

UNIT – I

History of MATLAB

1. MATLAB was not a programming language but was a simple interactive calculator.
2. 1970 there was EISPACK (Matrix Eigen System PACKAGE) and LINPACK (LINEar Equation PACKAGE) which was invented and was invented in FORTRAN.
3. After invention of these 2 packages the MATLAB was invented in late of 1970's by **CLEVE MOLER**, he was working in computer science department at university of New Mexico.
4. After this he tried to develop MATix LABoratory (Software Libraries for numerical Computing using FORTRAN).
5. Cleve Moler with Jack Little and Steve Bangert worked in MATLAB using C and founded MathWorks.
6. In 1984 rewrote to MATLAB using C and the software libraries were known as JACKPACK and LINPACK.
7. In every 6 months they launch new version and updates.

Features of MATLAB.

1. MATLAB is a high-level language.
 - a. Study Data Structures
 - b. Control Flow Statements
 - c. Object Oriented Programming
 - d. Create and Solve Complex and large application.
2. MATLAB provides interactive environment
 - a. MATLAB allows interactive exploration, design and problem solving.
 - b. It consists of bunch of toolboxes.
 - c. It also consists of tools for development, handling, debugging, and profiling files.
3. Handling Graphics
 - a. It offers built in graphics
 - b. Tools for generating customized plots
 - c. Data visualization
 - d. 2D and 3D animations
 - e. Image Processing
 - f. Graphical Representation
4. Accessing Data
 - a. Supports sensor, video, image, telemetry, binary, and various real time data.
 - i. JDBC/ODBC Databases
 - b. Can read data from csv files
5. Application Program Interface (API)
6. Toolboxes
 - a. There are many toolboxes in MATLAB depending what kind of work we do.
 - b. Image Processing Toolbox
 - c. Aerospace Toolbox
 - d. Deep Learning
 - e. Simulink
7. Large libraries of mathematical functions
 - a. Integration
 - b. Trigonometric Functions

- c. Logical Functions
- 8. Interaction with other languages
- 9. Simulink
 - a. Designing Based Library Package
 - b. Design Control System power system etc
- 10. Interface with other languages.

Advantages of MATLAB

- 1. Has Easy User Interface
- 2. Various types of inbuilt functions / libraries
- 3. Predefined Algorithms
- 4. Data Visualization
- 5. Debugging of codes
- 6. Huge Committee of MATLAB
- 7. Platform Independent

Disadvantages of MATLAB

- 1. Very Expensive
- 2. All the errors are not much informative
- 3. Cross-Compilation of Languages is difficult
- 4. It needs fast computers

MATLAB as a good programming language

- 1. Use various types of variables / codes / tables / inbuilt functions / inbuilt libraries etc.
- 2. Use of Descriptive variable names
- 3. Write own functions and can-do things over again
- 4. Write our own scripts
- 5. Indenting (if else loop spacing)
- 6. Combine 2 or more codes simultaneously



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MATLAB

Unit 1-Lecture 9

BTech (CSBS) -Semester VII

9 August 2022, 09:35AM



Introduction to MATLAB

- History,
- basic features,
- strengths and weaknesses,
- good programming practices
- plan your code



History

- The first MATLAB was not a programming language; it was a simple interactive matrix calculator.
- In 1970, a group of researchers developed EISPACK (Matrix Eigensystem Package) and LINPACK (Linear Equation Package) in FORTRAN
- The development of the MATLAB started in the late 1970s by Cleve Moler, the chairman of the Computer Science department at the University of New Mexico. Cleve wanted to make his students able to use LINPACK & EISPACK (software libraries for numerical computing, written in FORTRAN), and without learning FORTRAN.
- In 1984, Cleve Moler with Jack Little & Steve Bangert rewrote MATLAB in C and founded MathWorks. These libraries were known as JACKPAC at that time, later these were revised in 2000 for matrix manipulation and named as LAPACK (Linear Algebra Package)



Features of MATLAB

1. MATLAB is high-level language

This is a high-level programming language with data structures, control flow statements, functions, output/input, and object-oriented programming. It permits both, rapidly creating speedy throw-away programs, and creating complete, complex and large application programs.

2. Interactive Environment

MATLAB provides an interactive environment that allows iterative exploration, design, and problem-solving. It is a bunch of tools that a programmer can use. It includes abilities for handling the variables in the workspace & importing/exporting data. It also contains tools for development, handling, debugging, and profiling MATLAB files.



Features of MATLAB

3. Handling Graphics

It offers built-in graphics useful for data visualization, and tools for generating custom plots. MATLAB holds high-level instructions specially for creating two and three-dimensional data visualizations, animations, image processing, and graphical presentation. It allows users to modify graphics through GUI

4. Accessing data

MATLAB can natively support the sensor, video, image, telemetry, binary, and various real-time data from JDBC/ODBC databases. Reading data from different databases, CSV, audio, images, and video is super simple from an integrated environment.



Features of MATLAB

3. Application Program Interface (API)

MATLAB APIs allow users to write C / C++ and Fortran programs that directly interact with MATLAB. These include options for calling programs from MATLAB (dynamic linking), reading and writing MAT-files and using MATLAB as an interface to run applications.

6. Toolboxes

A "Toolbox" is a set of functions designed for a specific purpose and compiled as a package. These Toolboxes include MATLAB code, apps, data, examples and the documentation which helps users to utilize each Toolbox. There are separate Toolboxes available from Mathworks, to be used for specific purposes, for example, text analytics, image processing, signal processing, deep learning, statistic & machine learning, and many more.



Features of MATLAB

7. A large library of Mathematical functions

MATLAB has a huge inbuilt library of functions required for mathematical analysis of any data. It has common math functions like sqrt, factorial etc. It has functions required for statistical analysis like median, mode and std (to find standard deviation), and much more. MATLAB also has functions for signal processing like filter, butter(Butterworth filter design) audio read, Conv, xcorr, fft, fftshift etc. It also supports image processing and some common functions required for image processing in MATLAB are rgb2gray, rgb2hsv, adaptthresh etc.



Features of MATLAB

8. MATLAB and Simulink:

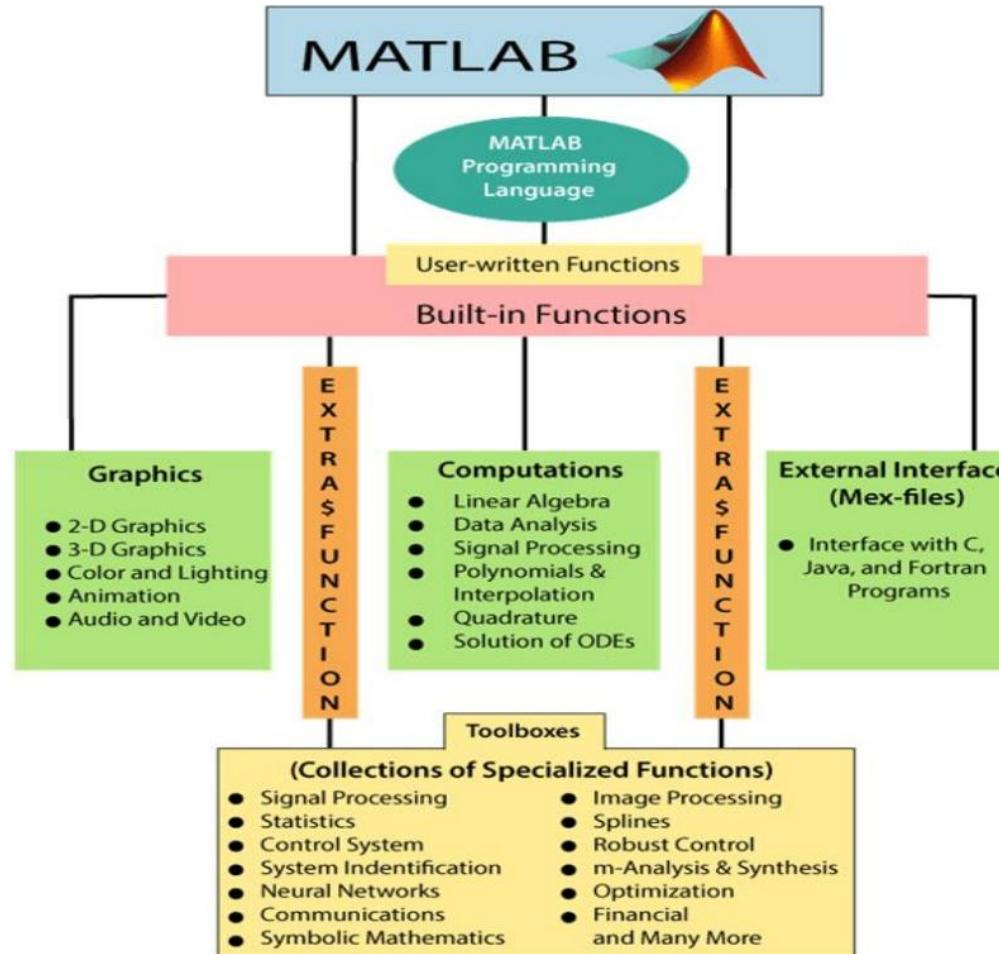
MATLAB has an inbuilt feature of Simulink wherein we can model the control systems and see their real-time behavior. We can design any system either using code or building blocks and see their real-time working through various inbuilt tools. It has lucid examples of basic control systems and their working.

9. Interface with other languages:

We can write a set of codes (libraries) in languages like PERL and JAVA, and we can call those libraries from within the MATLAB itself. MATLAB also supports ActiveX and .NET libraries.



Schematic of MATLAB



MATLAB

Unit 1-Lecture 10

BTech (CSBS) -Semester VII

12 August 2022, 09:35AM



Introduction to MATLAB

- History,
- basic features,
- strengths and weaknesses,
- good programming practices
- plan your code



Advantages of MATLAB

- **Easy to use interface:** A user-friendly interface with features you want to use is one click away.
- **A large inbuilt database of algorithms:** MATLAB has numerous important algorithms you want to use already built-in, and you just have to call them in your code.
- **Extensive data visualization and processing:** We can process a large amount of data in MATLAB and visualize them using plots and figures.



Advantages of MATLAB

- **Debugging of codes easy:** There are many inbuilt tools like analyzer and debugger for analysis and debugging of codes written in MATLAB.
- **Huge community:** It has huge community support where many of the questions will be answered
- **Platform-independent:** MATLAB is platform independent and hence it can be installed on different Operating Systems such as Windows, Vista, Linux and Macintosh.



Disadvantages of MATLAB

- Sometimes, the error messages are not much informative, so you have to figure out the error yourself.
- Matlab is more expensive. The license is very costly, and users need to buy each and every module and need to pay for the same.
- Cross-compiling of Matlab code to other languages is very difficult and requires deep Matlab knowledge to deal with errors produced.



Disadvantages of MATLAB

- Matlab is used mainly for scientific research and is not suitable for development activities that are user-specific.
- Matlab is an interpreted language; thus, it can be very slow. Poor programming practices can contribute to making Matlab unacceptably slow.
- It requires fast computer with sufficient amount of memory. This adds to the cost for individuals willing to use it for programming.



MATLAB good programming practices

- Use variables instead of hard coded numbers. Put these numbers at the top of your scripts and functions
- Write functions for things you do over and over again
- Use descriptive variable names
- Put in comments to describe tricky parts of your code
- Document your functions

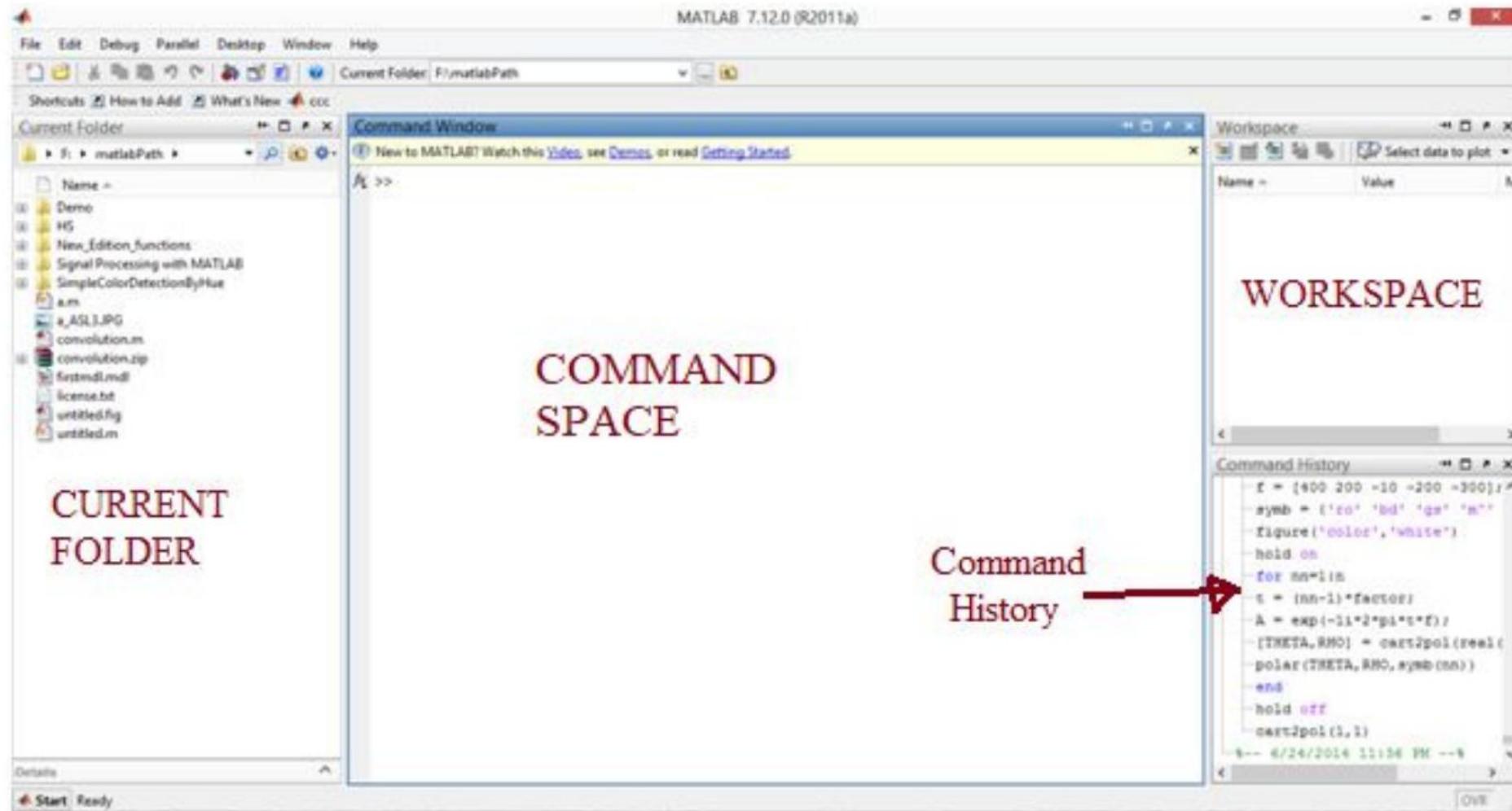


MATLAB good programming practices

- Use MATLAB built-in functions when they are available.
- Learn how to use structures and cell arrays well
- Check your code
- Learn how to use the MATLAB debugger functions.
- Write scripts for each figure you need to make.
- Always indent the body of an if construct by two or more spaces to improve the readability of the code



MATLAB good programming practices



MATLAB

Lab1

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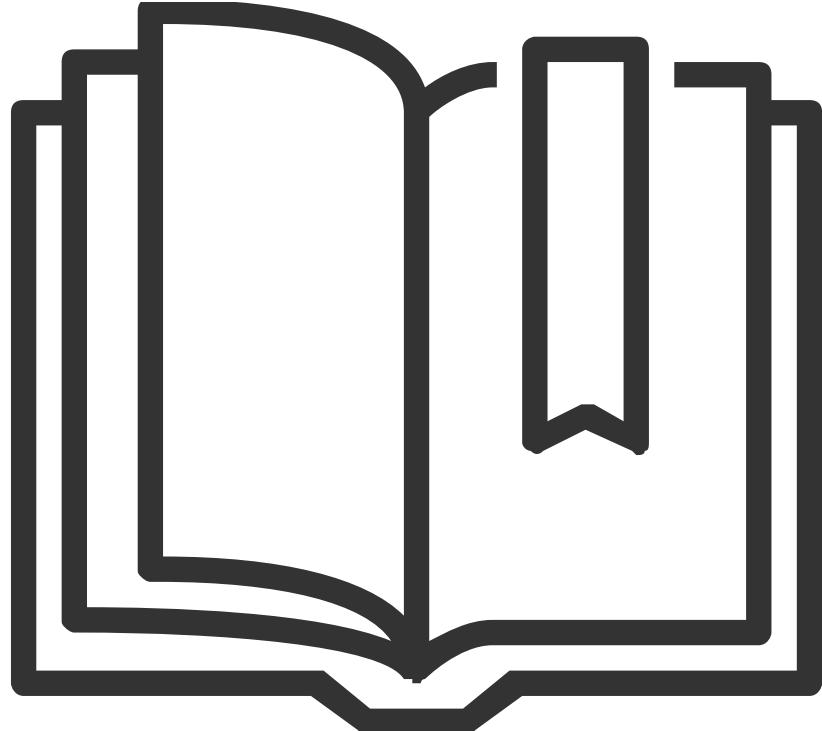
12 July 2022, 10:45AM



EXPERIMENT 1:Basic Mathematics using MATLAB

Compute the following quantities at command prompt:

- 1) $2^5/(2^5-1)$ and compare with $[1-(1/2^5)]-1$
- 2) $[3(\sqrt{5}-1)/(\sqrt{5}+1)*2] - 1$
- 3) Area = πr^2 with $r=\pi^{1/3}-1$
- 4) $e^3, \ln(e^3), \log_{10}(e^3), \log_{10}(10^5)$
- 5) $e^{\pi\sqrt{163}}, \sin(2\pi/6)+\cos(2\pi/6)$
- 6) $y= \cosh 2x - \sinh 2x$; where $x=32\pi$
- 7) Solve $3^x=17$ for x
- 8) $1+(3i/(1-3i)), e^{i\pi/4}$
- 9) Execute the commands $\exp(pi/2*i)$ and $\exp(pi/2i)$.
- 10) $\cot(0), \tan^{-1}(\infty)$



**Thank you for
listening**

09:30AM

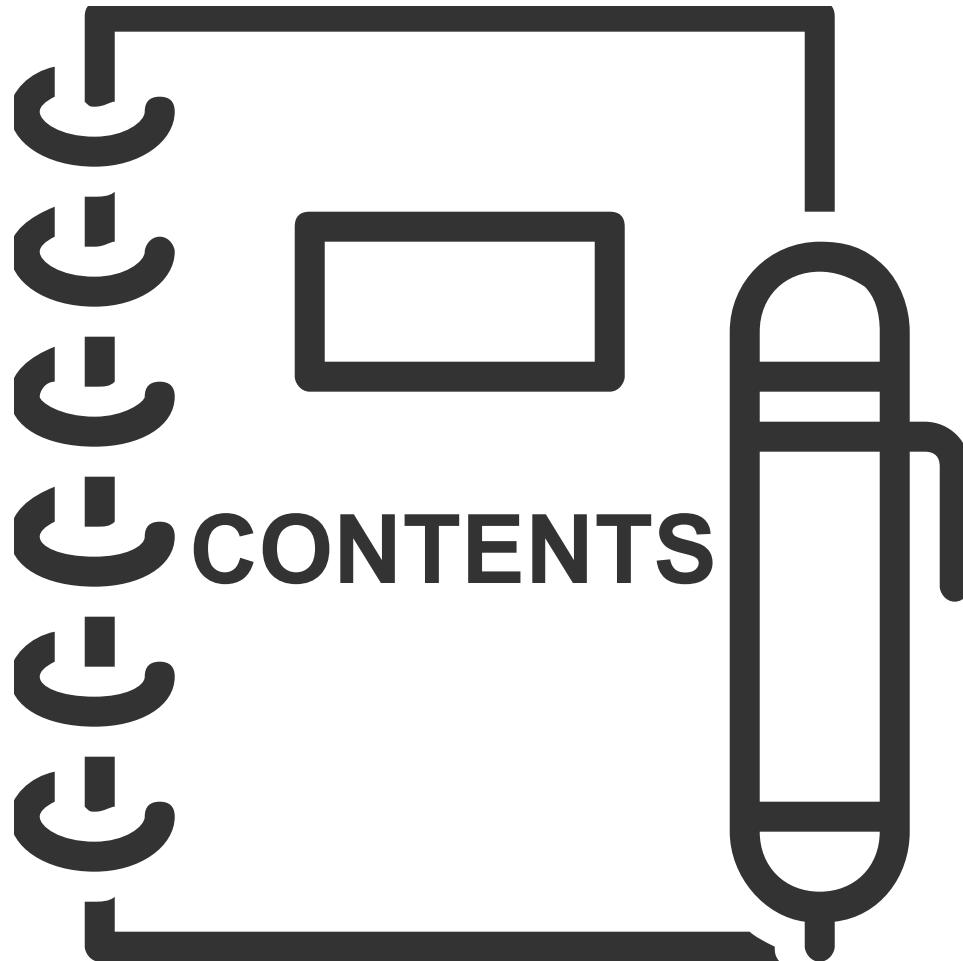
Image and Video Processing

MATLAB

Unit 2-Lecture 1

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12 July 2022, 09:35AM



Teaching plan



Assessment analysis



Text/Reference books



Unit 1-Lecture 1



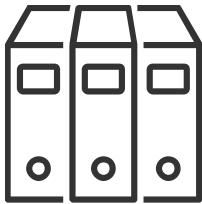
Teaching plan/Assessment analysis

Teaching plan

Teaching Scheme				Evaluation Scheme	
Lecture (Hours/week)	Practical (Hours/week)	Tutorial (Hours/week)	Credit	Internal Continuous Assessment (ICA) As per Institute Norms (50 Marks)	Theory (3 Hrs, 100 Marks)
2	2	0	3	Marks Scaled to 50	Marks Scaled to 50

Assessment analysis

Assessment Component	ICA (100 Marks) (Marks scaled to 50)					TEE (100 marks) (Marks scaled to 50)
	Lab Performance	Lab Exam and Viva	Research activity (beyond syllabus)	Class Test 1 and Class Test 2	Class Partition	
Weightage	10%	5%	10%	20%	5%	50%
Marks	20	10	20	20+20	10	100
Date/week of activity	Weekly	10 th and 11 th week	14 th week	T1: 16-23 August, 2022 T2: 10-15 October, 2022	2 nd and 13 th Week	16 th Nov.2022 to 2 nd Dec., 2022



Text/Reference books

Text Books:

- 1) Rafael C. Gonzalez, Richard E. Woods, Steven Eddins, “*Digital Image Processing using MATLAB*”, Pearson Education, Inc., Second Edition, 2004.
- 2) Stormy Attaway, Butterworth-Heinemann, “*MATLAB: A Practical Introduction to Programming and Problem Solving*”, Butterworth-Heinemann is an imprint of Elsevier, Fourth Edition, 2017.

Reference Books:

- 1) Cleve Moler, “*Experiments with Matlab*”, MathWorks, Inc., 2011.



Unit 1-Lecture 1→Agenda

- 1) Desktop Basics
- 2) Numbers & Arithmetic Operations
- 3) Workspace Variables



1: Introduction

When you start MATLAB, the desktop appears in its default layout.

- The desktop includes these panels:
- **Current Folder** — Access your files.
- **Command Window** — Enter commands at the command line, indicated by the prompt (`>>`).
- **Workspace** — Explore data that you create or import from files.
- **Command History** — View or rerun commands that you entered at the command line.

Command Window

- type commands

Current Directory

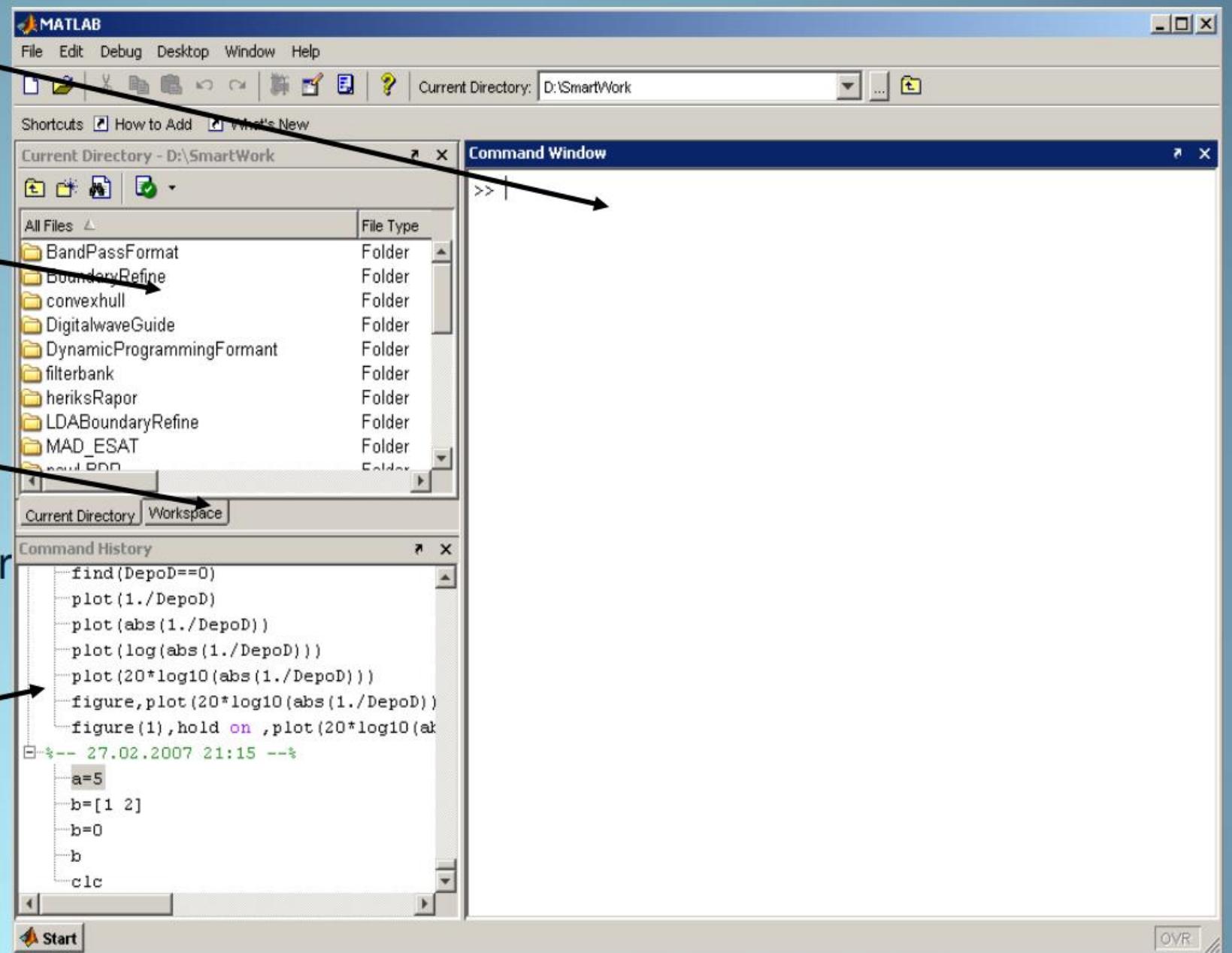
- View folders and m-files

Workspace

- View program variables
- Double click on a variable
- to see it in the Array Editor

Command History

- view past commands
- save a whole session using diary





MATLAB window

- Figure Window -contains output from graphic commands
- Help Window -provides help information
- Editor Window -creates and debugs script and function files
- Current directory Window -shows files in current directory
- Launch Pad Window -provides access to tools,demos and documentation



Command window

>> type code

Press enter

Command executed and output displayed

semicolon (;

output not displayed

Ellipsis(...) if a command is too long to fit in one line

Command can continue line after line up to 4096 characters.



common commands

Matlab commands **case sensitive**

- % -comment
- clc -clear screen
- ↑ -recall previously typed commands
- ↓ -move down to previously typed



Arithmetic Operations With Scalars

<u>Operation</u>	<u>Symbol</u>	<u>Example</u>
Addition	+	$5+3$
Subtraction	-	$5-3$
Multiplication	*	$5*3$
Right division	/	$5/3$
Left division	\	$5\backslash 3=3/5$
Exponentiation	^	$5^3=125$



Order of Precedence

Parentheses

Exponentiation

Multiplication and division

Addition and subtraction



Display Formats

Command	Description
format short	Fixed-point with 4 decimal digits
format long	Fixed-point with 14 decimal digits
format bank	2 decimal digits
format compact	Eliminates empty lines
format loose	Adds empty lines



Elementary Math functions

Function	Description
<code>sqrt (x)</code>	Square root
<code>exp (x)</code>	Exponential (e^x)
<code>abs (x)</code>	Absolute value
<code>log (x)</code>	Natural logarithm Base e logarithm
<code>Log10(x)</code>	Base 10 logarithm
<code>factorial(x)</code>	Factorial function $x!$



Trigonometric/rounding Math functions

$\sin(x), \cos(x),$
 $\tan(x), \cot(x)$

Rounding function

Function	Description
round(x)	Round to the nearest integer
fix(x)	Round towards zero
ceil(x)	Round towards infinity
floor(x)	Round towards minus infinity
rem(x,y)	Returns remainder after x is divided by y



Trigonometric/rounding Math functions

Elementary functions (sin, cos, sqrt, abs, exp, log10, round)
-type **help elfun**

Advanced functions (bessel, beta, gamma, erf)
-type **help specfun**
-type **help elmat**



Defining scalar variables

variable is a name made of a letter or a combination of several letters that is assigned a numerical value

- actually name of a memory location
- assignment operator “=”

eg.

`>>x=15`

`>>x=3*x-12`

When new variable is created matlab assigns appropriate memory space where assigned value can be stored

- When variable is used stored data is used
- If assigned new value content of memory is replaced

eg. `>>ABB=72;`

`>>ABB=9;`

`>>ABB`

`ABB=`



Rules about variable names

- Variable names are case sensitive.
- Variable names can contain up to 63 characters (as of MATLAB 6.5 and newer).
- Variable names must start with a letter followed by letters, digits, and underscores.
- Must begin with a letter.
- Avoid using names of built-in functions for variable.

MATLAB

Unit 2-Lecture 2

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15 July 2022, 09:35AM



Predefined variables

variable	description
ans	Value of last expression
eps	Smallest difference between 2 numbers
i	$\sqrt{-1}$
inf	Infinity
j	Same as i
NaN	Not a number
pi	The number π



Some Useful MATLAB commands

- `who` List known variables
- `whos` List known variables plus their size
- `help` `>> help sqrt` (Help on using sqrt)
- `clear` Clear all variables from work space
- `clear x y` Clear variables x and y from work space
- `clc` Clear the command window



Variable and assignment statement

variable name = expression

Command window:

```
>> mynum = 6
mynum =
    6
>>
```

Correction: The variable name must always be written on left, and expression on right.

Now write in Command window:

```
>> 6 = mynum
    6 = mynum
    |
```

Error: The expression to the left of the equals sign is not a valid target for an assignment.

```
>>
```



Initializing, incrementing & decrementing

Frequently, values of variables change, as shown previously. Putting the first or initial value in a variable is called *initializing* the variable.

Adding to a variable is called *incrementing*. For example, the statement

```
mynum = mynum + 1
```

increments the variable *mynum* by 1.

Similarly, ***mynum=mynum-1***, will be *decrementing* variable.



Floating-Point Numbers

For floating point number there are two basic types:

- Double-Precision Floating Point
- Single-Precision Floating Point

The integer type are **int8**, **int16**, **int32**, **int64**.

These integers represent the **bits** used to store the value of data type.

type **char** is used to store the **character or string** eg. ‘cat’

type **logical** is used to store true/false.



Numerical Expression

Expressions can be created using values, variables that have already been created, operators, built-in functions, and parentheses. For numbers, these can include operators such as multiplication and functions such as trigonometric functions. An example of such an expression is:

```
>> 2 * sin(1.4)  
ans =  
1.9709
```



Fromat Command

This will remain in effect until the format is changed back to **short**, as demonstrated in the following.

```
>> format long  
>> 2 * sin(1.4)  
ans =  
1.970899459976920
```

```
>> format short  
>> 2 * sin(1.4)  
ans =  
1.9709
```



Fromat Command

The **format** command can also be used to control the spacing between the MATLAB command or expression and the result; it can be either **loose** (the default) or **compact**.

```
>> format loose
```

```
>> 5*33
```

```
ans =
```

```
165
```

```
>> format compact
```

```
>> 5*33
```

```
ans =
```

```
165
```

```
>>
```



Nested Parentheses

Within a given precedence level, the expressions are evaluated from left to right (this is called *associativity*).

For the operators that have been covered thus far, the following is the precedence (from the highest to the lowest):

()	parentheses
^	exponentiation
-	negation
*, /, \	all multiplication and division
+, -	addition and subtraction



Operator precedence rule:

Operators	Precedence
Parentheses: ()	Highest
Power ^	
Unary: Negation (-), not (~)	
Multiplication, division *, /, \	
Addition, subtraction +, -	
Relational <, <=, >, >=, ==, ~=	
And &&	
Or	
Assignment =	Lowest



Practice problem:

1. Think about what the results would be for the following expressions, and then type them in to verify your answers:

$1 \backslash 2$
 $-5 ^ 2$
 $(-5) ^ 2$
 $10 - 6 / 2$
 $5 * 4 / 2 * 3$

2. What would happen if you use the name of a function , eg abs, as a variable name?
3. Use plus operator and check the results.

Also, if a function name is typed incorrectly, MATLAB will suggest a correct name.

```
>> abso(-4)
Undefined function or variable 'abso'.
Did you mean:
>> abs(-4)
```



Constant/random number

pi 3.14159...

i $\sqrt{-1}$

j $\sqrt{-1}$

inf infinity ∞

NaN stands for "not a number," such as the result of 0/0

Practice problem:

```
>> rand  
ans =  
    0.8147  
>> rand  
ans =  
    0.9058
```

Generate a random

- real number in the range [0,1]
- real number in the range [0, 100]
- real number in the range [20, 35]
- integer in the inclusive range from 1 to 100
- integer in the inclusive range from 20 to 35



Relational Expression

Expressions that are conceptually either true or false are called *relational expressions*; they are also sometimes called *Boolean expressions* or *logical expressions*. These expressions can use both *relational operators*, which relate two expressions of compatible types, and *logical operators*, which operate on logical operands.

The relational operators in MATLAB are:

Operator	Meaning
>	greater than
<	less than
\geq	greater than or equals
\leq	less than or equals
==	equality
~=	inequality

Example:

```
>> 3 < 5
ans =
    1
```

```
>> 2 > 9
ans =
    0
>> class(ans)
ans =
logical
```



Practice question:

1. Assume that there is variable x that has been initialized, what would be the value of expression $3 < x < 5$, if the value of x is 4? what if the value is 7?



Practice question:

Think about what would be produced by the following expressions, and then type them in to verify your answers.

`3 == 5 + 2`

`'b' < 'a' + 1`

`10 > 5 + 2`

`(10 > 5) + 2`

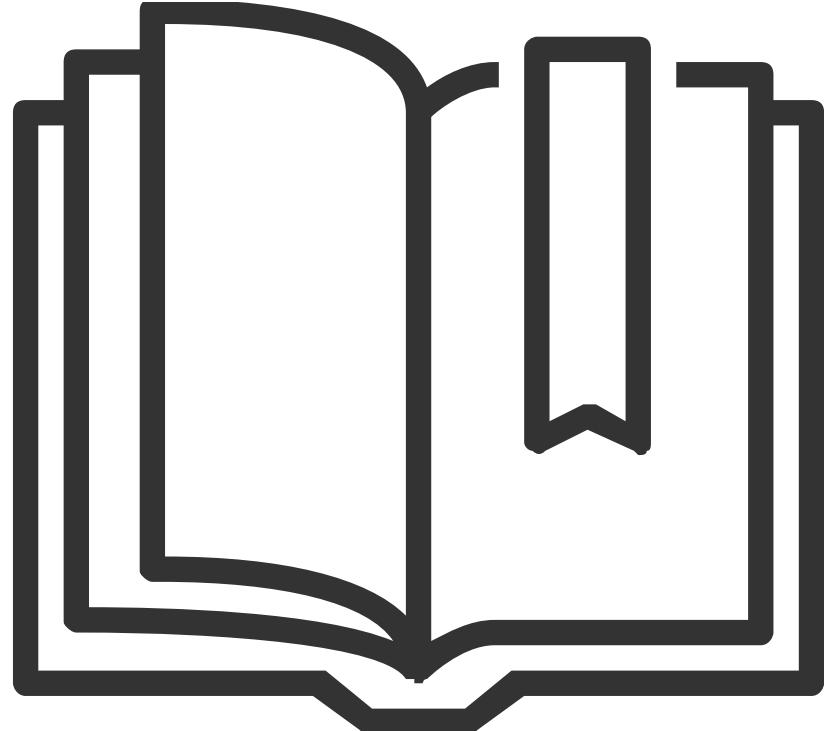
`'c' == 'd' - 1 && 2 < 4`

`'c' == 'd' - 1 || 2 > 4`

`xor('c' == 'd' - 1, 2 > 4)`

`xor('c' == 'd' - 1, 2 < 4)`

`10 > 5 > 2`



**Thank you for
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Unit 2-Lecture 3

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19 July 2022, 09:35AM



Creating 2D array(matrix)

Variable_name = [1st row elements; 2nd row elements;.....;last row elements]

- Matrix are used in science & eng to describe many physical quantities.
- All rows must have same number of elements



Zeros , ones and eye commands

- **zeros(m,n)**: mxn matrix of 0's.
- **ones(m,n)**: mxn matrix of 1's.
- **eye(n)**: nxn identity matrix



Array

List of numbers arranged in row and/or columns.

Simplest array

-1D array

-usually to represent vectors.

Complex array

-2D array

-represent matrixes



Creating vector from a known list of numbers

```
Variable_name = [type vector elements]
```

Row vector :- type elements with space or comma

Column vector :- type elements with semicolon (;) or press Enter key after each element

```
Variable_name = [m:q:n] or Variable_name = m:q:n
```

First term spacing last term

```
Variable_name = linspace(xi,xf,n)
```

First element last element no of elements (when omitted default value 100)



Vector and Matrix

5

3
7
4

5	88	3	11
---	----	---	----

9	6	3
5	7	2

The scalar is 1×1 , the column vector is 3×1 (three rows by one column), the row vector is 1×4 (one row by four columns), and the matrix is 2×3 (two rows by three columns). All of the values stored in these matrices are stored in what are called *elements*.



Creating row vector

There are several ways to create row vector variables. The most direct way is to put the values that you want in the vector in square brackets, separated by either spaces or commas. For example, both of these assignment statements create the same vector v :

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

```
v =
```

```
1 2 3 4
```

```
>> v = [1, 2, 3, 4]
```

```
v =
```

```
1 2 3 4
```



Colon Operator

If, as in the preceding examples, the values in the vector are regularly spaced, the *colon operator* can be used to *iterate* through these values. For example, `2:6` results in all of the integers from 2 to 6 inclusive:

```
>> vec = 2:6
vec =
2 3 4 5 6
```

In this vector, there are five elements; the vector is a 1×5 row vector. Note that in this case, the brackets `[]` are not necessary to define the vector.

With the colon operator, a *step value* can also be specified by using another colon, in the form `(first:step:last)`. For example, to create a vector with all integers from 1 to 9 in steps of 2:

```
>> nv = 1:2:9
nv =
1 3 5 7 9
```



Line space function

The **linspace** function creates a linearly spaced vector; **linspace(x,y,n)** creates a vector with n values in the inclusive range of x to y . If n is omitted, the default is 100 points. For example, the following creates a vector with five values linearly spaced between 3 and 15, including the 3 and 15:

```
>> ls = linspace(3,15,5)  
ls =  
    3     6     9    12    15
```



Concatenating Vector

Vector variables can also be created using existing variables. For example, a new vector is created here consisting first of all of the values from *nv* followed by all values from *ls*:

```
>> newvec = [nv ls]
newvec =
    1  3  5  7  9  3  6  9  12  15
```

Putting two vectors together like this to create a new one is called *concatenating* the vectors.



Logspace function

Similarly, the **logspace** function creates a logarithmically spaced vector; **logspace(x,y,n)** creates a vector with n values in the inclusive range from 10^x to 10^y . If n is omitted, the default is 50 points. For example, **logspace(1,4,4)** creates a vector with four elements, logarithmically spaced between 10^1 and 10^4 , or in other words 10^1 , 10^2 , 10^3 , and 10^4 .

```
>> logspace(1, 4, 4)
ans =
    10      100     1000    10000
```



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Unit 2-Lecture 4

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22 July 2022, 09:35AM



Workspace

- Managing the workspace
- Keeping track of your work session,
- Entering multiple statements per line



Workspace Browser

- The Workspace browser enables you to view and interactively manage the contents of the workspace in MATLAB®.
- For each variable or object in the workspace, the Workspace browser also can display statistics, when relevant, such as the minimum, maximum, and mean.
- You can edit the contents of scalar (1-by-1) variables directly in the Workspace browser. **Right-click the variable and select Edit Value.**
- To edit other variables, double-click the variable name in the Workspace browser to open it in the Variables editor.



Workspace Browser

Name	Value	Class	Min	Max	Mean
A	4x4 double	double	1	16	8.5000
B	[1;2;3;4]	double	1	4	2.5000
filename	'myfile.txt'	char			
patient	1x1 struct	struct			
t	'Hello'	char			
val1	2x3 cell	cell			
val2	[17,21,42]	double	17	42	26.6667
x	325	double	325	325	325
y	[9900,26025,39600]	uint32	9900	39600	
z	-Inf	double	-Inf	-Inf	-Inf



Open the Workspace Browser

To open the Workspace browser if it is not currently visible, do one of the following:

- MATLAB Toolstrip: On the **Home** tab, in the **Environment** section, click **Layout**. Then, in the **Show** section, select **Workspace**.
- MATLAB command prompt: Enter **workspace**.

You also can minimize the Workspace browser by collapsing the panel in which it resides. eg. if the Workspace browser is in the left side panel, click the button at the bottom left corner of the panel to collapse the panel. To restore the panel, click the button. If the Workspace browser is in the left or right side panel and the panel contains multiple tools, you also can minimize it by clicking the button to the left of the Workspace browser title bar.



Workspace Variables

Functions

<code>load</code>	Load variables from file into workspace
<code>save</code>	Save workspace variables to file
<code>matfile</code>	Access and change variables in MAT-file without loading file into memory
<code>disp</code>	Display value of variable
<code>formattedDisplayText</code>	Capture display output as string
<code>who</code>	List variables in workspace
<code>whos</code>	List variables in workspace, with sizes and types
<code>clear</code>	Remove items from workspace, freeing up system memory
<code>clearvars</code>	Clear variables from memory
<code>openvar</code>	Open workspace variable in Variables editor or other graphical editing tool
Workspace Browser	Open Workspace browser to manage workspace



Save Workspace Variables

There are several ways to save workspace variables interactively:

- To save all workspace variables to a MAT-file, on the **Home** tab, in the **Variable** section, click **Save Workspace**.
- To save a subset of your workspace variables to a MAT-file, select the variables in the Workspace browser, right-click, and then select **Save As**. You also can drag the selected variables from the Workspace browser to the Current Folder browser.
- To save variables to a MATLAB script, click the **Save Workspace** button or select the **Save As** option, and in the **Save As** window, set the **Save as type** option to **MATLAB Script**. Variables that cannot be saved to a script are saved to a MAT-file with the same name as that of the script.



Save Workspace Variables

You also can save workspace variables programmatically using the **save** function.

```
save('june10')
```

To save only variables A and B to the file june10.mat, use the command

```
save('june10', 'A' , 'B')
```



Load Workspace Variables

- To load saved variables from a MAT-file into your workspace, double-click the MAT-file in the Current Folder browser.
- To load a subset of variables from a MAT-file on the **Home** tab, in the **Variable** section, click **Import Data**. Select the MAT-file you want to load and click **Open**. You also can drag the desired variables from the Current Folder browser Details panel of the selected MAT-file to the Workspace browser. The Details panel is not available in MATLAB Online.
- To load variables saved to a MATLAB script into the workspace, simply run the script.



Load Workspace Variables

You also can load saved variables programmatically, use the load function.

```
load('durer')
```

To load variables X and map from the file durer.mat

```
load('durer', 'X', 'map')
```



Keep a track of work

Write to a Diary File

To keep an activity log of your MATLAB® session, use the **diary** function. **diary** creates a verbatim copy of your MATLAB session in a disk file (excluding graphics).



entering multiple statements per line

- **Enter Multiple Lines Without Running Them**
 - To enter multiple lines before running any of them, use **Shift+Enter** or **Shift+Return** after typing a line. This is useful, for example, when entering a set of statements containing keywords, such as `if ... end`. The cursor moves down to the next line, which does not show a prompt, where you can type the next line. Continue for more lines. Then press **Enter** or **Return** to run all of the lines.
 - This allows you to edit any of the lines you entered before you pressing **Enter** or **Return**.
- **Entering Multiple Functions in a Line**
 - To enter multiple functions on a single line, separate the functions with a **comma** (,) or **semicolon** (;). Using the semicolon instead of the comma will suppress the output for the command preceding it. For example, put three functions on one line to build a table of logarithms by typing

```
format short; x = (1:10)'; logs = [x log10(x)]
```

and then press **Enter** or **Return**. The functions run in **left-to-right order**.



entering multiple statements per line

- **Entering Long Statements**
- For items in single quotation marks, such as strings, you must complete the string in the line on which it was started. For example, completing a string as shown here

```
headers = ['Author Last Name, Author First Name, ' ...
'Author Middle Initial']  
results in
```

```
headers =  
Author Last Name, Author First Name, Author Middle Initial
```

MATLAB

Unit 3-Lecture 5

BTech (CSBS) -Semester VII

26 July 2022, 09:35AM



Unit 3

- Matrix
- Array
- Basic mathematical functions



An array is MATLAB's basic data structure

Can have any number of dimensions. Most common are

- vector - one dimension (a single row or column)
- matrix - two or more dimensions
- Scalar - matrices with only one row and one column.

Arrays can have numbers or letters



Creating Matrices

In MATLAB, a vector is created by assigning the elements of the vector to a variable. This can be done in several ways depending on the source of the information.

- Enter an explicit list of elements
- Load matrices from external data files
- Using built-in functions
- Using own functions in M-files

A matrix can be created in MATLAB by typing the elements (numbers) inside square brackets []

```
>> matrix = [1 2 3 ; 4 5 6 ; 7 8 9]
```



Creating Matrices

```
>> A = [2 -3 5; -1 4 5] % Note MATLAB displays column vector vertically
```

```
A=
```

```
2 -3 5
```

```
-1 4 5
```

```
>> x = [1 4 7] % Note MATLAB displays row vector horizontally
```

```
x=
```

```
4
```

```
1 4 7
```

```
>> x = [1; 4; 7] %Optional commas may be used between the elements.Type the semicolon (or  
press Enter) to move to the next row
```

```
x=
```

```
1
```

```
4
```

```
7
```



Creating Matrices

```
>> cd=6; e=3; h=4;  
  
>> Mat=[e cd*h cos(pi/3);h^2 sqrt(h*h/cd) 14]  
  
Mat =  
    3.0000    24.0000    0.5000  
  16.0000    1.6330   14.0000
```



Concatenation of Matrices

Command Window

```
>> a=[1 2;3 4];  
b=[4 6 ;8 9];  
A=[a,b]
```

Row wise concate

```
A =
```

1	2	4	6
3	4	8	9

```
>> B=[a;b]
```

```
B =
```

1	I	2
3		4
4		6
8		9

Column wise concate

```
fxt >> |
```



Colon operator

The colon operator can be used to create a vector with constant spacing

$$x = m:q:n$$

- m is first number
- n is last number
- q is difference between consecutive numbers

```
>>x=[1:2:10]
```

$x =$

1 3 5 7 9

If omit q , spacing is one

$$y = m:n$$

```
>>y=1:5
```

$y =$

1 2 3 4 5



Colon operator

```
>> x=1:5:50  
  
x =  
  
1 6 11 16 21 26 31 36 41 46  
  
>> 1:5:50  
  
ans =  
  
1 6 11 16 21 26 31 36 41 46
```



Question 1

How can you use the colon operator to generate the vector shown below?

9 7 5 3 1



linspace function

$v = \text{linspace}(x_i, x_f, n)$

- x_i is first number
- x_f is last number
- n is number of terms
(= 100 if omitted)

```
>> linspace (4,8,50)
ans =
Columns 1 through 11
4.0000    4.0816    4.1633    4.2449    4.3265    4.4082    4.4898    4.5714    4.6531    4.7347    4.8163
Columns 12 through 22
4.8980    4.9796    5.0612    5.1429    5.2245    5.3061    5.3878    5.4694    5.5510    5.6327    5.7143
Columns 23 through 33
5.7959    5.8776    5.9592    6.0408    6.1224    6.2041    6.2857    6.3673    6.4490    6.5306    6.6122
Columns 34 through 44
6.6939    6.7755    6.8571    6.9388    7.0204    7.1020    7.1837    7.2653    7.3469    7.4286    7.5102
Columns 45 through 50
7.5918    7.6735    7.7551    7.8367    7.9184    8.0000
```



Misc Matrix

- `zeros(r,c)` - makes matrix of r rows and c columns, all with zeros
- `ones(r,c)` - makes matrix of r rows and c columns, all with ones
- `rand(r,c)` - makes matrix of r rows and c columns, with random numbers
- `eye(n)` - makes square matrix of n rows and columns. Main diagonal (upper left to lower right) has ones, all other elements are zero
- `magic(n)` - makes a special square matrix of n rows and c columns, called Durer's matrix



Misc Matrix

```
>> a=zeros(4,3)
```

```
a =
```

0	0	0
0	0	0
0	0	0
0	0	0

```
>> c=rand(4,3)
```

```
c =
```

0.8147	0.6324	0.9575
0.9058	0.0975	0.9649
0.1270	0.2785	0.1576
0.9134	0.5469	0.9706

```
>> e=magic(4)
```

```
e =
```

16	2	3	13
5	11	10	8
9	7	6	12
4	14	15	1

```
>> b=ones(4,3)
```

```
b =
```

1	1	1
1	1	1
1	1	1
1	1	1

```
>> d=eye(4)
```

```
d =
```

1	0	0	0
0	1	0	0
0	0	1	0
0	0	0	1



Creating Matrix variable

```
>> mat = [4 3 1; 2 5 6]
mat =
    4   3   1
    2   5   6
```

```
>> mat = [3 5 7; 1 2]
Error using vertcat
Dimensions of matrices being concatenated are not consistent.
```

```
>> mat = [2:4; 3:5]
mat =
    2   3   4
    3   4   5
```



Linear indexing

```
>> intmat = [100 77; 28 14]
intmat =
    100      77
    28      14
>> intmat(1)
ans =
    100
>> intmat(2)
ans =
    28
>> intmat(3)
ans =
    77
>> intmat(4)
ans =
    14
```



Dimension

```
>> vec = -2:1
vec =
-2 -1 0 1
>> length(vec)
ans =
4
>> size(vec)
ans =
1 4
```

```
>> mat = [1:3; 5:7] '
mat =
1 5
2 6
3 7
>> [r, c] = size(mat)
r =
3
c =
2
```

```
>> size(mat)
ans =
3 2
```



Question

How could you create a matrix of zeros with the same size as another matrix?



numel function

```
>> v=9:-2:1
```

```
v =
```

```
9      7      5      3      1
```

```
>> numel(v)
```

```
ans =
```

```
5
```

For vectors, **numel** is equivalent to the **length** of the vector. For matrices, it is the product of the number of rows and columns.



Question

```
mat = [1:3; 44 9  2; 5:-1:3]
mat(3,2)
mat(2,:)
size(mat)
mat(:,4) = [8;11;33]
numel(mat)
v = mat(3,:)
v(v(2))
v(1) = []
reshape(mat,2,6)
```

MATLAB

Unit 3-Lecture 6

BTech (CSBS) -Semester VII

29 July 2022, 09:35AM



Question

- 1) As the functions operate , how can we get an overall result for the matrix? Determine the overall maximum in the matrix?
- 2) Find the cummulative matrix from (1).
- 3) For vector v with a length n , $diff(v)$ will be $n-1$. Create a random integer matrix and find difference on each coloumn.
- 4) Create a matrix of all 10's.
- 5) Create a vector variable and substract 3 from every element.



Question

- 6) Create a matrix variable and divide every element by 3.
- 7) Create a matrix variable and square every element.
- 8) You are provided with following vector

```
>>vec=[5 9 3 4 6 11]
```

```
>>v=[0 1 0 0 1 1]
```

```
>>vec(v)
```

Error: Array indices must be positive integers or logical values.

Define this error and give correction for it



Question

- 9) Find logical true or false of vec from (8), for value greater than 9
- 10) Find same for value less than 9
- 11) Assume a vector vec that erroneously stores negative values, how can we eliminate those negative values?
- 12) With same vec from (11), using ‘find’ command and logical operators, instead of deleting negative values, retain only the positive values only.



Question

13) When two matrix have same dimension and are square, both array and matrix multiplication can be performed on them. For the following two matrices, perform $A.*B$, $A*B$ and $B*A$.

$$A = \begin{bmatrix} 1 & 4 \\ 3 & 3 \end{bmatrix} \text{ and } B = \begin{bmatrix} 1 & 2 \\ -1 & 0 \end{bmatrix}$$



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Unit 3-Lecture 7

BTech (CSBS) -Semester VII

2 August 2022, 09:35AM



Matrices

1. Create a matrix, *mat*. Is there a **rot180** function? Is there a **rot90** function (to rotate clockwise)?
2. Use above *mat*, and try to flip the matrix from left to right.
3. Use same *mat*, and flip up to down.
4. Create an empty vector and find the length of this vector.
5. Create a vector in 1 to 10 range and delete 4 element from same vector.



Matrices

6. Create a vector, `vec`, ranging 3 to 15. Delete a subset vector range from 9 to 12
7. From above given vector, check if individual elements could be deleted.
8. From the matrix as obtained in (1), remove the second coloumn.
9. Find the absolute vaule of vector in range -5 to 1
10. Find the sign of below given matrix

$$\begin{matrix} -4 & 2 & 8 \\ 0 & -10 & -42 \\ -9 & 15 & 0 \end{matrix}$$



Matrices

11. Find if below strings are equal:

str1= “hello”;

str2= “howdy”;



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Unit 3-Lecture 8

BTech (CSBS) -Semester VII

5 August 2022, 09:35AM



Solving Linear Equation

Solve System of Linear Equations Using linsolve:

A system of linear equations

$$a_{11}x_1 + a_{12}x_2 + \dots + a_{1n}x_n = b_1$$

$$a_{21}x_1 + a_{22}x_2 + \dots + a_{2n}x_n = b_2$$

...

$$a_{m1}x_1 + a_{m2}x_2 + \dots + a_{mn}x_n = b_m$$

can be represented as the matrix equation $A \cdot \vec{x} = \vec{b}$ where A is the coefficient matrix,



Solving Linear Equation...contd.

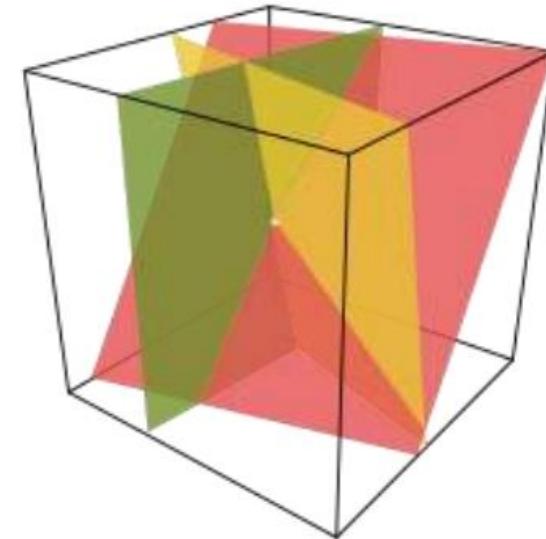
- Ex: Find values $x_1, x_2, x_3 \in \mathbb{R}$ that satisfy
 - $3x_1 + 2x_2 - x_3 - 1 = 0$
 - $2x_1 - 2x_2 + x_3 + 2 = 0$
 - $-x_1 - \frac{1}{2}x_2 - x_3 = 0$

Solution:

- Step 1: write the system of linear equations as a matrix equation

$$A = \begin{bmatrix} 3 & 2 & -1 \\ 2 & -2 & 1 \\ -1 & -\frac{1}{2} & -1 \end{bmatrix}, x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}, b = \begin{bmatrix} 1 \\ -2 \\ 0 \end{bmatrix}.$$

- Step 2: Solve for $Ax = b$





Example 1

```
>> A = [5 -3 2; -3 8 4; 2 4 -9]; % Enter matrix A
>> b = [10; 20; 9]; % Enter column vector b
>> x = A\b % Solve for x
x =
    3.4442
    3.1982
    1.1868
>> c = A*x % check the solution
c =
    10.0000
    20.0000
    9.0000
```

The backslash (\) or the left division is used to solve a linear system of equations $\{A\}\{x\} = \{b\}$. For more information, type: help slash.



Question 1

- What's the A , x , and b for the following linear equations?
 - $2x_2 - 7 = 0$
 - $2x_1 - 3x_3 + 2 = 0$
 - $4x_2 + 2x_3 = 0$
 - $x_1 + 3x_3 = 0$

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 2 & 0 & -3 \\ 0 & 4 & 2 \\ 1 & 0 & 3 \end{bmatrix}, x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix}, b = \begin{bmatrix} 7 \\ -2 \\ 0 \\ 0 \end{bmatrix}.$$



Question

```
LinearEquation.m  ✘ +  
1  syms x y z  
2  eqn1= 5*x + y + 4*z == 12;  
3  eqn2= -x + y - 2*z == 43;  
4  eqn3= x - y + z== -10;  
5  [A,B]=equationsToMatrix([eqn1,eqn2,eqn3], [x,y,z])  
6  X=linsolve(A,B)
```

Command Window

```
>> LinearEquation
```

```
A =
```

```
[ 5, 1, 4]  
[-1, 1, -2]  
[ 1, -1, 1]
```

```
B =
```

```
12  
43  
-10
```

```
X =
```

```
167/6  
29/6  
-33
```



Solve System of Linear Equations Using `solve`

Use `solve` instead of `linsolve` if you have the equations in the form of expressions and not a matrix of coefficients.

```
8      %-----using solve function-----
9      sol=solve([eqn1, eqn2, eqn3], [x,y,z])
10     xSol = sol.x
11     ySol = sol.y
12     zSol = sol.z
```

```
sol =
struct with fields:
x: 167/6
y: 29/6
z: -33
```

```
xSol =
```

```
167/6
```

```
ySol =
```

```
29/6
```

```
zSol =
```

```
-33
```



Question

1. **Linear algebraic equations:** Find the solution of the following set of linear algebraic equations, as advised below.

$$x + 2y + 3z = 1$$

$$3x + 3y + 4z = 1$$

$$2x + 3y + 3z = 2.$$

- Write the equation in matrix form and solve for $\mathbf{x} = [x \ y \ z]^T$ using the left division \.



Gaussian elimination method

MATLAB has a built-in function, rref, that does precisely this reduction, i.e., transforms the matrix to its row reduced echelon form.

```
A=[1 2 3; 3 3 4; 2 3 3];  
B=[1; 1; 2];  
%C=B\A  
%linsolve(A,B)  
%transpose (C)  
%-----Gaussian elimination method  
C=[A B];  
Cr=rref(C)
```

```
Cr =  
1.0000 0 0 -0.5000  
0 1.0000 0 1.5000  
0 0 1.0000 -0.5000
```



Find eigenvalues and eigenvectors

Step 1: Enter matrix A and type $[V, D] = \text{eig}(A)$

```
>> A = [ 5 -3 2; -3 8 4; 2 4 -9];
```

```
>> [V, D] = eig(A)
```

```
V =
```

-0.1709	0.8729	0.4570
-0.2365	0.4139	-0.8791
0.9565	0.2583	-0.1357

```
D =
```

-10.3463	0	0
0	4.1693	0
0	0	10.1770

Step 2: Extract what you need:

'V' is an ' $n \times n$ ' matrix whose columns are eigenvectors

'D' is an ' $n \times n$ ' diagonal matrix that has the eigenvalues of 'A' on its diagonal.



Question

2. **Eigenvalues and eigenvectors:** Consider the following matrix.

$$\mathbf{A} = \begin{bmatrix} 3 & -3 & 4 \\ 2 & -3 & 4 \\ 0 & -1 & 1 \end{bmatrix}$$

- Find the eigenvalues and eigenvectors of \mathbf{A} .
- Show, by computation, that the eigenvalues of \mathbf{A}^2 are square of the eigenvalues of \mathbf{A} .
- Compute the square of the eigenvalues of \mathbf{A}^2 . You have now obtained the eigenvalues of \mathbf{A}^4 . From these eigenvalues, can you guess the structure of \mathbf{A}^4 ?
- Compute \mathbf{A}^4 . Can you compute \mathbf{A}^{-1} without using the `inv` function?



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Unit 4-Lecture 11

BTech (CSBS) -Semester VII

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Basic plotting

- Overview,
- axis labels, and annotations,
- adding titles,
- specifying line styles and colours.
- creating simple plots,
- multiple data sets in one plot,



Overview

The most basic and perhaps most useful command for producing a 2-D plot is

```
plot(xvalues, yvalues, 'style-option')
```

where *xvalues* and *yvalues* are vectors containing the *x*- and *y*-coordinates of points on the graph and the *style-option* is an optional argument that specifies the color, the line style (e.g., solid, dashed, dotted), and the point-marker style (e.g., *o*, *+*, ***). All three style options can be specified together. The two vectors *xvalues* and *yvalues* MUST have the same length. Unequal length of the two vectors is the most common source of error in the plot command. The **plot** function also works with a single-vector argument, in which case the elements of the vector are plotted against row or column indices. Thus, for two column vectors *x* and *y* each of length *n*,



Overview

- `plot(x,y)` plots y versus x with a solid line (the default line style),
- `plot(x,y,'--')` plots y versus x with a dashed line (more on this below), and
- `plot(x)` plots the elements of x against their row index.

*For on-line help
type:
help graph2d*



Style Options

Color Style-option	Line Style-option	Marker Style-option
y yellow	- solid	+
m magenta	-- dashed	o circle
c cyan	:	*
r red	-. dash-dot	x x-mark
g green	none	.
b blue		^ up triangle
w white		s square
k black		d diamond, etc.



Style Options

Examples:

`plot(x,y,'r')`

plots y versus x with a red solid line,

`plot(x,y,:')`

plots y versus x with a dotted line,

`plot(x,y,'b--')`

plots y versus x with a blue dashed line, and

`plot(x,y,'+')`

plots y versus x as unconnected points marked by +.

When no style-option is specified, MATLAB uses a blue solid line by default.



Label and title

Plots may be annotated with `xlabel`, `ylabel`, `title`, and `text` commands.

The first three commands take string arguments, whereas the last one requires three arguments—`text(x-coordinate, y-coordinate, 'text')`, where the coordinate values are taken from the current plot. Thus,

<code>xlabel('Pipe Length')</code>	labels the <i>x</i> -axis with Pipe Length,
<code>ylabel('Fluid Pressure')</code>	labels the <i>y</i> -axis with Fluid Pressure,
<code>title('Pressure Variation')</code>	titles the plot with Pressure Variation, and
<code>text(2,6,'Note this dip')</code>	writes “Note this dip” at the location (2.0,6.0) in the plot coordinates.



Label and title

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The first three commands take string arguments, whereas the last one requires three arguments—`text(x-coordinate, y-coordinate, 'text')`, where the coordinate values are taken from the current plot. Thus,

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<code>text(2,6,'Note this dip')</code>	writes “Note this dip” at the location (2.0,6.0) in the plot coordinates.



Legend

`legend(string1, string2, ...)` produces legend using the text in *string*1, *string*2, etc., as labels,
`legend(LineStyle1, string1, ...)` specifies the line style of each label,
`legend(..., pos)` writes the legend outside the plot-frame if *pos* = -1 and inside if *pos* = 0, (there are other options for *pos* too), and
`legend off` deletes the legend from the plot.



Axis Control

Once a plot is generated, you can change the axes limits with the **axis** command.
Typing

`axis([xmin xmax ymin ymax])`

changes the current axes limits to the specified new values *xmin* and *xmax* for the *x*-axis and *ymin* and *ymax* for the *y*-axis.

Examples:

```
axis([-5 10 2 22]);      sets the x-axis from -5 to 10, y-axis from 2 to 22,  
axy = [-5 10 2 22]; axis(axy);          same as above, and  
ax = [-5 10]; ay=[2 22]; axis([ax ay]);    same as above.
```



Axis Control

`axis('equal')`

sets equal scale on both axes,

`axis('square')`

sets the default rectangular frame to a square,

`axis('normal')`

resets the axis to default values,

`axis('axis')`

freezes the current axes limits, and

`axis('off')`

removes the surrounding frame and the tick marks.



Semi control of Axis

It is possible to control only part of the axes limits and let MATLAB set the other limits automatically. This is achieved by specifying the desired limits in the **axis** command along with **inf** as the values of the limits that you would like to be set automatically. For example,

`axis([-5 10 -inf inf])`

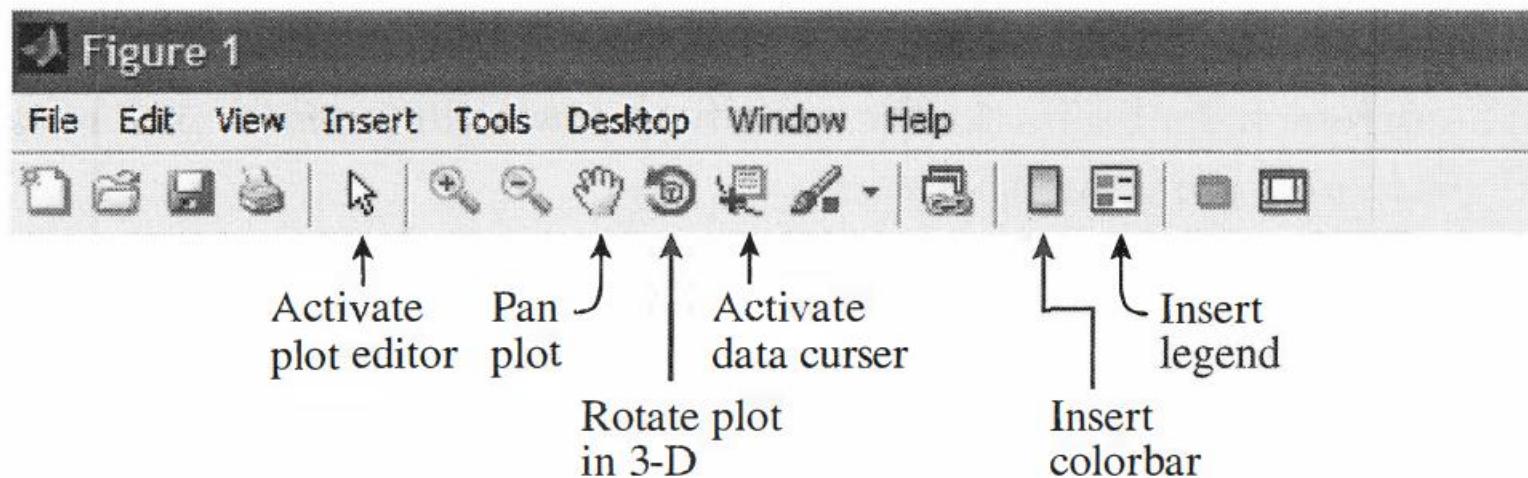
sets the *x*-axis limits at -5 and 10 and lets the *y*-axis limits be set automatically, and

`axis([-5 inf -inf 22])`

sets the lower limit of the *x*-axis and the upper limit of the *y*-axis, and leaves the other two limits to be set automatically.



Modify plot with Plot Editor



MATLAB

Unit 4-Lecture 12

BTech (CSBS) -Semester VII

26 August 2022, 09:35AM



Basic plotting

- Overview,
- axis labels, and annotations,
- **creating simple plots,**
- specifying line styles and colours
- adding titles,
- multiple data sets in one plot,



Overlay plot

Method 1: Using the `plot` command to generate overlay plots

```
plot(x1,y1, x2,y2,':', x3,y3,'o')
```

Method 2: Using the `hold` command to generate overlay plots

```
% - Script file to generate an overlay plot with the hold command -  
x = linspace(0,2*pi,100); % Generate vector x  
y1 = sin(x); % Calculate y1  
plot(x,y1) % Plot (x,y1) with solid line  
hold on % Invoke hold for overlay plots  
y2 = x; plot(x,y2,'--') % Plot (x,y2) with dashed line  
y3 = x - (x.^3)/6 + (x.^5)/120; % Calculate y3  
plot(x,y3,'o') % Plot (x,y3) as pts. marked by 'o'  
axis([0 5 -1 5]) % Zoom in with new axis limits  
hold off % Clear hold command
```



Overlay plot

Method 3: Using the line command to generate overlay plots

```
% -- Script file to generate an overlay plot with the line command --
% -----
% First, generate some data
t = linspace(0,2*pi,100);           % Generate vector t
y1 = sin(t);                      % Calculate y1, y2, y3
y2 = t;
y3 = t - (t.^3)/6 + (t.^5)/120;

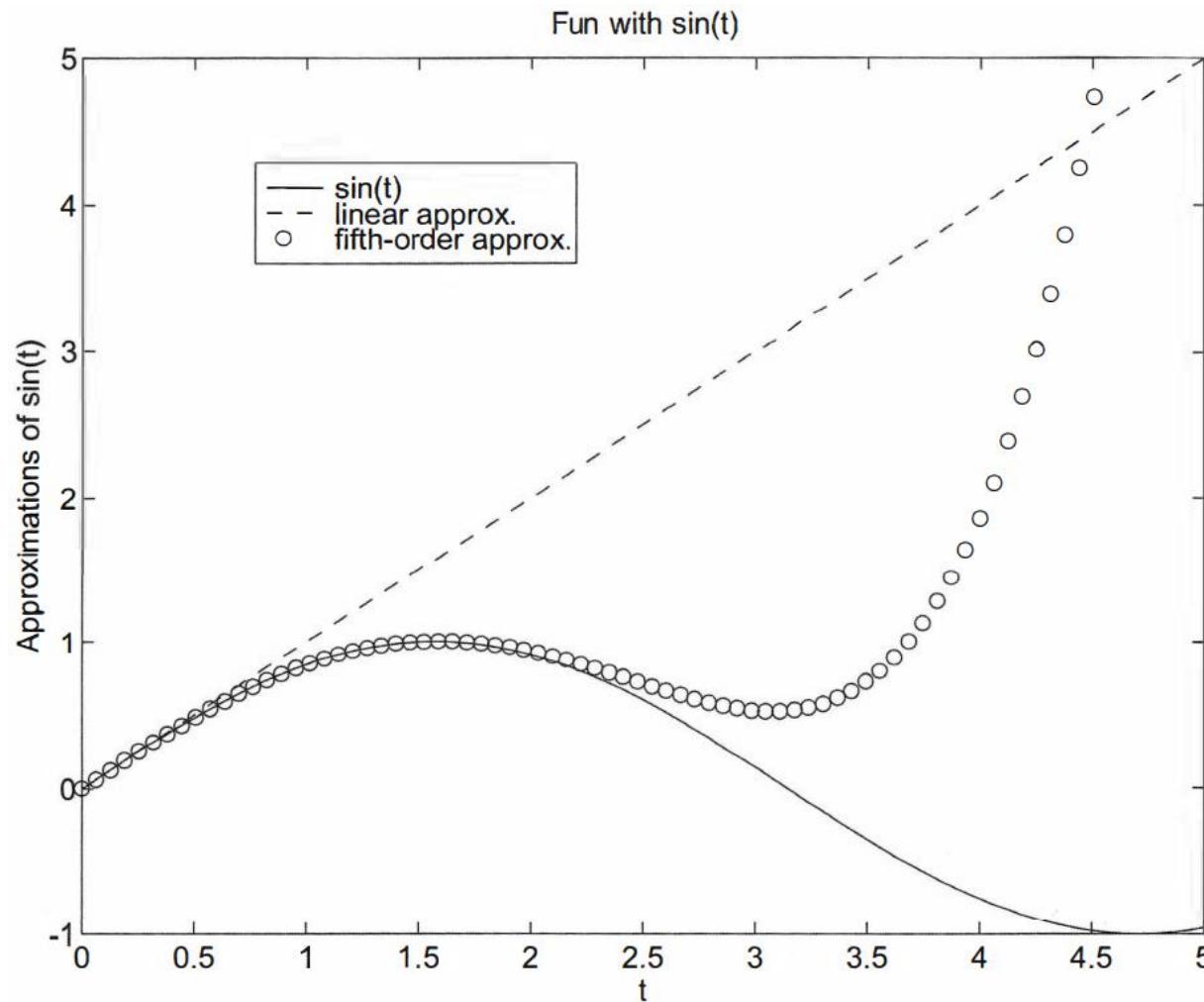
% Now, plot the three lines
plot(t,y1)                         % Plot (t,y1) with (default) solid line
line(t,y2,'linestyle','--')         % Add line (t,y2) with dashed line and
line(t,y3,'marker','o',...          % Add line (t,y3) plotted with circles--
    'linestyle', 'none')           % but no line
% Adjust the axes
axis([0 5 -1 5])                  % Zoom in with new axis limits

% Dress up the graph
xlabel('t')                         % Put x-label
ylabel('Approximations of sin(t)')   % Put y-label
title('Fun with sin(t)')            % Put title

legend('sin(t)', 'linear approx.', 'fifth-order approx.')
% add legend
```



Overlay plot





Specialized 2D plot

<code>area</code>	creates a filled area plot,
<code>bar</code>	creates a bar graph,
<code>barg</code>	creates a horizontal bar graph,
<code>comet</code>	makes an animated 2-D plot,
<code>compass</code>	creates arrow graph for complex numbers,
<code>contour</code>	makes contour plots,
<code>contourf</code>	makes filled contour plots,
<code>errorbar</code>	plots a graph and puts error bars,
<code>feather</code>	makes a feather plot,
<code>fill</code>	draws filled polygons of specified color,
<code>fplot</code>	plots a function of a single variable,



Specialized 2D plot

fplot	plots a function of a single variable,
hist	makes histograms,
loglog	creates plot with log scale on both the x -axis and the y -axis,
pareto	makes pareto plots,
pcolor	makes pseudocolor plot of a matrix,
pie	creates a pie chart,
plotyy	makes a double y -axis plot,
plotmatrix	makes a scatter plot of a matrix,
polar	plots curves in polar coordinates,
quiver	plots vector fields,
rose	makes angled histograms,
scatter	creates a scatter plot,



Specialized 2D plot

`semilogx`

`semilogy`

`stairs`

`stem`

makes semilog plot with log scale on the x -axis,
makes semilog plot with log scale on the y -axis,
plots a stair graph, and
plots a stem graph.



Specialized 2D plot

Function	Example Script	Output
fplot	$f(t) = t \sin t, 0 \leq t \leq 10\pi$ <code>fplot('x.*sin(x)',[0 10*pi])</code> Note that the function to be plotted must be written as a function of x .	
semilogx	$x = e^{-t}, y = t, 0 \leq t \leq 2\pi$ <code>t = linspace(0,2*pi,200); x = exp(-t); y = t; semilogx(x,y), grid</code>	

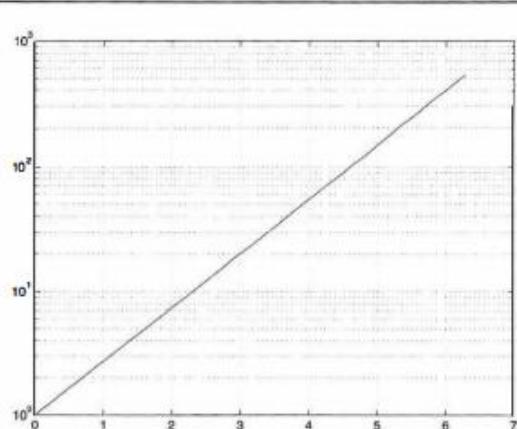


Specialized 2D plot

semilogy

$$x = t, y = e^t, 0 \leq t \leq 2\pi$$

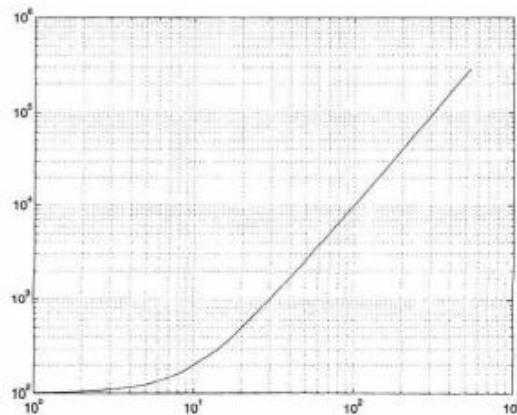
```
t = linspace(0,2*pi,200);
semilogy(t,exp(t))
grid
```



loglog

$$x = e^t, y = 100 + e^{2t}, 0 \leq t \leq 2\pi$$

```
t = linspace(0,2*pi,200);
x = exp(t);
y = 100 + exp(2*t);
loglog(x,y), grid
```





Specialized 2D plot

polar	$r^2 = 2 \sin 5t, 0 \leq t \leq 2\pi$ <pre>t = linspace(0,2*pi,200); r = sqrt(abs(2*sin(5*t))); polar(t,r)</pre>	
fill	$r^2 = 2 \sin 5t, 0 \leq t \leq 2\pi$ $x = r \cos t, y = r \sin t$ <pre>t = linspace(0,2*pi,200); r = sqrt(abs(2*sin(5*t))); x = r.*cos(t); y = r.*sin(t); fill(x,y,'k'), axis('square')</pre>	

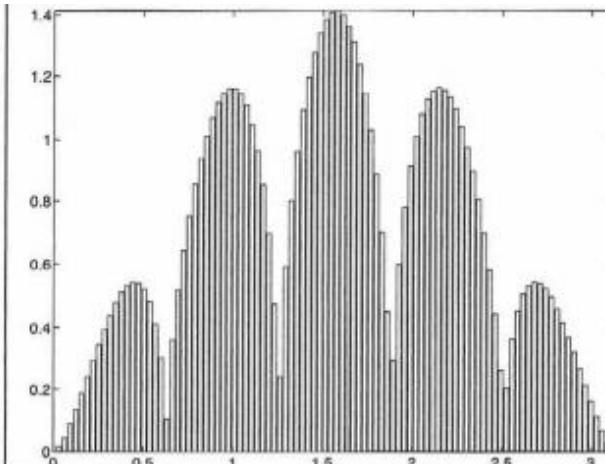


Specialized 2D plot

bar

$$\begin{aligned}r^2 &= 2 \sin 5t, \quad 0 \leq t \leq 2\pi \\y &= r \sin t\end{aligned}$$

```
t = linspace(0,2*pi,200);
r = sqrt(abs(2*sin(5*t)));
y = r.*sin(t);
bar(t,y)
axis([0 pi 0 inf]);
```

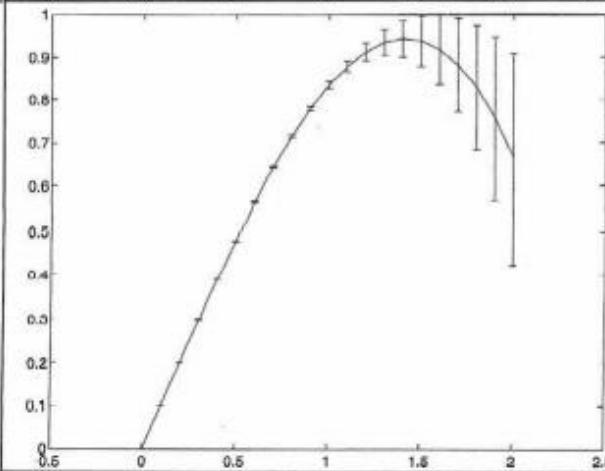


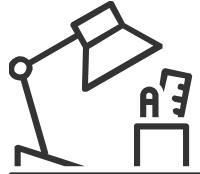
errorbar

$$f_{\text{approx}} = x - \frac{x^3}{3!}, \quad 0 \leq x \leq 2$$

$$\text{error} = f_{\text{approx}} - \sin x$$

```
x = 0:.1:2;
aprx2 = x - x.^3/6;
er = aprx2 - sin(x);
errorbar(x,aprx2,er)
```





Specialized 2D plot

barh	<p>World population by continents.</p> <pre>cont = char('Asia','Europe','Africa',... 'N. America','S. America'); pop = [3332;696;694;437;307]; barh(pop) for i=1:5, gtext(cont(i,:)); end xlabel('Population in millions') Title('World Population (1992)',... 'fontsize',18)</pre>	<table border="1"><caption>World Population (1992)</caption><thead><tr><th>Continent</th><th>Population (millions)</th></tr></thead><tbody><tr><td>Asia</td><td>3332</td></tr><tr><td>Europe</td><td>696</td></tr><tr><td>Africa</td><td>694</td></tr><tr><td>N. America</td><td>437</td></tr><tr><td>S. America</td><td>307</td></tr></tbody></table>	Continent	Population (millions)	Asia	3332	Europe	696	Africa	694	N. America	437	S. America	307
Continent	Population (millions)													
Asia	3332													
Europe	696													
Africa	694													
N. America	437													
S. America	307													
plotyy	$y_1 = e^{-x} \sin x, 0 \leq t \leq 10$ $y_2 = e^x$ <pre>x = 1:.1:10; y1 = exp(-x).*sin(x); y2 = exp(x); Ax = plotyy(x,y1,x,y2); hy1 = get(Ax(1),'ylabel'); hy2 = get(Ax(2),'ylabel'); set(hy1,'string','e^-x sin(x)'); set(hy2,'string','e^x');</pre>													



Specialized 2D plot

area	$y = \frac{\sin(x)}{x}, \quad -3\pi \leq x \leq 3\pi$ <pre>x = linspace(-3*pi,3*pi,100); y = -sin(x)./x; area(x,y) xlabel('x'), ylabel('sin(x)./x') hold on x1 = x(46:55); y1 = y(46:55); area(x1,y1,'facecolor','y')</pre>	
pie	<p>World population by continents.</p> <pre>cont = char('Asia','Europe','Africa',... 'N. America','S. America'); pop = [3332;696;694;437;307]; pie(pop) for i=1:5, gtext(cont(i,:)); end Title('World Population (1992)',... 'fontsize',18)</pre>	<p>World Population (1992)</p>



Using subplot to multiple plot

If you want to make a few plots and place the plots side by side (not overlay), use the `subplot` command to design your layout. The subplot command requires three integer arguments:

```
subplot(m,n,p)
```

MATLAB

Unit 4-Lecture 13

BTech (CSBS) -Semester VII

30 August 2022, 09:35AM



Basic plotting

- Overview,
- axis labels, and annotations,
- creating simple plots,
- specifying line styles and colours
- adding titles,
- multiple data sets in one plot,



Questions

Let's say that you want to plot these two equations in the same window:

$$\begin{aligned}y1 &= \cos(x) \\y2 &= x^2 - 1\end{aligned}$$



Steps for 2D Plots

1. Define your interval of interest, think of highest and lowest values, and a step.
2. Define your function $y = f(x)$. Take into account that you're working with arrays, not with scalars, use dot operators.
3. Use appropriate 2D built-in functions.



1. Define your Interval

Think:

- What values for x do I want to take into account? What steps in the array should I consider?



2. Define your Function(s)

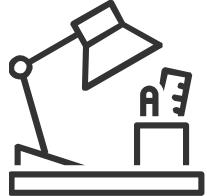
Think of lower and upper values, and steps

`x = -1 : 0.1 : 1.5;`

`y1 = cos(x);`

`y2 = x.^2 - 1;`

Now, x, y1 and y2 are vectors with appropriate values.



3. Use 2D built-in Functions

You can use functions such as:

plot

stem

polar, compass, rose

loglog, semilogx, semilogy

area, fill

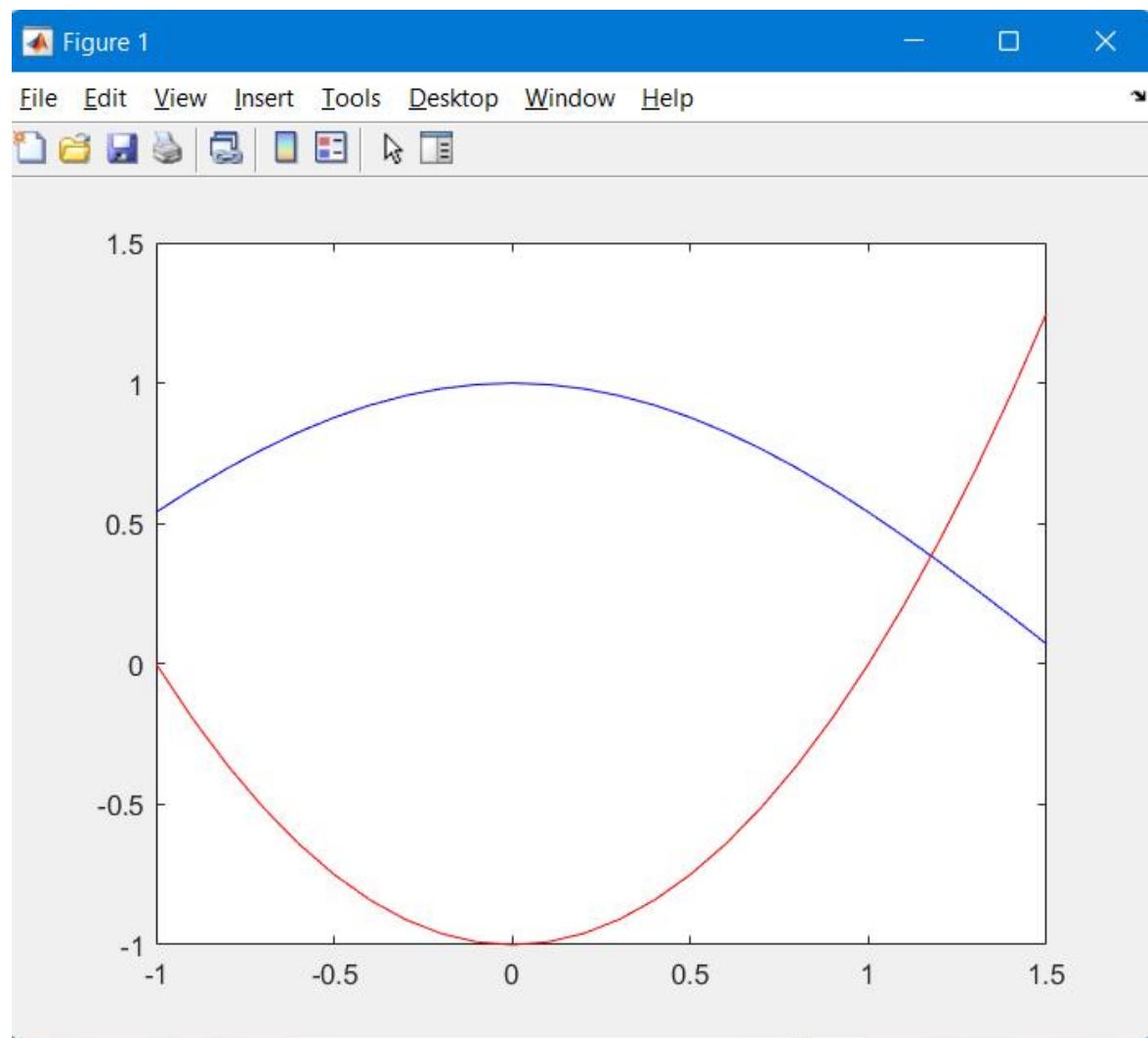
pie

hist, stairs



Solution

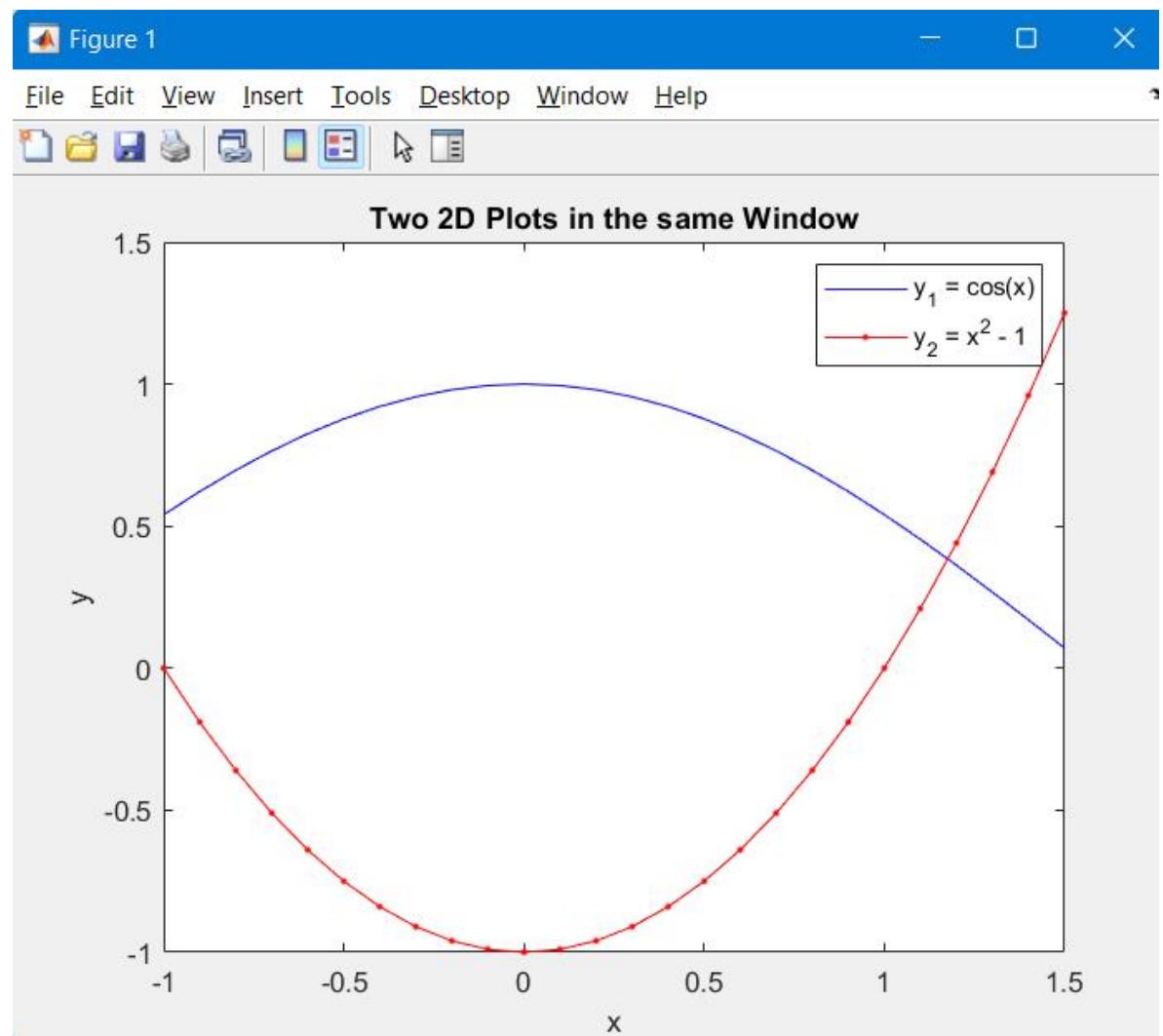
```
lab6.m  ×  +  
1      x = -1 : 0.1 : 1.5;  
2      y1 = cos(x);  
3      y2 = x.^2 - 1;  
4      plot(x, y1, 'b', x, y2, 'r')
```





Solution

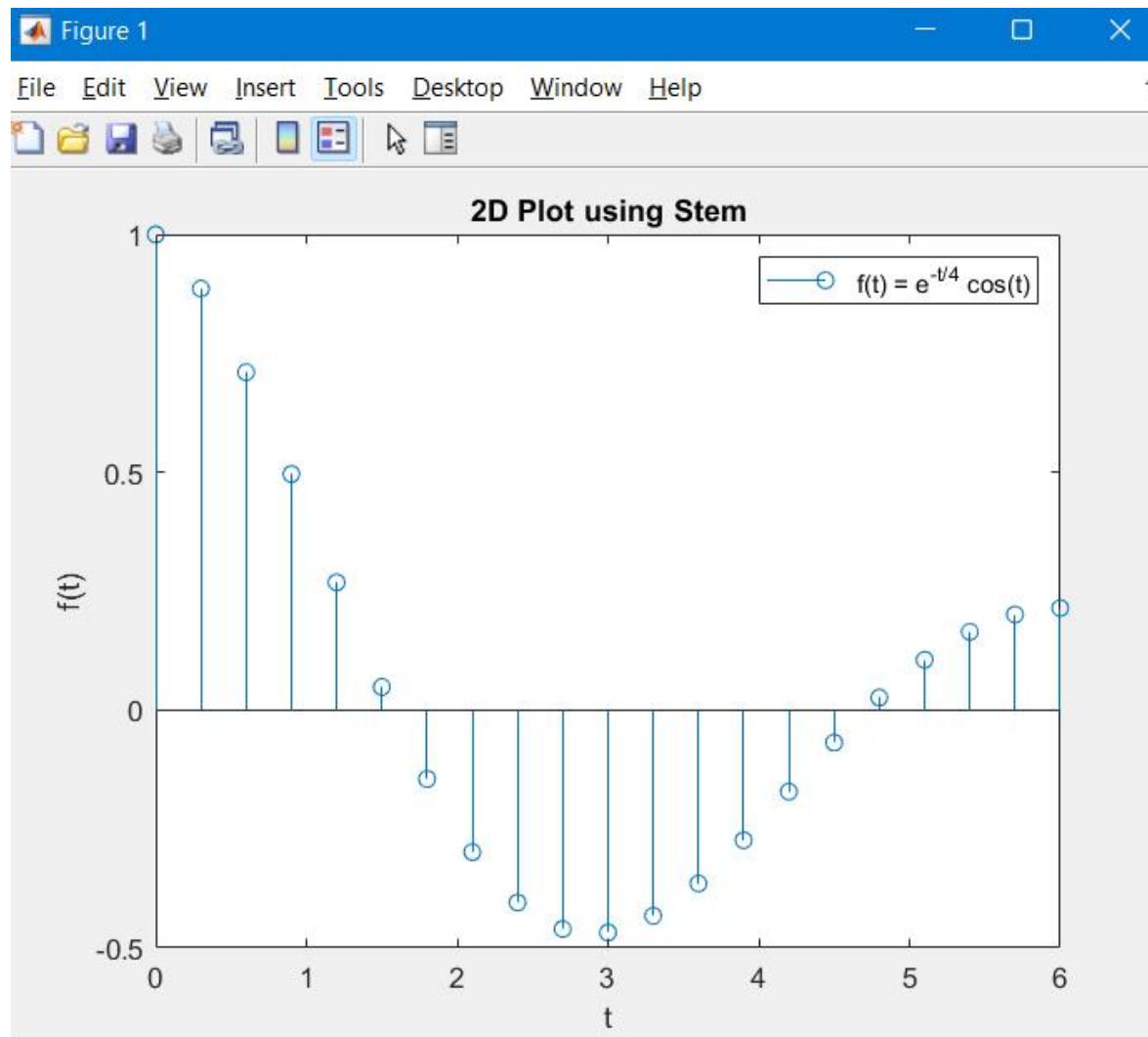
```
6 x = -1 : 0.1 : 1.5;
7 y1 = cos(x);
8 y2 = x.^2 - 1;
9 plot(x, y1, 'b', x, y2, 'r.-')
10 title('Two 2D Plots in the same Window')
11 legend('y_1 = cos(x)', 'y_2 = x^2 - 1')
12 xlabel('x')
13 ylabel('y')
```





Solution

```
15 t = 0 : .3 : 2*pi;
16 f = exp(-t/4) .* cos(t);
17 stem(t, f)
18 title('2D Plot using Stem')
19 legend('f(t) = e^{-t/4} cos(t)')
20 xlabel('t')
21 ylabel('f(t)')
22
```



MATLAB

Unit 4-Lecture 14

BTech (CSBS) -Semester VII

2 September 2022, 09:35AM



Basic plotting

- Overview,
- axis labels, and annotations,
- creating simple plots,
- specifying line styles and colours
- adding titles,
- multiple data sets in one plot,



fplot

- `fplot(@fun, lims)` - plots the function `fun` between the x-axis limits
- `lims = [xmin xmax ymin ymax]` – axis limits
- The function `fun(x)` must return a row vector for
- each element of vector `x`.



AXIS Control

1. axis scaling and appearance.
2. **axis([xmin xmax ymin ymax])**
3. Sets scaling for the x- and y-axes on the current plot.
4. **axis auto** - returns the axis scaling to its default, automatic mode
5. **axis off** - turns off all axis labeling, tick marks and background.
6. **axis on** - turns axis labeling, tick marks and background back on.
7. **axis equal** – makes both axes equal length



3D Plot

The general syntax for the `plot3` command is

```
plot3(x, y, z, 'style-option')
```

<code>plot3</code>	plots curves in space,
<code>stem3</code>	creates discrete data plot with stems in 3-D,
<code>bar3</code>	plots 3-D bar graph,
<code>bar3h</code>	plots 3-D horizontal bar graph,
<code>pie3</code>	makes 3-D pie chart,
<code>comet3</code>	makes animated 3-D line plot,
<code>fill3</code>	draws filled 3-D polygons,
<code>contour3</code>	makes 3-D contour plots,
<code>quiver3</code>	draws vector fields in 3-D,
<code>scatter3</code>	makes scatter plots in 3-D,
<code>mesh</code>	draws 3-D mesh surfaces (wire-frame),



3D Plot

meshc	draws 3-D mesh surfaces along with contours,
meshz	draws 3-D mesh surfaces with reference plane curtains,
surf	creates 3-D surface plots,
surfc	creates 3-D surface plots along with contours,
surfl	creates 3-D surface plots with specified light source,
trimesh	mesh plot with triangles,
trisurf	surface plot with triangles,
slice	draws a volumetric surface with slices,
waterfall	creates a <i>waterfall</i> plot of 3-D data,
cylinder	generates a cylinder,
ellipsoid	generates an ellipsoid, and
sphere	generates a sphere.



3D Plot: Question 1

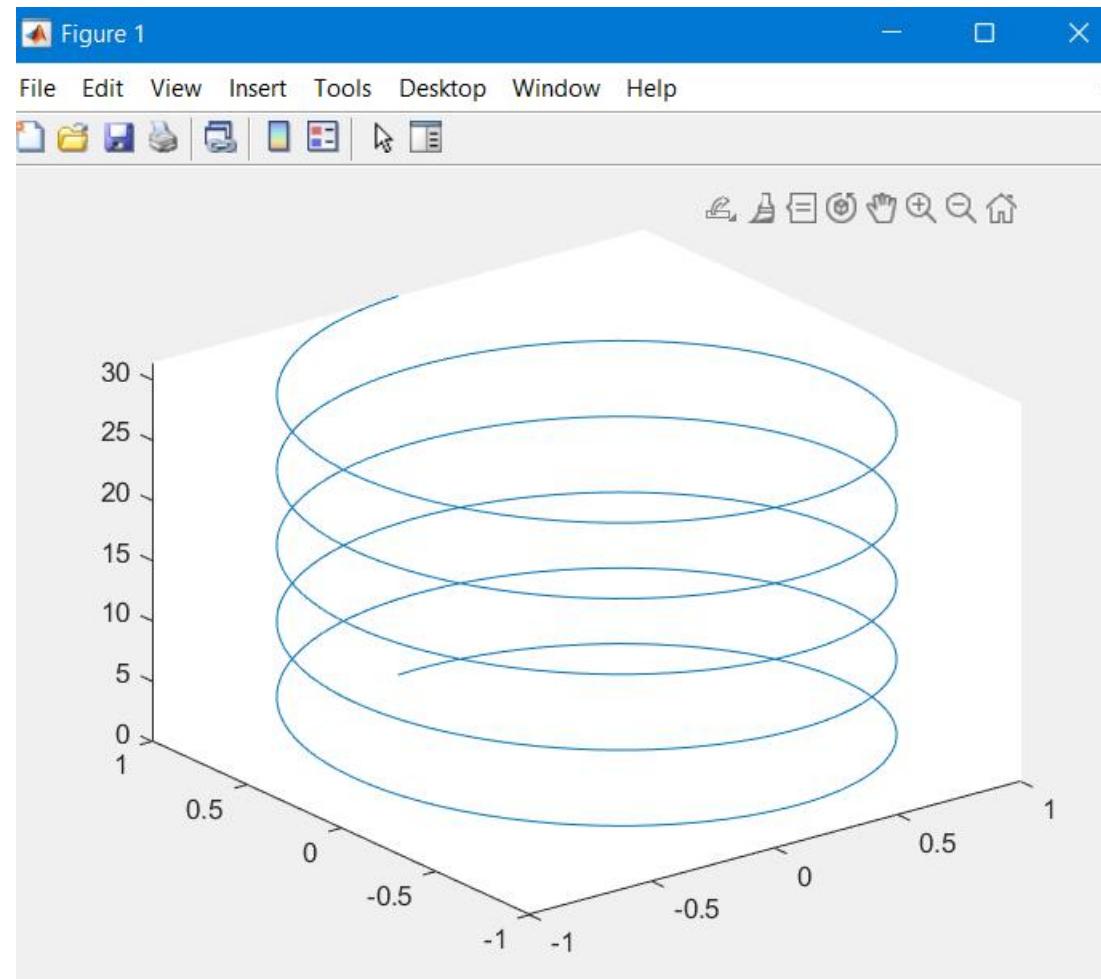
22

23

24

25

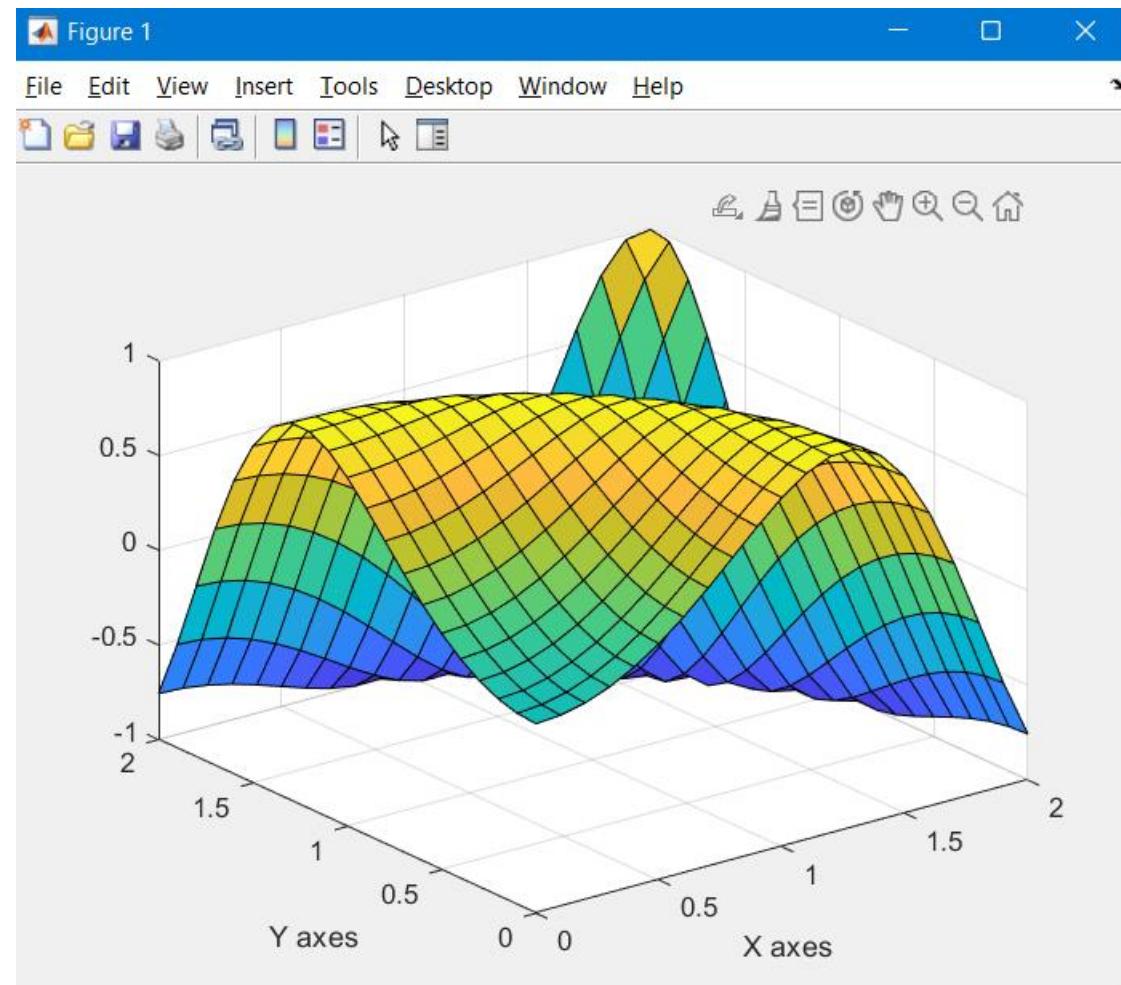
```
t = 0:pi/50:10*pi;  
plot3(sin(t),cos(t),t)
```





Surface Plot: Question 2

```
--  
26 x = 0:0.1:2;  
27 y = 0:0.1:2;  
28 [xx, yy] = meshgrid(x,y);  
29 zz=sin(xx.^2+yy.^2);  
30 surf(xx,yy,zz)  
31 xlabel('X axes')  
32 ylabel('Y axes')  
33
```



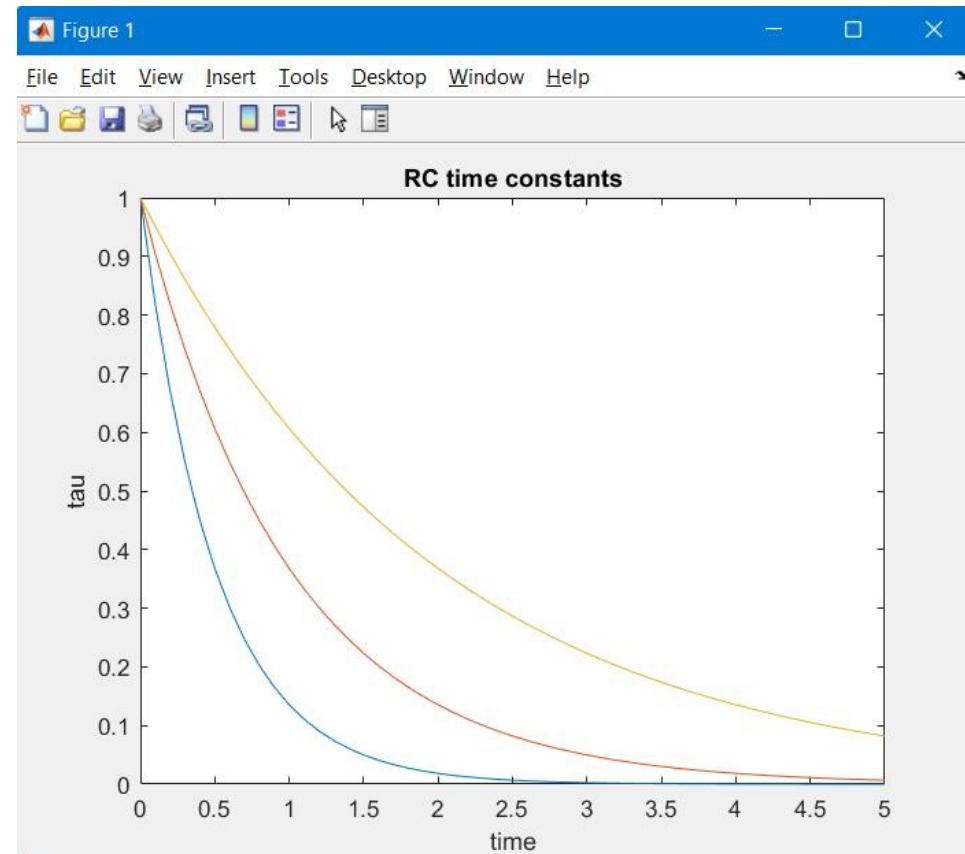


Question 3

Plot voltage vs time for various RC time constants

$$\frac{V}{V_0} = e^{-t/\tau}$$

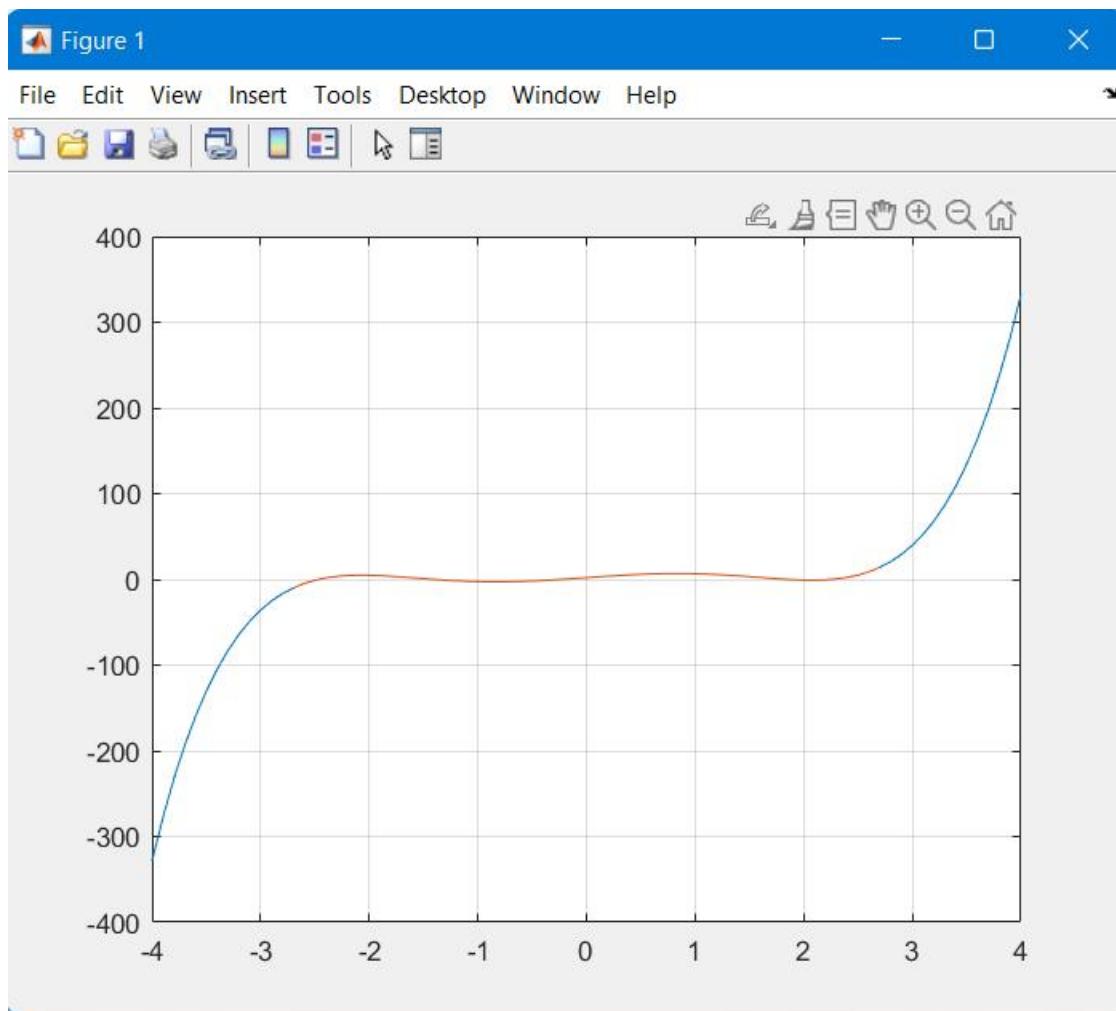
```
34 time = 0:0.1:5;
35 tau = [0.5 1.0 2.0];
36 [TIME TAU] = meshgrid(time,tau);
37 V = exp(-TIME./TAU);
38 plot(time,V)
39 xlabel('time')
40 ylabel('tau')
41 title('RC time constants')
```





Question 4

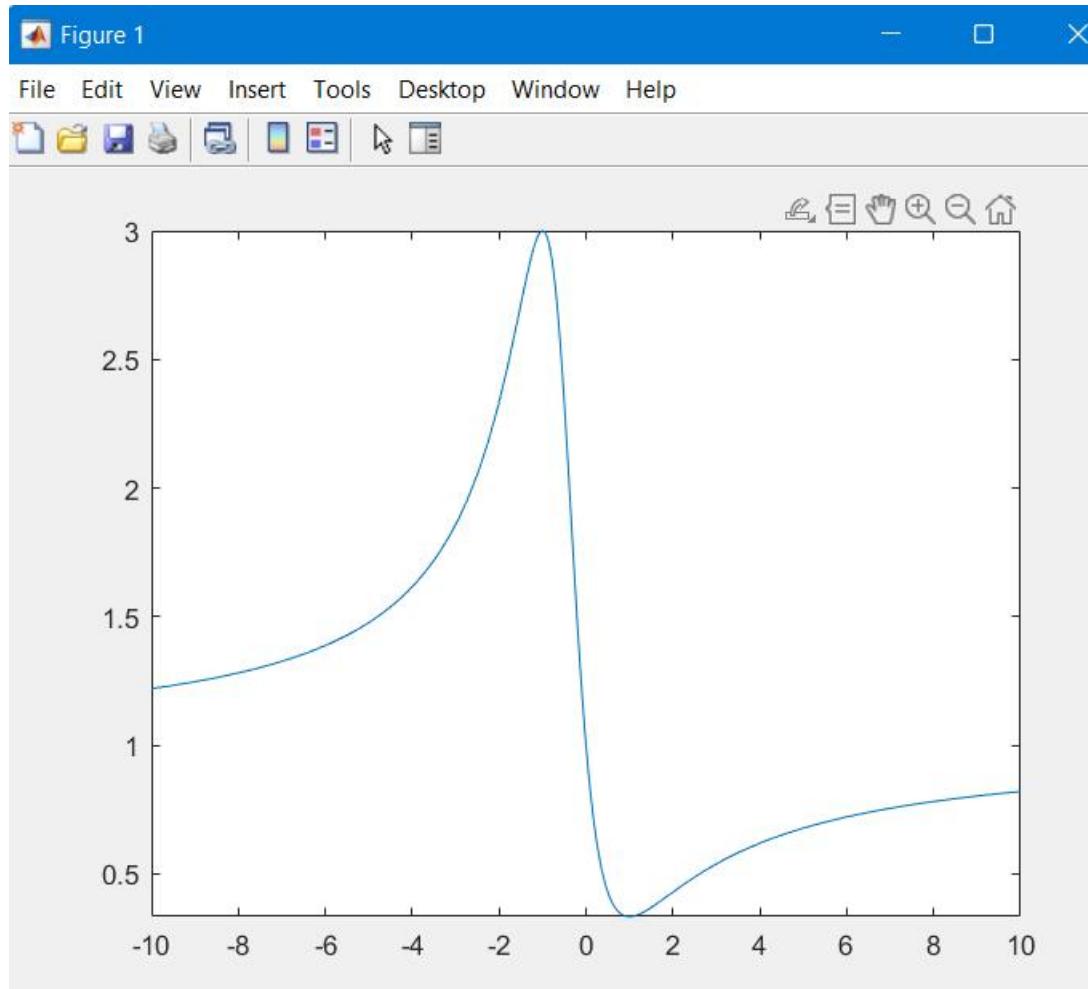
```
43 x1=-4:0.1:4;
44 x2 = -2.7:0.1:2.7;
45 f1 = 0.6*x1.^5-5*x1.^3+9*x1+2;
46 f2= 0.6*x2.^5-5*x2.^3+9*x2+2;
47 plot(x1,f1,x2,f2)
48 grid on
```





Question 5

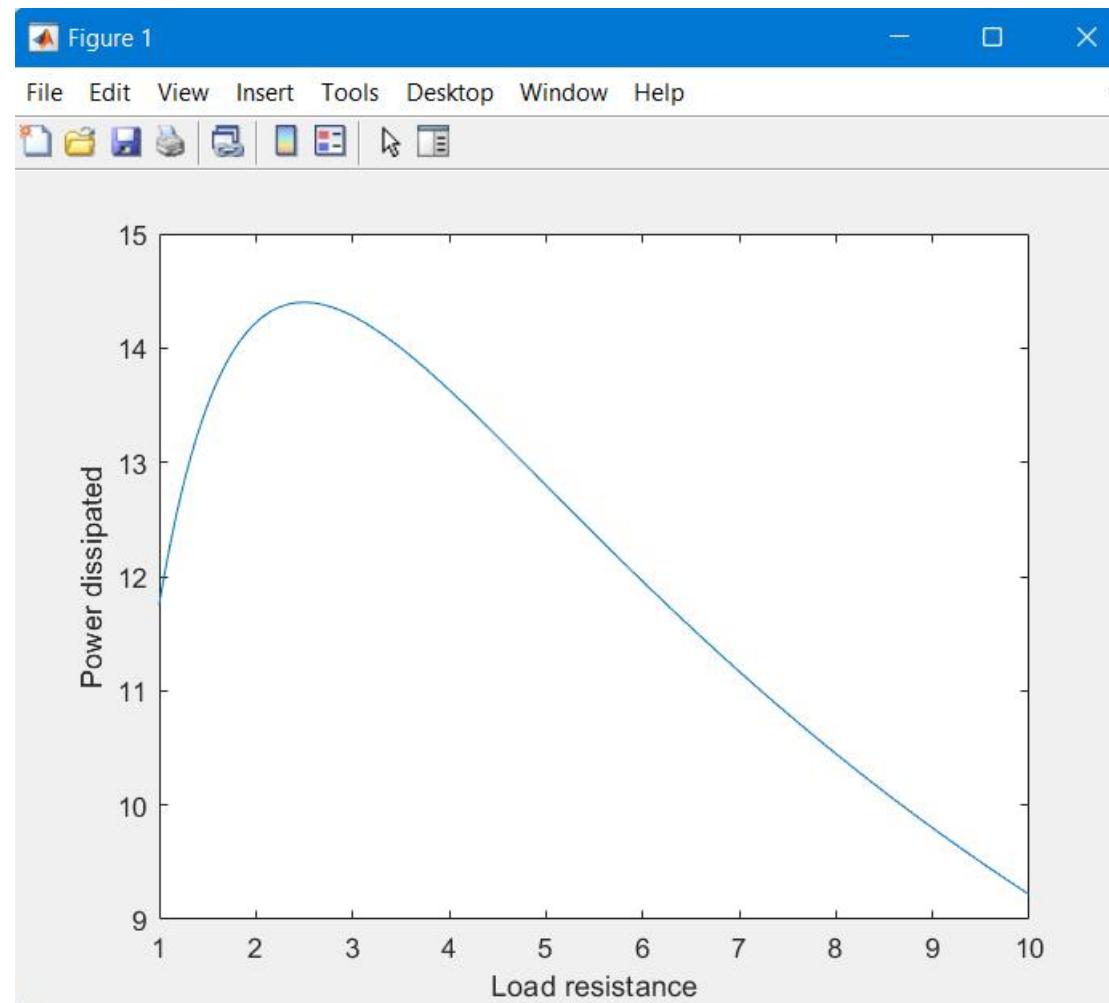
```
50 f=@(x)(x^2-x+1)/(x^2+x+1);  
51 l=[-10 10];  
52 fplot(f,l)
```





Question 6

```
54 RL = 1:0.01:10;
55 Vs = 12;
56 Rs = 2.5;
57 P = (Vs^2*RL)./(RL+Rs).^2;
58 plot(RL,P)
59 xlabel('Load resistance')
60 ylabel('Power dissipated')
```



MATLAB

Unit 5-Lecture 15

BTech (CSBS) -Semester VII

6 September 2022, 09:35AM



Introduction to programming

- 1) Introduction,
- 2) M-File Scripts,
- 3) script side-effects,
- 4) M-File functions,
- 5) anatomy of a M- File function,
- 6) input and output arguments,
- 7) input to a script file,
- 8) output commands.



Algorithm

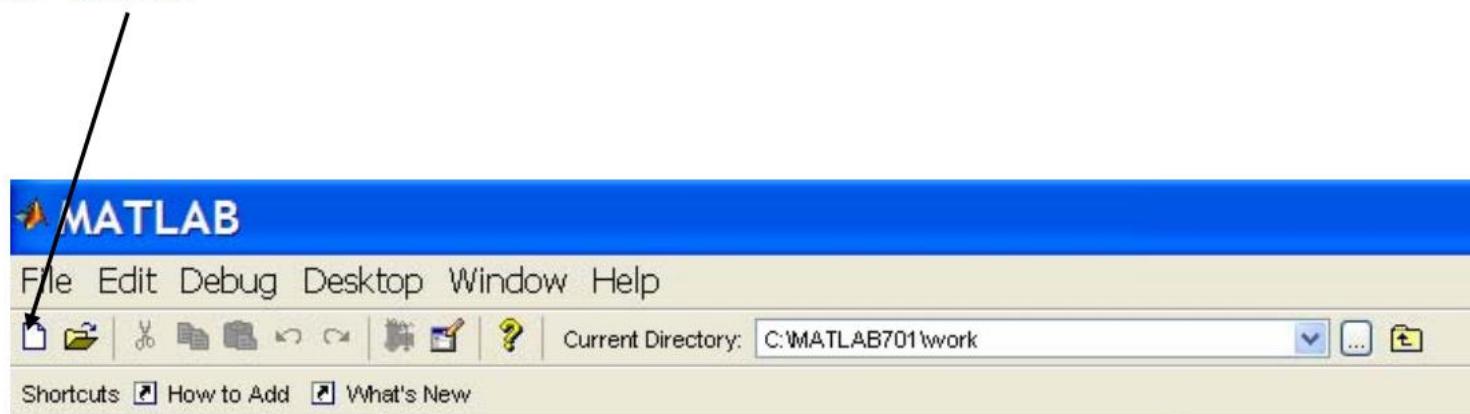
- An **algorithm** is a sequence of steps needed to solve a problem.
- In a **modular** approach, problem is broken into separate steps and then it is refined until results are manageable.
- The basic algorithm involves 3 steps:
 - Get the input: eg. the radius
 - Calculate the result: eg. the area
 - Display the output

This is known as ***top to down*** design



MATLAB script

- Scripts are
 - collection of commands executed in sequence
 - written in the MATLAB editor
 - saved as MATLAB files (.m extension)
- To create an MATLAB file from command-line
 - » `edit helloWorld.m`
- or click





Script-editor

Line numbers

MATLAB file path

* Means that it's not saved

Real-time error check

Debugging tools

```
Editor - C:\Documents and Settings\Danilo\My Documents\MATLAB\coinToss.m*  
File Edit Text Go Cell Tools Debug Desktop Window Help  
1 % coinToss.m  
2 % a script that flips a fair coin and displays the output  
3  
4 if rand<0.5 % if a random number is less than .5 say heads  
5 disp('HEADS');  
6 else % if greater than 0.5 say tails  
7 disp('TAILS');  
8 end  
script Ln 8 Col 4 OVR
```

Possible breakpoints

Courtesy of The MathWorks, Inc. Used with permission.



Script-editor

- **COMMENT!**
 - Anything following a **%** is seen as a comment
 - The first contiguous comment becomes the script's help file
 - Comment thoroughly to avoid wasting time later
- Note that scripts are somewhat static, since there is no input and no explicit output
- All variables created and modified in a script exist in the workspace even after it has stopped running



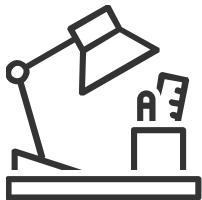
Script-exercise

```
% This is a MATLAB script file.  
% It has been saved as "g13.m".  
  
load g13.dat; %Load data file  
voltage = g13( :, 4); %Extract volts vector  
time = .005*[1:length(voltage)]; %Create time vector  
plot (time, voltage) %Plot volts vs time  
xlabel ('Time in Seconds') % Label x axis  
ylabel ('Voltage') % Label y axis  
title ('Bike Strain Gage Voltage vs Time')  
grid %Put a grid on graph
```



Script-Question

Write a script to calculate the circumference of circle ($C=2\pi r$).
Comment the script.



Documentation

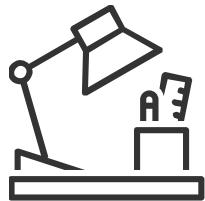
circlescript.m

```
% This script calculates the area of a circle  
  
% First the radius is assigned  
radius = 5  
  
% The area is calculated based on the radius  
area = pi * (radius ^2)
```

>> help circlescript

This script calculates the area of a circle

The first comment at the beginning of the script describes what the script does; this is sometimes called a ***block comment***. Then, throughout the script, comments describe different parts of the script (not usually a comment for every line, however!). Comments don't affect what a script does, so the output from this script would be the same as for the previous version.



Example of a script file

Let us write a script file to solve the following system of linear equations1 :

$$\begin{bmatrix} 5 & 2r & r \\ 3 & 6 & 2r - 1 \\ 2 & r - 1 & 3r \end{bmatrix} \begin{Bmatrix} x_1 \\ x_2 \\ x_3 \end{Bmatrix} = \begin{Bmatrix} 2 \\ 3 \\ 5 \end{Bmatrix}$$

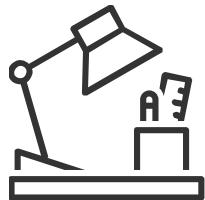
or $Ax = b$. Clearly, A depends on the parameter r . We want to find the solution of the equation for various values of the parameter r . We also want to find, say, the determinant of matrix A in each case.



Example of a script file

```
%----- This is the script file 'solvex.m' -----
% It solves equation (4.1) for x and also calculates det(A).

A = [5 2*r r; 3 6 2*r-1; 2 r-1 3*r]; % create matrix A
b = [2;3;5]; % create vector b
det_A = det(A) % find the determinant
x = A\b % find x
```



Example of a script file

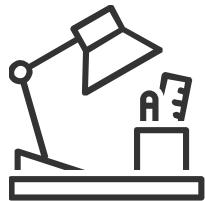
Let us now execute the script in MATLAB.

```
>> clear all % clear the workspace
>> r = 1; % specify a value of r
>> solvex % execute the script file solvex.m
```

```
det_A =
64
x =
-0.0312
0.2344
1.6875
>> who
```

This is the output. The values of the variables *det_A* and *x* appear on the screen because there is no semi-colon at the end of the corresponding lines in the script file.

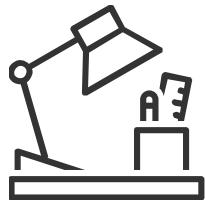
Check the variables in the workspace.



Precautions

- NE VER name a script file the same as the name o.f a variable it computes.
- The name of a script file must begin with a letter. The rest of the characters may include digits and the underscore character.
- You may give long names but MATLAB will take only the first 19 character.

eg. proj ecL23C.m, cee213_hw5_1 .m but proj ect.23C.m and cee2 13_hw5.1.m are not valid names.



Function Files

A function file is also an M-file, like a script file, except that the variables in a function file are all local .A function file begins with a function definition line, which has a well-defined list of inputs and outputs. Without this line, the file becomes a script file. The syntax of the function definition line is as follows:

```
function [output variables] = function_name(input variables);
```



Examples of Function Files

Function Definition Line

```
function [rho,H,F] = motion(x,y,t);  
function [theta] = angleTH(x,y);  
function theta = THETA(x,y,z);  
function [] = circle(r);  
function circle(r);
```

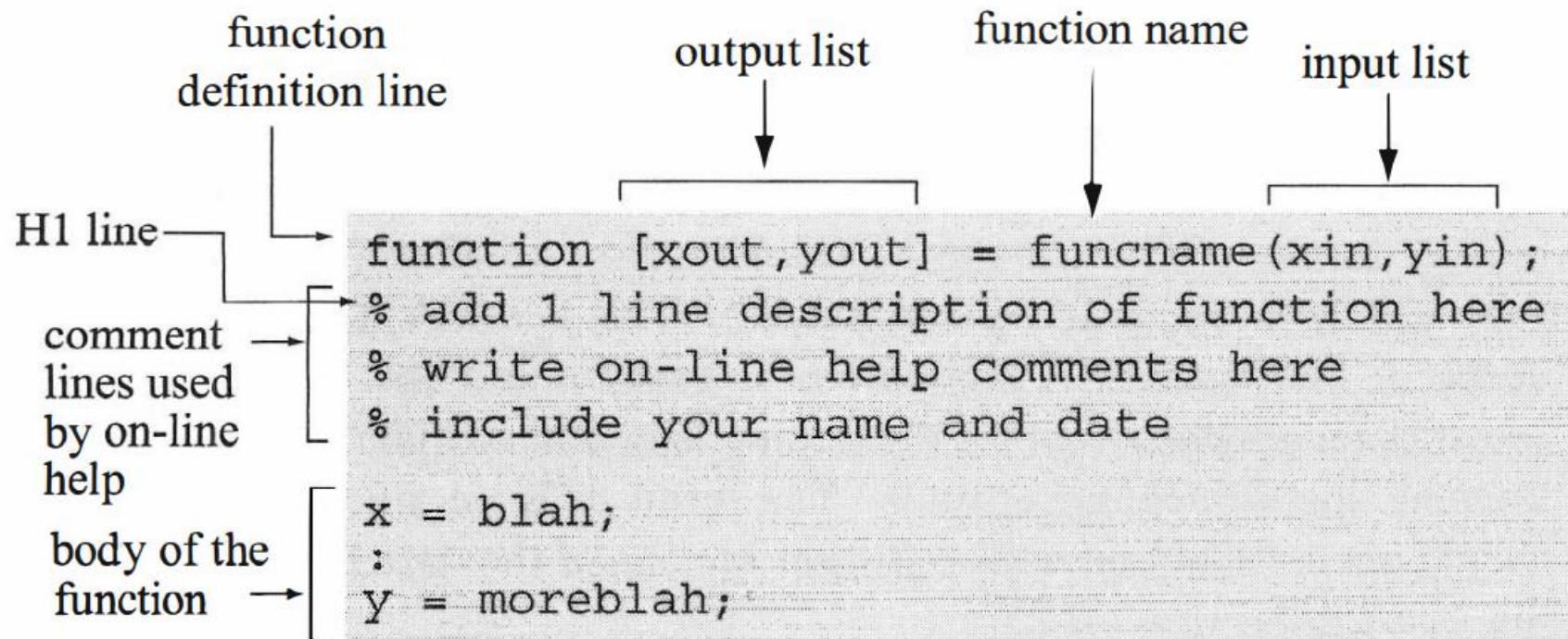
File Name

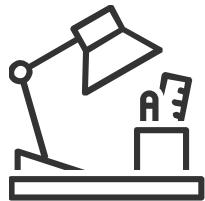
```
motion.m  
angleTH.m  
THETA.m  
circle.m  
circle.m
```

Caution: The first word in the function definition line, *function*, *must be typed in lowercase*. A common mistake is to type it as *Function*.



Anatomy of Function Files





Executing Function Files

This is the full syntax of calling a function. Both the output and input list are specified in the call. For example, if the function definition line of a function reads

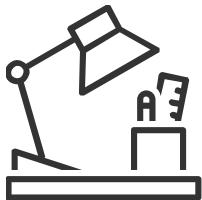
```
function [rho ,H,F] = motion (x ,y,t) ;
```

then all the following commands represent legal call (execution) statements:



Executing Function Files

- `[r,angmom,force]=motion(xt,yt,time);` The input variables *xt*, *yt*, and *time* must be defined before executing this command.
- `[r,h,f]=motion(rx,ry,[0:100]);` The input variables *rx* and *ry* must be defined beforehand; the third input variable *t* is specified in the call statement.
- `[r,h,f]=motion(2,3.5,0.001);` All input values are specified in the call statement.
- `[radius,h]=motion(rx,ry);` Call with partial list of input and output. The third input variable must be assigned a default value inside the function if it is required in calculations. The output corresponds to the first two elements of the output list of `motion`.



Example

```
>> clear all

>> [detA, y] = solvexf(1); % take r=1 and execute solvexf.m

>> detA % display the value of detA

detA =
64

>> y % display the value of y

y =
-0.0312
0.2344
1.6875

>> who

Your variables are:

detA y
```

Values of *detA* and *y* will be automatically displayed if the semi-colon at the end of the function command is omitted.

Note that only *detA* and *y* are in the workspace; no *A*, *b*, or *x*.

MATLAB

Unit 5-Lecture 16

BTech (CSBS) -Semester VII

13 September 2022, 09:35AM



Introduction to programming

- 1) Introduction,
- 2) M-File Scripts,
- 3) script side-effects,
- 4) M-File functions,
- 5) anatomy of a M- File function,
- 6) input and output arguments,
- 7) input to a script file,
- 8) output commands.



Introduction to programming

1) What is an m-file?

An m-file, or script file, is a simple text file where you can place MATLAB commands. When the file is run, MATLAB reads the commands and executes them exactly as it would if you had typed each command sequentially at the MATLAB prompt. All m-file names must end with the extension '.m' (e.g. test.m). If you create a new m-file with the same name as an existing m-file, MATLAB will choose the one which appears first in the path order (type `help path` in the command window for more information). To make life easier, choose a name for your m-file which doesn't already exist. To see if a `filename.m` already exists, type `help filename` at the MATLAB prompt.

2) Why use m-files?

For simple problems, entering your requests at the MATLAB prompt is fast and efficient. However, as the number of commands increases or trial and error is done by changing certain variables or values, typing the commands over and over at the MATLAB prompt becomes tedious. M-files will be helpful and almost necessary in these cases.



Introduction to programming

3) How to create, save or open an m-file?

If you are using PC or Mac:

- To create an m-file, choose New from the File menu and select Script. This procedure brings up a text editor window in which you can enter MATLAB commands.
- To save the m-file, simply go to the File menu and choose Save (remember to save it with the '.m' extension). To open an existing m-file, go to the File menu and choose Open.

If you are using Unix:

- To create an m-file, use your favorite text editor (pico, nedit, vi, emacs, etc.) to create a file with .m extension (e.g. filename.m).

4) How to run the m-file?

- After the m-file is saved with the name filename.m in the current MATLAB folder or directory, you can execute the commands in the m-file by simply typing filename at the MATLAB command window prompt.
- If you don't want to run the whole m-file, you can just copy the part of the m-file that you want to run and paste it at the MATLAB prompt.



Script M-file: Creating M-file

Quite often we need to be able to calculate the value of a function $y=f(x)$ for any value of x . Obviously, it is not practical to change value of x each time. For this purpose MATLAB has a special type of M-file, called M-function.

> The following script M-file finds the value of the function at $y= \sin x + x^3$ at $x = 3$.

```
% exercisefscript.m  
  
x = 3  
  
y = sin(x) + x^3
```

> Run this M-file by typing the following in the *Command Window*:

```
exercisefscript
```

> Then update the M-file to find the value of $f(x)$ for $x = 4, 5, 6$.



Properties of Function M-Files

A MATLAB file of a special format that contains code with optional inputs and outputs is called function M-file.

Some advantages:

- Functions can be called from inside of other script and function M-files.
- Inputs allow variable values to be modified when calling the function (eg from the Command Window).
- Outputs can be assigned to other variables at the Command Window or within a separate M-file.

Disadvantages:

- A slight disadvantage with a function M-file is that you must follow the prescribed format, or else it won't run correctly. Once you get the hang of that, you will see they are often very useful.



Properties of Function M-Files

- The following function M-file finds the value of the function $f(x) = \sin x + x^3$ for any value of x . Type it in and save as **exercise1func.m** in your *Current Directory*

```
% <insert your name and the date here>

% exercisefunc.m

% input: x

% output: p, solved in terms of x

function p = exercisefunc(x) %Note special format!

p = sin(x) + x^3
```

- Call this M-file from the *Command Window* using the following command and then update it to find the value of for $p(x)$ for $x=3, 4, 5, 6$.

```
exercisefunc(3) % returns value for x = 3
```

- Consider the case, when the variable x is an array $[3 4 5 6]$. Modify your function M-file so, that it will be able to work with arrays.



Constructing Function M-files

Function M-files allow you to define, construct and store your own functions.

First, let's recall some of the in-built MATLAB functions you have already used. If you type command `help <name of the function>` , such as `help abs`, in the Command Window, MATLAB will print description and correct syntax of this function. These functions have a few things in common and a few differences.

Function: `y = abs(x)`

Description: Assigns the value x to y if x is non-negative, or $-x$ if x is negative.

Input: 1 number: x

Output: 1 number: either x or $-x$



Constructing Function M-files

Function: `y=rem(a,b)`

Description: Assigns the remainder of a/b to y

Input: 2 numbers: a is the numerator, b is the denominator

Output: 1 number: remainder of a/b

Function: `plot(xArray,yArray)`

Description: Plots a graph, given an array of x-coordinates, $xArray$, and an array of y-coordinates, $yArray$.

Input: 2 arrays of equal length: $xArray$, $yArray$.

Note: there can be many additional optional inputs.

Output: A graph.



Constructing Function M-files

Exercise: Determining the Inputs & Outputs

- For the following function (which you may recall from the first practical), use MATLAB to help you write the description, inputs and outputs.

Function: `round(a)`

Description: _____

Inputs: _____

Outputs: _____



Constructing Function M-files

> Exercise: Creating a Customised Random Number Generator

> Create a function M-file called `myRand.m` that outputs a random number between the inputted values of `minRand` and `maxRand` by adding code in the starred lines.

The MATLAB `rand` function returns a random value between 0 and 1. You will need to use this function as well as calculating the scale and offset values.

Example: If you want to find a number between 3 and 10, your scale is 7 and your offset is 3.

```
% <insert your name and the date here>

% myRand.m

% inputs: minRand, maxRand

% outputs: y, a random number with value between

% minRand & maxRand
```



Constructing Function M-files

```
function y = myRand(minRand, maxRand)

% **calculate the scale**

% **calculate the offset**

% **calculate y, using your scale, offset and %MATLAB's rand function**
```

Note: Save your function in the *Current Directory*, otherwise you will need to switch to the directory you saved your function in or type in a full path.



Constructing Function M-files

➤ Type in the following lines to call this function from your Command Window and verify that it works.

```
myRand(1,10)
```

```
myRand(100,100+1)
```

```
myRand(3,pi)
```

```
myRand(20)
```

```
myRand(20,1)
```



Steps to Create

Steps for creating function M-files

1. The function name and its M-file name must be identical (except that the M-file must end with .m).
2. The first executable statement must be a function declaration of the form

```
function <outputVariables> = <functionName>(<inputVariables>)
```

► One of the following function declarations has been taken from the MATLAB `rem.m` function M-file. Determine which one must be correct declaration:

```
function rem = remainder(x,y)  
  
function out = rem(x,y)  
  
out = function rem(x,y)  
  
function out(x,y) = rem(x,y)
```



Excercise

Exercise: Writing Function Declarations

Write down the `<outputVariables>`, `<functionName>` and `<InputVariables>` for the two function M-files from the previous exercises and verify they match the function declaration statement.

Function M-file 1: $p(x) = \sin x + x^3$

Function Name: _____

Output Variables: _____

Input Variables: _____

Function M-file 2: Creating a Customised Random Number Generator

Function Name: _____

Output Variables: _____

Input Variables: _____



Exercise: Creating a Function M-file

Follow steps below to create a simple function M-file that computes and outputs the n^{th} power of 2, 2^n , where n is a number specified each time the function M-file is run.

- Q1. Create a blank M-file and save it as twoN.m
 - Q2. What should go at the top of every M-file? Add in header comments. This time, make sure you include the function description, inputs and outputs as well as your name and the date.
 - Q3. Type the function declaration into your file called twoN.m
 - a) replace <function Name> with twoN
 - b) decide upon an appropriate input variable name. In this case you may call it simply n.
 - c) decide upon an output variable name. The name y will be used in this case.
(In other examples you could use fn, f_n or another name of your choice as an output variable name.)
- Important: Every output variable must be assigned a value within your code.



Exercise: Creating a Function M-file

Now, you need to write your code. This function is pretty simple, so the code should only contain the following line: $y=2^n$

Note: if you have used different input/output variable names, you must change y to match your output variable name and n to match your input variable name.

Q5. OK, now you're ready to save and test your function M-file. After saving, make sure that your Current Directory matches the one you saved your M-file in.

Q6. Run the following lines in the Command Window to verify your function M-file works.

```
twoTo8 = twoN(8)
newNumber = twoN(5)
squareOfTwo = twoN(2)
twoN(9)
rootOfPower = twoN(5)^(1/2)
twoN %Why this does not work?
```



Exercise: Creating a Function M-file

Exercise: Writing your Own Function M-file

› Create a function M-file called `quadRoots` to find the roots of quadratic polynomials of the form $y=ax^2+bx+c$

Its inputs will be the coefficients a, b and c.

Its outputs will be the two roots, r_1 and r_2 and calculated by the formula:

$$r_1, r_2 = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

Test `quadRoots` in the Command Window with the following three polynomials:

$$y = x^2 + 3x + 2 \text{ (ans } r_1=-1, r_2=-2\text{)}$$

$$y = x^2 + 6x + 10 \text{ (ans } r_1=-3+i, r_2=-3-i\text{)}$$

$$y = x^2 + 6x + 13 \text{ (ans } r_1=-3+2i, r_2=-3-2i\text{)}$$



Functions on Functions

Suppose a function $y = \text{demoFun}(x)$ has been defined in a function M-file `demoFun.m`

<code>fplot(@demoFun, [a b])</code>	Plots the function for $a \leq x \leq b$ without setting up arrays
<code>fzero(@demoFun, [a b])</code>	Finds one value of x for $\text{demoFun}(x) = 0$ provided that the signs of $\text{demoFun}(a)$ and $\text{demoFun}(b)$ are opposite.
<code>fzero(@demoFun, c)</code>	Finds one value of x for $\text{demoFun}(x) = 0$ by starting a search at $x = c$
<code>fminbnd(@demoFun, a, b)</code>	Finds the coordinates of a minimum point of $\text{demoFun}(x)$ at the interval $a \leq x \leq b$
<code>quadl(@demoFun, a, b)</code>	Finds an accurate value for $\int_a^b y(x) dx$ Note: <code>quadl</code> uses arrays, so therefore you must set your function up treating x as an array and so using the dot notation for operations.

Exercise: Using Functions

1. Create a function M-file called `myCubic.m` whose output is the value of the function $y = x^3 + 2x^2 - 5x - 8$

Input: `x`

Output: `y`

> Verify that this function works by checking that `myCubic(-5)=-58` and `myCubic(5)=142`

2. Create a script M-file called `cubicExercise.m` that contains the following five cells with code that:

a) plots `myCubic(x)` between the values of `[-5, 5]`,

b) finds a local minimum of `myCubic(x)`, located between `0` and `5`,

c) finds the all three roots of `myCubic(x)` using appropriate intervals

`[a, b]`

d) finds the value of the definite integral of `myCubic(x)` between `-5` and `5`.

Hint: You will need to use the array dot notation so you can use the `quadl` function to calculate the integral of `y`.

3. Make sure `cubicExercise.m` is marked up using cell formatting and publish it.

MATLAB

Unit 5-Lecture 17

BTech (CSBS) -Semester VII

16 September 2022, 09:35AM



Introduction to programming

- 1) Introduction,
- 2) M-File Scripts,
- 3) script side-effects,
- 4) M-File functions,
- 5) anatomy of a M- File function,
- 6) **input and output arguments,**
- 7) **input to a script file,**
- 8) **output commands.**



Kinds of M files

Script M-Files	Function M-Files
Do not accept input arguments or return output arguments	Can accept input arguments and return output arguments
Operate on data in the workspace	Internal variables are local to the function by default
Useful for automating a series of steps you need to perform many times	Useful for extending the MATLAB language for your application



Example

Factorial.m

```
n=10;  
factorial=1;  
for i=1:1:n  
    factorial=factorial*i;  
end
```



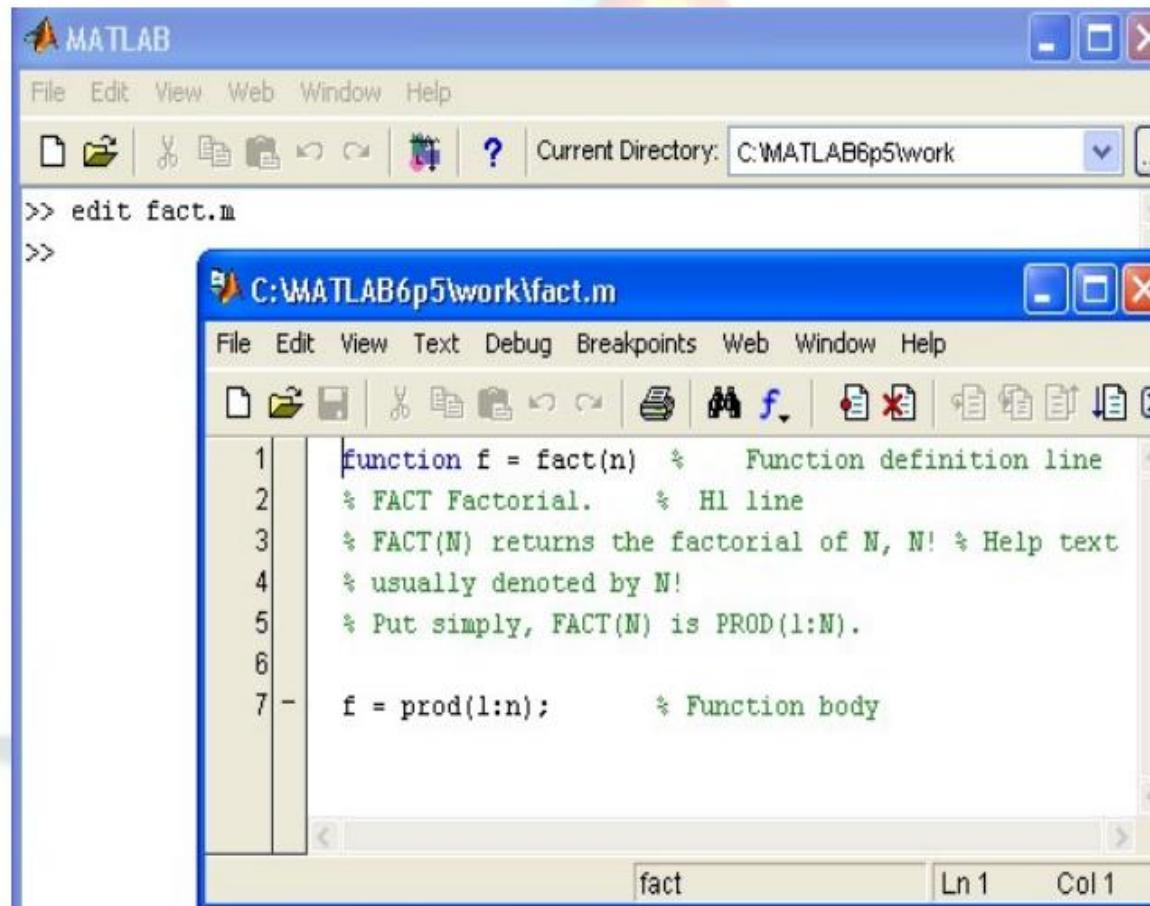
A screenshot of the MATLAB editor window showing the script `Factorial.m`. The window title is `C:\MATLAB6p5\work\Factorial.m`. The menu bar includes File, Edit, View, Text, Debug, Breakpoints, Web, Window, and Help. The toolbar below the menu bar contains various icons for file operations. The code editor displays the following MATLAB script:

```
1 | - n=10;  
2 | - factorial=1;  
3 | - for i=1:1:n  
4 | -     factorial=factorial*i;  
5 | - end
```



Accessing Text Editors

>> edit fact.m



The image shows the MATLAB desktop environment. The main window title is 'MATLAB'. The menu bar includes File, Edit, View, Web, Window, and Help. The toolbar contains various icons for file operations. The current directory is set to 'C:\MATLAB6p5\work'. A command window shows the command '>> edit fact.m' and its response '>>'. Below the command window is the MATLAB Editor window, titled 'C:\MATLAB6p5\work\fact.m'. The editor window has its own menu bar and toolbar. The code in 'fact.m' is as follows:

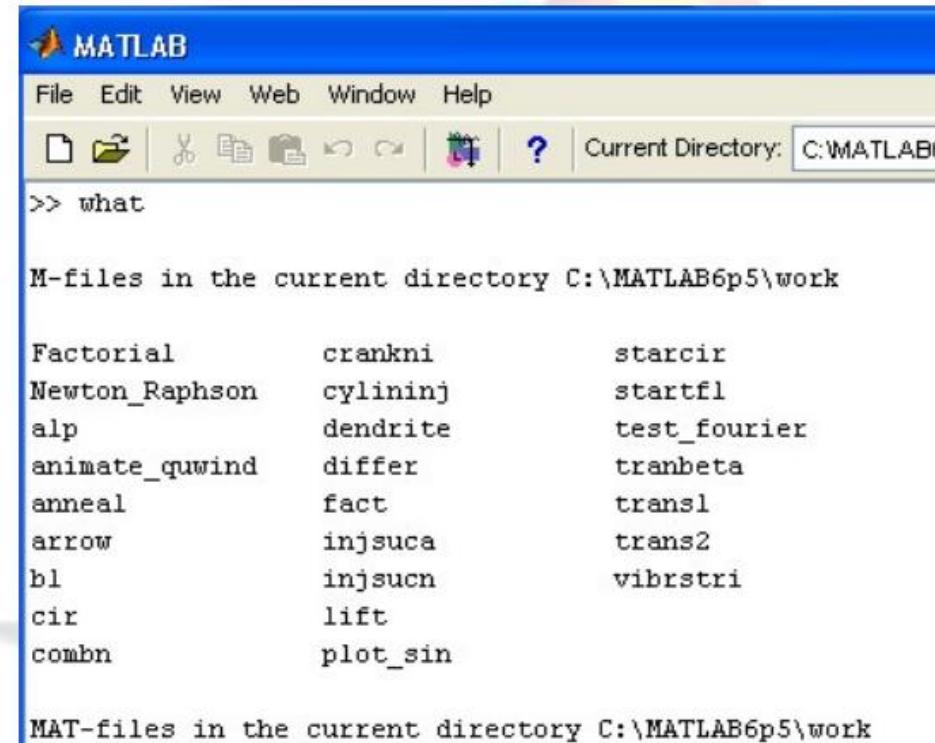
```
function f = fact(n) % Function definition line
% FACT Factorial. % Hl line
% FACT(N) returns the factorial of N, N! % Help text
% usually denoted by N!
% Put simply, FACT(N) is PROD(1:N).
f = prod(1:n); % Function body
```

The status bar at the bottom of the editor window shows 'fact' in the first field, 'Ln 1' in the second, and 'Col 1' in the third.



Listing files

>> what (List the names of the files in your current directory)



The image shows a screenshot of the MATLAB interface. The title bar says 'MATLAB'. The menu bar includes 'File', 'Edit', 'View', 'Web', 'Window', and 'Help'. The toolbar has icons for file operations. The current directory is set to 'C:\MATLAB6'. The command window shows the command 'what' entered. The output lists M-files and MAT-files in the current directory 'C:\MATLAB6p5\work'. The M-files listed are: Factorial, crankni, starcir, Newton_Raphson, cylininj, startfl, alp, dendrite, test_fourier, animate_quwind, differ, tranbeta, anneal, fact, transl, arrow, injsuca, trans2, bl, injsucn, vibrstri, cir, lift, and combin. The MAT-files listed are: plot_sin.

```
>> what

M-files in the current directory C:\MATLAB6p5\work

Factorial      crankni      starcir
Newton_Raphson cylininj      startfl
alp             dendrite     test_fourier
animate_quwind differ       tranbeta
anneal          fact         transl
arrow           injsuca      trans2
bl              injsucn     vibrstri
cir              lift
combn          plot_sin

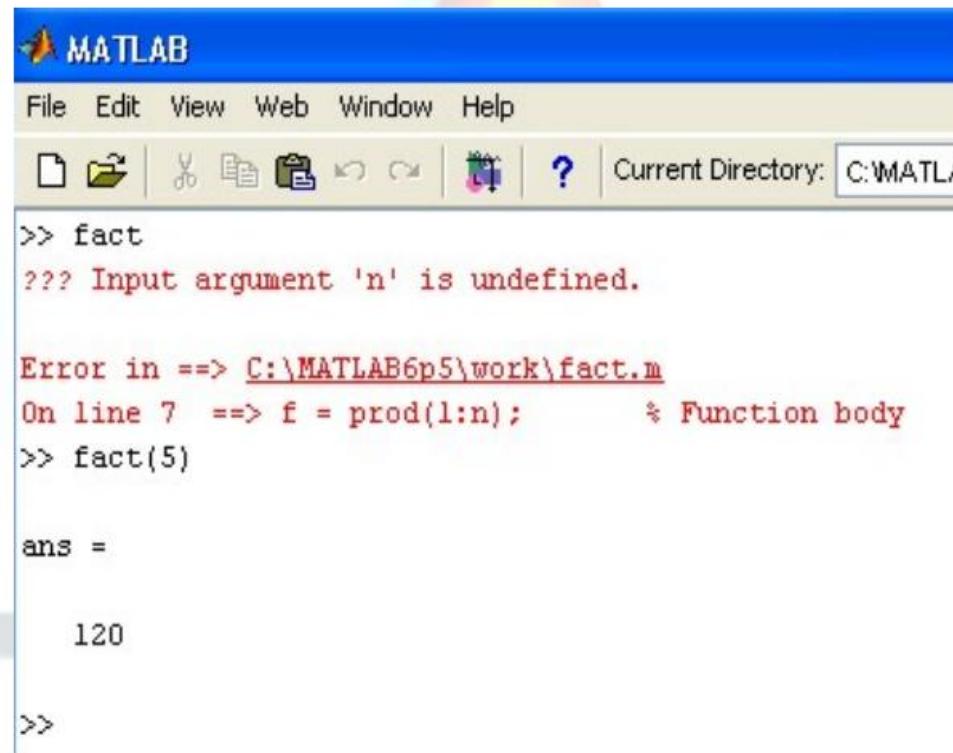
MAT-files in the current directory C:\MATLAB6p5\work
```



Calling function

Call the fact function

```
>> fact(5)
```



The screenshot shows the MATLAB desktop with the command window open. The window title is 'MATLAB'. The menu bar includes 'File', 'Edit', 'View', 'Web', 'Window', and 'Help'. The toolbar contains icons for file operations like Open, Save, and Print. The current directory is set to 'C:\MATLAB\'. The command window displays the following text:

```
>> fact
??? Input argument 'n' is undefined.

Error in ==> C:\MATLAB6p5\work\fact.m
On line 7  ==> f = prod(1:n);      % Function body
>> fact(5)

ans =

120

>>
```



Some m-File Functions

Function	Description
run	Run script that is not on current path
type filename	lists the contents of the file given a full pathname
Edit fun	opens the file fun.m in a text editor
mfilename	Name of currently running M-file
namelengthmax	Return maximum identifier length
echo	Echoes the script file contents as they are executed



Some m-File Functions

Function	Description
input	Request user input
Disp (variablename)	Displays results without printing variable names
beep	Makes computer beep
eval	Interpret strings containing MATLAB expressions
feval	Evaluate function



Some m-File Functions

Function	Description
pause	Pauses and waits until user presses any keyboard key.
pause (n)	Pause (n) pauses for n seconds and then continues
waitForButtonpress	Pauses until user presses mouse button or any keyboard key
keyboard	Temporarily gives control to keyboard. <ul style="list-style-type: none">➤ The keyboard mode is terminated by executing the command RETURN➤ DBQUIT can also be used to get out of keyboard mode but in this case the invoking M-file is terminated.



Input Functions

The simplest input function in MATLAB is called **input**. The **input** function is used in an assignment statement. To call it, a string is passed that is the prompt that will appear on the screen, and whatever the user types will be stored in the variable named on the left of the assignment statement. For ease of reading the prompt, it is useful to put a colon and then a space after the prompt. For example,

```
>> rad = input ('Enter the radius: ')
Enter the radius: 5
rad =
5
```



Input Functions

If character or string input is desired, 's' must be added as a second argument to the **input** function:

```
>> letter = input('Enter a char: ', 's')
Enter a char: g
letter =
g
```

If the user enters only spaces or tabs before hitting the Enter key, they are ignored and an *empty string* is stored in the variable:

```
>> mychar = input('Enter a character: ', 's')
Enter a character:
mychar =
''
```



Input Functions

However, if blank spaces are entered before other characters, they are included in the string. In the next example, the user hits the space bar four times before entering "go." The **length** function returns the number of characters in the string.

```
>> mystr = input ('Enter a string: ', 's')
Enter a string:      go
mystr =
      go
>> length(mystr)
ans =
      6
```



Question

What would be the result if the user enters blank spaces after other characters? For example, the user here entered "xyz " (four blank spaces):

```
>> mychar = input('Enter chars: ', 's')
Enter chars: xyz
mychar =
xyz
```

Answer: The space characters would be stored in the string variable. It is difficult to see earlier, but is clear from the length of the string.

```
>> length(mychar)
ans =
7
```

The string can actually be seen in the Command Window by using the mouse to highlight the value of the variable; the xyz and four spaces will be highlighted.



Input

It is also possible for the user to type quotation marks around the string rather than including the second argument 's' in the call to the **input** function.

```
>> name = input ('Enter your name: ')
Enter your name: 'Stormy'
name =
Stormy
```

or

```
>> name = input ('Enter your name: ', 's')
Enter your name: 'Stormy'
name =
'Stormy'
>> length(name)
ans =
```



Input

```
>> num = input ('Enter a number: ')
Enter a number: t
Error using input
Undefined function or variable 't'.
```

```
Enter a number: 3
num =
3
```

MATLAB gave an *error message* and repeated the prompt. However, if *t* is the name of a variable, MATLAB will take its value as the input.

```
>> t = 11;
>> num = input ('Enter a number: ')
Enter a number: t
num =
11
```



Input

Separate **input** statements are necessary if more than one input is desired. For example,

```
>> x = input ('Enter the x coordinate: ');  
>> y = input ('Enter the y coordinate: ');
```

Normally in a script the results from **input** statements are suppressed with a semicolon at the end of the assignment statements.

It is also possible to enter a vector. The user can enter any valid vector, using any valid syntax such as square brackets, the colon operator, or functions such as **linspace**.

```
>> v = input ('Enter a vector: ')  
Enter a vector: [3 8 22]  
v =  
3 8 22
```



Output: `disp` and `fprintf`

Output statements display strings and/or the results of expressions, and can allow for *formatting* or customizing how they are displayed. The simplest output function in MATLAB is `disp`, which is used to display the result of an expression or a string without assigning any value to the default variable *ans*. However, `disp` does not allow formatting. For example,

```
>> disp('Hello')
Hello
```

```
>> disp(4 ^ 3)
64
```



Output: disp and fprintf

Formatted output can be printed to the screen using the **fprintf** function. For example,

```
>> fprintf('The value is %d, for sure!\n', 4 ^ 3)
The value is 64, for sure!
>>
```

To the **fprintf** function, first a string (called the *format string*) is passed that contains any text to be printed, as well as formatting information for the expressions to be printed. In this case, the `%d` is an example of format information.

The `%d` is sometimes called a *place holder* because it specifies where the value of the expression that is after the string, is to be printed. The character in the place holder is called the *conversion character*, and it specifies the type of value that is being printed. There are others, but what follows is a list of the simple place holders:

<code>%d</code>	integer (it stands for decimal integer)
<code>%f</code>	float (real number)
<code>%c</code>	character (one character)
<code>%s</code>	string of characters



Output: question

What do you think would happen if the newline character is omitted from the end of an **fprintf** statement?

Answer: Without it, the next prompt would end up on the same line as the output. It is still a prompt, and so an expression can be entered, but it looks messy as shown here.

```
>> fprintf('The value is %d, surely!', 4 ^ 3)
The value is 64, surely!>> 5 + 3
ans =
8
```

What would happen if you use the %d conversion character but you're trying to print a real number?

Answer: MATLAB will show the result using exponential notation

```
>> fprintf('%d\n', 1234567.89)
1.234568e+006
```

Note that with the **disp** function, however, the prompt will always appear on the next line:

```
>> disp('Hi ')
Hi
>>
```

Also, note that an ellipsis can be used after a string but not in the middle.

Note that if you want exponential notation, this is not the correct way to get it; instead, there are conversion characters that can be used. Use the **help** browser to see this option, as well as many others!



Output: question

How can you get a blank line in the output?

Answer: Have two newline characters in a row.

```
>> fprintf('The value is %d, \n\nOK! \n', 4 ^3)  
The value is 64,  
  
OK!
```

This also points out that the newline character can be anywhere in the string; when it is printed, the output moves down to the next line.

What do you think would happen if you tried to print 1234.5678 in a field width of 3 with 2 decimal places?

```
>> fprintf('%3.2f\n', 1234.5678)
```

Answer: It would print the entire 1234, but round the decimals to two places, that is,

1234.57

If the field width is not large enough to print the number, the field width will be increased. Basically, to cut the number off would give a misleading result, but rounding the decimal places does not change the number significantly.

MATLAB

Unit 5-Lecture 18

BTech (CSBS) -Semester VII

20 September 2022, 09:35AM



Introduction to programming

- 1) Introduction,
- 2) M-File Scripts,
- 3) script side-effects,
- 4) M-File functions,
- 5) anatomy of a M- File function,
- 6) **input and output arguments,**
- 7) input to a script file,
- 8) output commands.



Scripts with input and output

circleIO.m

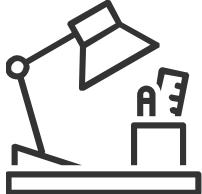
```
% This script calculates the area of a circle
% It prompts the user for the radius

% Prompt the user for the radius and calculate
% the area based on that radius
fprintf('Note: the units will be inches.\n')
radius = input('Please enter the radius: ');
area = pi * (radius ^2);

% Print all variables in a sentence format
fprintf('For a circle with a radius of %.2f inches,\n',...
    radius)
fprintf('the area is %.2f inches squared\n',area)
```

Executing the script produces the following output:

```
>> circleIO
Note: the units will be inches.
Please enter the radius: 3.9
For a circle with a radius of 3.90 inches,
the area is 47.78 inches squared
```



Example

plotonepoint.m

```
% This is a really simple plot of just one point!  
  
% Create coordinate variables and plot a red '*'  
x = 11;  
y = 48;  
plot(x,y,'r*')  
  
% Change the axes and label them  
axis([9 12 35 55])  
xlabel('Time')  
ylabel('Temperature')  
  
% Put a title on the plot  
title('Time and Temp')
```



Example

plot2figs.m

```
% This creates 2 different plots, in 2 different
% Figure Windows, to demonstrate some plot features

clf
x = 1:5; % Not necessary
y1 = [2 11 6 9 3];
y2 = [4 5 8 6 2];
% Put a bar chart in Figure 1
figure(1)
bar(x,y1)
% Put plots using different y values on one plot
% with a legend
figure(2)
plot(x,y1,'k')
hold on
plot(x,y2,'ko')
grid on
legend('y1', 'y2')
```



Example

`sinncos.m`

```
% This script plots sin(x) and cos(x) in the same Figure Window
% for values of x ranging from 0 to 2*pi

clf
x = 0: 2*pi/40: 2*pi;
y = sin(x);
plot(x,y, 'ro')
hold on
y = cos(x);
plot(x,y, 'b+')
legend('sin', 'cos')
xlabel('x')
ylabel('sin(x) or cos(x)')
title('sin and cos on one graph')
```



Question

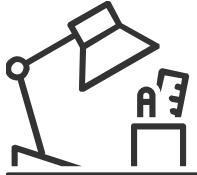
Sometimes files are not in the format that is desired. For example, a file "expresults.dat" has been created that has some experimental results, but the order of the values is reversed in the file:

```
4 53.4
3 44.3
2 50.0
1 55.5
```

How could we create a new file that reverses the order?

Answer: We can **load** from this file into a matrix, use the **flipud** function to "flip" the matrix up to down, and then **save** this matrix to a new file:

```
>> load expresults.dat
>> expresults
expresults =
    4.0000    53.4000
    3.0000    44.3000
    2.0000    50.0000
    1.0000    55.5000
>> correctorder = flipud(expresults)
correctorder =
    1.0000    55.5000
    2.0000    50.0000
    3.0000    44.3000
    4.0000    53.4000
>> save neworder.dat correctorder - ascii
```



Question

Could we pass a vector of radii to the *calcarea* function?

Answer: This function was written assuming that the argument was a scalar, so calling it with a vector instead would produce an error message:

```
>> calcarea(1:3)
Error using *
Inner matrix dimensions must agree.
```

```
Error in calcarea (line 6)
area = pi * rad * rad;
```

This is because the `*` was used for multiplication in the function, but `.*` must be used when multiplying vectors term by term. Changing this in the function would allow either scalars or vectors to be passed to this function:

calcarea.m

```
function area = calcareaii(rad)
% calcareaii returns the area of a circle
% The input argument can be a vector of radii
% Format: calcareaii(radVector)

area = pi * rad .* rad;
end
```

```
>> calcareaii(1:3)
ans =
3.1416 12.5664 28.2743
```

```
>> calcareaii(4)
ans =
50.2655
```

Note that the `.*` operator is only necessary when multiplying the radius vector by itself. Multiplying by `pi` is scalar multiplication, so the `.*` operator is not needed there. We could have also used:

```
area = pi * rad.^ 2;
```



Question

Nothing is technically wrong with the following function, but **Answer;** Why pass the third argument if it is not used? what about it does not make sense?

fun.m

```
function out = fun(a,b,c)
out = a*b;
end
```



Practise Question

PRACTICE 3.1

Write a script to calculate the circumference of a circle ($C = 2\pi r$). Comment the script.

PRACTICE 3.2

Create a script that would prompt the user for a length, and then 'f' for feet or 'm' for meters, and store both inputs in variables. For example, when executed it would look like this (assuming the user enters 12.3 and then m):

```
Enter the length: 12.3
Is that f(eet) or m(eters)?: m
```

PRACTICE 3.3

Write a script to prompt the user separately for a character and a number, and print the character in a field width of 3 and the number left-justified in a field width of 8 with 3 decimal places. Test this by entering numbers with varying widths.

PRACTICE 3.4

Modify the script *plotonepoint* to prompt the user for the time and temperature, and set the axes based on these values.



Practise Question

PRACTICE 3.5

Modify the *plot2figs* script using the **axis** function so that all points are easily seen.

PRACTICE 3.6

Write a script that plots $\exp(x)$ and $\log(x)$ for values of x ranging from 0 to 3.5.

PRACTICE 3.7

Prompt the user for the number of rows and columns of a matrix, create a matrix with that many rows and columns of random integers, and write it to a file.



Practise Question

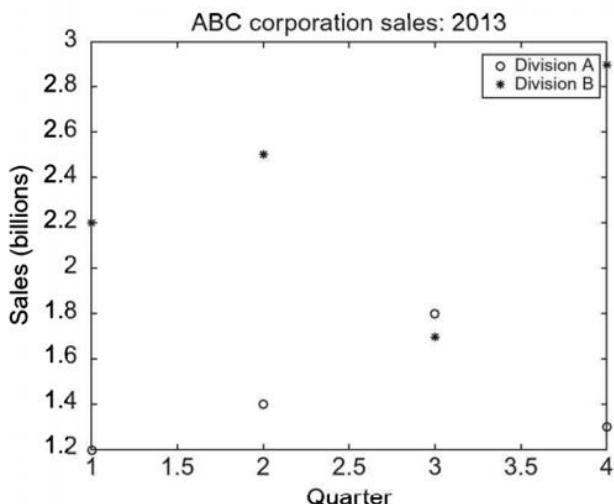
PRACTICE 3.8

The sales (in billions) for two separate divisions of the ABC Corporation for each of the four quarters of 2013 are stored in a file called "salesfigs.dat":

```
1.2 1.4 1.8 1.3
2.2 2.5 1.7 2.9
```

- First, create this file (just type the numbers in the Editor, and Save As "salesfigs.dat").
- Then, write a script that will

```
load the data from the file into a matrix
separate this matrix into 2 vectors.
create the plot seen in Fig. 3.7 (which uses black circles and stars as the plot symbols).
```





Practise Question

PRACTICE 3.9

Write a script that will prompt the user for the radius and height, call the function *conevol* to calculate the cone volume, and print the result in a nice sentence format. So, the program will consist of a script and the *conevol* function that it calls.

PRACTICE 3.10

For a project, we need some material to form a rectangle. Write a function *calcrectarea* that will receive the length and width of a rectangle in inches as input arguments, and will return the area of the rectangle. For example, the function could be called as shown, in which the result is stored in a variable and then the amount of material required is printed, rounded up to the nearest square inch.

```
>> ra = calcrectarea(3.1, 4.4)
ra =
13.6400

>> fprintf('We need %d sq in.\n', ceil(ra))
We need 14 sq in.
```

MATLAB

Unit 5-Lecture 19

BTech (CSBS) -Semester VII

23 September 2022, 09:35AM



Introduction to programming

- 1) Introduction,
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Scripts with input and output

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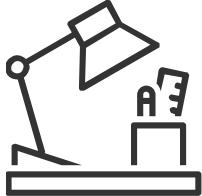
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```
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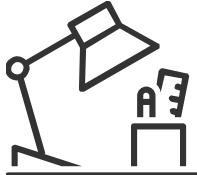
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Practise Question

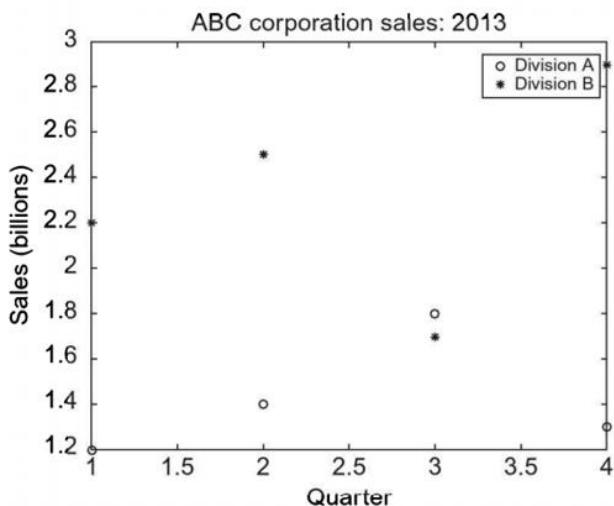
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>> fprintf('We need %d sq in.\n', ceil(ra))
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MATLAB

Unit 6-Lecture 20

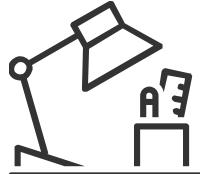
BTech (CSBS) -Semester VII

30 September 2022, 09:35AM



Control Flow and Operators

- 1) relational and logical operators
- 2) “if ... end” structure
- 3) “for ... end” loop
- 4) “while ... end” loop
- 5) other flow structures
- 6) operator precedence
- 7) saving output to a file



Relational operators

Relational operators compare the elements in two arrays and return logical true or false values to indicate where the relation holds.

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



Relational operators: Examples

Examples: If $x = [1 \ 5 \ 3 \ 7]$ and $y = [0 \ 2 \ 8 \ 7]$, then

$k = x < y$	results in $k = [0 \ 0 \ 1 \ 0]$	because $x_i < y_i$ for $i = 3$,
$k = x \leq y$	results in $k = [0 \ 0 \ 1 \ 1]$	because $x_i \leq y_i$ for $i = 3$ and 4 ,
$k = x > y$	results in $k = [1 \ 1 \ 0 \ 0]$	because $x_i > y_i$ for $i = 1$ and 2 ,
$k = x \geq y$	results in $k = [1 \ 1 \ 0 \ 1]$	because $x_i \geq y_i$ for $i = 1, 2$, and 4 ,
$k = x == y$	results in $k = [0 \ 0 \ 0 \ 1]$	because $x_i = y_i$ for $i = 4$, and
$k = x \sim= y$	results in $k = [1 \ 1 \ 1 \ 0]$	because $x_i \neq y_i$ for $i = 1, 2$, and 3 .



Logical operators

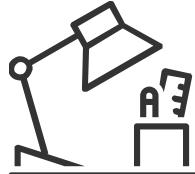
<code>&</code>	Find logical AND
<code>~</code>	Find logical NOT
<code> </code>	Find logical OR
<code>xor</code>	Find logical exclusive-OR
<code>all</code>	Determine if all array elements are nonzero or true
<code>any</code>	Determine if any array elements are nonzero
<code>false</code>	Logical 0 (false)
<code>find</code>	Find indices and values of nonzero elements
<code>islogical</code>	Determine if input is logical array
<code>logical</code>	Convert numeric values to logicals
<code>true</code>	Logical 1 (true)



Logical operators: Examples

Examples: For two vectors $x = [0 \ 5 \ 3 \ 7]$ and $y = [0 \ 2 \ 8 \ 7]$,

$m = (x > y) \& (x > 4)$ results in $m = [0 \ 1 \ 0 \ 0]$, because the condition is true only for x_2 ,
 $n = x \mid y$ results in $n = [0 \ 1 \ 1 \ 1]$, because either x_i or y_i is nonzero for $i = [2 \ 3 \ 4]$,
 $m = \sim(x \mid y)$ results in $m = [1 \ 0 \ 0 \ 0]$, which is the logical complement of $x \mid y$, and
 $p = \text{xor}(x, y)$ results in $p = [0 \ 0 \ 0 \ 0]$, because there is no such index i
for which x_i or y_i , but not both, is nonzero.



Logical operators: builtin functions

In addition to these logical operators, there are many useful built-in logical functions, such as:

<code>all</code>	true (= 1) if all elements of a vector are true, <i>Example:</i> <code>all(x<0)</code> returns 1 if each element of x is negative.
<code>any</code>	true (= 1) if any element of a vector is true, <i>Example:</i> <code>any(x)</code> returns 1 if any element of x is nonzero.
<code>exist</code>	true (= 1) if the argument (a variable or a function) exists,
<code>isempty</code>	true (= 1) for an empty matrix,
<code>isinf</code>	true for all infinite elements of a matrix,
<code>isfinite</code>	true for all finite elements of a matrix,
<code>isnan</code> ³	true for all elements of a matrix that are not a number (NaN), and
<code>find</code>	finds indices of nonzero elements of a matrix. <i>Examples:</i> <code>find(x)</code> returns [2 3 4] for $x=[0 \ 2 \ 5 \ 7]$ and <code>[r,c]=find(A>100)</code> returns the row and column indices i and j of A , in vectors r and c , for which $A_{ij} > 100$.

To complete this list of logical functions, we just mention `isreal`, `issparse`, `isstr`, and `ischar`.



Elementary math functions

Trigonometric functions

sin, sind	sine,	sinh	hyperbolic sine,
asin, asind	inverse sine,	asinh	inverse hyperbolic sine,
cos, cosd	cosine,	cosh	hyperbolic cosine,
acos,acosd	inverse cosine,	acosh	inverse hyperbolic cosine,
tan, tand	tangent,	tanh	hyperbolic tangent,
atan, atand	inverse tangent,	atanh	inverse hyperbolic tangent,
atan2	four-quadrant \tan^{-1} ,		
sec, secd	secant,	sech	hyperbolic secant,
asec, asecd	inverse secant,	asech	inverse hyperbolic secant,
csc, cscd	cosecant,	csch	hyperbolic cosecant,
acsc, acscd	inverse cosecant,	acsch	inverse hyperbolic cosecant,
cot, cotd	cotangent,	coth	hyperbolic cotangent,
acot, acotd	inverse cotangent, and	acoth	inverse hyperbolic cotangent.



Elementary math functions

The angles given to these functions as arguments must be in *radians* for **sin**, **cos**, etc., and in *degrees* for **sind**, **cosd**, etc. Thus, **sin(pi/2)** and **sind(90)** produce the same result. All of these functions, except **atan2**, take a single scalar, vector, or matrix as input argument. The function **atan2** takes two input arguments, **atan2(y,x)**, and produces the four-quadrant inverse tangent such that $-\pi \leq \tan^{-1} \frac{y}{x} \leq \pi$. This gives the angle a rectangular to polar conversion.

Examples: If $q=[0 \ pi/2 \ pi]$, $x=[1 \ -1 \ -1 \ 1]$, and $y=[1 \ 1 \ -1 \ -1]$, then

sin(q) gives $[0 \ 1 \ 0]$,

sinh(q) gives $[0 \ 2.3013 \ 11.5487]$,

atan(y./x) gives $[0.7854 \ -0.7854 \ 0.7854 \ -0.7854]$, and

atan2(y,x) gives $[0.7854 \ 2.3562 \ -2.3562 \ -0.7854]$.



Exponential Functions

exp

exponential,

Example: `exp(A)` produces a matrix with elements $e^{(A_{ij})}$.

So how do you compute e^A ? See the next section.

log

natural logarithm,

Example: `log(A)` produces a matrix with elements $\ln(A_{ij})$.

log10

base 10 logarithm,

Example: `log10(A)` produces a matrix with elements $\log_{10}(A_{ij})$.

sqrt

square root,

Example: `sqrt(A)` produces a matrix with elements $\sqrt{A_{ij}}$.

But what about \sqrt{A} ? See the next section.

nthroot

real n th root of real numbers,

Example: `nthroot(A, 3)` produces a matrix with elements $\sqrt[3]{A_{ij}}$.



Complex Functions

<code>abs</code>	absolute value, <i>Example</i> : <code>abs(A)</code> produces a matrix of absolute values $ A_{ij} $.
<code>angle</code>	phase angle, <i>Example</i> : <code>angle(A)</code> gives the phase angles of complex A .
<code>complex</code>	constructs complex numbers from given real and imaginary parts, <i>Example</i> : <code>complex(A,B)</code> produces $A + Bi$.
<code>conj</code>	complex conjugate, <i>Example</i> : <code>conj(A)</code> produces a matrix with elements \bar{A}_{ij} .
<code>imag</code>	imaginary part, <i>Example</i> : <code>imag(A)</code> extracts the imaginary part of A .
<code>real</code>	real part, <i>Example</i> : <code>real(A)</code> extracts the real part of A .



Round off Functions

fix	round toward 0, <i>Example: fix([-2.33 2.66]) = [-2 2].</i>
floor	round toward $-\infty$, <i>Example: floor([-2.33 2.66]) = [-3 2].</i>
ceil	round toward $+\infty$, <i>Example: ceil([-2.33 2.66]) = [-2 3].</i>
mod	modulus after division; <code>mod(a,b)</code> is the same as <code>a-floor(a./b)*b</code> , <i>Example: mod(26,5) = 1 and mod(-26,5) = 4.</i>
round	round toward the nearest integer, <i>Example: round([-2.33 2.66]) = [-2 3].</i>
rem	remainder after division, <code>rem(a,b)</code> is the same as <code>a-fix(a./b)*b</code> , <i>Example: If a=[-1.5 7], b=[2 3], then rem(a,b) = [-1.5 1].</i>
sign	signum function, <i>Example: sign([-2.33 2.66]) = [-1 1].</i>



Matrix Functions

- | | |
|-----------------------|---|
| <code>expm(A)</code> | finds the exponential of matrix A , e^A , |
| <code>logm(A)</code> | finds $\log(A)$ such that $A = e^{\log(A)}$, and |
| <code>sqrtm(A)</code> | finds \sqrt{A} . |

MATLAB

Unit 6-Lecture 21

Operators Precedence

BTech (CSBS) -Semester VII

30 September 2022, 09:35AM



Control Flow and Operators

- 1) relational and logical operators
- 2) “if ... end” structure
- 3) “for ... end” loop
- 4) “while ... end” loop
- 5) other flow structures
- 6) operator precedence
- 7) saving output to a file



Operators Precedence

1. Parentheses ()
2. Transpose (.'), power (.^), complex conjugate transpose ('), matrix power (^)
3. Power with unary minus (.^-), unary plus (.^+), or logical negation (.^~) as well as matrix power with unary minus (^-), unary plus (^+), or logical negation (^~).
4. Unary plus (+), unary minus (-), logical negation (~)
5. Multiplication (. *), right division (./), left division (. \), matrix multiplication (*), matrix right division (/), matrix left division (\)
6. Addition (+), subtraction (-)
7. Colon operator (:)
8. Less than (<), less than or equal to (<=), greater than (>), greater than or equal to (>=), equal to (==), not equal to (~=)
9. Element-wise AND (&)
10. Element-wise OR (|)

MATLAB

Unit 6-Lecture 22

“if ... end” structure

BTech (CSBS) -Semester VII

4 October 2022, 09:35AM



Control Flow and Operators

- 1) relational and logical operators
- 2) “if ... end” structure
- 3) “for ... end” loop
- 4) “while ... end” loop
- 5) other flow structures
- 6) operator precedence
- 7) saving output to a file



The “IF” statement

The if statement chooses whether another statement, or group of statements, is executed or not. The general form of the if statement is:

```
if condition
    action
end
```

For example, the following if statement checks to see whether the value of a variable is negative. If it is, the value is changed to a zero; otherwise, nothing is changed.

```
if num < 0
    num = 0
end
```



The “IF” statement: Example

sqrtifexam.m

```
% Prompt the user for a number and print its sqrt  
  
num = input ('Please enter a number: ');\n\n% If the user entered a negative number, change it  
if num < 0  
    num = 0;  
end  
fprintf ('The sqrt of %.1f is %.1f\n', num, sqrt (num))
```

Here are two examples of running this script:

```
>> sqrtifexam  
Please enter a number: -4.2  
The sqrt of 0.0 is 0.0
```

```
>> sqrtifexam  
Please enter a number: 1.44  
The sqrt of 1.4 is 1.2
```



The “IF” statement: Example

`sqrtifexampi.m`

```
% Prompt the user for a number and print its sqrt  
  
num = input('Please enter a number: ');\n\n% If the user entered a negative number, tell  
% the user and change it  
if num < 0  
    disp('OK, we''ll use the absolute value')  
    num = abs(num);  
end  
fprintf('The sqrt of %.1f is %.1f\n', num, sqrt(num))
```

```
>> sqrtifexampi  
Please enter a number: -25  
OK, we'll use the absolute value  
The sqrt of 25.0 is 5.0
```



The “IF” statement: Question

Assume that we want to create a vector of increasing integer values from *mymin* to *mymax*. We will write a function *createvec* that receives two input arguments, *mymin* and *mymax*, and returns a vector with values from *mymin* to *mymax* in steps of one. First, we would make sure that the value of *mymin* is less than the value of *mymax*. If not, we would need to exchange their values before creating the vector. How would we accomplish this?

Answer: To exchange values, a third variable, a temporary variable, is required. For example, let's say that we have two variables, *a* and *b*, storing the values:

```
a = 3;  
b = 5;
```

To exchange values, we could *not* just assign the value of *b* to *a*, as follows:

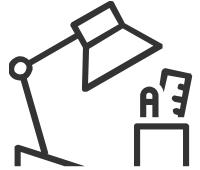
```
a = b;
```

If that were done, then the value of *a* (the 3), is lost! Instead, we need to assign the value of *a* first to a **temporary variable** so that the value is not lost. The algorithm would be:

- assign the value of *a* to *temp*
- assign the value of *b* to *a*
- assign the value of *temp* to *b*

```
>> temp = a;  
>> a = b  
a =  
5  
>> b = temp  
b =  
3
```

Now, for the function. An if statement is used to determine whether or not the exchange is necessary.



The “IF” statement: Question

createvec.m

```
function outvec = createvec (mymin, mymax)
% createvec creates a vector that iterates from a
% specified minimum to a maximum
% Format of call: createvec (minimum, maximum)
% Returns a vector

% If the "minimum" isn't smaller than the "maximum",
% exchange the values using a temporary variable
if mymin > mymax
    temp = mymin;
    mymin = mymax;
    mymax = temp;
end

% Use the colon operator to create the vector
outvec = mymin:mymax;
end
```

Examples of calling the function are:

```
>> createvec (4, 6)
ans =
    4    5    6
```

```
>> createvec (7, 3)
ans =
    3    4    5    6    7
```



“if-else” Statement

The if statement chooses whether or not an action is executed. Choosing between two actions, or choosing from among several actions, is accomplished using if-else, nested if-else, and switch statements.

The if-else statement is used to choose between two statements, or sets of statements. The general form is:

```
if condition
    action1
else
    action2
end
```



“if-else” Statement: Example

For example, to determine and print whether or not a random number in the range from 0 to 1 is less than 0.5, an if-else statement could be used:

```
if rand < 0.5
    disp('It was less than .5!')
else
    disp('It was not less than .5!')
end
```



“if-else” Statement: Example

One application of an if-else statement is to check for errors in the inputs to a script (this is called *error-checking*). For example, an earlier script prompted the user for a radius, and then used that to calculate the area of a circle. However, it did not check to make sure that the radius was valid (e.g., a positive number). Here is a modified script that checks the radius:

checkradius.m

```
% This script calculates the area of a circle
% It error-checks the user's radius
radius = input('Please enter the radius: ');
if radius <= 0
    fprintf('Sorry; %.2f is not a valid radius\n',radius)
else
    area = calcarea(radius);
    fprintf('For a circle with a radius of %.2f,',radius)
    fprintf(' the area is %.2f\n',area)
end
```



“if-else” Statement: Example

Examples of running this script when the user enters invalid and then valid radii are shown as follows:

```
>> checkradius
```

```
Please enter the radius: -4
```

```
Sorry; -4.00 is not a valid radius
```

```
>> checkradius
```

```
Please enter the radius: 5.5
```

```
For a circle with a radius of 5.50, the area is 95.03
```

```
>> if radius <= 0
```

```
    error('Sorry; %.2f is not a valid radius\n', radius)
```

```
end
```

```
Sorry; -4.00 is not a valid radius
```



“if-else” Statement: Example

Examples of running this script when the user enters invalid and then valid radii are shown as follows:

```
>> checkradius
```

```
Please enter the radius: -4
```

```
Sorry; -4.00 is not a valid radius
```

```
>> checkradius
```

```
Please enter the radius: 5.5
```

```
For a circle with a radius of 5.50, the area is 95.03
```

```
>> if radius <= 0
```

```
    error('Sorry; %.2f is not a valid radius\n', radius)
```

```
end
```

```
Sorry; -4.00 is not a valid radius
```



Nested “if-else” Statement

```
y = 1    if    x < -1
y = x2  if    -1 ≤ x ≤ 2
y = 4    if    x > 2
```

The value of y is based on the value of x , which could be in one of three possible ranges. Choosing which range could be accomplished with three separate if statements, is as follows:

```
if x < -1
    y = 1;
end
if x >= -1 && x <=2
    y = x2;
end
if x > 2
    y = 4;
end
```



Nested “if-else” Statement

Above example could also be written as below:

```
if x < -1
    y = 1;
else
    % If we are here, x must be >= -1
    % Use an if-else statement to choose
    % between the two remaining ranges
    if x <= 2
        y = x^2;
    else
        % No need to check
        % If we are here, x must be > 2
        y = 4;
    end
end
```



Nested “if-else” Statement

THE PROGRAMMING CONCEPT

In some programming languages, choosing from multiple options means using nested if-else statements. However, MATLAB has another method of accomplishing this using the elseif clause.

THE EFFICIENT METHOD

To choose from among more than two actions, the elseif clause is used. For example, if there are n choices (where $n > 3$ in this example), the following general form would be used:



Nested “if-else” Statement

THE EFFICIENT METHOD—CONT'D

```
if condition1
    action1
elseif condition2
    action2
elseif condition3
    action3
% etc: there can be many of these
else
    actionn    % the nth action
end
```

The actions of the if, elseif, and else clauses are naturally bracketed by the reserved words if, elseif, else, and end.



“elseif” Statement

For example, the previous example could be written using the elseif clause, rather than nesting if-else statements:

```
if x < -1
    y = 1;
elseif x <= 2
    y = x^2;
else
    y = 4;
end
```



“elseif” Statement

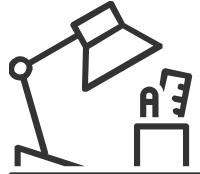
This could be implemented in a function that receives a value of x and returns the corresponding value of y :

`calcY.m`

```
function y = calcY(x)
% calcY calculates y as a function of x
% Format of call: calcY(x)
% y = 1          if x < -1
% y = x^2        if -1 <= x <= 2
% y = 4          if x > 2

if x < -1
    y = 1;
elseif x <= 2
    y = x^2;
else
    y = 4;
end
end
```

```
>> x = 1.1;
>> y = calcY(x)
y =
1.2100
```



“elseif” Statement

How could you write a function to determine whether an input argument is a scalar, a vector, or a matrix?

Answer: To do this, the **size** function can be used to find the dimensions of the input argument. If both the number of rows and columns is equal to 1, then the input argument is scalar. If, however, only one dimension is 1, the input argument is a vector (either a row or column vector). If neither dimension is 1, the input argument is a matrix. These three options can be tested using a nested **if-else** statement. In this example, the word ‘scalar,’ ‘vector,’ or ‘matrix’ is returned from the function.

Note that there is no need to check for the last case: if the input argument isn’t a scalar or a vector, it must be a matrix! Examples of calling this function are:

```
>> findargtype(33)
ans =
scalar

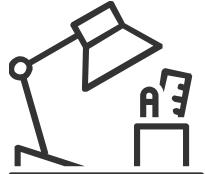
>> disp(findargtype(2:5))
vector

>> findargtype(zeros(2, 3))
ans =
matrix
```

findargtype.m

```
function outtype = findargtype(inputarg)
% findargtype determines whether the input
% argument is a scalar, vector, or matrix
% Format of call: findargtype(inputArgument)
% Returns a string

[r c] = size(inputarg);
if r == 1 && c == 1
    outtype = 'scalar';
elseif r == 1 || c == 1
    outtype = 'vector';
else
    outtype = 'matrix';
end
end
```



“elseif” Statement

letgrade.m

```
function grade = letgrade(quiz)
% letgrade returns the letter grade corresponding
% to the integer quiz grade argument
% Format of call: letgrade(integerQuiz)
% Returns a character

% First, error-check
if quiz < 0 || quiz > 10
    grade = 'X';

% If here, it is valid so figure out the
% corresponding letter grade
elseif quiz == 9 || quiz == 10
    grade = 'A';
elseif quiz == 8
    grade = 'B';
elseif quiz == 7
    grade = 'C';
elseif quiz == 6
    grade = 'D';
else
    grade = 'F';
end
end
```

Three examples of calling this function are:

```
>> quiz = 8;
>> lettergrade = letgrade(quiz)
lettergrade =
B

>> quiz = 4;
>> letgrade(quiz)
ans =
F

>> lg = letgrade(22)
lg =
X
```



Practise question

PRACTICE 4.1

Write an `if` statement that would print "Hey, you get overtime!" if the value of a variable `hours` is greater than 40. Test the `if` statement for values of `hours` less than, equal to, and greater than 40. Will it be easier to do this in the Command Window or in a script?

PRACTICE 4.3

Modify the function `findargtype` to return either 'scalar,' 'row vector,' 'column vector,' or 'matrix,' depending on the input argument.

PRACTICE 4.4

Modify the original function `findargtype` to use three separate `if` statements instead of a nested `if-else` statement.



Practise question

PRACTICE 4.2

Write a script *printsindegorrad* that will:

- prompt the user for an angle
- prompt the user for (r)adians or (d)egrees, with radians as the default
- if the user enters 'd,' the **sind** function will be used to get the sine of the angle in degrees; otherwise, the **sin** function will be used. Which sine function to use will be based solely on whether the user entered a 'd' or not ('d' means degrees, so **sind** is used; otherwise, for any other character the default of radians is assumed so **sin** is used)
- print the result.

Here are examples of running the script:

```
>> printsindegorrad
Enter the angle: 45
(r)adians (the default) or (d)egrees: d
The sin is 0.71
```

```
>> printsindegorrad
Enter the angle: pi
(r)adians (the default) or (d)egrees: r
The sin is 0.00
```

MATLAB

Unit 6-Lecture 23

“for ... end” structure

BTech (CSBS) -Semester VII

7 October 2022, 09:35AM



Control Flow and Operators

- 1) relational and logical operators
- 2) “if ... end” structure
- 3) “for ... end” loop
- 4) “while ... end” loop
- 5) other flow structures
- 6) operator precedence
- 7) saving output to a file



Question

Loop through the matrix and assign each element a new value. Assign 2 on the main diagonal, -1 on the adjacent diagonals and 0 everywhere else.

Given: nrows=4; nclos=6; A=ones(nrows,nclos);

```
for c = 1:ncols
    for r = 1:nrows

        if r == c
            A(r,c) = 2;
        elseif abs(r-c) == 1
            A(r,c) = -1;
        else
            A(r,c) = 0;
        end

    end
end
A
```

A = 4x6

2	-1	0	0	0	0
-1	2	-1	0	0	0
0	-1	2	-1	0	0
0	0	-1	2	-1	0



example using “any”

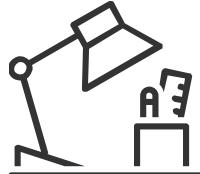
```
limit = 0.75;  
A = rand(10,1)
```

A = 10x1

0.8147
0.9058
0.1270
0.9134
0.6324
0.0975
0.2785
0.5469
0.9575
0.9649

```
if any(A > limit)  
    disp('There is at least one value above the limit.')  
else  
    disp('All values are below the limit.')  
end
```

There is at least one value above the limit.



example using “isequal”

Test Arrays for Equality

Compare arrays using `isequal` rather than the `==` operator to test for equality, because `==` results in an error when the arrays are different sizes.

Create two arrays.

```
A = ones(3,4)  
B = rand(3,4)
```

If `size(A)` and `size(B)` are the same, concatenate the arrays; otherwise, display a warning and return an empty array.

```
if isequal(size(A),size(B))  
    C = [A; B]    % append  
else  
    disp('A and B are not the same size.')  
    C = [];  
end
```

```
A = 3x4  
1 1 1 1  
1 1 1 1  
1 1 1 1  
  
B = 3x4  
0.8055 0.2399 0.4899 0.7127  
0.5767 0.8865 0.1679 0.5005  
0.1829 0.0287 0.9787 0.4711  
  
C = 6x4  
1.0000 1.0000 1.0000 1.0000  
1.0000 1.0000 1.0000 1.0000  
1.0000 1.0000 1.0000 1.0000  
0.8055 0.2399 0.4899 0.7127  
0.5767 0.8865 0.1679 0.5005  
0.1829 0.0287 0.9787 0.4711
```



Evaluate multiple condition in an expression

Q: Determine if a value falls within a specified range.

```
x = 10;  
minVal = 2;  
maxVal = 6;  
  
if (x >= minVal) && (x <= maxVal)  
    disp('Value within specified range.')  
elseif (x > maxVal)  
    disp('Value exceeds maximum value.')  
else  
    disp('Value is below minimum value.')  
end
```

Value exceeds maximum value.



Evaluate multiple condition in an expression

Compare Vectors Containing NaN Values

Create three vectors containing NaN values.

```
A1 = [1 NaN NaN]  
A2 = [1 NaN NaN]  
A3 = [1 NaN NaN]
```

Compare the vectors for equality.

```
tf = isequaln(A1,A2,A3)
```

The result is logical 1 (true) because `isequaln` treats the NaN values as equal to each other.

```
A1 = 1x3  
1   NaN   NaN
```

```
A2 = 1x3  
1   NaN   NaN
```

```
A3 = 1x3  
1   NaN   NaN
```

```
tf = logical  
1
```



Evaluate multiple condition in an expression

Compare Vectors Containing NaN Values

Create three vectors containing NaN values.

```
A1 = [1 NaN NaN]  
A2 = [1 NaN NaN]  
A3 = [1 NaN NaN]
```

Compare the vectors for equality.

```
tf = isequaln(A1,A2,A3)
```

The result is logical 1 (true) because `isequaln` treats the NaN values as equal to each other.

```
A1 = 1×3  
1   NaN   NaN
```

```
A2 = 1×3  
1   NaN   NaN
```

```
A3 = 1×3  
1   NaN   NaN
```

```
tf = logical  
1
```



The “for” loop

The general form of the for loop is:

```
for loopvar = range
    action
end
```

where *loopvar* is the loop variable, “range” is the range of values through which the loop variable is to iterate, and the action of the loop consists of all statements up to the end. Just like with if statements, the action is indented to make it easier to see. The range can be specified using any vector, but normally the easiest way to specify the range of values is to use the colon operator.



The “for” loop: Question

How could you print this column of integers (using the programming method):

0
50
100
150
200

Answer: In a loop, you could print these values starting at 0, incrementing by 50 and ending at 200. Each is printed using a field width of 3.

```
>> for i = 0:50:200  
    fprintf('%3d\n', i)  
end
```



The “for” loop that don’t use iterator

```
for i = 1:3
    fprintf('I will not chew gum\n')
end
```

produces the output:

```
I will not chew gum
I will not chew gum
I will not chew gum
```

The variable *i* is necessary to repeat the action three times, even though the value of *i* is not used in the action of the loop.

What would be the result of the following for loop?

```
for i = 4:2:8
    fprintf('I will not chew gum\n')
end
```

then 8 instead of 1, 2, 3. As the loop variable is not used in the action, this is just another way of specifying that the action should be repeated three times. Of course, using 1:3 makes more sense!

Answer: Exactly the same output as above! It doesn't matter that the loop variable iterates through the values 4, then 6,



Input for “for” loop

`forecho.m`

```
% This script loops to repeat the action of
% prompting the user for a number and echo-printing it

for iv = 1:3
    inputnum = input('Enter a number: ');
    fprintf('You entered %.1f\n', inputnum)
end
```

```
>> forecho
Enter a number: 33
You entered 33.0
Enter a number: 1.1
You entered 1.1
Enter a number: 55
You entered 55.0
```



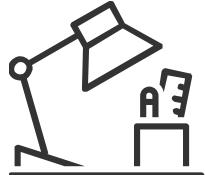
Find sum and product

sumnnums.m

```
% sumnnums calculates the sum of the n numbers
% entered by the user

n = randi([3 10]);
runsum = 0;
for i = 1:n
    inputnum = input('Enter a number: ');
    runsum = runsum + inputnum;
end
fprintf('The sum is %.2f\n', runsum)
```

```
>> sumnnums
Enter a number: 4
Enter a number: 3.2
Enter a number: 1.1
The sum is 8.30
```



Preallocating vector

forgenvec.m

```
% forgenvec creates a vector of length n
% It prompts the user and puts n numbers into a vector

n = randi([4 8]);
numvec = zeros(1, n);
for iv = 1:n
    inputnum = input('Enter a number: ');
    numvec(iv) = inputnum;
end
fprintf('The vector is: \n')
disp(numvec)
```

```
>> forgenvec
Enter a number: 44
Enter a number: 2.3
Enter a number: 11
The vector is:
44.0000  2.3000  11.0000
```

It is very important to notice that the loop variable iv is used as the index into the vector.



Question

QUICK QUESTION!

If you need to just print the sum or average of the numbers that the user enters, would you need to store them in a vector variable?

Answer: No. You could just add each to a running sum as you read them in a loop.

QUICK QUESTION!

What if you wanted to calculate how many of the numbers that the user entered were greater than the average?

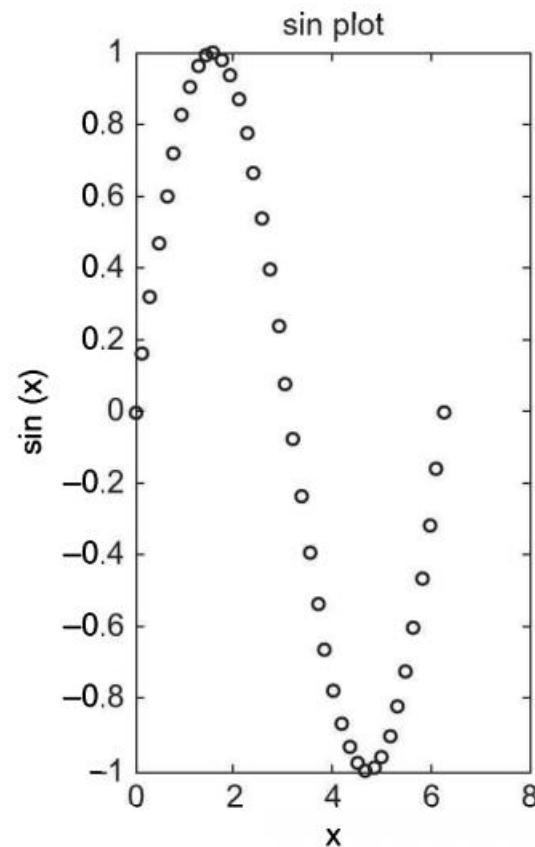
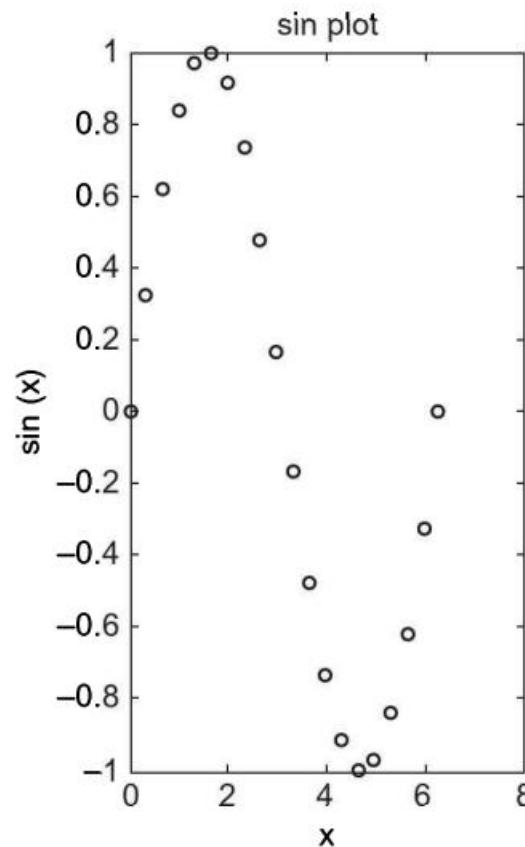
Answer: Yes, then you would need to store them in a vector because you would have to go back through them to count how many were greater than the average (or, alternatively, you could go back and ask the user to enter them again!!).



“for” loop-subplot

subplotex.m

```
% Demonstrates subplot using a for loop
for i = 1:2
    x = linspace(0,2*pi,20*i);
    y = sin(x);
    subplot(1,2,i)
    plot(x,y, 'ko')
    xlabel('x')
    ylabel('sin(x)')
    title('sin plot')
end
```

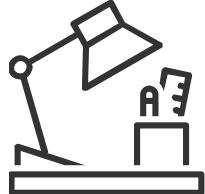




Nested “for” loop

The general form of a nested for loop is as follows:

```
for loopvarone = rangeone      ← outer loop
    % actionone includes the inner loop
    for loopvartwo = rangetwo    ← inner loop
        actiontwo
    end
end
```



Nested “for” loop

- For every row of output:
 - Print the required number of stars
 - Move the cursor down to the next line (print '\n')

printstars.m

```
% Prints a box of stars
% How many will be specified by two variables
% for the number of rows and columns

rows = 3;
columns = 5;
% loop over the rows
for i=1:rows
    % for every row loop to print *'s and then one \n
    for j=1:columns
        fprintf('*')
    end
    fprintf('\n')
end
```

Executing the script displays the output:

```
>> printstars
*****
*****
*****
```



Nested “for” loop

How could this script be modified to print a triangle of stars instead of a box such as the following:

```
*  
**  
***
```

Answer: In this case, the number of stars to print in each row is the same as the row number (e.g., one star is printed in row 1, two stars in row 2, and so on). The inner for loop does not loop to columns, but to the value of the row loop variable (so we do not need the variable *columns*):

`printtristar.m`

```
% Prints a triangle of stars  
% How many will be specified by a variable  
% for the number of rows  
rows = 3;  
for i=1:rows  
    % inner loop just iterates to the value of i  
    for j=1:i  
        fprintf('*')  
    end  
    fprintf('\n')  
end
```



Nested “for” loop

printloopvars.m

```
% Displays the loop variables
for i = 1:3
    for j = 1:2
        fprintf('i=%d, j=%d\n', i, j)
    end
    fprintf('\n')
end
```

>> *printloopvars*

i=1, j=1

i=1, j=2

i=2, j=1

i=2, j=2

i=3, j=1

i=3, j=2



Nested “for” loop

multtable.m

```
function outmat = multtable(rows, columns)
% multtable returns a matrix which is a
% multiplication table
% Format: multtable(nRows, nColumns)

% Preallocate the matrix
outmat = zeros(rows,columns);
for i = 1:rows
    for j = 1:columns
        outmat(i,j) = i*j;
    end
end
end
```

>> multtable(3,5)

ans =

1	2	3	4	5
2	4	6	8	10
3	6	9	12	15



Nested “for” loop

createmulttab.m

```
% Prompt the user for rows and columns and
% create a multiplication table to store in
% a file "mymulttable.dat"

num_rows = input('Enter the number of rows: ');
num_cols = input('Enter the number of columns: ');
multmatrix = multtable(num_rows, num_cols);
save mymulttable.dat multmatrix -ascii
```

```
>> createmulttab
Enter the number of rows: 6
Enter the number of columns: 4
```

```
>> load mymulttable.dat
```

```
>> mymulttable
mymulttable =
    1     2     3     4
    2     4     6     8
    3     6     9    12
    4     8    12    16
    5    10    15    20
    6    12    18    24
```

MATLAB

Unit 6-Lecture 24

“while ... end" loop

BTech (CSBS) -Semester VII

7 October 2022, 09:35AM



Control Flow and Operators

- 1) relational and logical operators
- 2) “if ... end” structure
- 3) “for ... end” loop
- 4) “while ... end” loop
- 5) other flow structures
- 6) operator precedence
- 7) saving output to a file



“while” loop

```
while condition
    action
end
```

factgthigh.m

```
function facgt = factgthigh(high)
% factgthigh returns the first factorial > input
% Format: factgthigh(inputInteger)

i=0;
fac=1;
while fac <= high
    i=i+1;
    fac = fac * i;
end
facgt = fac;
end
```

```
>> factgthigh(5000)
ans =
5040
```



Multiple condition in “while” loop

```
while x >= 0 && x <= 100
```

As another example, continuing the action of a loop may be desired as long as at least one of two variables is in a specified range:

```
while x < 50 || y < 100
```



Input in “while” loop

whileposnum.m

```
% Prompts the user and echo prints the numbers entered
% until the user enters a negative number

inputnum=input ('Enter a positive number: ');
while inputnum >= 0
    fprintf('You entered a %d.\n\n',inputnum)
    inputnum = input ('Enter a positive number: ');
end
fprintf('OK!\n')
```

```
>> whileposnum
Enter a positive number: 6
You entered a 6.

Enter a positive number: -2
OK!
```



Input in “while” loop

As we have seen previously, MATLAB will give an error message if a character is entered rather than a number.

```
>> whileposnum
Enter a positive number: a
Error using input
Undefined function or variable 'a'.

Error in whileposnum (line 4)
inputnum=input ('Enter a positive number: ') ;
Enter a positive number: - 4
OK!
```

However, if the character is actually the name of a variable, it will use the value of that variable as the input. For example:

```
>> a = 5;
>> whileposnum
Enter a positive number: a
You entered a 5.

Enter a positive number: - 4
OK!
```



Counting in “while” loop

countposnum.m

```
% Prompts the user for positive numbers and echo prints as
% long as the user enters positive numbers

% Counts the positive numbers entered by the user
counter=0;
inputnum=input('Enter a positive number: ');
while inputnum >= 0
    fprintf('You entered a %d.\n\n',inputnum)
    counter = counter+1;
    inputnum = input('Enter a positive number: ');
end
fprintf('Thanks, you entered %d positive numbers.\n',counter)
```

```
>> countposnum
Enter a positive number: 4
You entered a 4.

Enter a positive number: 11
You entered a 11.

Enter a positive number: -4
Thanks, you entered 2 positive numbers.
```



Error checking input in “while” loop

readonenum.m

```
% Loop until the user enters a positive number  
  
inputnum=input('Enter a positive number: ');\nwhile inputnum < 0  
    inputnum = input('Invalid! Enter a positive number: ');\nend  
fprintf('Thanks, you entered a %.1f \n',inputnum)
```

An example of running this script follows:

```
>> readonenum  
Enter a positive number: -5  
Invalid! Enter a positive number: -2.2  
Invalid! Enter a positive number: c  
Error using input  
Undefined function or variable 'c'.  
Error in readonenum (line 5)  
    inputnum = input('Invalid! Enter a positive number: ');\nInvalid! Enter a positive number: 44  
Thanks, you entered a 44.0
```



Question

How could we vary the previous example so that the script asks the user to enter positive numbers n times, where n is an integer defined to be 3?

Answer: Every time the user enters a value, the script checks and in a while loop keeps telling the user that it's

`readnnums.m`

```
% Loop until the user enters n positive numbers
n=3;
fprintf('Please enter %d positive numbers\n\n',n)
for i=1:n
    inputnum=input('Enter a positive number: ');
    while inputnum < 0
        inputnum = input('Invalid! Enter a positive number: ');
    end
    fprintf('Thanks, you entered a %.1f \n',inputnum)
end
```

invalid until a valid positive number is entered. By putting the error-check in a for loop that repeats n times, the user is forced eventually to enter three positive numbers, as shown in the following.

```
>> readnnums
Please enter 3 positive numbers

Enter a positive number: 5.2
Thanks, you entered a 5.2
Enter a positive number: 6
Thanks, you entered a 6.0
Enter a positive number: -7.7
Invalid! Enter a positive number: 5
Thanks, you entered a 5.0
```



Question

MATLAB has a **cumsum** function that will return a vector of all of the running sums of an input vector. However, many other languages do not, so how could we write our own?

Answer: Essentially, there are two programming methods that could be used to simulate the **cumsum** function. One method is to start with an empty vector and extend the vector by adding each running sum to it as the running sums are calculated. A better method is to preallocate the vector to the correct size and then change the value of each element to be successive running sums.

`myveccumsum.m`

```
function outvec = myveccumsum(vec)
% myveccumsum imitates cumsum for a vector
% It preallocates the output vector
% Format: myveccumsum(vector)

outvec = zeros(size(vec));
runsum = 0;
for i = 1:length(vec)
    runsum = runsum + vec(i);
    outvec(i) = runsum;
end
end
```

An example of calling the function follows:

```
>> myveccumsum([5 9 4])
ans =
    5 14 18
```



Practise question

PRACTICE 5.1

Write a for loop that will print a column of five *'s.

PRACTICE 5.2

Write a script *prodnums* that is similar to the *sumnums* script but will calculate and print the product of the numbers entered by the user.



Practise question

PRACTICE 5.3

For each of the following (they are separate), determine what would be printed. Then, check your answers by trying them in MATLAB.

```
mat = [7 11 3; 3:5];
[r, c] = size(mat);
for i = 1:r
    fprintf('The sum is %d\n', sum(mat(i,:)))
end
-----
for i = 1:2
    fprintf('%d: ', i)
    for j = 1:4
        fprintf('%d ', j)
    end
    fprintf('\n')
end
```



Practise question

PRACTICE 5.4

Write a function *mymatmin* that finds the minimum value in each column of a matrix argument and returns a vector of the column minimums. An example of calling the function follows:

```
>> mat = randi(20, 3, 4)
```

```
mat =
```

```
15    19    17    5
 6    14    13   13
 9     5     3   13
```

```
>> mymatmin(mat)
```

```
ans =
```

```
6    5    3    5
```



Practise question

PRACTICE 5.5

Write a script *avenegnum* that will repeat the process of prompting the user for negative numbers, until the user enters a zero or positive number, as just shown. Instead of echo printing them, however, the script will print the average (of just the negative numbers). If no negative numbers are entered, the script will print an error message instead of the average. Use the programming method. Examples of executing this script follow:

```
>> avenegnum
Enter a negative number: 5
No negative numbers to average.
```

```
>> avenegnum
Enter a negative number: -8
Enter a negative number: -3
Enter a negative number: -4
Enter a negative number: 6
The average was -5.00
```

MATLAB

Unit 6-Lecture 25

Other flow structure

BTech (CSBS) -Semester VII

11 October 2022, 09:35AM



Control Flow and Operators

- 1) relational and logical operators
- 2) “if ... end” structure
- 3) “for ... end” loop
- 4) “while ... end” loop
- 5) other flow structures
- 6) operator precedence
- 7) saving output to a file



Other flow structures

Repeat Statements Until Expression Is False

Use a while loop to calculate factorial(10).

```
n = 10;
f = n;
while n > 1
    n = n-1;
    f = f*n;
end
disp(['n! = ' num2str(f)])
```

n! = 3628800

% num2str - converts numeric array to character array



Switch,case, otherwise

Syntax

```
switch switch_expression
    case case_expression
        statements
    case case_expression
        statements
    ...
    otherwise
        statements
end
```

Description

`switch switch_expression, case case_expression, end` evaluates an expression and chooses to execute one of several groups of statements. Each choice is a case.

The switch block tests each case until one of the case expressions is true. A case is true when:

- For numbers, `case expression == switch expression`.
- For character vectors, `strcmp(case_expression, switch_expression) == 1`.



Example

Compare Single Values

Display different text conditionally, depending on a value entered at the command prompt.

```
n = input('Enter a number: ');\n\nswitch n\n    case -1\n        disp('negative one')\n    case 0\n        disp('zero')\n    case 1\n        disp('positive one')\n    otherwise\n        disp('other value')\nend
```

At the command prompt, enter the number 1.

positive one

Repeat the code and enter the number 3.

other value

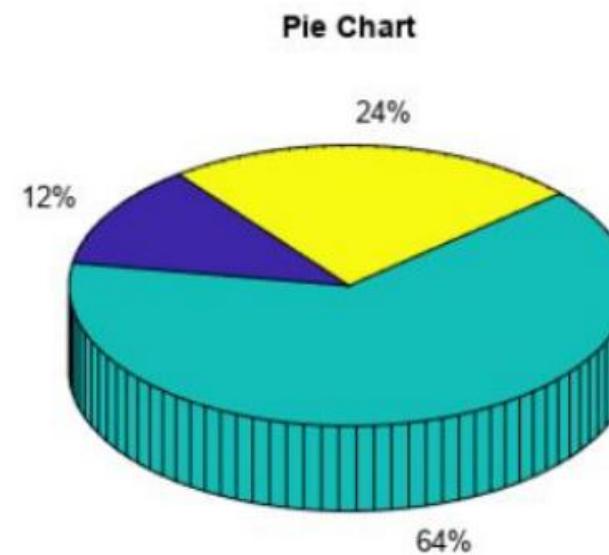


Compare against multiple value

Determine which type of plot to create based on the value of `plottype`. If `plottype` is either 'pie' or 'pie3', create a 3-D pie chart. Use a cell array to contain both values.

```
x = [12 64 24];
plottype = 'pie3';

switch plottype
    case 'bar'
        bar(x)
        title('Bar Graph')
    case {'pie','pie3'}
        pie3(x)
        title('Pie Chart')
    otherwise
        warning('Unexpected plot type. No plot created.')
end
```



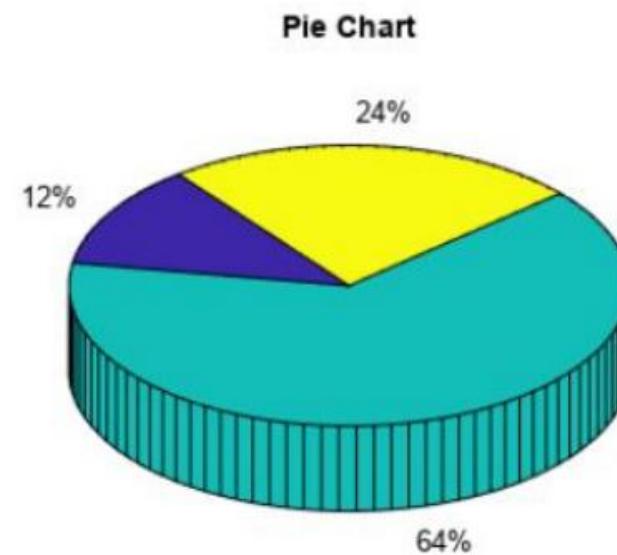


Compare against multiple value

Determine which type of plot to create based on the value of `plottype`. If `plottype` is either 'pie' or 'pie3', create a 3-D pie chart. Use a cell array to contain both values.

```
x = [12 64 24];
plottype = 'pie3';

switch plottype
    case 'bar'
        bar(x)
        title('Bar Graph')
    case {'pie','pie3'}
        pie3(x)
        title('Pie Chart')
    otherwise
        warning('Unexpected plot type. No plot created.')
end
```



MATLAB

Unit 7-Lecture 26

Debugging M-files

BTech (CSBS) -Semester VII

14 October 2022, 09:35AM



Debugging M-files

- 1) Preparing for debugging,
- 2) Examining values,
- 3) Debugging process
- 4) setting breakpoints
- 5) running with breakpoints
- 6) correcting and ending debugging,
- 7) correcting an M- file



Debug MATLAB Code Files

You can diagnose problems in your MATLAB® code files by debugging your code interactively in the Editor and Live Editor or programmatically by using debugging functions in the Command Window. There are several ways to debug your code:

- 1) Display output by removing semicolons.
- 2) Run the code to a specific line and pause by clicking the Run to Here button .
- 3) Step into functions and scripts while paused by clicking the Step In button .
- 4) Add breakpoints to your file to enable pausing at specific lines when you run your code.



Debug MATLAB Code Files

Before you begin debugging, to avoid unexpected results, save your code files and make sure that the code files and any files they call exist on the search path or in the current folder. MATLAB handles unsaved changes differently depending on where you are debugging from:

- 1) Editor — If a file contains unsaved changes, MATLAB saves the file before running it.
- 2) Live Editor — MATLAB runs all changes in a file, whether they are saved or not.
- 3) Command Window — If a file contains unsaved changes, MATLAB runs the saved version of the file. You do not see the results of your changes.



Display Output: Example

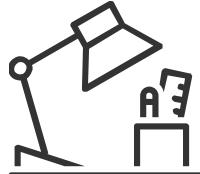
For example, suppose that you have a script called **plotRand.m** that plots a vector of random data and draws a horizontal line on the plot at the mean.

```
n = 50;  
r = rand(n,1);  
plot(r)  
  
m = mean(r);  
hold on  
plot([0,n],[m,m])  
hold off  
title('Mean of Random Uniform Data')
```

Command Window

```
>> plotRand  
  
r =  
  
0.9631  
0.5468  
0.5211  
0.2316  
0.4889  
0.6241  
0.6791
```

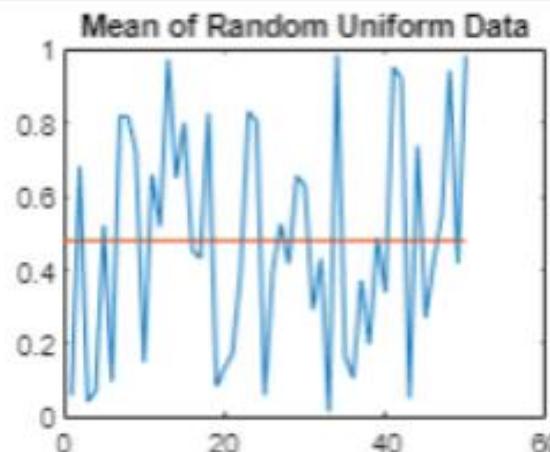
fx



Display Output: Example

```
1 n = 50;
2 r = rand(n,1)
3 plot(r)
4
5 m = mean(r);
6 hold on
7 plot([0,n],[m,m])
8 hold off
9 title('Mean of Random Uniform Data')
```

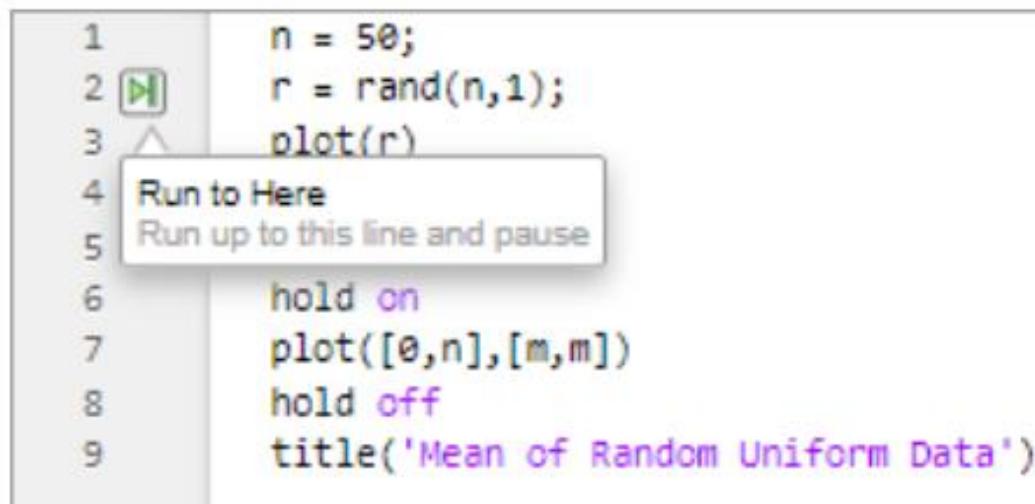
```
r = 50x1
0.0596
0.6820
0.0424
0.0714
0.5216
0.0967
0.8181
0.8175
0.7224
0.1499
:
:
```





Debug Using Run to Here

When debugging, the Run to Here button  becomes the Continue to Here button  In functions and classes, running to a specified line and then pausing is only available when debugging using the Continue to Here button .



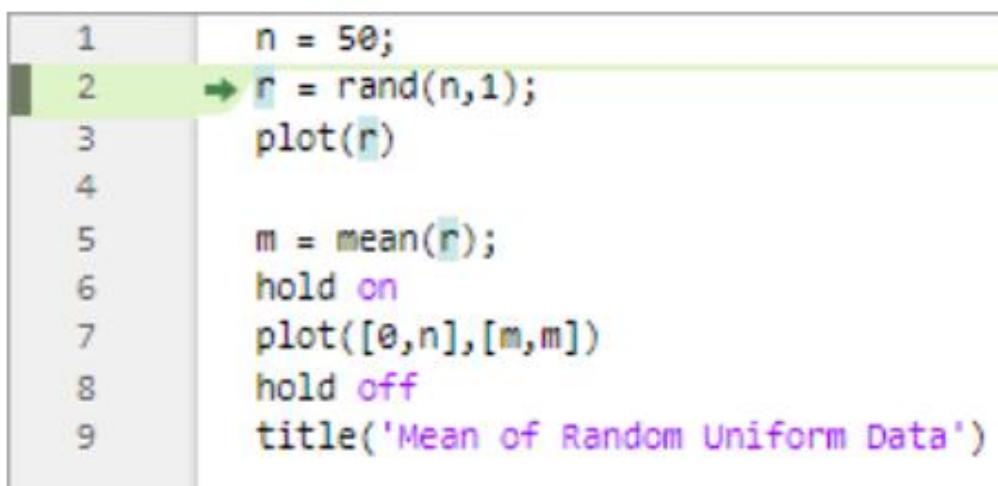
```
1 n = 50;
2 
3 plot(r)
4 Run to Here
5 Run up to this line and pause
6 hold on
7 plot([0,n],[m,m])
8 hold off
9 title('Mean of Random Uniform Data')
```



Debug Using Run to Here

When MATLAB pauses, multiple changes occur:

- 1) The Run button in the **Editor** or Live Editor tab changes to a Continue button.
- 2) The prompt in the Command Window changes to K>> indicating that MATLAB is in debug mode and that the keyboard is in control.
- 3) MATLAB indicates the line at which it is paused by using a green arrow and green highlighting.



```
1 n = 50;
2 r = rand(n,1);
3 plot(r)
4
5 m = mean(r);
6 hold on
7 plot([0,n],[m,m])
8 hold off
9 title('Mean of Random Uniform Data')
```



Debug Using Run to Here

The line at which MATLAB is paused does not run until after you continue running the code. To continue running the code, click the  **Continue** button. MATLAB continues running the file until it reaches the end of the file or a breakpoint. You also can click the Continue to Here button  to the left of the line of code that you want to continue running to.

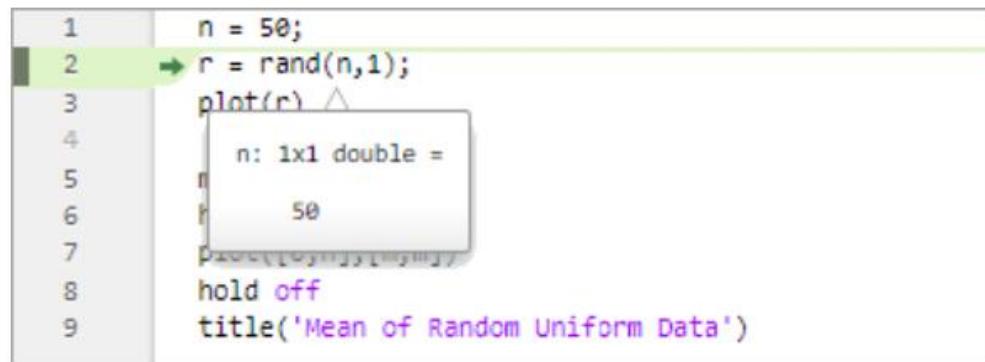
To continue running the code line-by-line, on the **Editor** or **Live Editor** tab, click  **Step**. MATLAB executes the current line at which it is paused and the pauses at the next line.

```
1 n = 50;
2 r = rand(n,1);
3 plot(r)
4
5 m = mean(r);
6 hold on
7 plot([0,n],[m,m])
8 hold off
9 title('Mean of Random Uniform Data')
```



View Variable Value While Debugging

To view the value of a variable while MATLAB is paused, place your cursor over the variable. The current value of the variable appears in a data tip. The data tip stays in view until you move the cursor. To disable data tips, go to the **View** tab and click the  **Datatips** button off.



The screenshot shows the MATLAB Editor with a script containing the following code:

```
1 n = 50;
2 r = rand(n,1);
3 plot(r) ▲
4 n: 1x1 double =
5
6 r
7
8 hold off
9 title('Mean of Random Uniform Data')
```

A data tip is displayed over the variable `n` in line 4. The tip shows the variable's value: `n: 1x1 double = 50`. The data tip has a small triangle icon in the top right corner.

You also can view the value of a variable by typing the variable name in the Command Window. For example, to see the value of the variable `n`, type `n` and press **Enter**. The Command Window displays the variable name and its value. To view all the variables in the current workspace, use the Workspace browser.



Pause a Running File

You can pause long running code while it is running to check on the progress and ensure that it is running as expected. To pause running code, go to the **Editor** or **Live Editor** tab and click the  **Pause** button. MATLAB pauses at the next executable line, and the  **Pause** button changes to a  **Continue** button. To continue running the code, press the  **Continue** button.



Note

Clicking the  **Pause** button can cause MATLAB to pause in a file outside your own code.



Examine Values While Debugging

When debugging a code file, you can view the value of any variable currently in the workspace while MATLAB® is paused. If you want to determine whether a line of code produces the expected result or not, examining values is useful. If the result is as expected, you can continue running the code or step to the next line. If the result is not as you expect, then that line, or a previous line, might contain an error.



View Variable Value

There are several ways to view the value of a variable while debugging:

- Workspace browser — The Workspace browser displays all variables in the current workspace. The Value column of the Workspace browser shows the current value of the variable.

Name	Value	Class
n	6	double
x	[1,2,4,8,16,32,1,1,1,1]	double



View Variable Value

To view more details, double-click the variable. The Variables Editor opens, displaying the content for that variable. You also can use the `openvar` function to open a variable in the Variables Editor.

- **Editor and Live Editor** — To view the value of a variable in the Editor and Live Editor, place your cursor over the variable. The current value of the variable appears in a data tip. The data tip stays in view until you move the cursor. If you have trouble getting the data tip to appear, click the line containing the variable, and then move the pointer next to the variable.

A screenshot of a MATLAB data tip. The code in the background is:

```
for n = 2:6  
    x(n) = 2 * x(n-1);
```

 A data tip box is overlaid on the code, containing the variable `n` and its value:

n: 1x1 double =
6



View Variable Value Outside Current Workspace

You also can use the **dbstack** function to view the current workspace in the Command Window:

To examine the values of variables outside of the current workspace, select a different workspace. In the Editor or Live Editor, select a workspace from the drop-down list to the right of the function call stack at the top of the file.



```
dbstack
> In mean (line 48)
In plotRand (line 5)
```

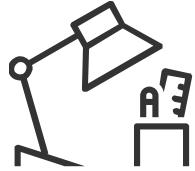


View Variable Value Outside Current Workspace

You also can use the **dbup** and **dbdown** functions in the Command Window to select the previous or next workspace in the function call stack. To list the variables in the current workspace, use **who** or **whos**. If you attempt to view the value of a variable in a different workspace while MATLAB is in the process of overwriting it, MATLAB displays an error in the Command Window.

```
K>> x
Variable "x" is inaccessible. When a variable appears on both sides of an assignment
statement, the variable may become temporarily unavailable during processing.
```

The error occurs whether you select the workspace by using the drop-down list to the right of the function call stack or the **dbup** command.



Debug by Using Keyboard Shortcuts or Functions

Action	Description	Keyboard Shortcut	Function
Continue ➤	Continue running file until the end of the file is reached or until another breakpoint is encountered.	F5	<code>dbcont</code>
Step ⏪	Run the current line of code.	F10 (Shift+Command+O on macOS systems)	<code>dbstep</code>
Step In ⏴	Run the current line of code, and, if the line contains a call to another function, step into that function.	F11 (Shift+Command+I on macOS systems)	<code>dbstep in</code>
Step Out ⏵	After stepping in, run the rest of the called function, leave the called function, and then pause.	Shift+F11 (Shift+Command+U on macOS systems)	<code>dbstep out</code>
Stop ■	End debugging session.	Shift+F5	<code>dbquit</code>
Set Breakpoint	Set a breakpoint at the current line, if no breakpoint exists.	F12	<code>dbstop</code>
Clear Breakpoint	Clear the breakpoint at the current line.	F12	<code>dbclear</code>



Function Call Stack

When you step into a called function or file, MATLAB displays the list of the functions it executed before pausing at the current line. The list, also called the **function call stack**, is shown at the top of the file and displays the functions in order, starting on the left with the first called script or function, and ending on the right with the current script or function in which MATLAB is paused.



For each function in the function call stack, there is a corresponding workspace. Workspaces contain variables that you create within MATLAB or import from data files or other programs. Variables that you assign through the Command Window or create by using scripts belong to the base workspace. Variables that you create in a function belong to their own function workspace.



HW

dbcont	
dbclear	
dbstack	
dbstatus	
dbstop	
dbstep	

MATLAB

Unit 7-Lecture 27

Debugging process , setting breakpoints

BTech (CSBS) -Semester VII

14 October 2022, 09:35AM



Debugging M-files

- 1) preparing for debugging,
- 2) examining values,
- 3) Debugging process
- 4) setting breakpoints
- 5) running with breakpoints
- 6) correcting and ending debugging
- 7) correcting an M- file



Build Process

- Before you can build an executable program or shared library for a model, choose and set up a compiler or IDE and configure the target environment.
- Several methods are available for initiating the build process.
- Tooling is available for reloading, rebuilding, and relocating generated code.
- If your system includes referenced models, reduce build time and control whether the code generator regenerates code for the top model.
- To improve the speed of code execution, consider using available profiling capabilities.

Functions

▼ Initiate Build Process	
<code>packNGo</code>	Package generated code in ZIP file for relocation
<code>rtw_precompile_libs</code>	Build model libraries without building model
<code>codebuild</code>	Compile and link generated code
<code>rtwrebuild</code>	Rebuild generated code from model
<code>slbuild</code>	Build standalone executable file or model reference target for model



Build Process

▼ Get or Modify Build Process Controls

<code>coder.buildstatus.close</code>	Close Build Status window
<code>coder.buildstatus.open</code>	Open Build Status window
<code>RTW.getBuildDir</code>	Get build folder information from model build information
<code>Simulink.fileGenControl</code>	Specify root folders for files generated by diagram updates and model builds
<code>switchTarget</code>	Select target for model configuration set



Debugging Approaches

There are probably a lot of ways to debug programs. These include:

- 1) editing the code and removing semicolons or adding a **keyboard** statement at judicious locations
- 2) **setting a breakpoint** at a particular line and stepping through code from there
- 3) using a variant of setting a breakpoint by using **dbstop if error**
- 4) seeing if the **mlint code analyser** can help (also reachable from the Tools menu)
- 5) comparing variants of the code using the **File and Folder Comparisons** tool or **visdiff** for command-line access



Set Breakpoint

Setting breakpoints pauses the execution of your MATLAB® program so that you can examine values where you think an issue might have occurred. You can set breakpoints interactively in the Editor or Live Editor, or by using functions in the Command Window.

There are three types of breakpoints:

- 1) Standard
- 2) Conditional
- 3) Error



Set Breakpoint

By default, when MATLAB reaches a breakpoint, it opens the file containing the breakpoint.

To disable this option:

1. From the **Home** tab, in the **Environment** section, click  **Preferences**.
2. In the Preferences window, select **MATLAB > Editor/Debugger**.
3. Clear the **Automatically open file when MATLAB reaches a breakpoint** option and click **OK**.



Standard Breakpoints

A standard breakpoint pauses at a specific line in a file. To set a standard breakpoint, click the gray area to the left of the executable line where you want to set the breakpoint. Alternatively, you can press the F12 key to set a breakpoint at the current line. If you attempt to set a breakpoint at a line that is not executable, such as a comment or a blank line, MATLAB sets it at the next executable line.

```
1 n = 50;
2 r = rand(n,1);
3 plot(r)
4
5 m = mean(r);
6 hold on
7 plot([0,n],[m,m])
8 hold off
9 title('Mean of Random Uniform Data')
```



Standard Breakpoints

To set a standard breakpoint programmatically, use the **dbstop** function.

```
dbstop in plotRand at 3
```

When debugging a file that contains a loop, set the breakpoint inside the loop to examine the values at each increment of the loop. Otherwise, if you set the breakpoint at the start of the loop, MATLAB pauses at the loop statement only once. For example, this code creates an array of ten ones and uses a for loop to perform a calculation on items two through six of the array:

```
x = ones(1:10);  
  
for n = 2:6  
    x(n) = 2 * x(n-1);  
end
```



Standard Breakpoints

For MATLAB to pause at each increment of the for loop (a total of five times), set a breakpoint at line four.

A screenshot of a MATLAB code editor. On the left, a vertical line of numbers 3, 4, and 5 is displayed. The number 4 is highlighted with a red box, indicating it is a breakpoint. To the right of the numbers is the MATLAB code:

```
for n = 2:6
    x(n) = 2 * x(n-1);
end
```



Conditional Breakpoints

- To set a conditional breakpoint, right-click the gray area to the left of the executable line where you want to set the breakpoint and select Set Conditional Breakpoint.
- If a breakpoint already exists on that line, select Set/Modify Condition. In the dialog box that opens, enter a condition and click OK.
- A condition is any valid MATLAB expression that returns a logical scalar value.
- **Example:** Set a conditional breakpoint at line four with the condition $n \geq 4$. When you run the code, MATLAB runs through the for loop twice and pauses on the third iteration at line four when n is 4. If you continue running the code, MATLAB pauses again at line four on the fourth iteration when n is 5, and then once more, when n is 6.



Conditional Breakpoints: Example

Code:

```
x = ones(1:10)  
  
for n = 2:6  
    x(n) = 2 * x(n-1);  
end
```

Result:

```
1 x = ones(1:10);  
2  
3  
4  
5 for n = 2:6  
    x(n) = 2 * x(n-1);  
end
```

Stop the file:

```
dbstop in myprogram at 6 if n>=4
```



Error Breakpoints

To set an error breakpoint, on the **Editor** tab, click  **Run** and select from these options:

- **Pause on Errors** to pause on all errors.
- **Pause on Warnings** to pause on all warnings.
- **Pause on NaN or Inf** to pause on NaN (not-a-number) or Inf (infinite) values.

```
dbstop if error
```

```
dbstop if caught error MATLAB:ls:InputsMustBeStrings
```

MATLAB

Unit 7-Lecture 27

Debugging process , setting breakpoints

BTech (CSBS) -Semester VII

14 October 2022, 09:35AM



Debugging M-files

- 1) preparing for debugging,
- 2) examining values,
- 3) Debugging process
- 4) setting breakpoints
- 5) running with breakpoints
- 6) correcting and ending debugging
- 7) correcting an M- file



Build Process

- Before you can build an executable program or shared library for a model, choose and set up a compiler or IDE and configure the target environment.
- Several methods are available for initiating the build process.
- Tooling is available for reloading, rebuilding, and relocating generated code.
- If your system includes referenced models, reduce build time and control whether the code generator regenerates code for the top model.
- To improve the speed of code execution, consider using available profiling capabilities.

Functions

▼ Initiate Build Process	
<code>packNGo</code>	Package generated code in ZIP file for relocation
<code>rtw_precompile_libs</code>	Build model libraries without building model
<code>codebuild</code>	Compile and link generated code
<code>rtwrebuild</code>	Rebuild generated code from model
<code>slbuild</code>	Build standalone executable file or model reference target for model



Build Process

▼ Get or Modify Build Process Controls

<code>coder.buildstatus.close</code>	Close Build Status window
<code>coder.buildstatus.open</code>	Open Build Status window
<code>RTW.getBuildDir</code>	Get build folder information from model build information
<code>Simulink.fileGenControl</code>	Specify root folders for files generated by diagram updates and model builds
<code>switchTarget</code>	Select target for model configuration set



Debugging Approaches

There are probably a lot of ways to debug programs. These include:

- 1) editing the code and removing semicolons or adding a **keyboard** statement at judicious locations
- 2) **setting a breakpoint** at a particular line and stepping through code from there
- 3) using a variant of setting a breakpoint by using **dbstop if error**
- 4) seeing if the **mlint code analyser** can help (also reachable from the Tools menu)
- 5) comparing variants of the code using the **File and Folder Comparisons** tool or **visdiff** for command-line access



Set Breakpoint

Setting breakpoints pauses the execution of your MATLAB® program so that you can examine values where you think an issue might have occurred. You can set breakpoints interactively in the Editor or Live Editor, or by using functions in the Command Window.

There are three types of breakpoints:

- 1) Standard
- 2) Conditional
- 3) Error



Set Breakpoint

By default, when MATLAB reaches a breakpoint, it opens the file containing the breakpoint.

To disable this option:

1. From the **Home** tab, in the **Environment** section, click  **Preferences**.
2. In the Preferences window, select **MATLAB > Editor/Debugger**.
3. Clear the **Automatically open file when MATLAB reaches a breakpoint** option and click **OK**.



Standard Breakpoints

A standard breakpoint pauses at a specific line in a file. To set a standard breakpoint, click the gray area to the left of the executable line where you want to set the breakpoint. Alternatively, you can press the F12 key to set a breakpoint at the current line. If you attempt to set a breakpoint at a line that is not executable, such as a comment or a blank line, MATLAB sets it at the next executable line.

```
1 n = 50;
2 r = rand(n,1);
3 plot(r)
4
5 m = mean(r);
6 hold on
7 plot([0,n],[m,m])
8 hold off
9 title('Mean of Random Uniform Data')
```



Standard Breakpoints

To set a standard breakpoint programmatically, use the **dbstop** function.

```
dbstop in plotRand at 3
```

When debugging a file that contains a loop, set the breakpoint inside the loop to examine the values at each increment of the loop. Otherwise, if you set the breakpoint at the start of the loop, MATLAB pauses at the loop statement only once. For example, this code creates an array of ten ones and uses a for loop to perform a calculation on items two through six of the array:

```
x = ones(1:10);  
  
for n = 2:6  
    x(n) = 2 * x(n-1);  
end
```



Standard Breakpoints

For MATLAB to pause at each increment of the for loop (a total of five times), set a breakpoint at line four.

A screenshot of a MATLAB code editor. On the left, a vertical line of numbers 3, 4, and 5 is displayed. The number 4 is highlighted with a red box, indicating it is a breakpoint. To the right of the numbers is the MATLAB code:

```
for n = 2:6
    x(n) = 2 * x(n-1);
end
```



Conditional Breakpoints

- To set a conditional breakpoint, right-click the gray area to the left of the executable line where you want to set the breakpoint and select Set Conditional Breakpoint.
- If a breakpoint already exists on that line, select Set/Modify Condition. In the dialog box that opens, enter a condition and click OK.
- A condition is any valid MATLAB expression that returns a logical scalar value.
- **Example:** Set a conditional breakpoint at line four with the condition $n \geq 4$. When you run the code, MATLAB runs through the for loop twice and pauses on the third iteration at line four when n is 4. If you continue running the code, MATLAB pauses again at line four on the fourth iteration when n is 5, and then once more, when n is 6.



Conditional Breakpoints: Example

Code:

```
x = ones(1:10)  
  
for n = 2:6  
    x(n) = 2 * x(n-1);  
end
```

Result:

```
1 x = ones(1:10);  
2  
3  
4  
5 for n = 2:6  
    x(n) = 2 * x(n-1);  
end
```

Stop the file:

```
dbstop in myprogram at 6 if n>=4
```



Error Breakpoints

To set an error breakpoint, on the **Editor** tab, click  **Run** and select from these options:

- **Pause on Errors** to pause on all errors.
- **Pause on Warnings** to pause on all warnings.
- **Pause on NaN or Inf** to pause on NaN (not-a-number) or Inf (infinite) values.

```
dbstop if error
```

```
dbstop if caught error MATLAB:ls:InputsMustBeStrings
```

MATLAB

Unit 7-Lecture 28 and 29

Debugging M-files

BTech (CSBS) -Semester VII

18 October 2022, 09:35AM



Control Flow and Operators

- 1) preparing for debugging,
- 2) examining values,
- 3) Debugging process
- 4) setting breakpoints
- 5) running with breakpoints
- 6) correcting an M- file
- 7) correcting and ending debugging



Running with breakpoints

Code:

```
local_max.m x +  
1 [-] function [vals,locs]=local_max(v)  
2 n=length(v);  
3 vals=[];  
4 locs=[];  
5  
6 [-] for m=2:n  
7 if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0  
8     vals=[vals;v(m)];  
9     locs=[locs;m];  
10    end  
11 end  
12 figure; plot (v);  
13 hold on;  
14 plot (locs,vals,'ro');
```



Running with breakpoints

Run:

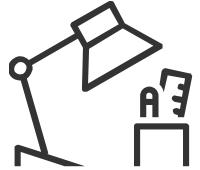
Command Window

```
>> local_max  
Not enough input arguments.
```

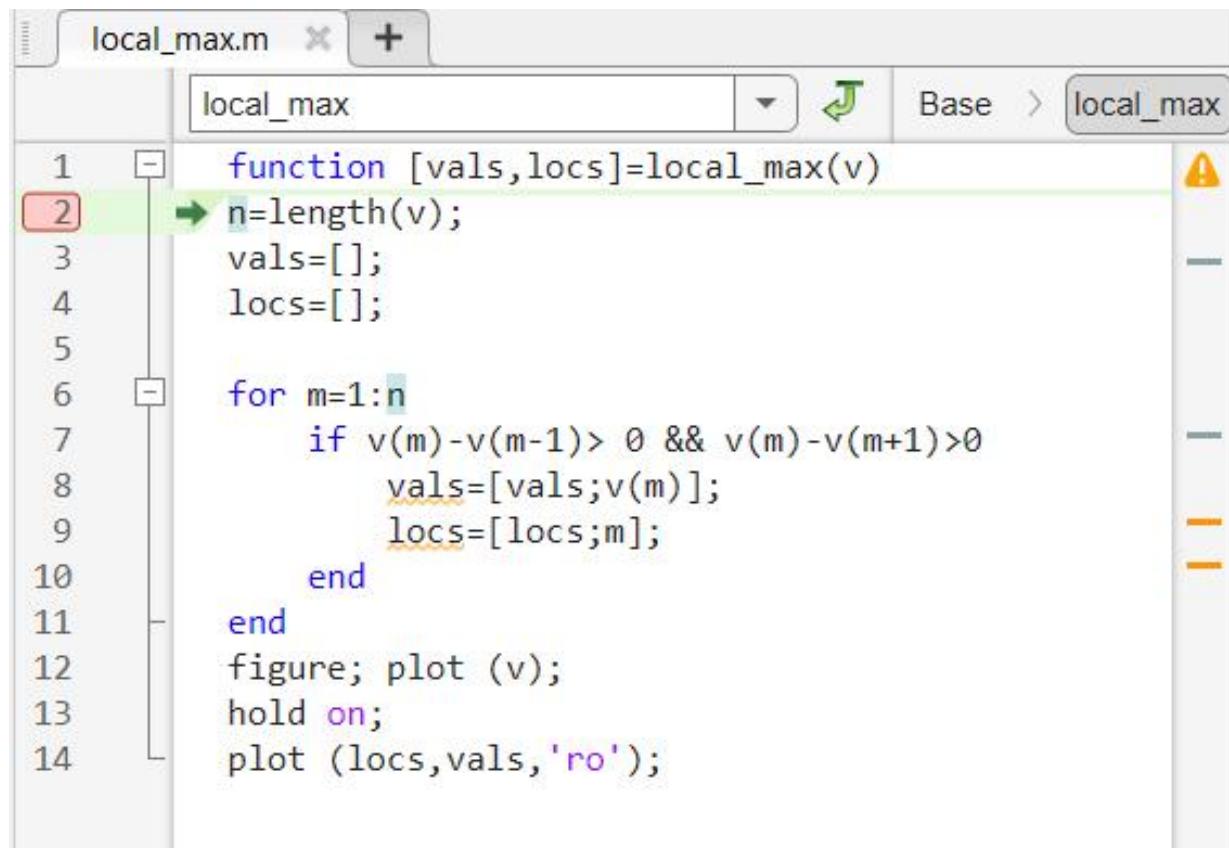
```
Error in local_max (line 2)  
n=length(v);
```

Run
some
value:

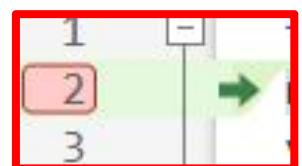
```
>> a=rand(10,1);  
>> [V,L]=local_max(a);  
Array indices must be positive integers or logical values.  
  
Error in local_max (line 7)  
if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
```



Set the breakpoint



```
1 function [vals,locs]=local_max(v)
2 n=length(v);
3 vals=[];
4 locs=[];
5
6 for m=1:n
7     if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
8         vals=[vals;v(m)];
9         locs=[locs;m];
10    end
11 end
12 figure; plot (v);
13 hold on;
14 plot (locs,vals,'ro');
```



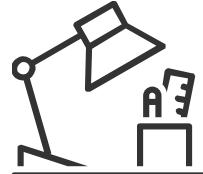
This means the code is not executed yet

Result:

```
>> a=rand(10,1);
>> [v,L]=local_max(a);
2 n=length(v);
fx K>> |
```

All workspace variable are gone:

Workspace - local_max	
Name	Value
v	[0.6557;0.0357;0.8491;0.934...



Execute line: Press Step

Step

local_max.m

```
1 function [vals,locs]=local_max(v)
2 n=length(v);
3 vals=[];
4 locs=[];
5
6 for m=1:n
7     if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
8         vals=[vals;v(m)];
9         locs=[locs;m];
10    end
11 end
12 figure; plot (v);
13 hold on;
14 plot (locs,vals,'ro');
```

Workspace is declared with n values

Workspace - local_max	
Name	Value
n	10
v	[0.6557;0.0357;0.8491;0.934...



Execute line: Press Step



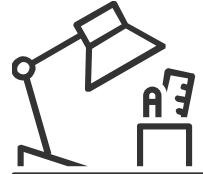
again and again till error line

local_max.m

```
1 function [vals,locs]=local_max(v)
2 n=length(v);
3 vals=[];
4 locs=[];
5
6 for m=1:n
7     if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
8         vals=[vals;v(m)];
9         locs=[locs;m];
10    end
11 end
12 figure; plot (v);
13 hold on;
14 plot (locs,vals,'ro');
```

Workspace is declared with n values

Workspace - local_max	
Name	Value
n	10
v	[0.6557;0.0357;0.8491;0.934...
vals	[]



Execute line: Press Step



again and again till error line

Editor - C:\Users\91887\Desktop\Onedrive\OneDrive - Indian Institute o... X

local_max.m +

local_max

local_max

```
1
2
3
4
5
6 for m=1:n
7     if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
8         vals=[vals;v(m)];
9         locs=[locs;m];
10    end
11 end
12 figure; plot (v);
13 hold on;
14 plot (locs,vals,'ro');
```

Workspace is declared with n values

Workspace - local_max

Name	Value
locs	[]
n	10
v	[0.6557;0.0357;0.8491;0.934...
vals	[]



Execute line: Press Step



again and again till error line

local_max.m

```
1 function [vals,locs]=local_max(v)
2 n=length(v);
3 vals=[];
4 locs=[];
5
6 for m=1:n
7     if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
8         vals=[vals;v(m)];
9         locs=[locs;m];
10    end
11 end
12 figure; plot (v);
13 hold on;
14 plot (locs,vals,'ro');
```

Workspace is declared with n values

Workspace - local_max

Name	Value
locs	[]
m	1
n	10
v	[0.6557;0.0357;0.8491;0.934...
vals	[]



Error line

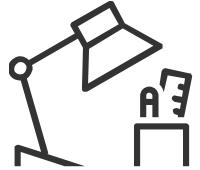
local_max.m

```
1 function [vals,locs]=local_max(v)
2 n=length(v);
3 vals=[];
4 locs=[];
5
6 for m=1:n
7     if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
8         vals=[vals;v(m)];
9         locs=[locs;m];
10    end
11 end
12 figure; plot (v);
13 hold on;
14 plot (locs,vals,'ro');
```

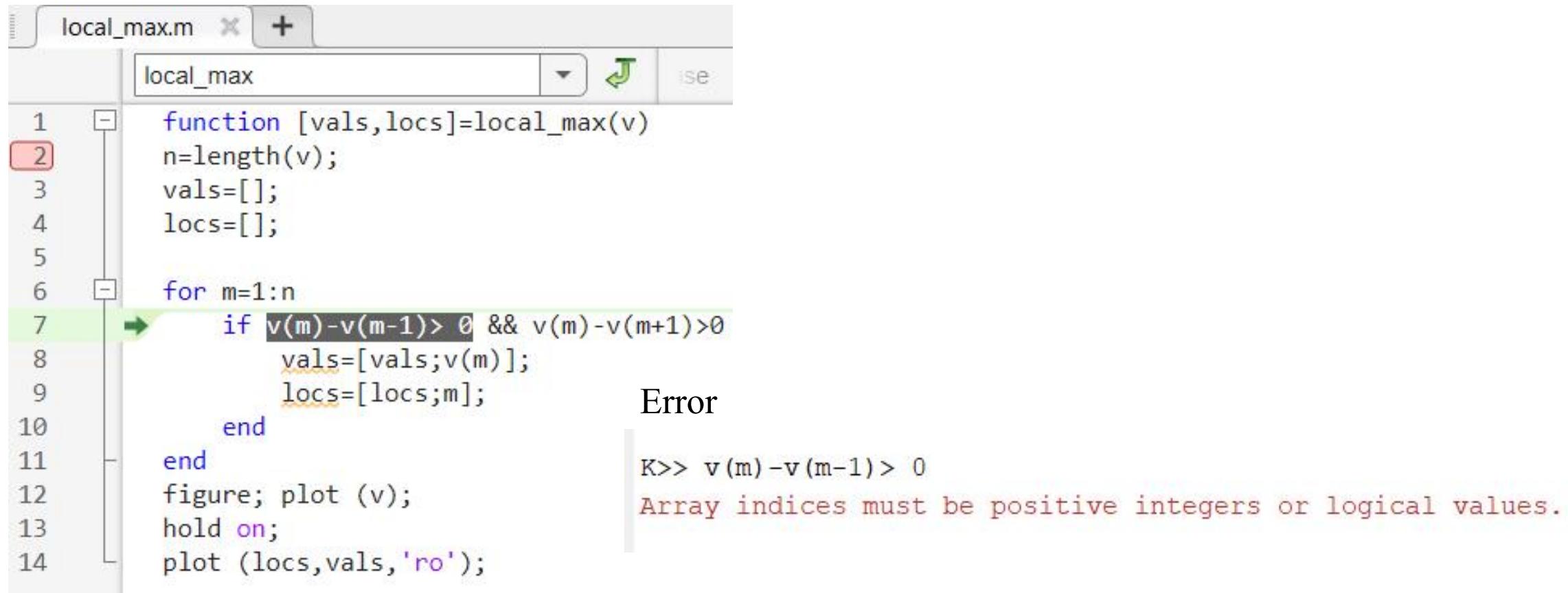


Error

```
>> a=rand(10,1);
>> [V,L]=local_max(a);
2 n=length(v);
K>> v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
Array indices must be positive integers or logical values.
```



Breaking the Error line furthur



```
local_max.m
function [vals,locs]=local_max(v)
n=length(v);
vals=[];
locs=[];
for m=1:n
    if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
        vals=[vals;v(m)];
        locs=[locs;m];
    end
end
figure; plot (v);
hold on;
plot (locs,vals,'ro');
```

1 **2**

3

4

5

6 **7** **Error**

8

9

10

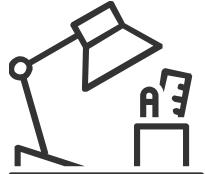
11

12

13

14

K>> v (m) -v (m-1) > 0
Array indices must be positive integers or logical values.



Checking individual terms

```
local_max.m x + local_max 1 2 3 4 5 6 7 8 9 10 11 12 13 14
```

```
function [vals,locs]=local_max(v)
n=length(v);
vals=[];
locs=[];
for m=1:n
    if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
        vals=[vals;v(m)];
        locs=[locs;m];
    end
end
figure; plot (v);
hold on;
plot (locs,vals,'ro');
```

Run:

```
K>> v (m)
ans =
0.66
```



Checking individual terms

```
local_max.m x + local_max
1
2
3
4
5
6
7
8
9
10
11
12
13
14
```

```
function [vals,locs]=local_max(v)
n=length(v);
vals=[];
locs=[];
for m=1:n
    if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
        vals=[vals;v(m)];
        locs=[locs;m];
    end
end
figure; plot (v);
hold on;
plot (locs,vals,'ro');
```

Run:

```
K>> v(m-1)
Array indices must be positive integers or logical values.
```

Since, value of m in line 6 starts from 1. so $v(m-1)$ will be $1-1=0$.

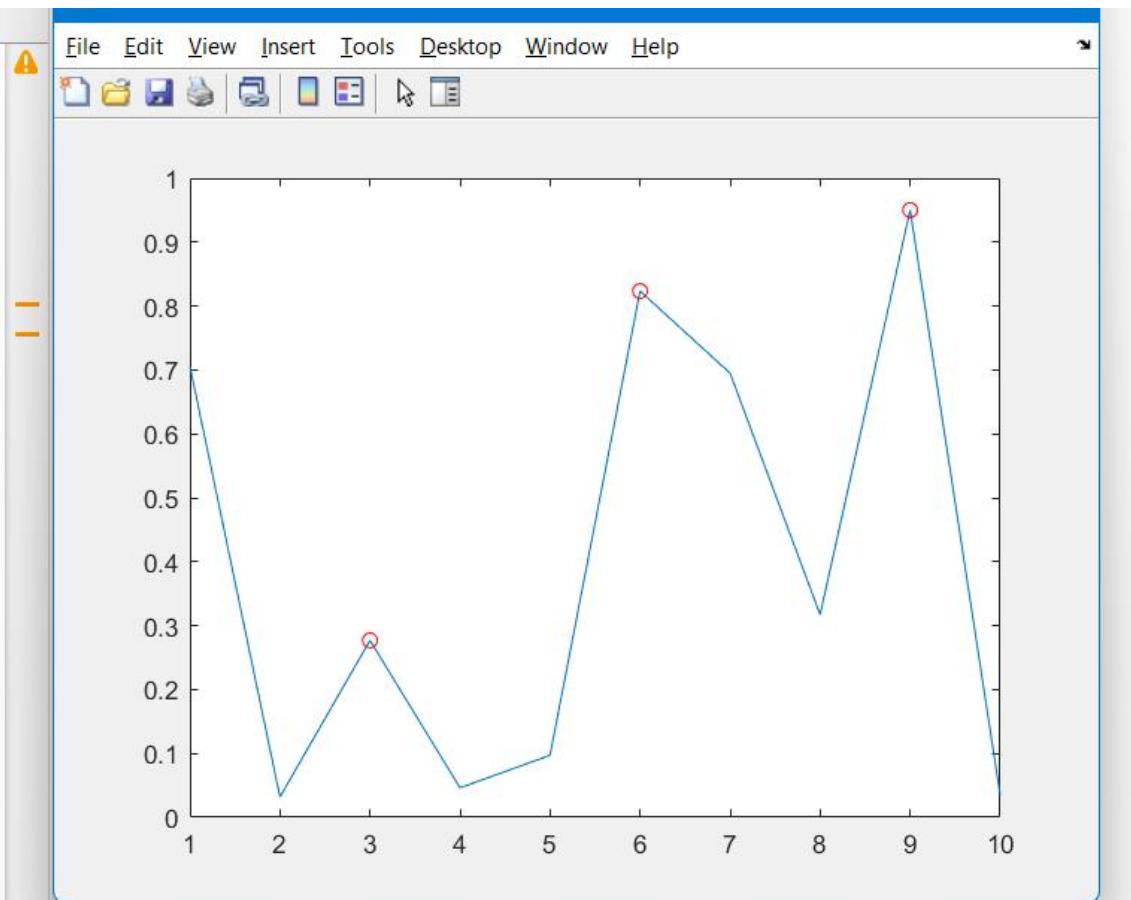
Thus there is an error and need to be corrected.



Correct the code

Quit debugger here, come to the normal .m file, remove breakpoint and run the code

```
local_max.m ✘ +  
1 function [vals,locs]=local_max(v)  
2 n=length(v);  
3 vals=[];  
4 locs=[];  
5  
6 for m=2:n  
7     if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0  
8         vals=[vals;v(m)];  
9         locs=[locs;m];  
10    end  
11 end  
12 figure; plot (v);  
13 hold on;  
14 plot (locs,vals, 'ro');
```



```
K>> v(m-1)  
Array indices must be positive integers or logical values.  
  
>> a=rand(10,1);  
>> [V,L]=local_max(a);  
fr <<
```



Check the values

- write m under for loop
- quit debugger
- stop breakpoint
- save the file
- execute the code

```
local_max.m  ✘ +  
1  [-] function [vals,locs]=local_max(v)  
2      n=length(v);  
3      vals=[];  
4      locs=[];  
5  
6  [-] for m=2:n  
7      m  
8          if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0  
9              vals=[vals;v(m)];  
10             locs=[locs;m];  
11         end  
12     end  
13     figure; plot (v);  
14     hold on;  
15     plot (locs,vals,'ro');
```



Execute the code

```
>> [V,L]=local_max(a);
```

```
m =
```

```
2.00
```

```
m =
```

```
3.00
```

```
m =
```

```
4.00
```

```
m =
```

```
5.00
```

```
m =
```

```
6.00
```

```
m =
```

```
7.00
```

```
m =
```

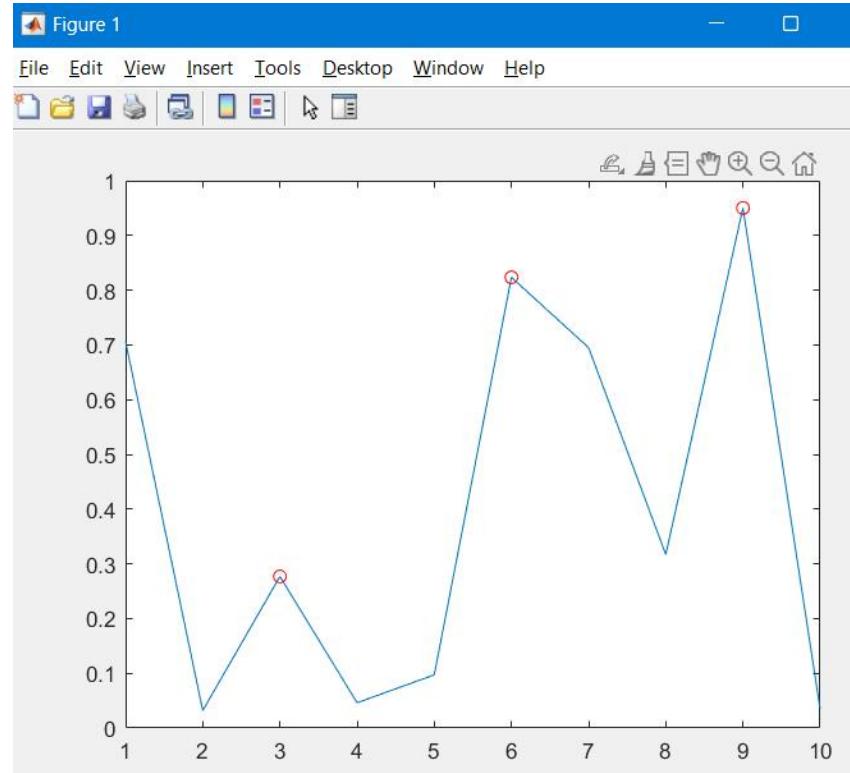
```
8.00
```

```
m =
```

```
9.00
```

```
m =
```

```
10.00
```



Code is executed properly, is there any problem?

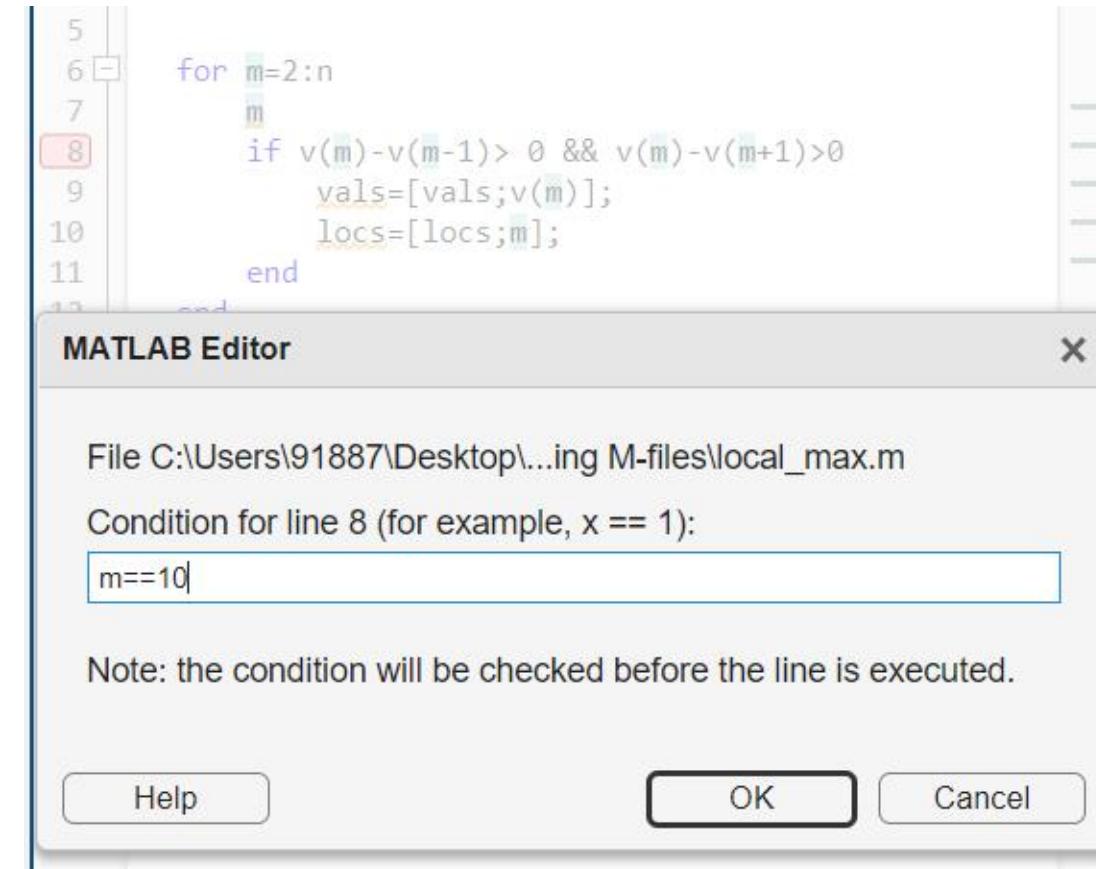


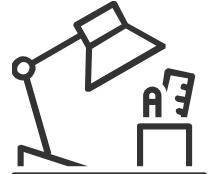
Set a condition breakpoint

```
local_max.m x +  
1 function [vals,locs]=local_max(v)  
2 n=length(v);  
3 vals=[];  
4 locs=[];  
5  
6 for m=2:n  
7 m  
8 if v(m)-v(m-1)>0 && v(m)-v(m+1)>0  
9     vals=[vals;v(m)];  
10    locs=[locs;m];  
11 end  
12 end
```

Line 8 is highlighted with a red box. A context menu is open at this line, showing the following options:

- Set/Modify Condition...
- Disable Breakpoint
- Clear Breakpoint
- Disable All Breakpoints in File
- Clear All Breakpoints
- Clear All Breakpoints in File
- Show Code Folding Margin





Execute file

local_max.m

```
function [vals,locs]=local_max(v)
n=length(v);
vals=[];
locs=[];
for m=2:n
    m
    if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0
        vals=[vals;v(m)];
        locs=[locs;m];
    end
end
figure; plot (v);
hold on;
plot (locs,vals,'ro');
```

m = 5.00

m = 6.00

m = 7.00

m = 8.00

m = 9.00

m = 10.00

8 if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0

fx K>>

Workspace - local_max

Name	Value
locs	[3;6;9]
m	10
n	10
v	[0.7060;0.0318;0.2769;0.046...
vals	[0.2769;0.8235;0.9502]



Error found in line 8 again

```
8         if v(m)-v(m-1)> 0  && v(m)-v(m+1)>0
K>> v(m+1)
Index exceeds the number of array elements. Index must not exceed 10.
```

Now correct the code at line 6, the new code will be



New code

```
local_max.m  ✘ +  
1  [-] function [vals,locs]=local_max(v)  
2      n=length(v);  
3      vals=[];  
4      locs=[];  
5  
6  [-]     for m=2:n-1|  
7      |     m  
8      |     if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0  
9      |     |     vals=[vals;v(m)];  
10     |     |     locs=[locs;m];  
11     |     end  
12   |   end  
13   |   figure; plot (v);  
14   |   hold on;  
15   |   plot (locs,vals,'ro');
```

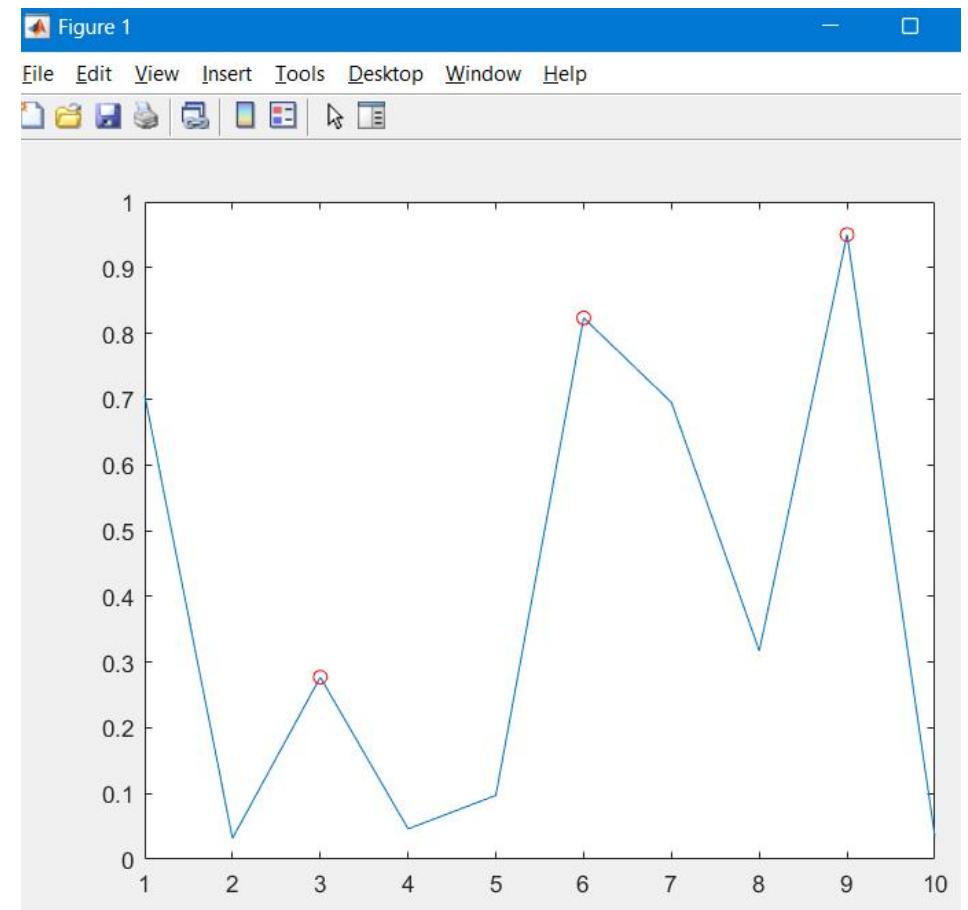
- quit debugger
- stop breakpoint
- save the file
- execute the code



Final code and result

```
local_max.m +  
1 function [vals,locs]=local_max(v)  
2 n=length(v);  
3 vals=[];  
4 locs=[];  
5  
6 for m=2:n-1  
7 m  
8 if v(m)-v(m-1)> 0 && v(m)-v(m+1)>0  
9 vals=[vals;v(m)];  
10 locs=[locs;m];  
11 end  
12 end  
13 figure; plot (v);  
14 hold on;  
15 plot (locs,vals, 'ro');
```

```
Command Window  
m = 4.00  
m = 5.00  
m = 6.00  
m = 7.00  
m = 8.00  
m = 9.00
```



MATLAB

Unit 7-Lecture 30

correcting and ending debugging

BTech (CSBS) -Semester VII

18 October 2022, 09:35AM



Control Flow and Operators

- 1) Debugging process,
- 2) preparing for debugging,
- 3) setting breakpoints,
- 4) running with breakpoints,
- 5) examining values,
- 6) correcting an M- file
- 7) **correcting and ending debugging,**



End Debugging Session

After you identify a problem, to end the debugging session, go to the **Editor** or **Live Editor** tab and click  Stop. After you end debugging, the normal `>>` prompt in the Command Window reappears in place of the `K>>` prompt. You no longer can access the function call stack.

To avoid confusion, make sure to end your debugging session every time you are done debugging. If you make changes to a file and save it while debugging, MATLAB ends the debugging session. If MATLAB becomes unresponsive when it pauses, press **Ctrl+C** to end debugging.



Quit debug mode

Syntax

```
dbquit  
dbquit all
```

dbquit terminates debug mode. The Command Window then displays the standard prompt (>>). The file being executed is not completed and no result is returned. All breakpoints remain in effect. If MATLAB® is in debug mode for more than one function, **dbquit** only terminates debugging for the active function.

For example, if you debug file1 and also debug file2, then running **dbquit** terminates debugging for file2, while file1 remains in debug mode until you run **dbquit** again. However, if you debug file3 and step into file4, then running **dbquit** terminates debugging for both file.

dbquit all ends debugging for all files simultaneously.



Quit debug mode

Create a file, `buggy.m`, that contains these statements.

```
function z = buggy(x)
n = length(x);
z = (1:n)./x;
```

Create a second file, `buggy2.m`, that contains these statements.

```
function z2 = buggy2(y)
m = length(y);
z2 = (1:m).*y;
```

Set breakpoints in `buggy` and `buggy2` and run both files. MATLAB pauses at the first line in `buggy` and `buggy2`.

```
dbstop in buggy
dbstop in buggy2
buggy(5)
buggy2(5)
```



Quit debug mode

Call the `dbstack` command to check the debugging status.

```
dbstack
```

```
In buggy2 (line 2)  
In buggy (line 2)
```

Quit debugging. MATLAB ends debugging for `buggy2`, while `buggy` remains in debug mode.

```
dbquit  
dbstack
```

```
In buggy (line 2)
```

Run `dbquit` again to exit debug mode for `buggy`.

Alternatively, `dbquit all` ends debugging for both files simultaneously.