Software Development with MATLAB

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What are your software development concerns?

- Accuracy
- Software Speed
- Development Time
- Cost
- Compatibility
- Documentation
- Reusability
- Effective Testing
- Integration
- Ease of Collaboration
- Legacy Code
- Liability
- Maintainability
- Model Risk
- Robustness
- Developer Expertise
- Software Stack Complexity
- …?
Software development practices can help

Treat your software like an asset → reuse it

Developers often spend 4X the effort to maintain vs build software

…but this doesn’t need to be true!

Journal paper: “Faster issue resolution with higher technical quality of software”, Software Quality Journal, 201100
Software development practices can help

- Software development approaches like Agile help improve code quality
- The tools and practices we discuss today support Agile development
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How do you currently manage your files and paths?

- One big folder of files?
- Many folders of files?
- Organize your code in packages?
- Manual path management?
Successful collaborative development requires …

- Same source code, tests, documentation, requirements, compiler…
- Consistent, shared environment
- Integration with source control
Projects (MATLAB Projects)

- Manage your files and path
- Analyze file dependencies
- Function refactoring
- Run startup & shutdown tasks
- Create project shortcuts
- Label and filter files
- Integrate source control
Example: Building a Value at Risk Model on a Portfolio

Prototype VaR Model  Refactor and Test Code  Continuous Integration and Deployment
Managing your code with Projects

1. Create project
Managing your code with Projects

1. Create project
2. Set path and startup tasks
Managing your code with Projects

1. Create project
2. Set path and startup tasks
3. Explore dependencies
Managing your code with Projects

1. Create project
2. Set path and startup tasks
3. Explore dependencies
4. Label files

Identify and run tests
…on Continuous Integration (CI) servers
Managing your code with Projects

1. Create project
2. Set path and startup tasks
3. Explore dependencies
4. Label files
Managing your code with Projects

1. Create project
2. Set path and startup tasks
3. Explore dependencies
4. Label files
5. Integrate source control
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How do you keep track of and share your code as it changes?

- Do you:
  - make copies of your code?
  - e-mail yourself copies of your code?
  - keep a spreadsheet of changes?

- Or do you not keep track of your changes?

There’s a better way!
Source Control

- A system to manage changes to code, documents, etc.

- Benefits of source control:
  - Maintain backups, history, and ability to restore
  - Track changes and responsibility
  - Simplify reconciling conflicting changes
  - Generate discussion
  - Save you from yourself
Source Control integration

- Manage your code from within the MATLAB Desktop
- Git integrated into:
  - Projects
  - Current Folder browser
- Use Comparison Tool to view and merge changes between revisions
Co-authoring workflows

Creating a repo:
- Initialize
- Add
- Clone

Making changes:
- Commit
- Push
- Branch
- Merge

```
Repo

% Make prediction
RUL = predictRUL(mdl,data,n);
```

```
Repo

% Make prediction only when slope changes
if ~isempty(mdl.SlopeDetectionInstant)
    RUL = predictRUL(mdl,data,n);
else
    RUL = old_state.RUL;
end
```

```
Repo

% Make prediction only when slope changes
if ~isempty(mdl.SlopeDetectionInstant)
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What defines “better” code?

- Better organized?
- Smaller?
- Faster?
- More stable?
- More portable?
- Easier to maintain?
- …

YES!
Considerations when writing better, robust, and portable code

- Input validation
- Error handling
- Writing faster code using the MATLAB Profiler
- Writing code faster using the Live Editor
- Refactoring code to reduce complexity
- Writing code that works on all operating systems
- Sharing your code via apps, toolboxes, and deployment
- Integrating with other languages
- And more…
Writing more robust code

>> y = myfunc(1:5)
Index exceeds matrix dimensions.

Error in mypkg1.mypkg1a.mypkg1ab.myfunc1 (line 9)
y(idx) = u(idx)*log(u_hat(idx))+(1-u(idx))*log(1-u_hat(idx));

Error in mypkg2.mypkg2a.myfunc2 (line 5)
y = mypkg1.mypkg1a.mypkg1ab.myfunc1( myVar1 .* myVar2 );

Error in mypkg3.mypkg3a.myfunc3>@(x)mypkg2.mypkg2a.myfunc2(x) (line 4)
y = arrayfun( @(x) mypkg2.mypkg2a.myfunc2( x ), myVar );

Error in mypkg3.mypkg3a.myfunc3 (line 4)
y = arrayfun( @(x) mypkg2.mypkg2a.myfunc2( x ), myVar );

Error in myfunc (line 10)
Writing more robust code – Validating inputs

- `validateattributes`
- `assert`
- `isempty`, `isnan`, `isfinite`, ...
- `narginchk`
- `inputParser`
- Property validation for classes

```matlab
function y = myfunc( x )
% Validate inputs
validateattributes(x, 'double', {'size', [1 3], 'increasing'});

>> myfunc( 1:5 )
Error using myfunc (line 4)
Expected input to be of size 1x3, but it is of size 1x5.

>> myfunc([2 3 1])
Error using myfunc (line 4)
Expected input to be increasing valued.
```

```matlab
classdef ValidatorFunction
    properties
        Data(:,1) double {mustBePositive, mustBeFinite} = [1 2 3]
        Interp {mustBeMember(Interp,{'linear','spline'})} = 'linear'
    end
end
```
Writing more robust code – Handling errors more elegantly

- **error and warning**
  - Use identifiers

- **try/catch**

- **MException**

- **errordlg and warndlg**
Writing faster code – MATLAB Profiler

- Total number of function calls
- Time per function call
- Highlights largest code bottlenecks
- Statement coverage of code
Writing code faster – Programming aids in the Live Editor

- Automatically closed parentheses, loops, and conditional blocks

- Context-aware coding guides
  - Automatically suggest function names, variables, or file names
  - List available Name/Value pairs
Writing code faster – Quickly and safely refactoring code

- Live Editor shortcuts to refactor blocks of code into functions

```
function [z3, zSum] = myMathFunction(x, y)
z1 = x+y;
z2 = x-y;
z3 = y-x;
z4 = x*y;
zSum = z1 + z2 + z3 + z4;
end
```
Writing code faster – Quickly and safely refactoring code

- Function refactoring across files in Projects
Simple code quality and complexity assessment – checkcode

- Analyze all warnings and errors in a code

```matlab
code checkcode standardizeEmployeeInfo
L 13 (C 14-24): The value assigned here to 'maxDatetime' appears to be unused. Consider replacing it by ~.
L 80 (C 1-27): The value assigned to variable 'emailsInUsernameFormatParts' might be unused.
L 116 (C 1-17): The value assigned to variable 'validEmployeeData' might be unused.
L 118 (C 1-28): The value assigned to variable 'emailsInFirstLastFormatParts' might be unused.
```

- McCabe Cyclomatic Complexity
  - Measures complexity based on the number of linearly independent paths through a code

```matlab
code checkcode -cyc standardizeEmployeeInfo
L 1 (C 14-36): The McCabe cyclomatic complexity of 'standardizeEmployeeInfo' is 13.
```
Writing more portable code – Code that runs everywhere

- Operating System-aware code
  - `fullfile`
  - `ismac`, `ismac`, `isunix`

- More reliable portability with Projects
  - Consistent path management
  - Automated startup/shutdown procedures
  - Built-in file dependency analysis

```python
>>> fullfile("..","data","2019","April")
```

Windows:  
```
..\data\2019\April
```

Mac/Linux:  
```
../data/2019/April
```
Sharing your code – The traditional way

- Unzip the zip file
- Find the instructions and release notes
- Decide whether you want the thing
- Remove folders from old versions from the path
- Add folders to the path
- Save the path for next time
- Find the documentation
- Do work
Sharing your code – How should you share code?

It depends on who you are sharing your code with:

- Co-authors → Project
- End-user with MATLAB → Toolbox or App
- End-user without MATLAB → Deployment (application, library, C code …)
Sharing your code with MATLAB users – Packaging your code

- Toolbox Packaging
- App Packaging

- Combine files into one installation file
- Installs in MATLAB Add-Ons or Apps tab
- Documents required products
Sharing your code outside of MATLAB – Application Deployment

Share your applications as:
- Standalone software
- Web applications
- Language-specific libraries
- Generated code

- MATLAB Compiler
- MATLAB Compiler
- MATLAB Compiler SDK
- MATLAB Coder
Integrating with other languages – External interfaces

Calling Libraries Written in Another Language
- Java
- Python
- C/C++
- Fortran
- COM components and ActiveX® controls
- RESTful, HTTP, and WSDL web services

Calling MATLAB from Another Language
- Java
- Python
- C/C++
- Fortran
- COM Automation server
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Code Maintenance – The hidden cost of development

- How do you ensure code doesn’t break over time?
- How do you keep new features from breaking existing features?
- How do you maintain confidence that your code is working as expected?
Upgrading to the latest MATLAB – Code Compatibility Report

- Tool to help upgrade code to latest and greatest MATLAB
- Identifies potential compatibility issues
- Hundreds of checks for incompatibilities, errors, and warnings

Link to documentation for updates

Go directly to the line of code
Test early, test often, test automatically

- Reduce risk of code breaking
- Catch problems early
- Improve code quality
- Document expected behaviour

Credit: http://geek-and-poke.com/
Testing Frameworks

*Test your code early and often*

- MATLAB Unit Testing Framework
- Performance Testing Framework
- App Testing Framework
Testing Frameworks – Flexible development

- Script-based test
- Function-based test
- Class-based test
- Test integration with Projects

Image: Test Pump Fault Model

This includes unit tests for the predictions

**Test: Model type**
Load the models and ensure they are the right types.

```matlab
load MLModels trainedModel
dml = trainedModel.ClassificationEnsemble;
assert(isa(dml,'classreg.learning.classif.CompactClassificationEnsemble'),...
     'Model is not a CompactClassificationEnsemble. ')
```

**Test: Prediction**
Ensure a prediction is returned from the model using predictFcn.

```matlab
load MLModels trainedModel
load MLData data
FaultType = trainedModel.predictFcn(data);
assert(length(FaultType) == height(data))
assert(iscategorical(FaultType))
```
Testing Frameworks – Easily customize and run existing tests

- Added buttons to make testing more readily accessible
- Testing your code should be as easy as hitting the “Run” button!
Testing Frameworks – App Testing Framework

- Verify app behavior with tests that programmatically perform gestures on a UI component

```javascript
testCase.press(myApp.checkbox)

testCase.choose(myApp.discreteKnob, "Medium")

testCase.drag(myApp.continuousKnob, 10, 90)

testCase.type(myApp.editfield, myTextVar)
```
Automated Testing – Continuous Integration (CI)

- A system to automate the building, testing, integration, and deployment of code as it is being developed and maintained

- Popular CI systems: Jenkins, Travis, CircleCI, Bamboo, and others...

- Benefits:
  - Detect integration bugs early
  - Allow you to stop bugs from being accepted
  - Track and report testing history
  - Flexible testing schedules and triggers
Automated Testing – Continuous Integration workflow

Continuous Integration System

Source Control
- Push
- Merge Request
- Pull Request
- Check In
- Periodic
- Manual

Trigger

Build
- Run MATLAB / Simulink Tests
- Run Performance Tests
- Generate Code
- Package Toolboxes

Post Build
- Publish:
  - Test Results
  - Coverage Results
  - Performance Results
- Accept Merge Request
- Email Notification
Automated Testing – Jenkins plugin

- Easily connect and configure MATLAB with Jenkins
- Schedule automatic code execution and testing:
  - based on time of day
  - whenever new code changes are committed
Automated Testing – Jenkins plugin – Configuration

- Easy configuration
  - Locate MATLAB
  - Identify repository to load
  - Set build triggers
  - Add build step
Automated Testing – Jenkins plugin – Testing reports

- View testing results
- View code coverage
- View testing reports
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Key Takeaways

- You will save you time, effort, money, and frustration with good software development practices.

- MATLAB provides tools that enable agile software development.

- We’re adding more software development tools and features every release!
MATLAB

is the easiest and most productive environment for engineers and scientists