

#### **30.5.2019 Modern Tools for Financial Analysis and Modeling 2019**

# Master Class Application Development Workflow From Algorithm to Production Systems



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www.mathworks.com



# **MATLAB and Simulink**

#### • MATLAB

- Engineering tool and interactive environment for scientific and technical computations
- built-in functions calculations, graphics
- Graphical user interface (GUI, APPS)
- Open system
- Simulink
  - MATLAB extension
  - Model, simulate and analyze your dynamic systems
  - Block diagrams
  - Model Based Design platform
- Toolboxes





# **Data Analysis Workflow**





# **MATLAB Live Editor**

- Scripts that combine code and outputs in an executable notebook
  - Code, outputs
  - Title, headings, formatted text
  - Equations, images, hyperlinks
  - Publish as HTML, PDF, Latex, Word
- Symbolic math
  - Formatted equations
- Interactive
  - Lectures
  - Presentations
- Live editor webinar



#### MATLAB Live Editor

- http://www.humusoft.cz/events/www-seminars/



# **Demo – Fuel Economy Analysis**

- Historical fuel economy data
- Various cars
  - built from year 2000 up to 2012
- Data import
- Visualization
  - All cars
  - Grouped visualizations
- Curve fitting
- Model visualization
  - All cars
  - Grouped Visualizations





# **Graphical user interfaces in MATLAB**

- Point-and-click control of analysis with GUI front end
- Algorithm "runs in background"
- Creating a MATLAB App
  - App Designer
  - GUIDE
  - Programmatically
- From GUIDE to App Designer
  - GUIDE to App Designer Migration Tool for MATLAB
- Difference between GUIDE and App Designer
  - Comparing GUIDE and App Designer
- App Designer recommended for new applications





# **GUI building – Design view**

- Canvas
- Component library
  - button, slider, check box
  - Edit field (text), text area, list box, ...
- Menu and toolbars
- Predefined dialog boxes file, color
- Grid layout
- Customize components
  - size
  - color
  - default values
- Keyboard Shortcuts

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Inspector Callbacks







## **Algorithm**











#### • Class

- Object group with similar properties
- Defines behavior of objects
- filename class\_name.m
- Object
  - instance of class
  - specific values for properties
  - object = class\_name
- Class includes:
  - Data ... properties
  - Algorithm... methods
- Access control attributes

- classdef class\_name
  - properties
    variables;
    - end
  - methods
    - function f1
      - commands;
    - end
    - function f2
      - commands;
    - ↓ end
  - end
- end



# **GUI building – Code view**

- App programming
- Code View
  - OOP App is class
  - Graphical components properties
  - Callbacks methods
  - Other functions
- Code Browser
  - Properties and methods list
- Data sharing
  - Properties
- Special methods
  - Startup, CloseRequest

```
Design View
                                                                Code View
properties (Access = private)
    dataDir:
    selectedYears = [];
    lastData;
end
methods (Access = private)
    function updateYearList(app)
        files = dir(fullfile(app.dataDir, '*.xlsx'));
        if isempty(files)
            years = \{\};
        else
            years = {files.name};
            years = cellfun(@(x) strtok(x, 'd'), years, 'UniformOutput
        end
        app.yearListBox.Items = years;
        app.yearListBox.Value = years{1};
        app.selectedYears = [];
    end
   function [cf, gof] = MPG(app, carData, CarTruck, CityHighway, CI)
            % MPG(carData, CARTRUCK, CITYHIGHWAY, CI)
            %
                             : car data (table object)
                carData
            %
                             : 'car' or 'truck' or 'all'
                CARTRUCK
            %
               CITYHIGHWAY : 'city' or 'highway' or 'all'
```



# **MATLAB Programs Can be Shared With Anyone**

#### Share With Other MATLAB Users



#### Share With People Who do Not Have MATLAB





# **Share with MATLAB Users**





# App Packaging

- Package your app as single installation file ullet
- Workflow
  - 1. Create app
  - 2. Package app
  - 3. Select main file
  - Files included through analysis 4.
  - 5. **Describe your app**
- Easy distribution
- Installation into the apps gallery •
- Automatically includes all necessary files •
- **Documents required products**  $\bullet$



point).



# **MATLAB Programs Can be Shared With Anyone**

**Share With Other MATLAB Users** 



#### Share With People Who do Not Have MATLAB





## **Share with People Who Do Not Have MATLAB**





# **Share Applications Built Completely in MATLAB**

- MATLAB programs as standalone executables
  - Users don't need MATLAB license
- Royalty-free distribution
  - Creator needs only MATLAB Compiler
- MATLAB Compiler encrypts your MATLAB code
- MATLAB Runtime
  - free to download MathWorks website
  - can be added to application
- Interactively
  - App Application Compiler
- Programmatically
  - Command line mcc





# **Share Applications Built Completely in MATLAB**





# Integrate MATLAB Programs With Your Own Software







# **Small web apps**

- Web App Compiler
- Apps to web apps transformation
  - Only apps created via App Designer
  - Not all input functions supported
- Integrated WebAppServer
- MATLAB Runtime
- Security limitations/recommendations
  - Restrict network access
  - Server software only on dedicated hardware
  - Data or code injection eval and disk operation usage
- Maximum number of sessions is limited to 32
- Licensed users who can upload and run web apps is limited to 10

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		Apply	Restor	e Default	s



# **Using MATLAB with Excel**

- Passing data between MATLAB and Excel
  - MATLAB
  - table, timetable, tall
  - readtable, writetable
- Accessing MATLAB from an Excel spreadsheet
  - MATLAB
  - Spreadsheet Link (for Microsoft Excel)
- Deploying MATLAB as an Excel add-in
  - MATLAB
  - MATLAB Compiler

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# **Excel add-in**

- Sharing with Excel users
  - analysis
  - graphical outputs
- Library Compiler
  - Excel Add-in
- Output
  - Add-ins
  - Macros

#### Workflow

- 1. Create function
- 2. Package with Library Compiler
- 3. Deploy to user/Excel
- 4. Create Macro





## Resources

- Web pages
  - www.humusoft.cz
  - www.mathworks.com
- MATLAB Central
  - Community for MATLAB and Simulink users
  - www.mathworks.com/matlabcentral/
- Social networks
  - Public Facebook group MATLAB a Simulink (SK CZ)
  - <u>www.facebook.com/groups/matlab4students/</u>
  - Facebook
  - www.facebook.com/humusoft



## Resources

- Webinars
  - Free on-line seminars (EN, CZ, SK), access to recorded webinars
  - www.humusoft.cz/wwwseminare
- Workshops
  - Practical introduction to MATLAB & Simulink
  - www.humusoft.cz/workshop/
- Training
  - MATLAB, Simulink, dSPACE, COMSOL Multiphysics
  - www.humusoft.cz/skoleni
- MATLAB Trial
  - MATLAB for testing, time restricted 30 days
  - request at info@humusoft.cz



# End of Part 1



# Application development workflow: From algorithm to Production systems

Part 2

Jorge Paloschi MathWorks Consulting Services, Spain







### Agenda

- Version control
- Testing
- Deploying to Production



# Source control (version control)



#### Source control

- MATLAB supports
  - Subversion (SVN)
  - GIT

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# **Automated Testing**



#### Why use Automated Testing?

- Improve quality
- Understand and document code
- Reduce and not introduce risk
- Catch bugs early and often





## **Authoring Tests**

- Script, function, and class based tests
- Setup and teardown for four phase testing
- Rich qualifications and diagnostics
- Parameterization to build combinations of inputs



Type of Test	Verification	Assumption	Assertion	Fatal Assertion
Value is true.	verifyTrue	assumeTrue	assertTrue	fatalAssertTrue
Value is false.	verifyFalse	assumeFalse	assertFalse	fatalAssertFalse
Value is equal to specified value.	verifyEqual	assumeEqual	assertEqual	fatalAssertEqual
Value is not equal to specified value.	verifyNotEqual	assumeNotEqual	assertNotEqual	fatalAssertNotEqual
Two values are handles to same instance.	verifySameHandle	assumeSameHandle	assertSameHandle	fatalAssertSameHandle
Value is not	verifyNotSameHandle	assumeNotSameHandle	assertNotSameHandle	fatalAssertNotSameHandle



#### **Testing Infrastructure**

- Run suites of tests from many files, directories, and packages
- Select tests based on tags or parameters
- Shared fixtures (e.g. path management, temporary folders)

Command Window
>> TS = TestSuite.fromPackage('Test.Visualization', 'IncludingSubPackages', true
TS =
1×34 <b><u>Test</u></b> array with properties:
Name
BaseFolder
ProcedureName
SharedTestFixtures
Parameterization
Tags
Tests Include:
<u>6 Unique Parameterizations</u> , 0 Shared Test Fixture Classes, 0 Tags.

import matlab.unittest.fixtures.TemporaryFolderFixture
tdir = testCase.applyFixture(TemporaryFolderFixture);

```
properties (TestParameter)
```

end

```
RasterImageTypes = { 'bmp', 'png', 'jpg', 'gif' } % Different raster image types
StreamOutputTypes = { 'uint8', 'int8' } % Different byte stream data types
```



_								
Т	est (	Out	puts	Coverage results	h. m			
			•	Show coverage for parent directory	,		tedal musica ditedal	Total coverage: 88.2%
				chow coverage for parent directory		1	Model.TrainedModel	Total time: 0.0 seconds
				Total lines in function 28		28		Total lines: 6
				Non codo linos (commonte, blank	(linee)	21	Model.predict	Coverage: 100.0% Total time: 10.6 seconds
		/era	ge report	Non-code lines (comments, biane	( intes)	<u> </u>		Total lines: 2
				Code lines (lines that can run)		7	<u>Model.set.ModelName</u>	Coverage: 100.0% Total time: 0.0 seconds Total lines: 3
				Code lines that did run		4	Model.set.ModelType	Coverage: 100.0% Total time: 0.0 seconds Total lines: 4
				Code lines that did not run		3	Model.predictImpl	
				code intes that did not full		5		
				Coverage (did run/can run)		57 14 %		Total coverage: 81.3%
				ooverage (ald rankean ran)		57.14.70	egressionComparer.RegressionCompa	rer Coverage: 100.0%
Function	listing		-				_	Total time: 0.1 seconds Total lines: 9
Color high	light code a	ccording t	to noncoverage 🔻		Regress	sionComparer>1	RegressionComparer.compareImpl	Coverage: 57.1%
time	Calls	line				-		Total time: 10.8 seconds
		46	function [bestmo	odel, modelvalues] = compareImpl(obj,	CurrentM	lodel m		1 otal lines: 7
		63	% Verify eve	erything is a Regression Model	Currente	IOGET : III		Tatal asymptotic 75 00/
< 0.01	3	64	mt = cellfur	1(@(x)1sa(x, 'LoadForecaster.Predictio				Total coverage: 75.0%
< 0.01	3	<u>60</u>	II ~all(mt)	contion (II and Foregoeter, Drediction, De	Current	Model>Current	tModel.CurrentModel	Total time: 0.0 seconds
		67	me - MES	Coller (mo):				Total lines: 13
		68	end	aller (me);	Current	Model>Current	tModel.predict	
		69	ena	(				
		70	% Use superc	class compareImpl				
10.40	3		[bestmodel,	modelvalues] = compareImpl@LoadForecas	ster.Pred	liction.Model	Comparer(obj, models, modelpvpa	irs);

0.01

72

end

<u> MathWo</u>rks<sup>®</sup>

#### **Test Outputs**

Test results report

#### MATLAB<sup>®</sup> Test Report

 Timestamp:
 22-Sep-2017 12:16:21

 Host:
 AH-SDEWOLSK

 Platform:
 win64

 MATLAB Version:
 9.3.0.701794 (R2017b)

Number of Tests: 9 Testing Time: 4.7620 seconds

Overall Result: FAILED



#### Failure Summary

3 tests failed.

Name of Failing Test	Failure Reasons	
Test.DataManagement.TestDatabase/testGetData	Failed by verification.	( <u>Details</u>
Test.DataManagement.TestDatabase/testAllNansInGetSynchronize	Failed by verification.	( <u>Details</u>
Test.DataManagement.TestDatabase/testGetDataOneSource	Failed by verification.	( <u>Details</u>

#### Overview

C:\Documents\MATLAB\DataAnalytics\LoadForecastingApplication\Source\ Test.DataManagement.TestDatabase 4.7620 seconds testClosedConnection The test passed. Duration: 0.0932 seconds (Overview) 🛚 testGetData The test failed. Duration: 2.1368 seconds Event: Verification failed. Framework Diagnostic: verifyEqual failed. --> The objects are not equal using "isequal". Actual Value: 0×2 empty timetable Expected Value: 4×3 timetable Time N\_Y\_C\_ TemperatureF KLGA Dewpoint KLGA 01-May-2007 00:00:00 4854.4 58 30 01-May-2007 00:05:00 4802.3 58.08333333333333 29.833333333333333 01-May-2007 00:10:00 4740.3 58.166666666666 29.666666666666 01-May-2007 00:15:00 4700.34155844156 58.25 29.5 Event Location: Test.DataManagement.TestDatabase/testGetData Stack: In C:\Documents\MATLAB\DataAnalytics\LoadForecastingApplication\Source\+Test\+DataManagement\TestDatabase.m (TestDatabase.testGetData) at 98



#### **Continuous Integration**

- Runs tests after code changes to track development progress
- Support for TAP, jUnit XML



					1
	59	- Test.DataMa	nagement. IestWUAPI/testDefaultTimeRange		
	60	- Test.DataMa	nagement.TestWUAPI/testWUWebsiteAccess		
	61	- Test.DataMar	nagement.TestWUAPI/testOfflineIsConnected		
	62	- Test.DataMar	nagement.TestWUAPI/testGetDataOffline		
	63	- Test.DataMa	nagement.TestWUAPI/testSevenDaysAgoKLGA		
	Event				
		Event Name	ExceptionThrown		
		Event Location	Test.DataManagement.TestWUAPI/testSevenDaysAgoKLGA		
		Error Identifier	MATLAB:datetime:InvalidTimeZone		
		Error Report	Error using datetime (line 515) A time zone must be specified as a character vector.		
			Error in LoadForecaster.DataManagement.WUAPI/getWUHistoryByStation (line 167) Time = datetime(double(wudate.string_year), double(wudate.string_mon),		
			Error in LoadForecaster.DataManagement.WUAPI/getWUHistory (line 124) data{ii} = getWUHistoryByStation(obj, stations{ii}, dates, key);		
			<pre>Error in LoadForecaster.DataManagement.WUAPI/getDataImpl (line 38)</pre>		
			Error in LoadForecaster.DataManagement.DataSource/getData (line 49) data = getDataImpl(obj, trange, vars);		
			Error in Test.DataManagement.TestWUAPI/testSevenDaysAgoKLGA (line 73) data = getData(api, 'TimeRange', [daystart dayend], 'SelectedVariables', {'KLG4	A'});	
		Stack	In C:\Program Files\MATLAB\R2017a\toolbox\matlab\timefun\@datetime\datetime.m (datetime.dat In C:\Users\sdewolsk\.jenkins\workspace\LoadForecaster\Source\+LoadForecaster\+DataManageme (WUAPI.getWUHistoryByStation) at 167	tetime) at 515 ent\WUAPI.m	
			In C:\Users\sdewolsk\.jenkins\workspace\LoadForecaster\Source\+LoadForecaster\+DataManageme	ent\WUAPI.m (WUAPI.getWUHisto	ory) at
			<pre>In C:\Users\sdewolsk\.jenkins\workspace\LoadForecaster\Source\+LoadForecaster\+UataManageme In C:\Users\sdewolsk\.jenkins\workspace\LoadForecaster\Source\+LoadForecaster\+DataManageme</pre>	ent\WUAPI.m (WUAPI.getDataImp ent\DataSource.m (DataSource.	ol) at 38 .getData)
	Build			_	
	Exec	ute Windows	batch command	×	
-	Com	ımand <mark>"C:∖F</mark> "addr	<pre>Program Files\MATLAB\R2017a\bin\matlab.exe" -nosplash -nodesktop -wait -r path('.\Source');rehash;Test.setTestingPreferences();Test.runLoadForecastingTests()"</pre>		
ł				<u></u>	
		See <u>th</u>	e list of available environment variables	Advanced	
	Add buil	d step 🔻			11



MATLAB code deployment



#### MATLAB Programs Can be Shared With Anyone

#### Share With Other MATLAB Users



#### Share With People Who do Not Have MATLAB





#### Share with People Who Do Not Have MATLAB



• IP Protection via Encryption



## Share Applications Built Completely in MATLAB





#### Scale Up with MATLAB Production Server

Most efficient path for creating enterprise applications

Deploy MATLAB programs into production

- Manage multiple MATLAB programs and versions
- Hot Deployment: Update programs without server restarts
- Reliably service concurrent requests

Integrate with web, database, and application servers





## MATLAB Production Server

Enterprise Class Framework For Running Packaged MATLAB Programs

- Server software
  - Manages packaged MATLAB programs and worker pool
- MATLAB Runtime libraries
  - Single server can use runtimes from different releases
- RESTful JSON interface and lightweight client library (C/C++, .NET, Python, and Java)





#### Example - Integrating with IT systems





#### Developing code for MPS

- Test server
- Possible to debug if using test server
- Code needs to be prepared to work under MPS
  - Functionality to be able to reproduce issues



## Deploying CTF components with Compiler

A Production Server	r Compiler - untitled1.prj*			– 🗆 X
COMPILER				>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>>
New Open Save	Deployable Archive (.ctf)     Deployable Archive with Excel Integration	CreateFitEOLModel.n Settings Test Client Package		
FILE	TYPE	EXPORTED FUNCTIONS SETTINGS TEST PACKAGE		Ā
		Archive information		
		createFitEOLModel		
		Additional files required for your archive to run		
		H TC1Data.mat		
			+	
		Files packaged for redistribution		
		🛃 createFitEOLMod 💽 readme.txt		
			+	
		Include MATLAB function signature file	Ø	
		Add or create a function signature file to help clients use your MATLAB functions.	U	
			Add Existing File Create File	



#### Test server

A Production Server Compiler - untitled1.prj*				_		×
COMPILER TEST	Reference in the second	16	Ê	9 ¢	ē ?	
Port 9910						
Enable CORS Enable Discovery						
SERVER CONFIGURATION SERVER ACTIONS CLOSE						
Server Address					-	
http://localhost:9910/createFitEOLModel						
MATLAB Execution Requests					0	
Start server and client.						
		C	lear Al	l Reque	sts	
▼ Server Log						
					_	
				<u> </u>		
		Sav	e Log	Clear L	og	





