. The following table lists only those inherited methods used in this example.

“Handle Class Methods” on page 7-11 provides a complete list of methods that are inherited when you subclass the handle class.

<table>
<thead>
<tr>
<th>Methods Inherited from Handle Class</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>addlistener</td>
<td>Register a listener for a specific event and attach listener to event-defining object.</td>
</tr>
<tr>
<td>notify</td>
<td>Trigger an event and notify all registered listeners.</td>
</tr>
</tbody>
</table>

### Using the fcneval and fcnview Classes

This section explains how to use the classes.

- Create an instance of the fcneval class to contain the MATLAB expression of a function of two variables and the range over which you want to evaluate this function
- Use the fcnview class static function createViews to visualize the function
- Change the MATLAB expression or the limits contained by the fcneval object and all the fcnview objects respond to the events generated.

You create a fcneval object by calling its constructor with two arguments—an anonymous function and a two-element, monotonically increasing vector. For example:

```matlab
feobject = fcneval(@(x,y) x.*exp(-x.^2-y.^2),[-2 2]);
```

Use the createViews static method to create the graphs of the function. Use the class name to call a static function:

```matlab
fcnview.createViews(feobject);
```

The createView method generates four views of the function contained in the fcneval object.
Each subplot defines a context menu that can enable and disable the listeners associated with that graph. For example, if you disable the listeners on subplot 221 (upper left) and change the MATLAB expression contained by the `fcneval` object, only the remaining three subplots update when the `UpdateGraph` event is triggered:

```matlab
feobject.FofXY = @(x,y) x.*exp(-x.^0.5-y.^0.5);
```

Similarly, if you change the limits by assigning a value to the `feobject.Lm` property, the `feobject` triggers a `PostSet` property event and the listener callbacks update the graph.

```matlab
feobject.Lm = [-8 3];
```
In this figure, the listeners are reenabled via the context menu for subplot 221. Because the listener callback for the property PostSet event also updates the surface data, all views are now synchronized.

**Implement UpdateGraph Event and Listener**

The UpdateGraph event occurs when the MATLAB representation of the mathematical function contained in the fcneval object is changed. The fcnview objects that contain the surface graphs are listening for this event, so they can update the graphs to represent the new function.

**Define and Trigger UpdateGraph Event**

The UpdateGraph event is a class-defined event. The fcneval class names the event and calls notify when the event occurs.
The `fcnview` class defines a listener for this event. When `fcneval` triggers the event, the `fcnview` listener executes a callback function that performs the following actions:

- Determines if the handle of the surface object stored by the `fcnview` object is still valid (that is, does the object still exist)
- Updates the surface `XData`, `YData`, and `ZData` by querying the `fcneval` object’s `Data` property.

The `fcneval` class defines an event name in an `event` block:

```matlab
events
  UpdateGraph
end
```

**Determine When to Trigger Event**

The `fcneval` class defines a property set method for the `FofXY` property. `FofXY` is the property that stores the MATLAB expression for the mathematical function. This expression must be a valid MATLAB expression for a function of two variables.

The `set.FofXY` method:

- Determines the suitability of the expression
• If the expression is suitable:
  • Assigns the expression to the FofXY property
  • Triggers the UpdateGraph event

If fcneval.isSuitable does not return an MException object, the set.FofXY method assigns the value to the property and triggers the UpdateGraph event.

```matlab
function set.FofXY(obj,func)
% Determine if function is suitable to create a surface
  me = fcneval.isSuitable(func);
  if ~isempty(me)
    throw(me)
  end
% Assign property value
  obj.FofXY = func;
% Trigger UpdateGraph event
  notify(obj,'UpdateGraph');
end
```

Determine Suitability of Expression

The set.FofXY method calls a static method (fcneval.isSuitable) to determine the suitability of the specified expression. fcneval.isSuitable returns an MException object if it determines that the expression is unsuitable. fcneval.isSuitable calls the MException constructor directly to create more useful error messages for the user.

set.FofXY issues the exception using the throw method. Issuing the exception terminates execution of set.FofXY and prevents the method from making an assignment to the property or triggering the UpdateGraph event.

Here is the fcneval.isSuitable method:

```matlab
function isOk = isSuitable(funcH)
  v = [1 1;1 1];
  % Can the expression except 2 numeric inputs
  try
    funcH(v,v);
  catch %#ok<CTCH>
    me = MException('DocExample:fcneval',...% 'The function ',func2str(funcH),' Is not a suitable F(x,y)');
    isOk = me;
    return
  end
  % Does the expression return non-scalar data
  if isscalar(funcH(v,v));
    me = MException('DocExample:fcneval',...% '[The function ',func2str(funcH),' Returns a scalar when evaluated']);
    isOk = me;
    return
  end
isOk = [];
end
```

The fcneval.isSuitable method could provide additional test to ensure that the expression assigned to the FofXY property meets the criteria required by the class design.
Other Approaches

The class could have implemented a property set event for the FofXY property and would, therefore, not need to call notify (see “Listen for Changes to Property Values” on page 11-32). Defining a class event provides more flexibility in this case because you can better control event triggering.

For example, suppose that you wanted to update the graph only if the new data is different. If the new expression produced the same data within some tolerance, the set.FofXY method could not trigger the event and avoid updating the graph. However, the method could still set the property to the new value.

Listener and Callback for UpdateGraph Event

The fcnview class creates a listener for the UpdateGraph event using the addlistener method:

```matlab
obj.HLUpdateGraph = addlistener(obj.FcnObject,'UpdateGraph',@(src,evnt)listenUpdateGraph(obj,src,evnt)); % Add obj to argument list
```

The fcnview object stores a handle to the event.listener object in its HLUpdateGraph property, which is used to enable/disable the listener by a context menu (see “Enable and Disable Listeners” on page 11-49).

The fcnview object (obj) is added to the two default arguments (src, evnt) passed to the listener callback. Keep in mind, the source of the event (src) is the fcneval object, but the fcnview object contains the handle of the surface object that the callback updates.

The listenUpdateGraph function is defined as follows:

```matlab
function listenUpdateGraph(obj,src,evnt)
    if ishandle(obj.HSurface) % If surface exists
        obj.updateSurfaceData % Update surface data
    end
end
```

The updateSurfaceData function is a class method that updates the surface data when a different mathematical function is assigned to the fcneval object. Updating a graphics object data is more efficient than creating a new object using the new data:

```matlab
function updateSurfaceData(obj)
    % Get data from fcneval object and set surface data
    set(obj.HSurface,...
        'XData',obj.FcnObject.Data.X,...
        'YData',obj.FcnObject.Data.Y,...
        'ZData',obj.FcnObject.Data.Matrix);
end
```

The PostSet Event Listener

All properties support the predefined PostSet event (See “Property-Set and Query Events” on page 11-14 for more information on property events). This example uses the PostSet event for the fcneval Lm property. This property contains a two-element vector specifying the range over which the mathematical function is evaluated. Just after this property is changed (by a statement like obj.Lm = [-3 5];), the fcnview objects listening for this event update the graph to reflect the new data.
Sequence During the Lm Property Assignment

The `fcneval` class defines a set function for the `Lm` property. When a value is assigned to this property during object construction or property reassignment, the following sequence occurs:

1. An attempt is made to assign argument value to `Lm` property.
   
   ```
   obj.Lm = [-3 5];
   ```

2. The `SetObservable` attribute of `Properties` is set to `true`, so setting the property automatically triggers a `PostSet` event. Note that methods and events did not have to be declared in `myfunceval`.

3. A message is broadcast.

4. A listener awaiting the message executes its callback.

5. The callback function is executed.

Enable PostSet Property Event

To create a listener for the `PostSet` event, you must set the property's `SetObservable` attribute to `true`:

```matlab
properties (SetObservable = true)
    Lm = [-2*pi 2*pi];  % specifies default value
end
```

MATLAB automatically triggers the event so it is not necessary to call `notify`.

“Specify Property Attributes” on page 8-5 provides a list of all property attributes.
**Listener and Callback for PostSet Event**

The fcnview class creates a listener for the PostSet event using the addlistener method:

```matlab
obj.HLLm = addlistener(obj.FcnObject,'Lm','PostSet', ... @(src,evnt)listenLm(obj,src,evnt)); % Add obj to argument list
```

The fcnview object stores a handle to the event.listener object in its HLLm property, which is used to enable/disable the listener by a context menu (see “Enable and Disable Listeners” on page 11-49).

The fcnview object (obj) is added to the two default arguments (src, evnt) passed to the listener callback. Keep in mind, the source of the event (src) is the fcneval object, but the fcnview object contains the handle of the surface object that the callback updates.

The callback sets the axes limits and updates the surface data because changing the limits causes the mathematical function to be evaluated over a different range:

```matlab
function listenLm(obj,src,evnt)
    if ishandle(obj.HAxes) % If there is an axes
        lims(obj); % Update its limits
    end
    if ishandle(obj.HSurface) % If there is a surface
        obj.updateSurfaceData % Update its data
    end
end
```

**Enable and Disable Listeners**

Each fcnview object stores the handle of the listener objects it creates so that the listeners can be enabled or disabled via a context menu after the graphs are created. All listeners are instances of the event.listener class, which defines a property called Enabled. By default, this property has a value of true, which enables the listener. If you set this property to false, the listener still exists, but is disabled. This example creates a context menu active on the axes of each graph that provides a way to change the value of the Enabled property.

**Context Menu Callback**

There are two callbacks used by the context menu corresponding to the two items on the menu:

- **Listen** — Sets the Enabled property for both the UpdateGraph and PostSet listeners to true and adds a check mark next to the Listen menu item.
- **Don't Listen** — Sets the Enabled property for both the UpdateGraph and PostSet listeners to false and adds a check mark next to the Don't Listen menu item.

Both callbacks include the fcnview object as an argument (in addition to the required source and event data arguments) to provide access to the handle of the listener objects.

The enableLisn function is called when the user selects Listen from the context menu.

```matlab
function enableLisn(obj,src,evnt)
    obj.HLUpdateGraph.Enabled = true; % Enable listener
    obj.HLLm.Enabled = true; % Enable listener
    set(obj.HEnableCm,'Checked','on') % Check Listen
    set(obj.HDisableCm,'Checked','off') % Uncheck Don't Listen
end
```
The `disableLisn` function is called when the user selects **Don't Listen** from the context menu.

```matlab
function disableLisn(obj, src, evnt)
    obj.HLUpdateGraph.Enabled = false; % Disable listener
    obj.HLLm.Enabled = false; % Disable listener
    set(obj.HEnableCm,'Checked','off') % Uncheck Listen
    set(obj.HDisableCm,'Checked','on') % Check Don't Listen
end
```

**@fcneval/fcneval.m Class Code**

```matlab
classdef fcneval < handle
    properties
        FofXY
    end

    properties (SetObservable = true)
        Lm = [-2*pi 2*pi]
    end % properties SetObservable = true

    properties (Dependent = true)
        Data
    end

    events
        UpdateGraph
    end

    methods
        function obj = fcneval(fcn_handle,limits)  % Constructor returns object
            if nargin > 0
                obj.FofXY = fcn_handle;                 % Assign property values
                obj.Lm = limits;
            end
        end

        function set.FofXY(obj,func)
            me = fcneval.isSuitable(func);
            if ~isempty(me)
                throw(me)
            end
            obj.FofXY = func;
            notify(obj,'UpdateGraph');
        end

        function set.Lm(obj,lim)
            if ~all(lim(:)<lim(2))
                error('Limits must be monotonically increasing')
            else
                obj.Lm = lim;
            end
        end

        function data = get.Data(obj)
            [x,y] = fcneval.grid(obj.Lm);
            matrix = obj.FofXY(x,y);
            data.X = x;
            data.Y = y;
            data.Matrix = real(matrix);
        end
    end % methods

    methods (Static = true)
        function [x,y] = grid(lim)
            inc = (lim(2)-lim(1))/20;
            [x,y] = meshgrid(lim(1):inc:lim(2));
        end
    end % methods
```

11-50
function isOk = isSuitable(funcH)
    v = [1 1; 1 1];
    try
        funcH(v,v);
        catch  %#ok<CTCH>
            me = MException('DocExample:fcneval','The function ',func2str(funcH),', Is not a suitable F(x,y)');
            isOk = me;
            return
        end
    if isscalar(funcH(v,v));
        me = MException('DocExample:fcneval','The function ',func2str(funcH),', Returns a scalar when evaluated');
        isOk = me;
        return
    end
    isOk = [];
end

@fcnview/fcnview.m Class Code

classdef fcnview < handle
    properties
        FcnObject     % fcneval object
        HAxes         % subplot axes handle
        HLUpdateGraph % UpdateGraph listener handle
        HLLm          % Lm property PostSet listener handle
        HEnableCm     % "Listen" context menu handle
        HDisableCm    % "Don't Listen" context menu handle
        HSurface      % Surface object handle
    end

    methods
        function obj = fcnview(fcnobj)
            if nargin > 0
                obj.FcnObject = fcnobj;
                obj.createLisn;
            end
        end

        function createLisn(obj)
            obj.HLUpdateGraph = addlistener(obj.FcnObject,'UpdateGraph',...
                @(src,evnt)listenUpdateGraph(obj,src,evnt));
            obj.HLLm = addlistener(obj.FcnObject,'Lm','PostSet',...
                @(src,evnt)listenLm(obj,src,evnt));
        end

        function lims(obj)
            lmts = obj.FcnObject.Lm;
            set(obj.HAxes,'XLim',lmts);
            set(obj.HAxes,'Ylim',lmts);
        end

        function updateSurfaceData(obj)
            data = obj.FcnObject.Data;
            set(obj.HSurface,...
'XData', data.X, ...
'YData', data.Y, ...
'ZData', data.Matrix);}

function listenUpdateGraph(obj, ~, ~)
  if ishandle(obj.HSurface)
    obj.updateSurfaceData
  end
end

function listenLm(obj, ~, ~)
  if ishandle(obj.HAxes)
    lims(obj);
    if ishandle(obj.HSurface)
      obj.updateSurfaceData
    end
  end
end

function delete(obj)
  if ishandle(obj.HAxes)
    delete(obj.HAxes);
  else
    return
  end
end

methods (Static)
  createViews(a)
end
end

@fcnview/createViews

function createViews(fcnevalobj)
  p = pi; deg = 180/p;
  hfig = figure('Visible','off', ...
    'Toolbar','none');

  for k = 4:-1:1
    fcnvobj(k) = fcnview(fcnevalobj);
    axh = subplot(2,2,k);
    fcnvobj(k).HAxes = axh;
    hcm(k) = uicontextmenu;
    set(axh,'Parent',hfig,...
    'FontSize',8,...
    'UIContextMenu',hcm(k))
    fcnvobj(k).HEnableCm = uimenu(hcm(k),...
    'Label','Listen',...
    'Checked','on',...
    'Callback', @(src,evt)enableLisn(fcnviewobj(k),src,evnt));
    fcnvobj(k).HDisableCm = uimenu(hcm(k),...
    'Label','Don''t Listen',...
    'Checked','off',...
    'Callback', @(src,evt)disableLisn(fcnviewobj(k),src,evnt));
    az = p/k*deg;
view(axh,az,30)
title(axh,['View: ','num2str(az),', '30'])
fcnviewobj(k).lims;
surfLight(fcnviewobj(k),axh)
end
set(hfig,'Visible','on')
end
function surfLight(obj,axh)
    obj.HSurface = surface(obj.FcnObject.Data.X,...
        obj.FcnObject.Data.Y,...
        obj.FcnObject.Data.Matrix,...
        'FaceColor',[.8 .8 0],'EdgeColor',[.3 .3 .2],...
        'FaceLighting','phong',...
        'FaceAlpha',.3,...
        'HitTest','off',...
        'Parent',axh);
    lims(obj)
camlight left; material shiny; grid off
colormap copper
end

function enableLisn(obj,~,~)
    obj.HLUpdateGraph.Enabled = true;
    obj.HLLm.Enabled = true;
    set(obj.HEnableCm,'Checked','on')
    set(obj.HDisableCm,'Checked','off')
end

function disableLisn(obj,~,~)
    obj.HLUpdateGraph.Enabled = false;
    obj.HLLm.Enabled = false;
    set(obj.HEnableCm,'Checked','off')
    set(obj.HDisableCm,'Checked','on')
end
How to Build on Other Classes

- “Hierarchies of Classes — Concepts” on page 12-2
- “Subclass Syntax” on page 12-5
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- “Determine Array Class” on page 12-69
- “Abstract Classes and Class Members” on page 12-72
- “Define an Interface Superclass” on page 12-76
Hierarchies of Classes — Concepts

In this section...

“Classification” on page 12-2
“Develop the Abstraction” on page 12-3
“Design of Class Hierarchies” on page 12-3
“Super and Subclass Behavior” on page 12-3
“Implementation and Interface Inheritance” on page 12-4

Classification

Organizing classes into hierarchies facilitates the reuse of code and the reuse of solutions to design problems that have already been solved. You can think of class hierarchies as sets — supersets (referred to as superclasses or base classes), and subsets (referred to as subclasses or derived classes). For example, the following picture shows how you could represent an employee database with classes.

The root of the hierarchy is the Employees class. It contains data and operations that apply to the set of all employees. Contained in the set of employees are subsets whose members, while still employees, are also members of sets that more specifically define the type of employee. Subclasses like TestEngineer are examples of these subsets.
Develop the Abstraction

Classes are representations of real world concepts or things. When designing a class, form an abstraction of what the class represents. Consider an abstraction of an employee and what are the essential aspects of employees for the intended use of the class. Name, address, and department can be what all employees have in common.

When designing classes, your abstraction contains only those elements that are necessary. For example, the employee hair color and shoe size certainly characterize the employee, but are probably not relevant to the design of this employee class. Their sales region is relevant only to some employee so this characteristic belongs in a subclass.

Design of Class Hierarchies

As you design a system of classes, put common data and functionality in a superclass, which you then use to derive subclasses. The subclasses inherit the data and functionality of the superclass and define only aspects that are unique to their particular purposes. This approach provides advantages:

• Avoid duplicating code that is common to all classes.
• Add or change subclasses at any time without modifying the superclass or affecting other subclasses.
• If the superclass changes (for example, all employees are assigned a number), then the subclass automatically get these changes.

Super and Subclass Behavior

Subclass objects behave like objects of the superclass because they are specializations of the superclass. This fact facilitates the development of related classes that behave similarly, but are implemented differently.

A Subclass Object “Is A” Superclass Object

You can usually describe the relationship between an object of a subclass and an object of its superclass with a statement like:

The subclass is a superclass. For example: An Engineer is an Employee.

This relationship implies that objects belonging to a subclass have the same properties, methods, and events as the superclass. Subclass objects also have any new features defined by the subclass. Test this relationship with the isa function.

Treat Subclass Objects like Superclass Objects

You can pass a subclass object to a superclass method, but you can access only those properties that the superclass defines. This behavior enables you to modify the subclasses without affecting the superclass.

Two points about super and subclass behavior to keep in mind are:

• Methods defined in the superclass can operate on subclass objects.
• Methods defined in the subclass cannot operate on superclass objects.
Therefore, you can treat an Engineer object like any other Employees object, but an Employee object cannot pass for an Engineer object.

**Limitations to Object Substitution**

MATLAB determines the class of an object based on its most specific class. Therefore, an Engineer object is of class Engineer, while it is also an Employees object, as using the `isa` function reveals.

Generally, MATLAB does not allow you to create arrays containing a mix of superclass and subclass objects because an array can be of only one class. If you attempt to concatenate objects of different classes, MATLAB looks for a converter method defined by the less dominant class.

See “Concatenating Objects of Different Classes” on page 10-15 for more information.

See `matlab.mixin.Heterogeneous` for information on defining heterogeneous class hierarchies.

See “Object Converters” on page 17-10 for information on defining converter methods.

**Implementation and Interface Inheritance**

MATLAB classes support both the inheritance of implemented methods from a superclass and the inheritance of interfaces defined by abstract methods in the superclass.

Implementation inheritance enables code reuse by subclasses. For example, an employee class can have a `submitStatus` method that all employee subclasses can use. Subclasses can extend an inherited method to provide specialized functionality, while reusing the common aspects. See “Modify Inherited Methods” on page 12-13 for more information on this process.

Interface inheritance is useful in these cases:

- You want a group of classes to provide a common interface.
- Subclasses create specialized implementations of methods and properties.

Create an interface using an abstract class as the superclass. This class defines the methods and properties that you must implement in the subclasses, but does not provide an implementation.

The subclasses must provide their own implementation of the abstract members of the superclass. To create an interface, define methods and properties as abstract using their `Abstract` attribute. See “Abstract Classes and Class Members” on page 12-72 for more information and an example.

**See Also**

**Related Examples**

- “Design Subclass Constructors” on page 12-7
Subclass Syntax

In this section...
“Subclass Definition Syntax” on page 12-5
“Subclass double” on page 12-5

Subclass Definition Syntax

To define a class that is a subclass of another class, add the superclass to the classdef line after a < character:

classdef ClassName < SuperClass

When inheriting from multiple classes, use the & character to indicate the combination of the superclasses:

classdef ClassName < SuperClass1 & SuperClass2

See “Class Member Compatibility” on page 12-18 for more information on deriving from multiple superclasses.

Class Attributes

Subclasses do not inherit superclass attributes.

Subclass double

Suppose you want to define a class that derived from double and restricts values to be positive numbers. The PositiveDouble class:

• Supports a default constructor (no input arguments). See “No Input Argument Constructor Requirement” on page 9-19
• Restricts the inputs to positive values using mustBePositive.
• Calls the superclass constructor with the input value to create the double numeric value.

classdef PositiveDouble < double
methods
    function obj = PositiveDouble(data)
        if nargin == 0
            data = 1;
        else
            mustBePositive(data)
        end
        obj = obj@double(data);
    end
end

Create an object of the PositiveDouble class using a 1-by-5 array of numbers:

a = PositiveDouble(1:5);

You can perform operations on objects of this class like any double.
sum(a)
ans =
    15

Objects of the PositiveDouble class must be positive values.

a = PositiveDouble(0:5);
Error using mustBePositive (line 19)
Value must be positive.

Error in PositiveDouble (line 7)
    mustBePositive(data)

See Also

Related Examples
- “Design Subclass Constructors” on page 12-7
- “Subclasses of MATLAB Built-In Types” on page 12-41
Design Subclass Constructors

In this section...

“Call Superclass Constructor Explicitly” on page 12-7
“Call Superclass Constructor from Subclass” on page 12-7
“Subclass Constructor Implementation” on page 12-8
“Call Only Direct Superclass from Constructor” on page 12-9

Call Superclass Constructor Explicitly

Explicitly calling each superclass constructor from a subclass constructor enables you to:

- Pass arguments to superclass constructors
- Control the order in which MATLAB calls the superclass constructors

If you do not explicitly call the superclass constructors from the subclass constructor, MATLAB implicitly calls these constructors with no arguments. The superclass constructors must support the no argument syntax to support implicit calls.

MATLAB does not guarantee any specific calling order when there are multiple superclasses. If the order in which MATLAB calls the superclass constructors is important, call the superclass constructors explicitly from the subclass constructor.

If you do not define a subclass constructor, you can call the default constructor with superclass arguments. For more information, see “Default Constructor” on page 9-17 and “Implicit Call to Inherited Constructor” on page 9-21.

Call Superclass Constructor from Subclass

To call the constructor for each superclass within the subclass constructor, use the following syntax:

```
obj@SuperClass1(args,...);
...
obj@SuperclassN(args,...);
```

Where `obj` is the output of the subclass constructor, `SuperClass...` is the name of a superclass, and `args` are any arguments required by the respective superclass constructor.

For example, the following segment of a class definition shows that a class called `Stocks` that is a subclass of a class called `Assets`.

```matlab
classdef Stocks < Assets
    methods
        function s = Stocks(asset_args,...)
            if nargin == 0
                % Assign values to asset_args
            end
            % Call asset constructor
            s@Assets(asset_args);
    end
end
```
“Subclass Constructors” on page 9-19 provides more information on creating subclass constructor methods.

**Reference Superclasses Contained in Packages**

If a superclass is contained in a package, include the package name. For example, the `Assets` class is in the `finance` package:

```matlab
classdef Stocks < finance.Assets
    methods
        function s = Stocks(asset_args,...)
            if nargin == 0
                ...
            end
            % Call asset constructor
            s@finance.Assets(asset_args);
            ...
        end
    end
end
```

**Initialize Objects Using Multiple Superclasses**

To derive a class from multiple superclasses, initialize the subclass object with calls to each superclass constructor:

```matlab
classdef Stocks < finance.Assets & Taxable
    methods
        function s = Stocks(asset_args,tax_args,...)
            if nargin == 0
                ...
            end
            % Call asset and member class constructors
            s@finance.Assets(asset_args)
            s@Taxable(tax_args)
            ...
        end
    end
end
```

**Subclass Constructor Implementation**

To ensure that your class constructor supports the zero arguments syntax, assign default values to input argument variables before calling the superclass constructor. You cannot conditionalize a subclass call to the superclass constructor. Locate calls to superclass constructors outside any conditional code blocks.

For example, the `Stocks` class constructor supports the no argument case with the `if` statement, but calls the superclass constructor outside of the `if` code block.

```matlab
classdef Stocks < finance.Assets
    properties
```
NumShares
Symbol
end
methods
function s = Stocks(description,numshares,symbol)
    if nargin == 0
        description = ''; 
        numshares = 0;
        symbol = ''; 
    end
    s@finance.Assets(description);
    s.NumShares = numshares;
    s.Symbol = symbol;
end
end
end

Call Only Direct Superclass from Constructor

Call only direct superclass constructors from a subclass constructor. For example, suppose class B derives from class A and class C derives from class B. The constructor for class C cannot call the constructor for class A to initialize properties. Class B must initialize class A properties.

The following implementations of classes A, B, and C show how to design this relationship in each class.

Class A defines properties x and y, but assigns a value only to x:

classdef A
    properties
        x
        y
    end
    methods
        function obj = A(x)
            ...
            obj.x = x;
        end
    end
end

Class B inherits properties x and y from class A. The class B constructor calls the class A constructor to initialize x and then assigns a value to y.

classdef B < A
    methods
        function obj = B(x,y)
            ...
            obj@A(x);
            obj.y = y;
        end
    end
end

Class C accepts values for the properties x and y, and passes these values to the class B constructor, which in turn calls the class A constructor:
classdef C < B
    methods
        function obj = C(x,y)
            ...
            obj@B(x,y);
        end
    end
end

See Also

Related Examples
- “No Input Argument Constructor Requirement” on page 9-19
Control Sequence of Constructor Calls

MATLAB does not guarantee the sequence in which superclass constructors are called when constructing a subclass object. However, you can control this order by calling superclass constructors explicitly from the subclass constructor.

If you explicitly call a superclass constructor from the most specific subclass constructor (`ClassC` in the following diagram), then MATLAB calls the most specific subclass constructor first. If you do not make an explicit call to a superclass constructor from the subclass constructor, MATLAB makes the implicit call when accessing the object.

Suppose that you have a hierarchy of classes in which `ClassC` derives from `ClassB`, which derives from `ClassA`. The constructor for a subclass can call only direct superclasses. Therefore, each class constructor can call the direct superclass constructor:

```
classdef ClassB < ClassA
    ...
    function obj = ClassB
        obj@ClassA
end

classdef ClassC < ClassB
    ...
    function obj = ClassC
        obj@ClassB
end
```

In cases of multiple inheritance, the subclass constructor can call each superclass constructor. To ensure that a specific superclass constructor calling sequence is followed, call all direct superclass constructors explicitly from the most specific subclass constructor:

```
classdef ClassC < ClassB & ClassA
    ...
    function obj = ClassC
        obj@ClassA
        obj@ClassB
```
See Also

Related Examples
- “Call Only Direct Superclass from Constructor” on page 12-9
- “Class Constructor Methods” on page 9-16
Modify Inherited Methods

When to Modify Superclass Methods

Class design enable you to pass a subclass object to a superclass method and have the method execute properly. At the same time, subclass methods can apply special processing to the unique aspects of the subclass. Some useful techniques include:

- Extend — Calling a superclass method from within a subclass method
- Redefine — Reimplementing in the subclass, the protected methods that are called from within a public superclass method
- Override — Defining the same named methods in both super and subclass, but using different implementations

Extend Superclass Methods

Subclass methods can call superclass methods of the same name. This technique enables you to extend a superclass method in a subclass without completely redefining the superclass method.

For example, suppose that both superclass and subclass define a method called foo. The method names are the same so the subclass method can call the superclass method. However, the subclass method can also perform other steps before and after the call to the superclass method. It can operate on the specialized parts to the subclass that are not part of the superclass.

For example, this subclass defines a foo method that calls the superclass foo method

```matlab
classdef Sub < Super
    methods
        function foo(obj)
            % preprocessing steps
            ...
            foo@Super(obj);
            % postprocessing steps
            ...
        end
    end
end
```

Redefine Superclass Methods in Subclass

A superclass method can define a process that executes in a series of steps using a protected method for each step (Access attribute set to protected). Then, subclasses can create their own versions of the protected methods that implement the individual steps in the process.

Implement this technique as shown here:
The subclass does not reimplement the `foo` method, it reimplements only the methods that carry out the series of steps (`step1(obj)`, `step2(obj)`, `step3(obj)`). That is, the subclass can specialize the actions taken by each step, but does not control the order of the steps in the process. When you pass a subclass object to the superclass `foo` method, MATLAB calls the subclass step methods because of the dispatching rules.

### Override Superclass Methods

You can completely redefine a superclass method in a subclass. In this case, both the superclass and the subclass would define a method with the same name. However, the implementation would be different and the subclass method would not call the superclass method.
classdef Sub < Super
    methods
        function foo(obj)
            % Subclass implementation
        end
    end
end

See Also

Related Examples
•   “Invoking Superclass Methods in Subclass Methods” on page 9-15
Modify Inherited Properties

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**Superclass Property Modification**

There are two separate conditions under which you can redefine superclass properties:

- The value of the superclass property `Abstract` attribute is `true`
- The values of the superclass property `SetAccess` and `GetAccess` attributes are `private`

If a superclass defines a property as abstract, the subclass must implement a concrete version of this property or the subclass is also abstract. Superclasses define abstract properties to create a consistent interface among subclasses.

If a superclass defines a property with private access, then only the superclass can access this property. The subclass can implement a different property with the same name.

**Private Local Property Takes Precedence in Method**

When superclass and subclass define a property with the same name, methods that refer to this property access the property of the class defining the method.

For example, if a subclass property has the same name as a superclass private property, and a method of the superclass references the property name, MATLAB accesses the property defined by the superclass.

Consider the following classes, `Super` and `Sub`:

```matlab
classdef Super
    properties (Access = private)
        Prop = 2
    end
    methods
        function p = superMethod(obj)
            p = obj.Prop;
        end
    end
end

classdef Sub < Super
    properties
        Prop = 1
    end
end
```

If you create an instance of the `Sub` class and use it to call the superclass method, MATLAB accesses the private property of the superclass:

```matlab
subObj = Sub
```
subObj =
    Sub with properties:
    Prop: 1
subObj.superMethod
ans =
    2

See Also

More About
• "Property Attributes" on page 8-7
Subclassing Multiple Classes

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Specify Multiple Superclasses

When inheriting from multiple classes, use the & character to indicate the combination of the superclasses:

classdef ClassName < SuperClass1 & SuperClass2

For more information on class syntax, see “Subclass Syntax” on page 12-5.

Class Member Compatibility

When you create a subclass derived from multiple superclasses, the subclass inherits the properties, methods, and events defined by all specified superclasses. If more than one superclass defines a property, method, or event having the same name, there must be an unambiguous resolution to the multiple definitions. You cannot derive a subclass from any two or more classes that define incompatible class members.

Here are various situations where you can resolve name and definition conflicts.

Property Conflicts

If two or more superclasses define a property with the same name, then at least one of the following must be true:

- All, or all but one of the properties must have their SetAccess and GetAccess attributes set to private
- The properties have the same definition in all superclasses (for example, when all superclasses inherited the property from a common base class)

Method Conflicts

If two or more superclasses define methods with the same name, then at least one of the following must be true:

- The method Access attribute is private so only the defining superclass can access the method.
- The method has the same definition in all subclasses. This situation can occur when all superclasses inherit the method from a common base class and none of the superclasses override the inherited definition.
- The subclass redefines the method to disambiguate the multiple definitions across all superclasses. Therefore, the superclass methods must not have their Sealed attribute set to true.
- Only one superclass defines the method as Sealed, in which case, the subclass adopts the sealed method definition.
• The superclasses define the methods as Abstract and rely on the subclass to define the method.

**Event Conflicts**

If two or more superclasses define events with the same name, then at least one of the following must be true:

• The event ListenAccess and NotifyAccess attributes must be private.
• The event has the same definition in all superclasses (for example, when all superclasses inherited the event from a common base class)

**Multiple Inheritance**

Resolving the potential conflicts involved when defining a subclass from multiple classes often reduces the value of this approach. For example, problems can arise when you enhance superclasses in future versions and introduce new conflicts.

Reduce potential problems by implementing only one unrestricted superclass. In all other superclasses, all methods are

• Abstract
• Defined by a subclass
• Inherited from the unrestricted superclass

When using multiple inheritance, ensure that all superclasses remain free of conflicts in definition.

**See Also**

**Related Examples**

• “Design Subclass Constructors” on page 12-7
• “Handle Compatible Classes” on page 12-32
Specify Allowed Subclasses

In this section...

“Basic Knowledge” on page 12-20
“Why Control Allowed Subclasses” on page 12-20
“Specify Allowed Subclasses” on page 12-20
“Define Sealed Hierarchy of Classes” on page 12-21

Basic Knowledge

The material presented in this section builds on an understanding of the following information:

- “Class Metadata” on page 16-2
- “Attribute Specification” on page 5-18

Why Control Allowed Subclasses

A class definition can specify a list of classes that it allows as subclasses. Classes not in the list cannot be defined as subclass of the class. To specify the allowed subclasses, use the AllowedSubclasses class attribute.

The AllowedSubclasses attribute provides a design point between Sealed classes, which do not allow subclassing, and the default behavior, which does not restrict subclassing.

By controlling the allowed subclasses, you can create a sealed hierarchy of classes. That is, a system of classes that enables a specific set of classes to derive from specific base classes, but that does not allow unrestricted subclassing.

See “Define Sealed Hierarchy of Classes” on page 12-21 for more about this technique.

Specify Allowed Subclasses

Specify a list of one or more allowed subclasses in the classdef statement by assigning meta.class objects to the AllowedSubclasses attribute. Create the meta.class object referencing a specific class using the ? operator and the class name:

classdef (AllowedSubclasses = ?ClassName) MySuperClass
    ...
end

Use a cell array of meta.class objects to define more than one allowed subclass:

classdef (AllowedSubclasses = {?ClassName1,?ClassName2,...?ClassNameN}) MySuperClass
    ...
end

Always use the fully qualified class name when referencing the class name:

classdef (AllowedSubclasses = ?Package.SubPackage.ClassName) MySuperClass
    ...
end

Assigning an empty cell array to the AllowedSubclasses attribute is effectively the same as defining a Sealed class.
classdef (AllowedSubclasses = {}) MySuperClass
    ...
end

**Note** Use only the `?` operator and the class name to generate `meta.class` objects. Values assigned to the `AllowedSubclasses` attribute cannot contain any other MATLAB expressions, including functions that return either `meta.class` objects or cell arrays of `meta.class` objects.

**Result of Declaring Allowed Subclasses**

Including a class in the list of `AllowedSubclasses` does not define that class as a subclass or require you to define the class as a subclass. It just allows the referenced class to be defined as a subclass.

Declaring a class as an allowed subclass does not affect whether this class can itself be subclassed.

A class definition can contain assignments to the `AllowedSubclasses` attribute that reference classes that are not currently defined or available on the MATLAB path. However, any referenced subclass that MATLAB cannot find when loading the class is effectively removed from the list without causing an error or warning.

**Note** If MATLAB does not find any of the classes in the allowed classes list, the class is effectively sealed. A sealed class is equivalent to `AllowedSubclasses = {}`.

Use the `meta.class` property `RestrictSubclassing` to determine if a class is sealed or specifies `AllowedSubclasses`.

**Define Sealed Hierarchy of Classes**

The `AllowedSubclasses` attribute enables you to define a sealed class hierarchy by sealing the allowed subclasses:

```matlab
classdef (AllowedSubclasses = {?SubClass1,?SubClass2}) SuperClass
    ...
end
```

Define the allowed subclasses as sealed:

```matlab
classdef (Sealed) SubClass1
    ...
end
classdef (Sealed) SubClass2
    ...
end
```

Sealed class hierarchies enable you to use the level of abstraction that your design requires while maintaining a closed system of classes.
See Also

Related Examples
  • “Handle Compatible Classes” on page 12-32
Class Members Access

In this section...

“Basic Knowledge” on page 12-23
“Applications for Access Control Lists” on page 12-24
“Specify Access to Class Members” on page 12-24
“Properties with Access Lists” on page 12-25
“Methods with Access Lists” on page 12-25
“Abstract Methods with Access Lists” on page 12-28

Basic Knowledge

The material presented in this section builds on an understanding of the following information:

Related Topics

• “Class Metadata” on page 16-2
• “Attribute Specification” on page 5-18

Terminology and Concepts

• Class members — Properties, methods, and events defined by a class
• Defining class — The class defining the class member for which access is being specified
• Get access — Permission to read the value of a property, controlled by the property GetAccess attribute
• Set access — Permission to assign a value to a property; controlled by the property SetAccess attribute
• Method access — Determines what other methods and functions can call the class method; controlled by the method Access attribute
• Listen access — Permission to define listeners; controlled by the event ListenAccess attribute
• Notify access — Permission to trigger events, controlled by the event NotifyAccess attribute

Possible Values for Access to Class Members

The following class member attributes can contain a list of classes:

• Properties — Access, GetAccess, and SetAccess. For a list of all property attributes, see “Property Attributes” on page 8-7.
• Methods — Access. For a list of all method attributes, see “Method Attributes” on page 9-4.
• Events — ListenAccess and NotifyAccess. For a list of all event attributes, see “Event Attributes” on page 11-16.

These attributes accept the following possible values:

• public — Unrestricted access
• protected — Access by defining class and its subclasses
• private — Access by defining class only
• Access list — A list of one or more classes. Only the defining class and the classes in the list have access to the class members to which the attribute applies. If you specify a list of classes, MATLAB does not allow access by any other class (that is, access is private, except for the listed classes).

**Applications for Access Control Lists**

Access control lists enable you to control access to specific class properties, methods, and events. Access control lists specify a list of classes to which you grant access to these class members.

This technique provides greater flexibility and control in the design of a system of classes. For example, use access control lists to define separate classes, but not allow access to class members from outside the class system.

**Specify Access to Class Members**

Specify the classes that are allowed to access a particular class member in the member access attribute statement. For example:

```matlab
methods (Access = {?ClassName1,?ClassName2,})
```

Use the class `meta.class` object to refer to classes in the access list. To specify more than one class, use a cell array of `meta.class` objects. Use the package name when referring to classes that are in packages.

**Note** Specify the `meta.class` objects explicitly (created with the `?` operator), not as values returned by functions or other MATLAB expressions.

**How MATLAB Interprets Attribute Values**

• Granting access to a list of classes restricts access to only:
  • The defining class
  • The classes in the list
  • Subclasses of the classes in the list
  • Including the defining class in the access list gives all subclasses of the defining class access.
  • MATLAB resolves references to classes in the access list only when the class is loaded. If MATLAB cannot find a class that is included in the access list, that class is effectively removed from access.
  • MATLAB replaces unresolved `meta.class` entries in the list with empty `meta.class` objects.
  • An empty access list (that is, an empty cell array) is equivalent to private access.

**Specify Metaclass Objects**

Generate the `meta.class` objects using only the `?` operator and the class name. Values assigned to the attributes cannot contain any other MATLAB expressions, including functions that return allowed attribute values:

• `meta.class` objects
• Cell arrays of `meta.class` objects
• The values public, protected, or private
Specify these values explicitly, as shown in the example code in this section.

**Properties with Access Lists**

These sample classes show the behavior of a property that grants read access (GetAccess) to a class. The GrantAccess class gives GetAccess to the NeedAccess class for the Prop1 property:

```matlab
classdef GrantAccess
    properties (GetAccess = ?NeedAccess)
        Prop1 = 7
    end
end
```

The NeedAccess class defines a method that uses the value of the GrantAccess Prop1 value. The dispObj method is defined as a Static method, however, it could be an ordinary method.

```matlab
classdef NeedAccess
    methods (Static)
        function dispObj(GrantAccessObj)
            disp([ 'Prop1 is: ',num2str(GrantAccessObj.Prop1)])
        end
    end
end
```

Get access to Prop1 is private so MATLAB returns an error if you attempt to access the property from outside the class definition. For example, from the command line:

```matlab
a = GrantAccess;
a.Prop1
```

Getting the 'Prop1' property of the 'GrantAccess' class is not allowed.

However, MATLAB allows access to Prop1 by the NeedAccess class:

```matlab
NeedAccess.dispObj(a)
```

**Prop1 is: 7**

**Methods with Access Lists**

Classes granted access to a method can:

- Call the method using an instance of the defining class.
- Define their own method with the same name (if not a subclass).
- Override the method in a subclass only if the superclass defining the method includes itself or the subclass in the access list.

These sample classes show the behavior of methods called from methods of other classes that are in the access list. The class AcListSuper gives the AcListNonSub class access to its m1 method:

```matlab
classdef AcListSuper
    methods (Access = {?AcListNonSub})
        function obj = m1(obj)
            disp ('Method m1 called')
        end
    end
end
```
Because AcListNonSub is in the access list of m1, its methods can call m1 using an instance of AcListSuper:

classdef AcListNonSub
  methods
    function obj = nonSub1(obj,AcListSuper_Obj)
      % Call m1 on AcListSuper class
      AcListSuper_Obj.m1;
    end
    function obj = m1(obj)
      % Define a method named m1
      disp(['Method m1 defined by ',class(obj)])
    end
  end
end

Create objects of both classes:

a = AcListSuper;
b = AcListNonSub;

Call the AcListSuper m1 method using an AcListNonSub method:

b.nonSub1(a);

Method m1 called

Call the AcListNonSub m1 method:

b.m1;

Method m1 defined by AcListNonSub

Subclasses Without Access

Including the defining class in the access list for a method grants access to all subclasses derived from that class. When you derive from a class that has a method with an access list and that list does not include the defining class:

• Subclass methods cannot call the superclass method.
• Subclass methods can call the superclass method indirectly using an instance of a class that is in the access list.
• Subclasses cannot override the superclass method.
• Methods of classes that are in the superclass method access list, but that are not subclasses, can call the superclass method.

For example, AcListSub is a subclass of AcListSuper. The AcListSuper class defines an access list for method m1. However, this list does not include AcListSuper, so subclasses of AcListSuper do not have access to method m1:

classdef AcListSub < AcListSuper
  methods
    function obj = sub1(obj,AcListSuper_Obj)
      % Access m1 via superclass object (***NOT ALLOWED***)
      AcListSuper_Obj.m1;
    end
  end
end
function obj = sub2(obj,AcListNonSub_Obj,AcListSuper_Obj)
    % Access m1 via object that is in access list (is allowed)
    AcListNonSub_Obj.nonSub1(AcListSuper_Obj);
end
end
end

No Direct Call to Superclass Method

Attempting to call the superclass m1 method from the sub1 method results in an error because subclasses are not in the access list for m1:

```matlab
a = AcListSuper;
c = AcListSub;
c.sub1(a);
```

Cannot access method 'm1' in class 'AcListSuper'.

Error in AcListSub/sub1 (line 4)
AcListSuperObj.m1;

Indirect Call to Superclass Method

You can call a superclass method from a subclass that does not have access to that method using an object of a class that is in the superclass method access list.

The AcListSub sub2 method calls a method of a class (AcListNonSub) that is on the access list for m1. This method, nonSub1, does have access to the superclass m1 method:

```matlab
a = AcListSuper;
b = AcListNonSub;
c = AcListSub;
c.sub2(b,a);
```

Method m1 called

No Redefining Superclass Method

When subclasses are not included in the access list for a method, those subclasses cannot define a method with the same name. This behavior is not the same as cases in which the method Access is explicitly declared as private.

For example, adding the following method to the AcListSub class definition produces an error when you attempt to instantiate the class.

```matlab
methods (Access = {?AcListNonSub})
    function obj = m1(obj)
        disp('AcListSub m1 method')
    end
end

c = AcListSub;
```

Class 'AcListSub' is not allowed to override the method 'm1' because neither it nor its superclasses have been granted access to the method by class 'AcListSuper'.

12-27
Call Superclass from Listed Class Via Subclass

The AcListNonSub class is in the m1 method access list. This class can define a method that calls the m1 method using an object of the AcListSub class. While AcListSub is not in the access list for method m1, it is a subclass of AcListSuper.

For example, add the following method to the AcListNonSub class:

```matlab
methods
    function obj = nonSub2(obj,AcListSub_Obj)
        disp('Call m1 via subclass object:')
        AcListSub_Obj.m1;
    end
end
```

Calling the nonSub2 method results in execution of the superclass m1 method:

```matlab
b = AcListNonSub;
c = AcListSub;
b.nonSub2(c);
```

This behavior is consistent with the behavior of any subclass object, which can substitute for an object of its superclass.

Abstract Methods with Access Lists

A class containing a method declared as Abstract is an abstract class. It is the responsibility of subclasses to implement the abstract method using the function signature declared in the class definition.

When an abstract method has an access list, only the classes in the access list can implement the method. A subclass that is not in the access list cannot implement the abstract method so that subclass is itself abstract.

See Also

Related Examples

- “Property Access List” on page 12-29
- “Method Access List” on page 12-30
- “Event Access List” on page 12-31
**Property Access List**

This class declares access lists for the property GetAccess and Access attributes:

```matlab
classdef PropertyAccess
    properties (GetAccess = {?ClassA, ?ClassB}, SetAccess = private)
        Prop1
    end
    properties (Access = ?ClassC)
        Prop2
    end
end
```

The class `PropertyAccess` specifies the following property access:

- Gives the classes `ClassA` and `ClassB` get access to the `Prop1` property.
- Gives all subclasses of `ClassA` and `ClassB` get access to the `Prop1` property.
- Does not provide get access to `Prop1` from subclasses of `PropertyAccess`.
- Defines private set access for the `Prop1` property.
- Gives set and get access to `Prop2` for `ClassC` and its subclasses.

**See Also**

**Related Examples**

- “Properties with Access Lists” on page 12-25
Method Access List

This class declares an access list for the method Access attribute:

```matlab
classdef MethodAccess
        function listMethod(obj)
            ...
        end
    end
end
```

The MethodAccess class specifies the following method access:

- Access to `listMethod` from an instance of `MethodAccess` by methods of the classes `ClassA` and `ClassB`.
- Access to `listMethod` from an instance of `MethodAccess` by methods of subclasses of `MethodAccess`, because of the inclusion of `MethodAccess` in the access list.
- Subclasses of `ClassA` and `ClassB` are allowed to define a method named `listMethod`, and `MethodAccess` is allowed to redefine `listMethod`. However, if `MethodAccess` was not in the access list, its subclasses could not redefine `listMethod`.

See Also

Related Examples

- “Methods with Access Lists” on page 12-25
Event Access List

This class declares an access list for the event ListenAccess attribute:

```matlab
classdef EventAccess
    events (NotifyAccess = private, ListenAccess = {?ClassA, ?ClassB})
    Event1
    Event2
end
end
```

The class EventAccess specifies the following event access:

- Limits notify access for Event1 and Event2 to EventAccess; only methods of the EventAccess can trigger these events.
- Gives listen access for Event1 and Event2 to methods of ClassA and ClassB. Methods of EventAccess, ClassA, and ClassB can define listeners for these events. Subclasses of MyClass cannot define listeners for these events.

See Also

Related Examples

- “Events and Listeners Syntax” on page 11-18
Handle Compatible Classes

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Basic Knowledge

The material presented in this section builds on knowledge of the following information.

- “Design Subclass Constructors” on page 12-7
- “Subclassing Multiple Classes” on page 12-18
- “Comparison of Handle and Value Classes” on page 7-2

Key Concepts

Handle-compatible class — a class that you can include with handle classes in a class hierarchy, even if the class is not a handle class.

- All handle classes are handle-compatible.
- All superclasses of handle-compatible classes must also be handle compatible.

HandleCompatible — the class attribute that defines nonhandle classes as handle compatible.

When to Use Handle Compatible Classes

Typically, when deriving a MATLAB class from other classes, all the superclasses are handle classes, or else none of them are handle classes. However, there are situations in which a class provides some utility that is used by both handle and non-handle subclasses. Because it is not legal to combine handle and non-handle classes, the author of the utility class must implement two distinct versions of the utility.

The solution is to use handle-compatible classes. Handle compatible classes are a type of class that you can use with handle classes when forming sets of superclasses. Designate a nonhandle compatible class as handle-compatible by using the HandleCompatible class attribute.

```matlab
classdef (HandleCompatible) MyClass
    ...
end
```

Handle Compatibility Rules

Handle-compatible classes (that is, classes whose HandleCompatible attribute is set to true) follow these rules:

- All superclasses of a handle-compatible class must also be handle compatible
- If a class explicitly sets its HandleCompatibility attribute to false, then none of the class superclasses can be handle classes.
• If a class does not explicitly set its HandleCompatible attribute and, if any superclass is a handle, then all superclasses must be handle compatible.
• The HandleCompatible attribute is not inherited.

A class that does not explicitly set its HandleCompatible attribute to true is:
• A handle class if any of its superclasses are handle classes
• A value class if none of the superclasses are handle classes

**Identify Handle Objects**

To determine if an object is a handle object, use the `isa` function:

```matlab
isa(obj,'handle')
```

**See Also**

**Related Examples**

• “How to Define Handle-Compatible Classes” on page 12-34
How to Define Handle-Compatible Classes

In this section...

“What Is Handle Compatibility?” on page 12-34
“Subclassing Handle-Compatible Classes” on page 12-36

What Is Handle Compatibility?

A class is handle compatible if:

- It is a handle class
- Its `HandleCompatible` attribute is set to `true`

The `HandleCompatible` class attribute identifies classes that you can combine with handle classes when specifying a set of superclasses.

Handle compatibility provides greater flexibility when defining abstract superclasses. For example, when using superclasses that support both handle and value subclasses, handle compatibility removes the need to define both a handle version and a nonhandle version of a class.

A Handle Compatible Class

The `Utility` class is useful to both handle and value subclasses. In this example, the `Utility` class defines a method to reset property values to the default values defined in the respective class definition:

```matlab
classdef (HandleCompatible) Utility
    methods
        function obj = resetDefaults(obj)
            mc = metaclass(obj);
            mp = mc.PropertyList;
            for k=1:length(mp)
                if mp(k).HasDefault && ~strcmp(mp(k).SetAccess,'private')
                    obj.(mp(k).Name) = mp(k).DefaultValue;
                end
            end
        end
    end
end
```

The `Utility` class is handle compatible. Therefore, you can use it in the derivation of classes that are either handle classes or value classes. See “Class Introspection and Metadata” for information on using meta-data classes.

Return Modified Objects

The `resetDefaults` method defined by the `Utility` class returns the object it modifies. When you call `resetDefaults` with a value object, the method must return the modified object. It is important to implement methods that work with both handle and value objects in a handle compatible superclass. See “Object Modification” on page 5-49 for more information on modifying handle and value objects.

Consider the behavior of a value class that subclasses the `Utility` class. The `PropertyDefaults` class defines three properties, all of which have default values:
classdef PropertyDefaults < Utility
    properties
        p1 = datestr(rem(now,1)) % Current time
        p2 = 'red'               % Character vector
        p3 = pi/2                % Result of division operation
    end
end

Create a PropertyDefaults object. MATLAB evaluates the expressions assigned as default property values when the class is first loaded. MATLAB uses these same default values whenever you create an instance of this class in the current MATLAB session.

pd = PropertyDefaults

pd = 
    PropertyDefaults with properties:
        p1: ' 4:42 PM'
        p2: 'red'
        p3: 1.5708

Assign new values that are different from the default values:

pd.p1 = datestr(rem(now,1));
pd.p2 = 'green';
pd.p3 = pi/4;

All pd object property values now contain values that are different from the default values originally defined by the class:

pd

pd = 
    PropertyDefaults with properties:
        p1: ' 4:45 PM'
        p2: 'green'
        p3: 0.7854

Call the resetDefaults method, which is inherited from the Utility class. Because the PropertyDefaults class is not a handle class, return the modified object.

pd = pd.resetDefaults

pd = 
    PropertyDefaults with properties:
        p1: ' 4:54 PM'
        p2: 'red'
        p3: 1.5708

If the PropertyDefaults class was a handle class, then you would not need to save the object returned by the resetDefaults method. To design a handle compatible class like Utility, ensure that all methods work with both kinds of classes.
Subclassing Handle-Compatible Classes

According to the rules described in “Handle Compatibility Rules” on page 12-32, when you combine a handle superclass with a handle-compatible superclass, the result is a handle subclass, which is handle compatible.

However, subclassing a handle-compatible class does not necessarily result in the subclass being handle compatible. Consider the following two cases, which demonstrate two possible results.

**Combine Nonhandle Utility Class with Handle Classes**

Suppose that you define a class that subclasses a handle class, and the handle compatible Utility class discussed in “A Handle Compatible Class” on page 12-34. The `HPropertyDefaults` class has these characteristics:

- It is a handle class (it derives from `handle`).
- All its superclasses are handle compatible (handle classes are handle compatible by definition).

```matlab
classdef HPropertyDefaults < handle & Utility
    properties
        GraphPrim = line
        Width = 1.5
        Color = 'black'
    end
end
```

The `HPropertyDefaults` class is handle compatible:

```matlab
hpd = HPropertyDefaults;
mc = metaclass(hpd);
mc.HandleCompatible
ans =
      1
```

**Nonhandle Subclasses of a Handle-Compatible Class**

If you subclass both a value class that is not handle compatible and a handle compatible class, the subclass is a nonhandle compatible value class. The `ValueSub` class:

- Is a value class (it does not derive from `handle`).
- One of its superclasses is handle compatible (the Utility class).

```matlab
classdef ValueSub < MException & Utility
    methods
        function obj = ValueSub(str1,str2)
            obj = obj@MException(str1,str2);
        end
    end
end
```

The `ValueSub` class is a nonhandle-compatible value class because the `MException` class does not define the `HandleCompatible` attribute as true:

```matlab
hv = ValueSub('MATLAB:narginchk:notEnoughInputs',... 'Not enough input arguments.');
mc = metaclass(hv);
mc.HandleCompatible

ans =

0

See Also

Related Examples

- "Methods for Handle Compatible Classes" on page 12-38
Methods for Handle Compatible Classes

Objects passed to methods of handle compatible classes can be either handle or value objects. There are two different behaviors to consider when implementing methods for a class that operate on both handles and values:

- If an input object is a handle object and the method alters the handle object, these changes are visible to all workspaces that contain the same handle.
- If an input object is a value object, then changes to the object made inside the method affect only the value inside the method workspace.

Handle compatible methods generally do not alter input objects because the effects of such changes are not the same for handle and nonhandle objects.

See “Object Modification” on page 5-49 for information about modifying handle and value objects.

Modify Value Objects in Methods

If a method operates on both handle and value objects, the method must return the modified object. For example, the `setTime` method returns the object it modifies:

```matlab
classdef (HandleCompatible) Util
    % Utility class that adds a time stamp
    properties
        TimeStamp
    end
    methods
        function obj = setTime(obj)
            obj.TimeStamp = now;
        end
    end
end
```

See Also

Related Examples

- “Handle-Compatible Classes and Heterogeneous Arrays” on page 12-39
Heterogeneous Arrays

A heterogeneous array contains objects of different classes. Members of a heterogeneous array have a common superclass, but can belong to different subclasses. See the `matlab.mixin.Heterogeneous` class for more information on heterogeneous arrays. The `matlab.mixin.Heterogeneous` class is a handle-compatible class.

Methods Must Be Sealed

You can invoke only those methods that are sealed by the common superclass on heterogeneous arrays (`Sealed` attribute set to `true`). Sealed methods prevent subclasses from overriding those methods and guarantee that methods called on heterogeneous arrays have the same definition for the entire array.

Subclasses cannot override sealed methods. In situations requiring subclasses to specialize methods defined by a utility class, you can employ the design pattern referred to as the template method.

Template Technique

Suppose that you implement a handle compatible class that works with heterogeneous arrays. This approach enables you to seal public methods, while providing a way for each subclass to specialize how the method works on each subclass instance. In the handle compatible class:

- Define a sealed method that accepts a heterogeneous array as input.
- Define a protected, abstract method that each subclass must implement.
- Within the sealed method, call the overridden method for each array element.

Each subclass in the heterogeneous hierarchy implements a concrete version of the abstract method. The concrete method provides specialized behavior required by the particular subclass.

The `Printable` class shows how to implement a template method approach:

```matlab
classdef (HandleCompatible) Printable
    methods(Sealed)
        function print(aryIn)
            n = numel(aryIn);
            for k=1:n
                printElement(aryIn(k));
            end
        end
    end
    methods(Access=protected, Abstract)
        printElement(objIn)
    end
end
```
See Also

Related Examples

- “Handle Compatible Classes” on page 12-32
Subclasses of MATLAB Built-In Types

MATLAB Built-In Types

Built-in types represent fundamental kinds of data such as numeric arrays, logical arrays, and character arrays. Other built-in types like cell arrays and structures contain data belonging to any class.

Built-in types define methods that perform operations on objects of these classes. For example, you can perform operations on numeric arrays such as, sorting, arithmetic, and logical operations.

See “Fundamental MATLAB Classes” for more information on MATLAB built-in classes.

Note: It is an error to define a class that has the same name as a built-in class.

Built-In Types You Can Subclass

You can subclass MATLAB numeric classes and the logical class. For a list of numeric types, see “Numeric Types”.

You cannot subclass any class that has its Sealed attribute set to true. To determine if the class is Sealed, query the class metadata:

```
mc = ClassName;
mc.Sealed
```

A value of 0 indicates that the class is not Sealed and can be subclasses.

Why Subclass Built-In Types

Subclass a built-in class to extend the operations that you can perform on a particular class of data. For example, when you want to:

- To perform unique operations on class data.
- Be able to use methods of the built-in class and other built-in functions directly with objects of the subclass. For example, you do not need to reimplement all the mathematical operators if you derived from a class such as double that defines these operators.
Which Functions Work with Subclasses of Built-In Types

Consider a class that defines enumerations. It can derive from an integer class and inherit methods that enable you to compare and sort values. For example, integer classes like int32 support all the relational methods (eq, ge, gt, le, lt, ne).

To see a list of functions that the subclass has inherited as methods, use the `methods` function:

```matlab
methods('SubclassName')
```

Generally, you can use an object of the subclass with any:

- Inherited methods
- Functions that normally accept input arguments of the same class as the superclass.

Behavior of Built-In Functions with Subclass Objects

When you define a subclass of a built-in class, the subclass inherits all the methods defined by that built-in class. MATLAB also provides additional methods to subclasses of built-in classes that override several built-in functions.

Built-in functions and methods that work on built-in classes can behave differently when called with subclasses of built-in classes. Their behavior depends on which function you are using and whether your subclass defines properties.

Behavior Categories

When you call an inherited method on a subclass of a built-in class, the result depends on the nature of the operation performed by the method. The behaviors of these methods fit into several categories.

- Operations on data values return objects of the superclass. For example, if you subclass `double` and perform addition on two subclass objects, MATLAB adds the numeric values and returns a value of class `double`.
- Operations on the orientation or structure of the data return objects of the subclass. Methods that perform these kinds of operations include, `reshape`, `permute`, `transpose`, and so on.
- Converting a subclass object to a built-in class returns an object of the specified class. Functions such as `uint32`, `double`, `char` work with subclass objects the same as they work with built-in objects.
- Comparing objects or testing for inclusion in a specific set returns logical or built-in objects, depending on the function. Functions such as `isequal`, `ischar`, `isObject` work with subclass objects the same as they work with superclass objects.
- Indexing expressions return objects of the subclass. If the subclass defines properties, then default indexing no longer works. The subclass must define its own indexing methods.
- Concatenation returns an object of the subclass. If the subclass defines properties, then default concatenation no longer works and the subclass must define its own concatenation methods.

To list the built-in functions that work with a subclass of a built-in class, use the `methods` function.
**Built-In Subclasses That Define Properties**

When a subclass of a built-in class defines properties, MATLAB no longer supports indexing and concatenation operations. MATLAB cannot use the built-in functions normally called for these operations because subclass properties can contain any data.

The subclass must define what indexing and concatenation mean for a class with properties. If your subclass needs indexing and concatenation functionality, then the subclass must implement the appropriate methods.

**Methods for Indexing**

To support indexing operations, the subclass must implement these methods:

- `subsasgn` — Implement dot notation and indexed assignments
- `subsref` — Implement dot notation and indexed references
- `subsindex` — Implement object as index value

**Methods for Concatenation**

To support concatenation, the subclass must implement the following methods:

- `horzcat` — Implement horizontal concatenation of objects
- `vertcat` — Implement vertical concatenation of objects
- `cat` — Implement concatenation of object arrays along specified dimension

**See Also**

**Related Examples**

- “Representing Hardware with Classes” on page 12-66
- “Subclasses of Built-In Types with Properties” on page 12-54
- “Subclasses of Built-In Types Without Properties” on page 12-48
Behavior of Inherited Built-In Methods

Subclass double

Most built-in functions used with built-in classes are actually methods of the built-in class. For example, the double and single classes define several methods to perform arithmetic operations, indexing, matrix operation, and so on. All these built-in class methods work with subclasses of the built-in class.

Subclassing double enables your class to use features without implementing the methods that a MATLAB built-in class defines.

The DocSimpleDouble class subclasses the built-in double class.

classdef DocSimpleDouble < double
    methods
        function obj = DocSimpleDouble(data)
            if nargin == 0
                data = 0;
            end
            obj = obj@double(data);
        end
    end
end

Create an instance of the class DocSimpleDouble.

sc = DocSimpleDouble(1:10)

sc =
    1x10 DocSimpleDouble:
    double data:
        1    2    3    4    5    6    7    8    9    10

Call a method inherited from class double that operates on the data, such as sum. sum returns a double and, therefore, uses the display method of class double:

sum(sc)

ans =
    55

Index sc like an array of doubles. The returned value is the class of the subclass:

a = sc(2:4)

a =
    1x3 DocSimpleDouble:
Indexed assignment works the same as the built-in class. The returned value is the class of the subclass:

\[
\text{sc}(1:5) = 5:-1:1
\]

\[
\text{sc} = \\
\begin{array}{cccccccc}
5 & 4 & 3 & 2 & 1 & 6 & 7 & 8 & 9 & 10
\end{array}
\]

Calling a method that modifies the order of the data elements operates on the data, but returns an object of the subclass:

\[
\text{sc} = \text{DocSimpleDouble}(1:10);
\]

\[
\text{sc}(1:5) = 5:-1:1;
\]

\[
a = \text{sort}(	ext{sc})
\]

\[
a = \\
\begin{array}{cccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10
\end{array}
\]

**Built-In Data Value Methods**

When you call a built-in data value method on a subclass object, MATLAB uses the superclass part of the subclass object as inputs to the method. The value returned is same class as the built-in class. For example:

\[
\text{sc} = \text{DocSimpleDouble}(1:10);
\]

\[
a = \sin(\text{sc});
\]

\[
\text{class}(a)
\]

\[
\text{ans} =
\]

\[
double
\]

**Built-In Data Organization Methods**

This group of built-in methods reorders or reshapes the input argument array. These methods operate on the superclass part of the subclass object, but return an object of the same type as the subclass.

\[
\text{sc} = \text{DocSimpleDouble} \left( \text{randi(9,1,10)} \right)
\]

\[
\text{sc} = \text{DocSimpleDouble} \left( \text{randi(9,1,10)} \right)
\]

\[
\text{sc} =
\]

\[
\begin{array}{cccccccc}
6 & 1 & 8 & 9 & 7 & 7 & 7 & 4 & 6 & 2
\end{array}
\]

\[
b = \text{sort}(	ext{sc})
\]
Methods in this group include:

- reshape
- permute
- sort
- transpose
- ctranspose

**Built-In Indexing Methods**

Built-in classes use specially implemented versions of the subsref, subsasgn, and subsindex methods to implement indexing. When you index a subclass object, only the built-in data is referenced (not the properties defined by your subclass).

For example, indexing element 2 in the DocSimpleDouble subclass object returns the second element in the vector:

```matlab
sc = DocSimpleDouble(1:10);
a = sc(2)
```

```matlab
a =
DocSimpleDouble
double data:
  2
```

The value returned from an indexing operation is an object of the subclass. You cannot make indexed references if your subclass defines properties, unless your subclass overrides the default subsref method.

Assigning a new value to the second element in the DocSimpleDouble object operates only on the superclass data:

```matlab
sc(2) = 12
```

```matlab
sc =
1x10 DocSimpleDouble:
double data:
  1  12  3  4  5  6  7  8  9 10
```

The subsref method also implements dot notation for methods.

**Built-In Concatenation Methods**

Built-in classes use the functions horzcat, vertcat, and cat to implement concatenation. When you use these functions with subclass objects of the same type, MATLAB concatenates the superclass data to form a new object. For example, you can concatenate objects of the DocSimpleDouble class:
```matlab
sc1 = DocSimpleDouble(1:10);
sc2 = DocSimpleDouble(11:20);
[sc1,sc2]

ans =
1x20 DocSimpleDouble:
double data:
Columns 1 through 13
  1    2    3    4    5    6    7    8    9   10   11   12   13
Columns 14 through 20
  14   15   16   17   18   19   20

[sc1;sc2]

ans =
2x10 DocSimpleDouble:
double data:
     1    2    3    4    5    6    7    8    9   10
     11   12   13   14   15   16   17   18   19   20

Concatenate two objects along a third dimension:
c = cat(3,sc1,sc2)
c =
1x10x2 DocSimpleDouble:
double data:
(:,:,1) =
     1    2    3    4    5    6    7    8    9   10

(:,:,2) =
  11   12   13   14   15   16   17   18   19   20

If the subclass of a built-in class defines properties, you cannot concatenate objects of the subclass.
There is no way to determine how to combine properties of different objects. However, your subclass
can define custom `horzcat` and `vertcat` methods to support concatenation in whatever way makes
sense for your subclass.

See Also

Related Examples
- “Subclasses of Built-In Types Without Properties” on page 12-48
- “Subclasses of Built-In Types with Properties” on page 12-54
```
Subclasses of Built-In Types Without Properties

In this section...

“Specialized Numeric Types” on page 12-48
“A Class to Manage uint8 Data” on page 12-48
“Using the DocUint8 Class” on page 12-49

Specialized Numeric Types

Subclass built-in numeric types to create customized data types that inherit the functionality of the built-in type. Add functionality to that provided by the superclass by implementing class methods. Subclasses without properties store numeric data as the superclass type. If your subclass design does not require properties to store other data, the implementation is simpler because you do not need to define indexing and concatenation methods.

For more information, see “Subclasses of MATLAB Built-In Types” on page 12-41.

A Class to Manage uint8 Data

This example shows a class derived from the built-in uint8 class. This class simplifies the process of maintaining a collection of intensity image data defined by uint8 values. The basic operations of the class include:

• Capability to convert various classes of image data to uint8 to reduce object data storage.
• A method to display the intensity images contained in the subclass objects.
• Ability to use all the methods supported by uint8 data (for example, size, indexing, reshape, bitshift, cat, fft, arithmetic operators, and so on).

The class data are matrices of intensity image data stored in the superclass part of the subclass object. This approach requires no properties.

The DocUint8 class stores the image data, which converts the data, if necessary:

```matlab
classdef DocUint8 < uint8
    methods
        function obj = DocUint8(data)
            if nargin == 0
                data = uint8(0);
            end
            obj = obj@uint8(data); % Store data on superclass
        end
        function h = showImage(obj)
            data = uint8(obj);
            figure; colormap(gray(256))
            h = imagesc(data,[0 255]);
            axis image
            brighten(.2)
        end
    end
end
```
Using the DocUint8 Class

Create DocUint8 Objects

The DocUint8 class provides a method to display all images stored as DocUint8 objects in a consistent way. For example:

```
cir = imread('circuit.tif');
img1 = DocUint8(cir);
img1.showImage;
```

Because DocUint8 subclasses uint8, you can use any uint8 methods. For example,
```
size(img1)
```
```
ans =
   280   272
```
returns the size of the image data.

Indexing Operations

Inherited methods perform indexing operations, but return objects of the same class as the subclass. Therefore, you can index into the image data and call a subclass method:
```
showImage(img1(100:200,1:160));
```
Subscripted reference operations (controlled by the inherited `subsref` method) return a `DocUint8` object.

You can assign values to indexed elements:

```
img1(100:120,140:160) = 255;
img1.showImage;
```

Subscripted assignment operations (controlled by the inherited `subsasgn` method) return a `DocUint8` object.
Concatenation Operations

Concatenation operations work on DocUint8 objects because this class inherits the uint8 horzcat and vertcat methods, which return a DocUint8 object:

```matlab
showImage([img1 img1]);
```
Data Operations

Methods that operate on data values, such as arithmetic operators, always return an object of the built-in type (not of the subclass type). For example, multiplying DocUint8 objects returns a uint8 object, so calling showImage throws an error:

```
a = img1.*1.8;
showImage(a);
```

Check for missing argument or incorrect argument data type in call to function 'showImage'.

To perform operations of this type, implement a subclass method to override the inherited method. The times method implements array (element-by-element) multiplication.

Add this method to the DocUint8 class:

```
function o = times(obj,val)
    u8 = uint8(obj).*val;
    o = DocUint8(u8);
end
```

When you override a uint8 method, MATLAB calls the subclass method, not the base class method. The subclass method must:

- Call the uint8 times method on the DocUint8 object data.
- Construct a new DocUint8 object using the uint8 data.
After adding the times method to the DocUint8 class, the output of multiplication expressions is an object of the DocUint8 class:

```matlab
showImage(img1.*1.8);
```

**See Also**

**Related Examples**

- “Operator Overloading” on page 17-38
- “Subclasses of Built-In Types with Properties” on page 12-54
Subclasses of Built-In Types with Properties

Specialized Numeric Types with Additional Data Storage

Subclass built-in numeric types to create customized data types that inherit the functionality of the built-in type. Add or modify functionality to that provided by the superclass by implementing class methods.

Providing additional data storage in the subclass by defining properties can be a useful extension to the built-in data class. However, the addition of properties to the subclass requires the subclass to define methods to implement standard array behaviors.

For more information, see “Subclasses of MATLAB Built-In Types” on page 12-41.

Subclasses with Properties

When a subclass of a built-in class defines properties, default indexing and concatenation do not work. The default subsref, subsasgn, horzcat, and vertcat functions cannot work with unknown property types and values. Therefore, the subclass must define these behaviors by implementing these methods.

This sample implementation of the ExtendDouble class derives from the double class and defines a single property. The ExtendDouble class definition demonstrates how to implement indexing and concatenation for subclasses of built-in classes.

Property Added

The ExtendDouble class defines the DataString property to contain text that describes the data. The superclass part of the class contains the numeric data.

Methods Implemented

The following methods modify the behavior of the ExtendDouble class:

- ExtendDouble — The constructor supports a no argument syntax that initializes properties to empty values.
- subsref — Enables subscripted reference to the superclass part of the subclass, dot notation reference to the DataString property, and dot notation reference the built-in data via the name Data.
• **subsasgn** — Enables subscripted assignment to the superclass part of the subclass, dot notation reference to the `DataString` property, and dot notation reference the built-in data via the name `Data`.

• **horzcat** — Defines horizontal concatenation of `ExtendDouble` objects. Concatenates the superclass part using the `double` class `horzcat` method and forms a cell array of the `DataString` properties.

• **vertcat** — The vertical concatenation equivalent of `horzcat` (both are required).

• **char** — A `ExtendDouble` to `char` converter used by `horzcat` and `vertcat`.

• **disp** — `ExtendDouble` implements a `disp` method to provide a custom display for the object.

### Class Definition Code

The `ExtendDouble` class extends `double` and implements methods to support subscripted indexing and concatenation.

```matlab
classdef ExtendDouble < double
    properties
        DataString
    end
    methods
        function obj = ExtendDouble(data,str)
            if nargin == 0
                data = 0;
                str = '';
            elseif nargin == 1
                str = '';
            end
            obj = obj@double(data);
            obj.DataString = str;
        end
        function sref = subsref(obj,s)
            switch s(1).type
                case '.'
                    switch s(1).subs
                        case 'DataString'
                            sref = obj.DataString;
                        case 'Data'
                            d = double(obj);
                            if length(s)<2
                                sref = d;
                            elseif length(s)>1 && strcmp(s(2).type,'()')
                                sref = subsref(d,s(2:end));
                            end
                        otherwise
                            error('Not a supported indexing expression')
                        end
                case '('
                    d = double(obj);
                    newd = subsref(d,s(1:end));
                    sref = ExtendDouble(newd,obj.DataString);
                case '{'}
                    error('Not a supported indexing expression')
            end
        end
    end
end
```

Subclasses of Built-In Types with Properties

12-55
function obj = subsasgn(obj,s,b)
    switch s(1).type
    case '.'
        switch s(1).subs
        case 'DataString'
            obj.DataString = b;
        case 'Data'
            if length(s)<2
                obj = ExtendDouble(b,obj.DataString);
            elseif length(s)>1 && strcmp(s(2).type,'()')
                d = double(obj);
                newd = subsasgn(d,s(2:end),b);
                obj = ExtendDouble(newd,obj.DataString);
            end
        otherwise
            error('Not a supported indexing expression')
        end
    case '()'
        d = double(obj);
        newd = subsasgn(d,s(1),b);
    case '{}'
        error('Not a supported indexing expression')
    end
end

function newobj = horzcat(varargin)
    d1 = cellfun(@double,varargin,'UniformOutput',false);
    data = horzcat(d1{:});
    str = horzcat(cellfun(@char,varargin,'UniformOutput',false));
    newobj = ExtendDouble(data,str);
end

function newobj = vertcat(varargin)
    d1 = cellfun(@double,varargin,'UniformOutput',false);
    data = vertcat(d1{:});
    str = vertcat(cellfun(@char,varargin,'UniformOutput',false));
    newobj = ExtendDouble(data,str);
end

function str = char(obj)
    str = obj.DataString;
end

function disp(obj)
    disp(obj.DataString)
    disp(double(obj))
end

Using ExtendDouble

Create an instance of ExtendDouble and notice that the display is different from the default:
Inherited Methods

The ExtendDouble class inherits methods from the class double. To see a list of all public methods defined by the double class, use the methods function:

methods(double.empty)

The sum function continues to operate on the superclass part of the object:

sum(ed)
ans =
  55

The sort function works on the superclass part of the object:

sort(ed(10:-1:1))
ans =
  1    2    3    4    5    6    7    8    9   10

Arithmetic operators work on the superclass part of the object:

ed.^2
ans =
   1    4    9   16   25   36   49   64   81  100

Subscripted Indexing

Because the ExtendDouble class defines a property, the class must implement its own subsref and subsasgn methods.

This class implements the following subscripted indexing expressions for reference and assignment.

- obj.DataString — access the DataString property.
- obj.Data, obj.Data(ind) — access the data using a property-style reference. Reference returns values of type double.
- obj(ind) — access the numeric data (same as obj.Data(ind)). Reference returns values of type ExtendDouble.

The class subsref method enables you to use ExtendDouble objects like numeric arrays to reference the numeric data:

ed = ExtendDouble(1:10,'One to ten');
ed(10:-1:1)
ans =
Access the numeric data of the `ExtendDouble` using property-style indexing with the arbitrarily chosen name `Data`:

```matlab
ed.Data(10:-1:1)
ans =
One to ten
     10     9     8     7     6     5     4     3     2     1
```

Access the `DataString` property:

```matlab
ed.DataString
ans =
One to ten
```

Subscripted assignment implements similar syntax in the class `subsasgn` method.

```matlab
ed = ExtendDouble(1:10,'One to ten');
ed(11:13) = [11,12,13];
ed.DataString = 'one to thirteen';
ed
```

```matlab
ed =
One to thirteen
     1     2     3     4     5     6     7     8     9    10    11    12    13
```

The `ExtendDouble` inherits converter methods from the `double` class. For example, MATLAB calls the `char` method to perform this assignment statement.

```matlab
ed(11:13) = ['a','b','c']
ed
```

```matlab
e
      one to thirteen
           1     2     3     4     5     6     7     8     9    10    11    12    13
```

**Class of Value Returned by Indexing Expression**

The `ExtendDouble` implements two forms of indexed reference in the `subsref` method:

- `obj.Data` and `obj.Data(ind)` — Return values of class `double`
- `obj(ind)` — Return values of class `ExtendDouble`

For example, compare the values returned by these expressions.

```matlab
ed = ExtendDouble(1:10,'One to ten');
a = ed(1)
a =
One to ten
     1
b = ed.Data(1)
```
b =

1

whos

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Bytes</th>
<th>Class</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>1x1</td>
<td>132</td>
<td>ExtendDouble</td>
<td></td>
</tr>
<tr>
<td>b</td>
<td>1x1</td>
<td>8</td>
<td>double</td>
<td></td>
</tr>
<tr>
<td>ed</td>
<td>1x10</td>
<td>204</td>
<td>ExtendDouble</td>
<td></td>
</tr>
</tbody>
</table>

The increased flexibility of the implementation of indexed reference in the ExtendDouble class.

**Concatenation of ExtendDouble Objects**

Create these two objects:

```plaintext
ed1 = ExtendDouble([1:10], 'One to ten');
ed2 = ExtendDouble([10:-1:1], 'Ten to one');
```

Concatenate these objects along the horizontal dimension:

```plaintext
hcat = [ed1, ed2]
```

```
    'One to ten'     'Ten to one'
Columns 1 through 13:
    1     2     3     4     5     6     7     8     9    10    10     9     8
Columns 14 through 20:
    7     6     5     4     3     2     1
```

whos

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Bytes</th>
<th>Class</th>
<th>Attributes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ed1</td>
<td>1x10</td>
<td>204</td>
<td>ExtendDouble</td>
<td></td>
</tr>
<tr>
<td>ed2</td>
<td>1x10</td>
<td>204</td>
<td>ExtendDouble</td>
<td></td>
</tr>
<tr>
<td>hcat</td>
<td>1x20</td>
<td>528</td>
<td>ExtendDouble</td>
<td></td>
</tr>
</tbody>
</table>

Vertical concatenation works in a similar way:

```plaintext
vcat = [ed1; ed2]
```

```
    'One to ten'     'Ten to one'
    1     2     3     4     5     6     7     8     9    10
    10     9     8     7     6     5     4     3     2     1
```

Both horzcat and vertcat return a new object of the same class as the subclass.
See Also

Related Examples
• “Subclasses of Built-In Types Without Properties” on page 12-48
**Use of size and numel with Classes**

<table>
<thead>
<tr>
<th>In this section...</th>
</tr>
</thead>
<tbody>
<tr>
<td>“size and numel” on page 12-61</td>
</tr>
<tr>
<td>“Built-In Class Behavior” on page 12-61</td>
</tr>
<tr>
<td>“Subclasses Inherit Behavior” on page 12-62</td>
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<tr>
<td>“Change the Behavior of size or numel” on page 12-64</td>
</tr>
<tr>
<td>“Overload numArgumentsFromSubscript Instead of numel” on page 12-65</td>
</tr>
</tbody>
</table>

**size and numel**

The `size` function returns the dimensions of an array. The `numel` function returns the number of elements in an array, which is equivalent to `prod(size(objArray))`. That is, the product of the array dimensions.

The `size` and `numel` functions work consistently with arrays of user-defined objects. There is generally no need to overload `size` or `numel` in user-defined classes.

Several MATLAB functions use `size` and `numel` to perform their operations. Therefore, if you do overload either of these functions in your class, be sure that objects of your class work as designed with other MATLAB functions.

If your class modifies array indexing, see “Overload numArgumentsFromSubscript Instead of numel” on page 12-65

**Built-In Class Behavior**

When you use the `size` and `numel` functions in classes derived from built-in classes, these functions behave the same as they behave in the superclass.

Consider the built-in class `double`:

```matlab
d = 1:10;
size(d)
an =
    1   10
numel(d)
an =
    10
dsub = d(7:end);
size(dsub)
an =
    1   4
```
The `double` class defines these behaviors, including parentheses indexing.

**Subclasses Inherit Behavior**

Unless the subclass explicitly overrides superclass behavior, subclasses behave like their superclasses. For example, `SimpleDouble` subclasses `double` and defines no properties:

```matlab
classdef SimpleDouble < double
def
    function obj = SimpleDouble(data)
    if nargin == 0
        data = 0;
    end
    obj = obj@double(data);
    end
end
end
```

Create an object and assign the values `1:10`:

```matlab
sd = SimpleDouble(1:10);
```

The `size` function returns the size of the superclass part:

```matlab
size(sd)
```

ans =

```
    1    10
```

The `numel` function returns the number of elements in the superclass part:

```matlab
numel(sd)
```

ans =

```
    10
```

Object arrays return the size of the superclass arrays:

```matlab
size([sd;sd])
```

ans =

```
    2    10
```

```matlab
numel([sd;sd])
```

ans =

```
    20
```

The `SimpleDouble` class inherits the indexing behavior of the `double` class:

```matlab
sdsub = sd(7:end);
size(sdsub)
```
Classes Not Derived from Built-In Classes

Consider a simple value class. This class does not inherit the array-like behaviors of the double class. For example:

```matlab
classdef VerySimpleClass
    properties
        Value
    end
end
```

Create an object and assign a 10-element array to the `Value` property:

```matlab
vs = VerySimpleClass;
vs.Value = 1:10;
size(vs)
```

```matlab
ans =
   1   1
```

```matlab
numel(vs)
```

```matlab
ans =
   1
```

```matlab
size([vs;vs])
```

```matlab
ans =
   2   1
```

```matlab
numel([vs;vs])
```

```matlab
ans =
   2
```

`vs` is a scalar object. The `Value` property is an array of doubles:

```matlab
size(vs.Value)
```

```matlab
ans =
   1   10
```

Apply indexing expressions to the object property:

```matlab
vssub = vs.Value(7:end);
size(vssub)
```

```matlab
ans =
   1   4
```
The `vs.Value` property is an array of class `double`:

class(vs.Value)
ans =
double

Create an array of `VerySimpleClass` objects:

`vsArray(1:10) = VerySimpleClass;`

The `Value` property for array elements 2 through 10 is empty:

`isempty([vsArray(2:10).Value])`
ans =
1

MATLAB does not apply scalar expansion to object array property value assignment. Use the `deal` function for this purpose:

`[vsArray.Value] = deal(1:10);`  
`isempty([vsArray.Value])`
ans =
0

The `deal` function assigns values to each `Value` property in the `vsArray` object array.

Indexing rules for object arrays are equivalent to the rules for arrays of `struct`:

`vsArray(1).Value`
ans =
1 2 3 4 5 6 7 8 9 10

`vsArray(1).Value(6)`
ans =
6

**Change the Behavior of `size` or `numel`**

Subclasses of built-in numeric classes inherit a `size` method, which operates on the superclass part of the subclass object (these methods are hidden). If you want `size` or `numel` to behave differently, override them by defining a `size` or `numel` method in your subclass.

Other MATLAB functions use the values returned by these functions. If you change the way that `size` and `numel` behave, ensure that the values returned make sense for the intended use of your class.
Overload `numArgumentsFromSubscript` Instead of `numel`

If classes implement a `numArgumentsFromSubscript` method, MATLAB calls it instead of `numel` to determine the number of elements returned by indexed expressions that return comma-separated lists. For example, expressions such as:

```matlab
A(1:2).Prop
```

Both `subsref` and `subsasgn` use `numArgumentsFromSubscript`:

- `subsref` — `numArgumentsFromSubscript` computes the number of expected outputs (`nargout`) returned by `subsref`.
- `subsasgn` — `numArgumentsFromSubscript` computes the number of expected inputs (`nargin`) that MATLAB assigns as a result of a call to `subsasgn`.

Subclasses of built-in classes always return scalar objects as a result of subscripted reference and always use scalar objects for subscripted assignment.

If you define a class in which `nargout` for `subsref` or `nargin` for `subsasgn` must be a specific value, then overload `numArgumentsFromSubscript` to return that value.

**See Also**

`numArgumentsFromSubscript`

**Related Examples**

- “Modify `nargout` and `nargin` for Indexing Methods” on page 17-7
Representing Hardware with Classes

In this section...

| “Objective” on page 12-66 |
| “Why Derive from int32” on page 12-66 |
| “Implementation” on page 12-66 |
| “Construct MuxCard Object” on page 12-67 |
| “Call Methods of int32” on page 12-67 |

Objective

This example implements a class to represent an optical multiplex card. These cards typically have several input ports and an output port. The MuxCard class represents the ports by the port names and port data rates. The output rate of a multiplex card is the sum of the input port data rates.

Why Derive from int32

The MuxCard class derives from the int32 class because 32-bit integers represent the input port data rates. The MuxCard class inherits the methods of the int32 class, which simplifies the implementation of this subclass. For example, numeric array indexing and arithmetic operations work on MuxCard objects because the class inherits these operations from the int32 class.

Implementation

Here is the definition of the MuxCard class. Notice that the input port rates initialize the int32 portion of class.

```matlab
classdef MuxCard < int32
    properties
        InPutNames
        OutPutName
    end

    properties (Dependent = true)
        OutPutRate
    end

    methods
        function obj = MuxCard(inptnames, inptrates, outpname)
            obj = obj@int32(inptrates);
            obj.InPutNames = inptnames;
            obj.OutPutName = outpname;
        end

        function x = get.OutPutRate(obj)
            x = sum(obj);
        end

        function x = subsref(card, s)
            if strcmp(s(1).type,'.')
                base = subsref@int32(card, s(1));
            end
```
if isscalar(s)
    x = base;
else
    x = subsref(base, s(2:end));
end
else
    x = subsref(int32(card), s);
end
end

Construct MuxCard Object

The constructor takes three arguments:

- `inptnames` — Cell array of input port names
- `inptrates` — Vector of input port rates
- `outpname` — Name for the output port

```matlab
omx = MuxCard({'inp1','inp2','inp3','inp4'},[3 12 12 48],'outp')
```

```matlab
omx =

1x4 MuxCard array with properties:

  InPutNames: {'inp1'  'inp2'  'inp3'  'inp4'}
  OutPutName: 'outp'
  OutPutRate: 75

int32 data:
    3     12     12     48
```

Call Methods of int32

Use a MuxCard object like an array of int32 values. For example, this indexing statement accesses the data in the object to determine the names of the input ports that have a rate of 12:

```matlab
omx.InPutNames(omx==12)
```

```matlab
ans =
    inp2    inp3
```

The indexing statement generates a logical array index:

```matlab
omx == 12
```

```matlab
ans =
    0     1     1     0
```

Indexing the MuxCard object accesses the int32 vector of input port rates:

```matlab
omx(1:2)
```

```matlab
ans =
    3     12
The `OutPutRate` property get access method uses `sum` to sum the output port rates:

```java
omx.OutPutRate
ans = 75
```

**See Also**

**Related Examples**
- “Subclasses of Built-In Types with Properties” on page 12-54
Determine Array Class

In this section...

"Query the Class Name" on page 12-69
"Test for Array Class" on page 12-69
"Test for Specific Types" on page 12-70
"Test for Most Derived Class" on page 12-70

Query the Class Name

To determine the class of an array, use the \texttt{class} function:

\begin{verbatim}
a = [2, 5, 7, 11];
class(a)
\end{verbatim}

\begin{verbatim}
ans =
double
\end{verbatim}

\begin{verbatim}
str = 'Character array';
class(str)
\end{verbatim}

\begin{verbatim}
ans =
char
\end{verbatim}

Test for Array Class

The \texttt{isa} function enables you to test for a specific class or a category of numeric class (\texttt{numeric}, \texttt{float}, \texttt{integer}):

\begin{verbatim}
a = [2, 5, 7, 11];
isa(a, 'double')
\end{verbatim}

\begin{verbatim}
ans =
1
\end{verbatim}

Floating-point values (single and double precision values):

\begin{verbatim}
isa(a, 'float')
\end{verbatim}

\begin{verbatim}
ans =
1
\end{verbatim}

Numeric values (floating-point and integer values):

\begin{verbatim}
isa(a, 'numeric')
\end{verbatim}

\begin{verbatim}
ans =
1
\end{verbatim}

\texttt{isa} Returns True for Subclasses

\texttt{isa} returns true for classes derived from the specified class. For example, the \texttt{SubInt} class derives from the built-in type \texttt{int16}:

\begin{verbatim}
isa Returns True for Subclasses
\end{verbatim}
classdef SubInt < int16
    methods
        function obj = SubInt(data)
            if nargin == 0
                data = 0;
            end
            obj = obj@int16(data);
        end
    end
end

By definition, an instance of the SubInt class is also an instance of the int16 class:

aInt = SubInt;
isa(aInt,'int16')
ans =
1

Using the integer category also returns true:

isa(aInt,'integer')
ans =
1

**Test for Specific Types**

The class function returns the name of the most derived class of an object:

class(aInt)
ans =
SubInt

Use the strcmp function with the class function to check for a specific class of an object:

a = int16(7);
strcmp(class(a),'int16')
ans =
1

Because the class function returns the class name as a char vector, the inheritance does not affect the result of the comparison performed by strcmp:

aInt = SubInt;
strcmp(class(aInt),'int16')
ans =
0

**Test for Most Derived Class**

If you define functions that require inputs that are:

- MATLAB built-in types
• Not subclasses of MATLAB built-in types

Use the following techniques to exclude subclasses of built-in types from the input arguments.

• Define a cell array that contains the names of built-in types accepted by your function.
• Call `class` and `strcmp` to test for specific types in a MATLAB control statement.

Test an input argument:

```matlab
if strcmp(class(inputArg),'single')
    % Call function
else
    inputArg = single(inputArg);
end
```

**Test for Category of Types**

Suppose that you create a MEX-function, `myMexFcn`, that requires two numeric inputs that must be of type `double` or `single`:

```matlab
outArray = myMexFcn(a,b)
```

Define a cell array that contains the character arrays `double` and `single`:

```matlab
floatTypes = {'double','single'};
```

% Test for proper types
```matlab
if any(strcmp(class(a),floatTypes)) && ...
    any(strcmp(class(b),floatTypes))
    outArray = myMexFcn(a,b);
else
    % Try to convert inputs to avoid error
    ...
end
```

**Another Test for Built-In Types**

Use `isobject` to separate built-in types from subclasses of built-in types. The `isobject` function returns `false` for instances of built-in types:

```matlab
% Create a int16 array
a = int16([2,5,7,11]);
isobject(a)
```

ans =
0

Determine if an array is one of the built-in integer types:

```matlab
if isa(a,'integer') && ~isobject(a)
    % a is a built-in integer type
    ...
end
Abstract Classes and Class Members

Abstract Classes

Abstract classes are useful for describing functionality that is common to a group of classes, but requires unique implementations within each class.

Abstract Class Terminology

abstract class — A class that cannot be instantiated, but that defines class components used by subclasses.

abstract members — Properties or methods declared in an abstract class, but implemented in subclasses.

concrete class — A class that can be instantiated. Concrete classes contain no abstract members.

concrete members — Properties or methods that are fully implemented by a class.

interface — An abstract class describing functionality that is common to a group of classes, but that requires unique implementations within each class. The abstract class defines the interface of each subclass without specifying the actual implementation.

An abstract class serves as a basis (that is, a superclass) for a group of related subclasses. An abstract class can define abstract properties and methods that subclasses implement. Each subclass can implement the concrete properties and methods in a way that supports their specific requirements.

Implementing a Concrete Subclass

A subclass must implement all inherited abstract properties and methods to become a concrete class. Otherwise, the subclass is itself an abstract class.

MATLAB does not force subclasses to implement concrete methods with the same signature or attributes.

Abstract classes:

- Can define properties and methods that are not abstract
- Pass on their concrete members through inheritance
- Do not need to define any abstract members

Declare Classes as Abstract

A class is abstract when it declares:
• The Abstract class attribute
• An abstract method
• An abstract property

If a subclass of an abstract class does not define concrete implementations for all inherited abstract methods or properties, it is also abstract.

**Abstract Class**

Declare a class as abstract in the classdef statement:

```matlab
classdef (Abstract) AbsClass
...
end
```

For classes that declare the Abstract class attribute:

• Concrete subclasses must redefine any properties or methods that are declared as abstract.
• The abstract class does not need to define any abstract methods or properties.

When you define any abstract methods or properties, MATLAB automatically sets the class Abstract attribute to true.

**Abstract Methods**

Define an abstract method:

```matlab
methods (Abstract)
    abstMethod(obj)
end
```

For methods that declare the Abstract method attribute:

• Do not use a function...end block to define an abstract method, use only the method signature.
• Abstract methods have no implementation in the abstract class.
• Concrete subclasses are not required to support the same number of input and output arguments and do not need to use the same argument names. However, subclasses generally use the same signature when implementing their version of the method.
• Abstract methods cannot define arguments blocks.

**Abstract Properties**

Define an abstract property:

```matlab
properties (Abstract)
    AbsProp
end
```

For properties that declare the Abstract property attribute:

• Concrete subclasses must redefine abstract properties without the Abstract attribute.
• Concrete subclasses must use the same values for the SetAccess and GetAccess attributes as those attributes used in the abstract superclass.
• Abstract properties cannot define access methods and cannot specify initial values. The subclass that defines the concrete property can create access methods and specify initial values.

For more information on access methods, see “Property Access Methods” on page 8-39.

**Determine If a Class Is Abstract**

Determine if a class is abstract by querying the Abstract property of its meta.class object. For example, the AbsClass defines two abstract methods:

```matlab
classdef AbsClass
    methods(abstract)
        result = absMethodOne(obj)
        output = absMethodTwo(obj)
    end
end
```

Use the logical value of the meta.class Abstract property to determine if the class is abstract:

```matlab
mc = ?AbsClass;
if ~mc.Abstract
    % not an abstract class
end
```

**Display Abstract Member Names**

Use the meta.abstractDetails function to display the names of abstract properties or methods and the names of the defining classes:

```matlab
meta.abstractDetails('AbsClass');
```

Abstract methods for class AbsClass:
- absMethodTwo % defined in AbsClass
- absMethodOne % defined in AbsClass

**Find Inherited Abstract Properties and Methods**

The meta.abstractDetails function returns the names and defining class of any inherited abstract properties or methods that you have not implemented in your subclass. Use this function if you want the subclass to be concrete and must determine what abstract members the subclass inherits.

For example, suppose that you create a subclass of the AbsClass class that is defined in the previous section. In this case, the subclass implements only one of the abstract methods defined by AbsClass.

```matlab
classdef SubAbsClass < AbsClass
    % Does not implement absMethodOne
    % defined as abstract in AbsClass
    methods
        function out = absMethodTwo(obj)
            ...
        end
    end
end
```

Determine if you implemented all inherited class members using meta.abstractDetails:
The `SubAbsClass` class is abstract because it has not implemented the `absMethodOne` method defined in `AbsClass`.

If you implement both methods defined in `AbsClass`, the subclass becomes concrete.

**See Also**

**Related Examples**

- “Define an Interface Superclass” on page 12-76
Define an Interface Superclass

In this section...

“Interfaces” on page 12-76
“Interface Class Implementing Graphs” on page 12-76

Interfaces

The properties and methods defined by a class form the interface that determines how class users interact with objects of the class. When creating a group of related classes, interfaces define a common interface to all these classes. The actual implementations of the interface can differ from one class to another.

Consider a set of classes designed to represent various types of graphs. All classes must implement a Data property to contain the data used to generate the graph. However, the form of the data can differ considerably from one type of graph to another. Each class can implement the Data property differently.

The same differences apply to methods. All classes can have a draw method that creates the graph, but the implementation of this method changes with the type of graph.

The basic idea of an interface class is to specify the properties and methods that each subclass must implement without defining the actual implementation. This approach enables you to enforce a consistent interface to a group of related objects. As you add more classes in the future, the interface remains the same.

Interface Class Implementing Graphs

This example creates an interface for classes used to represent specialized graphs. The interface is an abstract class that defines properties and methods that the subclasses must implement, but does not specify how to implement these components.

This approach enforces the use of a consistent interface while providing the necessary flexibility to implement the internal workings of each specialized subclass differently.

In this example, a package folder contains the interface, derived subclasses, and a utility function:

+graphics/GraphInterface.m % abstract interface class
+graphics/LineGraph.m      % concrete subclass

Interface Properties and Methods

The graph class specifies the following properties, which the subclasses must define:

- **Primitive** — Handle of the graphics object used to implement the specialized graph. The class user has no need to access these objects directly so this property has protected SetAccess and GetAccess.
- **AxesHandle** — Handle of the axes used for the graph. The specialized graph objects can set axes object properties. This property has protected SetAccess and GetAccess.
- **Data** — All subclasses of the GraphInterface class must store data. The type of data varies and each subclass defines the storage mechanism. Subclass users can change the data values so this property has public access rights.
The `GraphInterface` class names three abstract methods that subclasses must implement. The `GraphInterface` class also suggests in comments that each subclass constructor must accept the plot data and property name/property value pairs for all class properties.

- Subclass constructor — Accept data and P/V pairs and return an object.
- `draw` — Used to create a drawing primitive and render a graph of the data according to the type of graph implemented by the subclass.
- `zoom` — Implementation of a zoom method by changing the axes `CameraViewAngle` property. The interface suggests the use of the `camzoom` function for consistency among subclasses. The zoom buttons created by the `addButtons` static method use this method as a callback.
- `updateGraph` — Method called by the `set.Data` method to update the plotted data whenever the `Data` property changes.

**Interface Guides Class Design**

The package of classes that derive from the `GraphInterface` abstract class implement the following behaviors:

- Creating an instance of a specialized `GraphInterface` object (subclass object) without rendering the plot
- Specifying any or none of the object properties when you create a specialized `GraphInterface` object
- Changing any object property automatically updates the currently displayed plot
- Allowing each specialized `GraphInterface` object to implement whatever additional properties it requires to give class users control over those characteristics.

**Define the Interface**

The `GraphInterface` class is an abstract class that defines the methods and properties used by the subclasses. Comments in the abstract class describe the intended implementation:

```matlab
classdef GraphInterface < handle
    % Abstract class for creating data graphs
    % Subclass constructor should accept
    % the data that is to be plotted and
    % property name/property value pairs
    properties (SetAccess = protected, GetAccess = protected)
        Primitive
        AxesHandle
    end
    properties
        Data
    end
    methods (Abstract)
        draw(obj)
            % Use a line, surface,
            % or patch graphics primitive
        zoom(obj,factor)
            % Change the CameraViewAngle
            % for 2D and 3D views
            % use camzoom for consistency
        updateGraph(obj)
            % Update the Data property and
            % update the drawing primitive
    end
end
```
methods
    function set.Data(obj,newdata)
        obj.Data = newdata;
        updateGraph(obj)
    end

    function addButtons(gobj)
        hfig = get(gobj.AxesHandle,'Parent');
        uicontrol(hfig,'Style','pushbutton','String','Zoom Out',...  
              'Callback',@(src,evnt)zoom(gobj,.5));
        uicontrol(hfig,'Style','pushbutton','String','Zoom In',...  
              'Callback',@(src,evnt)zoom(gobj,2),...  
              'Position',[100 20 60 20]);
    end
end
end

The GraphInterface class implements the property set method (set.Data) to monitor changes to the Data property. An alternative is to define the Data property as Abstract and enable the subclasses to determine whether to implement a set access method for this property. The GraphInterface class defines a set access method that calls an abstract method (updateGraph, which each subclass must implement). The GraphInterface interface imposes a specific design on the whole package of classes, without limiting flexibility.

Method to Work with All Subclasses

The addButtons method adds push buttons for the zoom methods, which each subclass must implement. Using a method instead of an ordinary function enables addButtons to access the protected class data (the axes handle). Use the object zoom method as the push-button callback.

function addButtons(gobj)
    hfig = get(gobj.AxesHandle,'Parent');
    uicontrol(hfig,'Style','pushbutton',...  
        'String','Zoom Out',...  
        'Callback',@(src,evnt)zoom(gobj,.5));
    uicontrol(hfig,'Style','pushbutton',...  
        'String','Zoom In',...  
        'Callback',@(src,evnt)zoom(gobj,2),...  
        'Position',[100 20 60 20]);
end

Derive a Concrete Class — LineGraph

This example defines only a single subclass used to represent a simple line graph. It derives from GraphInterface, but provides implementations for the abstract methods draw, zoom, updateGraph, and its own constructor. The base class GraphInterface and subclass are all contained in a package (graphics), which you must use to reference the class name:

classdef LineGraph < graphics.GraphInterface

Add Properties

The LineGraph class implements the interface defined in the GraphInterface class and adds two additional properties—LineColor and LineType. This class defines initial values for each property, so specifying property values in the constructor is optional. You can create a LineGraph object with no data, but you cannot produce a graph from that object.
properties
    LineColor = [0 0 0];
    LineType = ' -';
end

The LineGraph Constructor

The constructor accepts a struct with x and y coordinate data, and property name/property value pairs:

function gobj = LineGraph(data,varargin)
    if nargin > 0
        gobj.Data = data;
        if nargin > 2
            for k=1:2:length(varargin)
                gobj.(varargin{k}) = varargin{k+1};
            end
        end
    end
end

Implement the draw Method

The LineGraph draw method uses property values to create a line object. The LineGraph class stores the line handle as protected class data. To support the use of no input arguments for the class constructor, draw checks the Data property to determine if it is empty before proceeding:

function gobj = draw(gobj)
    if isempty(gobj.Data)
        error('The LineGraph object contains no data')
    end
    h = line(gobj.Data.x,gobj.Data.y,...
        'Color',gobj.LineColor,...
        'LineStyle',gobj.LineType);
    gobj.Primitive = h;
    gobj.AxesHandle = get(h,'Parent');
end

Implement the zoom Method

The LineGraph zoom method follows the comments in the GraphInterface class which suggest using the camzoom function. camzoom provides a convenient interface to zooming and operates correctly with the push buttons created by the addButtons method.

Define the Property Set Methods

Property set methods provide a convenient way to execute code automatically when the value of a property changes for the first time in a constructor. (See “Property Set Methods” on page 8-44.) The linegraph class uses set methods to update the line primitive data (which causes a redraw of the plot) whenever a property value changes. The use of property set methods provides a way to update the data plot quickly without requiring a call to the draw method. The draw method updates the plot by resetting all values to match the current property values.

Three properties use set methods: LineColor, LineType, and Data. LineColor and LineType are properties added by the LineGraph class and are specific to the line primitive used by this class. Other subclasses can define different properties unique to their specialization (for example, FaceColor).
The `GraphInterface` class implements the `Data` property set method. However, the `GraphInterface` class requires each subclass to define a method called `updateGraph`, which handles the update of plot data for the specific drawing primitive used.

**The LineGraph Class**

Here is the `LineGraph` class definition.

```matlab
classdef LineGraph < graphics.GraphInterface
    properties
        LineColor = [0 0 0]
        LineType = '-'
    end

    methods
        function gobj = LineGraph(data,varargin)
            if nargin > 0
                gobj.Data = data;
                if nargin > 1
                    for k=1:2:length(varargin)
                        gobj.(varargin{k}) = varargin{k+1};
                    end
                end
            end
        end

        function gobj = draw(gobj)
            if isempty(gobj.Data)
                error('The LineGraph object contains no data')
            end
            h = line(gobj.Data.x,gobj.Data.y,...
                'Color',gobj.LineColor,...
                'LineStyle',gobj.LineType);
            gobj.Primitive = h;
            gobj.AxesHandle = h.Parent;
        end

        function zoom(gobj,factor)
            camzoom(gobj.AxesHandle,factor)
        end

        function updateGraph(gobj)
            set(gobj.Primitive,...
                'XData',gobj.Data.x,...
                'YData',gobj.Data.y)
        end

        function set.LineColor(gobj,color)
            gobj.LineColor = color;
            set(gobj.Primitive,'Color',color)
        end

        function set.LineType(gobj,ls)
            gobj.LineType = ls;
            set(gobj.Primitive,'LineStyle',ls)
        end
    end
end
```
Use the LineGraph Class

The LineGraph class defines the simple API specified by the graph base class and implements its specialized type of graph:

```matlab
d.x = 1:10;
d.y = rand(10,1);
lg = graphics.LineGraph(d,'LineColor','b','LineType',':');
lg.draw;
lg.addButton;
```

Clicking the **Zoom In** button shows the `zoom` method providing the callback for the button.

Changing properties updates the graph:

```matlab
d.y = rand(10,1);
lg.Data = d;
lg.LineColor = [0.9,0.1,0.6];
```

Now click **Zoom Out** and see the new results:
See Also

Related Examples
• “Abstract Classes and Class Members” on page 12-72
Saving and Loading Objects

- “Save and Load Process for Objects” on page 13-2
- “Reduce MAT-File Size for Saved Objects” on page 13-4
- “Save Object Data to Recreate Graphics Objects” on page 13-5
- “Improve Version Compatibility with Default Values” on page 13-7
- “Avoid Property Initialization Order Dependency” on page 13-9
- “Modify the Save and Load Process” on page 13-12
- “Basic saveobj and loadobj Pattern” on page 13-14
- “Maintain Class Compatibility” on page 13-17
- “Initialize Objects When Loading” on page 13-22
- “Save and Load Objects from Class Hierarchies” on page 13-24
- “Restore Listeners” on page 13-26
Save and Load Process for Objects

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Save and Load Objects

Use `save` and `load` to store and reload objects:

```
save filename object
load filename object
```

What Information Is Saved?

Saving objects in MAT-files saves:

- The full name of the object class, including any package qualifiers
- Values of dynamic properties
- All property default values defined by the class at the time the first object of the class is saved to the MAT-file.
- The names and values of all properties, with the following exceptions:
  - Properties are not saved if their current values are the same as the default values specified in the class definition.
  - Properties are not saved if their Transient, Constant, or Dependent attributes set to `true`.

For a description of property attributes, see “Specify Property Attributes” on page 8-5

To save graphics objects, see `savefig`.

**Note** Do not use the `pack` command with objects that define events and listeners. The `pack` command causes the destruction of any listeners defined for the objects in the workspace. For information on restoring listeners when saving objects, see “Restore Listeners” on page 13-26.

How Is the Property Data Loaded?

When loading objects from MAT-files, the `load` function restores the object.

- `load` creates a new object.
- If the class `ConstructOnLoad` attribute is set to `true`, `load` calls the class constructor with no arguments. Otherwise, `load` does not call the class constructor.
- `load` assigns the saved property values to the object properties. These assignments result in calls to property set methods defined by the class (except in the case of `Dependent`, `Constant`, or `Transient` properties, which are not saved or loaded).
• **load** assigns the default values saved in the MAT-file to properties whose values were not saved because the properties were set to the default values when saved. These assignments result in calls to property set methods defined by the class.

MATLAB calls property set methods to ensure that property values are still valid in cases where the class definition has changed.

For information on property set methods, see “Property Set Methods” on page 8-44.

**Errors During Load**

If a new version of a class removes, renames, or changes the validation for a property, **load** can generate an error when attempting to set the altered or deleted property.

When an error occurs while an object is being loaded from a file, MATLAB does one of the following:

- If the class defines a **loadobj** method, MATLAB returns the saved values to the **loadobj** method in a **struct**.
- If the class does not define a **loadobj** method, MATLAB silently ignores the errors. The **load** function reconstitutes the object with property values that do not produce an error.

In the **struct** passed to the **loadobj** method, the field names correspond to the property names. The field values are the saved values for the corresponding properties.

If the saved object derives from multiple superclasses that have private properties with same name, the **struct** contains only the property value of the most direct superclass.

For information on how to implement **saveobj** and **loadobj** methods, see “Modify the Save and Load Process” on page 13-12.

**Changes to Property Validation**

If a class definition changes property validation such that loaded property values are no longer valid, MATLAB substitutes the currently defined default value for that property. The class can define a **loadobj** method or converter methods to provide compatibility among class versions.

For information on property validation, see “Validate Property Values” on page 8-20.

**See Also**

**Related Examples**

- “Object Save and Load”
Reduce MAT-File Size for Saved Objects

In this section...

| “Default Values” on page 13-4 |
| “Dependent Properties” on page 13-4 |
| “Transient Properties” on page 13-4 |
| “Avoid Saving Unwanted Variables” on page 13-4 |

Default Values

If a property often has the same value, define a default value for that property. When the user saves the object to a MAT-file, MATLAB does not save the value of a property if the current value equals the default value. MATLAB saves the default value on a per class basis to avoid saving the value for every object.

For more information on how MATLAB evaluates default value expressions, see “Property Default Values” on page 8-14.

Dependent Properties

Use a dependent property when the property value must be calculated at run time. A dependent property is not saved in the MAT-file when you save an object. Instances of the class do not allocate memory to hold a value for a dependent property.

Dependent is a property attribute (see “Property Attributes” on page 8-7 for a complete list.)

Transient Properties

MATLAB does not store the values of transient properties. Transient properties can store data in the object temporarily as an intermediate computation step or for faster retrieval. Use transient properties when you easily can reproduce the data at run time or when the data represents intermediate state that can be discarded.

Avoid Saving Unwanted Variables

Do not save variables that you do not want to load. Be sure that an object is still valid before you save it. For example, if you save a deleted handle object, MATLAB loads it as a deleted handle.

See Also

Related Examples

- “Modify the Save and Load Process” on page 13-12
- “Object Save and Load”
Save Object Data to Recreate Graphics Objects

In this section...

“What to Save” on page 13-5
“Regenerate When Loading” on page 13-5
“Change to a Stairstep Chart” on page 13-6

What to Save

Use transient properties to avoid saving what you can recreate when loading the object. For example, an object can contain component parts that you can regenerate from data that is saved. Regenerating these components also enables newer versions of the class to create the components in a different way.

Regenerate When Loading

The YearlyRainfall class illustrates how to regenerate a graph when loading objects of that class. YearlyRainfall objects contain a bar chart of the monthly rainfall for a given location and year. The Location and Year properties are ordinary properties whose values are saved when you save the object.

The Chart property contains the handle to the bar chart. When you save a bar chart, MATLAB also saves the figure, axes, and Bar object and the data required to create these graphics objects. The YearlyRainfall class design eliminates the need to save objects that it can regenerate:

- The Chart property is Transient so the graphics objects are not saved.
- ChartData is a private property that provides storage for the Bar object data (YData).
- The load function calls the set.ChartData method, passing it the saved bar chart data.
- The setup method regenerates the bar chart and assigns the handle to the Chart property. Both the class constructor and the set.ChartData method call setup.

classdef YearlyRainfall < handle
    properties
        Location
        Year
    end
    properties(Transient)
        Chart
    end
    properties(Access = private)
        ChartData
    end
    methods
        function rf = YearlyRainfall(data)
            setup(rf,data);
        end
        function set.ChartData(obj,V)
            setup(obj,V);
        end
        function V = get.ChartData(obj)
            V = obj.Chart.YData;
    end
end
methods(Access = private)
  function setup(rf,data)
    rf.Chart = bar(data);
  end
end

Change to a Stairstep Chart

An advantage of the `YearlyRainfall` class design is the flexibility to modify the type of graph used without making previously saved objects incompatible. Loading the object recreates the graph based only on the data that is saved to the MAT-file.

For example, change the type of graph from a bar chart to a stair-step graph by modifying the `setup` method:

```matlab
methods(Access = private)
  function setup(rf, data)
    rf.Chart = stairs(data);
  end
end
```

See Also

Related Examples
- “Modify the Save and Load Process” on page 13-12
- “Object Save and Load”
**Improve Version Compatibility with Default Values**

**In this section...**

“Version Compatibility” on page 13-7
“Using a Default Property Value” on page 13-7

**Version Compatibility**

Default property values can help you implement version compatibility for saved objects. For example, suppose that you add a property to version 2 of your class. Having a default value enables MATLAB to assign a value to the new property when loading a version 1 object.

Similarly, suppose version 2 of your class removes a property. If a version 2 object is saved and loaded into version 1, your `loadobj` method can use the default value from version 1.

**Using a Default Property Value**

The `EmployeeInfo` class shows how to use property default values as a way to enhance compatibility among versions. Version 1 of the `EmployeeInfo` class defines three properties — `Name`, `JobTitle`, and `Department`.

```matlab
classdef EmployeeInfo
    properties
        Name
        JobTitle
        Department
    end
end
```

Version 2 of the `EmployeeInfo` class adds a property, `Country`, for the country name of the employee location. The `Country` property has a default value of 'USA'.

```matlab
classdef EmployeeInfo
    properties
        Name
        JobTitle
        Department
        Country = 'USA'
    end
end
```

The character array, 'USA', is a good default value because:

- MATLAB assigns an empty double `[]` to properties that do not have default values defined by the class. Empty double is not a valid value for the `Country` property.
- In version 1, all employees were in the USA. Therefore, any version 1 object loaded into version 2 receives a valid value for the `Country` property.
See Also

Related Examples
- “Modify the Save and Load Process” on page 13-12
- “Object Save and Load”
Avoid Property Initialization Order Dependency

In this section...

“Control Property Loading” on page 13-9
“Dependent Property with Private Storage” on page 13-9
“Property Value Computed from Other Properties” on page 13-11

Control Property Loading

Problems can occur if property values depend on the order in which `load` sets the property values.

Suppose that your class design is such that both of the following are true:

• A property set method changes another property value.
• A property value is computed from other property values.

Then the final state of an object after changing a series of property values can depend on the order in which you set the properties. This order dependency can affect the result of loading an object.

The `load` function sets property values in a particular order. This order can be different from the order in which you set the properties in the saved object. As a result, the loaded object can have different property values than the object had when it was saved.

Restore Nondependent Properties

If a property set function changes the values of other properties, then define the `Dependent` attribute of that property as `true`. MATLAB does not save or restore dependent property values.

Use nondependent properties for storing the values set by the dependent property. Then the `load` function restores the nondependent properties with the same values that were saved. The `load` function does not call the dependent property set method because there is no value in the saved file for that property.

Dependent Property with Private Storage

The `Odometer` class avoids order dependences when loading objects by controlling which properties are restored when loading:

• The `Units` property is dependent. Its property set method sets the `TotalDistance` property. Therefore `load` does not call the `Units` property set method.
• The load function restores `TotalDistance` to whatever value it had when you saved the object.

```matlab
classdef Odometer
    properties(Constant)
        ConversionFactor = 1.6
    end
    properties
        TotalDistance = 0
    end
    properties(Dependent)
        Units
```
end
properties(Access=private)
    PrivateUnits = 'mi'
end
methods
    function unit = get.Units(obj)
        unit = obj.PrivateUnits;
    end
    function obj = set.Units(obj,newUnits)
        % validate newUnits to be a char vector
        switch(newUnits)
            case 'mi'
                if strcmp(obj.PrivateUnits,'km')
                    obj.TotalDistance = obj.TotalDistance / ... 
                    obj.ConversionFactor;
                    obj.PrivateUnits = newUnits;
                end
            case 'km'
                if strcmp(obj.PrivateUnits,'mi')
                    obj.TotalDistance = obj.TotalDistance * ... 
                    obj.ConversionFactor;
                    obj.PrivateUnits = newUnits;
                end
            otherwise
                error('Odometer:InvalidUnits', ... 
                'Units ''%s'' is not supported.', newUnits);
            end
        end
    end
end

Suppose that you create an instance of Odometer and set the following property values:

odObj = Odometer;
odObj.Units = 'km';
odObj.TotalDistance = 16;

When you save the object:

• ConversionFactor is not saved because it is a Constant property.
• TotalDistance is saved.
• Units is not saved because it is a Dependent property.
• PrivateUnits is saved and provides the storage for the current value of Units.

When you load the object:

• ConversionFactor is obtained from the class definition.
• TotalDistance is loaded.
• Units is not loaded, so its set method is not called.
• PrivateUnits is loaded from the saved object.

If the Units property was not Dependent, loading it calls its set method and causes the TotalDistance property to be set again.
Property Value Computed from Other Properties

The Odometer2 class TripDistance property depends only on the values of two other properties, TotalDistance and TripMarker.

The class avoids order dependence when initializing property values during the load process by making the TripDistance property dependent. MATLAB does not save or load a value for the TripDistance property, but does save and load values for the two properties used to calculate TripDistance in its property get method.

classdef Odometer2
    properties
        TotalDistance = 0
        TripMarker = 0
    end
    properties(Dependent)
        TripDistance
    end
    methods
        function distance = get.TripDistance(obj)
            distance = obj.TotalDistance - obj.TripMarker;
        end
    end
end

See Also

Related Examples
- “Modify the Save and Load Process” on page 13-12
- “Object Save and Load”
Modify the Save and Load Process

When to Modify the Save and Load Process

The primary reason for modifying the save and load process is to support backward and forward compatibility of classes. Consider modifying the save and load process when you:

- Rename a class
- Remove properties
- Define a circular reference of handle objects where initialization order is important
- Must call the constructor with arguments and, therefore, cannot use ConstructOnLoad

How to Modify the Save and Load Process

The most versatile technique for modifying the save and load process is to implement `loadobj`, and if necessary, `saveobj` methods for your class. MATLAB executes these methods when you call `save` or `load` on an object of the class.

The `save` function calls your class `saveobj` method before performing the save operation. The `save` function then saves the value returned by the `saveobj` method. You can use `saveobj` to return a modified object or a `struct` that contains property values.

`load` calls your class `loadobj` method after loading the object. The `load` function loads the value returned by the `loadobj` method into the workspace. A `loadobj` method can modify the object being loaded or can reconstruct an object from the data saved by the class `saveobj` method.

Implementing saveobj and loadobj Methods

Implement a `saveobj` method that modifies the object being saved, then implement a `loadobj` method to return the object to the correct state when loading it.

Implement the `loadobj` method as a `Static` method because MATLAB can call the `loadobj` method with a `struct` instead of an object of the class.

Implement the `saveobj` method as an ordinary method (that is, calling it requires an instance of the class).

MATLAB saves the object class name so that `load` can determine which `loadobj` method to call in cases where your `saveobj` method saves only the object data in a structure. Therefore, the class must be accessible to MATLAB when you load the object.

Use a `loadobj` method when:
• The class definition has changed since the object was saved, requiring you to modify the object before loading.

• A `saveobj` method modified the object during the save operation, possibly saving data in a `struct`. Implement the `loadobj` method to reconstruct the object from the output of `saveobj`.

### Additional Considerations

When you decide to modify the default save and load process, keep the following points in mind:

• If loading any property value from the MAT-file produces an error, `load` passes a `struct` to `loadobj`. The `struct` field names correspond to the property names extracted from the file.

• `loadobj` must always be able to accept a `struct` as input and return an object, even if there is no `saveobj` or `saveobj` does not return a `struct`.

• If `saveobj` returns a `struct`, then `load` always passes that `struct` to `loadobj`.

• Subclass objects inherit superclass `loadobj` and `saveobj` methods. Therefore, if you do not implement a `loadobj` or `saveobj` method in the subclass, MATLAB calls only the inherited methods.

    If a superclass implements a `loadobj` or `saveobj` method, then a subclass can also implement a `loadobj` or `saveobj` method that calls the superclass methods. For more information, see “Save and Load Objects from Class Hierarchies” on page 13-24.

• The `load` function does not call the constructor by default. For more information, see “Initialize Objects When Loading” on page 13-22.

### See Also

### Related Examples

• “Basic `saveobj` and `loadobj` Pattern” on page 13-14

• “Object Save and Load”
Basic saveobj and loadobj Pattern

Using saveobj and loadobj

Depending on the requirements of your class, there are various ways you can use saveobj and loadobj methods. This pattern is a flexible way to solve problems that you cannot address by simpler means.

The basic process is:

• Use saveobj to save all essential data in a struct and do not save the entire object.
• Use loadobj to reconstruct the object from the saved data.

This approach is not useful in cases where you cannot save property values in a struct field. Data that you cannot save, such as a file identifier, you can possibly regenerate in the loadobj method.

If you implement a saveobj method without implementing a loadobj method, MATLAB loads a default object of the class using the current class definition. Add a loadobj method to the class to create an object using the data saved with the saveobj method.

saveobj

For this pattern, define saveobj as an ordinary method that accepts an object of the class and returns a struct.

• Copy each property value to a structure field of the same name.
• You can save only the data that is necessary to rebuild the object. Avoid saving whole objects hierarchies, such as those created by graphs.

```matlab
methods
    function s = saveobj(obj)
        s.Prop1 = obj.Prop1;
        s.Prop2 = obj.Prop2
        s.Data = obj.GraphHandle.YData;
    end
end
```

loadobj

Define loadobj as a static method. Create an object by calling the class constructor. Then assign values to properties from the struct passed to loadobj. Use the data to regenerate properties that were not saved.

```matlab
methods(Static)
    function obj = loadobj(s)
        if isstruct(s)
            newObj = ClassConstructor;
            newObj.Prop1 = s.Prop1;
            newObj.Prop2 = s.Prop2
        end
    end
```
newObj.GraphHandle = plot(s.Data);
obj = newObj;
else
    obj = s;
end
end

If the load function encounters an error, load passes loadobj a struct instead of an object. Your loadobj method must always be able to handle a struct as the input argument. The input to loadobj is always a scalar.

Handle Load Problems

loadobj can handle a struct input even if you are not using a saveobj method.

The GraphExpression class creates a graph of a MATLAB expression over a specified range of data. GraphExpression uses its loadobj method to regenerate the graph, which is not saved with the object.

classdef GraphExpression
    properties
        FuncHandle
        Range
    end
    methods
        function obj = GraphExpression(fh,rg)
            obj.FuncHandle = fh;
            obj.Range = rg;
            makeGraph(obj)
        end
        function makeGraph(obj)
            rg = obj.Range;
            x = min(rg):max(rg);
            data = obj.FuncHandle(x);
            plot(data)
        end
    end
    methods (Static)
        function obj = loadobj(s)
            if isstruct(s)
                fh = s.FuncHandle;
                rg = s.Range;
                obj = GraphExpression(fh,rg);
            else
                makeGraph(s);
                obj = s;
            end
        end
    end
end

Save and Load Object

Create an object with an anonymous function and a range of data as inputs:

h = GraphExpression(@(x)x.^4,[1:25])
GraphExpression with properties:

    FuncHandle: @(x)x.^4
    Range: [1x25 double]

Save the GraphExpression object and close the graph:

    save myFile h
    close

Load the object. MATLAB recreates the graph:

    load myFile h

If the load function cannot create the object and passes a struct to loadobj, loadobj attempts to create an object with the data supplied.

See Also

Related Examples

- “Modify the Save and Load Process” on page 13-12
- “Object Save and Load”
Maintain Class Compatibility

In this section...

“Rename Property” on page 13-17
“Update Property When Loading” on page 13-18
“Maintaining Compatible Versions of a Class” on page 13-19
“Version 2 of the PhoneBookEntry Class” on page 13-20

Rename Property

Suppose that you want to rename a property, but do not want to cause errors in existing code that refer to the original property. For example, rename a public property called OfficeNumber to Location. Here is the original class definition:

classdef EmployeeList
    properties
        Name
        Email
        OfficeNumber % Rename as Location
    end
end

Use of a hidden dependent property can achieve the desired results.

• In the class definition, set the OfficeNumber property attributes to Dependent and Hidden.
• Create a property set method for OfficeNumber that sets the value of the Location property.
• Create a property get method for OfficeNumber that returns the value of the Location location property.

While the OfficeNumber property is hidden, existing code can continue to access this property. The Hidden attribute does not affect access.

Because OfficeNumber is dependent, there is no redundancy in storage required by adding the new property. MATLAB does not store or save dependent properties.

Here is the updated class definition.

classdef EmployeeList
    properties
        Name
        Email
        Location
    end
    properties (Dependent, Hidden)
        OfficeNumber
    end
    methods
        function obj = set.OfficeNumber(obj,val)
            obj.Location = val;
        end
        function val = get.OfficeNumber(obj)
            val = obj.Location;
        end
end
Saving and Loading EmployeeList Objects

You can load old instances of the EmployeeList class in the presence of the new class version. Code that refers to the OfficeNumber property continues to work.

Forward and Backward Compatibility

Suppose that you want to be able to load new EmployeeList objects into systems that still have the old version of the EmployeeList class. To achieve compatibility with old and new versions:

- Define the OfficeNumber property as Hidden, but not Dependent.
- Define the Location property as Dependent.

In this version of the EmployeeList class, the OfficeNumber property saves the value used by the Location property. Loading an object assigns values of the three original properties (Name, Email, and OfficeNumber), but does not assign a value to the new Location property. The lack of the Location property in the old class definition is not a problem.

classdef EmployeeList
    properties
        Name
        Email
    end
    properties (Dependent)
        Location
    end
    properties (Hidden)
        OfficeNumber
    end
end
methods
    function obj = set.Location(obj,val)
        obj.OfficeNumber = val;
    end
    function val = get.Location(obj)
        val = obj.OfficeNumber;
    end
end

Update Property When Loading

Suppose that you modify a class so that a property value changes in its form or type. Previously saved objects of the class must be updated when loaded to have a conforming property value.

Consider a class that has an AccountID property. Suppose that all account numbers must migrate from eight-digit numeric values to 12-element character arrays.

You can accommodate this change by implementing a loadobj method.

The loadobj method:

- Tests to determine if the load function passed a struct or object. All loadobj methods must handle both struct and object when there is an error in load.
• Tests to determine if the AccountID number contains eight digits. If so, change it to a 12-element character array by calling the paddAccID method.

After updating the AccountID property, loadobj returns a MyAccount object that MATLAB loads into the workspace.

classdef MyAccount
    properties
        AccountID
    end
    methods
        function obj = padAccID(obj)
            ac = obj.AccountID;
            acstr = num2str(ac);
            if length(acstr) < 12
                obj.AccountID = [acstr,repmat('0',1,12-length(acstr))];
            end
        end
    end
    methods (Static)
        function obj = loadobj(a)
            if isstruct(a)
                obj = MyAccount;
                obj.AccountID = a.AccountID;
                obj = padAccID(obj);
            elseif isa(a,'MyAccount')
                obj = padAccID(a);
            end
        end
    end
end

You do not need to implement a saveobj method. You are using loadobj only to ensure that older saved objects are brought up to date while loading.

Maintaining Compatible Versions of a Class

The PhoneBookEntry class uses a combination of techniques to maintain compatibility with new versions of the class.

Suppose that you define a class to represent an entry in a phone book. The PhoneBookEntry class defines three properties: Name, Address, and PhoneNumber.

classdef PhoneBookEntry
    properties
        Name
        Address
        PhoneNumber
    end
end

However, in future releases, the class adds more properties. To provide flexibility, PhoneBookEntry saves property data in a struct using its saveobj method.

methods
    function s = saveobj(obj)
        s.Name = obj.Name;
    end
end
The `loadobj` method creates the `PhoneBookEntry` object, which is then loaded into the workspace.

```matlab
methods (Static)
    function obj = loadobj(s)
        if isstruct(s)
            newObj = PhoneBookEntry;
            newObj.Name = s.Name;
            newObj.Address = s.Address;
            newObj.PhoneNumber = s.PhoneNumber;
            obj = newObj;
        else
            obj = s;
        end
    end
end
```

### Version 2 of the `PhoneBookEntry` Class

In version 2 of the `PhoneBookEntry` class, you split the `Address` property into `StreetAddress`, `City`, `State`, and `ZipCode` properties.

With these changes, you could not load a version 2 object in a previous release. However, version 2 employs several techniques to enable compatibility:

- Preserve the `Address` property (which is used in version 1) as a `Dependent` property with private `SetAccess`.
- Define an `Address` property get method (`get.Address`) to build a `char` vector that is compatible with the version 2 `Address` property.
- The `saveobj` method invokes the `get.Address` method to assign the object data to a `struct` that is compatible with previous versions. The `struct` continues to have only an `Address` field built from the data in the new `StreetAddress`, `City`, `State`, and `ZipCode` properties.
- When the `loadobj` method sets the `Address` property, it invokes the property set method (`set.Address`), which extracts the substrings required by the `StreetAddress`, `City`, `State`, and `ZipCode` properties.
- The `Transient` (not saved) property `SaveInOldFormat` enables you to specify whether to save the version 2 object as a `struct` or an object.

```matlab
classdef PhoneBookEntry
    properties
        Name
        StreetAddress
        City
        State
        ZipCode
        PhoneNumber
    end
    properties (Constant)
        Sep = ', ';
    end
end
```
properties (Dependent, SetAccess=private)
    Address
end
properties (Transient)
    SaveInOldFormat = false;
end
methods (Static)
    function obj = loadobj(s)
        if isstruct(s)
            obj = PhoneBookEntry;
            obj.Name = s.Name;
            obj.Address = s.Address;
            obj.PhoneNumber = s.PhoneNumber;
        else
            obj = s;
        end
    end
end
methods
    function address = get.Address(obj)
        address = [obj.StreetAddress,obj.Sep,obj.City,obj.Sep,...
            obj.State,obj.Sep,obj.ZipCode];
    end
    function obj = set.Address(obj,address)
        addressItems = regexp(address,obj.Sep,'split');
        if length(addressItems) == 4
            obj.StreetAddress = addressItems{1};
            obj.City = addressItems{2};
            obj.State = addressItems{3};
            obj.ZipCode = addressItems{4};
        else
            error('PhoneBookEntry:InvalidAddressFormat', ...
                'Invalid address format.');</n    end
end
function s = saveobj(obj)
    if obj.SaveInOldFormat
        s.Name = obj.Name;
        s.Address = obj.Address;
        s.PhoneNumber = obj.PhoneNumber;
    end
end
end

See Also

Related Examples
•  “Modify the Save and Load Process” on page 13-12
•  “Object Save and Load”


Initialize Objects When Loading

**Calling Constructor When Loading Objects**

MATLAB does not call the class constructor when loading an object from a MAT-file. However, if you set the `ConstructOnLoad` class attribute to `true`, `load` does call the constructor with no arguments.

Enable `ConstructOnLoad` when you do not want to implement a `loadobj` method, but must perform some actions at construction time. For example, enable `ConstructOnLoad` when you are registering listeners for another object. Ensure that MATLAB can call the class constructor with no arguments without generating an error.

Attributes set on superclasses are not inherited by subclasses. Therefore, MATLAB does not use the value of the superclass `ConstructOnLoad` attribute when loading objects. If you want MATLAB to call the class constructor, set the `ConstructOnLoad` attribute in your specific subclass.

If the constructor requires input arguments, use a `loadobj` method.

**Initializing Objects in the loadobj Method**

Use a `loadobj` method when the class constructor requires input arguments to perform object initialization.

The `LabResults` class shares the constructor object initialization steps with the `loadobj` method by performing these steps in the `assignStatus` method.

Objects of the `LabResults` class:

- Hold values for the results of tests.
- Assign a status for each value based on a set of criteria.

```matlab
classdef LabResult
    properties
        CurrentValue
    end
    properties (Transient)
        Status
    end
    methods
        function obj = LabResult(cv)
            obj.CurrentValue = cv;
            obj = assignStatus(obj);
        end
        function obj = assignStatus(obj)
            v = obj.CurrentValue;
            if v < 10
                obj.Status = 'Too low';
            end
        end
end
```
elseif v >= 10 && v < 100
    obj.Status = 'In range';
else
    obj.Status = 'Too high';
end
end
methods (Static)
function obj = loadobj(s)
    if isstruct(s)
        cv = s.CurrentValue;
        obj = LabResults(cv);
    else
        obj = assignStatus(s);
    end
end
end

The `LabResults` class uses `loadobj` to determine the status of a given test value. This approach provides a way to:

- Modify the criteria for determining status
- Ensure that objects always use the current criteria

You do not need to implement a `saveobj` method.

**See Also**

**Related Examples**
- “Modify the Save and Load Process” on page 13-12
- “Object Save and Load”
Save and Load Objects from Class Hierarchies

In this section...

“Saving and Loading Subclass Objects” on page 13-24
“Reconstruct the Subclass Object from a Saved struct” on page 13-24

Saving and Loading Subclass Objects

If the most specific class of an object does not define a loadobj or saveobj method, this class can inherit loadobj or saveobj methods from a superclass.

If any class in the hierarchy defines saveobj or loadobj methods:

• Define saveobj for all classes in the hierarchy.
• Call superclass saveobj methods from the subclass saveobj method because the save function calls only the most specific saveobj method.
• The subclass loadobj method can call the superclass loadobj, or other methods as required, to assign values to their properties.

Reconstruct the Subclass Object from a Saved struct

Suppose that you want to save a subclass object by first converting its property data to a struct in the class saveobj method. Then you reconstruct the object when loaded using its loadobj method. This action requires that:

• Superclasses implement saveobj methods to save their property data in the struct.
• The subclass saveobj method calls each superclass saveobj method and returns the completed struct to the save function. Then the save function writes the struct to the MAT-file.
• The subclass loadobj method creates a subclass object and calls superclass methods to assign their property values in the subclass object.
• The subclass loadobj method returns the reconstructed object to the load function, which loads the object into the workspace.

The following superclass (MySuper) and subclass (MySub) definitions show how to code these methods.

• The MySuper class defines a loadobj method to enable an object of this class to be loaded directly.
• The subclass loadobj method calls a method named reload after it constructs the subclass object.
• reload first calls the superclass reload method to assign superclass property values and then assigns the subclass property value.

```matlab
classdef MySuper
    properties
        X
        Y
    end
    methods
end
```
function S = saveobj(obj)
    S.PointX = obj.X;
    S.PointY = obj.Y;
end
function obj = reload(obj,S)
    obj.X = S.PointX;
    obj.Y = S.PointY;
end
methods (Static)
function obj = loadobj(S)
    if isstruct(s)
        obj = MySuper;
        obj = reload(obj,S);
    end
end
end
end

Call the superclass saveobj and loadobj methods from the subclass saveobj and loadobj methods.

classdef MySub < MySuper
    properties
        Z
    end
    methods
        function S = saveobj(obj)
            S = saveobj@MySuper(obj);
            S.PointZ = obj.Z;
        end
        function obj = reload(obj,S)
            obj = reload@MySuper(obj,S);
            obj.Z = S.PointZ;
        end
    end
    methods (Static)
        function obj = loadobj(S)
            if isstruct(s)
                obj = MySuper;
                obj = reload@MySuper(obj,S);
            end
        end
    end
end

See Also

Related Examples
• “Modify the Save and Load Process” on page 13-12
• “Object Save and Load”
Create Listener with loadobj

Suppose that you create a property listener and want to be able to save and restore the event source and the listener. One approach is to create a listener from the loadobj method.

Use Transient Property to Load Listener

The BankAccount class stores the account balance and an account status. A PostSet listener attached to the AccountBalance property controls the account status.

When the AccountBalance property value changes, the listener callback determines the account status. Important points include:

- The BankAccount class defines the AccountManagerListener property to contain the listener handle. This property enables the loadobj method to create a listener and return a reference to it in the object that is loaded into the workspace.
- The AccountManagerListener property is Transient because there is no need to store the listener handle with a BankAccount object. Create a listener that is attached to the new BankAccount object created during the load process.
- The AccountBalance listener sets the AccountStatus.
- Only the AccountManager class can access AccountStatus property.

```matlab
classdef BankAccount < handle
properties (SetObservable, AbortSet)
    AccountBalance
end
properties (Transient)
    AccountManagerListener
end
properties (Access = ?AccountManager)
    AccountStatus
end
methods
    function obj = BankAccount(initialBalance)
        obj.AccountBalance = initialBalance;
        obj.AccountStatus = 'New Account';
        obj.AccountManagerListener = AccountManager.addAccount(obj);
    end
end
methods (Static)
    function obj = loadobj(obj)
        if isstruct(obj) % Handle error
            initialBalance = obj.AccountBalance;
            obj = BankAccount(initialBalance);
        end
    end
```
else
    obj.AccountManagerListener = AccountManager.addAccount(obj);
end
end
end
end

Assume the AccountManager class provides services for various types of accounts. For the BankAccount class, the AccountManager class defines two Static methods:

- assignStatus — Callback for the AccountBalance property PostSet listener. This method determines the value of the BankAccount AccountStatus property.
- addAccount — Creates the AccountBalance property PostSet listener. The BankAccount constructor and loadobj methods call this method.

classdef AccountManager
    methods (Static)
        function assignStatus(BA,~)
            if BA.AccountBalance < 0 && BA.AccountBalance >= -100
                BA.AccountStatus = 'overdrawn';
            elseif BA.AccountBalance < -100
                BA.AccountStatus = 'frozen';
            else
                BA.AccountStatus = 'open';
            end
        end
        function lh = addAccount(BA)
            lh = addlistener(BA,'AccountBalance','PostSet', ...
                             @(src,evt)AccountManager.assignStatus(BA));
        end
    end
end

Using the BankAccount and AccountManager Classes

Create an instance of the BankAccount class.

ba = BankAccount(100)

ba =

    BankAccount with properties:
    AccountBalance: 100
    AccountManagerListener: [1x1 event.proplistener]
    AccountStatus: 'New Account'

Now set an account value to confirm that the AccountManager sets AccountStatus appropriately:

ba.AccountBalance = -10;
ba.AccountStatus

ans =

overdrawn
See Also

Related Examples
- “Modify the Save and Load Process” on page 13-12
- “Property Attributes” on page 8-7
- “Listen for Changes to Property Values” on page 11-32
- “Object Save and Load”
Enumerations

- “Named Values” on page 14-2
- “Define Enumeration Classes” on page 14-4
- “Refer to Enumerations” on page 14-9
- “Enumerations for Property Values” on page 14-14
- “Operations on Enumerations” on page 14-16
- “Hide Enumeration Members” on page 14-22
- “Enumeration Class Restrictions” on page 14-25
- “Enumerations Derived from Built-In Classes” on page 14-26
- “Mutable Handle vs. Immutable Value Enumeration Members” on page 14-31
- “Enumerations That Encapsulate Data” on page 14-36
- “Save and Load Enumerations” on page 14-39
Named Values

In this section...

“Kinds of Predefined Names” on page 14-2
“Techniques for Defining Enumerations” on page 14-2

Kinds of Predefined Names

MATLAB supports two kinds of predefined names:

• Constant properties
• Enumerations

Constant Properties

Use constant properties when you want a collection of related constant values whose values can belong to different types (numeric values, character strings, and so on). Define properties with constant values by setting the property Constant attribute. Reference constant properties by name whenever you need access to that particular value.

See “Define Class Properties with Constant Values” on page 15-2 for more information.

Enumerations

Use enumerations when you want to create a fixed set of names representing a single type of value. Use this new type in multiple places without redefining it for each class.

You can derive enumeration classes from other classes to inherit the operations of the superclass. For example, if you define an enumeration class that subclasses a MATLAB numeric class like `double` or `int32`, the enumeration class inherits all the mathematical and relational operations that MATLAB defines for those classes.

Using enumerations instead of character strings to represent a value, such as colors (`'red'`), can result in more readable code because:

• You can compare enumeration members with `==` instead of using `strcmp`.
• Enumerations maintain type information, `char` vectors do not. For example, passing a `char` vector `{'red'}` to functions means that every function must interpret what `red` means. If you define red as an enumeration, the actual value of `red` can change (from `[1 0 0]` to `[.93 .14 .14]`, for example) without updating every function that accepts colors, as you would if you defined the color as the `char` vector `'red'`.

Define enumerations by creating an `enumeration` block in the class definition.

See “Define Enumeration Classes” on page 14-4 for more information.

Techniques for Defining Enumerations

Enumerations enable you to define names that represent entities useful to your application, without using numeric values or character strings. All enumerations support equality and inequality operations. Therefore, `switch`, `if`, and several comparison functions like `isequal` and `ismember` work with enumeration members.
You can define enumeration classes in ways that are most useful to your application, as described in the following sections.

**Simple Enumerated Names**

Simple enumeration classes have no superclasses and no properties. These classes define a set of related names that have no underlying values associated with them. Use this kind of enumeration when you want descriptive names, but your application does not require specific information associated with the name.

See the `WeekDays` class in the “Enumeration Class” on page 14-4 and the “Define Methods in Enumeration Classes” on page 14-5 sections.

**Enumerations with Built-In Class Behaviors**

Enumeration classes that subclass MATLAB built-in classes inherit most of the behaviors of those classes. For example, an enumeration class derived from the `double` class inherits the mathematical, relational, and set operations that work with variables of the class.

Enumerations do not support the colon (`:`) operator, even if the superclass does.

**Enumerations with Properties for Member Data**

Enumeration classes that do not subclass MATLAB built-in numeric and logical classes can define properties. These classes can define constructors that set each member's unique property values.

The constructor can save input arguments in property values. For example, a `Color` class can specify a `Red` enumeration member color with three (Red, Green, Blue) values:

```matlab
enumeration
  Red (1,0,0)
end
```

**See Also**

**Related Examples**

- “Enumeration Class Restrictions” on page 14-25
- “Enumerations Derived from Built-In Classes” on page 14-26
- “Enumerations That Encapsulate Data” on page 14-36
Define Enumeration Classes

In this section...

- “Enumeration Class” on page 14-4
- “Construct an Enumeration Member” on page 14-4
- “Convert to Superclass Value” on page 14-4
- “Define Methods in Enumeration Classes” on page 14-5
- “Define Properties in Enumeration Classes” on page 14-6
- “Enumeration Class Constructor Calling Sequence” on page 14-6

Enumeration Class

Create an enumeration class by adding an enumeration block to a class definition. For example, the WeekDays class enumerates a set of days of the week.

```matlab
classdef WeekDays
    enumeration
        Monday, Tuesday, Wednesday, Thursday, Friday
    end
end
```

To execute the MATLAB code in the following sections, place the WeekDays class definition in a .m file on your path.

Construct an Enumeration Member

Refer to an enumeration member using the class name and the member name:

```matlab
ClassName.MemberName
```

For example, assign the enumeration member WeekDays.Tuesday to the variable today:

```matlab
today = WeekDays.Tuesday;
today
```

today is a variable of class WeekDays:

```matlab
whos
Name       Size            Bytes  Class       Attributes
today      1x1                104  WeekDays
```

today

today =

```
Tuesday
```

Convert to Superclass Value

If an enumeration class specifies a superclass, convert an enumeration object to the superclass by passing the object to the superclass constructor. However, the superclass constructor must be able to
accept its own class as input and return an instance of the superclass. MATLAB built-in numeric classes, such as uint32, allow this conversion.

For example, the Bearing class derives from the uint32 built-in class:

classdef Bearing < uint32
  enumeration
    North (0)
    East  (90)
    South (180)
    West  (270)
  end
end

Assign the Bearing.East member to the variable a:

a = Bearing.East;

Pass a to the superclass constructor and return a uint32 value:

b = uint32(a);

whos

Name      Size            Bytes  Class      Attributes
a         1x1                60  Bearing
b         1x1                 4  uint32

The uint32 constructor accepts an object of the subclass Bearing and returns an object of class uint32.

**Define Methods in Enumeration Classes**

Define methods in an enumeration class like any MATLAB class. For example, here is the WeekDays class with a method called isMeetingDay added:

classdef WeekDays
  enumeration
    Monday, Tuesday, Wednesday, Thursday, Friday
  end
  methods
    function tf = isMeetingDay(obj)
      tf = ~(WeekDays.Tuesday == obj);
    end
  end
end

Call isMeetingDay with an instance of the WeekDays class:

today = WeekDays.Tuesday;
today.isMeetingDay

ans =

0

Use the enumeration member directly as input to the method:
Define Properties in Enumeration Classes

Add properties to an enumeration class when you must store data related to the enumeration members. Set the property values in the class constructor. For example, the SyntaxColors class defines three properties whose values the constructor assigns to the values of the input arguments when you reference a class member.

```matlab
classdef SyntaxColors
    properties
        R
        G
        B
    end
    methods
        function c = SyntaxColors(r, g, b)
            c.R = r; c.G = g; c.B = b;
        end
    end
end
```

When you refer to an enumeration member, the constructor initializes the property values:

```matlab
e = SyntaxColors.Error;
e.R
```

```matlab
ans =

1
```

Because SyntaxColors is a value class (it does not derive from handle), only the class constructor can set property values:

```matlab
e.R = 0
```

You cannot set the read-only property 'R' of SyntaxColors.

For more information on enumeration classes that define properties, see “Mutable Handle vs. Immutable Value Enumeration Members” on page 14-31.

Enumeration Class Constructor Calling Sequence

Each statement in an enumeration block is the name of an enumeration member, optionally followed by an argument list. If the enumeration class defines a constructor, MATLAB calls the constructor to create the enumerated instances.
MATLAB provides a default constructor for all enumeration classes that do not explicitly define a constructor. The default constructor creates an instance of the enumeration class:

- Using no input arguments, if the enumeration member defines no input arguments
- Using the input arguments defined in the enumeration class for that member

For example, the input arguments for the `Bool` class are 0 for `Bool.No` and 1 for `Bool.Yes`.

```matlab
classdef Bool < logical
    enumeration
        No (0)
        Yes (1)
    end
end
```

The values of 0 and 1 are of class `logical` because the default constructor passes the argument to the first superclass. That is, this statement:

```matlab
n = Bool.No;
```

Results in a call to `logical` that is equivalent to the following statement in a constructor:

```matlab
function obj = Bool(val)
    obj@logical(val)
end
```

MATLAB passes the member argument only to the first superclass. For example, suppose `Bool` derived from another class:

```matlab
classdef Bool < logical & MyBool
    enumeration
        No (0)
        Yes (1)
    end
end
```

The `MyBool` class can add some specialized behavior:

```matlab
classdef MyBool
    methods
        function boolValues = testBools(obj)
            ...
        end
    end
end
```

The default `Bool` constructor behaves as if defined like this function:

- Argument passed to first superclass constructor
- No arguments passed to subsequent constructors

```matlab
function obj = Bool(val)
    obj@logical(val)
    obj@MyBool
end
```
See Also

Related Examples

- “Refer to Enumerations” on page 14-9
- “Operations on Enumerations” on page 14-16
Instances of Enumeration Classes

Enumeration members are instances of the enumeration class. You can assign enumeration members to variables and form arrays of enumeration members. If an enumeration class derives from a superclass, you can substitute an enumeration member for an instance of the superclass.

The `WeekDays` class defines enumeration members for five days of the week.

```matlab
classdef WeekDays
    enumeration
        Monday, Tuesday, Wednesday, Thursday, Friday
    end
end
```

Create objects of the `WeekDays` class representing specific days.

```matlab
today = WeekDays.Monday;
tomorrow = WeekDays.Tuesday;
```

The variables `today` and `tomorrow` are objects of the `WeekDays` class.

The `PPM` class defines three enumeration members. Each member has an associated numeric value derived from the class superclass.

```matlab
classdef PPM < double
    enumeration
        High (1000)
        Medium (100)
        Low (10)
    end
end
```

Assign an enumeration member to a variable.

```matlab
level = PPM.High;
```

When you substitute enumeration members for instances of the superclass, MATLAB coerces the enumeration member to the superclass. For example, add an enumeration member of the `PPM` class with a numeric value.

```matlab
levelNew = level + 100
levelNew =
    1100
```

The result is of class `double`. 
You can substitute superclass values for enumeration members when the values correspond. For example, pass one of the numeric values defined in the enumeration class to the `PPMSwitch` function.

```matlab
function PPMSwitch(ppm)
    switch ppm
        case PPM.Low
            disp Low
        case PPM.Medium
            disp Medium
        case PPM.High
            disp High
    end
end
```

`PPMSwitch(100)`

Medium

You can also use an enumeration member directly:

`PPMSwitch(PPM.Medium)`

Medium

For information on operations you can perform on enumeration class instances, see “Operations on Enumerations” on page 14-16.

**Conversion of Characters to Enumerations**

Enumeration classes can convert `char` vectors to enumeration members when the `char` vector represents an enumeration member defined by the class. This conversion enables you to pass a valid `char` vector or a cell array of `char` vectors when enumerations are expected.

Use a `char` vector instead of a direct reference to an enumeration member when you want to use a simple character strings to specify an enumeration member. However, specifying an enumeration member directly eliminates the conversion from `char` to enumeration.

Enumeration classes provide a converter function using the constructor syntax.

```matlab
today = WeekDays('Tuesday');
```

Because the `char` vector 'Tuesday' matches the enumeration member `WeekDays.Tuesday`, the `Weekdays char` method can perform the conversion.

```matlab
class(today)
ans =
WeekDays
```

Create an enumeration array using the `WeekDay` class constructor and a cell array of `char` vectors.
wd = WeekDays({'Monday','Wednesday','Friday'})
wd =
    Monday       Wednesday    Friday
class(wd)
ans =
    WeekDays

All char vectors in the cell array must correspond to an enumeration member defined by the class.

**Coercion of char to Enumerations**

MATLAB coerces char vectors into enumerations members when the dominant argument is an enumeration. Because user-defined classes are dominant over the char class, MATLAB attempts to convert the char vector to a member of the enumeration class.

Create an enumeration array. Then insert a char vector that represents an enumeration member into the array.

```matlab
a = [WeekDays.Monday,WeekDays.Wednesday,WeekDays.Friday]
a =
    Monday       Wednesday    Friday
a(end+1) = 'Tuesday'
a =
    Monday       Wednesday    Friday       Tuesday
```

MATLAB coerces the char vector to a WeekDays enumeration member.

```matlab
class(a)
an =
    WeekDays
```

**Substitute Enumeration Members for char Vectors**

You can use enumeration members in place of char vectors in cases where functions require char vectors. For example, this call to sprintf expects a char vector, designated by the %s format specifier.

```matlab
sprintf('Today is %s',WeekDays.Friday)
an =
    Today is Friday
```

The automatic conversion of enumeration classes to char enable you to use enumeration members in this case.
**Enumeration Arrays**

Create enumeration arrays by:

- Concatenating enumeration members using `[]`
- Assigning enumeration members to an array using indexed assignment

Create an enumeration array of class `WeekDays` by concatenating enumeration members:

```matlab
wd = [WeekDays.Tuesday, WeekDays.Wednesday, WeekDays.Friday];
```

Create an enumeration array of class `WeekDays` by indexed assignment:

```matlab
a(1) = WeekDays.Tuesday;
a(2) = WeekDays.Wednesday;
a(3) = WeekDays.Friday;
```

**Mixed Enumeration Members and char Vectors**

You can concatenate enumeration members and `char` vectors as long as the `char` vector represents an enumeration member.

```matlab
clear a
a = [WeekDays.Wednesday, 'Friday'];
class(a)
ans = WeekDays
```

You can also assign a `char` vector to an enumeration array:

```matlab
clear a
a(1) = WeekDays.Wednesday;
a(2) = 'Friday';
class(a)
ans = WeekDays
```

**Default Enumeration Member**

The default member an enumeration class is the first enumeration member defined in the enumeration block. For the `WeekDays` class, the default enumeration member is `WeekDays.Monday`.

```matlab
classdef WeekDays
    enumeration
        Monday, Tuesday, Wednesday, Thursday, Friday
    end
end
```

MATLAB allows assignment to any element of an array, even if the array variable does not previously exist. To fill in unassigned array elements, MATLAB uses the default enumeration member.

For example, assign a value to element 5 of an array, `a`:
clear a
a(5) = WeekDays.Tuesday;

MATLAB must initialize the values of array elements \( a(1:4) \) with the default enumeration member. The result of the assignment to the fifth element of the array \( a \) is:

\[
a = \\
\text{Monday} \quad \text{Monday} \quad \text{Monday} \quad \text{Monday} \quad \text{Tuesday}
\]

See Also

Related Examples

- “Operations on Enumerations” on page 14-16
Enumerations for Property Values

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</tbody>
</table>

**Syntax for Property/Enumeration Definition**

You can restrict the values that are allowed for a property to members of an enumeration class. Define the property as restricted to a specific enumeration class in the class definition using this syntax:

```
properties
    PropName EnumerationClass
end
```

This syntax restricts values of PropName to members of the enumeration class EnumerationClass.

**Example of Restricted Property**

For example, the Days class defines a property named Today. The allowed values for the Today property are enumeration members of the WeekDays class.

The WeekDays class defines the enumerations:

```
classdef WeekDays
enumeration
    Monday, Tuesday, Wednesday, Thursday, Friday
end
end
```

Use the WeekDays enumerations to restrict the allowed values of the Today property:

```
classdef Days
properties
    Today WeekDays
end
end
```

Create an object of the Days class.

```
d = Days;
d.Today = WeekDays.Tuesday;
d =
```

Days with properties:

Today: Tuesday

**Representing Enumeration Members with char Vectors**

The automatic conversion feature enables users of the Days class to assign values to the Today property as either enumeration members, char vectors, or string scalars. The Today property is
restricted to members of the WeekDays enumeration class. Therefore, you can assign a char vector that represents a member of the WeekDays class.

```matlab
d = Days;
d.Today = 'Tuesday';
```

Also, you can use a string scalar:

```matlab
d = Days;
d.Today = "Tuesday";
```

For more information on restricting property values, see “Validate Property Values” on page 8-20 and “Property Class and Size Validation” on page 8-25.
Operations on Enumerations

In this section...

"Operations Supported by Enumerations" on page 14-16
"Enumeration Class" on page 14-16
"Default Methods" on page 14-16
"Convert Enumeration Member to Characters" on page 14-17
"Convert Enumeration Array to Cell Array of char Vectors" on page 14-17
"Enumerations and char Vectors in Relational Operations" on page 14-17
"Enumerations in switch Statements" on page 14-18
"Enumeration Set Membership" on page 14-19
"Enumeration Text Comparison Methods" on page 14-20
"How to Get Information About Enumerations" on page 14-20
"Testing for an Enumeration" on page 14-20

Operations Supported by Enumerations

You can use logical, set membership, and string comparison operations on enumerations. These operations also allow the use of enumeration in conditional statements, such as switch and if statements. Converters enable you to use char vectors and cell arrays of strings as enumerations.

Enumeration Class

The WeekDays class defines members that enumerate days of the week. This topic uses the WeekDays class to illustrate how to perform operations on enumerations.

```matlab
classdef WeekDays
enumeration
    Monday, Tuesday, Wednesday, Thursday, Friday
end
end
```

For information on defining enumerations, see “Define Enumeration Classes” on page 14-4.

Default Methods

Enumeration classes have the following default methods:

```matlab
methods('WeekDays')
```

Methods for class WeekDays:

<table>
<thead>
<tr>
<th>Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>WeekDays</td>
<td>char</td>
</tr>
<tr>
<td>cellstr</td>
<td>eq</td>
</tr>
<tr>
<td>intersect</td>
<td>ismember</td>
</tr>
<tr>
<td>setdiff</td>
<td>strcmp</td>
</tr>
<tr>
<td>strcmp</td>
<td>strcmpi</td>
</tr>
<tr>
<td>strncmp</td>
<td>union</td>
</tr>
</tbody>
</table>

The WeekDays method converts char vectors, a cell array of char vectors, or string array elements to enumerations.

Other methods behave similarly to the equivalent function when used with enumerations. For information on a specific method, see the documentation for that function.
### Convert Enumeration Member to Characters

Conversion to `char` is useful because you can define enumeration members with descriptive names. For example:

```matlab
today = WeekDays.Friday;
['Today is ',char(today)]
```

```plaintext
ans =
Today is Friday
```

### Convert Enumeration Array to Cell Array of char Vectors

Use `cellstr` to convert an enumeration array to a cell array of `char` vectors.

```matlab
cia = cellstr([WeekDays.Tuesday,WeekDays.Thursday]);
class(ca)
```

```plaintext
ans =
cell
```

Both cells in the cell array contain `char` vectors:

```matlab
class([ca{1:2}])
```

```plaintext
ans =
char
```

### Enumerations and char Vectors in Relational Operations

Expression involving the relational operators, `eq` and `ne`, in which one operand is an enumeration allow the other operand to be of type `char`. Before performing the operation, MATLAB converts `char` vectors to scalar enumerations or cell arrays of `char` vectors to enumeration arrays.

**Note**  Enumeration classes that derive from MATLAB built-in classes cannot substitute `char` vectors for enumeration members.

```matlab
today = WeekDays.Friday;
today == 'Friday'
```

```plaintext
ans =
1
```

Compare enumeration array to `char` vector:

```matlab
wd = [WeekDays.Monday,WeekDays.Wednesday,WeekDays.Friday];
wd == 'Friday'
```

```plaintext
```
Compare enumeration array to cell array of char vectors:

```matlab
ans =
     0     0     1
```

```matlab
cv = {'Monday','Wednesday','Friday'};
md = [WeekDays.Tuesday,WeekDays.Thursday,WeekDays.Friday];
md ~= cv
```

```matlab
ans =
     1     1     0
```

The char vector Wednesday is equal to (==) the enumeration member WeekDays.Wednesday. You can use this equality in conditional statements:

```matlab
today = 'Wednesday';
if today == WeekDays.Wednesday
    disp('Team meeting at 2:00')
end
```

### Enumerations in switch Statements

Equality (eq) and inequality (ne) methods enable you to use enumeration members in switch statements. For example, using the WeekDays class defined previously, construct a switch statement:

```matlab
function c = Reminder(day)
    % Add error checking here
    switch(day)
        case WeekDays.Monday
            c = 'Department meeting at 10:00';
        case WeekDays.Tuesday
            c = 'Meeting Free Day!';
        case {WeekDays.Wednesday WeekDays.Friday}
            c = 'Team meeting at 2:00';
        case WeekDays.Thursday
            c = 'Volleyball night';
    end
end
```

Pass a member of the WeekDays enumeration class to the Reminder function:

```matlab
today = WeekDays.Wednesday;
Reminder(today)
```

```matlab
ans =
    Team meeting at 2:00
```

For more information, see “Objects In Conditional Statements” on page 5-29.

### Substitute char Vectors

**Note** Enumeration classes that derive from MATLAB built-in classes cannot substitute char vectors for enumeration members.
You can use char vectors to represent specific enumeration members:

```matlab
function c = Reminder2(day)
    switch(day)
        case 'Monday'
            c = 'Department meeting at 10:00';
        case 'Tuesday'
            c = 'Meeting Free Day!';
        case {'Wednesday' 'Friday'}
            c = 'Team meeting at 2:00';
        case 'Thursday'
            c = 'Volleyball night';
    end
end
```

Although you can use char vectors instead of specifying enumerations explicitly, MATLAB must convert the char to an enumeration. Eliminate the need for this conversion if it is not necessary.

**Enumeration Set Membership**

Enumeration classes provide methods to determine set membership.

- `ismember` — True for elements of an enumeration array if in a set
- `setdiff` — Set difference for enumeration arrays
- `intersect` — Set intersection for enumeration arrays
- `setxor` — Set exclusive-or for enumeration arrays
- `union` — Set union for enumeration arrays

Determine if today is a meeting day for your team. Create a set of enumeration members corresponding to the days on which the team has meetings.

```matlab
today = WeekDays.Tuesday;
teamMeetings = [WeekDays.Wednesday WeekDays.Friday];
```

Use `ismember` to determine if `today` is part of the `teamMeetings` set:

```matlab
ismember(today,teamMeetings)
ans =
0
```

**Mixed Sets of Enumeration and char**

If you pass both enumeration and char arguments to an enumeration class method, the class attempts to convert the char to the class of the enumeration.

Determine if char vector is a member of the enumeration array.

```matlab
teamMeetings = [WeekDays.Wednesday WeekDays.Friday];
ismember('Friday',teamMeetings)
ans =
1
```

Determine if the enumeration member is a member of the cell array of char vectors.
Enumeration Text Comparison Methods

Enumeration classes provide methods to compare enumeration members with char vectors. One of the arguments to the string comparison method must be a char vector. Comparing two enumeration members returns false.

- `strcmp` — Compare enumeration members
- `strncmp` — Compare first n characters of enumeration members
- `strcmpi` — Case insensitive comparison of enumeration members
- `strncmpi` — Case insensitive first n character comparison of enumeration members

Comparing Enumeration Member with char Vector

The string comparison methods can compare enumeration members and char vectors.

today = WeekDays.Tuesday;
strcmp(today,'Friday')
ans =
0

strcmp(today,'Tuesday')
ans =
1

How to Get Information About Enumerations

Obtain information about enumeration classes using the `enumeration` function. For example:

```
enumeration WeekDays

Enumeration members for class 'WeekDays':
  Monday
  Tuesday
  Wednesday
  Thursday
  Friday

See also "Metaclass EnumeratedValues Property" on page 16-7
```

Testing for an Enumeration

To determine if a variable is an enumeration, use the `isenum` function. For example:
today = WeekDays.Wednesday;
isenum(today)

ans =
   1

isenum returns true for empty enumeration objects:

noday = WeekDays.empty;
isenum(noday)

ans =
   1

To determine if the class of a variable class is an enumeration class, use the meta.class object.

today = WeekDays.Wednesday;
mc = metaclass(today);
mc.Enumeration

ans =
   1

See Also

Related Examples
•   “Enumeration Class Restrictions” on page 14-25
Hide Enumeration Members

Hiding enumeration members enables class authors to change enumeration member names without causing incompatibilities in existing code. To hide members, create an enumeration block that sets the `Hidden` attribute. Members defined in a `Hidden` enumeration block are not visible when enumeration members are queried using the `enumeration` function.

When an enumeration class derives from another class, such as a numeric or logical class, then each member can have a value associated with it. If two members have the same value assigned to them, then the member defined first in the class definition masks the second member. Both names are valid enumeration members, but the first one defined is the primary member. While masking makes it possible to use one member name in place of another, it does not hide the secondary name from the class users.

Using the `Hidden` attribute removes the masked member names from user view. For example, the `HighlightColor` class defines enumeration members that represent syntax highlighting colors.

```matlab
classdef HighlightColor < int32
    enumeration
        red   (1)
        green (2)
        blue  (3)
    end
end
```

A new version of the class uses more descriptive member names, but the class needs to avoid breaking existing code that uses the original member names, red, green, and blue. Using the `Hidden` attribute for enumeration members enables the class to hide the original members.

```matlab
classdef HighlightColor < int32
    enumeration
        error   (1)
        comment (2)
        keyword (3)
    end
    enumeration (Hidden)
        red   (1)
        green (2)
        blue  (3)
    end
end
```

Code that uses the original member names continues to work. For example, existing references to the now-hidden member `HighlightColor.blue` is compatible with the same-valued nonhidden member `HighlightColor.keyword`.

```matlab
% a = HighlightColor.blue
a =
    HighlightColor enumeration
    keyword
a == HighlightColor.Keyword
```
ans =

logical

1

For enumeration members that represent values, the first member defined in the class is the primary member for that value. For example, in the HighlightColor class, keyword is the primary member and blue is the secondary member, both representing the value 3. Typically, the primary member is not hidden while the secondary member is hidden. However, if the class design requires that the primary member is hidden, then the secondary member must be hidden too.

**Hide Pure Enumerations**

Pure enumeration members have no underlying values, so there is no way to identify one member as a replacement for another. However, you can use the `Hidden` attribute to remove a member from the user view while avoiding incompatibilities with existing uses of the hidden member.

For example, the PCComponents class defines enumerations that are used in an online form for a computer order. While the FloppyDrive component is obsolete, the enumeration member can remain in the class as a hidden member. The form can exclude FloppyDrive from the list of choices, but the class author can keep this member available so that existing forms that refer to FloppyDrive are still valid.

```matlab
classdef PCComponents
    enumeration
        USBSlots
        CDPlayer
    end
    enumeration (Hidden)
        FloppyDrive
    end
end
```

**Find Hidden Enumeration Members**

Find information about hidden enumeration members using class metadata. The `meta.EnumeratedValue` class provides information on enumeration members. For example, accessing the metadata for the HighlightColor class used in preceding examples can show the names of hidden members.

```matlab
mc = ?HighlightColor
mc =

class with properties:

    Name: 'HighlightColor'
    Description: '
    DetailedDescription: 'Hidden: 0
    Sealed: 0
    Abstract: 0
    Enumeration: 1
    ConstructOnLoad: 0
```
Each enumeration member is described by a `meta.EnumeratedValue` object that is contained in the `EnumerationMemberList` property. For example, the fourth element in the `EnumerationMemberList` array contains the `meta.EnumerationValue` object for the member with the name `red`.

```matlab
mc.EnumerationMemberList(4)
ans =

EnumeratedValue with properties:
    Name: 'red'
    Description: ''
    DetailedDescription: ''
    Hidden: 1
```

To list the names of all hidden members, use the handle class `findobj` method:

```matlab
findobj(mc.EnumerationMemberList,'Hidden',true).Name
ans =
    'red'

ans =
    'green'

ans =
    'blue'
```

**See Also**

`enumeration` | `findobj`
Enumeration Class Restrictions

Enumeration classes restrict certain aspects of their use and definition:

• Enumeration classes are implicitly sealed. You cannot define a subclass of an enumeration class because doing so would expand the set.

• The properties of value-based enumeration classes are immutable. Only the constructor can assign property values. MATLAB implicitly defines the SetAccess attributes of all properties defined by value-based enumeration classes as immutable. You cannot set the SetAccess attribute to any other value.

• All properties inherited by a value-based enumeration class that are not defined as constant must have immutable SetAccess.

• The properties of handle-based enumeration classes are mutable. You can set property values on instances of the enumeration class. See “Mutable Handle vs. Immutable Value Enumeration Members” on page 14-31.

• An enumeration member cannot have the same name as a property, method, or event defined by the same class.

• Enumerations do not support colon (a:b) operations. For example, FlowRate.Low:FlowRate.High causes an error even if the FlowRate class derives from a numeric superclass.

• Classes that define enumerations cannot restrict properties of the same class to an enumeration type. Create a separate enumeration class to restrict property values to an enumeration. For information on restricting property values, see “Example of Restricted Property” on page 14-14.

• If the primary enumeration member sets the Hidden attribute, then the secondary member (one with the same underlying value) must also set the Hidden attribute. For more information, see See Also

See Also

Related Examples

• “Enumerations Derived from Built-In Classes” on page 14-26
Enumerations Derived from Built-In Classes

### In this section...
- “Subclassing Built-In Classes” on page 14-26
- “Derive Enumeration Class from Numeric Class” on page 14-26
- “How to Alias Enumeration Names” on page 14-27
- “Superclass Constructor Returns Underlying Value” on page 14-28
- “Default Converter” on page 14-29

### Subclassing Built-In Classes

Enumeration classes can subclass MATLAB built-in classes. Deriving an enumeration class from built-in classes is useful to extend the usefulness of the enumeration members.

- Enumerations inherit functionality from the built-in class.
- You can associate a numeric or logical value with enumeration members.

For a more basic discussion of enumeration classes, see “Define Enumeration Classes” on page 14-4.

### Derive Enumeration Class from Numeric Class

**Note** Enumeration classes derived from built-in numeric and logical classes cannot define properties.

If an enumeration class subclasses a built-in numeric class, the subclass inherits ordering and arithmetic operations that you can apply to the enumerated names.

For example, the `Results` class subclasses the `int32` built-in class. This class associates an integer value with each of the four enumeration members — `First`, `Second`, `Third`, and `NoPoints`.

```matlab
classdef Results < int32
    enumeration
        First   (100)
        Second  (50)
        Third   (10)
        NoPlace (0)
    end
end
```

The enumeration member inherits the methods of the `int32` class (except the colon operator). Use these enumerations like numeric values (summed, sorted, averaged).

```matlab
isa(Results.Second,'int32')
```

```matlab
ans =
    1
```

For example, use enumeration names instead of numbers to rank two teams:

```matlab
Team1 = [Results.First, Results.NoPlace, Results.Third, Results.Second];
Team2 = [Results.Second, Results.Third, Results.First, Results.First];
```
Perform int32 operations on these Results enumerations:

```matlab
sum(Team1)
ans =
    160
mean(Team1)
ans =
    40
sort(Team2,'descend')
ans =
    First    First    Second    Third
Team1 > Team2
ans =
    1     0     0     0
sum(Team1) < sum(Team2)
ans =
    1
```

**How to Create Enumeration Instances**

When you first refer to an enumeration class that derives from a built-in class such as, int32, MATLAB passes the input arguments associated with the enumeration members to the superclass constructor. For example, referencing the Second Results member, defined as:

Second (50)

means that MATLAB calls:

```matlab
int32(50)
```

to initialize the int32 aspect of this Results object.

**How to Alias Enumeration Names**

Enumeration classes that derive from MATLAB built-in numeric and logical classes can define more than one name for an underlying value. The first name in the enumeration block with a given underlying value is the actual name for that underlying value and subsequent names are aliases.

Specify aliased names with the same superclass constructor argument as the actual name:

```matlab
classdef Bool < logical
    enumeration
        No  (0)
        Yes (1)
        off (0)
```
For example, the actual name of an instance of the Bool.off enumeration member is No:

```
a = Bool.No
a = No
b = Bool.off
b = No
```

**Superclass Constructor Returns Underlying Value**

The actual underlying value associated with an enumeration member is the value returned by the built-in superclass. For example, consider the `Bool` class defined with constructor arguments that are of class `double`:

```
classdef Bool < logical
    enumeration
        No  (0)
        Yes (100)
    end
end
```

This class derives from the built-in `logical` class. Therefore, underlying values for an enumeration member depend only on what value `logical` returns when passed that value:

```
a = Bool.Yes
a = Yes
logical(a)
ans = 1
```

**How to Subclass Numeric Built-In Classes**

The `FlowRate` enumeration class defines three members, Low, Medium, and High.

```
classdef FlowRate < int32
    enumeration
        Low    (10)
        Medium (50)
        High   (100)
    end
end
```

Reference an instance of an enumeration member:
setFlow = FlowRate.Medium;

This statement causes MATLAB to call the default constructor with the argument value of 50. MATLAB passes this argument to the first superclass constructor (int32(50) in this case). The result is an underlying value of 50 as a 32-bit integer for the FlowRate.Medium member.

Because FlowRate subclasses a built-in numeric class (int32), this class cannot define properties. However FlowRate inherits int32 methods including a converter method. Programs can use the converter to obtain the underlying value:

```
setFlow = FlowRate.Medium;
int32(setFlow)
```
```
ans =
 50
```

**Default Converter**

If an enumeration is a subclass of a built-in numeric class, you can convert from built-in numeric data to the enumeration using the name of the enumeration class. For example:

```
a = Bool(1)
a =
  Yes
```

An enumerated class also accepts enumeration members of its own class as input arguments:

```
Bool(a)
```
```
ans =
  Yes
```

The converter returns an object of the same size as in input:

```
Bool([0,1])
```
```
ans =
  No     Yes
```

Create an empty enumeration array using the empty static method:

```
Bool.empty
```
```
ans =
0x0 empty Boolean enumeration.
```
See Also

Related Examples
• “Mutable Handle vs. Immutable Value Enumeration Members” on page 14-31
• “Fundamental MATLAB Classes”
Mutable Handle vs. Immutable Value Enumeration Members

In this section...

- "Select Handle- or Value-Based Enumerations" on page 14-31
- "Value-Based Enumeration Classes" on page 14-31
- "Handle-Based Enumeration Classes" on page 14-32
- "Represent State with Enumerations" on page 14-34

Select Handle- or Value-Based Enumerations

Use a handle enumeration to enumerate a set of objects whose state can change over time. Use a value enumeration to enumerate a set of abstract (and immutable) values. For information about handle and value classes, see “Comparison of Handle and Value Classes” on page 7-2.

Value-Based Enumeration Classes

A value-based enumeration class has a fixed set of specific values. Modify these values by changing the values of properties. Doing so expands or changes the fixed set of values for this enumeration class.

Inherited Property SetAccess Must Be Immutable

Value-based enumeration classes implicitly define the SetAccess attributes of all properties as immutable. You cannot set the SetAccess attribute to any other value.

However, all superclass properties must explicitly define property SetAccess as immutable.

Enumeration Members Remain Constant

An instance of a value-based enumeration class is unique until the class is cleared and reloaded. For example, given this class:

```matlab
classdef WeekDays
    enumeration
        Monday, Tuesday, Wednesday, Thursday, Friday
    end
end
```

MATLAB considers `a` and `b` as equivalent:

```matlab
a = WeekDays.Monday;
b = WeekDays.Monday;
isequal(a,b)
```

```matlab
ans =
    1
```

```matlab
a == b
```

```matlab
ans =
    1
```
Enumeration Member Properties Remain Constant

Value-based enumeration classes that define properties are immutable. For example, the Colors enumeration class associates RGB values with color names.

```matlab
classdef Colors
    properties
        R = 0
        G = 0
        B = 0
    end
    methods
        function c = Colors(r,g,b)
            c.R = r; c.G = g; c.B = b;
        end
    end
    enumeration
        Red   (1, 0, 0)
        Green (0, 1, 0)
        Blue  (0, 0, 1)
    end
end
```

The constructor assigns the input arguments to R, G, and B properties:

```matlab
red = Colors.Red;
```

```
ans =
    1     0     0
```

You cannot change a property value:

```matlab
red.G = 1;
```

You cannot set the read-only property 'G' of Colors.

Handle-Based Enumeration Classes

Handle-based enumeration classes that define properties are mutable. Derive enumeration classes from the handle class when you must be able to change property values on instances of that class.

**Note** You cannot derive an enumeration class from `matlab.mixin.Copyable` because the number of instances you can create are limited to the ones defined inside the enumeration block.

An Enumeration Member Remains Constant

Given a handle-based enumeration class with properties, changing the property value of an instance causes all references to that instance to reflect the changed value.

For example, the HandleColors enumeration class associates RGB values with color names, the same as the Colors class in the previous example. However, HandleColors derives from handle:

```matlab
classdef HandleColors < handle
    properties
```
R = 0
G = 0
B = 0
end
methods
    function c = HandleColors(r, g, b)
        c.R = r; c.G = g; c.B = b;
    end
end
enumeration
    Red    (1, 0, 0)
    Green  (0, 1, 0)
    Blue   (0, 0, 1)
end
end

Create an instance of HandleColors.Red and return the value of the R property:

    a = HandleColors.Red;
    a.R

ans =

    1

MATLAB constructs the HandleColors.Red enumeration member, which sets the R property to 1, the G property to 0, and the B property to 0.

Change the value of the R property to 0.8:

    a.R = 0.8;

After setting the value of the R property to 0.8, create another instance, b, of HandleColors.Red:

    b = HandleColors.Red;
    b.R

ans =

    0.8000

The value of the R property of the newly created instance is also 0.8. A MATLAB session has only one value for any enumeration member at any given time.

Clearing the workspace variables does not change the current definition of the enumeration member HandleColors.Red:

    clear
    a = HandleColors.Red;
    a.R

ans =

    0.8000

Clear the class to reload the definition of the HandleColors class:
clear classes
a = HandleColors.Red;
a.R
ans =
  1

To prevent reassignment of a given property value, set that property's SetAccess attribute to immutable.

Equality of Handle-Based Enumerations

Assign two variables to a particular enumeration member:

a = HandleColors.Red;
b = HandleColors.Red;

Compare a and b using isequal:

isequal(a,b)
an =
  1

The property values of a and b are the same, so isequal returns true. However, unlike handle classes that are not enumeration classes, a and b are the same handle because there is only one enumeration member. Determine handle equality using == (the handle eq method).

a == b
ans =
  1

See the handle eq method for information on how isequal and == differ when used with handles.

Represent State with Enumerations

The MachineState class defines two enumeration members to represent the state of a machine, either running or not running.

classdef MachineState
    enumeration
        Running
        NotRunning
    end
end

The Machine class represents a machine with start and stop operations. The MachineState enumerations are easy to work with because of their eq and char methods, and they result in code that is easy to read.

classdef Machine < handle
    properties (SetAccess = private)
        State = MachineState.NotRunning
        }
end

methods
function start(machine)
    if machine.State == MachineState.NotRunning
        machine.State = MachineState.Running;
    end
    disp (machine.State.char)
end

function stop(machine)
    if machine.State == MachineState.Running
        machine.State = MachineState.NotRunning;
    end
    disp (machine.State.char)
end

end

Create a Machine object and call start and stop methods

m = Machine;
m.start

Running

m.stop

NotRunning

See Also

Related Examples
• "Enumerations That Encapsulate Data" on page 14-36
Enumerations That Encapsulate Data

In this section...

“Enumeration Classes with Properties” on page 14-36
“Store Data in Properties” on page 14-36

Enumeration Classes with Properties

Enumeration classes can define properties to store data values. The enumeration members represent specific values for these properties, which MATLAB assigns in the class constructor. For information on defining enumeration classes, see “Define Enumeration Classes” on page 14-4.

Store Data in Properties

Note  Enumeration classes that subclass built-in numeric or logical classes cannot define or inherit properties. For more information on this kind of enumeration class, see “Enumerations Derived from Built-In Classes” on page 14-26.

Define properties in an enumeration class if you want to associate specific data with enumeration members, but do not need to inherit arithmetic, ordering, or other operations that MATLAB defines for specific built-in classes.

Representing Colors

Define an enumeration class to represent the RGB values of the colors in a color set. The Colors class defines names for the colors, each of which uses the RGB values as arguments to the class constructor:

```matlab
classdef Colors
    properties
        R = 0
        G = 0
        B = 0
    end
    methods
        function c = Colors(r, g, b)
            c.R = r; c.G = g; c.B = b;
        end
    end
    enumeration
        Blueish   (18/255,104/255,179/255)
        Reddish   (237/255,36/255,38/255)
        Greenish  (155/255,190/255,61/255)
        Purplish  (123/255,45/255,116/255)
        Yellowish (1,199/255,0)
        LightBlue (77/255,190/255,238/255)
    end
end
```

You can access the property values via the enumeration member:

```
Colors.Reddish.R
```
Suppose that you want to create a plot with the new shade of red named Reddish:

```matlab
a = Colors.Reddish;
```

Use these values by accessing the enumeration member properties. For example, the `myPlot` function accepts a `Colors` enumeration member as an input argument. The function accesses the RGB values defining the color from the property values.

```matlab
function h = myPlot(x, y, LineColor)
    h = line('XData', x, 'YData', y);
    r = LineColor.R;
    g = LineColor.G;
    b = LineColor.B;
    h.Color = [r g b];
end
```

The `Colors` class encapsulates the definitions of a standard set of colors. You can change the enumeration class definition of the colors and not affect functions that use the enumerations.

### Enumerations Defining Categories

The `Cars` class defines categories used to inventory automobiles. The `Cars` class derives from the `CarPainter` class, which derives from `handle`. The abstract `CarPainter` class defines a paint method, which modifies the `Color` property when a car is painted another color.

The `Cars` class uses the `Colors` enumeration members to specify a finite set of available colors. The exact definition of any given color can change independently of the `Cars` class.

```matlab
classdef Cars < CarPainter
    enumeration
        Hybrid (2, 'Manual', 55, Colors.Reddish)
        MiniVan(6, 'Automatic', 24, Colors.Blueish)
        SUV (8, 'Automatic', 12, Colors.Yellowish)
    end
    properties  (SetAccess = private)
        Cylinders
        Transmission
        MPG
        Color
    end
    methods
        function obj = Cars(cyl, trans, mpg, colr)
            obj.Cylinders = cyl;
            obj.Transmission = trans;
```
function paint(obj,colorobj)
    if isa(colorobj,'Colors')
        obj.Color = colorobj;
    else
        [~,cls] = enumeration('Colors');
        disp('Not an available color')
        disp(cls)
    end
end
end
end

The CarPainter class requires its subclasses to define a method called `paint`:

```matlab
classdef CarPainter < handle
    methods (Abstract)
        paint(carobj,colorobj)
    end
end
```

Define an instance of the `Cars` class:

```matlab
c1 = Cars.Compact;
```

The color of this car is `Greenish`, as defined by the `Colors.Greenish` enumeration:

```matlab
c1.Color
ans =

    Greenish
```

Use the `paint` method to change the car color:

```matlab
c1.paint(Colors.Reddish)
c1.Color
ans =

    Reddish
```

See Also

Related Examples

- “Save and Load Enumerations” on page 14-39
- “Enumerations for Property Values” on page 14-14
Save and Load Enumerations

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Basic Knowledge

See the `save` and `load` functions and “Save and Load Process for Objects” on page 13-2 for general information on saving and loading objects.

To see a list of enumeration names defined by a class, use the `enumeration` function.

Built-In and Value-Based Enumeration Classes

When you save enumerations that derive from built-in classes or that are value-based classes with properties, MATLAB saves the names of the enumeration members and the definition of each member.

When loading these enumerations, MATLAB preserves names over underlying values. If the saved named value is different from the current class definition, MATLAB uses the value defined in the current class, and then issues a warning.

Simple and Handle-Based Enumeration Classes

When you save simple enumerations that have no properties, superclasses, or values associated with the member names or enumerations derived from the `handle` class, MATLAB saves the names and any underlying values.

When loading these types of enumerations, MATLAB does not check the values associated with the names in the current class definition. This behavior results from the fact that simple enumerations have no underlying values and handle-based enumerations can legally have values that are different than those values defined by the class.

Causes: Load as struct Instead of Object

If you add a new named value or a new property to a class after saving an enumeration, MATLAB does not warn during load.

If the changes to the enumeration class definition do not prevent MATLAB from loading the object (that is, all the named values in the MAT-File are present in the modified class definition), then MATLAB issues a warning that the class has changed and loads the enumeration.

In the following cases, MATLAB issues a warning and loads as much of the saved data as possible as a struct:

- MATLAB cannot find the class definition
• The class is no longer an enumeration class
• MATLAB cannot initialize the class
• There are one or more enumeration members in the loaded enumeration that is not in the class definition
• If the class is a value-based enumeration with properties and a property that exists in the file, is not present in the class definition

**struct Fields**

The returned **struct** has these fields:

• **ValueNames** — A cell array of strings, one per unique value in the enumeration array.
• **Values** — An array of the same dimension as **ValueNames** containing the corresponding values of the enumeration members named in **ValueNames**. Depending on the kind of enumeration class, **Values** can be one of the following:
  • If the enumeration class derives from a built-in class, the array class is the same as the built-in class. The values in the array are the underlying values of each enumeration member.
  • Otherwise, a **struct** array representing the property name — property values pairs of each enumeration member. For simple and handle-based enumerations, the **struct** array has no fields.
• **ValueIndices** — a **uint32** array of the same size as the original enumeration. Each element is an index into the **ValueNames** and **Values** arrays. The content of **ValueIndices** represents the value of each object in the original enumeration array.

**See Also**

**More About**

• “Named Values” on page 14-2
Constant Properties
Define Class Properties with Constant Values

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Defining Named Constants

You can define constants that you can refer to by name by creating a MATLAB class that defines constant properties.

Use constant properties to define constant values that you can access by name. Create a class with constant properties by declaring the **Constant** attribute in the property blocks. Setting the **Constant** attribute means that, once initialized to the value specified in the property block, the value cannot be changed.

Assigning Values to Constant Properties

Assign any value to a **Constant** property, including a MATLAB expression. For example:

```matlab
classdef NamedConst
    properties (Constant)
       R = pi/180
       D = 1/NamedConst.R
       AccCode = '0145968740001110202NPQ'
       RN = rand(5)
    end
end
```

MATLAB evaluates the expressions when loading the class. Therefore, the values MATLAB assigns to RN are the result of a single call to the rand function and do not change with subsequent references to NamedConst.RN. Calling clear classes causes MATLAB to reload the class and reinitialize the constant properties.

Referencing Constant Properties

Refer to the constant using the class name and the property name:

```
ClassName.PropName
```

For example, to use the NamedConst class defined in the previous section, reference the constant for the degree to radian conversion, R:

```matlab
radi = 45*NamedConst.R
radi =

0.7854
```

Constants in Packages

To create a library for constant values that you can access by name, first create a package folder, then define the various classes to organize the constants. For example, to implement a set of
constants that are useful for making astronomical calculations, define a `AstroConstants` class in a package called `constants`:

```
+constants/@AstroConstants/AstroConstants.m
```

The class defines a set of `Constant` properties with values assigned:

```matlab
classdef AstroConstants
    properties (Constant)
        C = 2.99792458e8 % m/s
        G = 6.67259 % m/kgs
        Me = 5.976e24 % Earth mass (kg)
        Re = 6.378e6 % Earth radius (m)
    end
end
```

To use this set of constants, reference them with a fully qualified class name. For example, the following function uses some of the constants defined in `AstroConstants`:

```matlab
function E = energyToOrbit(m,r)
    E = constants.AstroConstants.G * constants.AstroConstants.Me * m * ...
        (1/constants.AstroConstants.Re-0.5*r);
end
```

Importing the package into the function eliminates the need to repeat the package name (see `import`):

```matlab
function E = energyToOrbit(m,r)
    import constants::*;
    E = AstroConstants.G * AstroConstants.Me * m * ...
        (1/AstroConstants.Re - 0.5 * r);
end
```

### Constant Property Assigned a Handle Object

If a class defines a constant property with a value that is a handle object, you can assign values to the handle object properties. To access the handle object, create a local variable.

For example, the `ConstMapClass` class defines a constant property. The value of the constant property is a handle object (a `containers.Map` object).

```matlab
classdef ConstMapClass < handle
    properties (Constant)
        ConstMapProp = containers.Map
    end
end
```

To assign the current date to the `Date` key, return the handle from the constant property, then make the assignment using the local variable on the left side of the assignment statement:

```matlab
localMap = ConstMapClass.ConstMapProp
localMap('Date') = datestr(clock);
```

You cannot use a reference to a constant property on the left side of an assignment statement. For example, MATLAB interprets the following statement as the creation of a `struct` named `ConstMapClass` with a field `ConstMapProp`:

```matlab
ConstMapClass.ConstMapProp('Date') = datestr(clock);
```
Constant Property Assigned Any Object

You can assign an instance of the defining class to a constant property. MATLAB creates the instance assigned to the constant property when loading the class. Use this technique only when the defining class is a handle class.

The MyProject is an example of such a class:

classdef MyProject < handle
    properties (Constant)
        ProjectInfo = MyProject
    end
    properties
        Date
        Department
        ProjectNumber
    end
    methods (Access = private)
        function obj = MyProject
            obj.Date = datestr(clock);
            obj.Department = 'Engineering';
            obj.ProjectNumber = 'P29.367';
        end
    end
end

Reference property data via the Constant property:

MyProject.ProjectInfo.Date
ans =
    18-Apr-2002 09:56:59

Because MyProject is a handle class, you can get the handle to the instance that is assigned to the constant property:

p = MyProject.ProjectInfo;

Access the data in the MyProject class using this handle:

p.Department
ans =
    Engineering

Modify the nonconstant properties of the MyProject class using this handle:

p.Department = 'Quality Assurance';

p is a handle to the instance of MyProject that is assigned to the ProjectInfo constant property:

MyProject.ProjectInfo.Department
ans =
    Quality Assurance
Clearing the class results in the assignment of a new instance of `MyProject` to the `ProjectInfo` property.

```matlab
clear MyProject
MyProject.ProjectInfo.Department
ans =
Engineering
```

You can assign an instance of the defining class as the default value of a property only when the property is declared as `Constant`.

**Constant Properties — No Support for Get Events**

Constant properties do not support property `PreGet` or `PostGet` events. MATLAB issues a warning during class initialization if you set the `GetObservable` attribute of a `Constant` property to `true`.

**See Also**

**Related Examples**

- “Static Data” on page 4-2

**More About**

- “Named Values” on page 14-2
Information from Class Metadata

- “Class Metadata” on page 16-2
- “Class Introspection with Metadata” on page 16-5
- “Find Objects with Specific Values” on page 16-9
- “Get Information About Properties” on page 16-12
- “Find Default Values in Property Metadata” on page 16-17
Class Metadata

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What Is Class Metadata?

Class metadata is information about class definitions that is available from various metaclasses objects. Use metaclass objects to obtain information without having to create instances of the class. Metadata enables the programmatic inspection of classes. Each metaclass has properties, methods, and events that contain information about the class or class component it describes.

All class components have an associated metaclass, which you access from the meta.class object. For example, create the meta.class object for the matlab.mixin.Copyable class:

```matlab
mc = ?matlab.mixin.Copyable
```

```matlab
class with properties:
    Name: 'matlab.mixin.Copyable'
    Description: 'Implement copy method for handle objects in MA...'
    DetailedDescription: ''
    Hidden: 0
    Sealed: 0
    Abstract: 1
    Enumeration: 0
    ConstructOnLoad: 1
    HandleCompatible: 1
    InferiorClasses: {0x1 cell}
    ContainingPackage: [1x1 meta.package]
    PropertyList: [0x1 meta.property]
    MethodList: [19x1 meta.method]
    EventList: [1x1 meta.event]
    EnumerationMemberList: [0x1 meta.EnumeratedValue]
    SuperclassList: [1x1 meta.class]
```

The meta Package

The meta package contains metaclasses that describe the definition of classes and class components. The class name indicates the component described by the metaclass. For example, each class property has a meta.property associated with it. Attributes defined for class components correspond to properties in the respective metaclass object.

- meta.package — Access from meta.class ContainingPackage property.
- meta.class — Create from class name or class object using metaclass function or ? operator.
- meta.property — Access from meta.class PropertyList property.
- meta.DynamicProperty — Obtain from the addprop method.
- meta.method — Access from meta.class MethodList property.
- meta.event — Access from meta.class EventList property.
• meta.EnumeratedValue — Access from meta.class EnumerationMemberListList property.

**Metaclass Objects**

You cannot instantiate metaclasses directly by calling the respective class constructor. Create metaclass objects from class instances or from the class name.

- `?ClassName` — Returns a meta.class object for the named class. Use `meta.class.fromName` with class names stored as characters in variables.
- `meta.class.fromName('ClassName')` — returns the meta.class object for the named class (meta.class.fromName is a meta.class method).
- `metaclass(obj)` — Returns a metaclass object for the class instance (metaclass)

Create `meta.class` object from class name using the `?` operator:
```matlab
mc = ?MyClass;
```

Create `meta.class` object from class name using the `fromName` method:
```matlab
mc = meta.class.fromName('MyClass');
```

Create `meta.class` object from class instance
```matlab
obj = MyClass;
mc = metaclass(obj);
```

The `metaclass` function returns the `meta.class` object (that is, an object of the `meta.class` class). You can obtain other metaclass objects (`meta.property`, `meta.method`, and so on) from the `meta.class` object.

**Note** Metaclass is a term used here to refer to all the classes in the meta package. `meta.class` is a class in the meta package whose instances contain information about MATLAB classes. Metadata is information about classes contained in metaclasses.

**Metaclass Object Lifecycle**

When you change a class definition, MATLAB reloads the class definition. If instances of the class exist, MATLAB updates those objects according to the new definition.

However, MATLAB does not update existing metaclass objects to the new class definition. If you change a class definition while metaclass objects of that class exist, MATLAB deletes the metaclass objects and their handles become invalid. You must create a new metaclass object after updating the class.

For information on how to modify and reload classes, see “Automatic Updates for Modified Classes” on page 5-39.
See Also

Related Examples
- “Class Introspection with Metadata” on page 16-5
- “Find Objects with Specific Values” on page 16-9
- “Get Information About Properties” on page 16-12
- “Find Default Values in Property Metadata” on page 16-17
Class Introspection with Metadata

Using Class Metadata

Use class metadata to get information about classes and objects programmatically. For example, you can determine attribute values for class members or get a list of events defined by the class. For basic information about metadata, see “Class Metadata” on page 16-2.

Inspect the EmployeeData Class

The EmployeeData class is a handle class with two properties, one of which has private Access and defines a set access method.

```matlab
classdef EmployeeData < handle
    properties
        EmployeeName
    end
    properties (Access = private)
        EmployeeNumber
    end
    methods
        function obj = EmployeeData(name,ss)
            if nargin > 0
                obj.EmployeeName = name;
                obj.EmployeeNumber = ss;
            end
        end
        function set.EmployeeName(obj,name)
            if ischar(name)
                obj.EmployeeName = name;
            else
                error('Employee name must be a char vector')
            end
        end
    end
end
```

Inspect Class Definition

Using the EmployeeData class, create a meta.class object using the ? operator:

```matlab
mc = ?EmployeeData;
```

Determine from what classes EmployeeData derives. The returned value is a meta.class object for the handle superclass:

```matlab
a = mc.SuperclassList;
a.Name
```
The EmployeeData class has only one superclass. For classes having more than one direct superclass, a contains a meta.class object for each superclass.

Use an indexed reference to refer to any particular superclass:

```matlab
a(1).Name
```
or, directly from mc:

```matlab
mc.SuperclassList(1).Name
```

The SuperclassList property contains only direct superclasses.

**Inspect Properties**

Find the names of the properties defined by the EmployeeData class. First obtain an array of meta.properties objects from the meta.class PropertyList property.

```matlab
mc = ?EmployeeData;
mpArray = mc.PropertyList;
```
The length of mpArray indicates that there are two meta.property objects, one for each property defined by the EmployeeData class:

```matlab
length(mpArray)
ans =
   2
```
Now get a meta.property object from the array:

```matlab
prop1 = mpArray(1);
prop1.Name
ans =
EmployeeName
```
The Name property of the meta.property object identifies the class property represented by that meta.property object.

Query other meta.property object properties to determine the attributes of the EmployeeName properties.

**Find Component with Specific Attribute**

You can use indexing techniques to list class components that have specific attribute values. For example, this code lists the methods in the EmployeeData class that have private access:

```matlab
mc = ?EmployeeData;
mc.PropertyList(ismember({mc.PropertyList(:).SetAccess},'private')).Name
```
ans =
EmployeeNumber

Access is not a property of the meta.property class. Use SetAccess and GetAccess, which are properties of the meta.property class.

Find components with attributes that are logical values using a statement like this one:

mc = ?handle;
mc.MethodList(ismember([mc.MethodList(:).Hidden],true)).Name

ans =
empty

**Inspect Class Instance**

Create an EmployeeData object and determine property access settings:

EdObj = EmployeeData('My Name',1234567);
mcEdObj = metaclass(EdObj);
mpArray = mcEdObj.PropertyList;
EdObj.(mpArray(1).Name) % Dynamic field names work with objects

The value of the EmployeeName property is the text My Name, which was assigned in the constructor.

ans =
My Name

The value of the EmployeeNumber property is not accessible because the property has private Access.

EdObj.(mpArray(2).Name)

You cannot get the 'EmployeeNumber' property of EmployeeData.

mpArray(2).GetAccess

ans =
private

Obtain a function handle to the EmployeeName property set access function:

mpArray(1).SetMethod

ans =
@D:\MyDir\@EmployeeData\EmployeeData.m>EmployeeData.set.EmployeeName

**Metaclass EnumeratedValues Property**

The meta.class EnumeratedValues property contains an array of meta.EnumeratedValue objects, one for each enumeration member. Use the meta.EnumeratedValue Name property to obtain the enumeration member names defined by an enumeration class. For example, given the WeekDays enumeration class:

```matlab
classdef WeekDays
    enumeration
        Monday, Tuesday, Wednesday, Thursday, Friday
```
Query enumeration names from the `meta.class` object:

```plaintext
mc = ?WeekDays;
mc.EnumerationMemberList(2).Name

ans =
Tuesday
```

**See Also**

**Related Examples**

- “Find Objects with Specific Values” on page 16-9
Find Objects with Specific Values

In this section...

"Find Handle Objects" on page 16-9
"Find by Attribute Settings" on page 16-10

Find Handle Objects

Use the handle class findobj method to find objects that have properties with specific values. For example, the following class defines a PhoneBook object to represent a telephone book entry in a data base. The PhoneBook class subclasses the dynamicprops class, which derives from handle.

```matlab
classdef PhoneBook < dynamicprops
    properties
        Name
        Address
        Number
    end
    methods
        function obj = PhoneBook(n,a,p)
            obj.Name = n;
            obj.Address = a;
            obj.Number = p;
        end
    end
end
```

Here are three of the PhoneBook entries in the database:

```matlab
PB(1) = PhoneBook('Nancy Vidal','123 Washington Street','5081234567');
PB(2) = PhoneBook('Nancy Vidal','123 Main Street','5081234568');
PB(3) = PhoneBook('Nancy Wong','123 South Street','5081234569');
```

One of these three PhoneBook objects has a dynamic property:

```matlab
PB(2).addprop('HighSpeedInternet');
PB(2).HighSpeedInternet = '1M';
```

Find Property/Value Pairs

Find the object representing employee Nancy Wong and display the name and number by concatenating the strings:

```matlab
NW = findobj(PB,'Name','Nancy Wong');
[NW.Name,' - ',NW.Number]
ans =
Nancy Wong - 5081234569
```

Find Objects with Specific Property Names

Search for objects with specific property names using the -property option:

```matlab
H = findobj(PB,'-property','HighSpeedInternet');
H.HighSpeedInternet
```
The -property option enables you to omit the value of the property and search for objects using only the property name.

**Using Logical Expressions**

Search for specific combinations of property names and values:

```matlab
H = findobj(PB, 'Name', 'Nancy Vidal', '-and', 'Address', '123 Main Street');
H.Number
```

```matlab
ans =
5081234568
```

**Find by Attribute Settings**

All metaclasses derive from the `handle` class. You can use the `handle` `findobj` method to find class members that have specific attribute settings.

For example, find the abstract methods in a class definition by searching the `meta.class MethodList` for `meta.method` objects with their Abstract property set to true:

Use the class name in character format because class is abstract. You cannot create an object of the class:

```matlab
mc = meta.class.fromName('MyClass');
```

Search the MethodList list of `meta.method` objects for those methods that have their Abstract property set to true:

```matlab
absMethods = findobj(mc.MethodList, 'Abstract', true);
methodNames = {absMethods.Name};
```

The cell array, `methodNames`, contains the names of the abstract methods in the class.

**Find Properties That Have Public Get Access**

Find the names of all properties in the `containers.Map` class that have public GetAccess:

- Get the `meta.class` object.
- Use `findobj` to search the array of `meta.property` objects.
- Use braces to create a cell array of property names.

```matlab
mc = ?containers.Map;
mpArray = findobj(mc.PropertyList, 'GetAccess', 'public');
names = {mpArray.Name};
```

Display the names of all `containers.Map` properties that have public GetAccess:

```matlab
celldisp(names)
```
Count
names{2} =
KeyType
names{3} =
ValueType

**Find Static Methods**

Determine if any `containers.Map` class methods are static:

```matlab
~isempty(findobj([mc.MethodList(:)], 'Static', true))
```

ans =

1

`findobj` returns an array of `meta.method` objects for the static methods. In this case, the list of static methods is not empty. Therefore, there are static methods defined by this class.

Get the names of any static methods from the `meta.method` array:

```matlab
staticMethodInfo = findobj([mc.MethodList(:)], 'Static', true);
staticMethodInfo(:).Name
```

ans =

`empty`

The name of the static method (there is only one in this case) is `empty`. Here is the information from the `meta.method` object for the `empty` method:

```matlab
staticMethodInfo
```

method with properties:

- **Name**: `empty`
- **Description**: 'Returns an empty object array of the given size'
- **DetailedDescription**: ''
- **Access**: 'public'
- **Static**: 1
- **Abstract**: 0
- **Sealed**: 0
- **Hidden**: 1
- **InputNames**: {'varargin'}
- **OutputNames**: {'E'}
- **DefiningClass**: [1x1 meta.class]

**See Also**

`empty`

**Related Examples**

- “Get Information About Properties” on page 16-12
Get Information About Properties

In this section...

“The meta.property Object” on page 16-12
“How to Find Properties with Specific Attributes” on page 16-14

The meta.property Object

Use the meta.property class to determine the values of property attributes. The writable properties of a meta.property object correspond to the attributes of the associated property. The values of the writable meta.property properties correspond to the attribute values specified in the class definition.

Get the meta.property object for a property from the meta.class object. To get the meta.class object for a class:

- Use the metaclass function on an object of the class.
- Use the ? operator with the class name.

For example, the BasicHandle class defines three properties:

```matlab
classdef BasicHandle < handle
    properties (SetAccess = private)
        Date = date
        PassKey = randi(9,[1,7])
    end
    properties
        Category {mustBeMember(Category,{'new','change'})} = 'new'
    end
end
```

Create the meta.class object using the ? operator with the class name:

```matlab
mc = ?BasicHandle
```

```matlab
mc =
```

```matlab
class with properties:
```
```matlab
Name: 'BasicHandle'
Description: '
DetailedDescription: '
Hidden: 0
Sealed: 0
Abstract: 0
Enumeration: 0
ConstructOnLoad: 0
HandleCompatible: 1
InferiorClasses: {0x1 cell}
ContainingPackage: [0x0 meta.package]
RestrictsSubclassing: 0
PropertyList: [3x1 meta.property]
MethodList: [22x1 meta.method]
EventList: [1x1 meta.event]
```
The `meta.class` object property named `PropertyList` contains an array of `meta.property` objects, one for each property defined by the class. For example, the name of the property associated with the `meta.property` object in element 1 is:

```plaintext
mc.PropertyList(1).Name
```

```plaintext
ans =
Date
```

The `meta.class` object contains a `meta.property` object for all properties, including hidden properties. The `properties` function returns only public properties.

For a handle class, use the `handle findprop` method to get the `meta.property` object for a specific property.

For example, find the `meta.property` object for the `Category` property of the `BasicHandle` class.

```plaintext
mp = findprop(BasicHandle,'Category')
```

```plaintext
mp =

property with properties:
    Name: 'Category'
    Description: '
    DetailedDescription: '
    GetAccess: 'public'
    SetAccess: 'public'
    Dependent: 0
    Constant: 0
    Abstract: 0
    Transient: 0
    Hidden: 0
    GetObservable: 0
    SetObservable: 0
    AbortSet: 0
    NonCopyable: 0
    GetMethod: []
    SetMethod: []
    HasDefault: 1
    DefaultValue: 'new'
    DefiningClass: [1×1 meta.class]
```

The preceding `meta.property` display shows that a default `BasicHandle` object `Category` property:

- Has public `GetAccess` and `SetAccess`
- Has a default value of `new`

For a list of property attributes, see “Table of Property Attributes” on page 8-7.
How to Index Metaclass Objects

Access other metaclass objects directly from the `meta.class` object properties. For example, the statement:

```matlab
mc = ?containers.Map;
```

returns a `meta.class` object:

```matlab
class(mc)
ans =
meta.class
```

Referencing the `PropertyList` `meta.class` property returns an array with one `meta.property` object for each property of the `containers.Map` class:

```matlab
class(mc.PropertyList)
ans =
meta.property
```

Each array element is a single `meta.property` object:

```matlab
mc.Properties(1)
ans =
[1x1 meta.property]
```

The `Name` property of the `meta.property` object contains a `char` vector that is the name of the property:

```matlab
class(mc.PropertyList(1).Name)
ans =
char
```

Apply standard MATLAB indexing to access information in metaclass objects.

For example, the `meta.class PropertyList` property contains an array of `meta.property` objects. The following expression accesses the first `meta.property` object in this array and returns the first and last (C and t) letters of the `char` vector contained in the `meta.property Name` property.

```matlab
mc.PropertyList(1).Name([1 end])
ans =
Ct
```

How to Find Properties with Specific Attributes

This example implements a function that finds properties with specific attribute values. For example, you can:
• Find objects that define constant properties (Constant attribute set to true).
• Determine what properties are read-only (GetAccess = public, SetAccess = private).

The `findAttrValue` function returns a cell array of property names that set the specified attribute.

The `findAttrValue` function accesses information from metadata using these techniques:

• If input argument, `obj`, is a char vector, use the `meta.class.fromName` static method to get the `meta.class` object.
• If input argument, `obj`, is an object, use the `metaclass` function to get the `meta.class` object.
• Every property has an associated `meta.property` object. Obtain these objects from the `meta.class.PropertyList` property.
• Use the handle class `findprop` method to determine if the requested property attribute is a valid attribute name. All property attributes are properties of the `meta.property` object. The statement, `findobj(mp,'PropertyName')` determines whether the `meta.property` object, `mp`, has a property called `PropertyName`.
• Reference `meta.property` object properties using dynamic field names. For example, if `attrName = 'Constant'`, then MATLAB converts the expression `mp.(attrName)` to `mp.Constant`.
• The optional third argument enables you to specify the value of attributes whose values are not logical true or false (such as GetAccess and SetAccess).

```matlab
function cl_out = findAttrValue(obj, attrName, varargin)
    if ischar(obj)
        mc = meta.class.fromName(obj);
    elseif isobject(obj)
        mc = metaclass(obj);
    end
    ii = 0; numb_props = length(mc.PropertyList);
    cl_array = cell(1,numb_props);
    for c = 1:numb_props
        mp = mc.PropertyList(c);
        if isempty(findprop(mp, attrName))
            error('Not a valid attribute name')
        end
        attrValue = mp.(attrName);
        if attrValue
            if islogical(attrValue) || strcmp(varargin{1}, attrValue)
                ii = ii + 1;
                cl_array(ii) = {mp.Name};
            end
        end
    end
    cl_out = cl_array(1:ii);
end
```

**Find Property Attributes**

Suppose that you have the following `containers.Map` object:

```matlab
mapobj = containers.Map({'rose','bicycle'},{'flower','machine'});
```

Find properties with private SetAccess:

```matlab
findAttrValue(mapobj,'SetAccess','private')
```
ans =
    'Count'    'KeyType'    'ValueType'    'serialization'

Find properties with public GetAccess:
findAttrValue(mapobj,'GetAccess','public')
ans =
    'Count'    'KeyType'    'ValueType'

**See Also**

**Related Examples**
- “Find Default Values in Property Metadata” on page 16-17
Find Default Values in Property Metadata

In this section...

“Default Values” on page 16-17
“meta.property Data” on page 16-17

Default Values

Class definitions can specify explicit default values for properties (see “Property Default Values” on page 8-14). Determine if a class defines an explicit default value for a property and what the value of the default is from the property meta.property object.

meta.property Data

The meta.class object for a class contains a meta.property object for every property defined by the class, including properties with private and protected access.

For example, get the meta.class object for the PropertyWithDefault class shown here:

classdef PropertyWithDefault
    properties
        Date = date
        RandNumber = randi(9)
    end
end

Get an array of meta.property objects from the meta.class object:

mc = ?PropertyWithDefault; % meta.class object
mp = mc.PropertyList; % meta.property array

The second element in the mp array is the meta.property object for the RandNumber property. Listing the meta.property object shows the information contained in its properties:

mp(2)

    property with properties:

        Name: 'RandNumber'
        Description: ''
        DetailedDescription: ''
        GetAccess: 'public'
        SetAccess: 'public'
        Dependent: 0
        Constant: 0
        Abstract: 0
        Transient: 0
        Hidden: 0
        GetObservable: 0
        SetObservable: 0
        AbortSet: 0
        NonCopyable: 0
        GetMethod: []
        SetMethod: []
Two of the listed `meta.property` properties provide information on default values:

- **HasDefault** — true (displayed as 1) if the class specifies a default value for the property, false if it does not.
- **DefaultValue** — Contains the default value, when the class defines a default value for the property. If the default value is an expression, the value of `DefaultValue` is the result of evaluating the expression.

For more information on the evaluation of property default values defined by expressions, see “Evaluation of Expressions in Class Definitions” on page 6-8.

These properties provide a programmatic way to obtain property default values without opening class definition files. Use these `meta.property` object properties to obtain property default values for both built-in classes and classes defined in MATLAB code.

**Query Default Value**

The procedure for querying a default value involves:

1. Getting the `meta.property` object for the property whose default value you want to query.
2. Testing the logical value of the `meta.property HasDefault` property to determine if the property defines a default value. MATLAB returns an error when you query the `DefaultValue` property if the class does not define a default value for the property.
3. Obtaining the default value from the `meta.property DefaultValue` property if the `HasDefault` value is true.

Use the `?` operator, the `metaclass` function, or the `meta.class.fromName` static method (works with char vector variable) to obtain a `meta.class` object.

The `meta.class` object `PropertyList` contains an array of `meta.property` objects. Identify which property corresponds to which `meta.property` object using the `meta.property Name` property.

For example, this class defines properties with default values:

```matlab
classdef MyDefs
    properties
        Material = 'acrylic'
        InitialValue = 1.0
    end
end
```

Follow these steps to obtain the default value defined for the `Material` property. Include any error checking that is necessary for your application.

1. Get the `meta.class` object for the class:
   ```matlab
   mc = ?MyDefs;
   ```
2. Get an array of `meta.property` objects from the `meta.class PropertyList` property:
   ```matlab
   mp = mc.PropertyList;
   ```
3. The length of the `mp` array equals the number of properties. You can use the `meta.property Name` property to find the property of interest:
for k = 1:length(mp)
    if (strcmp(mp(k).Name,'Material'))
        ...
4
Before querying the default value of the Material property, test the HasDefault meta.property to determine if MyClass defines a default property for this property:

```
if mp(k).HasDefault
    dv = mp(k).DefaultValue;
end
```

The DefaultValue property is read-only. Changing the default value in the class definition changes the value of DefaultValue property. You can query the default value of a property regardless of its access settings.

Abstract and dynamic properties cannot define default values. Therefore, MATLAB returns an error if you attempt to query the default value of properties with these attributes. Always test the logical value of the meta.property HasDefault property before querying the DefaultValue property to avoid generating an error.

**Default Values Defined as Expressions**

Class definitions can define property default values as MATLAB expressions (see “Evaluation of Expressions in Class Definitions” on page 6-8 for more information). MATLAB evaluates these expressions the first time the default value is needed, such as the first time you create an instance of the class.

Querying the meta.property DefaultValue property causes MATLAB to evaluate a default value expression, if it had not yet been evaluated. Therefore, querying a property default value can return an error or warning if errors or warnings occur when MATLAB evaluates the expression. See “Property with Expression That Errors” on page 16-20 for an example.

**Property with No Explicit Default Value**

MyClass does not explicitly define a default value for the Foo property:

```
classdef MyFoo
    properties
        Foo
    end
end
```

The meta.property instance for property Foo has a value of false for HasDefault. Because the class does not explicitly define a default value for Foo, attempting to access the DefaultValue property causes an error:

```
mc = ?MyFoo;
mp = mc.PropertyList(1);
mp.HasDefault
ans =

    0

dv = mp.DefaultValue;
```

No default value has been defined for property Foo

16-19
Abstract Property

MyClass defines the Foo property as Abstract:

```matlab
classdef MyAbst
    properties (Abstract)
        Foo
    end
end
```

The `meta.property` instance for property Foo has a value of `false` for its `HasDefault` property because you cannot define a default value for an `Abstract` property. Attempting to access `DefaultValue` causes an error:

```matlab
mc = ?MyAbst;
mp = mc.PropertyList(1);
mp.HasDefault
```

ans =

0

dv = mp.DefaultValue;

Property Foo is abstract and therefore cannot have a default value.

Property with Expression That Errors

MyPropEr defines the Foo property default value as an expression that errors when evaluated.

```matlab
classdef MyPropEr
    properties
        Foo = sin(pie/2)
    end
end
```

The `meta.property` object for property Foo has a value of `true` for its `HasDefault` property because Foo does have a default value:

```
sin(pie/2)
```

However, this expression returns an error (`pie` is a function that creates a pie graph, not the value `pi`).

```matlab
mc = ?MyPropEr;
mp = mc.PropertyList(1);
mp.HasDefault
```

ans =

1

dv = mp.DefaultValue;

Error using pie (line 29)
Not enough input arguments.

Querying the default value causes the evaluation of the expression and returns the error.
Property With Explicitly Defined Default Value of Empty

MyEmptyProp assigns a default of [] (empty double) to the Foo property:

```matlab
classdef MyEmptyProp
    properties
        Foo = []
    end
end
```

The `meta.property` object for property Foo has a value of true for its HasDefault property. Accessing DefaultValue returns the value []:

```matlab
mc = ?MyEmptyProp;
mp = mc.PropertyList(1);
mp.HasDefault
ans =
    1
dv = mp.DefaultValue;
dv =
    []
```

See Also

Related Examples

- “Get Information About Properties” on page 16-12
Specialize Object Behavior

- “Methods That Modify Default Behavior” on page 17-2
- “Number of Arguments for subsref and subsasgn” on page 17-5
- “Modify nargout and nargin for Indexing Methods” on page 17-7
- “Concatenation Methods” on page 17-9
- “Object Converters” on page 17-10
- “Object Array Indexing” on page 17-12
- “Code Patterns for subsref and subsasgn Methods” on page 17-17
- “Indexed Reference” on page 17-23
- “Indexed Assignment” on page 17-25
- “end as Object Index” on page 17-28
- “Objects in Index Expressions” on page 17-30
- “Class with Modified Indexing” on page 17-32
- “Operator Overloading” on page 17-38
Methods That Modify Default Behavior

In this section...

“How to Customize Class Behavior” on page 17-2
“How Which Methods Control Which Behaviors” on page 17-2
“Overload Functions and Override Methods” on page 17-3

How to Customize Class Behavior

There are functions that MATLAB calls implicitly when you perform certain actions with objects. For example, a statement like \[ B(1); A(3) \] involves indexed reference and vertical concatenation.

You can change how user-defined objects behave by defining methods that control specific behaviors. To change a behavior, implement the appropriate method with the name and signature of the MATLAB function.

Which Methods Control Which Behaviors

The following table lists the methods to implement for your class and describes the behaviors that they control.

<table>
<thead>
<tr>
<th>Class Method to Implement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concatenating Objects</td>
<td></td>
</tr>
<tr>
<td>cat, horzcat, and vertcat</td>
<td>Customize behavior when concatenating objects</td>
</tr>
<tr>
<td></td>
<td>See “Subclasses of Built-In Types with Properties” on page 12-54</td>
</tr>
<tr>
<td>Creating Empty Arrays</td>
<td></td>
</tr>
<tr>
<td>empty</td>
<td>Create empty arrays of the specified class. See “Empty Arrays” on page 10-7</td>
</tr>
<tr>
<td>Displaying Objects</td>
<td></td>
</tr>
<tr>
<td>disp</td>
<td>Called when you enter disp(obj) on the command line</td>
</tr>
<tr>
<td>display</td>
<td>Called by statements that are not terminated by semicolons. disp is often used to implement display methods.</td>
</tr>
<tr>
<td></td>
<td>See “Overloading the disp Function” on page 18-34</td>
</tr>
<tr>
<td></td>
<td>See “Custom Display Interface” on page 18-2</td>
</tr>
<tr>
<td>Converting Objects to Other Classes</td>
<td>Convert an object to a MATLAB built-in class</td>
</tr>
<tr>
<td>converters like double and char</td>
<td>See “The Character Converter” on page 19-12 and “The Double Converter” on page 19-11</td>
</tr>
<tr>
<td>Indexing Objects</td>
<td></td>
</tr>
<tr>
<td>Class Method to Implement</td>
<td>Description</td>
</tr>
<tr>
<td>---------------------------</td>
<td>-------------</td>
</tr>
<tr>
<td>subsref and subsasgn</td>
<td>Enables you to create nonstandard indexed reference and indexed assignment</td>
</tr>
<tr>
<td></td>
<td>See “Object Array Indexing” on page 17-12</td>
</tr>
<tr>
<td>end</td>
<td>Supports end syntax in indexing expressions using an object; e.g., A(1:end)</td>
</tr>
<tr>
<td></td>
<td>See “end as Object Index” on page 17-28</td>
</tr>
<tr>
<td>numel</td>
<td>Determine the number of elements in an array</td>
</tr>
<tr>
<td></td>
<td>See “Modify nargin and nargout for Indexing Methods” on page 17-7</td>
</tr>
<tr>
<td>numArgumentsFromSubscript</td>
<td>Overload to specify the number of values to return from indexing expressions.</td>
</tr>
<tr>
<td></td>
<td>See “Number of Arguments for subsref and subsasgn” on page 17-5</td>
</tr>
<tr>
<td>size</td>
<td>Determine the dimensions of an array</td>
</tr>
<tr>
<td></td>
<td>See “Use of size and numel with Classes” on page 12-61</td>
</tr>
<tr>
<td>subsindex</td>
<td>Support using an object in indexing expressions</td>
</tr>
<tr>
<td></td>
<td>See “Objects in Index Expressions” on page 17-30</td>
</tr>
<tr>
<td>Saving and Loading Objects</td>
<td></td>
</tr>
<tr>
<td>loadobj and saveobj</td>
<td>Customize behavior when loading and saving objects</td>
</tr>
<tr>
<td></td>
<td>See “Object Save and Load”</td>
</tr>
<tr>
<td>Reshape and Rearrange</td>
<td></td>
</tr>
<tr>
<td>permute</td>
<td>Rearrange dimensions of N-D array</td>
</tr>
<tr>
<td>transpose</td>
<td>Transpose vector or matrix</td>
</tr>
<tr>
<td>ctranspose</td>
<td>Complex conjugate transpose</td>
</tr>
<tr>
<td>reshape</td>
<td>Reshape array</td>
</tr>
<tr>
<td>Determine Size and Shape</td>
<td></td>
</tr>
<tr>
<td>isscalar</td>
<td>Determine if the input is a scalar</td>
</tr>
<tr>
<td>isvector</td>
<td>Determine if the input is a vector</td>
</tr>
<tr>
<td>ismatrix</td>
<td>Determine if the input is a matrix</td>
</tr>
<tr>
<td>isempty</td>
<td>Determine if the input is empty</td>
</tr>
</tbody>
</table>

**Overload Functions and Override Methods**

Overloading and overriding are terms that describe techniques for customizing class behavior. Here is how we use these terms in MATLAB.
**Overloading**

Overloading means that there is more than one function or method having the same name within the same scope. MATLAB dispatches to a particular function or method based on the dominant argument. For example, the `timeseries` class overloads the MATLAB `plot` function. When you call `plot` with a `timeseries` object as an input argument, MATLAB calls the `timeseries` class method named `plot`.

To call the nonoverloaded function, use the `builtin` function.

**Overriding**

Overriding means redefining a method inherited from a superclass. MATLAB dispatches to the most specific version of the method. That is, if the dominant argument is an object of the subclass, then MATLAB calls the subclass method.

To control class dominance, use the `InferiorClasses` attribute.

**See Also**

**Related Examples**

- “Overload Functions in Class Definitions” on page 9-26
- “Object Precedence in Method Invocation” on page 9-36
- “Operator Overloading” on page 17-38
In this section...

"How MATLAB Determines Number of Arguments" on page 17-5
"Syntax for subsref, and subsasgn Methods" on page 17-6

How MATLAB Determines Number of Arguments

MATLAB calls \texttt{subsref} or \texttt{subsasgn} to determine the result of executing code that involves indexed reference or assignment. The number of elements referenced or assigned by an indexing operation determines the number of arguments MATLAB uses to call \texttt{subsref} and \texttt{subsasgn}. That is, the indexing code determines the number of arguments that MATLAB:

- Returns from the call to \texttt{subsref}
- Passes to the call to \texttt{subsasgn}

Therefore, the indexing code determines the value of \texttt{nargout} for the call to \texttt{subsref} and the value of \texttt{nargin} for the call to \texttt{subsasgn}.

For example, consider the \texttt{ValuesArray} class.

```matlab
classdef ValuesArray
    properties
        Values
    end
    methods
        function obj = ValuesArray(v)
            if nargin > 0
                obj.Values = v;
            end
        end
    end
end
```

Create an array of 10 \texttt{ValuesArray} objects.

```matlab
l = ValuesArray.empty;
for k = 1:10
    l(k) = ValuesArray(k);
end
```

This subscripted reference returns a comma-separated list of three elements. For this statement, the value of \texttt{nargout} in \texttt{subsref} is 3.

```matlab
l(1:3).Values
ans =
    1

ans =
    2
```
ans =
3

The left side of a subscripted assignment statement affects the number of input arguments that MATLAB uses to call subsasgn. This subscripted assignment assigns three values to the three elements added to the array. For this assignment, the value of nargin within subsasgn is 5 (the object, the indexing substructure, and the three values to assign).

[l(1:13).Values] = l(1:3).Values

l =

1x13 ValuesArray array with properties:
  Values

If the number of right-side arguments cannot satisfy the number of left-side arguments, MATLAB returns an error:

[l(11:13).Values] = l(1).Values

Insufficient number of outputs from right hand side of equal sign to satisfy assignment.

**Syntax for subsref, and subsasgn Methods**

If a class overloads subsref to support either '[]', '.', or both types of indexing, and the operation returns more than one value, overload subsref to return multiple values using varargin:

function varargout = subsref(A,S)
  ... 
end

If a class overloads subsasgn to support either '[]', '.', or both types of indexing, and the operation assigns more than one value, overload subsasgn to accept multiple values using varargin:

function A = subsasgn(A,S,varargin)
  ... 
end

**See Also**

**More About**

-  “Modify nargout and nargin for Indexing Methods” on page 17-7
-  “Comma-Separated Lists”
Modify nargout and nargin for Indexing Methods

When to Modify Number of Arguments

By default, the number of values referenced by an indexing operation determines how many output arguments MATLAB uses to call \texttt{subsref}. Similarly, the number of values to assign in an indexed assignment operation determines how many input arguments MATLAB uses to call \texttt{subsasgn}.

If your class design requires that indexing operations return or assign a different number of values than the number defined by the indexing operation, use \texttt{numArgumentsFromSubscript} to specify the required number. \texttt{numArgumentsFromSubscript} provides control over \texttt{nargout} for \texttt{subsref} and \texttt{nargin} for \texttt{subsasgn}.

If your class uses \texttt{numArgumentsFromSubscript}, implement \texttt{subsref} and \texttt{subsasgn} methods to define the actual values returned or assigned by indexing operations.

Before MATLAB release R2015b, MATLAB produced different results for some indexing expressions that return or assign to a comma-separated list. Use \texttt{numArgumentsFromSubscript} to support code that relies on the behavior of previous releases. Also, now you can overload \texttt{numArgumentsFromSubscript} instead of \texttt{numel} to achieve specific results without redefining how \texttt{numel} works.

How to Modify Number of Arguments

When a class overloads \texttt{numArgumentsFromSubscript}, MATLAB calls this method instead of \texttt{numel} to compute the number of arguments expected for \texttt{subsref} \texttt{nargout} and \texttt{subsasgn} \texttt{nargin}.

If classes do not overload \texttt{numArgumentsFromSubscript}, MATLAB calls \texttt{numel} to compute the values of \texttt{nargout} or \texttt{nargin}.

MATLAB calls \texttt{numArgumentsFromSubscript} with three input arguments:

\begin{verbatim}
function n = numArgumentsFromSubscript(obj,s,indexingContext)
  ...
end
\end{verbatim}

<table>
<thead>
<tr>
<th>Input Argument</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>\texttt{obj}</td>
<td>Object whose \texttt{subsref} or \texttt{subsasgn} method is called</td>
</tr>
<tr>
<td>\texttt{s}</td>
<td>Indexing structure that contains the indexing type and indices used in the operation</td>
</tr>
<tr>
<td>\texttt{indexingContext}</td>
<td>Context in which the indexing operation occurs: indexed reference used as a statement, index reference used as a function argument, and indexed assignment</td>
</tr>
</tbody>
</table>

MATLAB uses the value returned by \texttt{numArgumentsFromSubscript} for indexed reference and assignment. Determine the context in which the indexing operation executes by testing the value of
indexingContext in your implementation of numArgumentsFromSubscript. For example, test for any or all the possible indexing contexts.

```matlab
function n = numArgumentsFromSubscript(obj,~,indexingContext)
    switch indexingContext
        case matlab.mixin.util.IndexingContext.Statement
            n = ...; % nargout for indexed reference used as statement
        case matlab.mixin.util.IndexingContext.Expression
            n = ...; % nargout for indexed reference used as function argument
        case matlab.mixin.util.IndexingContext.Assignment
            n = ...; % nargin for indexed assignment
    end
end
```

For more information and examples, see numArgumentsFromSubscript.

**Note** For MATLAB version R2015b and later releases, overload numArgumentsFromSubscript instead of numel to customize indexing for your class.

**See Also**

**More About**

- “Number of Arguments for subsref and subsasgn“ on page 17-5
- “Use of size and numel with Classes“ on page 12-61
Concatenation Methods

In this section...

“Default Concatenation” on page 17-9
“Methods to Overload” on page 17-9

Default Concatenation

You can concatenate objects into arrays. For example, suppose that you have three instances of the class MyClass, obj1, obj2, obj3. You can form arrays of these objects using brackets. Horizontal concatenation calls horzcat:

HorArray = [obj1, obj2, obj3];

HorArray is a 1-by-3 array of class MyClass. You can concatenate the objects along the vertical dimension, which calls vertcat:

VertArray = [obj1; obj2; obj3]

VertArray is a 3-by-1 array of class MyClass. To concatenate arrays along different dimensions, use the cat function. For example:

ndArray = cat(3, HorArray, HorArray);

dArray is a 1-by-3-by-2 array.

Methods to Overload

Overload horzcat, vertcat, and cat to produce specialized behaviors in your class. Overload both horzcat and vertcat whenever you want to modify object concatenation because MATLAB uses both functions for any concatenation operation.

See Also

Related Examples

• “Subclasses of Built-In Types with Properties” on page 12-54
Object Converters

Why Implement Converters

You can convert an object of one class to an object of another class. A converter method has the same name as the class it converts to, such as char or double. Think of a converter method as an overloaded constructor method of another class. The converter takes an instance of its own class and returns an object of a different class.

Converters enable you to:

• Use methods defined for another class
• Ensure that expressions involving objects of mixed class types execute properly
• Control how instances are interpreted in other contexts

Suppose that you define a polynomial class. If you create a double method for the polynomial class, you can use it to call other functions that require inputs of type double.

```matlab
p = polynomial(...);
dp = double(p);
roots(dp)
```

*p* is a polynomial object, *double* is a method of the polynomial class, and *roots* is a standard MATLAB function whose input arguments are the coefficients of a polynomial.

Converters for Package Classes

Classes defined in packages can have names that are a dot-separated list of names. The last name is a class and preceding names are packages. Name the conversion methods using the package qualifiers in the method names. For example, a conversion method to convert objects of MyClass to objects of the PkgName.PkgClass class uses this method name:

```matlab
classdef MyClass
    ...
    methods
        function objPkgClass = PkgName.PkgClass(objMyclass)
            ...
        end
    end
end
```

You cannot define a converter method that uses dots in the name in a separate file. Define package-class converters in the `classdef` file.
Converters and Subscripted Assignment

When you make a subscripted assignment statement like:

\[ A(1) = \text{myobj}; \]

MATLAB compares the class of the Right-Side variable to the class of the Left-Side variable. If the classes are different, MATLAB attempts to convert the Right-Side variable to the class of the Left-Side variable. To do this conversion, MATLAB first searches for a method of the Right-Side class that has the same name as the Left-Side class. Such a method is a converter method, which is similar to a typecast operation in other languages.

If the Right-Side class does not define a method to convert from the Right-Side class to the Left-Side class, MATLAB calls the Left-Side class constructor, passing it the Right-Side variable.

For example, suppose that you make the following assignments:

\[ A(1) = \text{objA}; \quad \text{Object of class ClassA} \]
\[ A(2) = \text{objB}; \quad \text{Object of class ClassB} \]

MATLAB attempts to call a method of ClassB named ClassA. If no such converter method exists, MATLAB software calls the ClassA constructor, passing objB as an argument. If the ClassA constructor cannot accept objB as an argument, then MATLAB returns an error.

Use cell arrays to store objects of different classes.

See Also

Related Examples

- “Converter Methods” on page 10-17
- “The Double Converter” on page 19-11
Object Array Indexing

In this section...

“Default Indexed Reference and Assignment” on page 17-12
“What You Can Modify” on page 17-13
“When to Modify Indexing Behavior” on page 17-13
“Built-In subsref and subsasgn Called in Methods” on page 17-14
“Avoid Overriding Access Attributes” on page 17-15

Default Indexed Reference and Assignment

MATLAB classes support object array indexing by default. Many class designs require no modification to this behavior.

Arrays enable you to reference and assign elements of the array using a subscripted notation. This notation specifies the indices of specific array elements. For example, suppose that you create two arrays of numbers (using `randi` and concatenation).

Create a 3-by-4 array of integers from 1 through 9:

\[
A = \text{randi}(9,3,4)
\]

\[
A =
\begin{bmatrix}
4 & 8 & 5 & 7 \\
4 & 2 & 6 & 3 \\
7 & 5 & 7 & 7 \\
\end{bmatrix}
\]

Create a 1-by-3 array of the numbers 3, 6, 9:

\[
B = [3 6 9]
\]

Reference and assign elements of either array using index values in parentheses:

\[
B(2) = A(3,4);
\]

\[
B =
\begin{bmatrix}
3 & 7 & 9 \\
\end{bmatrix}
\]

When you execute a statement that involves indexed reference:

\[
C = A(3,4);
\]

MATLAB calls the built-in `subsref` function to determine how to interpret the statement. Similarly, if you execute a statement that involves indexed assignment:

\[
C(4) = 7;
\]

MATLAB calls the built-in `subsasgn` function to determine how to interpret the statement.

The MATLAB default `subsref` and `subsasgn` functions also work with user-defined objects. For example, create an array of objects of the same class:
for k=1:3
    objArray(k) = MyClass;
end

Referencing the second element in the object array, `objArray`, returns the object constructed when k = 2:

D = objArray(2);
class(D)

ans =

MyClass

You can assign an object to an array of objects of the same class, or an uninitialized variable:

newArray(3,4) = D;

Arrays of objects behave much like numeric arrays in MATLAB. You do not need to implement any special methods to provide standard array behavior with your class.

For general information about array indexing, see “Array Indexing”.

**What You Can Modify**

You can modify your class indexed reference and/or assignment behavior by implementing class methods called `subsref` and `subsasgn`. For syntax description, see their respective reference pages.

Once you add a `subsref` or `subsasgn` method to your class, then MATLAB calls only the class method, not the built-in function. Therefore, your class method must implement all the indexed reference and assignment operations that you want your class to support. These operations include:

- Dot notation calls to class methods
- Dot notation reference and assignment involving properties
- Any indexing using parentheses `()`
- Any indexing using braces `{}`

Implementing `subsref` and `subsasgn` methods gives you complete control over the interpretation of indexing expressions for objects of your class. Implementing the extent of behaviors that MATLAB provides by default is nontrivial.

**When to Modify Indexing Behavior**

Default indexing for object arrays and dot notation for access to properties and methods enables user-defined objects to behave like built-in classes. For example, suppose that you define a class with a property called `Data` that contains an array of numeric data.

This statement:

```matlab
obj.Data(2,3)
```

Returns the value contained in the second row, third column of the array. If you have an array of objects, use an expression like:

```matlab
objArray(3).Data(2,3)
```
This statement returns the value contained in the second row, third column of the third element in the array.

Modify the default indexing behavior when your class design requires behavior that is different from MATLAB default behavior.

**Built-In subsref and subsasgn Called in Methods**

MATLAB does not call class-defined `subsref` or `subsasgn` methods within the overloaded methods. Within class methods, MATLAB always calls the built-in `subsref` and `subsasgn` functions. This behavior occurs within the class-defined `subsref` and `subsasgn` methods too.

For example, within a class method, this dot reference:

```
obj.Prop
```
calls the built-in `subsref` function. To call the class-defined `subsref` method, use:

```
subsref(obj,substruct('.','Prop'))
```

Whenever a method requires the functionality of the class-defined `subsref` or `subsasgn` method, the class must call the overloaded methods as functions. Do not use the operators, `()', '{}', or '.'.

For example, suppose that you define a class to represent polynomial. This class has a `subsref` method that evaluates the polynomial with the value of the independent variable equal to the subscript. Assume that this statement defines the polynomial with its coefficients:

```
p = polynom([1 0 -2 -5]);
```
The MATLAB expression for the resulting polynomial is:

```
x^3 - 2*x - 5
```
This subscripted expression returns the value of the polynomial at `x = 3`:

```
p(3)
```
```
an =
  16
```
Suppose that you want to use this feature in another class method. To do so, call the `subsref` function directly. The `evalEqual` method accepts two `polynom` objects and a value at which to evaluate the polynomials:

```
methods
  function ToF = evalEqual(p1,p2,x)
    % Create arguments for subsref
    subs.type = '()';
    subs.subs = {x};
    % Need to call subsref explicitly
    y1 = subsref(p1,subs);
    y2 = subsref(p2,subs);
    if y1 == y2
      ToF = true;
    else
      ToF = false;
  
```

This behavior enables you to use standard MATLAB indexing to implement specialized behaviors. See “Class with Modified Indexing” on page 17-32 for examples of how to use both built-in and class-modified indexing.

**Avoid Overriding Access Attributes**

Because `subsref` is a class method, it has access to private class members. Avoid inadvertently giving access to private methods and properties as you handle various types of reference. Consider this `subsref` method defined for a class having private properties, `x` and `y`:

```matlab
classdef MyPlot
    properties (Access = private)
        x
        y
    end
    properties
        Maximum
        Minimum
        Average
    end
    methods
        function obj = MyPlot(x,y)
            obj.x = x;
            obj.y = y;
            obj.Maximum = max(y);
            obj.Minimum = min(y);
            obj.Average = mean(y);
        end
        function B = subsref(A,S)
            switch S(1).type
                case '.
                    switch S(1).subs
                        case 'plot'
                            % Reference to A.x and A.y call built-in subsref
                            B = plot(A.x,A.y);
                        otherwise
                            % Enable dot notation for all properties and methods
                            B = A.(S.subs);
                    end
                end
            end
    end
end
```

This `subsref` enables the use of dot notation to create a plot using the name `'plot'`. The statement:

```matlab
obj = MyPlot(1:10,1:10);
handles = obj.plot;
```

calls the `plot` function and returns the handle to the graphics object.

You do not need to code each method and property name. The `otherwise` code in the inner `switch` block manages any name reference that you do not explicitly specify in `case` statements. However, using this technique exposes any private and protected class members via dot notation. For example, you can reference the private property, `x`, with this statement:

```matlab
obj.x
```
The same issue applies to writing a `subsasgn` method that enables assignment to private or protected properties. Your `subsref` and `subsasgn` methods might need to code each specific property and method name explicitly to avoid violating the class design.

**See Also**

**Related Examples**
- “Code Patterns for subsref and subsasgn Methods” on page 17-17
- “Indexed Reference” on page 17-23
- “Indexed Assignment” on page 17-25
# Code Patterns for subsref and subsasgn Methods

## In this section...

- “Customize Indexed Reference and Assignment” on page 17-17
- “Syntax for subsref and subsasgn Methods” on page 17-17
- “Indexing Structure Describes Indexing Expressions” on page 17-17
- “Values of the Indexing Structure” on page 17-18
- “Typical Patterns for Indexing Methods” on page 17-19

## Customize Indexed Reference and Assignment

User-defined classes have the same indexing behaviors as that of built-in classes. Classes can customize indexing operations by overloading the functions that MATLAB calls to evaluate indexing expressions. Overload the `subsref` and `subsasgn` functions when you want to define special behaviors for indexed reference and assignment.

For an overview of object indexing, see “Object Array Indexing” on page 17-12.

## Syntax for subsref and subsasgn Methods

MATLAB calls the `subsref` and `subsasgn` methods of your class with these arguments.

<table>
<thead>
<tr>
<th>Method</th>
<th>Input</th>
<th>Output</th>
</tr>
</thead>
</table>
| `b = subsref(obj,s)` | • `obj` — Object or object array used in indexing expression  
                  | • `s` — Indexing structure                   | `b` — Result of indexing expression         |
| `obj = subsasgn(obj,s,b)` | • `obj` — Object or object array used in indexing expression  
                            | • `s` — Indexing structure                    | `obj` — Object or object array after assignment |

### Modifying Number of Arguments

If your class design requires that indexing operations return or assign a different number of values than the number defined by the default indexing operation, overload the `numArgumentsFromSubscript` function to control `nargout` for `subsref` and `nargin` for `subsasgn`. For more information and examples, see `numArgumentsFromSubscript`.

## Indexing Structure Describes Indexing Expressions

The indexing structure contains information that describes the indexing expression. Class methods use the information in the indexing structure to evaluate the expression and implement custom behavior.

For example, the `CustomIndex` class defines a property that you can use in indexing expressions.

```matlab
classdef CustomIndex
    properties
        ...
```
Create an object and assign a 5-by-5 matrix created by the magic function to the DataArray property.

```matlab
a = CustomIndex;
a.DataArray = magic(5);
```

This subscripted reference expression returns the first row of the 5-by-5 matrix.

```matlab
a.DataArray(1,:)
```

```
ans =
    17    24     1     8    15
```

This expression assigns new values to the first row of the array stored in the DataArray property.

```matlab
a.DataArray(1,:) = [1 2 3 4 5];
```

This assignment statement uses:

- A `.' type reference
- A property name following the dot (that is, DataArray)
- A range of indices (1,:) within parentheses

The indexing structure contains this information in the type and subs fields.

### Values of the Indexing Structure

When executing an indexing expression, MATLAB calls the class `subsref` or `subsasgn` method, if the class overloads these functions. One of the arguments passed to the method is the indexing structure. The indexing structure has two fields:

- **type** — One of the three possible indexing types: `.'`, `'()'`, `'{}'`
- **subs** — A char vector with the property name or cell array of the indices used in the expression, including `:` and `end`.

If the indexing expression is a compound expression, then MATLAB passes an array of structures, one struct for each level of indexing. For example, in this expression:

```matlab
a.DataArray(1,:)
```

the indexing structure array S has these values:

- S(1).type is set to `.'`, indicating that the first indexing operation is a dot.
- S(1).subs is set to the property name, 'DataArray'

The second level of indexing is in the second element of the indexing structure:

- S(2).types is set to `'('` indicating the second indexing operation is parentheses indexing
- S(2).subs is set to a cell array containing the indices `[[1],[::]]`
Typical Patterns for Indexing Methods

To overload the \texttt{subsref} and \texttt{subasgn} functions:

- Determine the full indexing expression using the \texttt{types} and \texttt{subs} fields of the indexing structure.
- Implement the specialized behaviors for the indexing operations supported by the class.
- Return the appropriate values or modified objects in response to the call by MATLAB.

A \texttt{switch} statement is a convenient way to detect the first level of indexing. There are three types of indexing—dot, parentheses, and braces. Each \texttt{case} block in the \texttt{switch} statement implements all indexing expressions that begin with that first-level type of indexing.

The methods must implement all indexing expressions that the class supports. If you do not customize a particular type of indexing, call the built-in function to handle that expression.

Use the length of the indexing structure array and indexing type define conditional statements for compound indexing expressions.

\textbf{Code Framework for subsref Method}

The following framework for the \texttt{subsref} method shows how to use information in the indexing structure in conditional statements. Your application can involve other expressions not shown here.

\begin{verbatim}
function varargout = subsref(obj,s)
    switch s(1).type
    case '.
        if length(s) == 1
            % Implement obj.PropertyName
            ...
        elseif length(s) == 2 && strcmp(s(2).type,'()')
            % Implement obj.PropertyName(indices)
            ...
        else
            [varargout{1:nargout}] = builtin('subsref',obj,s);
        end
    case '{'}
        if length(s) == 1
            % Implement obj(indices)
            ...
        elseif length(s) == 2 && strcmp(s(2).type,'.')
            % Implement obj(ind).PropertyName
            ...
        elseif length(s) == 3 && strcmp(s(2).type,'.') && strcmp(s(3).type,'()')
            % Implement obj(indices).PropertyName(indices)
            ...
        else
            % Use built-in for any other expression
            [varargout{1:nargout}] = builtin('subsref',obj,s);
        end
    case '()'
        if length(s) == 1
            % Implement obj(indices)
            ...
        elseif length(s) == 2 && strcmp(s(2).type,'.')
            % Implement obj(ind).PropertyName
            ...
        elseif length(s) == 3 && strcmp(s(2).type,'.') && strcmp(s(3).type,'()')
            % Implement obj(indices).PropertyName(indices)
            ...
        else
            % Use built-in for any other expression
            [varargout{1:nargout}] = builtin('subsref',obj,s);
        end
    otherwise
        error('Not a valid indexing expression')
    end
\end{verbatim}
Using `varargout` for the returned value enables the method to work with object arrays. For example, suppose that you want to support the return of a comma-separated list with an expression like this one:

\[ [x_1, \ldots, x_n] = \text{objArray.PropertyName}(\text{Indices}) \]

This expression results in a two-element indexing structure array. The first-level type is dot (`.'`) and the second level is parentheses (`'('`) . Build the `varargout` cell array with each value in the array.

```matlab
if length(s)==2 && strcmp(s(2).type,'()')
    prop = s(1).subs;  % Property name
    n = numel(obj);    % Number of elements in array
    varargout = cell(1,n);  % Preallocate cell array
    for k = 1:n
        varargout{k} = obj(k).(prop).(s(2).subs);
    end
end
```

### subsasgn Pattern

The following framework for the `subsasgn` method shows how to use the indexing structure in conditional statements that implement assignment operations.

```matlab
function obj = subsasgn(obj,s,varargin)
    sia
    switch s(1).type
        case '.
            if length(s) == 1
                % Implement obj.PropertyName = varargin{:}
            elseif length(s) == 2 && strcmp(s(2).type,'()')
                % Implement obj.PropertyName(indices) = varargin{:}
            else
                % Call built-in for any other case
                obj = builtin('subsasgn',obj,s,varargin{:});
            end
        case '{}
            if length(s) == 1
                % Implement obj{indices} = varargin{:}
            elseif length(s) == 2 && strcmp(s(2).type,'.')
                % Implement obj{indices}.PropertyName = varargin{:}
            else
                % Use built-in for any other expression
                obj = builtin('subsasgn',obj,s,varargin{:});
            end
        case '(
            if length(s) == 1
                % Implement obj(indices) = varargin{:}
            elseif length(s) == 2 && strcmp(s(2).type,'.')
                % Implement obj(indices).PropertyName = varargin{:}
            elseif length(s) == 3 && strcmp(s(2).type,'.') && strcmp(s(3).type,'()')
                % Implement obj(indices).PropertyName(indices) = varargin{:}
            else
                % Use built-in for any other expression
                obj = builtin('subsasgn',obj,s,varargin{:});
            end
```

Specialize Object Behavior
% Use built-in for any other expression
obj = builtin('subsasgn',obj,s,varargin{:});
end
otherwise
    error('Not a valid indexing expression')
end

Using varargin for the right-side value of the assignment statement enables the method to work with object arrays. For example, suppose that you want to support the assignment of a comma-separated list with an expression like this one:

\[
C = \{'one';'two';'three'\};
\]
[\texttt{objArray.PropertyName}] = \texttt{C{:}}

This expression results in an indexing structure with the dot type ('.') indexing. The cell array \( C \) on the right side of the assignment statement produces a comma-separated list. This code assigns one list item to each property in the object array.

\[
\texttt{case '.'}
\]
\[
\texttt{if length(s)==1}
\]
\[
\texttt{prop = s(1).subs;} \quad % \texttt{Property name}
\]
\[
\texttt{n = numel(obj);} \quad % \texttt{Number of elements in array}
\]
\[
\texttt{for k = 1:n}
\]
\[
\texttt{obj(k).(prop) = varargin{k};}
\]
\[
\texttt{end}
\]
\[
\texttt{end}
\]

### Subscripted Assignment with an Uninitialized Variable

Assigning to an element of an uninitialized variable results in a call to the \texttt{subsasgn} method of the class on the right side of the assignment. For example, this class defines a \texttt{subsasgn} method that simply calls the built-in \texttt{subsasgn} method for parenthesis indexing.

\begin{verbatim}
classdef MyClass
    methods
        function obj = subsasgn(obj,s,varargin)
            switch s(1).type
                case '()
                    obj = builtin('subsasgn',obj,s,varargin{:});
                end
            end
        end
    end
end
\end{verbatim}

When attempting to assign an object of \texttt{MyClass} to the first element of the uninitialized variable, \texttt{B(1)} in the following statement, MATLAB calls the \texttt{subsasgn} method of \texttt{MyClass} with an empty double ([]) as the first argument. The assignment can cause an error because the \texttt{subsasgn} method must be passed an object of the class.

\begin{verbatim}
clear B
B(1) = MyClass;
\end{verbatim}

The following error occurred converting from MyClass to double: Conversion to double from MyClass is not possible.

\begin{verbatim}
Error in MyClass/subsasgn (line 6)
    obj = builtin('subsasgn',obj,s,varargin{:});
\end{verbatim}
The `subsasgn` method can detect this situation and take the appropriate action, such as returning a useful error message if the class does not support this type of assignment, or converting the input to an object of the class and passing it to `subsasgn`.

For example, because `MyClass` can allow subscripted assignment to an uninitialized variable, the `subsasgn` method can change the first argument from the empty double to an empty `MyClass` object.

Use the `isequal` function to check the input and the `empty` static method to create the empty object.

```matlab
classdef MyClass
    methods
        function obj = subsasgn(obj,s,varargin)
            if isequal(obj,[])
                obj = MyClass.empty;
            end
            obj = builtin('subsasgn',obj,s,varargin{:});
        end
    end
end
```

Subscripted assignment to an uninitialized variable now avoids the previous error.

```matlab
clear B
A(1) = MyClass;
B = MyClass with no properties.
```

**See Also**

**Related Examples**

- “Class with Modified Indexing” on page 17-32
- “Representing Hardware with Classes” on page 12-66
- “Subclasses of Built-In Types with Properties” on page 12-54
Indexed Reference

**How Indexed Reference Works**

Object indexed references are in three forms — parentheses, braces, and dot-name:

- `A(I)`
- `A{I}`
- `A.name`

Each of these statements results in a call by MATLAB to the `subsref` of class `A`, or a call to the built-in `subsasgn` function if the class of `A` does not implement a `subsasgn` method.

MATLAB passes two arguments to `subsref` and requires `subsref` to return the result of the indexed reference:

```matlab
B = subsref(A,S)
```

The first argument is the object being referenced, `A`. The second argument, `S`, is a `substruct` with two fields:

- `S.type` is a char vector containing `'('`, `'{'}`, or `'. '` specifying the indexing type used.
- `S.subs` is a cell array or char vector containing the actual index or name. A colon used as an index is passed in the cell array as the colon character `':'`. Ranges specified using a colon (e.g., `2:5`) are expanded to `2 3 4 5`.

For example, the expression:

```matlab
A(1:4,:)
```

Causes MATLAB to call `subsref(A,S)`, where `S` is a 1-by-1 structure with a two-element cell array. The cell array contains the numbers `1, 2, 3, 4`, and the colon character `:`.

```matlab
S.type = '()'
S.subs = {1:4,':'}
```

Returning the contents of each cell of `S.subs` gives the index values for the first dimension and a char vector `':'` for the second dimension:

```matlab
S.subs{:}
```

```matlab
ans =
   1   2   3   4
```

```matlab
ans =
   :
```

The default `subsref` returns all array elements in rows 1 through 4 and all the columns in the array.
Similarly, this expression:

\[ A\{1:4\} \]

Uses a cell array containing the numbers 1, 2, 3, 4.

\[ S\text{.type }= '{'\} \]
\[ S\text{.subs }= \{1:4\} \]

The default \texttt{subsref} returns the contents of all cell array elements in rows 1 through 4 and all the columns in the array.

This expression:

\[ A\text{.Name} \]

Calls \texttt{subsref(A,S)}, where the \texttt{struct} \( S \) has these values:

\[ S\text{.type }= ',' \]
\[ S\text{.subs }= 'Name' \]

### Compound Indexed References

These simple calls are combined for more complicated indexing expressions. In such cases, \( \text{length}(S) \) is the number of indexing levels. For example,

\[ A\{1,2\}.PropertyName\{1:4\} \]

calls \texttt{subsref(A,S)}, where \( S \) is a 3-by-1 array of \texttt{structs} with the values:

\[
\begin{align*}
S(1).type &= '()' & S(2).type &= '.' & S(3).type &= '()' \\
S(1).subs &= \{1,2\} & S(2).subs &= 'PropertyName' & S(3).subs &= \{1:4\}
\end{align*}
\]

### See Also

**Related Examples**

- “Indexed Assignment” on page 17-25
- “Number of Arguments for subsref and subsasgn” on page 17-5
- “Modify nargout and nargin for Indexing Methods” on page 17-7
- “Code Patterns for subsref and subsasgn Methods” on page 17-17
Indexed Assignment

How Indexed Assignment Works

Object indexed assignments are in three forms — parentheses, braces, and dot-name:

\[
\begin{align*}
A(I) &= B \\
A{I} &= B \\
A.name &= B
\end{align*}
\]

Each of these statements results in a call by MATLAB to the \texttt{subsasgn} method of class \texttt{A}, or a call to the built-in \texttt{subsasgn} function if the class of \texttt{A} does not implement a \texttt{subsasgn} method.

MATLAB passes three arguments to \texttt{subsasgn} and requires \texttt{subsasgn} to return the result of the assignment:

\[
A = \texttt{subsasgn}(A, S, B)
\]

The first argument, \texttt{A}, is the object being assigned the value in the third argument \texttt{B}.

The second argument is the indexing structure, \texttt{substruct}. \texttt{S} has two fields:

- \texttt{S.type} is a char vector containing ‘(‘, ‘}’, or ‘.’ specifying the indexing type used.
- \texttt{S.subs} is a cell array or character array containing the actual indices or field name. A colon used as an index is passed in the cell array as the character ‘:’. Ranges specified using a colon (e.g., 2:5) are expanded to 2 3 4 5.

For example, the assignment statement:

\[
A(2,3) = B;
\]

generates a call to \texttt{subsasgn}:

\[
A = \texttt{subsasgn}(A, S, B)
\]

\texttt{S} contains:

\[
\begin{align*}
S.type &= '()' \\
S.subs &= \{2,3\}
\end{align*}
\]

The built-in \texttt{subsasgn}:

- Determines the class of \texttt{A}. If \texttt{B} is not the same class as \texttt{A}, then MATLAB tries to construct an object of the same class as \texttt{A} using \texttt{B} as an input argument. If this attempt fails, MATLAB returns an error.
- If \texttt{A} and \texttt{B} are, or can be made, into the same class, then MATLAB assigns the value of \texttt{B} to the array element at row 2, column 3.
• If \texttt{A} does not exist before you execute the assignment statement, then MATLAB initializes the five array elements that come before \texttt{A(2,3)} with default objects of class \texttt{B}.

Similarly, this expression
\begin{verbatim}
A{2,3} = B
\end{verbatim}

Uses these values for \texttt{S}:
\begin{verbatim}
S.type = '{}'
S.subs = {2,3}
\end{verbatim}

The built-in \texttt{subsasgn}:
• Assigns \texttt{B} to the cell array element at row 2, column 3.
• If \texttt{A} does not exist before you execute the assignment statement, MATLAB initializes the five cells that come before \texttt{A(2,3)} with \texttt{[]}. The result is a 2-by-3 cell array.

This expression:
\begin{verbatim}
A.Name = B
\end{verbatim}

Calls \texttt{A = subsasgn(A,S,B)} where the struct \texttt{S} has these values:
\begin{verbatim}
S.type = '.'
S.subs = 'Name'
\end{verbatim}

The built-in \texttt{subsasgn}:
• Assigns \texttt{B} to the struct field \texttt{Name}.
• If \texttt{A} does not exist before you execute the assignment statement, MATLAB creates a struct variable, \texttt{A} with field \texttt{Name} and assigns the value of \texttt{B} to this field location.
• If \texttt{struct A} exists, but has no field \texttt{Name}, then MATLAB adds the field \texttt{Name} and assigns the value of \texttt{B} to the new field location.
• If \texttt{struct A} exists and has a \texttt{Name} field, then MATLAB assigns the value of \texttt{B} to \texttt{Name}.

You can redefine all or some of these assignment behaviors by implementing a \texttt{subsasgn} method for your class.

**Indexed Assignment to Objects**

If \texttt{A} is an object, this expression:
\begin{verbatim}
A.Name = B
\end{verbatim}

Calls \texttt{A = subsasgn(A,S,B)} where, \texttt{S} has these values:
\begin{verbatim}
S.type = '.'
S.subs = 'Name'
\end{verbatim}

The default \texttt{subsasgn}:
• Attempts to assign \texttt{B} to the \texttt{Name} property.
• If the class of \texttt{A} does not have a \texttt{Name} property, MATLAB returns an error.
• If the Name property has restricted access (private or protected), MATLAB determines if the assignment is allowed based on the context in which the assignment is made.
• If the class of A defines a set method for property Name, MATLAB calls the set method.
• MATLAB applies all other property attributes before determining whether to assigning B to the property Name.

**Compound Indexed Assignments**

These simple calls are combined for more complicated indexing expressions. In such cases, length(S) is the number of indexing levels. For example,

A(1,2).PropertyName(1:4) = B

calls subsasgn(A,S,B), where S is a 3-by-1 array of structures with the values:

S(1).type = '()'   S(2).type = '.'                S(3).type = '{}'
S(1).subs = {1,2}  S(2).subs = 'PropertyName'   S(3).subs = {1:4}

**See Also**

**Related Examples**

• “Indexed Reference” on page 17-23
• “Number of Arguments for subsref and subsasgn” on page 17-5
• “Modify nargout and nargin for Indexing Methods” on page 17-7
• “Code Patterns for subsref and subsasgn Methods” on page 17-17
end as Object Index

Define end Indexing for an Object

When you use end in an object indexing expression, such as A(4:end), the end function returns the index value corresponding to the last element in that dimension.

Classes can overload the end function to implement specialized behavior. If your class defines an end method, MATLAB calls that method to determine how to interpret the expression.

The end method has the calling syntax:

\[ \text{ind} = \text{end}(A, k, n) \]

The arguments are described as follows:

- A is the object
- k is the index in the expression using the end syntax
- n is the total number of indices in the expression
- ind is the index value to use in the expression

For example, consider the 3-by-5 array A. When MATLAB encounters the expression:

\[ A(\text{end}-1,:) \]

MATLAB calls the end method defined for the object A using the arguments:

\[ \text{ind} = \text{end}(A, 1, 2) \]

These arguments mean that the end statement occurs in the first index and there are two indices. The end class method returns the index value for the last element of the first dimension (from which 1 is subtracted in this case). The original expression is evaluated as:

\[ A(3-1,:) \]

If your class implements an end method, ensure that it returns a value appropriate for the class.

The end Method

The end method for the MyDataClass example (see “Class with Modified Indexing” on page 17-32) operates on the contents of the Data property. The objective of this method is to return a value that can replace end in any indexing expression, such as:

\[ \text{obj}(4:\text{end}) \]
\[ \text{obj}.\text{Data}(2,3:\text{end}) \]

This end method determines a positive integer value for end. The method returns the value so that MATLAB can use it in the indexing expression.
function ind = end(obj,k,n)
szd = size(obj.Data);
if k < n
    ind = szd(k);
else
    ind = prod(szd(k:end));
end
end

See Also

Related Examples
- “Class with Modified Indexing” on page 17-32
- “Objects in Index Expressions” on page 17-30
## Objects in Index Expressions

### In this section...

- “Objects Indexes” on page 17-30
- “Ways to Implement Objects as Indices” on page 17-30
- “subsindex Implementation” on page 17-30

### Objects Indexes

MATLAB can use objects as indices in indexed expressions. The rules of array indexing apply — indices must be positive integers. Therefore, MATLAB must be able to derive a value from the object that is a positive integer for use in the indexed expression.

Indexed expressions like \( X(A) \), where \( A \) is an object, cause MATLAB to call the `subsindex` function. However, if an indexing expression results in a call to an overloaded `subsref` or `subsasgn` method defined by the class of \( X \), then MATLAB does not call `subsindex`.

### Ways to Implement Objects as Indices

There are several ways to implement indexing of one object by another object, \( X(A) \):

- Define a `subsindex` method in the class of \( A \) that converts \( A \) to an integer. MATLAB calls \( A \)'s `subsindex` method to perform indexing operations when the class of \( X \) does not overload `subsref` or `subsasgn`.
- If the class of \( X \) overloads `subsref` or `subsasgn`, these methods can call the `subsindex` method of \( A \) explicitly. The class of \( A \) must implement a `subsindex` method that returns an appropriate value.
- If the class of \( X \) overloads `subsref` or `subsasgn`, these methods can contain code that determines an integer index value. In this case, the class of \( A \) does not implement a `subsindex` method.

### subsindex Implementation

`subsindex` must return the value of the object as a zero-based integer index value in the range 0 to \( \text{prod}(\text{size}(X)) \)-1.

Suppose that you want to use object \( A \) to index into object \( B \). \( B \) can be a single object or an array, depending on the class designs.

\[ C = B(A); \]

Here are two examples of `subsindex` methods. The first assumes you can convert class \( A \) to a `uint8`. The second assumes class \( A \) stores an index value in a property.

- The `subsindex` method implemented by class \( A \) can convert the object to numeric format to be used as an index:

  ```matlab
  function ind = subsindex(obj)
    ind = uint8(obj);
  end
  ```
The class of obj implements a uint8 method to provide the conversion from the object to an integer value.

• Class A implements subsindex to return a numeric value that is stored in a property:

```matlab
function ind = subsindex(obj)
    ind = obj.ElementIndex;
end
```

**Note** subsindex values are 0-based, not 1-based.

**See Also**
numArgumentsFromSubscript | subsasgn | subsref

**Related Examples**
• “end as Object Index” on page 17-28

**More About**
• “Modify nargout and nargin for Indexing Methods” on page 17-7
Class with Modified Indexing

In this section...

“How to Modify Class Indexing” on page 17-32
“Class Description” on page 17-32
“Specialize Subscripted Reference — subsref” on page 17-33
“Specialize Subscripted Assignment — subsasgn” on page 17-34
“Implement Addition for Object Data — double and plus” on page 17-35
“MyDataClass.m” on page 17-36

How to Modify Class Indexing

This example defines a class that modifies the default indexing behavior by implementing subsref and subsasgn methods. The class also implements type conversion and addition by implementing a double converter method and a plus method.

The objective of the class design is to:

• Enable you to treat an object of the class as a numeric array
• Be able to contain nonnumeric and numeric data in an object of the class

Class Description

The class has three properties:

• Data — numeric test data
• Description — description of test data
• Date — date test was conducted

Assume that you have the following random data (randi):

d = randi(9,3,4)

d =

8 9 3 9
9 6 5 2
2 1 9 9

Create an instance of the class:

obj = MyDataClass(d,'Test001')

obj =

MyDataClass with properties:

Data: [3x4 double]
Description: 'Test001'
Date: [2012 1 7 9 32 34.5190]
The constructor arguments pass the values for the Data and Description properties. The clock function assigns the value to the Date property from within the constructor. This approach captures the time and date information when each instance is created.

Here is the preliminary code listing without the subsref, subsasgn double, and plus methods.

```matlab
classdef MyDataClass
    properties
        Data
        Description
    end
    properties (SetAccess = private)
        Date
    end
    methods
        function obj = MyDataClass(data,desc)
            if nargin > 0
                obj.Data = data;
            end
            if nargin > 1
                obj.Description = desc;
            end
            obj.Date = clock;
        end
    end
end
```

**Specialize Subscripted Reference — subsref**

Implement a subsref method to support both the default and a specialized type of indexing.

- The default indexed reference behavior for scalar objects:

  ```matlab
  obj.Data(2,3)
  ans =
  5
  ```

- And to add the functionality to index into the Data property with an expression like this statement:

  ```matlab
  obj(2,3)
  ```

If you redefine ‘()’ indexing to support access to the Data property, you cannot create arrays of MyDataClass objects and use ‘()’ indexing to access individual objects. You can reference only scalar objects.

To achieve the design goals, the subsref method must handle all indexing types. The subsref method:

- Calls the builtin subsref function for ‘.’ indexing
- Returns an error for ‘{}’ indexing
- Defines its own version of ‘()’ indexing.

The result: obj(i) is equivalent to obj.Data(i).
function sref = subsref(obj,s)
    % obj(i) is equivalent to obj.Data(i)
    switch s(1).type
    case '
        sref = builtin('subsref',obj,s);
    case '()
        if length(s) < 2
            sref = builtin('subsref',obj.Data,s);
        else
            sref = builtin('subsref',obj,s);
        end
    case '{}'
        error('MYDataClass:subsref',...'
             Not a supported subscripted reference')
    end
end

Specialize Subscripted Assignment — subsasgn

To support the equivalent of the indexed reference behavior with indexed assignment, implement a
subsasgn method.

• Support the default indexed assignment:
    obj.Data(2,3) = 9;
• Add the functionality to assign values to the Data property with an expression like this statement:
    obj(2,3) = 9;

Like the subsref method, the subsasgn method:

• Calls the builtin subsasgn function for '.' indexing
• Returns an error for '{}' indexing
• Defines its own version of '()' indexing.

The substruct function redefines the index type and index subscripts structure that MATLAB passes
to subsref and subsasgn.

function obj = subsasgn(obj,s,val)
    if isempty(s) && isa(val,'MyDataClass')
        obj = MyDataClass(val.Data,val.Description);
    end
    switch s(1).type
    case '
        obj = builtin('subsasgn',obj,s,val);
    case '()
        if length(s)<2
            if isa(val,'MyDataClass')
                error('MyDataClass:subsasgn',...'
                     Object must be scalar')
            elseif isa(val,'double')
                % Redefine the struct s to make the call: obj.Data(i)
                snew = substruct('.','Data','()',s(1).subs(:));
                obj = subsasgn(obj,snew,val);
            end
        end
    end
end
Implement Addition for Object Data — double and plus

First, implement a `double` method that converts an object to an array of doubles. By implementing a `double` converter method, it is possible to add a `MyDataClass` object to another class of object. However, the other class must implement a `double` method that also returns an array of doubles. For more information on type conversion, see “Object Converters” on page 17-10.

Allow direct addition of the `Data` property values by implementing a `plus` method. Implementing a `plus` method enables the use of the `+` operator for addition of `MyDataClass` objects.

Because the `plus` method implements addition by adding double arrays, MATLAB:

- Apply the rules of addition when adding `MyDataClass` objects
- Returns errors for any condition that can cause errors in default numeric addition. For example, dimension mismatch.

The `plus` method uses the `double` method to convert the object to numeric values before performing the addition:

```matlab
function a = double(obj)
    a = obj.Data;
end

function c = plus(obj, b)
    c = double(obj) + double(b);
end
```

For example, the `plus` method enables you to add a scalar number to the object `Data` array.

Here are the values of the `Data`, displayed using indexed reference:

```matlab
obj(:,:,:)
```

```matlab
ans =
     8     9     3     9
     9     6     9     2
     2     1     9     9
```

Add 7 to the array contained in the `Data` property:

```matlab
obj + 7
```

```matlab
ans =
    15    16    10    16
    16    13    16     9
     9     8    16    16
```
MyDataClass.m

This definition for MyDataClass includes the end indexing method discussed in “end as Object Index” on page 17-28. extraneous

classdef MyDataClass
    % Example for "A Class with Modified Indexing"
    properties
        Data
        Description
    end
    properties (SetAccess = private)
        Date
    end
end
methods
    function obj = MyDataClass(data,desc)
        % Support 0-2 args
        if nargin > 0
            obj.Data = data;
        end
        if nargin > 1
            obj.Description = desc;
        end
        obj.Date = clock;
    end
    function sref = subsref(obj,s)
        % obj(i) is equivalent to obj.Data(i)
        switch s(1).type
            case '.
                sref = builtin('subsref',obj,s);
            case '()'
                if length(s)<2
                    sref = builtin('subsref',obj.Data,s);
                else
                    sref = builtin('subsref',obj,s);
                end
            case '{}'
                error('MyDataClass:subsref',...
                    'Not a supported subscripted reference')
        end
    end
    function obj = subsasgn(obj,s,val)
        if isempty(s) && isa(val,'MyDataClass')
            obj = MyDataClass(val.Data,val.Description);
        end
        switch s(1).type
            case '.
                obj = builtin('subsasgn',obj,s,val);
            case '()'
                %
                if length(s)<2
                    if isa(val,'MyDataClass')
                        error('MyDataClass:subsasgn',...
                            'Object must be scalar')
                    elseif isa(val,'double')
                    end

17-36
```matlab
snew = substruct('.','Data', '()', s(1).subs(':));
obj = subsasgn(obj, snew, val);
end
end
case '{}'
    error('MyDataClass:subsasgn', ...
        'Not a supported subscripted assignment')
end
end
function a = double(obj)
a = obj.Data;
end
function c = plus(obj, b)
c = double(obj) + double(b);
end
function ind = end(obj, k, n)
szd = size(obj.Data);
if k < n
    ind = szd(k);
else
    ind = prod(szd(k:end));
end
end
end

See Also

Related Examples

- “end as Object Index” on page 17-28
- “Number of Arguments for subsref and subsasgn” on page 17-5
Operator Overloading

In this section...

“Why Overload Operators” on page 17-38
“How to Define Operators” on page 17-38
“Sample Implementation — Addable Objects” on page 17-39
“MATLAB Operators and Associated Functions” on page 17-40

Why Overload Operators

By implementing operators that are appropriate for your class, you can integrate objects of your class into the MATLAB language. For example, objects that contain numeric data can define arithmetic operations like +, *, - so that you can use these objects in arithmetic expressions. By implementing relational operators, you can use objects in conditional statements, like switch and if statements.

How to Define Operators

You can implement MATLAB operators to work with objects of your class. To implement operators, define the associated class methods.

Each operator has an associated function (e.g., the + operator has an associated plus.m function). You can implement any operator by creating a class method with the appropriate name. This method can perform whatever steps are appropriate for the operation being implemented.

For a list of operators and associated function names, see “MATLAB Operators and Associated Functions” on page 17-40.

Object Precedence in Operations

User-defined classes have a higher precedence than built-in classes. For example, suppose q is an object of class double and p is a user-defined class. Both of these expressions generate a call to the plus method in the user-define class, if it exists:

\[ q + p \]
\[ p + q \]

Whether this method can add objects of class double and the user-defined class depends on how you implement the method.

When p and q are objects of different classes, MATLAB applies the rules of precedence to determine which method to use.

“Object Precedence in Method Invocation” on page 9-36 provides information on how MATLAB determines which method to call.

Operator Precedence

Overloaded operators retain the original MATLAB precedence for the operator. For information on operator precedence, see “Operator Precedence”.
Sample Implementation — Addable Objects

The Adder class implements addition for objects of this class by defining a plus method. Adder defines addition of objects as the addition of the NumericData property values. The plus method constructs and returns an Adder object whose NumericData property value is the result of the addition.

The Adder class also implements the less than operator (<) by defining a lt method. The lt method returns a logical value after comparing the values in each object NumericData property.

classdef Adder
    properties
        NumericData
    end
    methods
        function obj = Adder(val)
            obj.NumericData = val;
        end
        function r = plus(obj1,obj2)
            a = double(obj1);
            b = double(obj2);
            r = Adder(a + b);
        end
        function d = double(obj)
            d = obj.NumericData;
        end
        function tf = lt(obj1,obj2)
            if obj1.NumericData < obj2.NumericData
                tf = true;
            else
                tf = false;
            end
        end
    end
end

Using a double converter enables you to add numeric values to Adder objects and to perform addition on objects of the class.

a = Adder(1:10)

a =

    Adder with properties:
        NumericData: [1 2 3 4 5 6 7 8 9 10]

Add two objects:

a + a

ans =

    Adder with properties:
        NumericData: [2 4 6 8 10 12 14 16 18 20]

Add an object with any value that can be cast to double:
\[ b = \text{uint8}(255) + a \]

\[ b = \]

Adder with properties:

- NumericData: \([256 \ 257 \ 258 \ 259 \ 260 \ 261 \ 262 \ 263 \ 264 \ 265]\)

Compare objects \(a\) and \(b\) using the < operator:

\[ a < b \]

\[ \text{ans} = \\
\]

1

Ensure that your class provides any error checking required to implement your class design.

**MATLAB Operators and Associated Functions**

The following table lists the function names for MATLAB operators. Implementing operators to work with arrays (scalar expansion, vectorized arithmetic operations, and so on), can also require modifying indexing and concatenation. Use the links in this table to find specific information on each function.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Method to Define</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a + b)</td>
<td>(\text{plus}(a,b))</td>
<td>Binary addition</td>
</tr>
<tr>
<td>(a - b)</td>
<td>(\text{minus}(a,b))</td>
<td>Binary subtraction</td>
</tr>
<tr>
<td>(-a)</td>
<td>(\text{uminus}(a))</td>
<td>Unary minus</td>
</tr>
<tr>
<td>(+a)</td>
<td>(\text{uplus}(a))</td>
<td>Unary plus</td>
</tr>
<tr>
<td>(a.*b)</td>
<td>(\text{times}(a,b))</td>
<td>Element-wise multiplication</td>
</tr>
<tr>
<td>(a*b)</td>
<td>(\text{mtimes}(a,b))</td>
<td>Matrix multiplication</td>
</tr>
<tr>
<td>(a./b)</td>
<td>(\text{rdivide}(a,b))</td>
<td>Right element-wise division</td>
</tr>
<tr>
<td>(a\backslash b)</td>
<td>(\text{ldivide}(a,b))</td>
<td>Left element-wise division</td>
</tr>
<tr>
<td>(a/b)</td>
<td>(\text{mrdivide}(a,b))</td>
<td>Matrix right division</td>
</tr>
<tr>
<td>(a)</td>
<td>(\text{mldivide}(a,b))</td>
<td>Matrix left division</td>
</tr>
<tr>
<td>(a.^b)</td>
<td>(\text{power}(a,b))</td>
<td>Element-wise power</td>
</tr>
<tr>
<td>(a^b)</td>
<td>(\text{mpower}(a,b))</td>
<td>Matrix power</td>
</tr>
<tr>
<td>(a &lt; b)</td>
<td>(\text{lt}(a,b))</td>
<td>Less than</td>
</tr>
<tr>
<td>(a &gt; b)</td>
<td>(\text{gt}(a,b))</td>
<td>Greater than</td>
</tr>
<tr>
<td>(a &lt;= b)</td>
<td>(\text{le}(a,b))</td>
<td>Less than or equal to</td>
</tr>
<tr>
<td>(a &gt;= b)</td>
<td>(\text{ge}(a,b))</td>
<td>Greater than or equal to</td>
</tr>
<tr>
<td>(a \sim b)</td>
<td>(\text{ne}(a,b))</td>
<td>Not equal to</td>
</tr>
<tr>
<td>(a == b)</td>
<td>(\text{eq}(a,b))</td>
<td>Equality</td>
</tr>
<tr>
<td>(a &amp; b)</td>
<td>(\text{and}(a,b))</td>
<td>Logical AND</td>
</tr>
<tr>
<td>(a</td>
<td>b)</td>
<td>(\text{or}(a,b))</td>
</tr>
<tr>
<td>Operation</td>
<td>Method to Define</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------</td>
<td>------------------------</td>
</tr>
<tr>
<td>~a</td>
<td>not(a)</td>
<td>Logical NOT</td>
</tr>
<tr>
<td>a:d:b</td>
<td>colon(a,d,b)</td>
<td>Colon operator</td>
</tr>
<tr>
<td>a:b</td>
<td>colon(a,b)</td>
<td></td>
</tr>
<tr>
<td>a'</td>
<td>ctranspose(a)</td>
<td>Complex conjugate transpose</td>
</tr>
<tr>
<td>a.'</td>
<td>transpose(a)</td>
<td>Matrix transpose</td>
</tr>
<tr>
<td>[a b]</td>
<td>horzcat(a,b,...)</td>
<td>Horizontal concatenation</td>
</tr>
<tr>
<td>[a; b]</td>
<td>vertcat(a,b,...)</td>
<td>Vertical concatenation</td>
</tr>
<tr>
<td>a(s1,s2,...sn)</td>
<td>subsref(a,s)</td>
<td>Subscripted reference</td>
</tr>
<tr>
<td>a(s1,...,sn) = b</td>
<td>subsasgn(a,s,b)</td>
<td>Subscripted assignment</td>
</tr>
<tr>
<td>b(a)</td>
<td>subsindex(a)</td>
<td>Subscript index</td>
</tr>
</tbody>
</table>

**See Also**

**Related Examples**
- “Define Arithmetic Operators” on page 19-16
- “Methods That Modify Default Behavior” on page 17-2
Customizing Object Display

- “Custom Display Interface” on page 18-2
- “How CustomDisplay Works” on page 18-7
- “Role of size Function in Custom Displays” on page 18-9
- “Customize Display for Heterogeneous Arrays” on page 18-10
- “Class with Default Object Display” on page 18-11
- “Choose a Technique for Display Customization” on page 18-15
- “Customize Property Display” on page 18-18
- “Customize Header, Property List, and Footer” on page 18-21
- “Customize Display of Scalar Objects” on page 18-26
- “Customize Display of Object Arrays” on page 18-30
- “Overloading the disp Function” on page 18-34
Custom Display Interface

In this section...

“Command Window Display” on page 18-2
“Default Object Display” on page 18-2
“CustomDisplay Class” on page 18-3
“Methods for Customizing Object Display” on page 18-3

Command Window Display

MATLAB displays information in the command window when a statements that is not terminated with a semicolon returns a variable. For example, this statement creates a structure with a field that contains the number 7.

\[
a . \text{field1} = 7
\]

MATLAB displays the variable name, class, and the value.

\[
a =
\begin{align*}
\text{struct with fields:} \\
\text{field1: 7}
\end{align*}
\]

MATLAB provides user-defined classes with similar display functionality. User-defined classes can customize how MATLAB displays objects of the class using the API provided by the \texttt{matlab.mixin.CustomDisplay} class. To use this API, derive your class from \texttt{matlab.mixin.CustomDisplay}.

Default Object Display

MATLAB adds default methods named \texttt{disp} and \texttt{display} to all MATLAB classes that do not implement their own methods with those names. These methods are not visible, but create the default simple display.

The default simple display consists of the following parts:

- A header showing the class name, and the dimensions for nonscalar arrays.
- A list of all nonhidden public properties, shown in the order of definition in the class.

The actual display depends on whether the object is scalar or nonscalar. Also, there are special displays for a scalar handle to a deleted object and empty object arrays. Objects in all of these states are displayed differently if the objects have no properties.

The \texttt{details} function creates the default detailed display. The detailed display adds these items to the simple display:

- Use of fully qualified class names
- Link to \texttt{handle} class, if the object is a handle
- Links to \texttt{methods}, \texttt{events}, and \texttt{superclasses} functions executed on the object.
See “Class with Default Object Display” on page 18-11 for an example of how MATLAB displays objects.

**Properties Displayed by Default**

MATLAB displays object properties that have public get access and are not hidden (see “Property Attributes” on page 8-7). Inherited abstract properties are excluded from display. When the object being displayed is scalar, any dynamic properties attached to the object are also included.

**CustomDisplay Class**

The `matlab.mixin.CustomDisplay` class provides an interface that you can use to customize object display for your class. To use this interface, derive your class from `CustomDisplay`:

```matlab
classdef MyClass < matlab.mixin.CustomDisplay
```

The `CustomDisplay` class is `HandleCompatible`, so you can use it in combination with both value and handle superclasses.

**Note** You cannot use `matlab.mixin.CustomDisplay` to derive a custom display for enumeration classes.

**disp, display, and details**

The `CustomDisplay` interface does not allow you to override `disp`, `display`, and `details`. Instead, override any combination of the customization methods defined for this purpose.

**Methods for Customizing Object Display**

There are two groups of methods that you use to customize object display for your class:

- Part builder methods build the strings used for the standard display. Override any of these methods to change the respective parts of the display.
- State handler methods are called for objects in specific states, like scalar, nonscalar, and so on. Override any of these methods to handle objects in a specific state.

All of these methods have protected access and must be defined as protected in your subclass of `CustomDisplay` (that is, `Access = protected`).

**Parts of an Object Display**

There are three parts that makeup the standard object display — header, property list, and footer.

For example, here is the standard object display for a `containers.Map` object:
The default object display does not include a footer. The detailed display provides more information:

```matlab
>> map1 = containers.Map({'Apr','Jul','Nov'},[4,7,11])
```

```
map1 =

Map with properties:

    Count: 3
    KeyType: char
    ValueType: double

```

The default object display does not include a footer. The detailed display provides more information:

```matlab
>> details(map1)
```

```
3x1 containers.Map handle array with properties:

    Count: 3
    KeyType: 'char'
    ValueType: 'double'

    Methods, Events, Superclasses
```

You can customize how MATLAB displays objects as a result of expressions that display objects in the command window such as unterminated statements that return objects or calls to `disp` and `display`. The results displayed when calling `details` on an object or object array are not changed by the `CustomDisplay` API.

## Part Builder Methods

Each part of the object display has an associated method that assembles the respective part of the display.

<table>
<thead>
<tr>
<th>Method</th>
<th>Purpose</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>getHeader</code></td>
<td>Create the text used for the header.</td>
<td>Returns the char vectors, <code>[class(obj), ' with properties:']</code> linking the class name to a help popup</td>
</tr>
<tr>
<td><code>getPropertyGroups</code></td>
<td>Define how and what properties display, including order, values, and grouping.</td>
<td>Returns an array of <code>PropertyGroup</code> objects, which determines how to display the properties</td>
</tr>
<tr>
<td><code>getFooter</code></td>
<td>Create the text used for the footer.</td>
<td>There are two footers:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Simple display — Returns an empty char vector</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Detailed display — Returns linked calls to <code>methods</code>, <code>events</code>, and <code>superclasses</code> for this class</td>
</tr>
</tbody>
</table>

18-4

Customizing Object Display
Object States That Affect Display

There are four object states that affect how MATLAB displays objects:
- Valid scalar object
- Nonscalar object array
- Empty object array
- Scalar handle to a deleted object

State Handler Methods

Each object state has an associated method that MATLAB calls whenever displaying objects that are in that particular state.

<table>
<thead>
<tr>
<th>State Handler Method</th>
<th>Called for Object in This State</th>
</tr>
</thead>
<tbody>
<tr>
<td>displayScalarObject</td>
<td>(isa(obj,'handle') &amp;&amp; isvalid(obj)) &amp;&amp; prod(size(obj)) == 1</td>
</tr>
<tr>
<td>displayNonScalarObject</td>
<td>prod(size(obj)) &gt; 1</td>
</tr>
<tr>
<td>displayEmptyObject</td>
<td>prod(size(obj)) == 0</td>
</tr>
<tr>
<td>displayScalarHandleToDeletedObject</td>
<td>isa(obj,'handle') &amp;&amp; isscalar(obj) &amp;&amp; ~isvalid(obj)</td>
</tr>
</tbody>
</table>

Utility Methods

The CustomDisplay class provides utility methods that return strings that are used in various parts of the different display options. These static methods return text that simplifies the creation of customized object displays.

If the computer display does not support hypertext linking, the strings are returned without the links.

<table>
<thead>
<tr>
<th>Method</th>
<th>Inputs</th>
<th>Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>convertDimensionsToString</td>
<td>Valid object array</td>
<td>Object dimensions converted to a char vector; determined by calling size(obj)</td>
</tr>
<tr>
<td>displayPropertyGroups</td>
<td>PropertyGroup array</td>
<td>Displays the titles and property groups defined</td>
</tr>
<tr>
<td>getClassNameForHeader</td>
<td>Object</td>
<td>Simple class name linked to the object’s documentation</td>
</tr>
<tr>
<td>getDeletedHandleText</td>
<td>None</td>
<td>Text 'handle to deleted' linked to the documentation on deleted handles</td>
</tr>
<tr>
<td>getDetailedFooter</td>
<td>Object</td>
<td>Text containing phrase 'Methods, Events, Superclasses', with each link executing the respective command on the input object</td>
</tr>
<tr>
<td>getDetailedHeader</td>
<td>Object</td>
<td>Text containing linked class name, link to handle page (if handle class) and 'with properties:'</td>
</tr>
<tr>
<td>Method</td>
<td>Inputs</td>
<td>Outputs</td>
</tr>
<tr>
<td>---------------</td>
<td>---------</td>
<td>-------------------------------------------------------------------------</td>
</tr>
<tr>
<td>getHandleText</td>
<td>None</td>
<td>Text 'handle' linked to a section of the documentation that describes handle objects</td>
</tr>
<tr>
<td>getSimpleHeader</td>
<td>Object</td>
<td>Text containing linked class name and the phrase 'with properties:'</td>
</tr>
</tbody>
</table>

**See Also**

**Related Examples**
- “How CustomDisplay Works” on page 18-7
How CustomDisplay Works

Steps to Display an Object

When displaying an object, MATLAB determines the state of the object and calls the appropriate method for that state (see "Object States That Affect Display" on page 18-5).

For example, suppose `obj` is a valid scalar object of a class derived from `CustomDisplay`. If you type `obj` at the command line without terminating the statement with a semicolon:

```matlab
>> obj
```

The following sequence results in the display of `obj`:

1. MATLAB determines the class of `obj` and calls the `disp` method to display the object.
2. `disp` calls `size` to determine if `obj` is scalar or nonscalar.
3. When `obj` is a scalar handle object, `disp` calls `isvalid` to determine if `obj` is the handle of a deleted object. Deleted handles in nonscalar arrays do not affect the display.
4. `disp` calls the state handler method for an object of the state of `obj`. In this case, `obj` is a valid scalar that results in a call to:
   ```matlab
displayScalarObject(obj)
   ```
5. `displayScalarObject` calls the display part-builder methods to provide the respective header, property list, and footer:
   ```matlab
   ...  
   header = getHeader(obj);
   disp(header)
   ...
   groups = getPropertyGroups(obj)
   displayPropertyGroups(obj,groups)
   ...  
   footer = getFooter
   disp(footer)
   ```

MATLAB follows a similar sequence for nonscalar object arrays and empty object arrays.

In the case of scalar handles to deleted objects, `disp` calls the `displayScalarHandleToDeletedObject` method, which displays the default text for handles to deleted objects without calling any part-builder methods.

Methods Called for a Given Object State

The following diagram illustrates the methods called to display an object that derives from `CustomDisplay`. The `disp` method calls the state handler method that is appropriate for the state of the object or object array being displayed.

Only an instance of a handle class can be in a state of scalar handle to a deleted object.
See Also

Related Examples

- “Class with Default Object Display” on page 18-11
Role of size Function in Custom Displays

In this section...
“How size Is Used” on page 18-9
“Precautions When Overloading size” on page 18-9

How size Is Used
In the process of building the custom display, CustomDisplay methods call the size function at several points:

• disp calls size to determine which state handler method to invoke.
• The default getHeader method calls size to determine whether to display a scalar or nonscalar header.
• The default displayPropertyGroups method calls size to determine if it should look up property values when the property group is a cell array of property names. By default, only scalar objects display the values of properties.

Precautions When Overloading size
If your class overloads the size function, then MATLAB calls the overloading version. You must ensure that the implementation of size is consistent with the way you want to display objects of the class.

An unusual or improper implementation of size can result in undesirable display behavior. For example, suppose a class overloads size reports an object as scalar when it is not. In this class, a property list consisting of a cell array of strings results in the property values of the first object of the array being displayed. This behavior can give the impression that all objects in the array have the same property values.

However, reporting an object as scalar when in fact the object is empty results in the object displaying as an empty object array. The default methods of the CustomDisplay interface always determine if the input is an empty array before attempting to access property values.

As you override CustomDisplay methods to implement your custom object display, consider how an overloading size method can affect the result.

See Also

Related Examples
• “Methods That Modify Default Behavior” on page 17-2
Customize Display for Heterogeneous Arrays

You can call only sealed methods on nonscalar heterogeneous arrays. If you want to customize classes that are part of a heterogeneous hierarchy, you must override and declare as Sealed all the methods that are part of the CustomDisplay interface.

The versions of disp and display that are inherited from matlab.mixin.CustomDisplay are sealed. However, these methods call all of the part builder (“Part Builder Methods” on page 18-4) and state handler methods (“State Handler Methods” on page 18-5).

To use the CustomDisplay interface, the root class of the heterogeneous hierarchy can declare these methods as Sealed and Access = protected.

If you do not need to override a particular method, then call the superclass method, as shown in the following code.

For example, the following code shows modifications to the getPropertyGroups and displayScalarObject methods, while using the superclass implementation of all others.

```matlab
classdef RootClass < matlab.mixin.CustomDisplay & matlab.mixin.Heterogeneous
    %... methods (Sealed, Access = protected)
    function header = getHeader(obj)
        header = getHeader@matlab.mixin.CustomDisplay(obj);
    end

    function groups = getPropertyGroups(obj)
        % Override of this method
        % ...
    end

    function footer = getFooter(obj)
        footer = getFooter@matlab.mixin.CustomDisplay(obj);
    end

    function displayNonScalarObject(obj)
        displayNonScalarObject@matlab.mixin.CustomDisplay(obj);
    end

    function displayScalarObject(obj)
        % Override of this method
        % ...
    end

    function displayEmptyObject(obj)
        displayEmptyObject@matlab.mixin.CustomDisplay(obj);
    end

    function displayScalarHandleToDeletedObject(obj)
        displayScalarHandleToDeletedObject@matlab.mixin.CustomDisplay(obj);
    end
end
```

You do not need to declare the inherited static methods as Sealed.

See Also

Related Examples

• “Designing Heterogeneous Class Hierarchies” on page 10-20
Class with Default Object Display

The EmployeeInfo Class

The EmployeeInfo class defines a number of properties to store information about company employees. This simple class serves as the example class used in display customization sample classes.

EmployeeInfo derives from the matlab.mixin.CustomDisplay class to enable customization of the object display.

EmployeeInfo is also a handle class. Therefore instances of this class can be in the state referred to as a handle to a deleted object. This state does not occur with value classes (classes not derived from handle).

```matlab
classdef EmployeeInfo < handle & matlab.mixin.CustomDisplay
    properties
        Name
        JobTitle
        Department
        Salary
        Password
    end
    methods
        function obj = EmployeeInfo
            obj.Name       = input('Name: ');
            obj.JobTitle   = input('Job Title: ');
            obj.Department = input('Department: ');
            obj.Salary     = input('Salary: ');
            obj.Password   = input('Password: ');
        end
    end
end
```

The matlab.mixin.CustomDisplay is handle compatible. Therefore, superclasses can be either handle or value classes.

Default Display — Scalar

Here is the creation and display of a scalar EmployeeInfo object. By default, MATLAB displays properties and their values for scalar objects.

Provide inputs for the constructor:
Emp123 = EmployeeInfo;
Name: 'Bill Tork'
Job Title: 'Software Engineer'
Department: 'Product Development'
Salary: 1000
Password: 'bill123'

Display the object:

Emp123

Emp123 =

EmployeeInfo with properties:

    Name: 'Bill Tork'
    JobTitle: 'Software Engineer'
    Department: 'Product Development'
    Salary: 1000
    Password: 'bill123'

Testing for Scalar Objects

To test for scalar objects, use iscalar.

Default Display — Nonscalar

The default display for an array of objects does not show property values. For example, concatenating two EmployeeInfo objects generates this display:

Emp123,Emp124]

ans

1x2 EmployeeInfo array with properties:

    Name
    JobTitle
    Department
    Salary
    Password

Testing for Nonscalar Objects

To test for nonscalar objects, use a negated call to iscalar.

Default Display — Empty Object Array

An empty object array has at least one dimension equal to zero.

Empt = EmployeeInfo.empty(0,5)

Empt =

0x5 EmployeeInfo array with properties:

Name
Testing for Empty Object Arrays

Use isempty to test for empty object arrays. An empty object array is not scalar because its dimensions can never be 1-by-1.

```matlab
>> emt = EmployeeInfo.empty
emt =
    0x0 EmployeeInfo array with properties:
        Name
        JobTitle
        Department
        Salary
        Password
```

```matlab
>> isscalar(emt)
an =
    0
```

Default Display — Handle to Deleted Object

When a handle object is deleted, the handle variable can remain in the workspace.

```matlab
>> delete(Emp123)
> Emp123
   handle to deleted EmployeeInfo
```

Testing for Handles to Deleted Objects

To test for a handle to a deleted object, use isValid.

**Note** isValid is a handle class method. Calling isValid on a value class object causes an error.

Default Display — Detailed Display

The details method does not support customization and always returns the standard detailed display:

```matlab
details(Emp123)
EmployeeInfo handle with properties:
    Name: 'Bill Tork'
    JobTitle: 'Software Engineer'
    Department: 'Product Development'
    Salary: 1000
    Password: 'bill123'
```
Methods, Events, Superclasses

See Also

Related Examples

• “Custom Display Interface” on page 18-2
Choose a Technique for Display Customization

<table>
<thead>
<tr>
<th>In this section...</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Ways to Implement a Custom Display” on page 18-15</td>
</tr>
<tr>
<td>“Sample Approaches Using the Interface” on page 18-15</td>
</tr>
</tbody>
</table>

Ways to Implement a Custom Display

The way you customize object display using the `matlab.mixin.CustomDisplay` class depends on:

- What parts of the display you want to customize
- What object states you want to use the custom display

If you are making small changes to the default layout, then override the relevant part builder methods (“Part Builder Methods” on page 18-4). For example, suppose you want to:

- Change the order or value of properties, display a subset of properties, or create property groups
- Modify the header text
- Add a footer

If you are defining a nonstandard display for a particular object state (scalar, for example), then the best approach is to override the appropriate state handler method (“State Handler Methods” on page 18-5).

In some cases, a combination of method overrides might be the best approach. For example, your implementation of `displayScalarObject` might

- Use some of the utility methods (“Utility Methods” on page 18-5) to build your own display strings using parts from the default display
- Call a part builder method to get the default text for that particular part of the display
- Implement a completely different display for scalar objects.

Once you override any `CustomDisplay` method, MATLAB calls your override in all cases where the superclass method would have been called. For example, if you override the `getHeader` method, your override must handle all cases where a state handler method calls `getHeader`. (See “Methods Called for a Given Object State” on page 18-7)

Sample Approaches Using the Interface

Here are some simple cases that show what methods to use for the particular customized display.

**Change the Display of Scalar Objects**

Use a nonstandard layout for scalar object display that is fully defined in the `displayScalarObject` method:

```matlab
classdef MyClass < matlab.mixin.CustomDisplay
    ...
    methods (Access = protected)
        function displayScalarObject(obj)
            % Implement the custom display for scalar obj
    end
end
```
Custom Property List with Standard Layout

Use standard display layout, but create a custom property list for scalar and nonscalar display:

```matlab
classdef MyClass < matlab.mixin.CustomDisplay
    ...
    methods(Access = protected)
        function groups = getPropertyGroups(obj)
            % Return PropertyGroup instances
        end
    end
end
```

Custom Property List for Scalar Only

Use standard display layout, but create a custom property list for scalar only. Call the superclass `getPropertyGroups` for the nonscalar case.

```matlab
classdef MyClass < matlab.mixin.CustomDisplay
    properties
        Prop1
        Prop2
        Prop3
    end
    methods(Access = protected)
        function groups = getPropertyGroups(obj)
            if isscalar(obj)
                % Scalar case: change order
                propList = {'Prop2','Prop1','Prop3'};
                groups = matlab.mixin.util.PropertyGroup(propList)
            else
                % Nonscalar case: call superclass method
                groups = getPropertyGroups@matlab.mixin.CustomDisplay(obj);
            end
        end
    end
end
```

Custom Property List with Modified Values

Change the values displayed for some properties in the scalar case by creating property/value pairs in a struct. This `getPropertyGroups` method displays only `Prop1` and `Prop2`, and displays the value of `Prop2` as `Prop1` divided by `Prop3`.

```matlab
classdef MyClass < matlab.mixin.CustomDisplay
    properties
        Prop1
        Prop2
        Prop3
    end
    methods(Access = protected)
        function groups = getPropertyGroups(obj)
            if isscalar(obj)
                % Specify the values to be displayed for properties
                propList = struct('Prop2',obj.Prop1,...
                                  'Prop1',obj.Prop1/obj.Prop3);
                groups = matlab.mixin.util.PropertyGroup(propList)
            else
                % Nonscalar case: call superclass method
                groups = getPropertyGroups@matlab.mixin.CustomDisplay(obj);
            end
        end
    end
end
```
Complete Class Definitions

For complete class implementations, see these sections:

• “Customize Property Display” on page 18-18
  “Customize Header, Property List, and Footer” on page 18-21
  “Customize Display of Scalar Objects” on page 18-26
  “Customize Display of Object Arrays” on page 18-30
Customize Property Display

<table>
<thead>
<tr>
<th>In this section...</th>
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<tbody>
<tr>
<td>“Objective” on page 18-18</td>
</tr>
<tr>
<td>“Change the Property Order” on page 18-18</td>
</tr>
<tr>
<td>“Change the Values Displayed for Properties” on page 18-18</td>
</tr>
</tbody>
</table>

**Objective**

Change the order and number of properties displayed for an object of your class.

**Change the Property Order**

Suppose your class definition contains the following property definition:

```matlab
properties
    Name
    JobTitle
    Department
    Salary
    Password
end
```

In the default scalar object display, MATLAB displays all the public properties along with their values. However, you want to display only `Department`, `JobTitle`, and `Name`, in that order. You can do this by deriving from `CustomDisplay` and overriding the `getPropertyGroups` method.

Your override

- Defines method `Access` as `protected` to match the definition in the `CustomDisplay` superclass
- Creates a cell array of property names in the desired order
- Returns a `PropertyGroup` object constructed from the property list cell array

```matlab
methods (Access = protected)
    function progrp = getPropertyGroups(~)
        proplist = {'Department','JobTitle','Name'};
        progrp = matlab.mixin.util.PropertyGroup(proplist);
    end
end
```

When you create a `PropertyGroup` object using a cell array of property names, MATLAB automatically

- Adds the property values for a scalar object display
- Uses the property names without values for a nonscalar object display (including empty object arrays)

The `getPropertyGroups` method is not called to create the display for a scalar handle to a deleted object.

**Change the Values Displayed for Properties**

Given the same class properties used in the previous section, you can change the value displayed for properties by building the property list as a `struct` and specifying values for property names. This
override of the `getPropertyGroups` method uses the default property display for nonscalar objects by calling the superclass `getPropertyGroups` method. For scalar objects, the override:

- Changes the value displayed for the `Password` property to a `'*'` character for each character in the password.
- Displays the text 'Not Available' for the `Salary` property.

```matlab
methods (Access = protected)
    function progrp = getPropertyGroups(obj)
        if ~isscalar(obj)
            progrp = getPropertyGroups@matlab.mixin.CustomDisplay(obj);
        else
            pd(1:length(obj.Password)) = '*';
            proplist = struct('Department',obj.Department,...
                'JobTitle',obj.JobTitle,...
                'Name',obj.Name,...
                'Salary','Not available',...
                'Password',pd);
            progrp = matlab.mixin.util.PropertyGroup(proplist);
        end
    end
end
end

The object display looks like this:

**EmployeeInfo with properties:**

- **Department:** 'Product Development'
- **JobTitle:** 'Software Engineer'
- **Name:** 'Bill Tork'
- **Salary:** 'Not available'
- **Password:** '*******'

### Full Class Listing

```matlab
classdef EmployeeInfo < handle & matlab.mixin.CustomDisplay
    properties
        Name
        JobTitle
        Department
        Salary
        Password
    end
    methods
        function obj = EmployeeInfo
            obj.Name = input('Name: ');
            obj.JobTitle = input('Job Title: ');
            obj.Department = input('Department: ');
            obj.Salary = input('Salary: ');
            obj.Password = input('Password: ');
        end
    end
    methods (Access = protected)
        function progrp = getPropertyGroups(obj)
            if ~isscalar(obj)
                progrp = getPropertyGroups@matlab.mixin.CustomDisplay(obj);
            else
                pd(1:length(obj.Password)) = '*';
                proplist = struct('Department',obj.Department,...
                    'JobTitle',obj.JobTitle,...
                    'Name',obj.Name,...
                    'Salary','Not available',...
                    'Password',pd);
                progrp = matlab.mixin.util.PropertyGroup(proplist);
            end
        end
    end
end
```
See Also

Related Examples

- “Choose a Technique for Display Customization” on page 18-15
**Customize Header, Property List, and Footer**

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<thead>
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<th>In this section...</th>
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<tr>
<td>“getFooter Override” on page 18-23</td>
</tr>
</tbody>
</table>

**Objective**

Customize each of the three parts of the display — header, property groups, and footer.

**Design of Custom Display**

**Note** This example uses the `EmployeeInfo` class described in the “Class with Default Object Display” on page 18-11 section.

For the header:
- Use default header for nonscalar object arrays.
- Build header text with linked class name and department name (from `Department` property)

For properties:
- Nonscalar object arrays display a subset of property names in a different order than the default.
- Scalar objects create two property groups that have titles (Public Info and Personal Info).

For the footer:
- Add a footer to the display, only when the object is a valid scalar that displays property values.

Here is the customized display of an object of the `EmployeeInfo` class.

`Emp123 =
EmployeeInfo Dept: Product Development
   Public Info
      Name: 'Bill Tork'
      JobTitle: 'Software Engineer'
   Personal Info
      Salary: 1000
      Password: 'bill123'

Company Private

Here is the custom display of an array of `EmployeeInfo` objects:
[Emp123,Emp124]
ans =
  1x2 EmployeeInfo array with properties:
      Department
     Name
     JobTitle

Here is the display of an empty object array:
>> EmployeeInfo.empty(0,5)
ans =
   0x5 EmployeeInfo array with properties:
      Department
     Name
     JobTitle

Here is the display of a handle to a delete object (EmployeeInfo is a handle class):
>> delete(Emp123)
>> Emp123
Emp123 =
      handle to deleted EmployeeInfo

Implementation

The EmployeeInfo class overrides three matlab.mixin.CustomDisplay methods to implement the display shown:
• getHeader
• getPropertyGroups
• getFooter

Each method must produce the desired results with each of the following inputs:
• Scalar object
• Nonscalar object array
• Empty object array

getHeader Method Override

MATLAB calls getHeader to get the header text. The EmployeeInfo class overrides this method to implement the custom header for scalar display. Here is how it works:
• Nonscalar (including empty object) arrays call the superclass getHeader, which returns the default header.
• Scalar handles to deleted objects do not result in a call to getHeader.
• Scalar inputs build a custom header using the `getClassNameForHeader` static method to return linked class name text, and the value of the `Department` property.

Here is the `EmployeeInfo` override of the `getHeader` method. The required protected access is inherited from the superclass.

```matlab
methods (Access = protected)
    function header = getHeader(obj)
        if ~isscalar(obj)
            header = getHeader(matlab.mixin.CustomDisplay(obj));
        else
            className = matlab.mixin.CustomDisplay.getClassNameForHeader(obj);
            newHeader = [className, ' Dept: ', obj.Department];
            header = sprintf('%s
', newHeader);
        end
    end
end
```

**getPropertyGroups Override**

MATLAB calls `getPropertyGroups` to get the `PropertyGroup` objects, which control how properties are displayed. This method override defines two different property lists depending on the object’s state:

• For nonscalar inputs, including empty arrays and arrays containing handles to deleted objects, create a property list as a cell array to reorder properties.

  By default, MATLAB does not display property values for nonscalar inputs.

• For scalar inputs, create two property groups with titles. The scalar code branch lists properties in a different order than the nonscalar case and includes `Salary` and `Password` properties. MATLAB automatically assigns property values.

• Scalar handles to deleted objects do not result in a call to `getPropertyGroups`.

Both branches return a `matlab.mixin.util.PropertyGroup` object, which determines how to displays the object properties.

Here is the `EmployeeInfo` override of the `getPropertyGroups` method. The protected access is inherited from the superclass.

```matlab
methods (Access = protected)
    function propgrp = getPropertyGroups(obj)
        if ~isscalar(obj)
            propList = {'Department', 'Name', 'JobTitle'};
            propgrp = matlab.mixin.util.PropertyGroup(propList);
        else
            gTitle1 = 'Public Info';
            gTitle2 = 'Personal Info';
            propList1 = {'Name', 'JobTitle'};
            propList2 = {'Salary', 'Password'};
            propgrp1 = matlab.mixin.util.PropertyGroup(propList1, gTitle1);
            propgrp2 = matlab.mixin.util.PropertyGroup(propList2, gTitle2);
        end
    end
end
```

**getFooter Override**

MATLAB calls `getFooter` to get the footer text. The `EmployeeInfo getFooter` method defines a footer for the display, which is included only when the input is a valid scalar object. In all other cases, `getFooter` returns an empty char vector.
Scalar handles to deleted objects do not result in a call to `getFooter`.

```matlab
methods (Access = protected)
    function footer = getFooter(obj)
        if isscalar(obj)
            footer = sprintf('%s
','Company Private');
        else
            footer = ' ';
        end
    end
end

Complete Class Listing

classdef EmployeeInfo < handle & matlab.mixin.CustomDisplay
    properties
        Name
        JobTitle
        Department
        Salary
        Password
    end
    methods
        function obj = EmployeeInfo
            obj.Name       = input('Name: ');
            obj.JobTitle   = input('Job Title: ');
            obj.Department = input('Department: ');
            obj.Salary     = input('Salary: ');
            obj.Password   = input('Password: ');
        end
    end
    methods (Access = protected)
        function header = getHeader(obj)
            if ~isscalar(obj)
                header = getHeader@matlab.mixin.CustomDisplay(obj);
            else
                className = matlab.mixin.CustomDisplay.getClassNameForHeader(obj);
                newHeader = [className,' Dept: ',obj.Department];
                header = sprintf('%s
',newHeader);
            end
        end
        function propgrp = getPropertyGroups(obj)
            if ~isscalar(obj)
                propList = {'Department','Name','JobTitle'};
                propgrp = matlab.mixin.util.PropertyGroup(propList);
            else
                gTitle1 = 'Public Info';
                gTitle2 = 'Personal Info';
                propList1 = {'Name','JobTitle'};
                propList2 = {'Salary','Password'};
                propgrp(1) = matlab.mixin.util.PropertyGroup(propList1,gTitle1);
                propgrp(2) = matlab.mixin.util.PropertyGroup(propList2,gTitle2);
            end
        end
        function footer = getFooter(obj)
            if isscalar(obj)
                footer = sprintf('%s
','Company Private');
            else
                footer = ' ';
            end
        end
end
```

18-24 Customizing Object Display
See Also

Related Examples
• “Choose a Technique for Display Customization” on page 18-15
Customize Display of Scalar Objects

**Objective**

Customize the display of scalar objects.

**Design Of Custom Display**

**Note** This example uses the `EmployeeInfo` class described in the “Class with Default Object Display” on page 18-11 section.

The objective of this customized display is to:

- Modify the header to include the department name obtained from the `Department` property
- Group properties into two categories titled Public Info and Personal Info.
- Modify which properties are displayed
- Modify the values displayed for Personal Info category
- Use the default displayed for nonscalar objects, including empty arrays, and scalar deleted handles

For example, here is the customized display of an object of the `EmployeeInfo` class.

```matlab
Emp123 =

EmployeeInfo Dept: Product Development

    Public Info
        Name: 'Bill Tork'
        JobTitle: 'Software Engineer'

    Personal Info
        Salary: 'Level: 10'
        Password: '*******'
```

**Implementation**

The `EmployeeInfo` class overrides two `matlab.mixin.CustomDisplay` methods to implement the display shown:

- `displayScalarObject` — Called to display valid scalar objects
- `getPropertyGroups` — Builds the property groups for display
displayScalarObject Method Override

MATLAB calls displayScalarObject to display scalar objects. The EmployeeInfo class overrides this method to implement the scalar display. Once overridden, this method must control all aspects of scalar object display, including creating the header, property groups, and footer, if used.

This implementation:

- Builds a custom header using the getClassNameForHeader static method to return linked class name text and the value of the Department property to get the department name.
- Uses sprintf to add a new line to the header text.
- Displays the header with the built-in disp function.
- Calls the.getPropertyGroups override to define the property groups (see following section).
- Displays the property groups using the displayPropertyGroups static method.

Here is the EmployeeInfo override of the displayScalarObject method. The required protected access is inherited from the superclass.

```matlab
function displayScalarObject(obj)
    className = matlab.mixin.CustomDisplay.getClassNameForHeader(obj);
    scalarHeader = [className,' Dept: ',obj.Department];
    header = sprintf('%s
',scalarHeader);
    disp(header)
    propgroup = getPropertyGroups(obj);
    matlab.mixin.CustomDisplay.displayPropertyGroups(obj,propgroup)
end
```

getPropertyGroups Override

MATLAB calls getPropertyGroups when displaying scalar or nonscalar objects. However, MATLAB does not call this method when displaying a scalar handle to a deleted object.

The EmployeeInfo class overrides this method to implement the property groups for scalar object display.

This implementation calls the superclass getPropertyGroups method if the input is not scalar. If the input is scalar, this method:

- Defines two titles for the two groups
- Creates a cell array of property names that are included in the first group. MATLAB adds the property values for the display.
- Creates a struct array of property names with associated property values for the second group. Using a struct instead of a cell array enables you to replace the values that are displayed for the Salary and Password properties without changing the personal information stored in the object properties.
- Constructs two matlab.mixin.util.PropertyGroup objects, which are used by the displayScalarObject method.

Here is the EmployeeInfo override of the getPropertyGroups method. The required protected access is inherited from the superclass.

```matlab
function propgrp = getPropertyGroups(obj)
end
```
if ~isscalar(obj)
    propgrp = getPropertyGroups@matlab.mixin.CustomDisplay(obj);
else
    gTitle1 = 'Public Info';
    gTitle2 = 'Personal Info';
    propList1 = {'Name','JobTitle'};
    pd(1:length(obj.Password)) = '*';
    level = round(obj.Salary/100);
    propList2 = struct('Salary',
        ['Level: ',num2str(level)],
        'Password',pd);
    propgrp(1) = matlab.mixin.util.PropertyGroup(propList1,gTitle1);
    propgrp(2) = matlab.mixin.util.PropertyGroup(propList2,gTitle2);
end
end
end

Complete Class Listing

classdef EmployeeInfo4 < handle & matlab.mixin.CustomDisplay
    properties
        Name
        JobTitle
        Department
        Salary
        Password
    end
    methods
        function obj = EmployeeInfo4
            obj.Name       = input('Name: ');
            obj.JobTitle   = input('Job Title: ');
            obj.Department = input('Department: ');
            obj.Salary     = input('Salary: ');
            obj.Password   = input('Password: ');
        end
    end
    methods (Access = protected)
        function displayScalarObject(obj)
            className = matlab.mixin.CustomDisplay.getClassNameForHeader(obj);
            scalarHeader = [className,' Dept: ',obj.Department];
            header = sprintf('%s\n',scalarHeader);
            disp(header)
            propgroup = getPropertyGroups(obj);
            matlab.mixin.CustomDisplay.displayPropertyGroups(obj,propgroup)
        end
        function propgrp = getPropertyGroups(obj)
            if ~isscalar(obj)
                propgrp = getPropertyGroups@matlab.mixin.CustomDisplay(obj);
            else
                gTitle1 = 'Public Info';
                gTitle2 = 'Personal Info';
                propList1 = {'Name','JobTitle'};
                pd(1:length(obj.Password)) = '*';
                level = round(obj.Salary/100);
                propList2 = struct('Salary',
                    ['Level: ',num2str(level)],
                    'Password',pd);
                propgrp(1) = matlab.mixin.util.PropertyGroup(propList1,gTitle1);
                propgrp(2) = matlab.mixin.util.PropertyGroup(propList2,gTitle2);
            end
        end
    end
end
See Also

Related Examples

• “Choose a Technique for Display Customization” on page 18-15
### Customize Display of Object Arrays

<table>
<thead>
<tr>
<th>In this section...</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Objective&quot; on page 18-30</td>
</tr>
<tr>
<td>&quot;Design of Custom Display&quot; on page 18-30</td>
</tr>
<tr>
<td>&quot;The displayNonScalarObject Override&quot; on page 18-31</td>
</tr>
<tr>
<td>&quot;The displayEmptyObject Override&quot; on page 18-32</td>
</tr>
</tbody>
</table>

#### Objective

Customize the display of nonscalar objects, including empty object arrays.

#### Design of Custom Display

**Note** This example uses the `EmployeeInfo` class described in the “Class with Default Object Display” on page 18-11 section.

The objective of this customized display is to:

- Construct a custom header using some elements of the default header
- Display a subset of property-specific information for each object in the array.
- List handles to deleted objects in the array using a `char` vector with links to documentation for handle objects and the class.
- Display empty objects with a slight modification to the default header

Here is the customized display of an array of three `EmployeeInfo` objects:

1x3 `EmployeeInfo` array with members:
1. Employee:
   - Name: 'Bill Tork'
   - Department: 'Product Development'

2. Employee:
   - Name: 'Alice Blackwell'
   - Department: 'QE'

3. Employee:
   - Name: 'Nancy Green'
   - Department: 'Documentation'

Deleted object handles in the array indicate their state:

1x3 `EmployeeInfo` members:
1. Employee:
   - Name: 'Bill Tork'
   - Department: 'Product Development'

2. handle to deleted `EmployeeInfo`
3. Employee:
   Name: 'Nancy Green'
   Department: 'Documentation'

To achieve the desired result, the EmployeeInfo class overrides the following methods of the matlab.mixin.CustomDisplay class:

- displayNonScalarObject — Called to display nonempty object arrays
- displayEmptyObject — Called to display empty object arrays

**The displayNonScalarObject Override**

MATLAB calls the displayNonScalarObject method to display object arrays. The override of this method in the EmployeeInfo class:

- Builds header text using convertDimensionsToString to obtain the array size and getClassNameForHeader to get the class name with a link to the help for that class.
- Displays the modified header text.
- Loops through the elements in the array, building two different subheaders depending on the individual object state. In the loop, this method:
  - Detects handles to deleted objects (using the isValid handle class method). Uses getDeletedHandleText and getClassNameForHeader to build text for array elements that are handles to deleted objects.
  - Builds a custom subheader for valid object elements in the array
  - Creates a PropertyGroup object containing the Name and Department properties for valid objects
  - Uses the displayPropertyGroups static method to generate the property display for valid objects.

Here is the implementation of displayNonScalarObjects:

```matlab
methods (Access = protected)
function displayNonScalarObject(objAry)
    dimStr = matlab.mixin.CustomDisplay.convertDimensionsToString(objAry);
    cName = matlab.mixin.CustomDisplay.getClassNameForHeader(objAry);
    headerStr = [dimStr,' ',cName,' members:'
    header = sprintf('%s
',headerStr);
    disp(header)
    for ix = 1:length(objAry)
        o = objAry(ix);
        if ~isvalid(o)
            str1 = matlab.mixin.CustomDisplay.getDeletedHandleText;
            str2 = matlab.mixin.CustomDisplay.getClassNameForHeader(o);
            headerInv = [str1,' ',str2];
            tmpStr = [num2str(ix),'. ',headerInv];
            numStr = sprintf('%s
',tmpStr);
            disp(numStr)
        else
            numStr = [num2str(ix),'. Employee:'
            disp(numStr)
            propList = struct('Name',o.Name,...
                        'Department',o.Department);
            propgrp = matlab.mixin.util.PropertyGroup(propList);
            matlab.mixin.CustomDisplay.displayPropertyGroups(o,propgrp);
        end
    end
end
end
```

18-31
The displayEmptyObject Override

MATLAB calls the displayEmptyObject method to display empty object arrays. The implementation of this method in the EmployeeInfo class builds a custom header for empty objects following these steps:

- Gets the array dimensions in character format using the convertDimensionsToString static method.
- Gets text with the class name linked to the helpPopup function using the getClassNameForHeader static method.
- Builds and displays the custom text for empty arrays.

```matlab
methods (Access = protected)
function obj = EmployeeInfo
    obj.Name = input('Name: ');
    obj.JobTitle = input('Job Title: ');
    obj.Department = input('Department: ');
    obj.Salary = input('Salary: ');
    obj.Password = input('Password: ');
end
end
methods (Access = protected)
function dimstr = matlab.mixin.CustomDisplay.convertDimensionsToString(obj);
    className = matlab.mixin.CustomDisplay.getClassNameForHeader(obj);
    emptyHeader = [dimstr,' ',className,' with no employee information'];
    header = sprintf('%s
',emptyHeader);
    disp(header)
end
end
```

For example, an empty EmployeeInfo object displays like this:

```
Empt = EmployeeInfo.empty(0,5)
Empt =
0x5 EmployeeInfo with no employee information
```

Complete Class Listing

classdef EmployeeInfo < handle & matlab.mixin.CustomDisplay
    properties
        Name
        JobTitle
        Department
        Salary
        Password
    end
    methods
        function obj = EmployeeInfo
            obj.Name = input('Name: ');
            obj.JobTitle = input('Job Title: ');
            obj.Department = input('Department: ');
            obj.Salary = input('Salary: ');
            obj.Password = input('Password: ');
        end
    end
    methods (Access = protected)
        function dimstr = matlab.mixin.CustomDisplay.convertDimensionsToString(objAry);
            className = matlab.mixin.CustomDisplay.getClassNameForHeader(objAry);
            headerStr = [dimstr,' ',className,' members:'];
            header = sprintf('%s
',headerStr);
            disp(header)
            for ix = 1:length(objAry)
                o = objAry(ix);
                if ~isvalid(o)
                    str1 = matlab.mixin.CustomDisplay.getDeletedHandleText;
                    str2 = matlab.mixin.CustomDisplay.getClassNameForHeader(o);
                    headerInv = [str1,' ',str2];
                    tmpStr = [num2str(ix),'. ',headerInv];
                    numStr = sprintf('%s
',tmpStr);
                    disp(numStr)
                end
            end
        end
    end
end
else
    numStr = [num2str(ix),'. Employee'];
    disp(numStr)
    propList = struct('Name',o.Name,...
    'Department',o.Department);
    propgrp = matlab.mixin.util.PropertyGroup(propList);
    matlab.mixin.CustomDisplay.displayPropertyGroups(o,propgrp);
end

function displayEmptyObject(obj)
    dimstr = matlab.mixin.CustomDisplay.convertDimensionsToString(obj);
    className = matlab.mixin.CustomDisplay.getClassNameForHeader(obj);
    emptyHeader = [dimstr,' ',className,' with no employee information'
    header = sprintf('%s
',emptyHeader);
    disp(header)
end

See Also

Related Examples
  • “Choose a Technique for Display Customization” on page 18-15
Overloading the disp Function

Display Methods

Subclassing `matlab.mixin.CustomDisplay` is the best approach to customizing object display. However, if you do not derive your class from `matlab.mixin.CustomDisplay`, overload the `disp` function to change how MATLAB displays objects of your class.

MATLAB calls the `display` function whenever an object is referred to in a statement that is not terminated by a semicolon. For example, the following statement creates the variable `a`. MATLAB calls `display`, which displays the value of `a` in the command line.

```matlab
a = 5
a =
 5
display then calls disp.
```

Overloaded disp

The built-in `display` function prints the name of the variable that is being displayed, if an assignment is made, or otherwise uses `ans` as the variable name. Then `display` calls `disp` to handle the actual display of the values.

If the variable that is being displayed is an object of a class that overloads `disp`, then MATLAB always calls the overloaded method. MATLAB calls `display` with two arguments and passes the variable name as the second argument.

Relationship Between disp and display

MATLAB invokes the built-in `display` function when the following occur:

- MATLAB executes a statement that returns a value and is not terminated with a semicolon.
- There is no left-side variable, then MATLAB prints `ans =` followed by the value.
- Code explicitly invokes the `display` function.

When invoking `display`:

- If the input argument is an existing variable, `display` prints the variable name and equal sign, followed by the value.
- If the input is the result of an expression, `display` does not print `ans =`.

MATLAB invokes the built-in `disp` function when the following occurs:
• The built-in display function calls disp.
• Code explicitly invokes disp.

For empty built-in types (numeric types, char, struct, and cell) the display function displays:
• [] — for numeric types
• "0x0 struct array with no fields." — for empty structs.
• "0x0 empty cell array" — for empty cell arrays.
• "0x0 empty char array" — for empty char arrays
• "0x0 empty string array" — for empty string arrays

disp differs from display in these ways:
• disp does not print the variable name or ans.
• disp prints nothing for built-in types (numeric types, char, struct, and cell) when the value is empty.

See Also

Related Examples
• “Custom Display Interface” on page 18-2
• “Overload disp for DocPolynom” on page 19-13
Defining Custom Data Types
Representing Polynomials with Classes

Object Requirements

This example implements a class to represent polynomials in the MATLAB language. The design requirements are:

- Value class behavior—a polynomial object should behave like MATLAB numeric variables when copied and passed to functions.
- Specialized display and indexing
- Objects can be scalar only. The specialization of display and indexing functionality preclude normal array behavior.
- Arithmetic operations
- Double converter simplifying the use of polynomial object with existing MATLAB functions that accept numeric inputs.

DocPolynom Class Members

The class definition specifies a property for data storage and defines a folder (@DocPolynom) that contains the class definition.

The following table summarizes the properties defined for the DocPolynom class.

<table>
<thead>
<tr>
<th>Name</th>
<th>Class</th>
<th>Default</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>coef</td>
<td>double</td>
<td>[]</td>
<td>Vector of polynomial coefficients [highest order ... lowest order]</td>
</tr>
</tbody>
</table>

The following table summarizes the methods for the DocPolynom class.
### DocPolynom Class Methods

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DocPolynom</td>
<td>Class constructor</td>
</tr>
<tr>
<td>double</td>
<td>Converts a DocPolynom object to a double (that is, returns its coefficients</td>
</tr>
<tr>
<td></td>
<td>in a vector)</td>
</tr>
<tr>
<td>char</td>
<td>Creates a formatted display of the DocPolynom object as powers of x and</td>
</tr>
<tr>
<td></td>
<td>is used by the disp method</td>
</tr>
<tr>
<td>disp</td>
<td>Determines how MATLAB displays DocPolynom objects on the command line</td>
</tr>
<tr>
<td>subsref</td>
<td>Enables you to specify a value for the independent variable as a subscript,</td>
</tr>
<tr>
<td></td>
<td>access the coef property with dot notation, and call methods with dot</td>
</tr>
<tr>
<td></td>
<td>notation.</td>
</tr>
<tr>
<td>plus</td>
<td>Implements addition of DocPolynom objects</td>
</tr>
<tr>
<td>minus</td>
<td>Implements subtraction of DocPolynom objects</td>
</tr>
<tr>
<td>mtimes</td>
<td>Implements multiplication of DocPolynom objects</td>
</tr>
</tbody>
</table>

### Using the DocPolynom Class

The following examples illustrate basic use of the DocPolynom class.

Create DocPolynom objects to represent the following polynomials. The argument to the constructor function contains the polynomial coefficients \( f(x) = x^3 - 2x - 5 \) and \( f(x) = 2x^4 + 3x^2 + 2x - 7 \).

\[
p1 = \text{DocPolynom}([1 \\ 0 \\ -2 \\ -5])
\]

\[
p1 = \begin{align*}
  x^3 & \quad 2x \quad -5
\end{align*}
\]

\[
p2 = \text{DocPolynom}([2 \\ 0 \\ 3 \\ 2 \\ -7])
\]

\[
p2 = \begin{align*}
  2x^4 & \quad 3x^2 \quad 2x \quad -7
\end{align*}
\]

Find the roots of the polynomial by passing the coefficients to the roots function.

\[
\text{roots}(p1.coef)
\]

\[
\begin{align*}
  \text{ans} &=  \\
  &\begin{align*}
    2.0946 & \quad 0.0000i \\
    -1.0473 & \quad 1.1359i \\
    -1.0473 & \quad -1.1359i 
  \end{align*}
\end{align*}
\]

Add the two polynomials \( p1 \) and \( p2 \).

MATLAB calls the plus method defined for the DocPolynom class when you add two DocPolynom objects.

\[
p1 + p2
\]

\[
\begin{align*}
  \text{ans} &=  \\
  &2x^4 \quad x^3 \quad 3x^2 \quad -12
\end{align*}
\]
### DocPolynom Class Synopsis

<table>
<thead>
<tr>
<th>Example Code</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>classdef</strong> DocPolynom</td>
<td>Value class that implements a data type for polynomials.</td>
</tr>
<tr>
<td><strong>properties</strong></td>
<td>Vector of polynomial coefficients [highest order ... lowest order]</td>
</tr>
<tr>
<td>coef</td>
<td>end</td>
</tr>
<tr>
<td><strong>methods</strong></td>
<td>For general information about methods, see “Ordinary Methods” on page 9-6</td>
</tr>
</tbody>
</table>

#### Class Constructor

```matlab
function obj = DocPolynom(c)
if nargin > 0
    if isa(c, 'DocPolynom')
        obj.coef = c.coef;
    else
        obj.coef = c(:).';
    end
end
end```

Class constructor creates objects using:
- Coefficient vector of existing object
- Coefficient vector passed as argument

See “The DocPolynom Constructor” on page 19-10

#### Set Method for coef Property

```matlab
function obj = set.coef(obj,val)
if ~isa(val, 'double')
    error('Coefficients must be doubles')
end
ind = find(val(:).'~=0);
if ~isempty(ind);
    obj.coef = val(ind(1):end);
else
    obj.coef = val;
end
end```

Set method for coef property:
- Allows coefficients only of type double
- Removes leading zeros from the coefficient vector.

See “Remove Irrelevant Coefficients” on page 19-11

#### Convert Method to double

```matlab
function c = double(obj)
c = obj.coef;
end```

Convert DocPolynom object to double by returning the coefficients.

See “Convert DocPolynom Objects to Other Types” on page 19-11
Example Code

```matlab
function str = char(obj)
    if all(obj.coef == 0)
        s = '0';
        str = s;
        return
    else
        d = length(obj.coef)-1;
        s = cell(1,d);
        ind = 1;
        for a = obj.coef;
            if a ~= 0;
                if ind ~= 1
                    if a > 0
                        s(ind) = {' + '};
                        ind = ind + 1;
                    else
                        s(ind) = {' - '};
                        a = -a;
                        ind = ind + 1;
                    end
                elseif a == -1
                    s(ind) = {'-'};
                    ind = ind + 1;
                else
                    s(ind) = {[num2str(a)};
                    ind = ind + 1;
                    if d > 0
                        s(ind) = {'*'};
                        ind = ind + 1;
                    end
                end
            end
            if d >= 2
                s(ind) = {'x^' int2str(d)};
                ind = ind + 1;
                elseif d == 1
                    s(ind) = {'x'};
                    ind = ind + 1;
                end
            end
            d = d - 1;
        end
        str = [s{:}];
    end
end
```

Discussion

Convert DocPolynom object to char that represents the expression:

\[ y = f(x) \]

See “Convert DocPolynom Objects to Other Types” on page 19-11

```
function disp(obj)
    c = char(obj);
    if iscell(c)
        disp(['     ' c{:}])
    else
        disp(c)
    end
end
```

Overload disp function. Display objects as output of char method.

For information about this code, see “Overload disp for DocPolynom” on page 19-13
<table>
<thead>
<tr>
<th>Example Code</th>
<th>Discussion</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>function dispPoly(obj,x)</code></td>
<td>Return evaluated expression with formatted output.</td>
</tr>
<tr>
<td>p = char(obj);</td>
<td>Uses output of <code>char</code> method to evaluate polynomial at specified values of independent variable.</td>
</tr>
<tr>
<td>e = @(x)eval(p);</td>
<td>For information about this code, see “Display Evaluated Expression” on page 19-13</td>
</tr>
<tr>
<td>y = zeros(length(x));</td>
<td></td>
</tr>
<tr>
<td>disp(['y = ',p])</td>
<td></td>
</tr>
<tr>
<td>for k = 1:length(x)</td>
<td></td>
</tr>
<tr>
<td>y(k) = e(x(k));</td>
<td></td>
</tr>
<tr>
<td>disp(['  ',num2str(y(k)),...</td>
<td></td>
</tr>
<tr>
<td>' = f(x = ',...</td>
<td></td>
</tr>
<tr>
<td>num2str(x(k)),')'])</td>
<td></td>
</tr>
<tr>
<td>end</td>
<td></td>
</tr>
<tr>
<td><code>function b = subsref(a,s)</code></td>
<td>Redefine indexed reference for DocPolynom objects.</td>
</tr>
<tr>
<td>switch s(1).type</td>
<td>For information about this code, see “Redefine Indexed Reference” on page 19-14</td>
</tr>
<tr>
<td>case '()'</td>
<td></td>
</tr>
<tr>
<td>ind = s.subs{:};</td>
<td></td>
</tr>
<tr>
<td>b = polyval(a.coef,ind);</td>
<td></td>
</tr>
<tr>
<td>case '.'</td>
<td></td>
</tr>
<tr>
<td>switch s(1).subs</td>
<td></td>
</tr>
<tr>
<td>case 'coef'</td>
<td></td>
</tr>
<tr>
<td>b = a.coef;</td>
<td></td>
</tr>
<tr>
<td>case 'disp'</td>
<td></td>
</tr>
<tr>
<td>disp(a)</td>
<td></td>
</tr>
<tr>
<td>otherwise</td>
<td></td>
</tr>
<tr>
<td>if length(s)&gt;1</td>
<td></td>
</tr>
<tr>
<td>b = a.(s(1).subs)(s(2).subs{:});</td>
<td></td>
</tr>
<tr>
<td>else</td>
<td></td>
</tr>
<tr>
<td>b = a.(s.subs);</td>
<td></td>
</tr>
<tr>
<td>end</td>
<td></td>
</tr>
<tr>
<td>otherwise</td>
<td></td>
</tr>
<tr>
<td>error('Specify value for x as obj(x)')</td>
<td></td>
</tr>
<tr>
<td>end</td>
<td></td>
</tr>
</tbody>
</table>
Example Code

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>function r = plus(obj1, obj2)</code></td>
<td>Define three arithmetic operators: Polynomial addition</td>
</tr>
<tr>
<td><code>obj1 = DocPolynom(obj1);</code></td>
<td>Polynomial subtraction</td>
</tr>
<tr>
<td><code>obj2 = DocPolynom(obj2);</code></td>
<td>Polynomial multiplication</td>
</tr>
<tr>
<td><code>k = length(obj2.coef) - length(obj1.coef);</code></td>
<td>For information about this code, see “Define Arithmetic Operators” on page 19-16.</td>
</tr>
<tr>
<td><code>zp = zeros(1,k);</code></td>
<td>For general information about defining operators, see “Operator Overloading” on page 17-38</td>
</tr>
<tr>
<td><code>zm = zeros(1,-k);</code></td>
<td></td>
</tr>
<tr>
<td><code>r = DocPolynom([zp, obj1.coef] + [zm, obj2.coef]);</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>function r = minus(obj1, obj2)</code></td>
<td></td>
</tr>
<tr>
<td><code>obj1 = DocPolynom(obj1);</code></td>
<td></td>
</tr>
<tr>
<td><code>obj2 = DocPolynom(obj2);</code></td>
<td></td>
</tr>
<tr>
<td><code>k = length(obj2.coef) - length(obj1.coef);</code></td>
<td></td>
</tr>
<tr>
<td><code>zp = zeros(1,k);</code></td>
<td></td>
</tr>
<tr>
<td><code>zm = zeros(1,-k);</code></td>
<td></td>
</tr>
<tr>
<td><code>r = DocPolynom([zp, obj1.coef] - [zm, obj2.coef]);</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>function r = mtimes(obj1, obj2)</code></td>
<td></td>
</tr>
<tr>
<td><code>obj1 = DocPolynom(obj1);</code></td>
<td></td>
</tr>
<tr>
<td><code>obj2 = DocPolynom(obj2);</code></td>
<td></td>
</tr>
<tr>
<td><code>r = DocPolynom(conv(obj1.coef, obj2.coef));</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
<tr>
<td><code>end</code></td>
<td></td>
</tr>
</tbody>
</table>

Expand for Class Code

classdef DocPolynom
% Documentation example
% A value class that implements a data type for polynomials
% See Implementing a Class for Polynomials in the
% MATLAB documentation for more information.

properties
    coef
end

% Class methods
methods
    function obj = DocPolynom(c)
        if nargin > 0
            if isa(c,'DocPolynom')
                obj.coef = c.coef;
            else
                obj.coef = c(:, :);
            end
        end
    end % DocPolynom

    function obj = set.coef(obj, val)
        if ~isa(val, 'double')
            error('Coefficients must be doubles')
        end
        % Remove leading zeros
ind = find(val(:).‘~=0);
if ~isempty(ind);
    obj.coef = val(ind(1):end);
else
    obj.coef = val;
end
end % set.coef

function c = double(obj)
c = obj.coef;
end % double

function str = char(obj)
    % Created a formatted display of the polynomial
    % as powers of x
    if all(obj.coef == 0)
        s = '0';
        str = s;
        return
    else
        d = length(obj.coef)-1;
        s = cell(1,d);
        ind = 1;
        for a = obj.coef;
            if a ~= 0;
                if ind ~= 1
                    if a > 0
                        s(ind) = {' + '};
                        ind = ind + 1;
                    else
                        s(ind) = {' - '};
                        a = -a; %#ok<FXSET>
                        ind = ind + 1;
                    end
                end
                if a ~= 1 || d == 0
                    if a == -1
                        s(ind) = {'-'};
                        ind = ind + 1;
                    else
                        s(ind) = {num2str(a)};
                        ind = ind + 1;
                        if d > 0
                            s(ind) = {'*'};
                            ind = ind + 1;
                        end
                    end
                end
                if d >= 2
                    s(ind) = {'x^ ' int2str(d)};
                    ind = ind + 1;
                elseif d == 1
                    s(ind) = {'x'};
                    ind = ind + 1;
                end
                d = d - 1;
            end
        end
function disp(obj)
% DISP Display object in MATLAB syntax
    c = char(obj);
    if iscell(c)
        disp(['     ' c{:}])
    else
        disp(c)
    end
end % disp

function dispPoly(obj,x)
% evaluate obj at x
    p = char(obj);
    e = @(x)eval(p);
    y = zeros(length(x));
    disp(['y = ',p])
    for k = 1:length(x)
        y(k) = e(x(k));
        disp(['  ',num2str(y(k)),...
            '= f(x = ',...
            num2str(x(k)),')'])
    end
end

function b = subsref(a,s)
% SUBSREF Implementing the following syntax:
% obj([1 ...])
% obj.coef
% obj.disp
% out = obj.method(args)
% out = obj.method
    switch s(1).type
    case '()'
        ind = s.subs{:};
        b = polyval(a.coef,ind);
    case '.'
        switch s(1).subs
        case 'coef'
            b = a.coef;
        case 'disp'
            disp(a)
        otherwise
            if length(s)>1
                b = a.(s1).subs(s2).subs{:});
            else
                b = a.(s.subs);
            end
        end
    otherwise
        error('Specify value for x as obj(x)')
    end
end % subsref

function r = plus(obj1,obj2)
% PLUS Implement obj1 + obj2 for DocPolynom
obj1 = DocPolynom(obj1);
obj2 = DocPolynom(obj2);
k = length(obj2.coef) - length(obj1.coef);
zp = zeros(1,k);
zm = zeros(1,-k);
r = DocPolynom([zp,obj1.coef] + [zm,obj2.coef]);
end % plus

function r = minus(obj1, obj2)
% MINUS Implement obj1 - obj2 for DocPolynoms.
obj1 = DocPolynom(obj1);
obj2 = DocPolynom(obj2);
k = length(obj2.coef) - length(obj1.coef);
zp = zeros(1,k);
zm = zeros(1,-k);
r = DocPolynom([zp,obj1.coef] - [zm,obj2.coef]);
end % minus

function r = mtimes(obj1, obj2)
% MTIMES Implement obj1 * obj2 for DocPolynoms.
obj1 = DocPolynom(obj1);
obj2 = DocPolynom(obj2);
r = DocPolynom(conv(obj1.coef, obj2.coef));
end % mtimes
end % methods
end % classdef

The DocPolynom Constructor

The following function is the DocPolynom class constructor, which is in the file @DocPolynom/DocPolynom.m:

methods
function obj = DocPolynom(c)
if isa(c,'DocPolynom')
    obj.coef = c.coef;
else
    obj.coef = c(:).';
end
end

Constructor Calling Syntax

It is possible to all the DocPolynom constructor with two different arguments:

- Input argument is a DocPolynom object — If you call the constructor function with an input argument that is already a DocPolynom object, the constructor returns a new DocPolynom object with the same coefficients as the input argument. The isa function checks for this input.
- Input argument is a coefficient vector — If the input argument is not a DocPolynom object, the constructor attempts to reshape the values into a vector and assign them to the coef property.

The coef property set method restricts property values to doubles. See “Remove Irrelevant Coefficients” on page 19-11 for a description of the property set method.

An example use of the DocPolynom constructor is the statement:
This statement creates an instance of the DocPolynom class with the specified coefficients. Note that the display of the object shows the equivalent polynomial using MATLAB language syntax. The DocPolynom class implements this display using the disp and char class methods.

**Remove Irrelevant Coefficients**

MATLAB software represents polynomials as row vectors containing coefficients ordered by descending powers. Zeros in the coefficient vector represent terms that drop out of the polynomial. Leading zeros, therefore, can be ignored when forming the polynomial.

Some DocPolynom class methods use the length of the coefficient vector to determine the degree of the polynomial. It is useful, therefore, to remove leading zeros from the coefficient vector so that its length represents the true value.

The DocPolynom class stores the coefficient vector in a property that uses a set method to remove leading zeros from the specified coefficients before setting the property value.

```matlab
function obj = set.coef(obj,val)
if ~isa(val,'double')
    error('Coefficients must be doubles')
end
ind = find(val(:).'~=0);
if ~isempty(ind);
    obj.coef = val(ind(1):end);
else
    obj.coef = val;
end
end
```

**Convert DocPolynom Objects to Other Types**

The DocPolynom class defines two methods to convert DocPolynom objects to other classes:

- **double** — Converts to the double numeric type so functions can perform mathematical operations on the coefficients.
- **char** — Converts to characters used to format output for display in the command window

**The Double Converter**

The double converter method for the DocPolynom class simply returns the coefficient vector:

```matlab
function c = double(obj)
c = obj.coef;
end
```

For the DocPolynom object `p`:

```matlab
p = DocPolynom([1 0 -2 -5]);
```
the statement:
\[ c = \text{double}(p) \]

returns:
\[ c = \begin{array}{cccc}
1 & 0 & -2 & -5 \\
\end{array} \]

which is of class `double`:
\[
\text{class}(c) \\
\text{ans} = \text{double}
\]

**The Character Converter**

The `char` method produces a `char` vector that represents the polynomial displayed as powers of \(x\). The `char` vector returned is a syntactically correct MATLAB expression.

The `char` method uses a cell array to collect the `char` vector components that make up the displayed polynomial.

The `disp` method uses the `char` method to format the `DocPolynom` object for display. The `evalPoly` method uses `char` to create the MATLAB expression to evaluate.

Users of `DocPolynom` objects are not likely to call the `char` or `disp` methods directly, but these methods enable the `DocPolynom` class to behave like other data classes in MATLAB.

Here is the `char` method.

```matlab
methods
function str = char(obj)
    if all(obj.coef == 0)
        s = '0';
        str = s;
        return
    else
        d = length(obj.coef)-1;
        s = cell(1,d);
        ind = 1;
        for a = obj.coef;
            if a ~= 0;
                if ind == 1
                    if a > 0
                        s(ind) = {' + '};
                        ind = ind + 1;
                    else
                        s(ind) = {' - '};
                        ind = ind + 1;
                    end
                end
                if a == -1
                    s(ind) = {' - '};
                    ind = ind + 1;
                else
                    s(ind) = {num2str(a)};
                    ind = ind + 1;
                end
            end
            if a ~= 0 || d == 0
                if a == -1
                    s(ind) = {'.'};
                    ind = ind + 1;
                else
                    s(ind) = {num2str(a)};
                    ind = ind + 1;
                    if d > 0
                        s(ind) = {' * '};
                        ind = ind + 1;
                    end
                end
            end
        end
    end
end
```
Overload disp for DocPolynom

To provide a more useful display of DocPolynom objects, this class overloads disp in the class definition.

This disp method relies on the char method to produce a text representation of the polynomial, which it then displays on the screen.

The char method returns a cell array or the character '0' if the coefficients are all zero.

methods
definition disp(obj)
c = char(obj);  
if iscell(c)
    disp(['     ' c{:}])
else
    disp(c)
end
definition
end

When MATLAB Calls the disp Method

The statement:

\[ p = \text{DocPolynom([1 0 -2 -5])} \]

creates a DocPolynom object. Because the statement is not terminated with a semicolon, the resulting output is displayed on the command line:

\[ p = x^3 - 2x - 5 \]

Display Evaluated Expression

The char converter method forms a MATLAB expression for the polynomial represented by a DocPolynom object. The dispPoly method evaluates the expression returned by the char method with a specified value for x.

methods
function dispPoly(obj,x)
p = char(obj);
e = @(x)eval(p);
definition
end
```
y = zeros(length(x));
disp(['y = ',p])
for k = 1:length(x)
y(k) = e(x(k));
disp(['  ',num2str(y(k)),...
  '= f(x = ',...
  num2str(x(k)),')'])
end
end
end
```

Create a DocPolynom object `p`:
```
p = DocPolynom([1 0 -2 -5])
p =
x^3 - 2*x - 5
```

Evaluate the polynomial at `x` equal to three values, `[3 5 9]`:
```
dispPoly(p,[3 5 9])
y = x^3 - 2*x - 5
16 = f(x = 3)
110 = f(x = 5)
706 = f(x = 9)
```

**Redefine Indexed Reference**

The DocPolynom class redefines indexed reference to support the use of objects representing polynomials. In the DocPolynom class, a subscripted reference to an object causes an evaluation of the polynomial with the value of the independent variable equal to the subscript.

For example, given the following polynomial:
```
f(x)=x^3 - 2x - 5
```
Create a DocPolynom object `p`:
```
p = DocPolynom([1 0 -2 -5])
p =
x^3 - 2*x - 5
```
The following subscripted expression evaluates the value of the polynomial at `x = 3` and at `x = 4`, and returns the resulting values:
```
p([3 4])
ans =
16   51
```

**Indexed Reference Design Objectives**

Redefine the default subscripted reference behavior by implementing a `subsref` method.
If a class defines a `subsref` method, MATLAB calls this method for objects of this class whenever a subscripted reference occurs. The `subsref` method must define all the indexed reference behaviors, not just a specific case that you want to change.

The `DocPolynom` subsref method implements the following behaviors:

- \( p(x = [a_1 \ldots a_n]) \) — Evaluate polynomial at \( x = a \).
- \( p.coef \) — Access \( coef \) property value
- \( p.disp \) — Display the polynomial as a MATLAB expression without assigning an output.
- \( obj = p.method(args) \) — Use dot notation to call methods arguments and return a modified object.
- \( obj = p.method \) — Use dot notation to call methods without arguments and return a modified object.

**subsref Implementation Details**

The `subsref` method overloads the `subsref` function.

For example, consider a call to the `polyval` function:

```matlab
p = DocPolynom([1 0 -2 -5])
p =
    x^3 - 2*x - 5
polyval(p.coef,[3 5 7])
an =
    16  110  324
```

The `polyval` function requires the:

- Polynomial coefficients
- Values of the independent variable at which to evaluate the polynomial

The `polyval` function returns the value of \( f(x) \) at these values. `subsref` calls `polyval` through the statements:

```matlab
    case '()'
        ind = s.subs{:};
        b = polyval(a.coef,ind);
    case '_coef'
        switch s(1).subs
            case 'coef'
                b = a.coef;
```

When implementing `subsref` to support method calling with arguments using dot notation, both the type and subs structure fields contain multiple elements.

The `subsref` method implements all subscripted reference explicitly, as show in the following code listing.
case 'disp'
    disp(a)
otherwise
    if length(s)>1
        b = a.(s(1).subs)(s(2).subs{:});
    else
        b = a.(s.subs);
    end
    end
otherwise
    error('Specify value for x as obj(x)')
end
end
end

**Define Arithmetic Operators**

Several arithmetic operations are meaningful on polynomials. The `DocPolynom` class implements these methods:

<table>
<thead>
<tr>
<th>Method and Syntax</th>
<th>Operator Implemented</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>plus(a,b)</code></td>
<td>Addition</td>
</tr>
<tr>
<td><code>minus(a,b)</code></td>
<td>Subtraction</td>
</tr>
<tr>
<td><code>mtimes(a,b)</code></td>
<td>Matrix multiplication</td>
</tr>
</tbody>
</table>

When overloading arithmetic operators, consider the data types you must support. The `plus`, `minus`, and `mtimes` methods are defined for the `DocPolynom` class to handle addition, subtraction, and multiplication on `DocPolynom — DocPolynom` and `DocPolynom — double` combinations of operands.

**Define + Operator**

If either `p` or `q` is a `DocPolynom` object, this expression:

```
p + q
```

Generates a call to a function `@DocPolynom/plus`, unless the other object is of higher precedence.

The following method overloads the `plus (+)` operator for the `DocPolynom` class:

```matlab
function r = plus(obj1, obj2)
    obj1 = DocPolynom(obj1);
    obj2 = DocPolynom(obj2);
    k = length(obj2.coef) - length(obj1.coef);
    zp = zeros(1,k);
    zm = zeros(1,-k);
    r = DocPolynom([zp, obj1.coef] + [zm, obj2.coef]);
end
end
```

Here is how the function works:

- Ensure that both input arguments are `DocPolynom` objects so that expressions such as
  ```matlab
  p + 1
  ```
  that involve both a `DocPolynom` and a `double`, work correctly.
• Access the two coefficient vectors and, if necessary, pad one of them with zeros to make both the same length. The actual addition is simply the vector sum of the two coefficient vectors.

• Call the `DocPolynom` constructor to create a properly typed object that is the result of adding the polynomials.

**Define - Operator**

Implement the minus operator (-) using the same approach as the plus (+) operator.

The `minus` method computes \( p - q \). The dominant argument must be a `DocPolynom` object.

```matlab
methods
    function r = minus(obj1,obj2)
        obj1 = DocPolynom(obj1);
        obj2 = DocPolynom(obj2);
        k = length(obj2.coef) - length(obj1.coef);
        zp = zeros(1,k);
        zm = zeros(1,-k);
        r = DocPolynom([zp,obj1.coef] - [zm,obj2.coef]);
    end
end
```

**Define the * Operator**

Implement the `mtimes` method to compute the product \( p*q \). The `mtimes` method implements matrix multiplication since the multiplication of two polynomials is the convolution (\texttt{conv}) of their coefficient vectors:

```matlab
methods
    function r = mtimes(obj1,obj2)
        obj1 = DocPolynom(obj1);
        obj2 = DocPolynom(obj2);
        r = DocPolynom(conv(obj1.coef,obj2.coef));
    end
end
```

**Using the Arithmetic Operators**

Given the `DocPolynom` object:

```
p = DocPolynom([1 0 -2 -5]);
```

The following two arithmetic operations call the `DocPolynom plus` and `mtimes` methods:

```matlab
q = p+1;
r = p*q;
```

to produce

```
q = x^3 - 2*x - 4
r = x^6 - 4*x^4 - 9*x^3 + 4*x^2 + 18*x + 20
```
Designing Related Classes
A Class Hierarchy for Heterogeneous Arrays

Interfaces Based on Heterogeneous Arrays

A heterogeneous class hierarchy lets you create arrays containing objects of different classes that are related through inheritance. You can define class methods that operate on these heterogeneous arrays as a whole.

A class design based on heterogeneous arrays provides a more convenient interface than, for example, extracting elements from a cell array and operating on these elements individually. For more information on the design of class hierarchies that support heterogeneous arrays, see “Designing Heterogeneous Class Hierarchies” on page 10-20.

All heterogeneous hierarchies derive from matlab.mixin.Heterogeneous.

Define Heterogeneous Hierarchy

Note This example does not use valid terminology or techniques for managing financial assets. The purpose of this example is only to illustrate techniques for defining heterogeneous class hierarchies.

This example implements a system of classes to represent financial assets, such as stocks, bonds, and cash. Classes to represent categories of assets have certain common requirements. Each instance has one of the following:

- Textual description
- Type (stock, bond, or cash)
- Means to determine the current value of the asset

Heterogeneous arrays of these objects need methods that can operate on the whole array. These operations include:

- Creating a table of information about all assets contained in the array
- Graphing the relative contribution of each asset type contained in the array

These requirements are factored into the class that is the root of the hierarchy. The root class derives from matlab.mixin.Heterogeneous. In the following diagram, the Assets class is the root of the
hierarchy. The Stocks, Bonds, and Cash classes provide the specialization required for each type of asset.
**Assets Class**

The Assets class:

- Derives directly from `matlab.mixin.Heterogeneous`
- Is the root of the heterogeneous hierarchy
- Is abstract
- Is the class of heterogeneous arrays composed of any mixture of Stock, Bond, and Cash objects

**Properties**

The Assets class defines two properties:

- Description — A general description of the individual asset constrained to be of class `char`.
- Type — The type of asset defined as an abstract property that each subclass implements.

**Methods**

The Assets class defines these methods:

- `pie` — A sealed method that creates a pie chart showing the relative mix of asset types.
- `makeReport` — A sealed method that creates a report listing the assets.
- `getCurrentValue` — An abstract method that each concrete subclass must implement to return the current value of the asset.
- `getDefaultScalarElement` — `matlab.mixin.Heterogeneous` class method overridden in the Assets class to specify a default object. The Assets class is abstract so it cannot be used as the default object. For more information, see “Default Object” on page 20-9.

**Methods in Heterogeneous Hierarchies**

Methods defined by the Assets class are either:

- Concrete methods (fully implemented) that subclasses do not override
- Abstract methods (signatures only) that subclasses implement

Concrete methods defined by superclasses in a heterogeneous hierarchy must specify the `Sealed` attribute. Sealing these methods prevents subclasses from overriding methods implemented by the superclass. When calling methods on a heterogeneous array, MATLAB calls the methods defined by the class of the array (Assets in this example).

The `pie` and `makeReport` methods are examples of sealed methods that operate on heterogeneous arrays composed of Stock, Bond, and Cash objects.

Abstract methods defined by the superclasses in a heterogeneous hierarchy must specify the `Abstract` attribute. Defining an abstract method in a superclass ensures that concrete subclasses have an implementation for that exact method name. Use these methods element-wise so that each object calls its own method.

The `getCurrentValue` method is an example of an abstract method that is implemented by each subclass to get the current value of each asset.

Each type of subclass object calculates its current value in a different way. If you add another category of asset by adding another subclass to the hierarchy, this class must implement its own
version of a `getCurrentValue` method. Because all subclasses implement a `getCurrentValue` method, the `pie` and `makeReport` methods work with newly added subclasses.

For more information on the Sealed and Abstract method attributes, see “Method Attributes” on page 9-4.

**Assets Class Code**

The `Assets` class and other classes in the hierarchy are contained in a package called `financial`.

```matlab
classdef Assets < matlab.mixin.Heterogeneous
    % file: +financial.@Assets/Assets.m
    properties
        Description char = 'Assets'
    end
    properties (Abstract, SetAccess = private)
        Type
    end
    methods (Abstract)
        % Not implemented by Assets class
        value = getCurrentValue(obj)
    end
    methods (Static, Sealed, Access = protected)
        function defaultObject = getDefaultScalarElement
defaultObject = financial.DefaultAsset;
    end
    methods (Sealed)
        % Implemented in separate files
        % +financial.@Assets/pie.m
        % +financial.@Assets/makeReport.m
        pie(assetArray)
        makeReport(assetArray)
    end
end
```

For code listings for `pie` and `makeReport`, see “Operating on an Assets Array” on page 20-11.

**Stocks Class**

The `Stocks` class represents a specific type of financial asset. It is a concrete class that implements the abstract members defined by the `Assets` class, and defines class properties and methods specific to this type of asset.

**Properties**

The `Stocks` class defines these properties:

- **NumShares** — The number of shares held for this asset.
- **Symbol** — The ticker symbol corresponding to this stock.
- **Type** — `Stocks` class implementation of the abstract property defined by the `Assets` class. This concrete property must use the same attributes as the abstract version (that is, SetAccess private).
- **SharePrice** — Dependent property for the price per share. The `get.SharePrice` method obtains the current share price from web services when this property is queried.
Methods

The Stocks class defines these methods:

- **Stocks** — The constructor assigns property values and supports a default constructor called with no input arguments.
- **getCurrentValue** — This method is the Stocks class implementation of the abstract method defined by the Assets class. It returns the current value of this asset.
- **get.SharePrice** — The property get method for the dependent SharePrice property returns the current share price of this stock. For information on how to access web services from MATLAB, see the webread function.

**Stocks Class Code**

classdef Stocks < financial.Assets
    properties
        NumShares double = 0
        Symbol string
    end
    properties (SetAccess = private)
        Type = "Stocks"
    end
    properties (Dependent)
        SharePrice double
    end
    methods
        function sk = Stocks(description,numshares,symbol)
            if nargin == 0
                description = '';
                numshares = 0;
                symbol = '';
            end
            sk.Description = description;
            sk.NumShares = numshares;
            sk.Symbol = symbol;
        end
        function value = getCurrentValue(sk)
            value = sk.NumShares*sk.SharePrice;
        end
        function pps = get.SharePrice(sk)
            % Implement web access to obtain
            % Current price per share
            % Returning dummy value
            pps = 1;
        end
    end
end

**Bonds Class**

The Bonds class represents a specific type of financial asset. It is a concrete class that implements the abstract members defined by the Assets class and defines class properties and methods specific to this type of asset.
Properties

The Bonds class defines these properties:

- **FaceValue** — Face value of the bond.
- **Yield** — Annual interest rate of the bond.
- **Type** — Bonds class implementation of the abstract property defined by the Assets class. This concrete property must use the same attributes as the abstract version (that is, SetAccess private).
- **CurrentYield** — Dependent property for the current yield, The get.CurrentYield property get method obtains the value from web services.

Methods

The Bonds class defines these methods:

- **Bonds** — The constructor assigns property values and supports a default constructor called with no input arguments.
- **getCurrentValue** — This method is the Bonds class implementation of the abstract method defined by the Assets class. It returns the current value of this asset.
- **get.CurrentYield** — The property get method for the dependent CurrentYield property returns the current yield on this bond. For information on how to access web services from MATLAB, see the webread function.

Bonds Class Code

```matlab
classdef Bonds < financial.Assets
    properties
        FaceValue double = 0
        Yield double = 0
    end
    properties (SetAccess = private)
        Type = "Bonds"
    end
    properties (Dependent)
        CurrentYield double = 0
    end
    methods
        function b = Bonds(description,facevalue,yield)
            if nargin == 0
                description = '';
                facevalue = 0;
                yield = 0;
            end
            b.Description = description;
            b.FaceValue = facevalue;
            b.Yield = yield;
            b.Type = AssetTypes.Bonds;
        end
        function mv = getCurrentValue(b)
            y = b.Yield;
            cy = b.CurrentYield;
            if cy <= 0 || y <= 0
                mv = b.FaceValue;
            else
```
Cash Class

The Cash class represents a specific type of financial asset. It is a concrete class that implements the abstract members defined by the Assets class and defines class properties and methods specific to this type of asset.

Properties

The Cash class defines these properties:

- **Amount** — The amount of cash held in this asset.
- **Type** — Cash class implementation of the abstract property defined by the Assets class. This concrete property must use the same attributes as the abstract version (that is, SetAccess private).

Methods

The Cash class defines these methods:

- **Cash** — The constructor assigns property values and supports a default constructor called with no input arguments.
- **getCurrentValue** — This method is the Cash class implementation of the abstract method defined by the Assets class. It returns the current value of this asset.
- **save** — This method adds the specified amount of cash to the existing amount and returns a new Cash object with the current amount.
- **spend** — This method deducts the specified amount from the current amount and returns a new Cash object with the current amount.

Cash Class Code

classdef Cash < financial.Assets
    properties
        Amount double = 0
    end
    properties (SetAccess = private)
        Type = "Cash"
    end
    methods
        function c = Cash(description,amount)
            if nargin == 0
                description = ''; amount = 0;
end
c.Description = description;
c.Amount = amount;
end
function value = getCurrentValue(c)
    value = c.Amount;
end
function c = save(c,amount)
    newValue = c.Amount + amount;
    c.Amount = newValue;
end
function c = spend(c,amount)
    newValue = c.Amount - amount;
    if newValue < 0
        c.Amount = 0;
        disp('Your balance is $0.00')
    else
        c.Amount = newValue;
    end
end

Default Object

The design of this class hierarchy uses an abstract root class (Assets). Therefore, the Assets class must specify a concrete class to use as a default object by overriding getDefaultScalarElement. In this case, options include:

- Use one of the existing concrete classes for the default object.
- Define a concrete class in the hierarchy to use for the default object.

This implementation adds the DefaultAsset class to the hierarchy as a subclass of the Assets class. MATLAB creates objects of this class when:

- Creating arrays using indexed assignment with gaps in index numbers
- Loading heterogeneous arrays from MAT-files when MATLAB cannot find the class of an array element.

This diagram shows the addition of the DefaultAsset class:
DefaultAsset Class Code

classdef DefaultAsset < financial.Assets
   % file: +financial.@DefaultAsset/DefaultAsset.m
   properties (SetAccess = private)
      Type = "DefaultAsset"
   end
end

Designing Related Classes
end
methods
  function obj = DefaultAsset
    obj.Description = 'Place holder';
  end
  function value = getCurrentValue(~)
    value = 0;
  end
end
end

Operating on an Assets Array

The Assets class defines these methods to operate on heterogeneous arrays of asset objects:

- **pie** — Creates a pie chart showing the mix of asset types in the array.
- **makeReport** — Uses the MATLAB table object to display a table of asset information.

To operate on a heterogeneous array, a method must be defined for the class of the heterogeneous array and must be sealed. In this case, the class of heterogeneous arrays is always the Assets class. MATLAB does not use the class of the individual elements of the heterogeneous array when dispatching to methods.

**makeReport Method Code**

The Assets class makeReport method builds a table using the common properties and getCurrentValue method for each object in the array.

```matlab
function makeReport(obj)
  numMembers = length(obj);
  descs = cell(1,numMembers);
  types(numMembers) = "";
  values(numMembers) = 0;
  for k = 1:numMembers
    descs{k} = obj(k).Description;
    types(k) = obj(k).Type;
    values(k) = obj(k).getCurrentValue;
  end
  t = table;
  t.Description = descs';
  t.Type = types';
  t.Value = values';
  disp(t)
end
```

The Assets class pie method calls the getCurrentValue method element-wise on objects in the array to obtain the data for the pie chart.

**pie Method Code**

```matlab
function pie(assetArray)
  stockAmt = 0; bondAmt = 0; cashAmt = 0;
  for k=1:length(assetArray)
    if isa(assetArray(k),'financial.Stocks')
      stockAmt = stockAmt + assetArray(k).getCurrentValue;
    elseif isa(assetArray(k),'financial.Bonds')
```
bondAmt = bondAmt + assetArray(k).getCurrentValue;
elseif isa(assetArray(k), 'financial.Cash')
    cashAmt = cashAmt + assetArray(k).getCurrentValue;
end
end
k = 1;
if stockAmt ~= 0
    label(k) = {'Stocks'};
    pieVector(k) = stockAmt;
    k = k +1;
end
if bondAmt ~= 0
    label(k) = {'Bonds'};
    pieVector(k) = bondAmt;
    k = k +1;
end
if cashAmt ~= 0
    label(k) = {'Cash'};
    pieVector(k) = cashAmt;
end
pie(pieVector,label)
tv = stockAmt + bondAmt + cashAmt;
stg = ['Total Value of Assets: $',num2str(tv,'%0.2f')];
title(stg,'FontSize',10)
end

Create an Assets Array

These statements create a heterogeneous array by concatenating the Stocks, Bonds, and Cash objects. Calling the makeReport and pie methods creates the output shown.

s = financial.Stocks('Acme Motor Company',100,string('A'));
b = financial.Bonds('3 Month T',700,0.3);
c(1) = financial.Cash('Bank Account',500);
c(2) = financial.Cash('Gold',500);
assetArray = [s,b,c];
makeReport(assetArray);
pie(assetArray)

<table>
<thead>
<tr>
<th>Description</th>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>'Acme Motor Company'</td>
<td>Stocks</td>
<td>1232.5</td>
</tr>
<tr>
<td>'3 Month T'</td>
<td>Bonds</td>
<td>807.69</td>
</tr>
<tr>
<td>'Bank Account'</td>
<td>Cash</td>
<td>500</td>
</tr>
<tr>
<td>'Gold'</td>
<td>Cash</td>
<td>500</td>
</tr>
</tbody>
</table>
Total Value of Assets: $2896.38

See Also

Related Examples

- “Designing Heterogeneous Class Hierarchies” on page 10-20
- “Validate Property Values” on page 8-20
- “Set and Get Methods for Dependent Properties” on page 8-49