MATLAB EXPO 2019

Software Development Practices within MATLAB

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I want to help you...



...your MATLAB tools



What are your software development concerns?

- Accuracy
- Execution performance
- Development time
- Cost
- Compatibility
- Documentation
- Reusability
- Effective testing
- Integration

- Ease of collaboration
- Legacy code
- Liability
- Maintainability
- Model risk
- Robustness
- Developer expertise
- Software stack complexity
- ...?



Agenda

- MATLAB Projects
- Version control integration
- Language features
- Development environment
- Testing & CI
- Toolbox distribution
- Design patterns





MATLAB Projects



Projects (MATLAB + Simulink 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





1. Create project





- 1. Create project
- 2. Set path and startup tasks

Se	Set Up Project (Step 2 of 2)	×	×
Sj Oj	Specify project files to automate startup tasks. Startup files automatically run (.m and .p files), load (.mat files), and open (Simulink models) when you open the project. Startup files:		
6	Simulation\pump_setup.m javasetup.m		-23
6	Add Remove Shutdown files:		
6			
6	Add Remove		
	Start Simulink before this project starts Refresh Simulink customizations		
_	Back Finish	5	



- 1. Create project
- 2. Set path and startup tasks
- 3. Explore dependencies





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



Identify and run tests



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

Project - StreamingPumpDemo					
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- 1. Create project
- 2. Set path and startup tasks
- 3. Explore dependencies
- 4. Label files
- 5. Integrate source control

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Version control



Version control

- Maintain backups, history, and ability to restore
- Track changes and responsibility
- Simplify reconciling conflicting changes
- Generate discussion
- Save you from yourself

📣 Branches	×
Current Branch Name: master HEAD: 48eb7581915372974ab7d9cd27e4b9d4348950af Branch Browser	Direct to HEAD
Branches: master	✓ 🛷 Switch 🖒 Merge 🔻
Author restricted access list for EnigmaReflectors and Merge branch 'master' into 'Adam_Branch' Merge branch 'master' into 'CommandLine clagunow <corey. Merge branch 'ULBRANCH' into 'master' clagunow <corey. Merge remote-tracking branch 'refs/re adding a few todos origin/Rele Merge remote-tracking Modified matrix transform to match \ added script for demo at Company M Merge branch 'ULBRANCH' of http://i unknown <clagu. added clearL og method to Enigma cla snap in new tests from Release_Beta fixed bug created by bad merge Merge branch 'ULBRANCH' into 'ULBRA clagunow <clagu. clagunow <clagu. Clag</clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </clagu. </corey. </corey. 	ID: 7336d307047eb5d67837071e9a308de789d06a4b Author: Cesar Rivadeneyra (cesar.rivadeneyra@mathworks.com) Committer: Cesar Rivadeneyra (cesar.rivadeneyra@mathworks.com) / Date: 2015-04-22 13:43:48 Message: Added capability to add enter Added capability to add space from feedback ✓ / Differences from parent 2708f110fab2143cfb / @Enigma / @EnigmaApp / @EnigmaApp.m / @EnigmaApp.m
Help	Close



Version 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

📣 MATLAB R2019a				×
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Co-authoring workflows

Creating a repo:

- Initialize
- Add
- Clone

Making changes:

- Commit
- Push
- Branch
- Merge





Implementation

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



Unactionable errors

>> y = myfunc(1:5)

Index exceeds matrix dimensions.

Error in mypkgl.mypkgla.mypkglab.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 <u>myfunc</u> (line 10) MATLAR FXPO 2019





Validating inputs

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

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

```
classdef ValidatorFunction
    properties
        Data(:,1) double {mustBePositive, mustBeFinite} = [1 2 3]
        Interp {mustBeMember(Interp,{'linear','spline'})} = 'linear'
    end
end
MATLAE FOR LAWER
```



Handling errors more elegantly

- error and warning
 - Use identifiers
- try/catch
- MException
- errordlg and warndlg





MATLAB Profiler

- Total number of function calls
- Time per function call
- Highlights largest code bottlenecks
- Statement coverage of code

0
Run and Time

Profiler

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Start Profiling Run this code:				
Profile Summary				
Generated 31-Aug-2015 15:28:51 using per	formance ti	me.		
Function Name	Calls	<u>Total Time</u>	<u>Self Time</u> *	Total Time Plot (dark band = self time)
<u>testFit</u>	1	6.525 s	3.591 s	
<u>xlswrite</u>	10	1.964 s	0.024 s	
<u>xlswrite>ExecuteWrite</u>	10	1.919 s	0.394 s	
iofun\private\openExcelWorkbook	10	0.894 s	0.720 s	
onCleanup>onCleanup.delete	10	0.583 s	0.001 s	
<u>xlswrite>@()xlsCleanup(Excel.file)</u>	10	0.582 s	0.002 s	
iofun\private\xIsCleanup	10	0.580 s	0.579 s	
<u>close</u>	1	0.477 s	0.005 s	
<u>close>request_close</u>	1	0.440 s	0.026 s	•
closereq	10	0.390 s	0.376 s	•
subplot	20	0.163 s	0.090 s	1
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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

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Quickly and safely refactoring code

• Live Editor shortcuts to refactor blocks of code into functions





Quickly and safely refactoring code

 Function refactoring across files in Projects

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Labels	torqueGear.m trqbrgfric1.m trqepi2.m	* * * *	+



Simple code quality and complexity assessment – checkcode

Analyze all warnings and errors in a 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

>> checkcode -cyc standardizeEmployeeInfo

L 1 (C 14-36): The McCabe cyclomatic complexity of 'standardizeEmployeeInfo' is 13.



Code that runs everywhere

- Operating System-aware code
 - fullfile
 - ispc, ismac, isunix
- More reliable portability with Projects
 - Consistent path management
 - Automated startup/shutdown procedures
 - Built-in file dependency analysis

>>	fullfile(""	,"data"	,"2019"	"April")
----	-----------	----	---------	---------	----------

Windows:	"\data\2019\April"
Mac/Linux:	"/data/2019/April"

Set Up Project (Step 1 of 2) Specify folders to add to the pr open the project, and removed	oject path. These folders are added to the MATLAB search path when you I when you close the project.
 MachineLearning MATLAB_Kafka_Producer; MATLAB_Kafka_Producer; mps_stream mps_stream\mps-utils mps_stream\mps-utils\Ka 	Add Folder Set Up Project (Step 2 of 2) Specify project files to automate startup tasks. Startup files automatically run (.m and .p files), load (.mat files), and open (Simulink models) when you open the project. Startup files:
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Simulation	Add Remove
	Start Simulink before this project starts Refresh Simulink customizations

Finish



Code maintenance

A MathWorks

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

(3 Errors) (ser - (3 Errors) Code Compati	bility Report					-	
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Testing Frameworks

- MATLAB Unit Testing Framework
- Performance Testing Framework
- App Testing Framework

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Number of Tests: Testing Time:	17 0.4516 seconds
Overall Result:	PASSED
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MATLAB Unit Testing Framework

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



Test Pump Fault Model

This includes unit tests for the predictions

```
Test: Model type
```

test_Predictions.mlx 🛛 🗶 🕇

1

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9

Load the models and ensure they are the right types.

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

Test: Prediction

Ensure a prediction is returned from the model using predictFcn.

```
load MLModels trainedModel
load MLData data
FaultType = trainedModel.predictFcn(data);
assert(length(FaultType) == height(data))
assert(iscategorical(FaultType))
```

LIHITHD EVLA TOTA



Editor integration

HOME

New

Added buttons to make testing more readily accessible

PLOTS

FILE

Open Save

🔄 Find Files

🚔 Print 💌

Compare 🔻

APPS

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즞 Go To 🔻

🔍 Find 🔻

NAVIGATE

EDITOR

Insert 🛃 fx

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EDIT

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Testing your code should be as easy as hitting the "Run" button!

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		Pauses execution wh	en an error occurs		3: Detailed	
		Pause on Warnings Pauses execution wh	en a warning occurs		4: Verbose	
		Pause on NaN or In Pauses execution wh	f en a NaN or Inf value is returned			



App Testing Framework

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



testCase.type(myApp.editfield, myTextVar)



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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





Continuous Integration workflow



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



ORebel



MathWorks[®]

JDK Tool

MATLAB EXPO 2019

Jenkins plugin configuration

- Locate MATLAB
- Identify repository to load
- Set build triggers
- Add build step









Jenkins plugin reports

- View testing results
- View code coverage
- View testing reports







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 \rightarrow Project
- End-user with MATLAB \rightarrow Toolbox or App
- End-user without MATLAB \rightarrow 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

Main file Add main function file (program's entry point). Add main file Files included through analysis These are the files found through dependency analysis. Refresh Shared resources and helper files Main file App Name Author Name Show contact info Show contact info Select screenshot Summary Description Output File C:\\App Name.mlappinstall Change output fold	Pick main file		Describe your app		Package into installation fi
Add main file (program's entry point). Add main file Files included through analysis These are the files found through dependency analysis. Refresh Shared resources and helper files	Main file	Â	App Name		
These are the files found through dependency analysis. Refresh Shared resources and helper files	Add main function file (program's entry point). Add main file		Select screenshot	Author Name Show contact info Summary	Package
Shared resources and helper files Change output fold	These are the files found through dependency analysis. Refresh		Description	E	Output File C:\\App Name.mlappinstall
Place images, data files, and GUIs (.fig	Shared resources and helper files Place images, data files, and GUIs (.fig				Change output folder
	Also place here				

📣 MathWorks[.]

Sharing your code outside of MATLAB – Application Deployment

Share your applications as:

- Standalone software MATLAB Compiler
- Web applications
 MATLAB Compiler
- Language-specific libraries MATLAB Compiler SDK
- Generated code

MATLAB Coder





Design Patterns



Preface: handles and values

- MATLAB has both value and handle classes
- Everyday MATLAB datatypes exhibit value behaviour
- Handle classes facilitate multiple references to the same object
- MATLAB's copy-on-write optimization limits memory consumption
- MATLAB's reference counter disposes of unused handle objects

Choose handle or value based on the need for multiple references.



*

Design patterns

- Observer
- Adapter
- Singleton
- Builder
- Memento



Elements of Reusable Object-Oriented Software

Erich Gamma Richard Helm Ralph Johnson John Vlissides



over art © 1994 M.C. Escher / Cordon Art - Baarn - Holland. All rights reserved.

Foreword by Grady Booch





Observer pattern

- When an object changes state, how can an arbitrary number of dependent objects react?
- How to avoid making the objects tightly coupled?
- Handle class for subject
- Event(s) on subject, possibly with custom event data
- Observers listen to events on subject
- Example: model with multiple views





Adapter pattern

- How can a class be reused that does not have an interface that a client requires?
- How can classes that have incompatible interfaces work together?
- How can an alternative interface be provided for a class?
- Private property to store an instance of the reused class
- Dependent properties to forward gets and sets
- Wrapper generator using meta.class APIs
- Examples: chart, modified timer, map services





Singleton pattern

- How can it be ensured that a class has only one instance?
- How can the sole instance of a class be accessed easily?
- How can a class control its instantiation?
- How can the number of instances of a class be restricted?
- Private constructor
- Private property to store the object
- getInstance static method
- Example: pointer manager





Builder pattern

- How can a class create different representations of a complex object?
- How can a class that includes creating a complex object be simplified?
- MATLAB handle class
- create* method(s)
- Example: create unit from database





Memento pattern

- How can the internal state of an object be saved externally so that the object can be restored to this state later?
- Saving to and loading from disk or database is a common case
- saveobj instance method
- loadobj static method
- ConstructOnLoad class attribute
- Examples: renaming a class, removing a property





Closing remarks



Recap

- MATLAB Projects
- Version control integration
- Language features
- Development environment
- Testing & CI
- Toolbox distribution
- Design patterns





Thank you.

Questions?