## MATLAB EXPO 2019

# Software Development Practices within MATLAB

**Emmanuel Blanchard** 





### How do we manage all that at MathWorks?

- Thousands of new features every year
- Over 2000 developers
- Different time zones, ...

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바옵 Dependency Analysis	<ul> <li>MachineLearning</li> <li>Simulation</li> <li>mps_stream</li> <li>README.md</li> <li>Elasticsearch</li> <li>Documents</li> <li>Dashboard</li> <li>SimExecutable</li> <li>ACI</li> <li>MATLAB_Kafka_Producer_Java</li> <li>+Test</li> <li>rawdata.mat</li> <li>javasetup.m</li> <li>resetEakeInform</li> </ul>	
Labels	<ul> <li>DocExample_MultiClassFaultDetectionU</li> <li>Main_ExampleWorkflow.mlx</li> <li>MLModels.mat</li> <li>genPumpData.m</li> </ul>	



### What are your software development concerns?

- Speed
- Development Time
- Cost
- Compatibility
- Documentation
- Reusability
- Effective Testing
- Integration
- Badly written code

- 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  $\rightarrow$  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





### Agenda

Managing your code
Tracking code changes and co-authoring workflows
Writing better, robust, and portable code
Testing and maintaining your code
Summary



### 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, doc, requirements, ...
- Consistent, shared environment
- Integration with source control





### **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





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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!

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### **Source Control**

- A system to manage changes to code, documents, etc.
- Maintain backups, history & ability to restore
- Track changes and responsibility
- Simplify reconciling conflicting changes

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### **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





### Agenda

Managing your code
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Writing better, robust, and portable code
Testing and maintaining your code
Summary



### What defines "better" code?

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





### Writing more robust code

>> 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 myfunc (line 10)
```



### Writing more robust code – Validating inputs

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

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

```
>> 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.
```



### Writing more robust code – Handling errors more elegantly

- error and warning
  - Use identifiers
- Mexception
- try/catch
- 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

Run and Time

Profiler

File Edit Debug Window Help

Start Profiling Run this code:				
Profile Summary Generated 31-Aug-2015 15:28:51 using perfor	rmance ti	me.		
Function Name	<u>Calls</u>	<u>Total Time</u>	<u>Self Time</u> *	Total Time Plot (dark band = self tim
<u>testFit</u>	1	6.525 s	3.591 s	
<u>xlswrite</u>	10	1.964 s	0.024 s	
xlswrite>ExecuteWrite	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	
xlswrite>@()xlsCleanup(Excel.file)	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&gt;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	I
title	20	0 100 -	0 10/ 0	1



### 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

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### Writing code faster – Quickly and safely refactoring code

• Live Editor shortcuts to refactor blocks of code into functions





### Writing code faster – Quickly and safely refactoring code

 Function refactoring across files in Projects

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### 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.

### Writing more portable code – 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")
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Windows:	"\data\2019\April"
Mac/Linux:	"/data/2019/April"

Set Up Project (Step 1 of 2)	×
Set Up Project (Step 1 of 2) Specify folders to add to the p open the project, and remove MachineLearning MATLAB_Kafka_Producer, MATLAB_Kafka_Producer, MATLAB_Kafka_Producer, mps_stream mps_stream mps_stream mps_stream mps_stream mps_stream mps_stream mps_stream mps_stream mps_stream mps_stream mps_stream mps_stream SimExecutable Simulation <	roject path. These folders are added to the MATLAB search path when you d when you close the project.   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:    Simulation\pump_setup.m   javasetup.m   Add   Remove   Shutdown files:   Add   Remove
	Environment:
	Start Simulink before this project starts     Refresh Simulink customizations

Back

Finish



### Agenda

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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

(3 Errors) ( Code	Compatibility Report	+ Report	Тор	3 <u>Errors</u>	1 <u>Warning</u>	304 <u>Checks</u>	2 <u>Files</u>	
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3	classifyBloodPressure.m	<u>24</u>	TREEVAL ha	TREEVAL has been removed. Use ClassificationTree or RegressionTree PREDICT methods instead.			e <u>Detai</u>	<u>S</u>
Warning	s and Other Recomn	andatio	5					
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1	classifyBloodPressure.m	Z	RAND or RA	RAND or RANDN with the 'seed', 'state', or 'twister' inputs is not recommended. Use RNG instead.		<u>Detai</u>	<u>S</u>	
-		Go	direc ine of	tly to tl f code	ne	_		_



### Test early, test often, test automatically

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









### **Testing Frameworks**

Test your code early and often

- MATLAB Unit Testing Framework
- Performance Testing Framework

App Testing Framework

	results =
	1×17 <b>TestResult</b> array with properties:
	Name
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	Failed
	Incomplete
	Duration
Ork	Details
	Totals:
	17 Passed, O Failed, O Incomplete.
	1.0937 seconds testing time.
	C:\Documents\WATLAB\OOP\Blip\Demos\Extensions\UnitTest\Class\
	BipTetts BipStetLengthTetts 0.1403 seconds 0000 BipTetts BipSubleagnTetts 0.1542 seconds
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MATLAD <sup>®</sup> Test Report	Details
Timestamp: 04-Jan-2017 13:28:06 Host: AH-SDE	C-\Documents\MATLAB\OOP\Blip\Demos\Extensions\UnitTest\Class\
Platform: win64 MATLAB Version: 9.1.0.441655 (R2016b)	BilpTests.BilpSizeLengthTests
Number of Tests: 17	The test passed. Duration: 0.0863 seconds (conview)
	© vector8lipSize The test passed.
	Duration: 0.0027 seconds (Deroted
	The test passed. Duration: 0.0044 seconds
17 passed	© vectorBipLength The test nasced
	Duration: 0.0468 seconds (Ontriant
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### **Testing Frameworks – Flexible development**

test\_Predictions.mlx

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- 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

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))
```



### **Testing Frameworks – Easily customize and run existing tests**

Insert 🛃 fx

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EDIT

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EDITOR

Added buttons to make testing more readily accessible

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PLOTS

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NAVIGATE

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

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		Output Detail Level		>		Default	
	ERROF	R HANDLING				1: Terse	
	Pause on Errors			~	2: Concise		
		Pauses execution wh	en an error occurs			3: Detailed	
		<b>Pause on Warnings</b> Pauses execution wh	en a warning occurs	-		4: Verbose	
	Pause on NaN or Inf Pauses execution wh		f en a NaN or Inf value is returi	ned			



### **Testing Frameworks – App Testing Framework**

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



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**



### **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

	Discover the 1000+ com building, deploying and a Browse I Find p	ns Inde munity contributed Jenkins p utomating any project.	Plugins to support
Browse categories	New Plugins	Recently updated	Trending
Platforms	OPabal	Mercurial	jQuery UI
User interface	MATLAB	VectorCAST Execution	Lockable Resources
Administration	MISKA Compliance Report	Klocwork Community	jQuery
Source code management	Zoom	OverOps Query	Analysis Model API
Build management	CodeBuilder: AWS CodeBuild	LoadNinja	Warnings Next Generation

ORebe



JDK Tool

### Automated Testing – Jenkins plugin – Testing reports

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





#### MathWorks<sup>®</sup>



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### Summary

- Good software development practices save you:
  - time money
  - effort frustration

- MATLAB makes good software development practices easy and automated
  - Projects
  - Source control
  - MATLAB Profiler
  - MATLAB Code Analyzer

- Interactive programming aids
- Code Compatibility Report
- MATLAB Testing Frameworks
- And more!
- We're adding more software development tools and features every release!



### Training (Self – paced or instructor led) / Consulting

#### **MATLAB Programming Techniques**

This two-day course provides hands-on experience using the features in the MATLAB<sup>®</sup> language to write efficient, robust, and well-organized code. These concepts form the foundation for writing full applications, developing algorithms, and extending built-in MATLAB capabilities. Details of performance optimization, as well as tools for writing, debugging, and profiling code are covered. Topics include:

- Utilizing development tools
- Verifying application behavior
- Creating robust applications
- Structuring code
- Structuring data
- · Managing data efficiently
- Creating a toolbox





Dates	Location	Language	Price	Register
On Demand	<ul> <li>Self-Paced</li> <li>180 days of full access from the day of purchase</li> </ul>	English	AUD 350	7