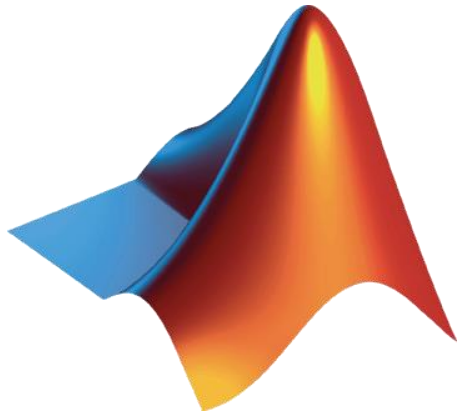
Welcome to Introduction to MATLAB Hands-On Workshop!

- Access MATLAB via your MathWorks account
- Associate your account to the campus license or the trial
- Start MATLAB on your machine

If you have trouble, ask for help from a MathWorker.

Introduction to MATLAB: Hands-On Workshop



Universität Bern, 11.02.2020, 9:00-12:30

Dr. Res Jöhr, MathWorks CH

Agenda

- Introduction
- Setup / Prework

- MATLAB environment
- Plotting Data
- Scripts and LiveScripts
- Data Analysis with MATLAB
- MATLAB as programming language
- Discussion

- Resources and Outlook

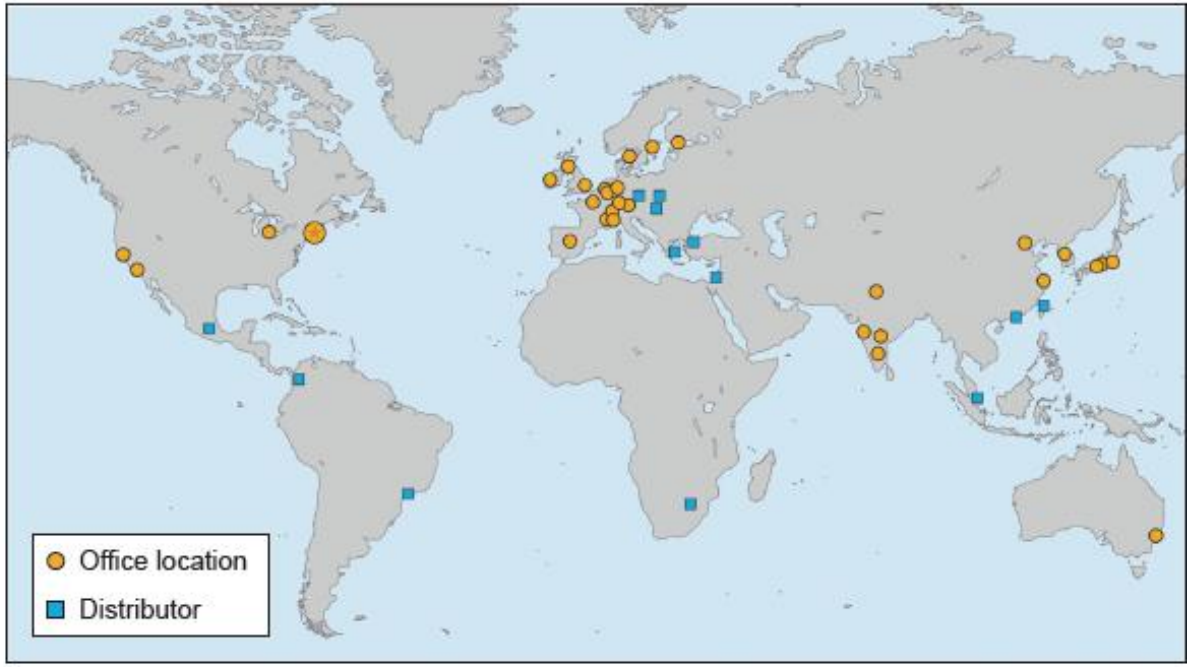
>>Hands-on Workshop

Introduction Round

- Your name and backgound?
- Current interests / job?
- What are you interested to learn / expectations?

MathWorks

- Headquarter near Boston (US)
- >5000 people employees worldwide
- More than 2 million users in 180+ countries
- Used by over 5000 universities worldwide



Where is MATLAB used today?

90,000+ business, government, and university sites

All of the top 10 auto manufacturers[1]

All of the top 10 aerospace companies[2]

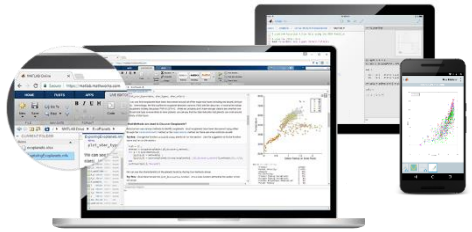
Three of the top five internet companies

[1]OICA: 2016 World Motor Vehicle Production

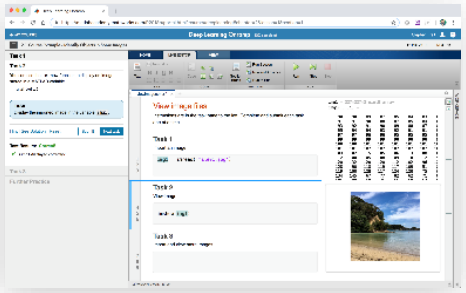
[2]PwC: Aerospace and Defense 2017 Year in Review

Campus-Wide License at University of Bern

University & lab computers



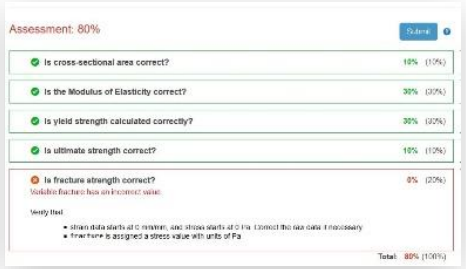
Personal Computers & Mobile Devices



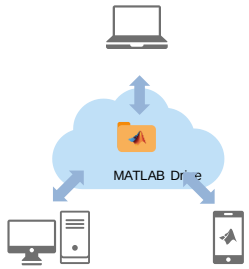
Self-paced online learning

Online access

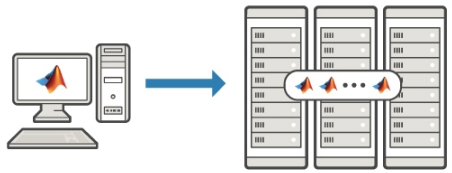
- License covers all faculty, staff, students and their devices
- Access on campus, in lab and field, and at home



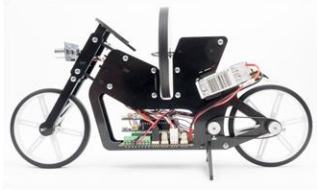
Auto-graded homework



Cloud Storage & Sharing



Clusters & HPC



Low-cost hardware support

Available Self-Paced Training Courses

Get started

MATLAB Onramp

Simulink Onramp

Deep Learning Onramp

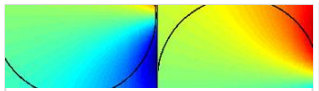
Stateflow Onramp

Machine Learning Onramp

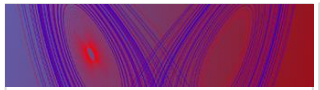
11 hours of FREE content – available for everyone

Computational Mathematics

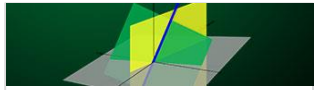
*Available only to users at universities that offer campus-wide training access.



Solving Nonlinear Equations with MATLAB



Solving Ordinary Differential Equations with MATLAB



Introduction to Linear Algebra with MATLAB

Introduction to Statistical Methods with MATLAB

Introduction to Symbolic Math with MATLAB

9 hours of short courses on computational mathematics topics

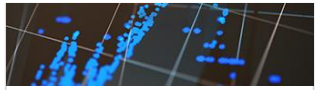
Core MATLAB

MATLAB Fundamentals

MATLAB Programming Techniques

MATLAB for Financial Applications

Data Science



MATLAB for Data Processing and Visualization

Machine Learning with MATLAB

Deep Learning with MATLAB

Over 80 hours of comprehensive MATLAB learning content

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- Setup / Prework

- MATLAB environment
- Plotting Data
- Scripts and LiveScripts
- Data Analysis with MATLAB
- MATLAB as programming language
- Selection of Applied Examples

- Resources and Outlook

Setup / Prework

- Create a MathWorks account on https://ch.mathworks.com/login
- Accept the invitation for the course contents send out by mail.
- Access MATLAB Online: https://www.mathworks.com/licensecenter/classroom/MO_3007706/

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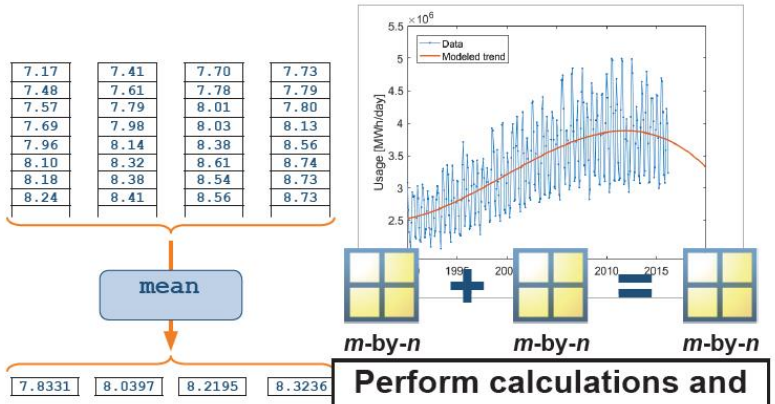
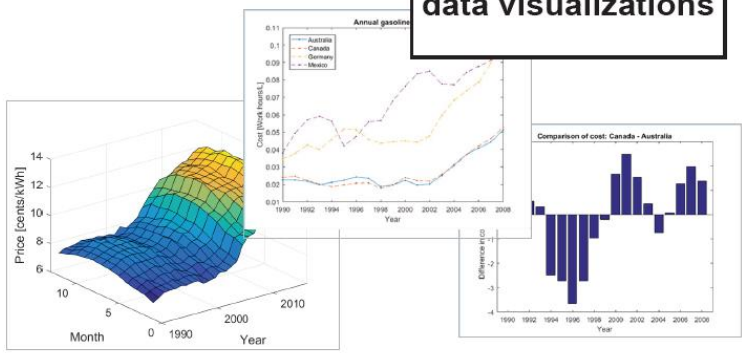
What can you do with MATLAB

Interactively import, analyze, and export data.

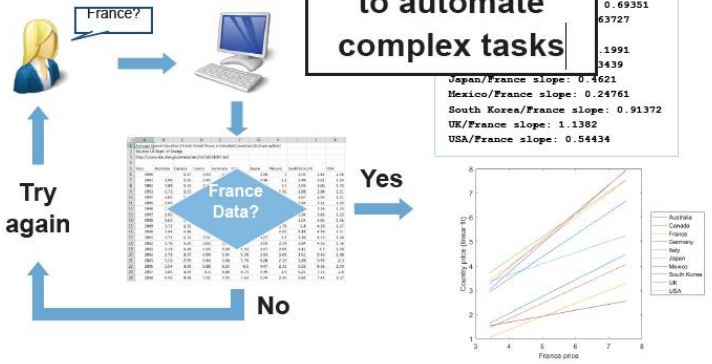


Perform calculations and analysis on data sets

Create informative data visualizations

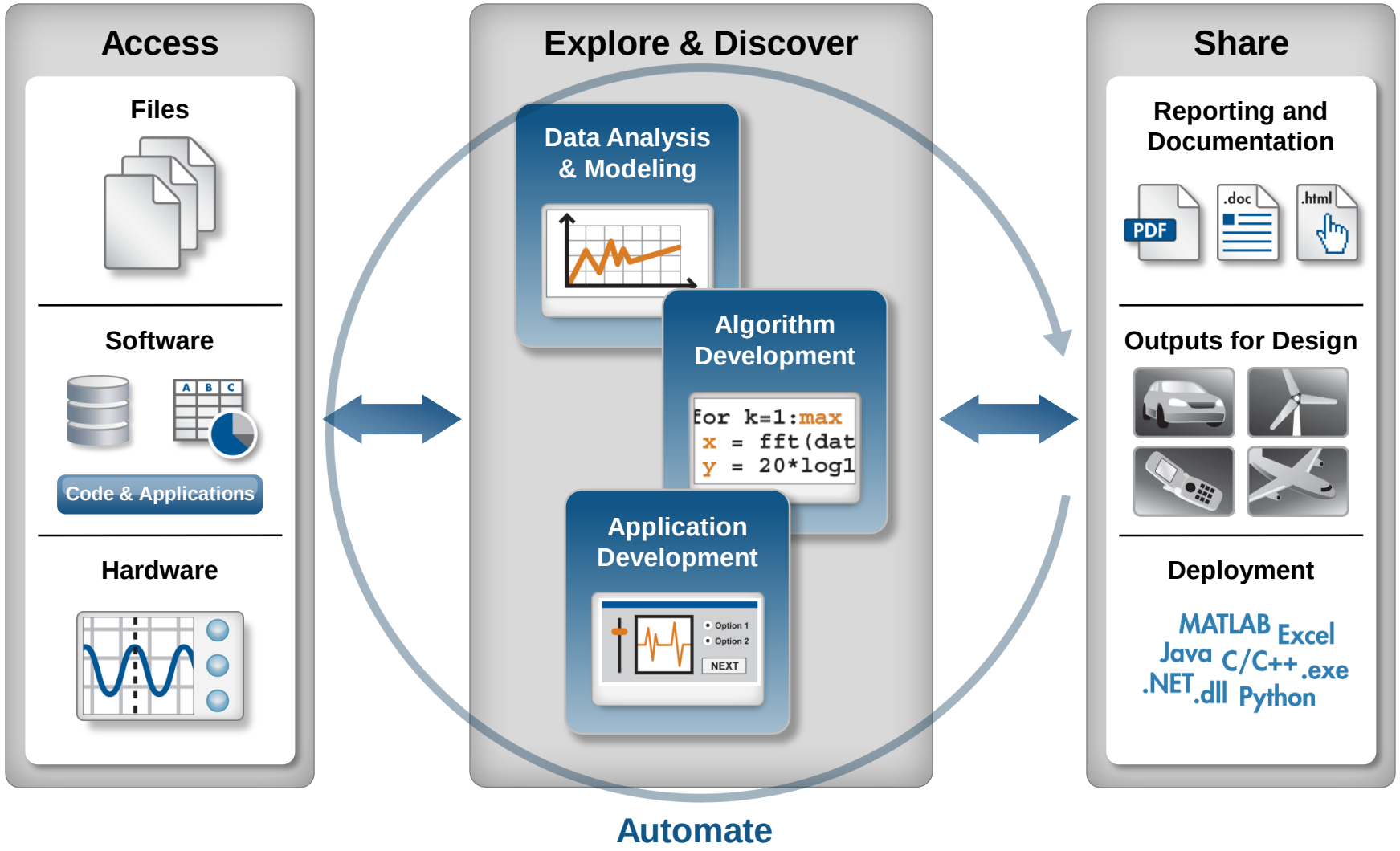


Write programs to automate complex tasks



https://ch.mathworks.com/videos/technical-computing-with-matlab-69042.html

Data Analysis Workflow



MATLAB User Interface

- The **Toolstrip** fast access to functionality and docu
- The **Command window** is where you type MATLAB commands following the prompt: >>
- The **Workspace window** shows all the variables you have defined in your current session. Variables can actually be manipulated within the workspace window.
- The **Command History** window displays all the MATLAB commands you have used recently – even includes some past sessions.
- The **Current Folder** window displays all the files in whatever folder you select to be current.

Naming Rules for Variables

1. Variable names must begin with a letter
2. Names can include any combinations of letters, numbers, and underscores
3. Maximum length for a variable name is 63 characters
4. The variable name A is different than the variable name a.
5. Avoid the following names: i, j, pi, and all built-in MATLAB® function names such as length, char, size, plot, break, cos, log, …
6. It is good programming practice to name your variables to reflect their function in a program rather than using generic x, y, z variables.

Exercises

1. Calculate the area and circumference of a circle with a radius of 4 cm.
   (Area = 50.27 cm^2 Circumference = 25.13 cm)

2. Create two variables a = 4 and b = 17.2 and perform the following calculations

$$\sqrt[3]{b + 9.8}$$

$$10\sqrt{5a + 16}$$

Creation of Arrays

Row vector

```
>> a = [1 2 3 4]

a = 1×4
     1   2   3   4
```

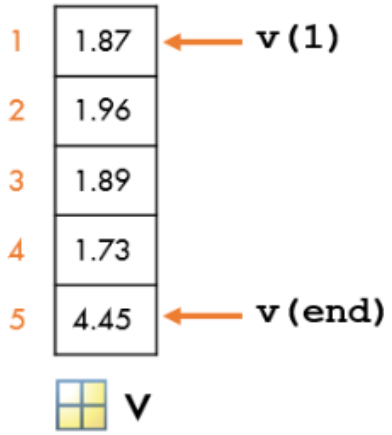
Column vector

```
>> a = [1; 2; 3; 4]

a = 4×1
     1
     2
     3
     4
```

Matrix

```
>> a = [1 2 3; 4 5 6; 7 8 10]

a = 3×3
     1   2   3
     4   5   6
     7   8  10
```

Indexing and modification:

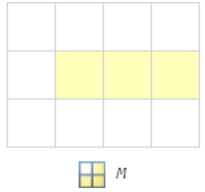


Accessing:

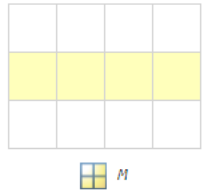
```
>> s=v(1:3)
s=
        1.87    1.96    1.89
```

Writing:

```
>> v(1:3)=[5.13    4.34    6.38]
s=
        1.87    1.96    1.89
```




```
>> s=M(2,2:end)
```



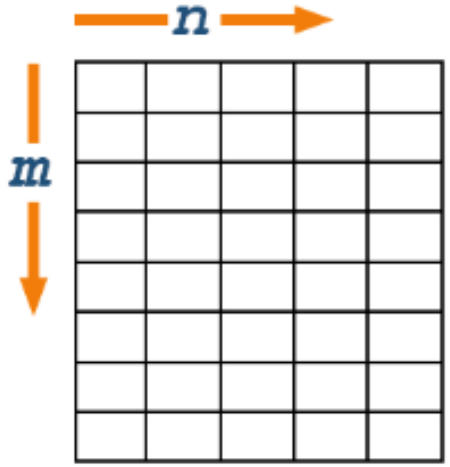

```
>> s=M(2,:)
```

Functions for Array Creation

- `start:step:end`
- `linspace(start, end, samples)`
- `logspace(start, end, samples)`

```
A = fun(m,n);
```

compan	pascal
eye	rand
gallery	randn
hadamard	rosser
hankel	toeplitz
hilb	vander
invhilb	wilkinson
magic	zeros
ones	



Most of these functions support the calling syntaxes shown below.

Calling syntax	Output
fun(m,n)	*m-by-n*
fun(n)	*n-by-n*

Vectorization

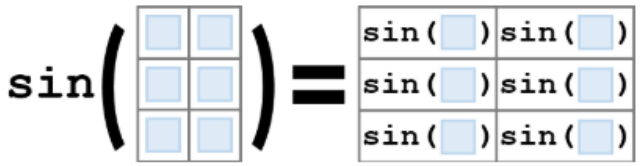
One command processes all elements of an array.
- avoid loops -> code more readable
- often more efficient.

→ Differentiation between standard operators from linear algebra and classical algebra needed.

→ Dot notation for elementwise operators such as multiplication, division and power.

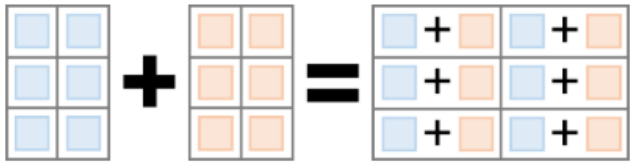
Example: elementwise multiplication of two vectors x and y with same size:

```
M=x.*y;
```



Other Similar Functions	
sin	Sine
cos	Cosine
log	Logarithm
round	Rounding Operation
sqrt	Square Root
mod	Modulus
Many more	

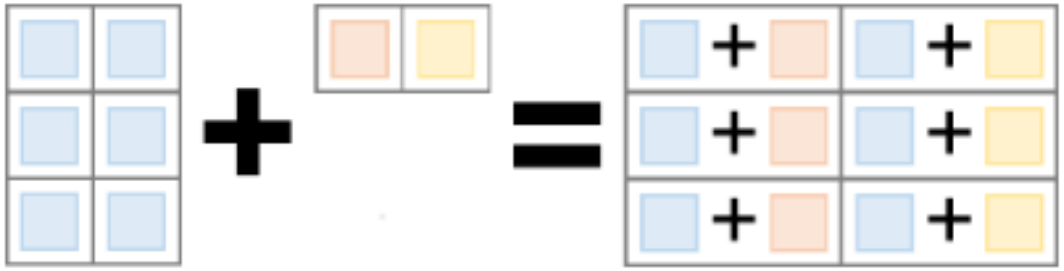
Arithmetic Operators



Operators	
+	Addition
-	Subtraction
.*	Element-wise Multiplication
./	Element-wise Division
.^	Element-wise Exponentiation

Linear Algebra function

Implicit Expansion



Operators	
+	Addition
-	Subtraction
.*	Element-wise Multiplication
./	Element-wise Division
.^	Element-wise Exponentiation

Array operations can be performed on operands of different compatible sizes. Two arrays have compatible sizes if the size of each dimension is either the same or one.

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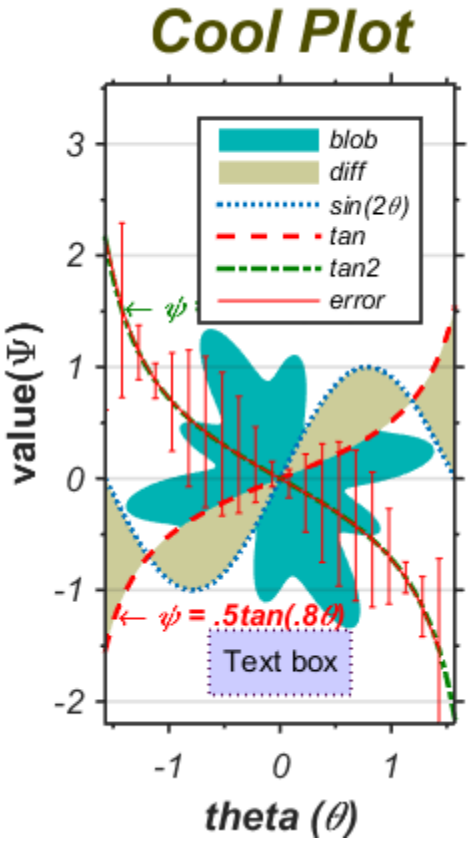
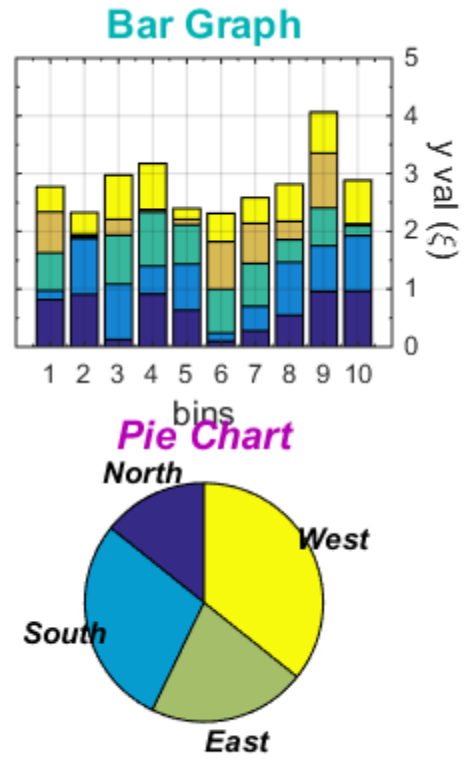
Plotting in MATLAB

- Publication ready graphics
- Wealth of 2-D and 3-D plotting functions.
- Support for images
- Customize interactively or programmatically



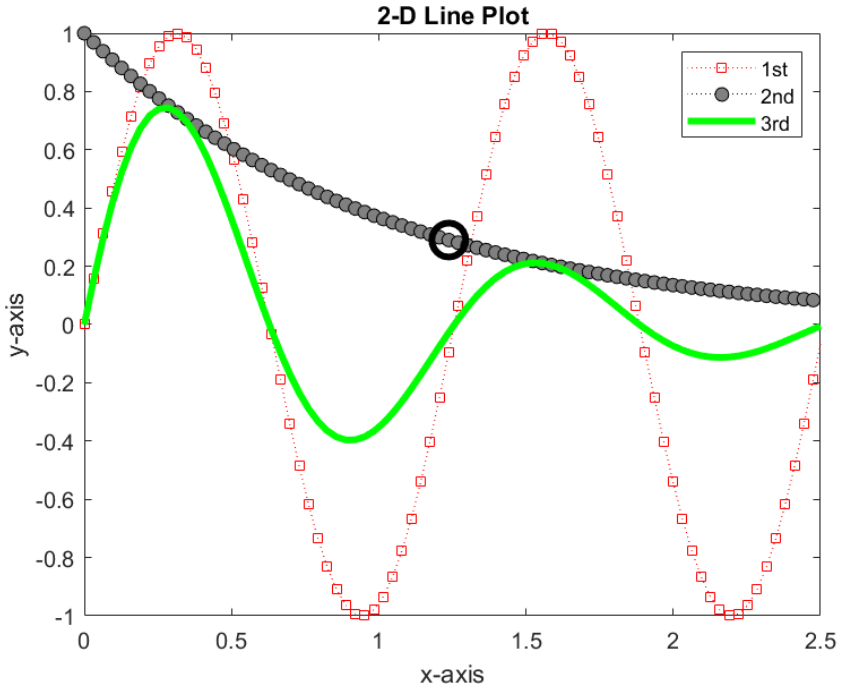


https://ch.mathworks.com/products/matlab/plot-gallery

Plotting Exercises

Exercise 1

- plot sin(5x) and exp(-x) from x=0:2pi
  - use 100 samples
  - dotted line and x markers for sin(5x)
  - Black o markers with grey filling for exp(-x)
- Plot the product with solid thick green line
- Add title, axes annotations and a legend
- Limit the y-axis range to 0:2.5



Exercise 2

- MATLAB Online Training Project 10.1: https://ch.mathworks.com/learn/tutorials/matlab-onramp.html

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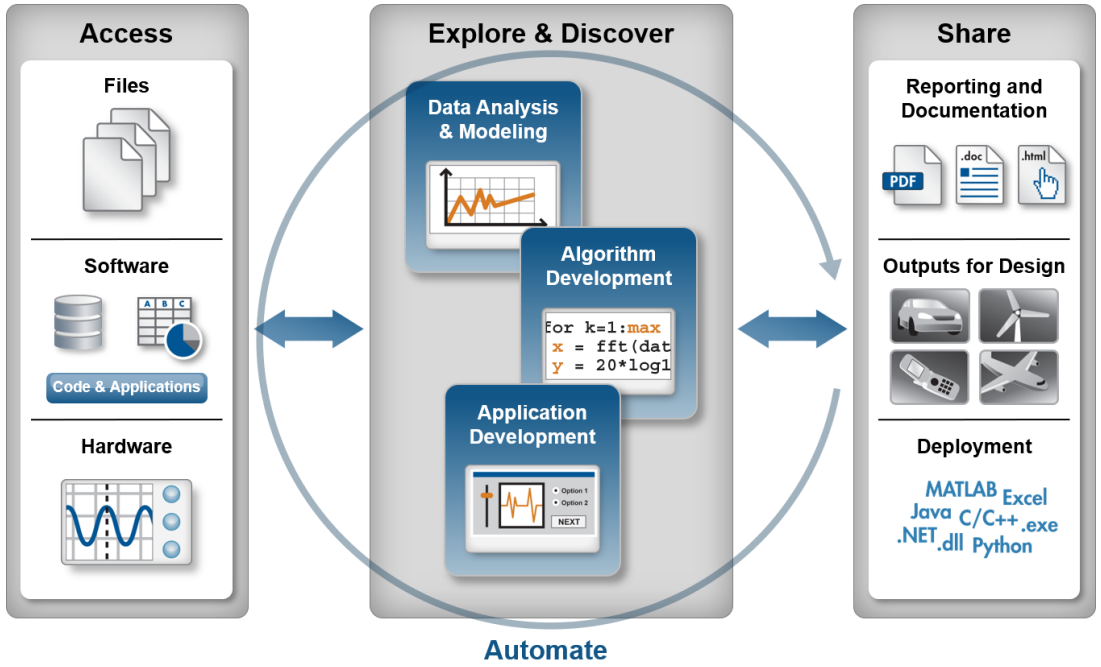
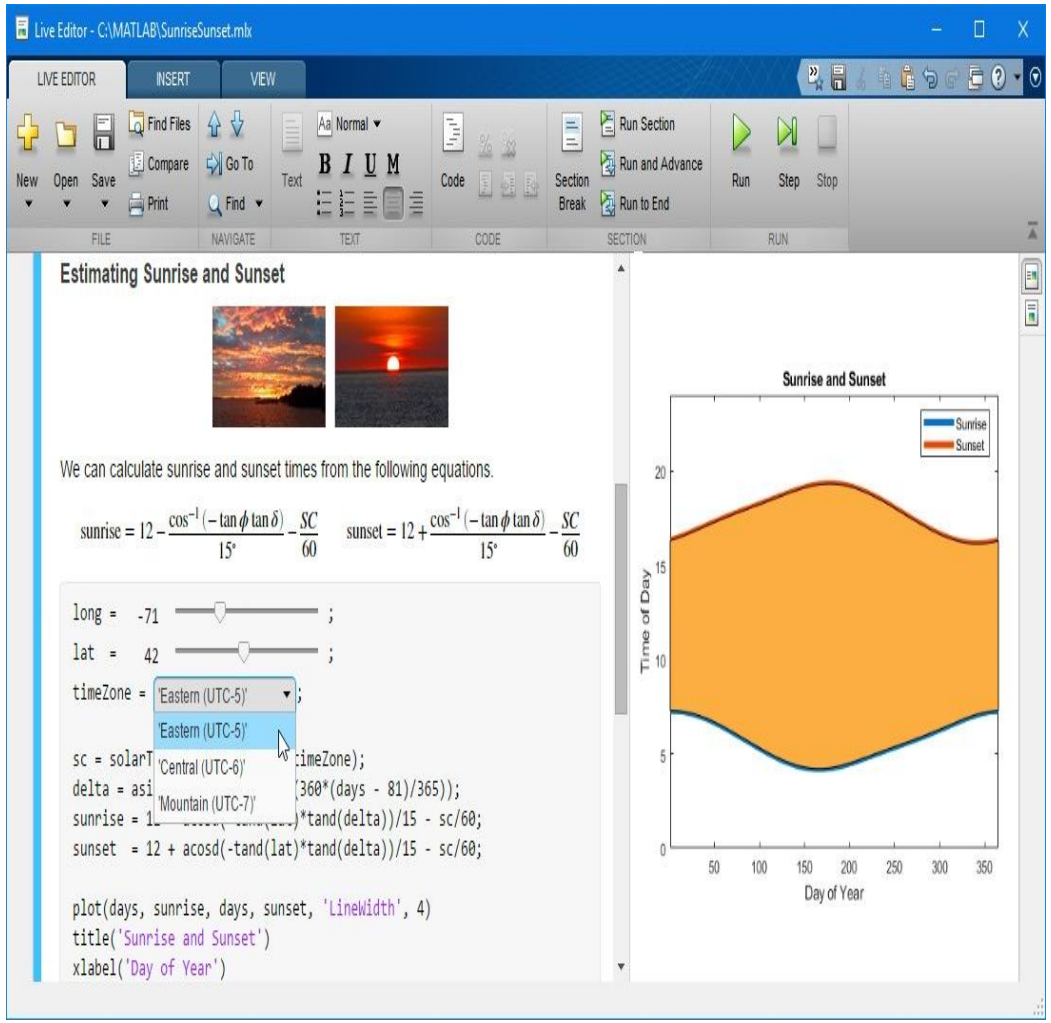
MATLAB the **technical computing language**

- Write programs or scripts using notebooks:
  - Standard Scripts (.m files)
  - LiveScripts (.mlx files)

- Benefits:
  - Faster prototyping
  - Programming
  - Sharing of your work
  - Better readability and documentation
  - Run from command line
  - Code analyzer

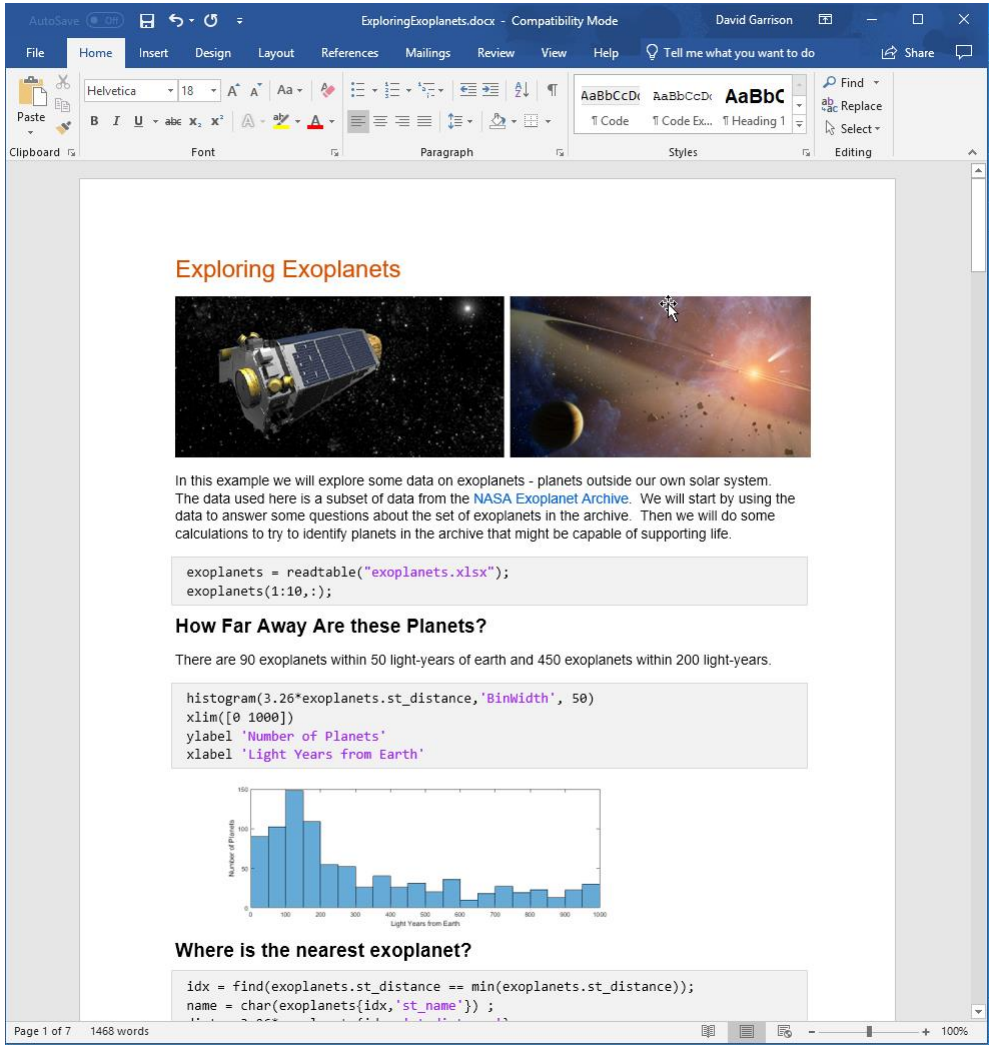
Use the **Live Editor** to create scripts that combine code, output, and formatted text in an executable notebook.





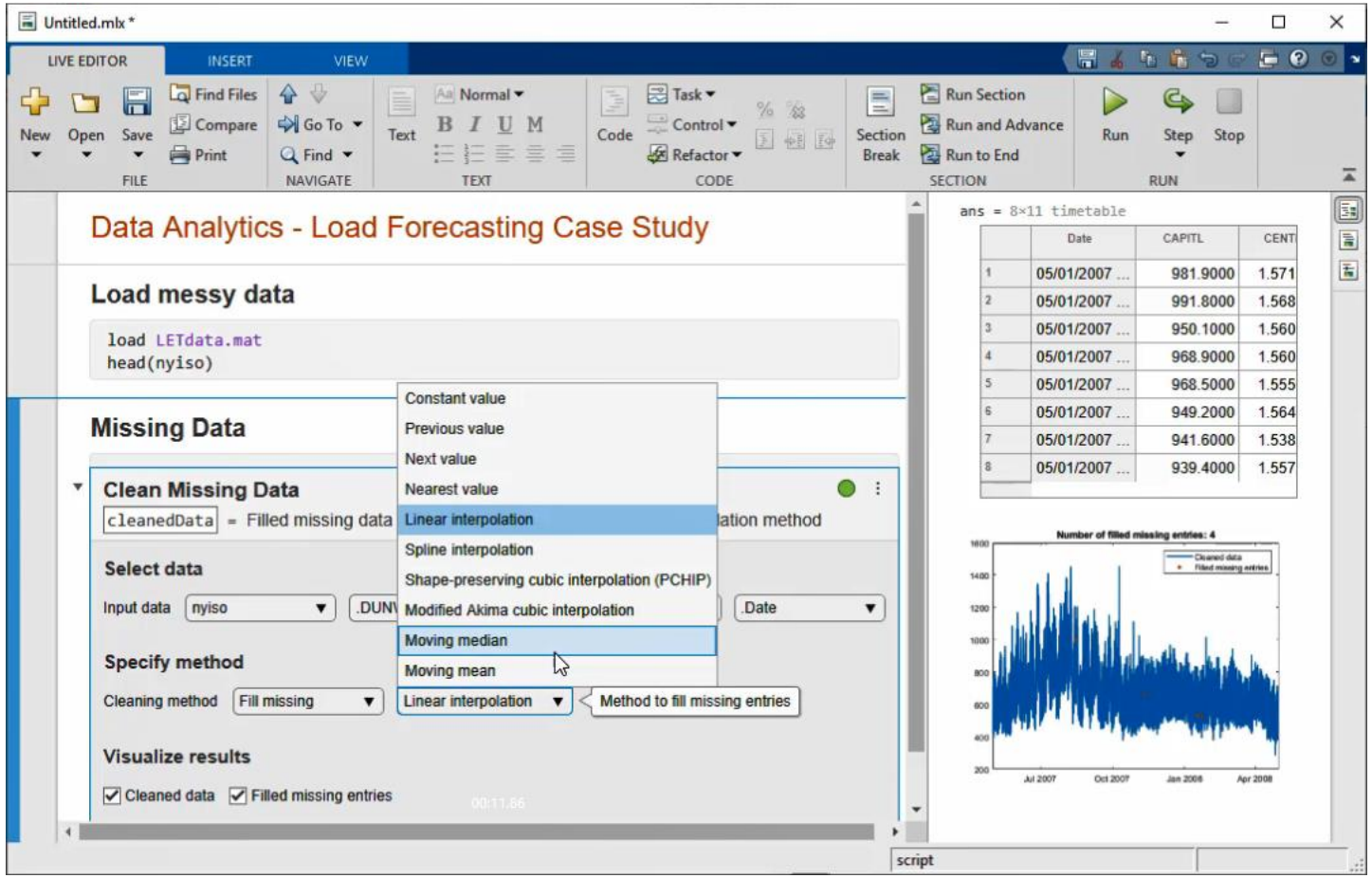
Live Editor Notebook Features

- Divide code into sections
- View output next to the code
- Add rich text formatting, equations, images, and hyperlinks
- Add interactive controls
- Enable animations in plots
- Save directly to PDF, HTML, Word, and LaTeX



Live Editor Coding Features

- Use contextual hints when calling functions
- Automatically generate code when interacting with plots and tables in the output
- Add Live Tasks to interactively explore parameters and options



Live Editor Keyboard Shortcuts* let you format as you type

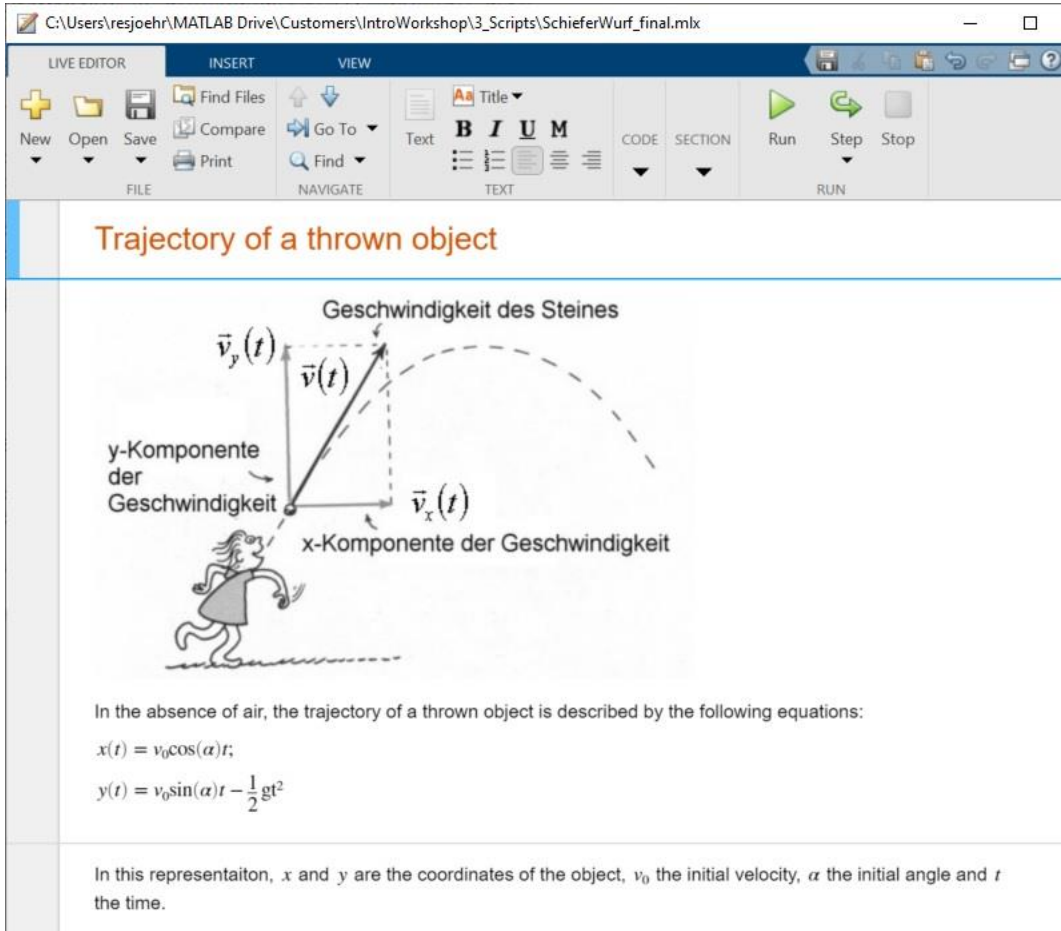
Formatting Style	Autoformatting Sequence	Keyboard Shortcut
Title	`# text` + **Enter**	**Ctrl + Alt + L**
Heading 1	`## text` + **Enter**	**Ctrl + Shift + 1**
Heading 2	`### text` + **Enter**	**Ctrl + Shift + 2**
Heading 3	`#### text` + **Enter**	**Ctrl + Shift + 3**
Section break	`%%` + **Enter**	**Ctrl + Alt + Enter**
	`---` + **Enter**	
	`***` + **Enter**	
Bulleted list	`* text`	**Ctrl + Alt + U**
	`- text`	
	`+ text`	
Numbered list	`number. text`	**Ctrl + Alt + O**
Italic	`*text*`	**Ctrl + I**
	`_text_`	
Bold	`**text**`	**Ctrl + B**
	`__text__`	
Underline	None	**Ctrl + U**
LaTeX equation	`$LaTeX$`	**Ctrl + Shift + L**

* This is a subset of available keyboard shortcuts. The full list can be found here:
https://www.mathworks.com/help/matlab/matlab_prog/format-live-scripts.html#bvackht-1

Exercises

1. Convert Trajectory_start.m into a live script
   - Change commented lines to text
   - Add sliders for the initial conditions
   - Plot the trajectory using xlim=ylim=[0:10]
   - Play around

2. Convert LiveEditor_start.m into a live script.
   - Change commented lines into formatted text
   - Format the fit equations and add live controls
   - Make a pdf report.



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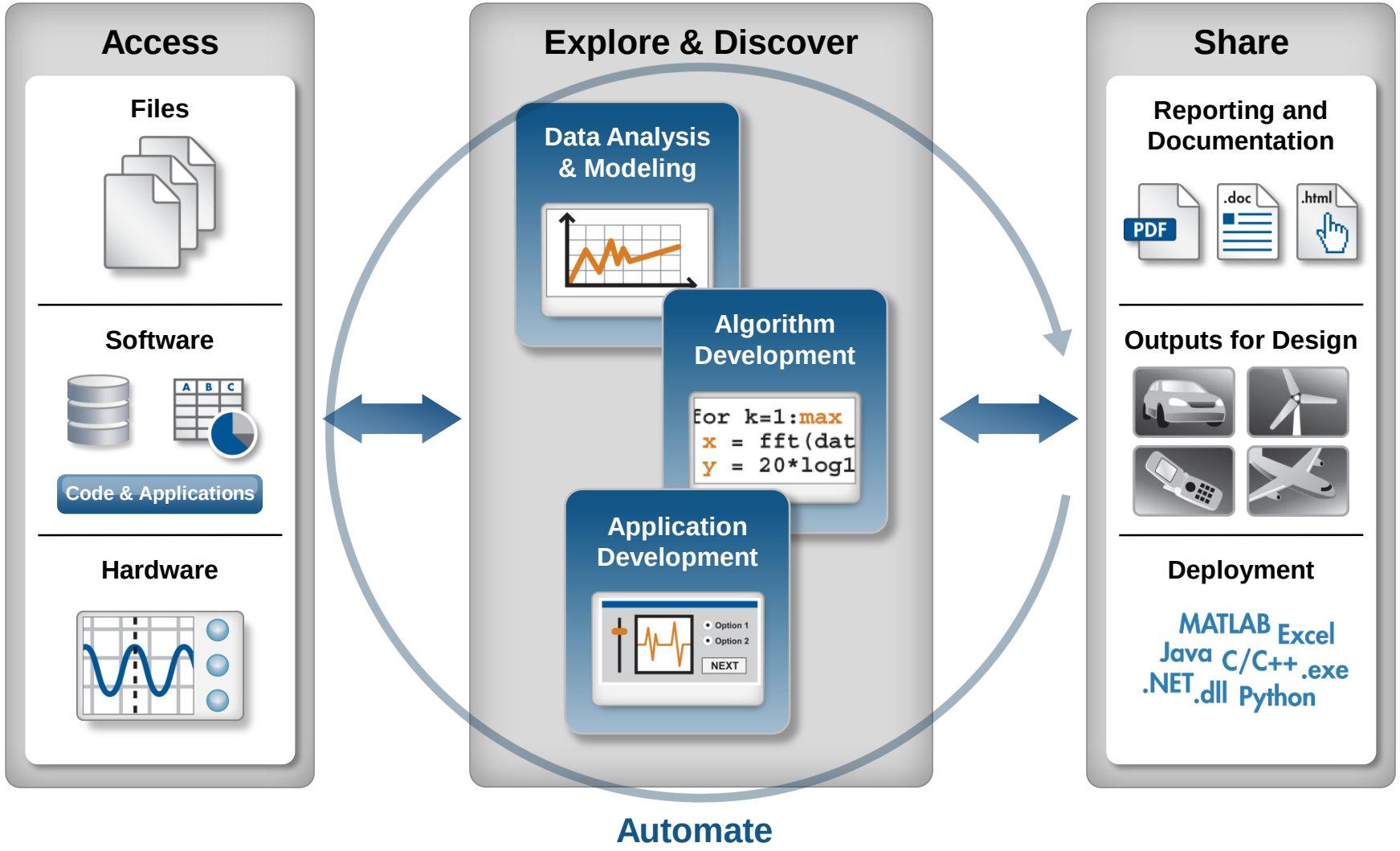
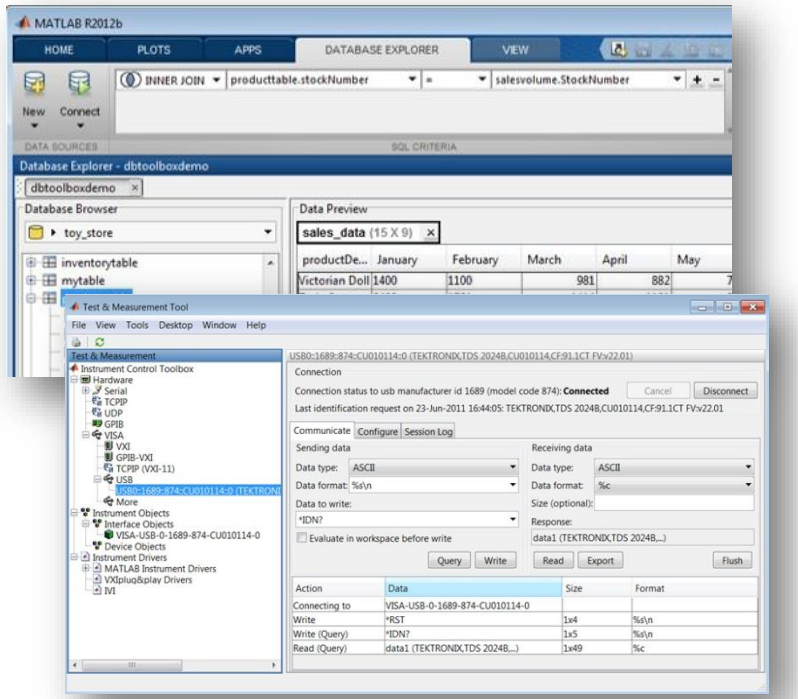
Data Analysis Workflow



Accessing Data from MATLAB

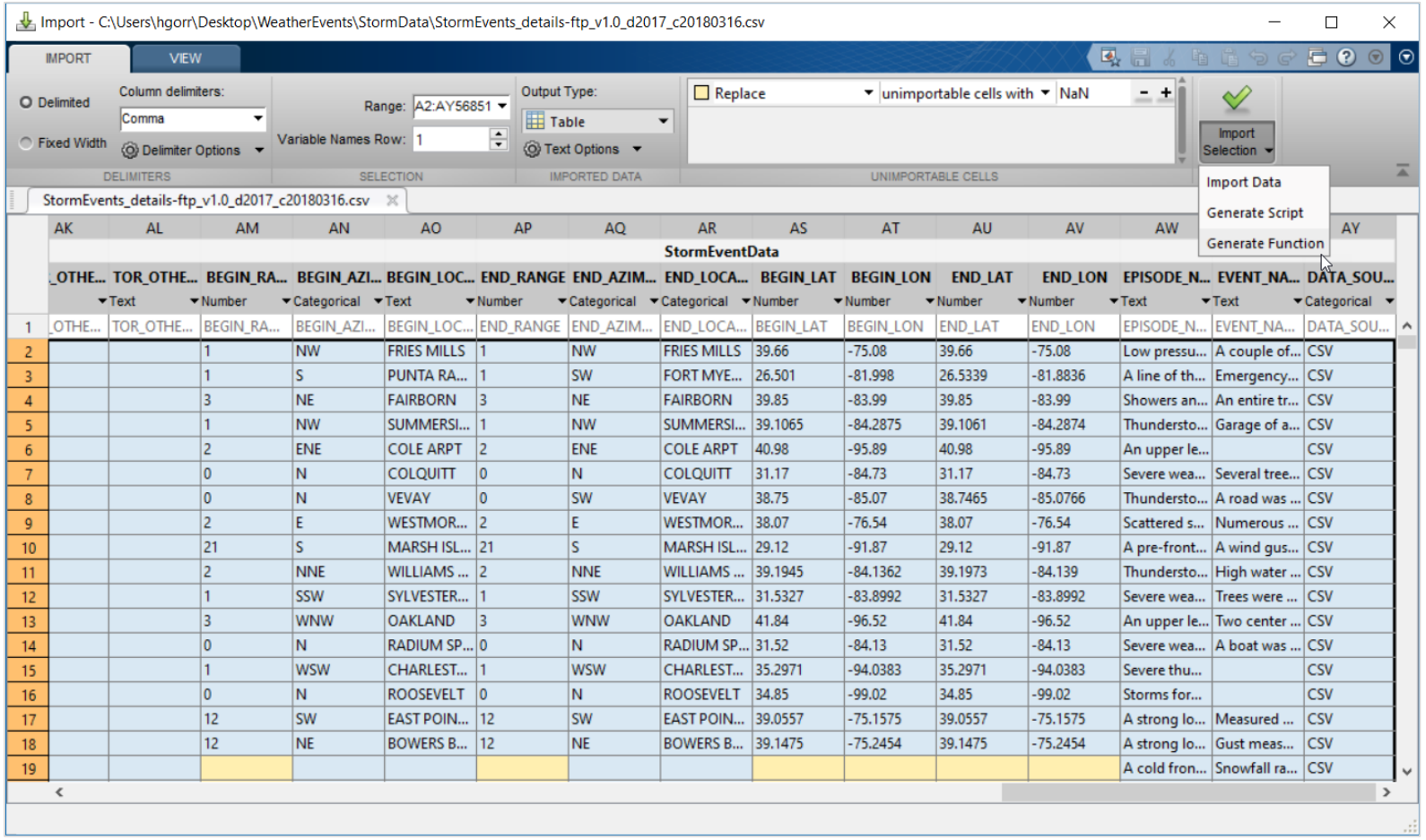
Access | Explore & Discover | Share

- Files
  - Excel, text, or binary
  - Audio and video, image
  - Scientific formats and XML
- Web Services
  - JSON, CSV, and image data
- Applications and languages
  - C/C++, Java, FORTRAN, Python
  - COM, .NET, shared libraries
  - Databases (*Database Toolbox*)
- Measurement hardware
  - Data acquisition hardware *(Data Acquisition Toolbox)*
  - Stand-alone instruments and devices *(Instrument Control Toolbox)*



Access data interactively using the Import Tool

- Select data types
- Choose what to do with missing data
- Generate MATLAB code



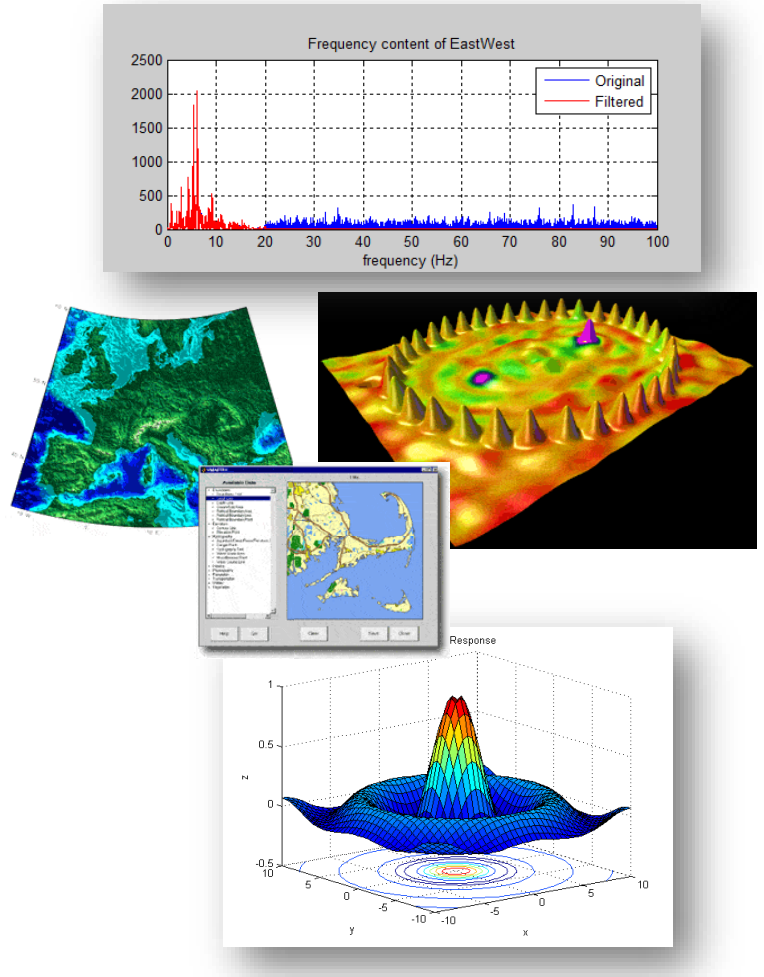
	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AY
	_OTHE...	TOR_OTHE...	BEGIN_RA...	BEGIN_AZI...	BEGIN_LOC...	END_RANGE	END_AZIM...	END_LOCA...	BEGIN_LAT	BEGIN_LON	END_LAT	END_LON	EPISODE_N...	DATA_SOU...
			Number	Categorical	Text	Number	Categorical	Categorical	Number	Number	Number	Number	Text	Categorical
1	_OTHE...	TOR_OTHE...	BEGIN_RA...	BEGIN_AZI...	BEGIN_LOC...	END_RANGE	END_AZIM...	END_LOCA...	BEGIN_LAT	BEGIN_LON	END_LAT	END_LON	EPISODE_N...	DATA_SOU...
2			1	NW	FRIES MILLS	1	NW	FRIES MILLS	39.66	-75.08	39.66	-75.08	Low pressu...	CSV
3			1	S	PUNTA RA...	1	SW	FORT MYE...	26.501	-81.998	26.5339	-81.8836	A line of th...	CSV
4			3	NE	FAIRBORN	3	NE	FAIRBORN	39.85	-83.99	39.85	-83.99	Showers an...	CSV
5			1	NW	SUMMERSI...	1	NW	SUMMERSI...	39.1065	-84.2875	39.1061	-84.2874	Thunderstо...	CSV
6			2	ENE	COLE ARPT	2	ENE	COLE ARPT	40.98	-95.89	40.98	-95.89	An upper le...	CSV
7			0	N	COLQUITT	0	N	COLQUITT	31.17	-84.73	31.17	-84.73	Severe wea...	CSV
8			0	N	VEVAY	0	SW	VEVAY	38.75	-85.07	38.7465	-85.0766	Thunderstо...	CSV
9			2	E	WESTMOR...	2	E	WESTMOR...	38.07	-76.54	38.07	-76.54	Scattered s...	CSV
10			21	S	MARSH ISL...	21	S	MARSH ISL...	29.12	-91.87	29.12	-91.87	A pre-front...	CSV
11			2	NNE	WILLIAMS ...	2	NNE	WILLIAMS ...	39.1945	-84.1362	39.1973	-84.139	Thunderstо...	CSV
12			1	SSW	SYLVESTER...	1	SSW	SYLVESTER...	31.5327	-83.8992	31.5327	-83.8992	Severe wea...	CSV
13			3	WNW	OAKLAND	3	WNW	OAKLAND	41.84	-96.52	41.84	-96.52	An upper le...	CSV
14			0	N	RADIUM SP...	0	N	RADIUM SP...	31.52	-84.13	31.52	-84.13	Severe wea...	CSV
15			1	WSW	CHARLEST...	1	WSW	CHARLEST...	35.2971	-94.0383	35.2971	-94.0383	Severe thu...	CSV
16			0	N	ROOSEVELT	0	N	ROOSEVELT	34.85	-99.02	34.85	-99.02	Storms for...	CSV
17			12	SW	EAST POIN...	12	SW	EAST POIN...	39.0557	-75.1575	39.0557	-75.1575	A strong lo...	CSV
18			12	NE	BOWERS B...	12	NE	BOWERS B...	39.1475	-75.2454	39.1475	-75.2454	A strong lo...	CSV
19													A cold fron...	CSV

Data Analysis and Visualization in MATLAB

Access | **Explore & Discover** | Share

- Data analysis
  - Manipulate, preprocess, and manage data
  - Fast, accurate analysis with pre-built math and engineering functions

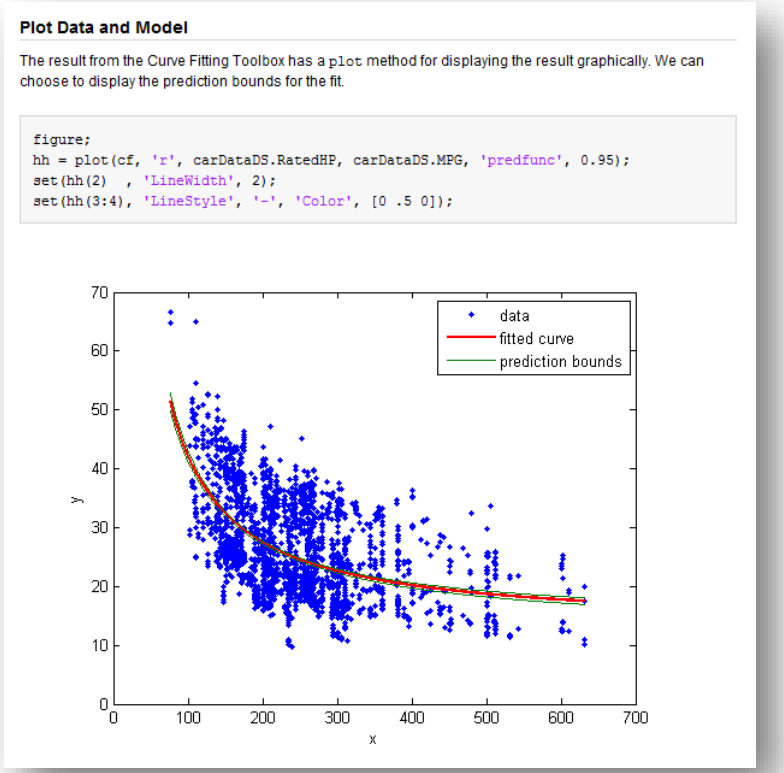
- Visualization
  - Built in graphics functions for engineering and science (2D, 3D, volume visualization)
  - Interactive tools to annotate and customize graphics



Sharing Results from MATLAB

Access | Explore & Discover | **Share**

- Automatically generate reports
  - Publish MATLAB files
  - Customize reports using MATLAB Report Generator
- Package as an app
- Deploy applications to other environments



Exercises

- MATLAB Online Training Project 10.2: https://ch.mathworks.com/learn/tutorials/matlab-onramp.html
- Exercise_DataAnalysis_start.mlx
- EcgDetrend_start.mlx

Agenda

- Introduction
- Setup / Prework

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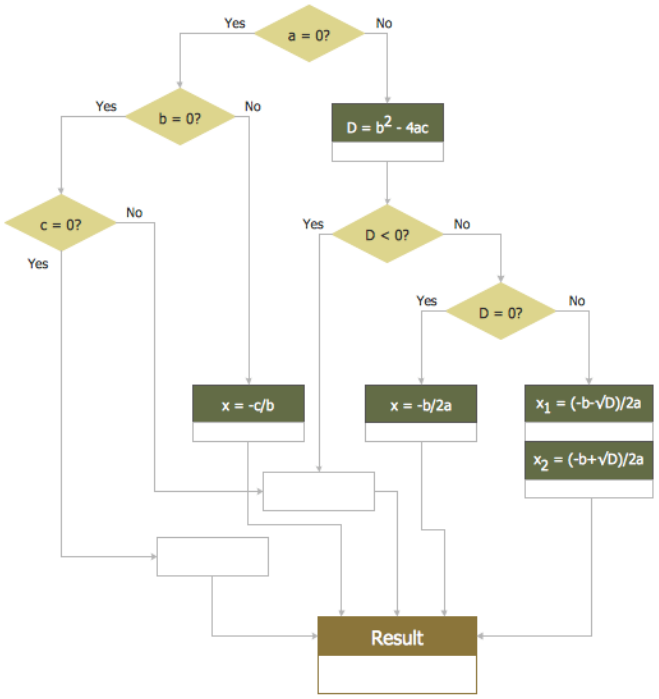
Programing methods with MATLAB

Ingredients needed to implement a computational task

- Data types in MATLAB
- Control structures and logicals
- Processes , scripts and functions
- Classes



Data types in MATLAB

Numeric

double, single, ...

logical

categorical

datetime

duration

calendarDuration

Heterogeneous

structure

cell

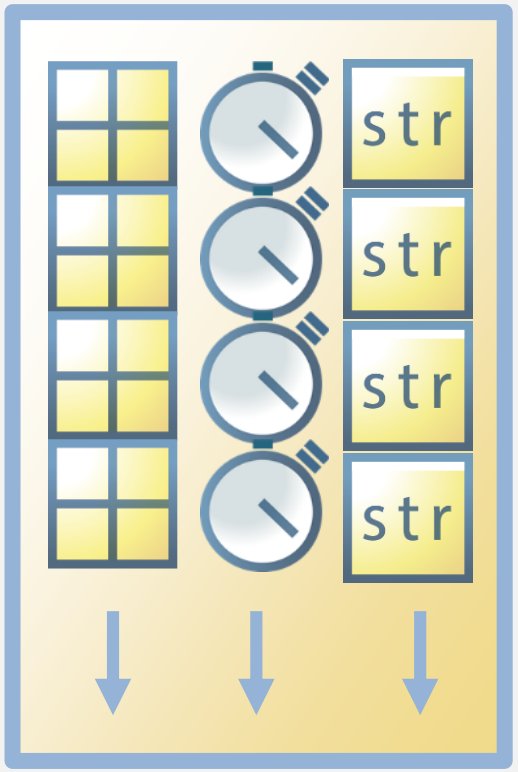
table

Text

char

cell string

timetable



string

tall

Logicals

- Represents true or false states using the numbers 1 and 0
- Comparison of variables (Relational operators)
- Check conditions
- Can be used for indexing or decision branching

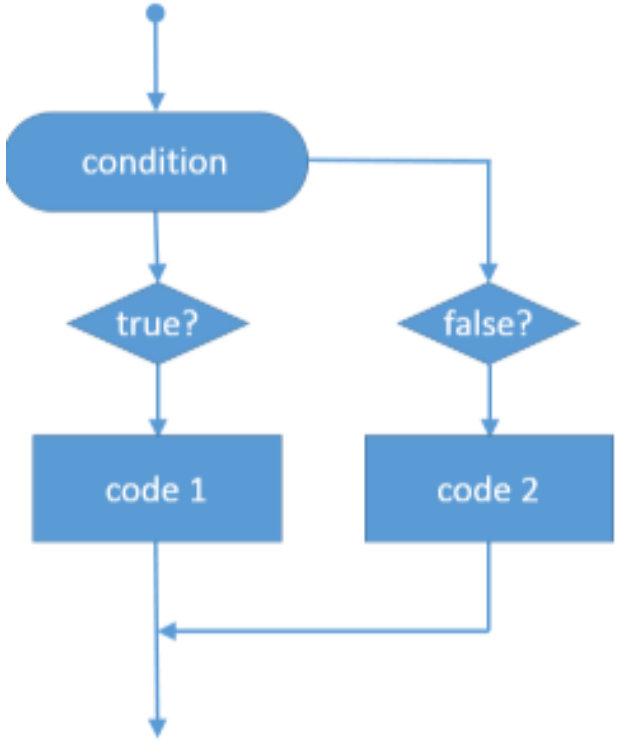
Relational operators

==	Determine equality
>=	Determine greater than or equal to
>	Determine greater than
<=	Determine less than or equal to
<	Determine less than
~=	Determine inequality
isequal	Determine array equality
isequaln	“, treating NaN values as equal

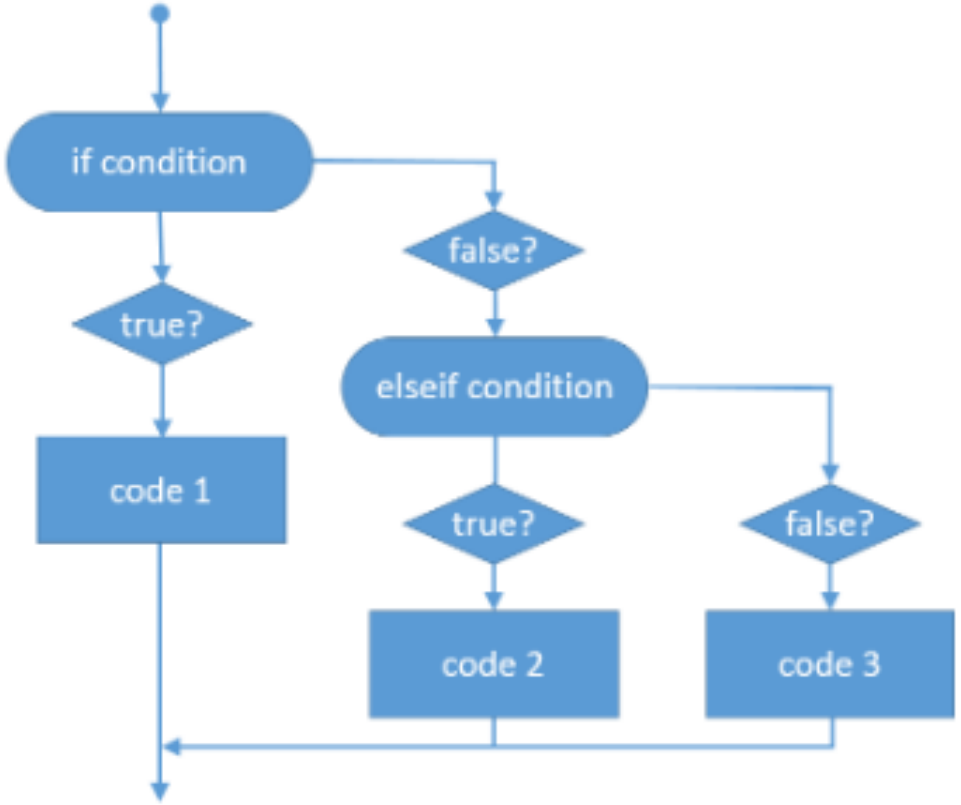
Logical operators

&&	Find logical AND
~	Find logical NOT
||	Find logical OR
xor	Find logical exclusive-OR
all	Determine if all array elements are nonzero or true
any	Determine if any array elements are nonzero
find	Find indices and values of nonzero elements
islogical	Determine if input is logical array

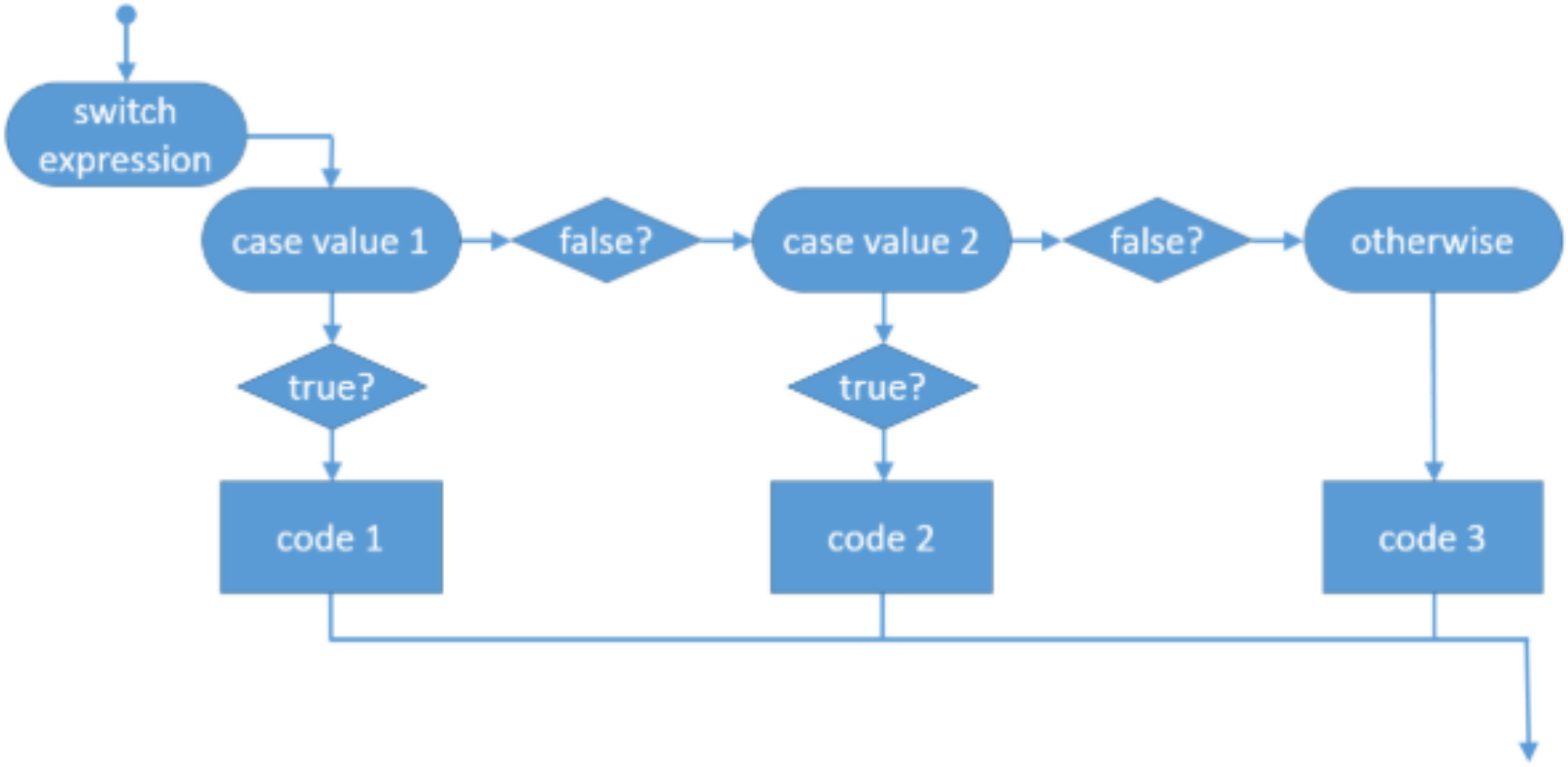
Control structures I
If-else, If-elseif-else




```
if condition
    code 1
else
    code 2
end
```



Control structures II
Switch-case Construction

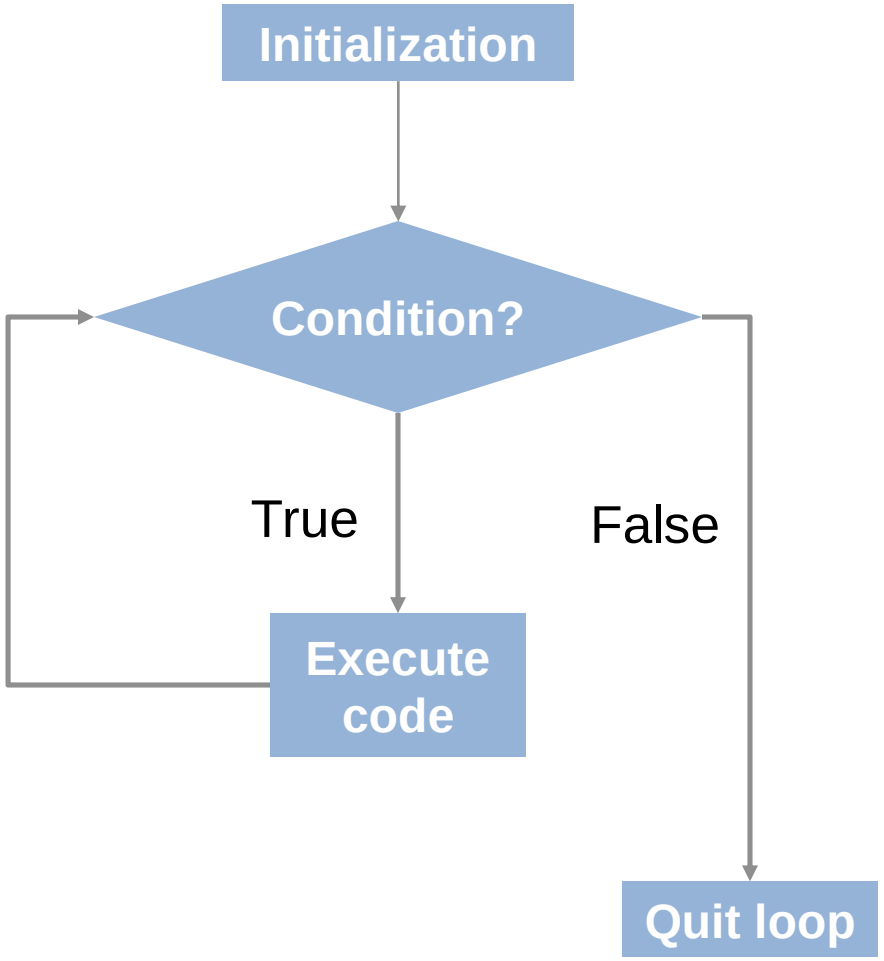



```
switch expression


    case value_1
        code_1
    case value_2
        code_2

    otherwise
        code_3


end
```

Loop Structures

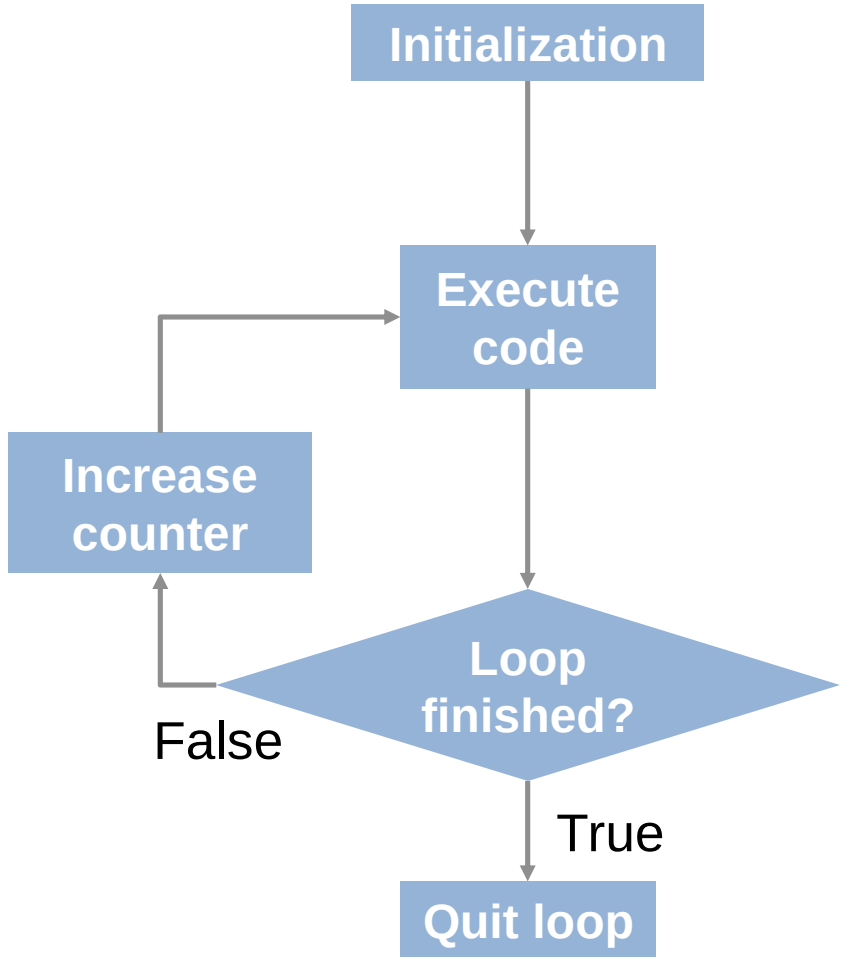
While loop

Runs code as long as condition is true



For loop

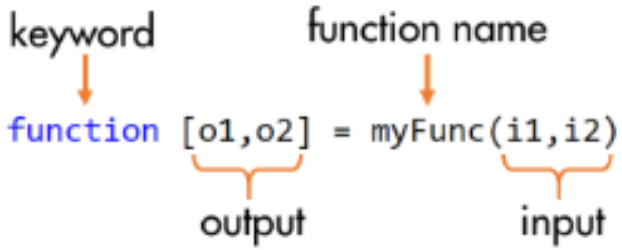
Runs a code for certain number of iterations

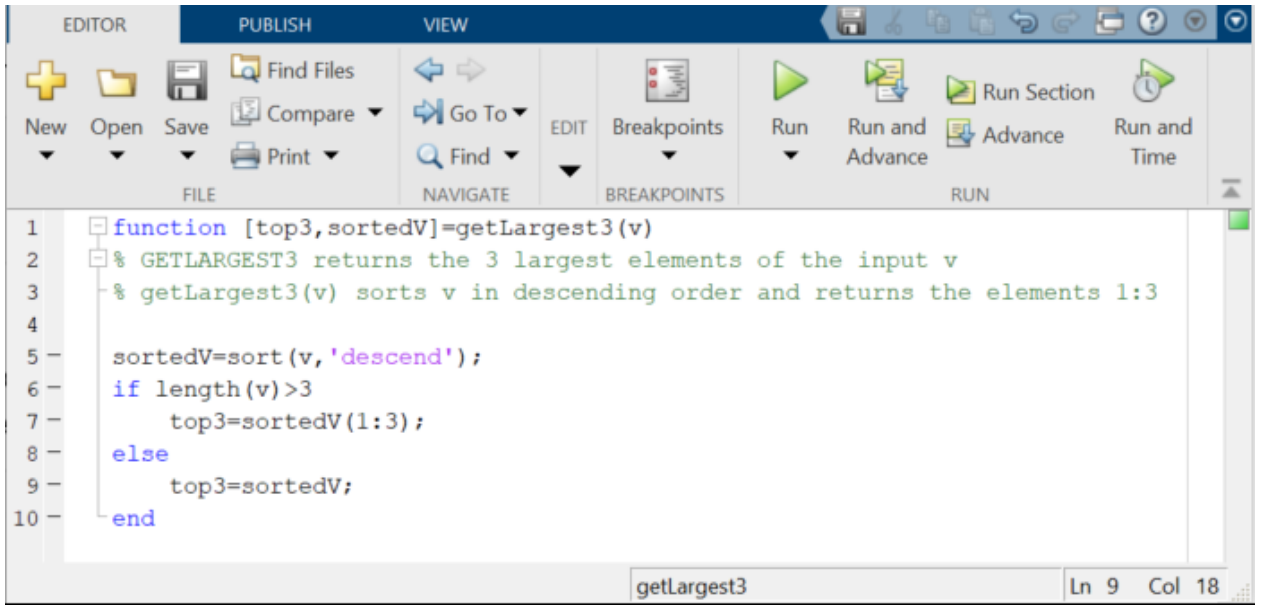


Functions

- Reusable code
- Run from command line
- Higher code readability
- Modularity
- Provide help

The syntax for defining a function is similar to the syntax for calling any MATLAB function with the keyword `function` at the beginning.





Anonymous functions

An anonymous function is a function that is:

- Not stored in a program file
- variable whose data type is function_handle.
- accept inputs and return outputs, (outputs are implicit)
- only a single executable statement.
- Handles can be used as inputs to other functions

```
>> sqr = @(x) x.^2;

>> a = sqr(5)
a = 25
>> q = integral(sqr,0,1);
>> q = integral(@(x) x.^2,0,1);
```

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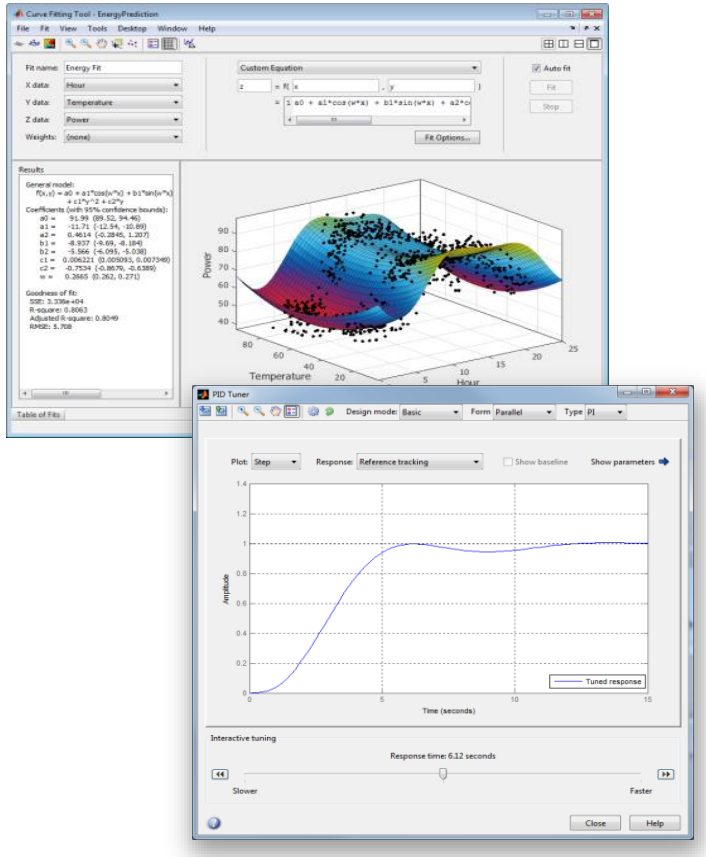
Expanding the Capabilities of MATLAB

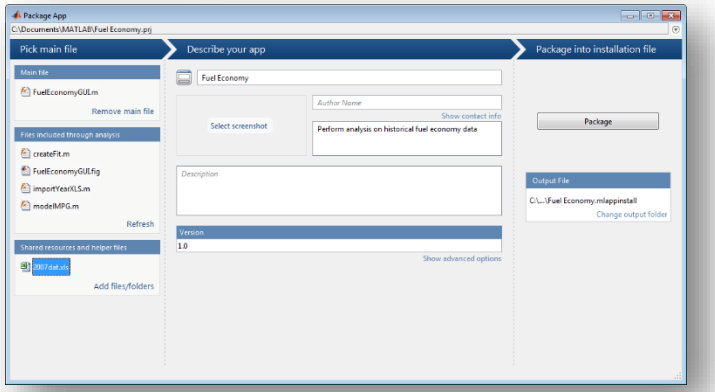
Access | **Explore & Discover** | Share

- MathWorks add-on tools for:
  - Math, statistics, and optimization
  - Control system design and analysis
  - Signal processing and communications
  - Image processing and computer vision
  - Parallel computing and more…
- Partner products provide:
  - Additional interfaces
  - Domain-specific analysis
  - Support for niche applications



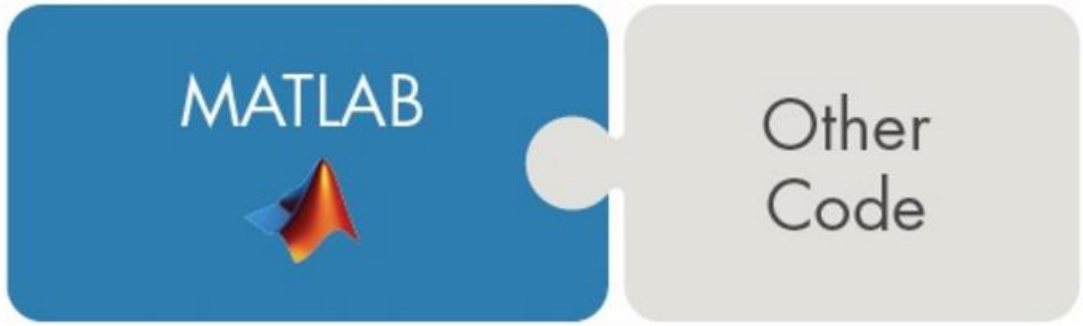
Packaging and Sharing MATLAB Apps

- MATLAB apps
  - Interactive applications to perform technical computing tasks
  - Displayed in apps gallery
- Included in many MATLAB products
- Package your own app
  - Create single file for distribution and installation into gallery
  - Packaging tool:
    - Automatically includes all necessary files
    - Documents required products



Using MATLAB with Other Languages

Calling Libraries Written in Another Language From MATLAB



- Java
- Python
- C
- C++
- Fortran
- COM components and ActiveX® controls
- RESTful, HTTP, and WSDL web services

Execute Python functions out of process R2019b

Call C++ libraries directly from MATLAB R2019a

Calling MATLAB from Another Language

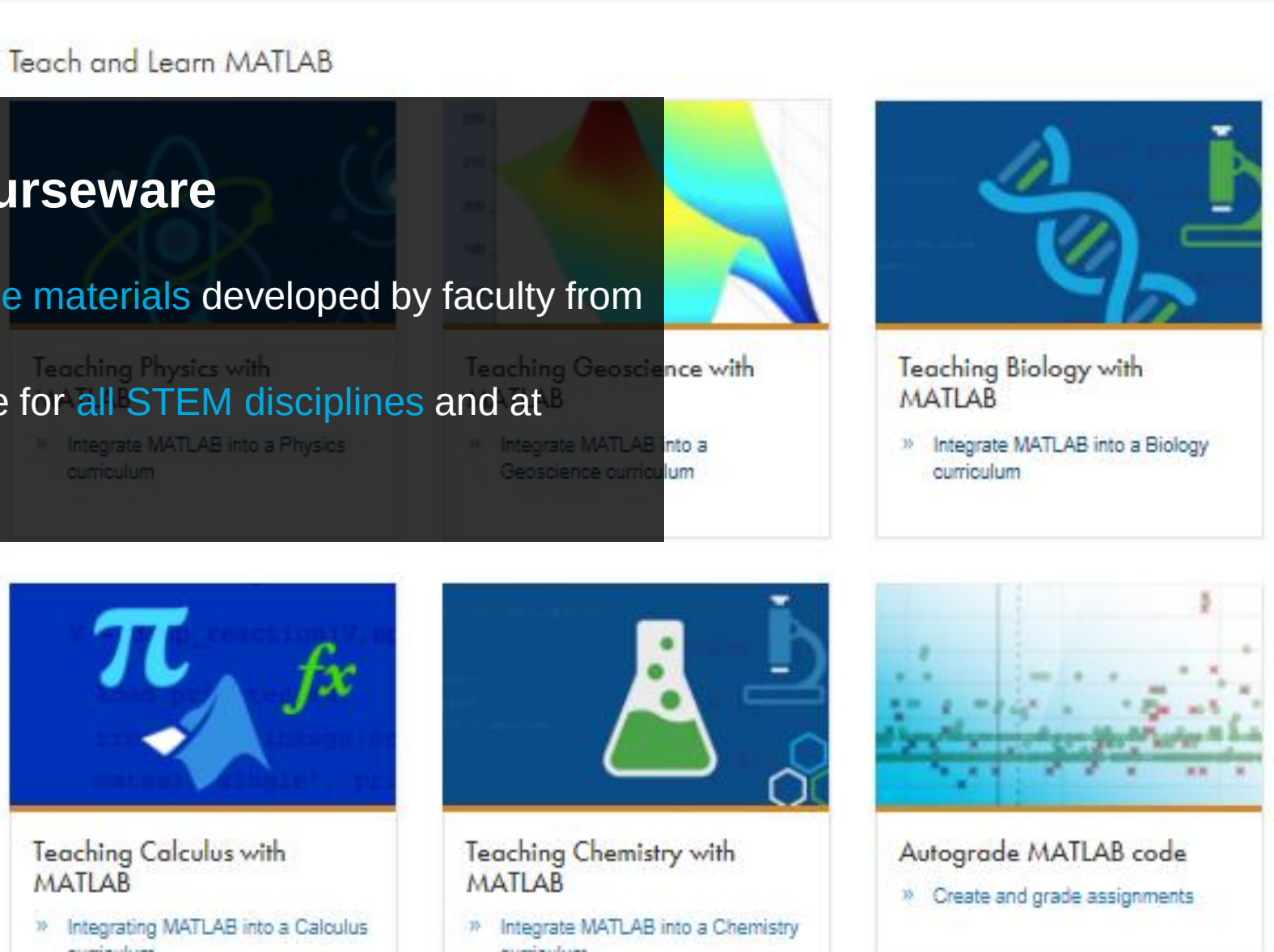
- Java
- Python
- C/C++
- Fortran
- COM Automation server

Teaching with MATLAB Courseware

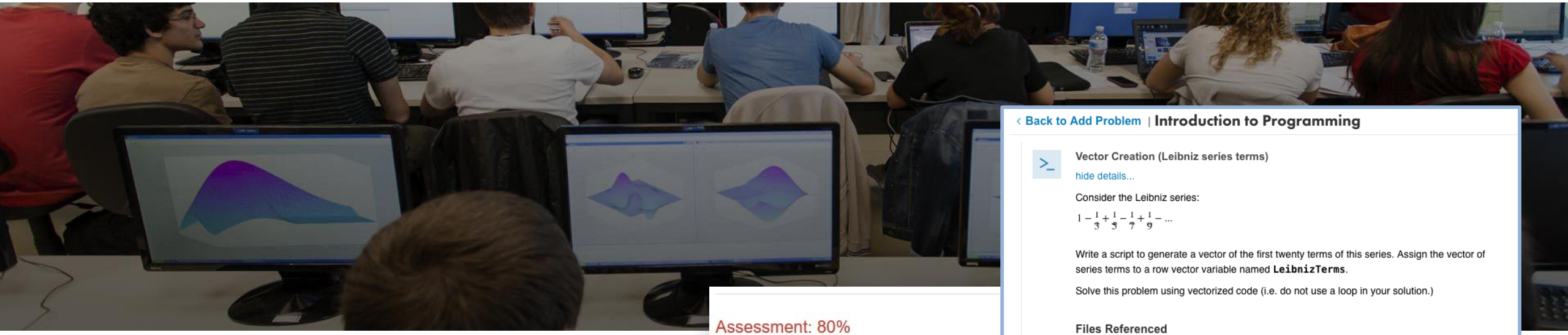
MATLAB Courseware

Free sets of course materials developed by faculty from top universities

Curricula available for all STEM disciplines and at multiple levels



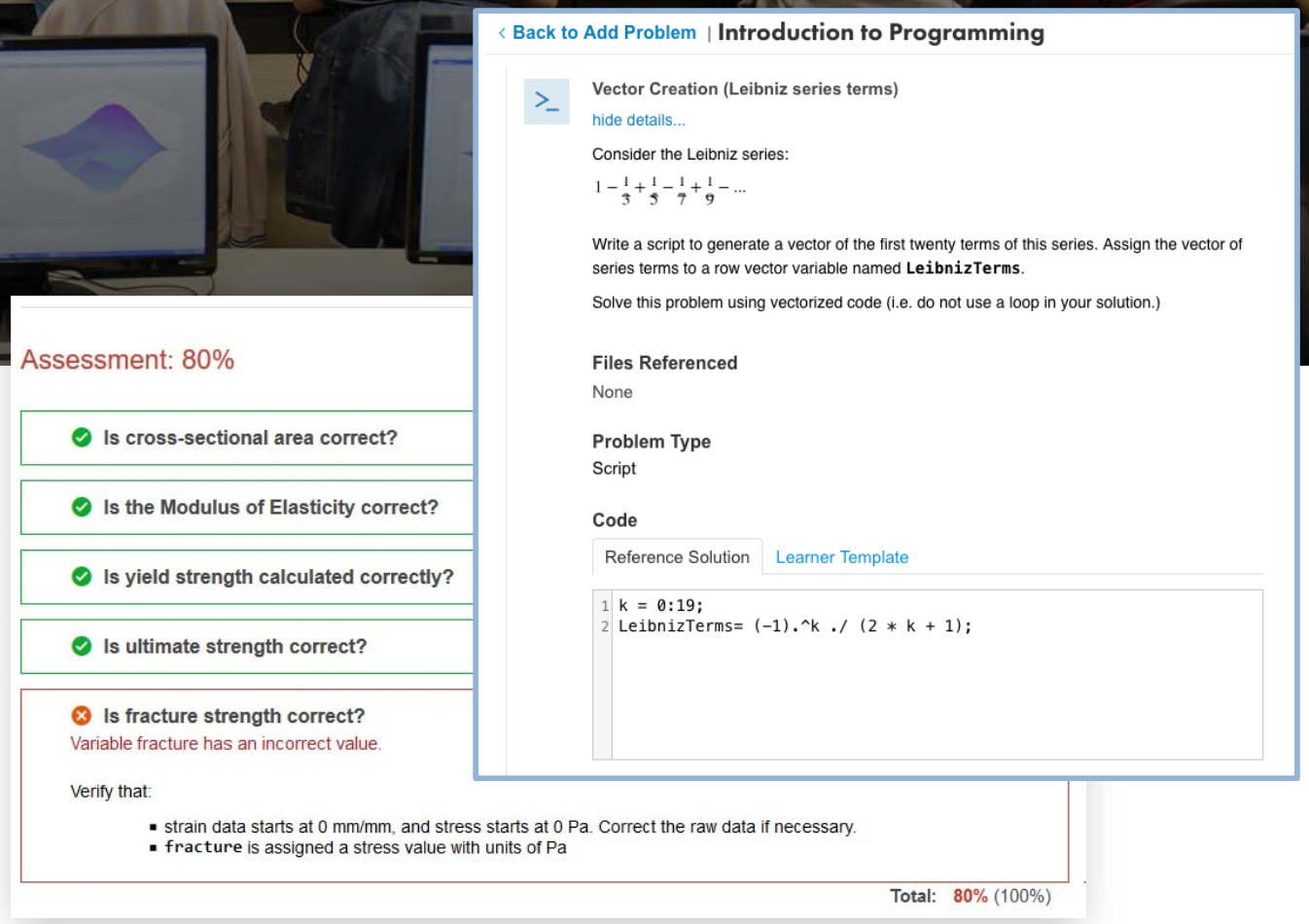
MATLAB Grader



Create interactive course assignments

Automatically grade student work and provide feedback

Run your assignments in any learning environment



MATLAB Central Community

Every month, over **2 million** MATLAB & Simulink users visit MATLAB Central to get questions answered, download code and improve programming skills.

MATLAB Central

Learn | Contribute | Connect

MATLAB Answers: Q&A forum; most questions get answered in only **60 minutes**

File Exchange: Download code from a huge repository of free code including **tens of thousands** of open source community files

Cody: Sharpen programming skills while having fun

Blogs: Get the inside view from Engineers who build and support MATLAB & Simulink

ThingSpeak: Explore IoT Data

And more for you to explore…