Using MATLAB & Simulink to Build Algorithms in Everything

Simplifying your work…

…often at higher levels of abstraction.
Using MATLAB & Simulink to Build Algorithms in Everything

Inputs ➔ Design ➔ Outputs
Artificial Intelligence

The capability of a machine to match or exceed intelligent human behavior by training a machine to learn the desired behavior
There are two ways to get a computer to do what you want

Traditional Programming

- Data
- Program
- COMPUTER
- Output
There are two ways to get a computer to do what you want

Machine Learning

Data → COMPUTER → Model

Output
Artificial Intelligence

Data → Machine Learning → Deep Learning → Model
Using MATLAB and Simulink to Build Deep Learning Models

- Data (Inputs)
- Machine Learning
- Deep Learning (Design)
- Model (Outputs)

MATLAB & SIMULINK®
Using Apps for Ground Truth Labeling
Image and Video Data

Computer Vision Toolbox
Using Apps for Ground Truth Labeling
Signal Data
Using Apps for Ground Truth Labeling

Audio Data

Audio Toolbox
Using Apps for Designing Deep Learning Networks
Using Transfer Learning with Pre-trained Models

- Inception-v3
- ResNet-101
- VGG-16
- Inception-ResNet-v2

- ResNet-18
- GoogLeNet
- DenseNet-201
- VGG-19

- SqueezeNet
- AlexNet
- ResNet-50
Using Models from Other Frameworks

- Keras-Tensorflow
- Caffe
- ONNX
- PyTorch
- Caffe2
- MXNet
- Core ML
- CNTK
- (...)
Deploying Deep Learning Applications

Deep Learning Networks

Pre-processing ➔ Post-processing ➔ Coder Products

Intel MKL-DNN Library

NVIDIA TensorRT & cuDNN Libraries

ARM Compute Library

MATLAB Coder
GPU Coder
Using MATLAB and Simulink for Reinforcement Learning

Inputs

Data

Machine Learning

Deep Learning

Output

Model

Reinforcement Learning Toolbox
Using MATLAB and Simulink for Reinforcement Learning
Using MATLAB and Simulink for Reinforcement Learning

Data → Machine Learning → Deep Learning → Model

Inputs → Design → Outputs

Reinforcement Learning Toolbox

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Using MATLAB and Simulink for Reinforcement Learning

Generate Data
- Scenario Design
- Simulation-based data generation

Inputs

Machine Learning
Deep Learning

Design

Model

Outputs

MATLAB & SIMULINK

Simulink
Reinforcement Learning Toolbox
Using MATLAB and Simulink for Reinforcement Learning
Using MATLAB & Simulink to Build Algorithms in Everything

Inputs → Design → Outputs

Inputs
Design
Outputs

MATLAB & SIMULINK®

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### Working with Text Data

**Vehicle_Repair.csv**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>AM/PM</th>
<th>JobNo</th>
<th>VehicleID</th>
<th>UnitNo</th>
<th>Reason</th>
<th>Notes</th>
<th>CostParts</th>
<th>CostLabor</th>
<th>CostTotal</th>
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<td></td>
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</tbody>
</table>
### Working with Text Data

```matlab
% Read a text file and display the first 20 rows of the table
filename = 'example.txt';
t = readtable(filename,'TextType','string');
disp(t(1:20,6:7))
```

<table>
<thead>
<tr>
<th>Reason</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;04&quot; DRIVER'S REPORT</td>
<td>&quot;PM SERVICE, CHECK TURN SIGNAL, CLUNKING NOISE WHEN DRIVING&quot;</td>
</tr>
<tr>
<td>&quot;08&quot; PM SERVICE</td>
<td>&quot;SERVICEROB,EXT,5604&quot;</td>
</tr>
<tr>
<td>&quot;04&quot; DRIVER'S REPORT</td>
<td>&quot;NEED 4 PLOW PINS&quot;</td>
</tr>
<tr>
<td>&quot;04&quot; DRIVER'S REPORT</td>
<td>&quot;INSTALL SPINNER ASSY&quot;</td>
</tr>
<tr>
<td>&quot;13&quot; SNOW BREAKDOWN</td>
<td>&quot;DON'T START&quot;</td>
</tr>
<tr>
<td>&quot;04&quot; DRIVER'S REPORT</td>
<td>&quot;DOG BONE PIN BROKEN&quot;</td>
</tr>
<tr>
<td>&quot;08&quot; PM SERVICE</td>
<td>&quot;NEED SERVICE, CHECK BRAKES&quot;</td>
</tr>
<tr>
<td>&quot;04&quot; DRIVER'S REPORT</td>
<td>&quot;HYD CAP CHECK ENGINE LIGHT ON&quot;</td>
</tr>
<tr>
<td>&quot;40&quot; NEGLIGENCE</td>
<td>&quot;TARP VALVE STICKING RIGHT SIDE MIRROR BRACKET BROKEN&quot;</td>
</tr>
<tr>
<td>&quot;13&quot; SNOW BREAKDOWN</td>
<td>&quot;HANDLES IN CAB LOOSE&quot;</td>
</tr>
<tr>
<td>&quot;04&quot; DRIVER'S REPORT</td>
<td>&quot;NO PLOW LIGHTS&quot;</td>
</tr>
<tr>
<td>&quot;10&quot; ROADCALL</td>
<td>&quot;WILL NOT START&quot;</td>
</tr>
<tr>
<td>&quot;10&quot; ROADCALL</td>
<td>&quot;WILL NOT START&quot;</td>
</tr>
<tr>
<td>&quot;10&quot; ROADCALL</td>
<td>&quot;WILL NOT START&quot;</td>
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<tr>
<td>&quot;10&quot; ROADCALL</td>
<td>&quot;WILL NOT START&quot;</td>
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<td>&quot;10&quot; ROADCALL</td>
<td>&quot;WILL NOT START&quot;</td>
</tr>
<tr>
<td>&quot;10&quot; ROADCALL</td>
<td>&quot;CONVEYOR NOT WORKING&quot;</td>
</tr>
<tr>
<td>&quot;10&quot; ROADCALL</td>
<td>&quot;DON'T START&quot;</td>
</tr>
<tr>
<td>&quot;10&quot; ROADCALL</td>
<td>&quot;DON'T START&quot;</td>
</tr>
<tr>
<td>&quot;10&quot; ROADCALL</td>
<td>&quot;DON'T START&quot;</td>
</tr>
</tbody>
</table>
Working with Text Data

Deep Learning Toolbox
Statistics and Machine Learning Toolbox
Text Analytics Toolbox
MATLAB
Working with Text Data

Nouns

Adjectives

Nouns

Adjectives
Creating Your Own Data
Identifying the Useful Data

1. Acquire Data
2. Preprocess Data
3. Identify Condition Indicators
4. Train Model
5. Deploy & Integrate

- Visualize data
- Extract Features
- Select the most useful features

Machine Learning
Identifying the Useful Data
Identifying the Useful Data

Signal Features
- Generate statistics from signals

Rotating Machinery Features
- Generate features from rotating machinery signals

Nonlinear Features
- Generate nonlinear features from signals

Predictive Maintenance Toolbox

Spectral Features
- Condition variables: faultCode
- Computation mode: use full signal

- Spectral peaks
  - Peak amplitude
  - Peak frequency
- Peak value lower threshold: $\text{Inf}$
- Number of peaks: 1
- Minimum frequency gap: 0.001
- Peak excursion tolerance: 0

- Modal coefficients

- Band power
Identifying the Useful Data
Designing Decision Logic with Stateflow in MATLAB

```matlab
inNormalRegion = true;
counter = 0;
for i=1:length(inData)
    if(inNormalRegion)
        if(inData(i)<t1)
            counter = counter+1;
            if(counter>=N1)
                inNormalRegion = false;
            end
        else
            counter = 0;
        end
    else
        if(inData(i)>=t2)
            counter = counter+1;
            if(counter==N2)
                inNormalRegion = true;
            end
        else
            counter = 0;
        end
    end
    if(inNormalRegion)
        outData(i) = inData(i);
    else
        outData(i) = 0;
    end
end
```

- Normal:
  - \(y = u\)
  - \([\text{count}(u < t1) = N1]\)

- Abnormal
  - \(y = 0\)
  - \([\text{count}(u \geq t2) = N2]\)
Using Stateflow in MATLAB

% Callbacks that handle component events
methods (Access = private)

% Code that executes after component creation
function startupFcn(app)
    app.lanternLogic = BlinkLanternLogic('app',app);
end

% Button pushed function: POWERButton
function POWERButtonPushed(app, event)
    app.lanternLogic.powerButton();
end

% Button pushed function: COLORButton
function COLORButtonPushed(app, event)
    app.lanternLogic.colorButton();
end

% Close request function: UIFigure
function UIFigureCloseRequest(app, event)
    delete(app.lanternLogic);
    delete(app);
end

% Button pushed function: BLINKButton
function BLINKButtonPushed(app, event)
    app.lanternLogic.blinkButton();
end
Editing at the Speed of Thought
Editing at the Speed of Thought
Editing at the Speed of Thought
Editing at the Speed of Thought
Editing at the Speed of Thought
Controlling the Execution of Model Components

Schedulable Rate-Based Model

Export Function Model
Controlling the Execution of Model Components
Simplifying Integration with External C/C++ Code

#include "rtwdemo_rowlutcol2row_workflow_rowrow.h"

/* Block parameters (default storage) */

PrtP = {
    /* Variable: Tbl_1 */
    /* Referenced by: '<Root>/2-D Lookup Table' */
    
    { 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 9.0, 10.0, 11.0, 12.0, 13.0, 14.0, 15.0, 16.0, 17.0, 18.0, 19.0, 20.0, 21.0, 22.0, 23.0, 24.0, 25.0, 26.0, 27.0, 28.0, 29.0, 30.0, 31.0, 32.0, 33.0, 34.0, 35.0, 36.0, 37.0, 38.0, 39.0, 40.0, 41.0, 42.0, 43.0, 44.0, 45.0, 46.0, 47.0, 48.0, 49.0, 50.0, 51.0, 52.0, 53.0, 54.0, 55.0, 56.0, 57.0, 58.0, 59.0, 60.0 };
};
Simplifying Integration with External C/C++ Code
Viewing Generated Code Alongside the Model
Viewing Generated Code Alongside the Model
Sharing Live Scripts

Estimating Sunrise and Sunset

Using the latitude ($\phi$), the sun's declination ($\delta$) and the solar time correction ($SC$) we can calculate sunrise and sunset times.

$\text{sunrise} = 12 - \frac{\cos^{-1}(-\tan \phi \tan \delta)}{15^\circ} - \frac{SC}{60}$

$\text{sunset} = 12 + \frac{\cos^{-1}(-\tan \phi \tan \delta)}{15^\circ}$

Refer to this page for background and details on the equations used.
Sharing Live Scripts

Exploring Exoplanets

In this example we will explore some data on exoplanets - planets outside our own solar system. The data used here is a subset of data from the NASA Exoplanet Archive. We will start by using the data to answer some questions about this set of exoplanets in the archive. Then we will do some calculations to try to identify planets in the archive that might be capable of supporting life.

```matlab
exoplanets = readtable('exoplanets.xlsx');
exoplanets(stlb);```

**How Far Away Are these Planets?**

There are 90 exoplanets within 50 light-years of earth and 460 exoplanets within 200 light-years.

```matlab
histogram(x.ecl+exoplanets.st_distance, 'BinWidth', 50)
xlabel('light distance (in AU)')
ylabel('Number of Planets')
```

**Where is the nearest exoplanet?**

```matlab
idx = find(exoplanets.st_distance == min(exoplanets.st_distance));
name = char(exoplanets(l, st_name));
```
Sharing Live Scripts
Creating Apps
Deploying Web Apps

MATLAB Web Apps

Transient Heat Conduction

Initial and Boundary Conditions
- Initial T (°C): 10
- Top T (°C): 0
- Bottom T (°C): 58
- Left T (°C): 25
- Right T (°C): 25

Geometry
- \( x (\text{m}) \): 0.05
- \( y (\text{m}) \): 0.05
- \( dx (\text{m}) \): 0.0025
- \( dy (\text{m}) \): 0.0025

Note: Numerical stability requires \( F \_\text{num} \)
Current \( F \_\text{num} = 0.0003 \)

Thermal Diffusivity
- Alpha (\text{m}^2/\text{s}): 1e-4

Time and Convergence
- dt (s): 0.01
- Total Time (s): 50
- Convergence Criterion: 1e-4

MATLAB Compiler

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Using MATLAB & Simulink to Build Algorithms in Everything

Inputs  →  Design  →  Outputs
Evaluating Architectures

Inputs → Architecture → Design → Outputs

MATLAB & SIMULINK®
Evaluating Architectures

Inputs → Architecture → Design → Outputs

MATLAB & SIMULINK®
Designing System and Software Architectures
Designing System and Software Architectures
Designing **Beyond** System and Software Architectures

**Systems and Software**

**SoC Hardware and Software**

**AUTOSAR Software**

- System Composer
- SoC Blockset
- AUTOSAR Blockset
Using MATLAB & Simulink to Build Algorithms in Everything

Inputs → Architecture → Design → Outputs

Test & Verification → Collaboration → Scaling

MATLAB & SIMULINK®
Using MATLAB & Simulink to Build Algorithms in Everything
Using MATLAB & Simulink to Build Algorithms in Everything

Inputs → Architecture → Design → Outputs

Test & Verification → Collaboration → Scaling

MATLAB & SIMULINK®
Integrating with Third-party Requirements Tools

External Requirements
- .doc
- .xls
- Database

Requirements Management Tools

Simulink Requirements
- External Requirements
- Authored Requirements

R2019a

Import
Edit
Export

ReqIF

Authoring Requirements Tools
Include Custom Code in Test & Verification

Simulink

C/C++

Simulink Design Verifier

Stateflow

C/C++

Simulink Design Verifier
Using the MATLAB Unit Test Framework

```matlab
>> result.table
ans =
    2x6 table

<table>
<thead>
<tr>
<th>Name</th>
<th>Passed</th>
<th>Failed</th>
<th>Incomplete</th>
<th>Duration</th>
<th>Details</th>
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<td>false</td>
<td>false</td>
<td>0.12241</td>
<td>[1x1 struct]</td>
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<tr>
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<td>true</td>
<td>true</td>
<td>0.11542</td>
<td>[1x1 struct]</td>
</tr>
</tbody>
</table>
```
Using the MATLAB App Testing Framework

testCase.press(myApp.checkbox)

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

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

testCase.type(myApp.editfield, myTextVar)
Using the MATLAB Performance Testing Framework
Using Continuous Integration

Plugins Index
Discover the 1000+ community contributed Jenkins plugins to support building, deploying and automating any project.

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MATLAB

https://plugins.jenkins.io/
Using Continuous Integration

MATLAB 1.0
Minimum Jenkins requirement: 2.7.3
ID: matlab

Installs: No usage data available
GitHub →
Last released: 2 days ago

Maintainers
MathWorks

Dependencies
bouncyCastle API v.2.16.0 (implies) (what's this?)
Command Agent Launcher v.1.0 (implies) (what's this?)
JDK Tool v.1.0 (implies) (what's this?)
JAXB v.2.3.0 (implies) (what's this?)

The Jenkins plugin for MATLAB® enables you to easily run your MATLAB tests and generate test artifacts in formats such as JUnit, TAP, and Cobertura code coverage reports.

Features
- Support to run MATLAB tests, present in the Jenkins workspace automatically. (This also includes the tests present in .prj files)
- Generate tests artifacts in JUnit, TAP & Cobertura code coverage formats.
- Support to run tests, using custom MATLAB command or custom MATLAB script file.

https://plugins.jenkins.io/matlab
Using Projects in MATLAB
Parallel Simulations in Simulink

Simulation Manager

Simulink
Parallel Computing Toolbox
Scaling Computations on Clusters and Clouds

MATLAB Parallel Computing Toolbox

MATLAB Parallel Server

Cloud

GPU

Multi-core CPU
Using MATLAB & Simulink to Build Algorithms in Everything
Specialized Tools for Building Algorithms in Everything

Communications

Physical interconnects

Analog Mixed-Signal

5G Toolbox

SerDes Toolbox

Mixed-Signal Blockset
Developing Autonomous Systems

Perception

Planning

Control
Evaluate Sensor Fusion Architectures

Sensor Fusion and Tracking Toolbox
Simulate Path Planning Algorithms
Design Lane-following and Spacing Control Algorithms
Developing Autonomous Systems

Lidar Processing & Tracking

HERE HD Maps & OpenDRIVE Roads

UAV Algorithms

Computer Vision Toolbox

Automated Driving Toolbox

Robotics System Toolbox
Using MATLAB & Simulink to Build Algorithms in Everything

Inputs → Architecture → Design → Outputs

- Test & Verification
- Collaboration
- Scaling
Read the Release Notes
Get Started

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Quickly learn the essentials of MATLAB.

Simulink Onramp
Learn to create, edit, and troubleshoot Simulink models.

Deep Learning Onramp
Learn to use deep learning techniques in MATLAB for image recognition.
MATLAB EXPO 2019