Introduction to MATLAB

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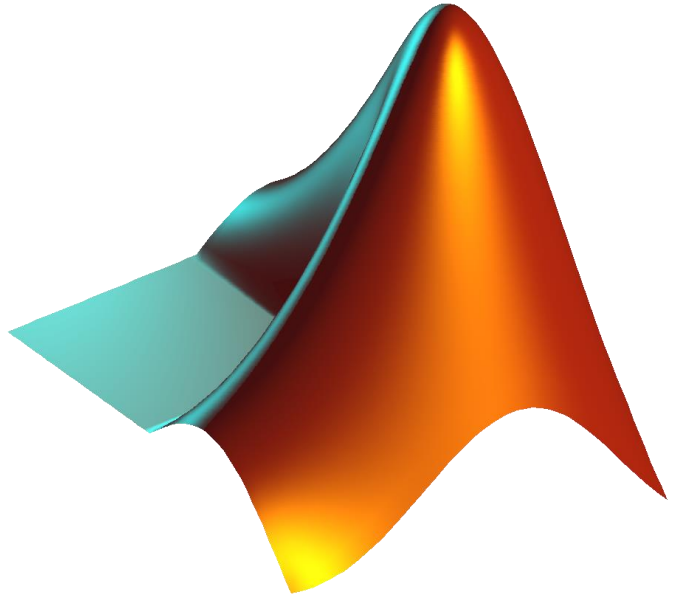
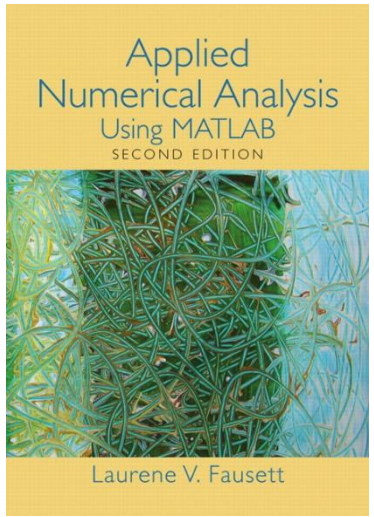
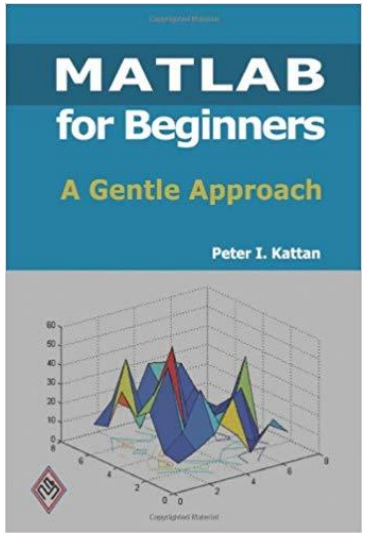
MATLAB

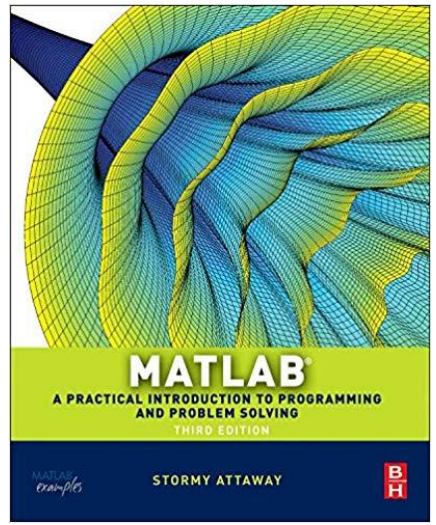


References

- Laurene v. Fausett, Applied Numerical Analysis Using MATLAB, 2nd Edition, 2008
- Matlab Primer, 2014b, The Mathworks Inc.
- Stormy Attarway, Matlab: A Practical Introduction to Programming and Problem Solving 3rd Edition, 2013
- Peter I. Kattan, MATLAB For Beginners: A Gentle Approach, 2018
- S. J. Chapman, Matlab Programming for Engineers, 2004







Best way to learn

- https://in.mathworks.com/help/index.html

Introduction

- MATLAB stands for **MATrix LABoratory**
- Originally written to provide easy access to matrix software
  - Developed by LINPACK and EISPACK projects
- High-performance language for technical Computing

Capability

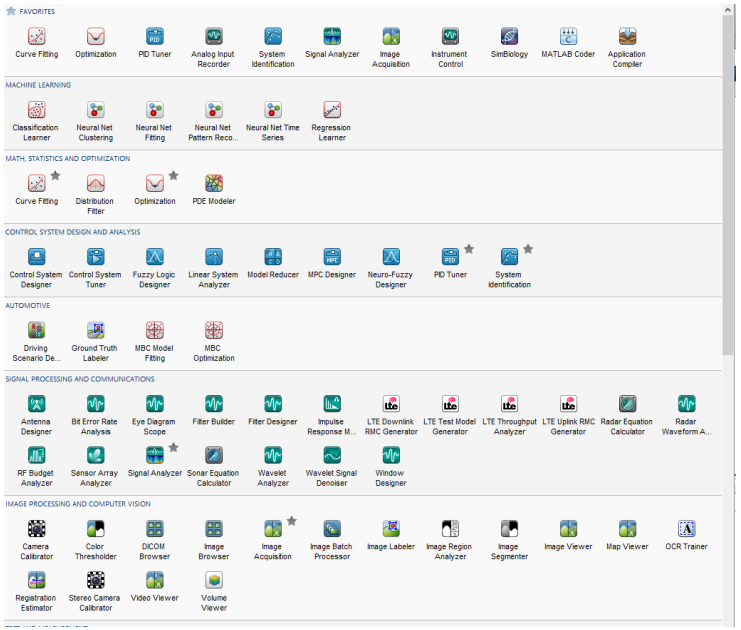
- Computation
- Visualization
- Programming
- Data Structures
- Debugging tool
- Object-Oriented Programming

Advantages over C or C++

- Interactive System
- Basic data is an array without any dimension
- Powerful built-in routines
- Graphics commands for visualization

Toolboxes

- Signal Processing
- Symbolic Computation
- Control theory
- Simulation
- Optimization
- Curve Fitting

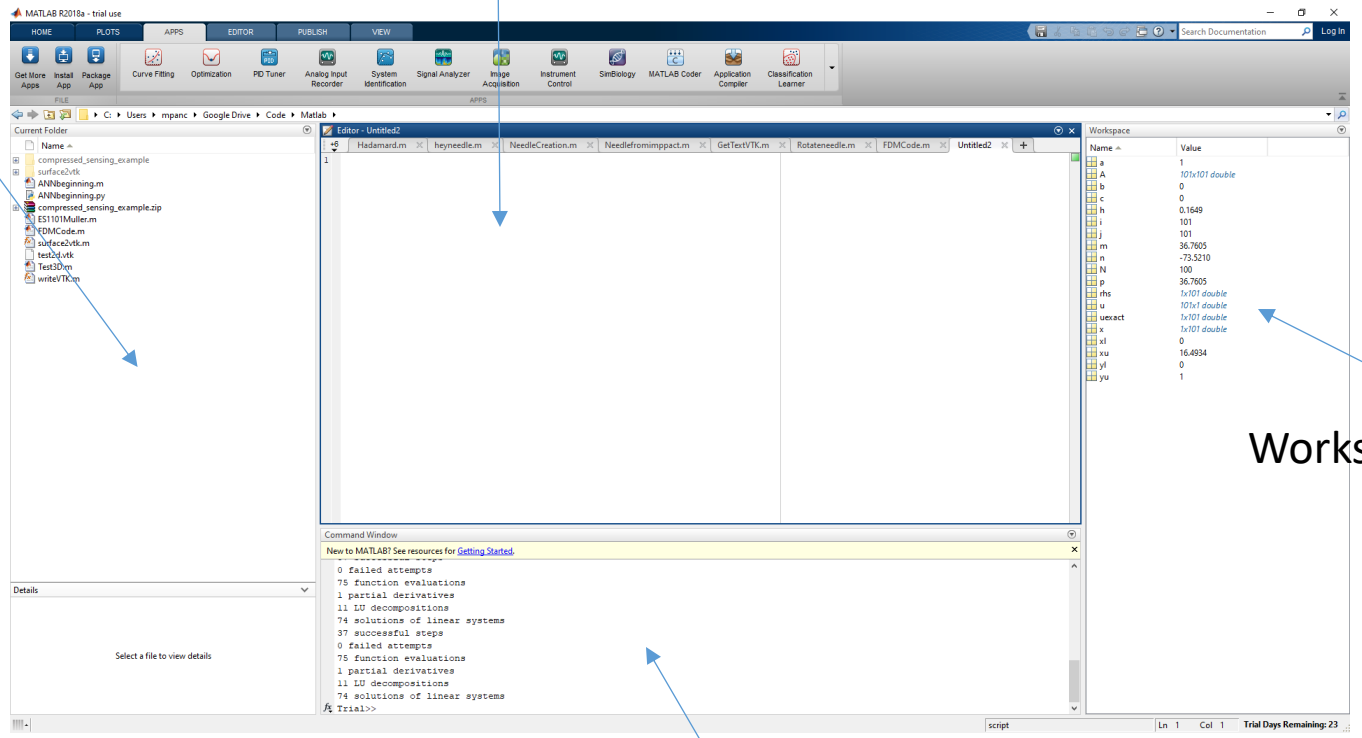


- PID Tuner
- Analog Input Recorder
- Image Acquisition
- Simbiology
- Machine Learning
- Distribution

Graphical Interface

Editor

File Browser



Workspace Variables

Command Window

First Program

1. Open a new file.
2. Save the file name. FirstProgram.m (.m denotes matlab file)
3. Type the following code

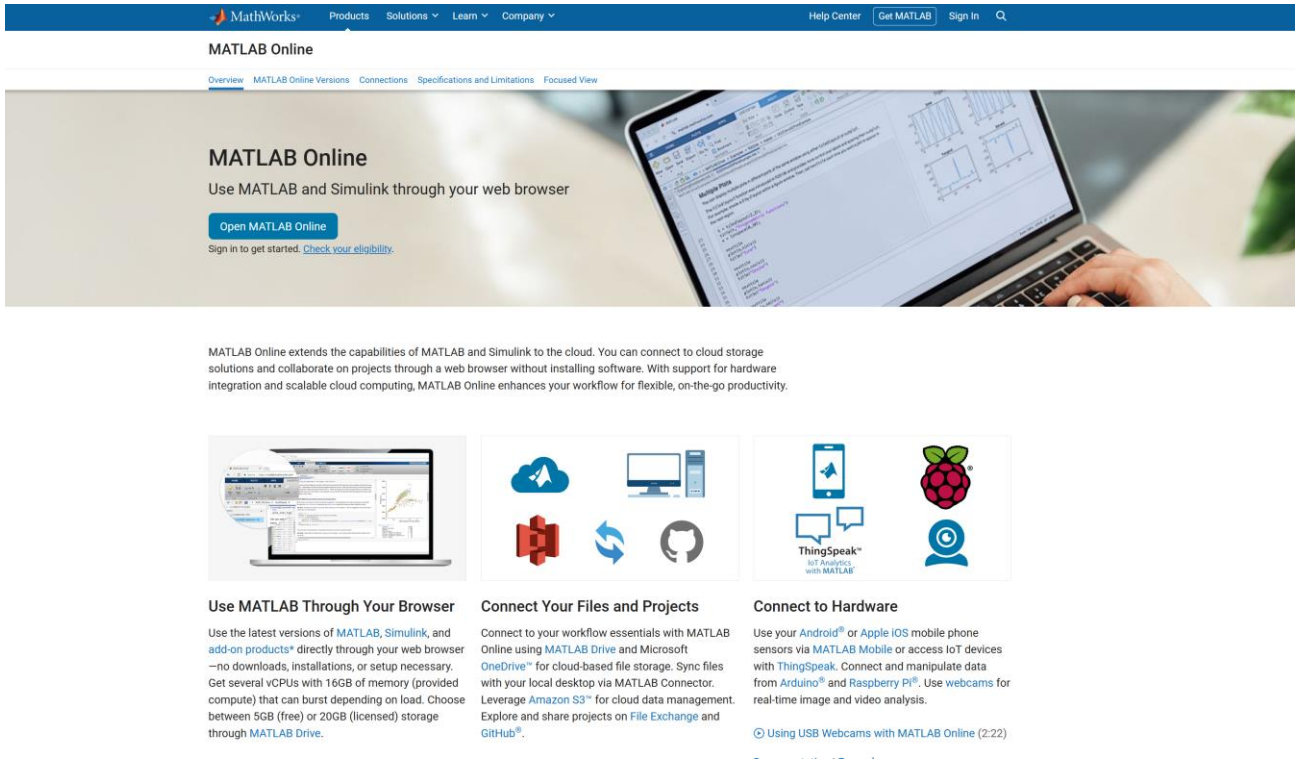
```
x = 1 + 2*3
Y=[2,3,4,5]
A=[1,2,3;4,5,6;7,8,9]
```

4. Save the file
5. Press F5 or go to Editor menu and then press RUN button
6. View the output

MATLAB Online

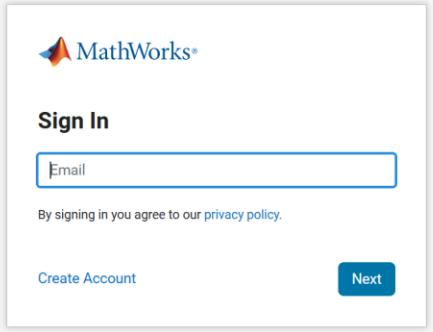
Visit the Following Link
https://in.mathworks.com/products/matlab-online.html

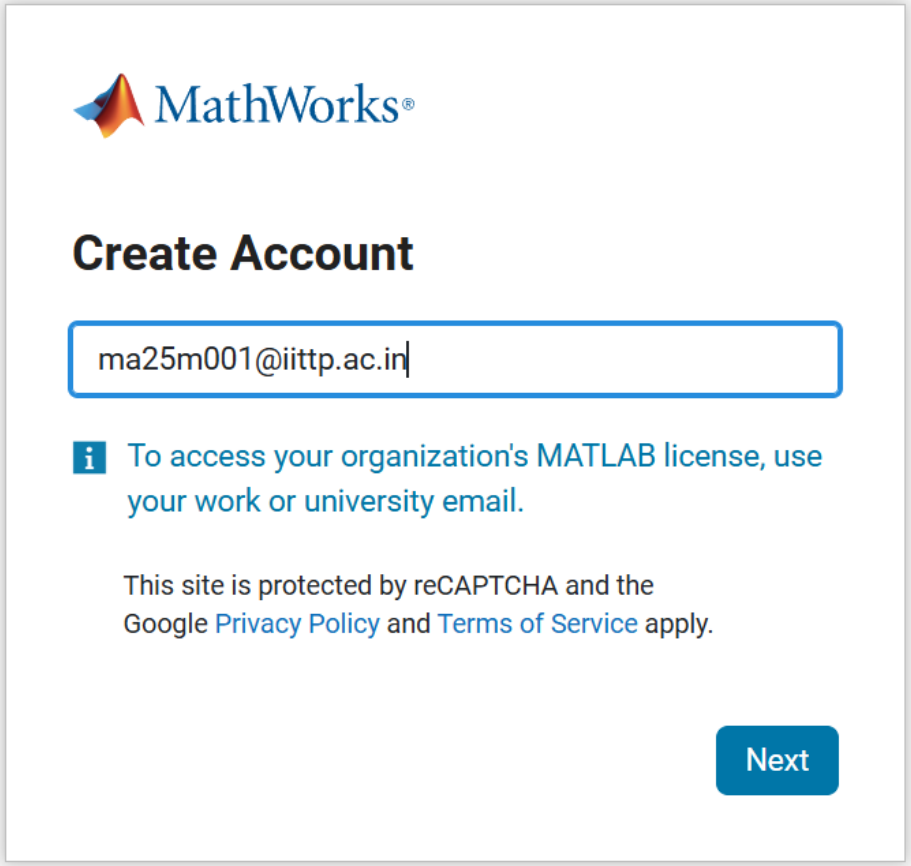
Click **Open MATLAB Online**



MATLAB Online

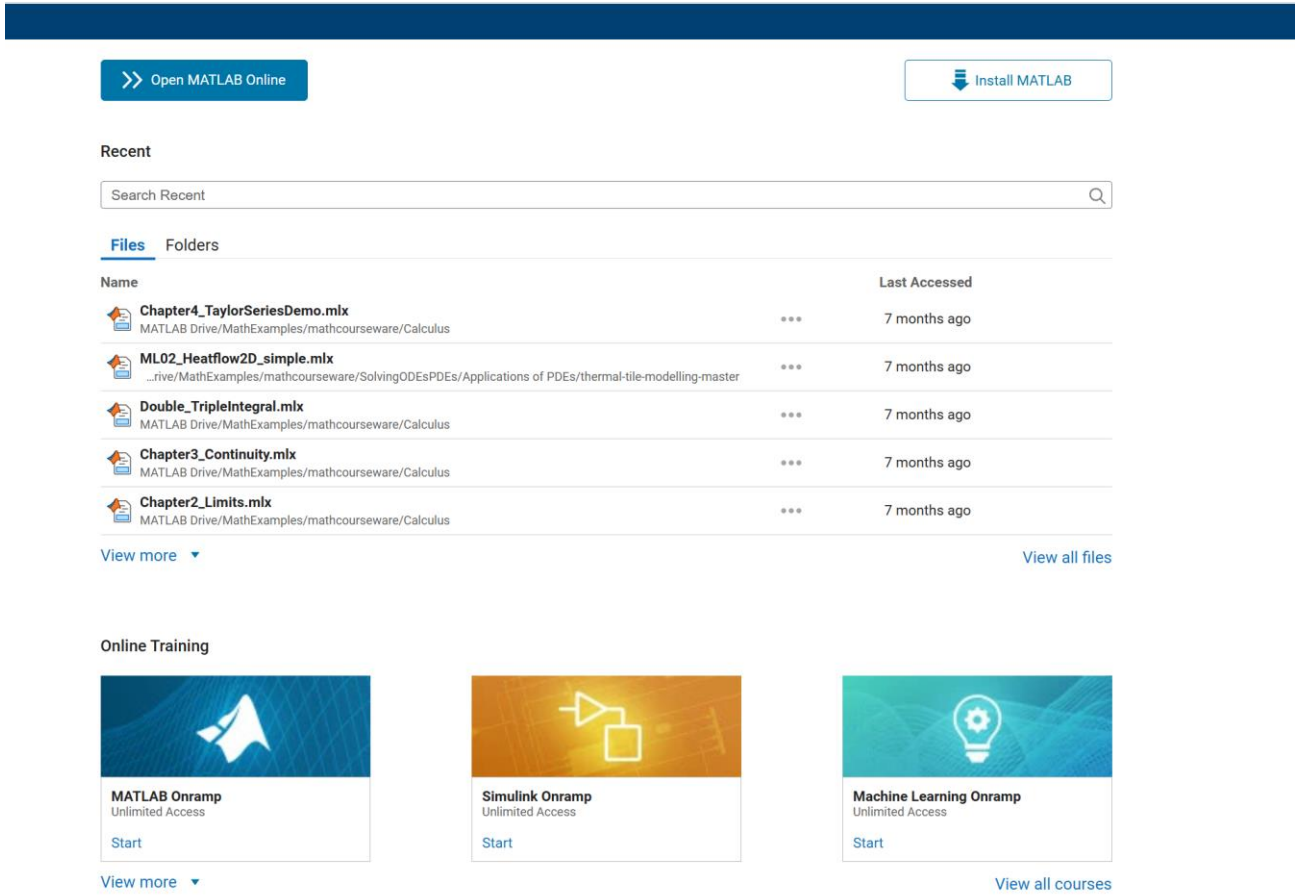
Create Account



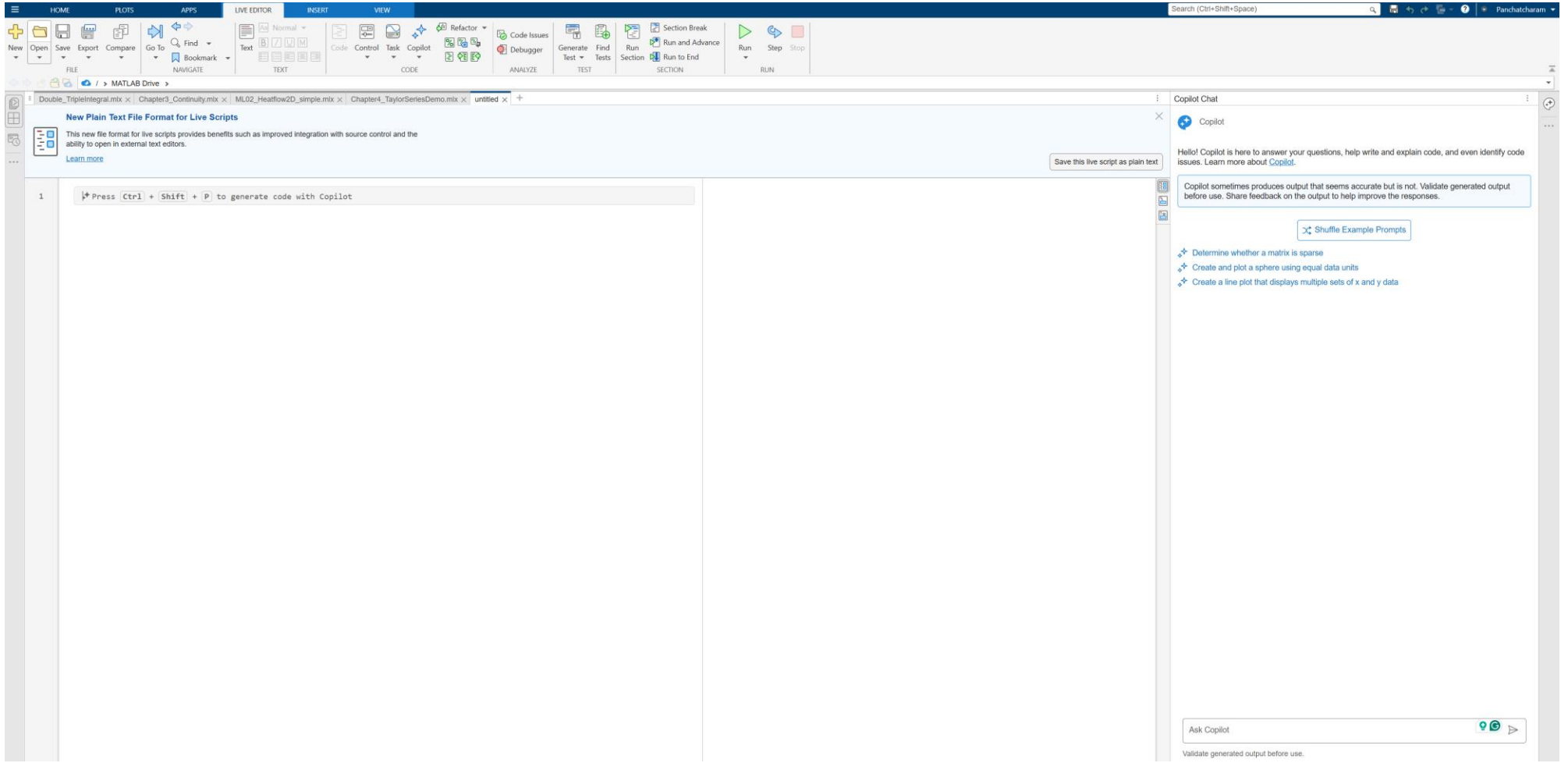


MATLAB Online

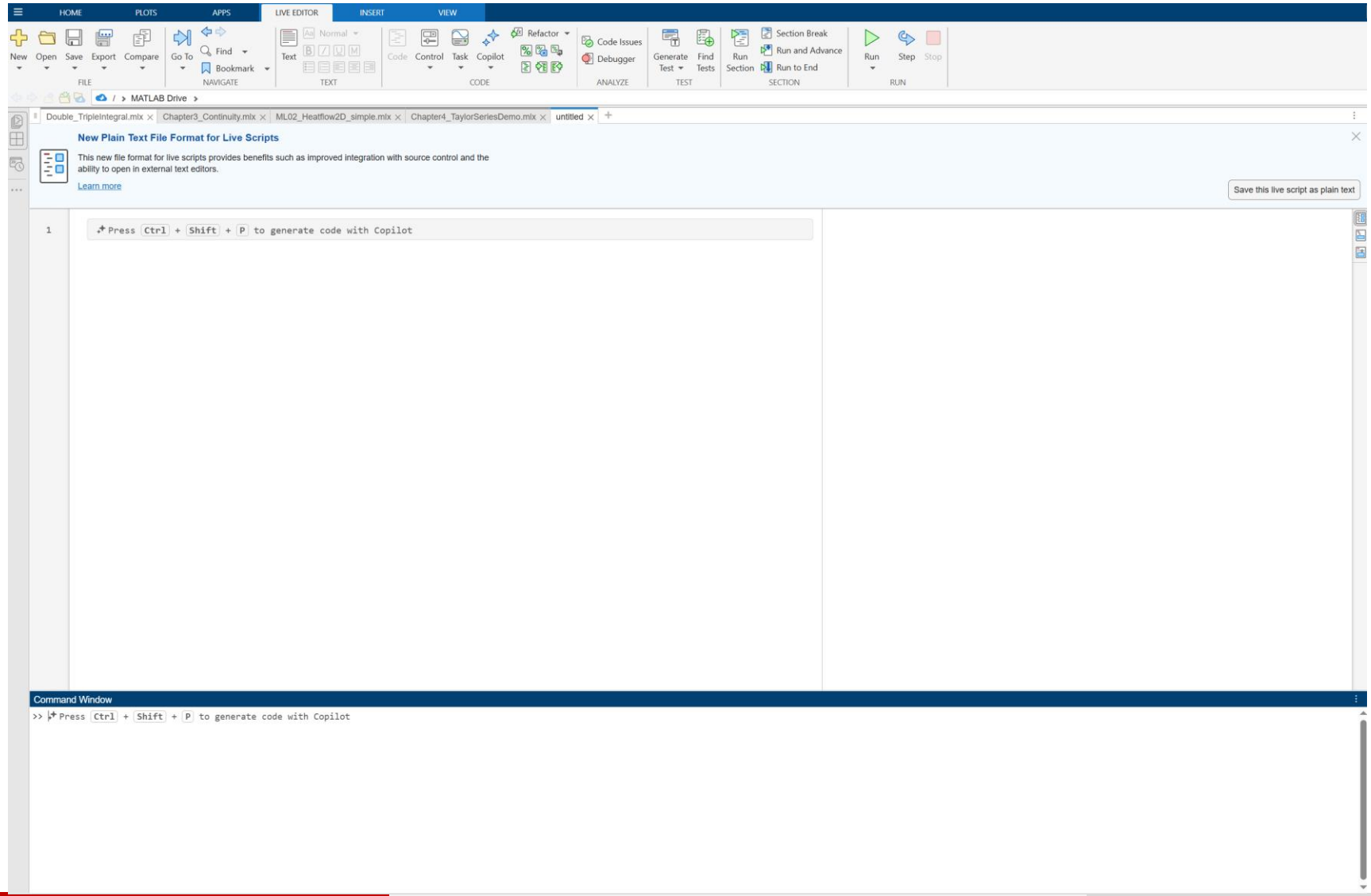
Open MATLAB Online



MATLAB Online



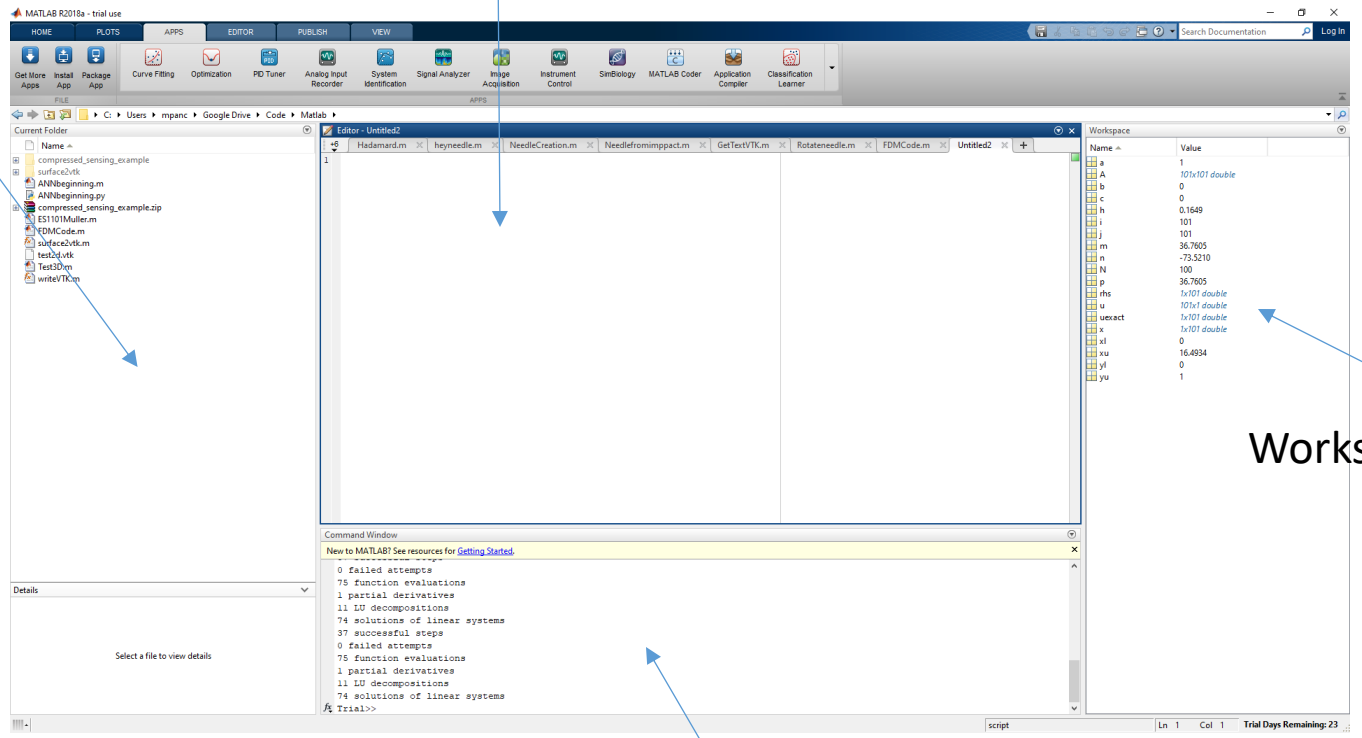
MATLAB Online



Graphical Interface

Editor

File Browser



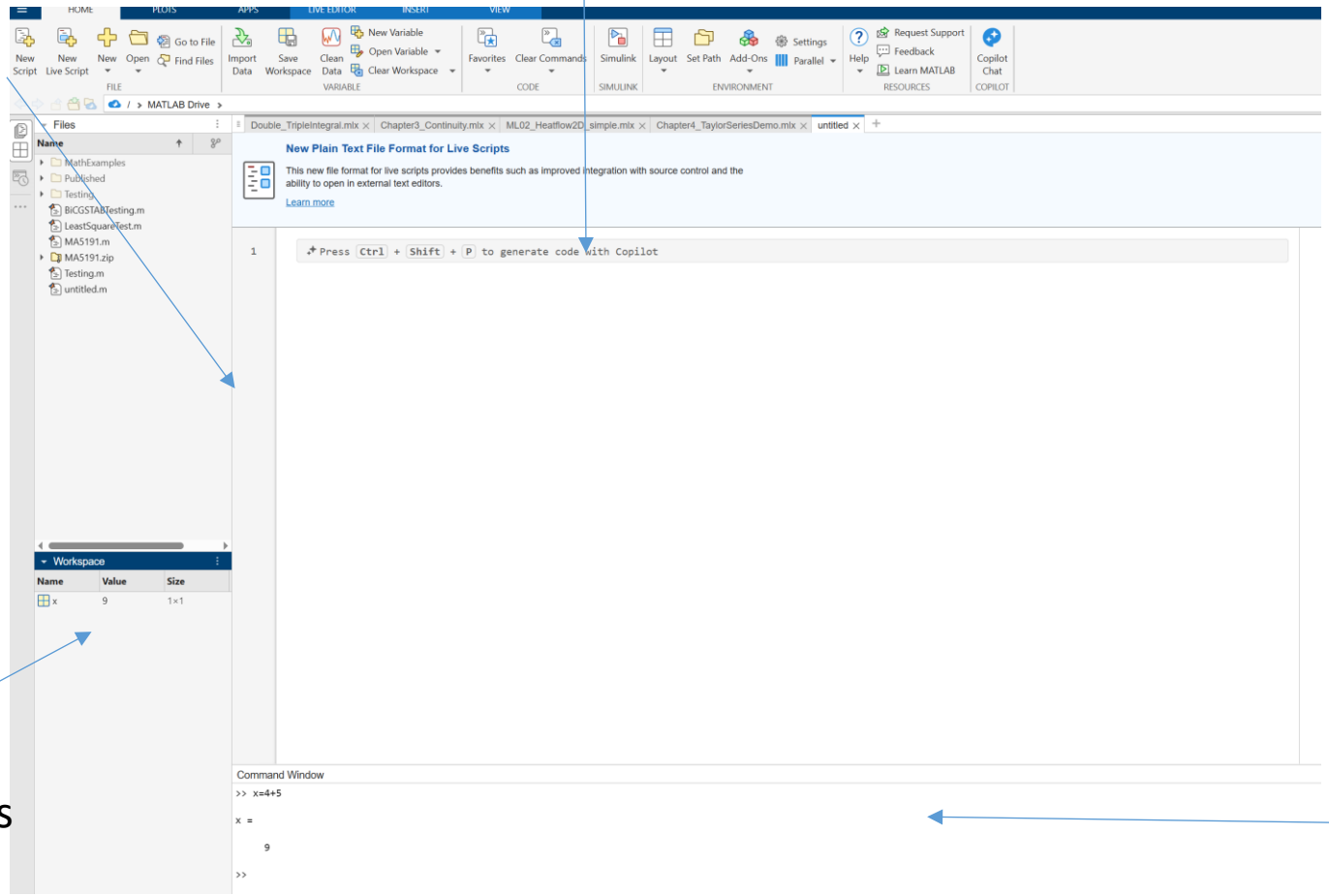
Workspace Variables

Command Window

Graphical Interface

Editor

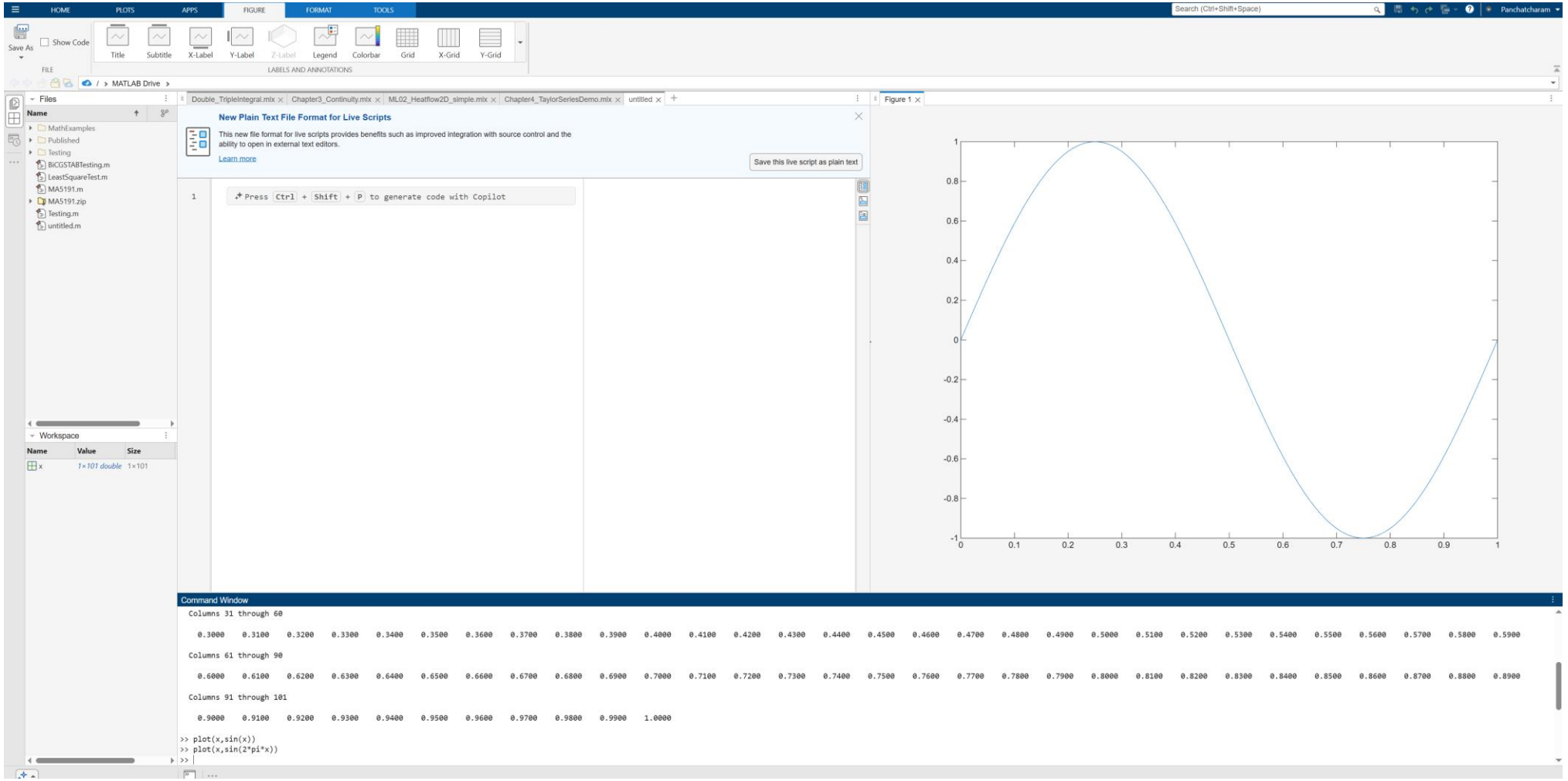
File Browser



Workspace Variables

Command Window

MATLAB Online



Variables

```
>> variable name = a value (or an expression)
Example:
X = expression
```

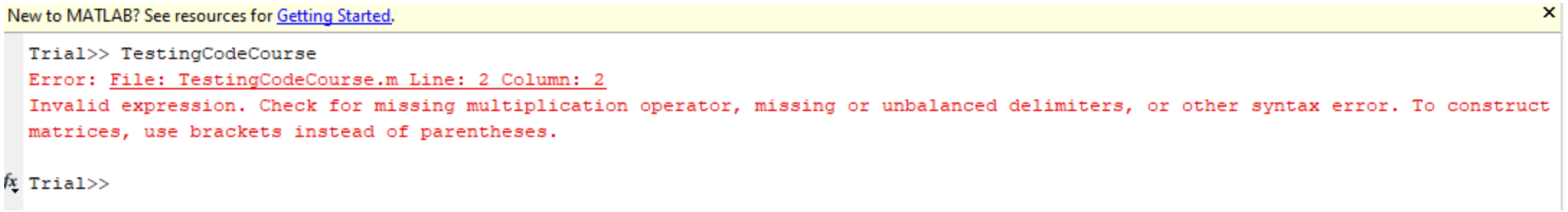
Symbol	Operation	Example
+	Addition	2+3
-	Subtraction	2-3
*	Multiplication	2*3
/	Division	2/3
^	Exponent	2^3

Error

- If you enter incorrect expression and run the file, you will get an error message saying type of error and the line number.
- Correct the error to proceed further

Example

```
x=3+5
2x
```



Workspace Management

```
clear all
clc
close all
who
diary
diary filename
help sqrt
doc plot
lookfor inverse
```

Mathematical Functions

Function	Description	Function	Description
`cos(x)`	Cosine	`abs(x)`	Absolute Value
`sin(x)`	Sine	`sign(x)`	Signum function
`tan(x)`	Tangent	`max(x)`	Maximum
`asin(x)`	Arcsin	`min(x)`	Minimum
`acos(x)`	Arc cosine	`ceil(x)`	Ceiling
`atan(x)`	Arc tangent	`floor(x)`	Floor
`exp(x)`	Exponential	`round(x)`	Round to nearest integer
`sqrt(x)`	Square root	`rem(x)`	Remainder
`log(x)`	Natural Log	`conj(x)`	Complex conjugate
`log10(x)`	Common log		

Constants

Function	Description
`pi`	
`i, j`	Imaginary unit
`Inf`	infinity
`Nan`	Not a Number

Vector

```
V=[1 4 7 10 13] %Row Vector
U=[1;2;3;4;5]%column vector
W=U' % Transpose
V(1:3) %slicing ans = 1 4 7
V(3:end) %slicing ans =7 10 13
V(:) %Complete vector (column)
V(1:end) %Complete Vector (row)
```

Indexing Starts at 1

End indices are inclusive

Matrix

```
A=[1 4 7; 10 13 14; 12 1 2] %3x3 matrix
A(2,1) %ans = 10

Indexing: A(i,j), i>=1, j>=1
```

No negative or zero scripts

Remember the brackets not square brackets [ ]

Instead ( )

Colon Operator

```
X=0:0.1:1
Ans
0  0.1  0.2  0.3  0.4  0.5  0.6  0.7  0.8  0.9  1
A=[1  4  7; 10  13  14; 12  1  2] %3x3 matrix
A(2,:)
Ans =  10  13  14
A(:,2:3)
4   7
13  14
1   2
```

Colon Operator

```
A=[1 4 7; 10 13 14; 12 1 2] %3x3 matrix
A(:,2)
Ans =
4
13
1
```

Submatrix

```
A=[1 2 3; 4 5 6; 7 8 9] %3x3 matrix
B=A([2,3],[1,2])
B=
4 5
7 8
C=A([2,1,3],:)
C=
4 5 6
1 2 3
7 8 9
```

Matrix to Vector

```
A=[1 2 3; 4 5 6; 7 8 9] %3x3 matrix
A(:)
1
4
7
2
5
3
3
6
9
```

Deleting row

```
A=[1 2 3; 4 5 6; 7 8 9] %3x3 matrix
A(3,:)=[]
A=
1 2 3
4 5 6
A=[A(1,:);A(2,:);[7 8 9]
A=
1 2 3
4 5 6
7 8 9
```

Dimension

```
A=[1 2 3; 4 5 6; 7 8 9] %3x3 matrix
size(A)
ans=
3 3
[m,n]=size(A)
A' % A transpose
```

Concatenating matrices

```
A=[1 2 3; 4 5 6; 7 8 9] %3x3 matrix
B=[A 10*A; -A [1 0 0; 0 1 0; 0 0 1]]
B =
     1     2     3    10    20    30
     4     5     6    40    50    60
     7     8     9    70    80    90
    -1    -2    -3     1     0     0
    -4    -5    -6     0     1     0
    -7    -8    -9     0     0     1
```

Matrix Generators

```
A= eye(m,n) % Diagonal 1, remaining zeros
A= eye(n) % Identity matrix
A=zeros(m,n) %Zero matrix
A=ones(m,n) % All entries 1
diag(A) % diagonal elements of A
A=rand(m,n) %Random matrix
A=hilb(n) % Hilbert matrix
A=invhilb(n) %Inverse Hilbert matrix
```

Matrix Generators

```
A= magic(n) %magic square
A=pascal(n) %Pascal matrix
A=hadamard(2^n) %Hadamard matrix
```

Linspace

```
Y=linspace(a,b)
```

Generates 100 points with equal intervals including a and b

```
Y=linspace(a,b,n)
```

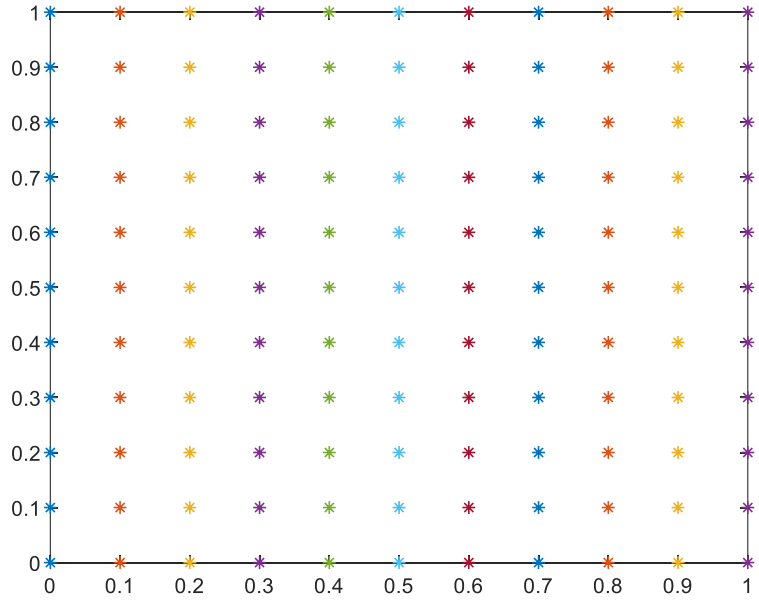
Generates n points

Meshgrid

```
[X,Y] = meshgrid(x,y);
```

`meshgrid(x,y)` returns 2-D grid coordinates based on the coordinates contained in vectors x and y. X is a matrix where each row is a copy of x, and Y is a matrix where each column is a copy of y. The grid represented by the coordinates X and Y has length(y) rows and length(x) columns.

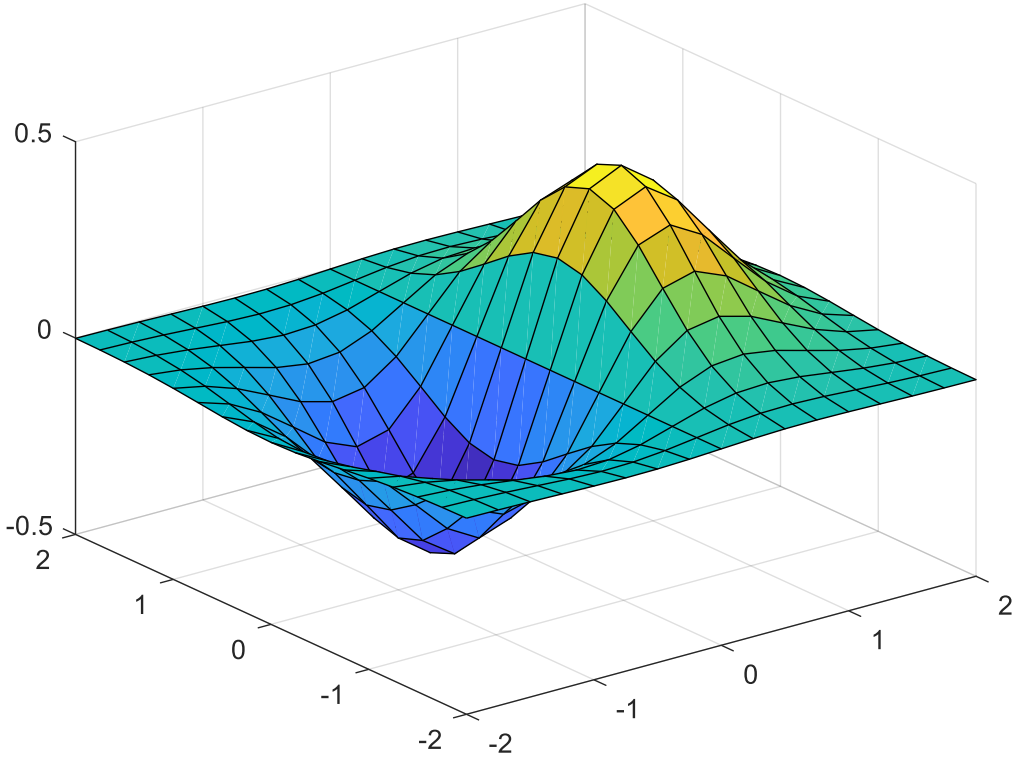
```
x = -1:0.1:1;
y = x;
[X,Y] = meshgrid(x);
plot(X,Y,'*')
```



https://in.mathworks.com/help/matlab/ref/meshgrid.html?searchHighlight=meshgrid&s_tid=doc_srchtitle

Meshgrid

```
x = -2:0.25:2;
y = x;
[X,Y] = meshgrid(x);
F = X.*exp(-X.^2-Y.^2);
surf(X,Y,F)
```



https://in.mathworks.com/help/matlab/ref/meshgrid.html?searchHighlight=meshgrid&s_tid=doc_srchtitle

Array operations

Symbol	Operation	Example
.*	Element-by-element multiplication	C=A.*B
./	Element-by-element division	C=A./B
.\	Left Division	C=A.\B
.^	Element-by-element exponentiation	C=A.^B
+	Addition	C=A+B
-	Subtraction	C=A-B

```
A=[1 2 3]
B=[1 2 -1]
C=A.*B
A.^2
C=A.^2
C=A./B
```

Matrix operations

Symbol	Operation	Example
*	Matrix Matrix Multiplication	C=A*B
/	Division (mrdivide)	C=A/B
\	Solution	C=A\B
+	Addition	C=A+B
-	Subtraction	C=A-B
^	Exponentiation	C=A^2

```
A=[1 2; 3 4]
B=[1 2; 2 -1]
C=A*B
A^2
C=A/B
```

Division (mrdivide): A/B

- If A and B are vectors, then A/B is the same as A./B
- If A is a square matrix and B is a matrix with n columns, then A/B is roughly B*inv(A)
- A/B=(B'\A')'

Matrix Functions

Function	Operation	Example
det	Determinant	det(A)
diag	Diagonal matrix	diag(A)
eig	Eigenvalues and eigenvectors	eig(A)
inv	Inverse of a matrix	inv(A)
norm	Norm of a matrix	norm(A)
rank	Rank of a matrix	rank(A)
trace	Trace of a matrix	trace(A)
lu	LU factorization	
cond	Condition number of a matrix	

Function	Operation
cross	Vector cross product
dot	Vector dot product
sum	Sum of array elements
reshape	Reshape array
prod	Product of array elements
min	Minimum value of array
kron	Kronecker tensor product
sort	Sort elements

If else if

```
if expression
      statements
elseif expression
      statements
else
      statements
end
```

```
Disc=b*b-4*a*c
if discr<0
   disp('imaginary')
end
```

Relational and Logical Operators

Operator	Description	Example
>	Greater than	A>B
<	Less than	A<B
>=	Greater than or equal to	A>=B
<=	Less than or equal to	A<=B
==	Equal to	A==B
~=	Not equal to	A~=B
&	AND operator	A&B
|	OR Operator	A|B
~	NOT operator	~A

For loop

```
for variable = expression
    statements
end
```

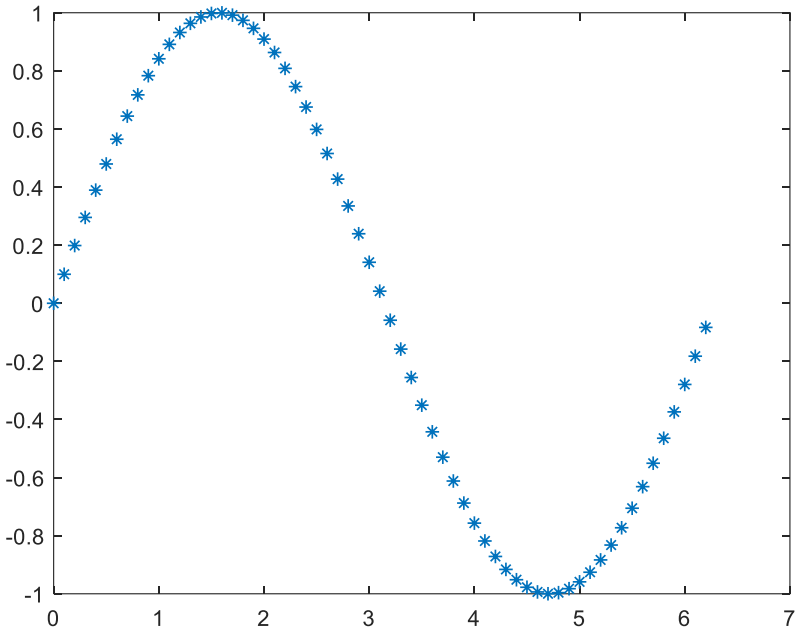
```
for i = 1:10
       x=i*i
end
```

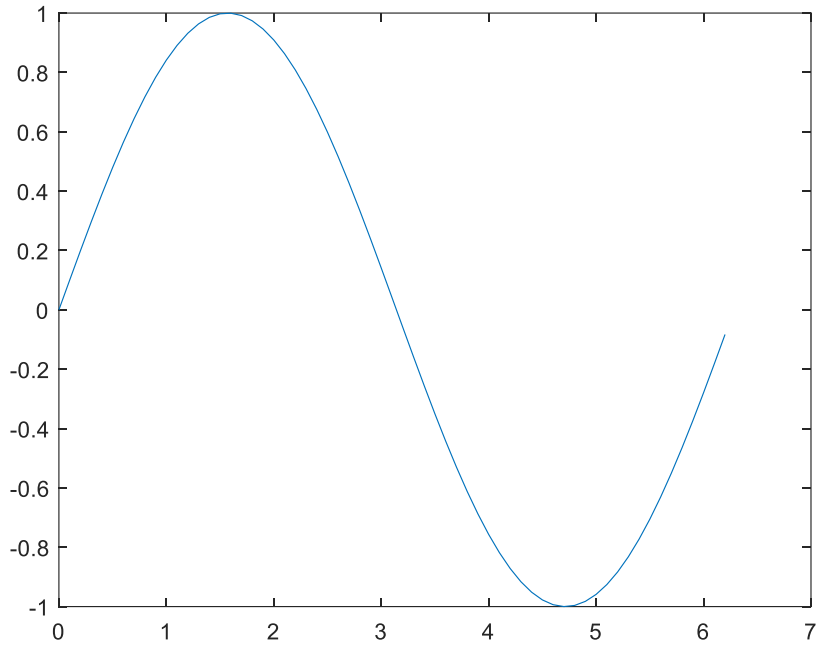
```
for i = 1:5
  for j=1:5
    if i==j
      A(i,j)=3
    elseif i==j+1 | i==j-1
       A(i,j)=1
    end
  end
end
```

Plotting

https://in.mathworks.com/help/matlab/ref/plot.html

```
X=0:0.1:2*pi
Y1=sin(X)
plot(X,Y1)
plot(X,Y1,'*')
```

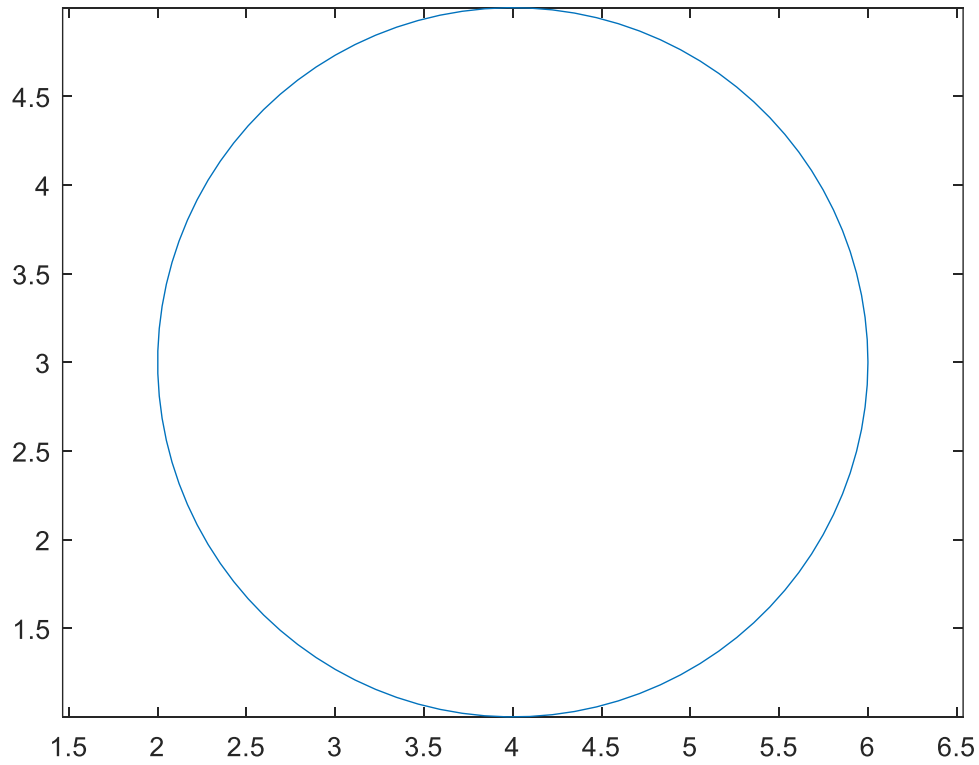




Plotting

https://in.mathworks.com/help/matlab/ref/plot.html

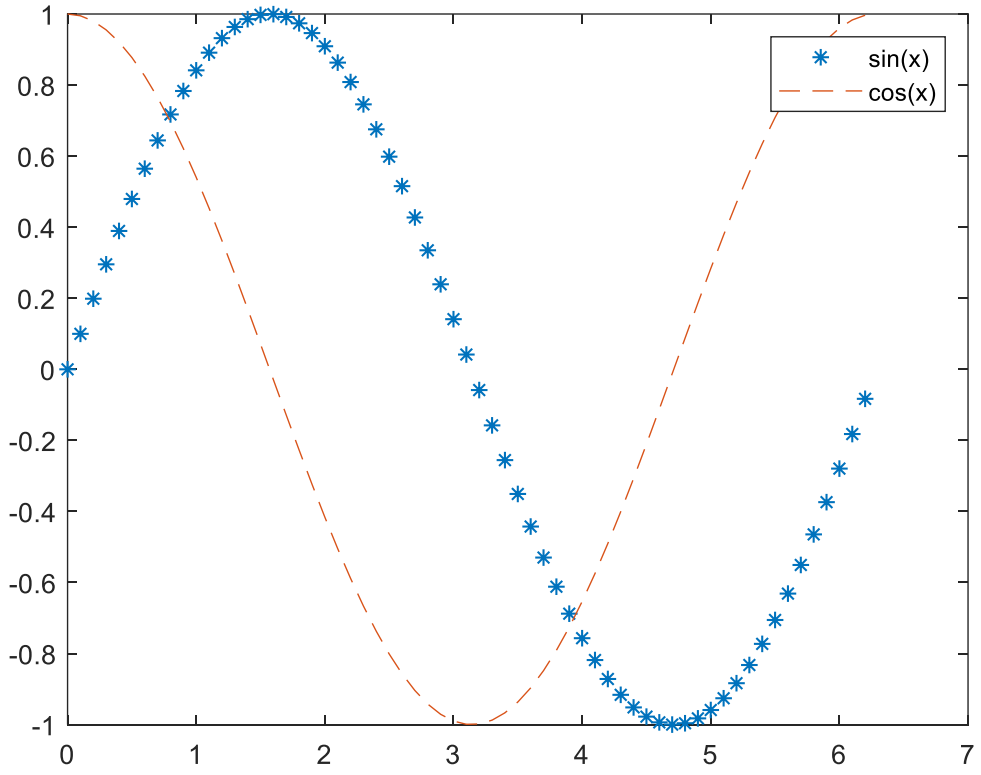
```
r = 2;
xc = 4;
yc = 3;

theta = linspace(0,2*pi);
x = r*cos(theta) + xc;
y = r*sin(theta) + yc;
plot(x,y)
axis equal
```



Plotting

https://in.mathworks.com/help/matlab/ref/plot.html

```
X=0:0.1:2*pi
Y1=sin(X)
Y2=cos(X)
plot(X,Y1,'*',X,Y2,'--')
legend('sin(x)','cos(x)')
```



Plotting

Symbol	Color
k	Black
r	Red
b	Blue
g	Green
c	Cyan
m	Magenta
y	Yellow

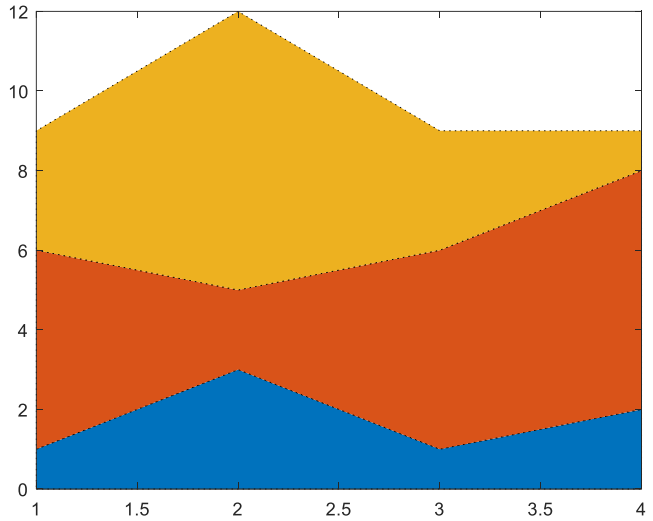
Symbol	Line Style
-	Solid
--	Dashed
:	Dotted
_.	Dash-dot

Symbol	Marker
+	Plus Sign
o	Circle
*	Asterisk
.	Point
x	Cross
S	Square
d	Diamond

Area Plot

https://in.mathworks.com/help/matlab/ref/area.html

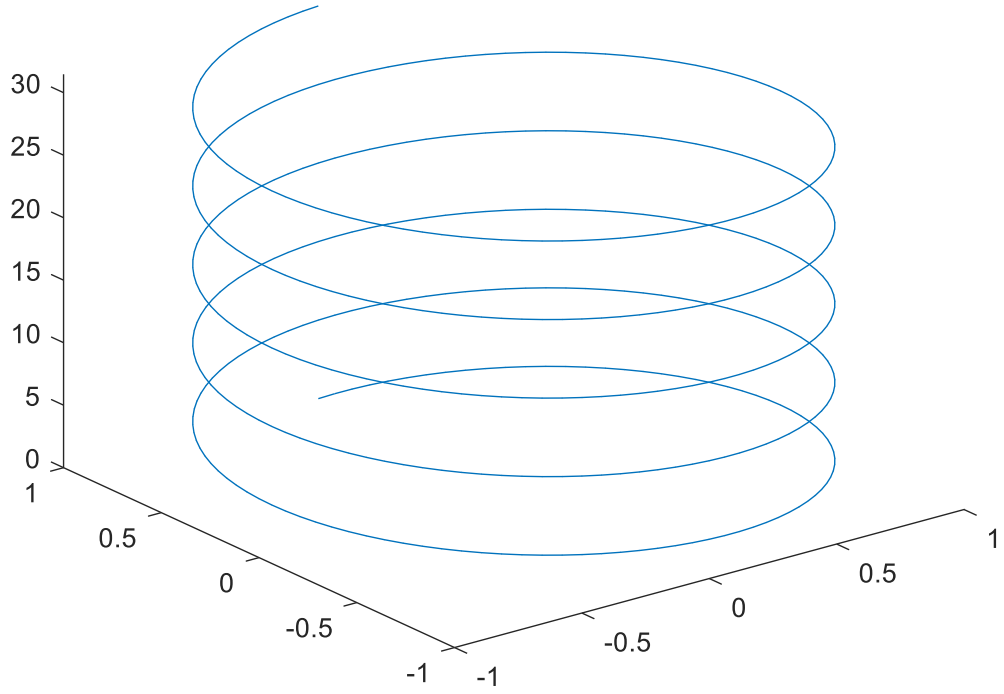
```
Y = [1, 5, 3;
     3, 2, 7;
     1, 5, 3;
     2, 6, 1];
h = area(Y,'LineStyle',':');
```



Plot3

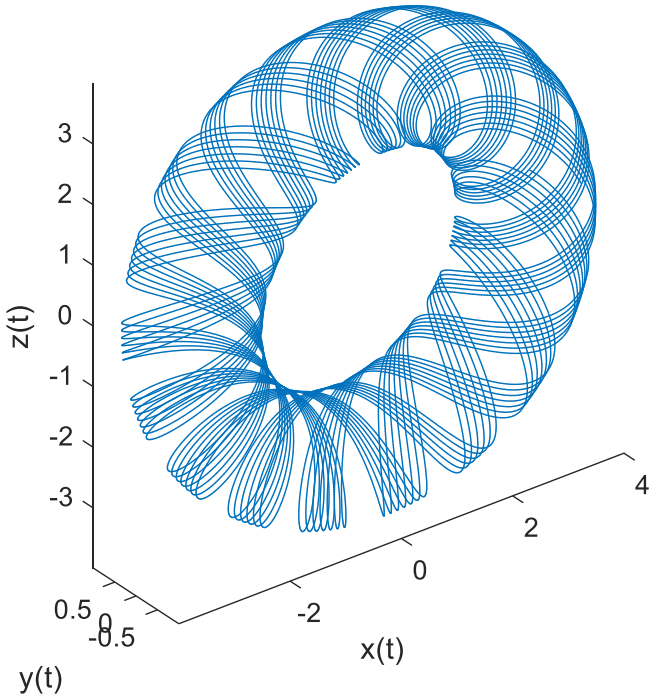
```
t=0:pi/50:10*pi
st=sin(t)
ct=cos(t)
plot3(st,ct,t)
```

https://in.mathworks.com/help/matlab/ref/plot3.html



Plot3

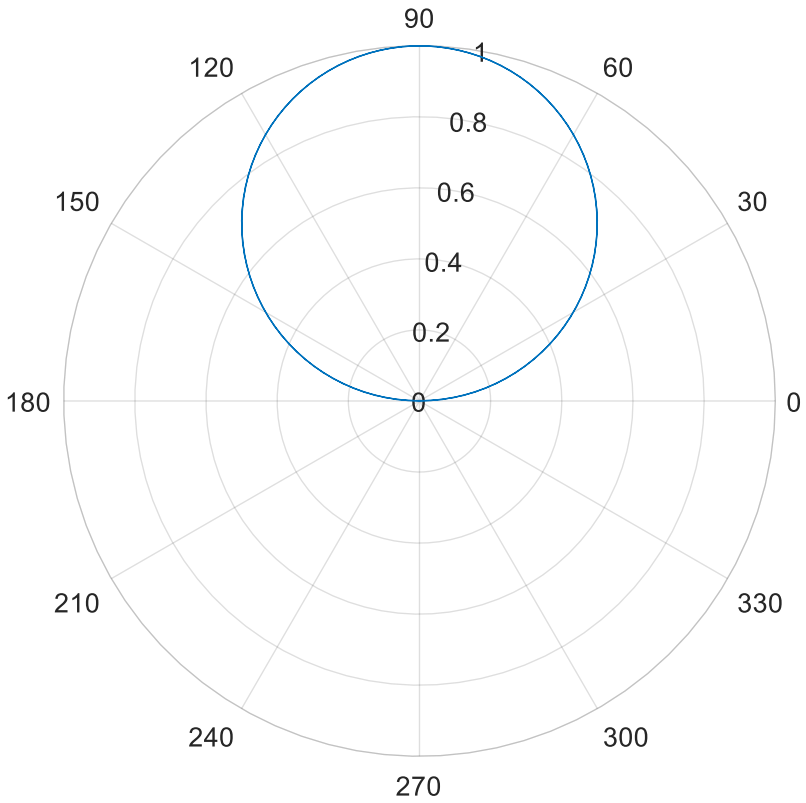
https://in.mathworks.com/help/matlab/ref/plot3.html




```
t = 0:pi/500:40*pi;
xt = (3 + cos(sqrt(32)*t)).*cos(t);
yt = sin(sqrt(32) * t);
zt = (3 + cos(sqrt(32)*t)).*sin(t);
plot3(xt,yt,zt)
axis equal
xlabel('x(t)')
ylabel('y(t)')
zlabel('z(t)')
```

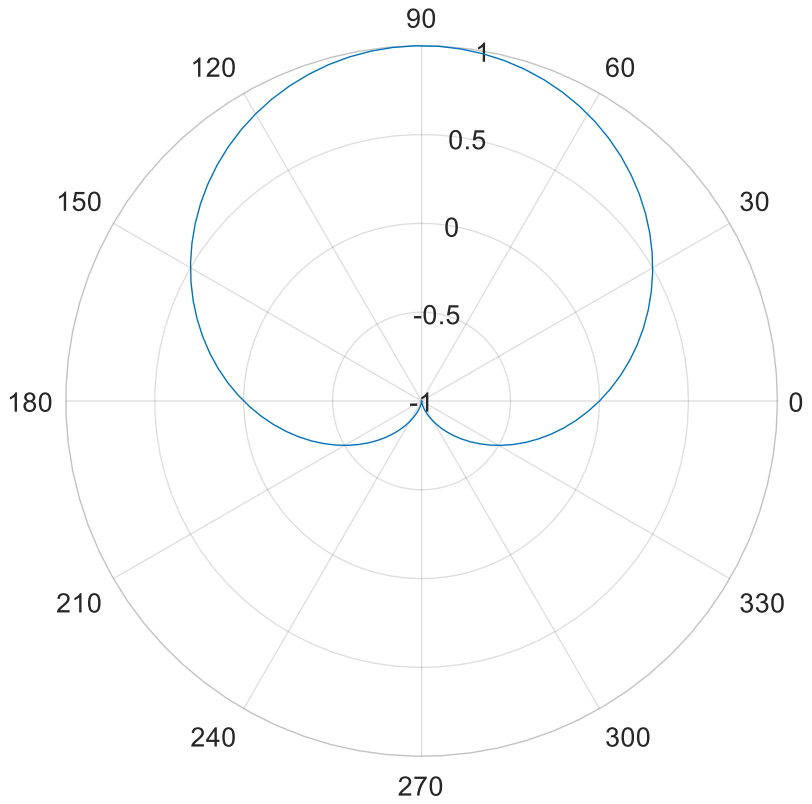
Polarplot

https://in.mathworks.com/help/matlab/ref/plot3.html




```
theta = linspace(0,2*pi);
rho = sin(theta);
polarplot(theta,rho)
```

Polarplot



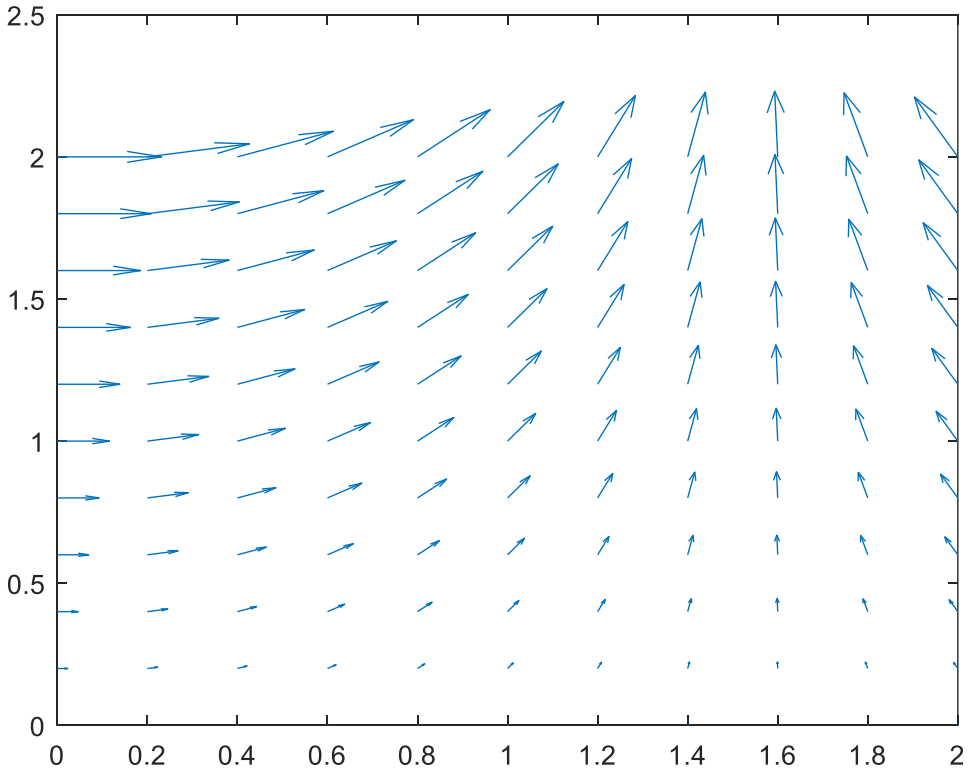
https://in.mathworks.com/help/matlab/ref/polarplot.html

```
theta = linspace(0,2*pi);
rho = sin(theta);
polarplot(theta,rho)
rlim([-1 1])
```

Vectorplot

https://in.mathworks.com/help/matlab/ref/quiver.html

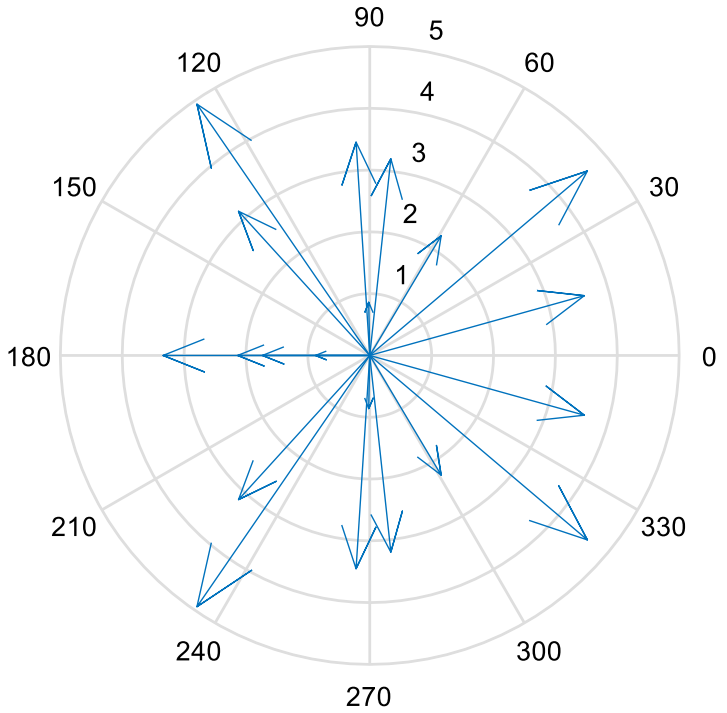
```
[x,y] = meshgrid(0:0.2:2,0:0.2:2);
u = cos(x).*y;
v = sin(x).*y;

figure
quiver(x,y,u,v)
```



Vectorplot

https://in.mathworks.com/help/matlab/ref/quiver.html

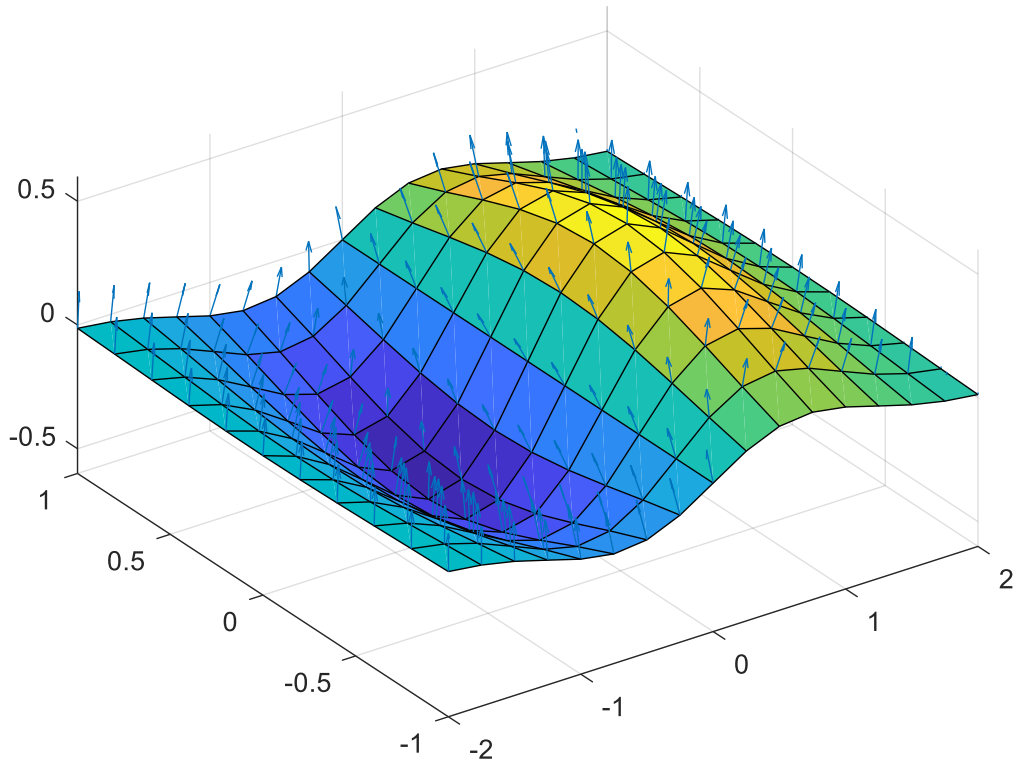
```
rng(0,'twister') % initialize
random number generator
M = randn(20,20);
Z = eig(M);

figure
compass(Z)
```



Vectorplot 3D

https://in.mathworks.com/help/matlab/ref/quiver3.html

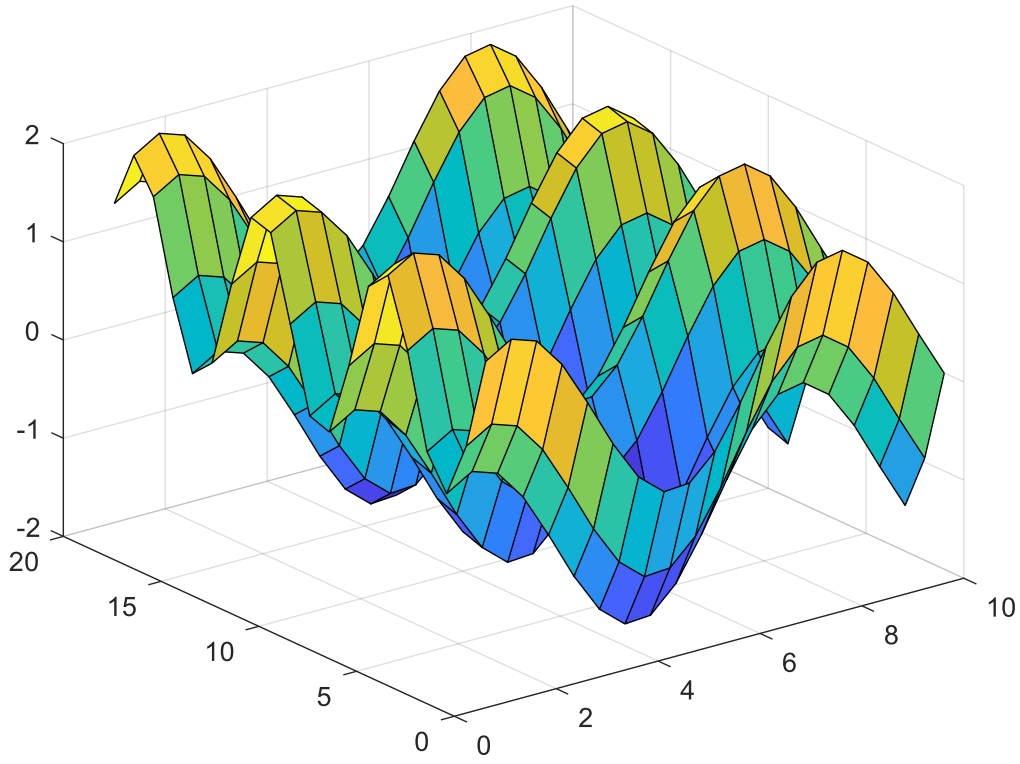
```
[X,Y] = meshgrid(-2:0.25:2,-1:0.2:1);
Z = X.* exp(-X.^2 - Y.^2);
[U,V,W] = surfnorm(X,Y,Z);

figure
quiver3(X,Y,Z,U,V,W,0.5)

hold on
surf(X,Y,Z)
view(-35,45)
axis([-2 2 -1 1 -.6 .6])
hold off
```



3D Surface Plot

https://in.mathworks.com/help/matlab/ref/surf.html

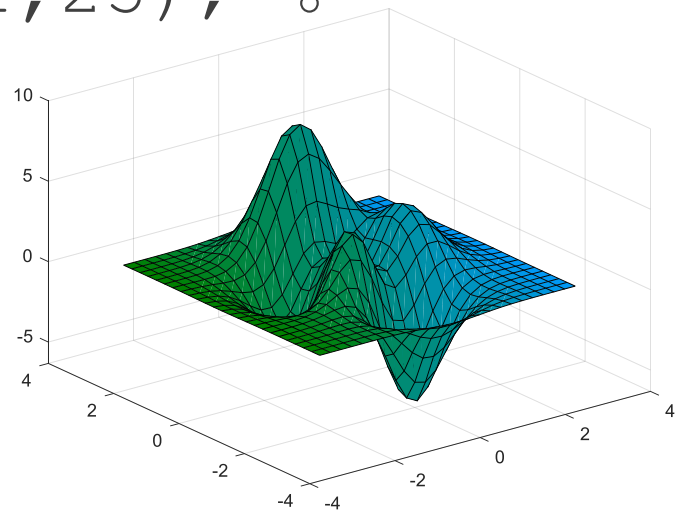
```
[X,Y] = meshgrid(1:0.5:10,1:20);
Z = sin(X) + cos(Y);
surf(X,Y,Z)
```



3D Surface Plot

https://in.mathworks.com/help/matlab/ref/surf.html

```
[X,Y,Z] = peaks(25);
CO(:,:,1) = zeros(25); % red
CO(:,:,2) =
ones(25).*linspace(0.5,0.6,25); % green
CO(:,:,3) = ones(25).*linspace(0,1,25); %
blue
surf(X,Y,Z,CO)
```



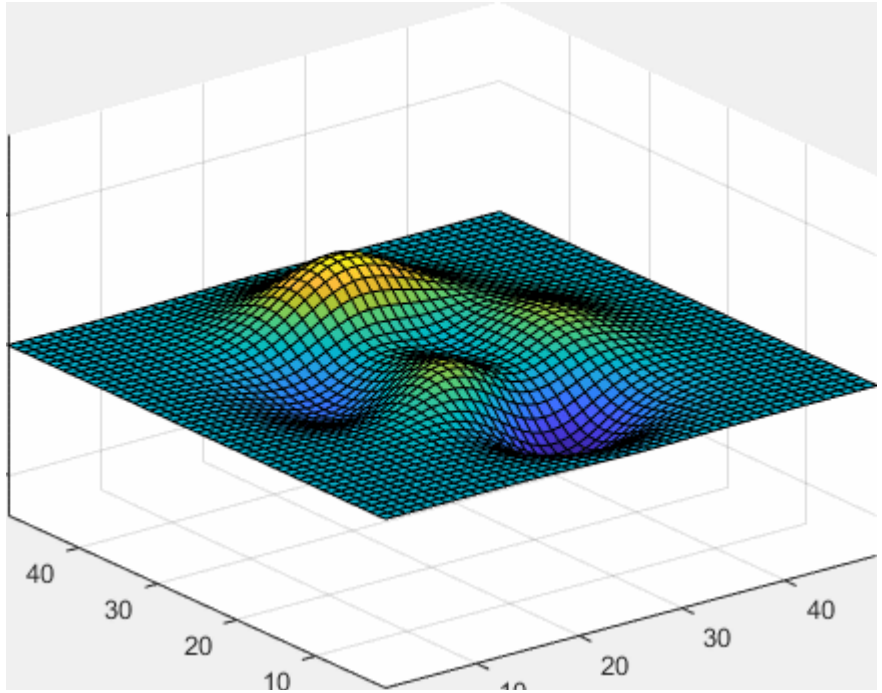
Other Plot Tools

- stairs
- errorbar
- stackedplot
- loglog
- semilogx
- semilogy
- fplot
- fimplicit
- fplot3
- histogram
- histogram2
- morebins
- fewerbins
- histcounts
- histcounts2
- scatter
- scatter3
- binscatter
- scatterhistogram
- spy
- plotmatrix
- pie
- pie3
- heatmap
- bar
- bar3
- stem
- stem3
- geoplot
- geoscatter
- geobubble
- polarscatter
- compass
- ezpolar
- contourc
- contourf
- contour3
- contourslice
- feather
- surfc
- surfl
- mesh
- surfnorm
- meshc
- meshz
- hidden
- fsurf
- waterfall
- ribbon
- peaks
- cylinder
- ellipsoid
- sphere
- flow
- isocaps
- isonormals
- isosurface
- reducepath
- reducevolume
- subvolume
- fill
- fill3

Animation

https://in.mathworks.com/help/matlab/animation-1.html?s_tid=CRUX_lftnav

```
figure
Z = peaks;
surf(Z)
axis tight manual
ax = gca;
ax.NextPlot = 'replaceChildren';


loops = 40;
F(loops) = struct('cdata',[],'colormap',[]);
for j = 1:loops
    X = sin(j*pi/10)*Z;
    surf(X,Z)
    drawnow
    F(j) = getframe;
end
```

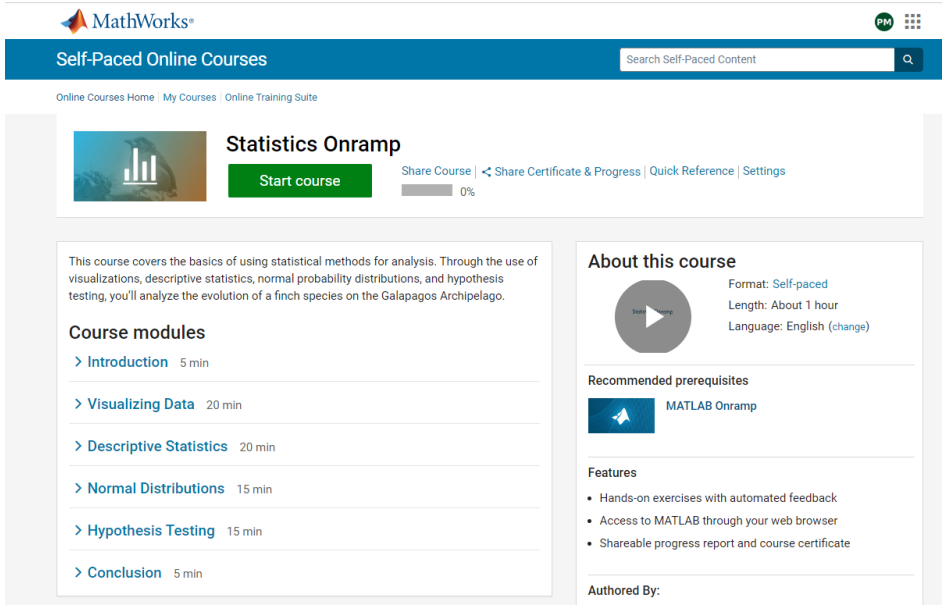


Best way to learn

- https://in.mathworks.com/help/index.html

Diwali Exercises

Course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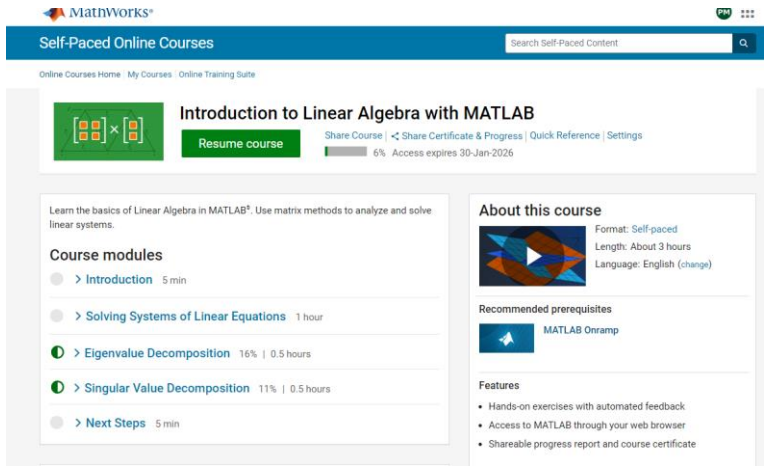
This course covers the basics of using statistical methods for analysis. Through the use of visualizations, descriptive statistics, normal probability distributions, and hypothesis testing, you'll analyze the evolution of a finch species on the Galapagos Archipelago.
Course modules
Introduction 5 min
Visualizing Data 20 min
Descriptive Statistics 20 min
Normal Distributions 15 min
Hypothesis Testing 15 min
Conclusion 5 min
About this course
Format: Self-paced
Length: About 1 hour
Language: English (change)
Recommended prerequisites
MATLAB Onramp
Features
Hands-on exercises with automated feedback
Access to MATLAB through your web browser
Shareable progress report and course certificate
Authored By: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Courses

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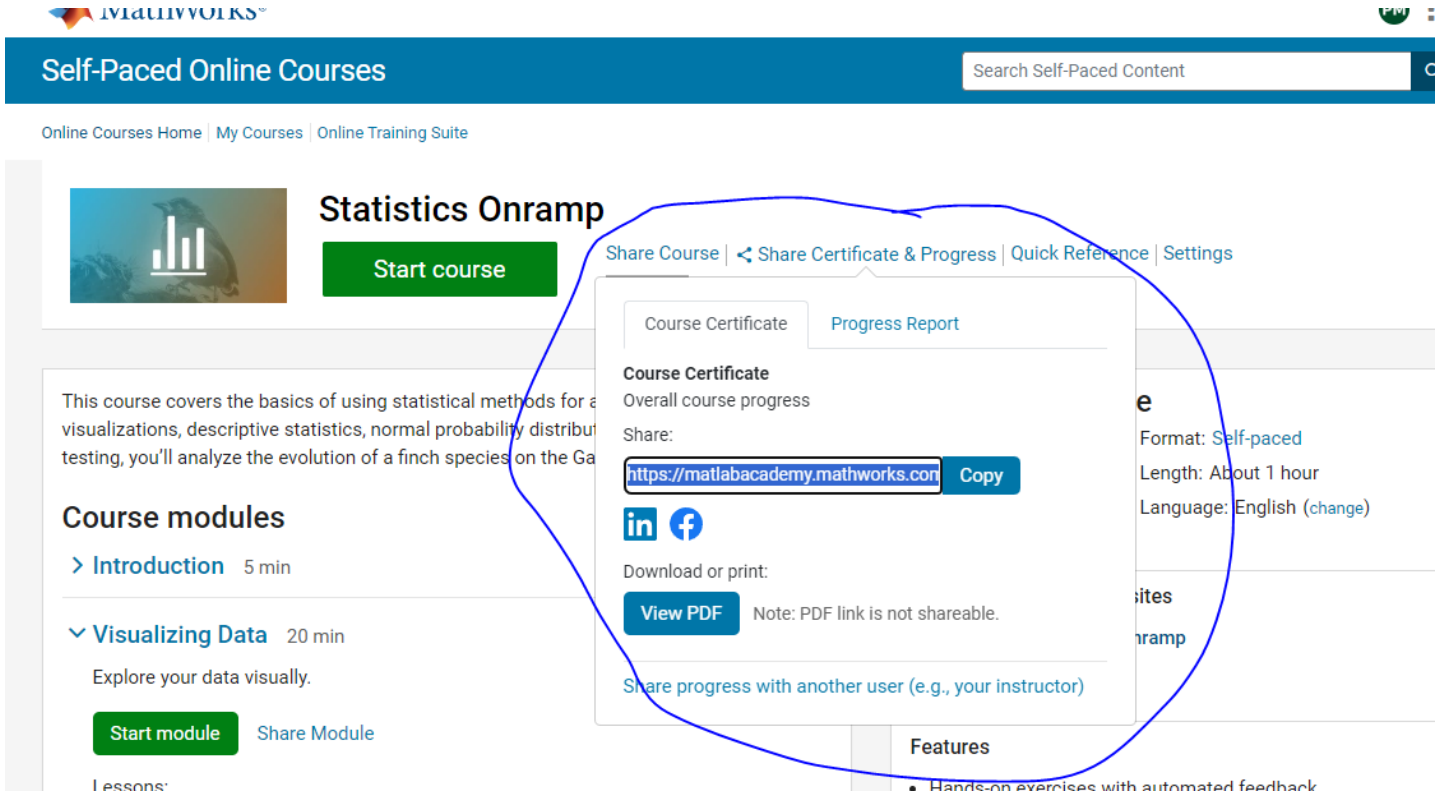
   - https://matlabacademy.mathworks.com/details/statistics-onramp/orst
3. Introduction to Linear Algebra with MATLAB
   - https://matlabacademy.mathworks.com/details/introduction-to-linear-algebra-with-matlab/linalg
4. Machine Learning onramp
   - https://matlabacademy.mathworks.com/details/machine-learning-onramp/machinelearning
5. How MATLAB Graphics Work
   - https://matlabacademy.mathworks.com/details/how-matlab-graphics-work/otmlhgw

Course

- After completion of the course Share Both Certificates as a PDF file by clicking the following link



Course

- Visit this Course and understand how to read an image (imread command) and show it as a matrix
  - https://matlabacademy.mathworks.com/details/image-processing-onramp/imageprocessing
- Extract a grayscale image or RGB image and convert it to a matrix format
- Compute the SVD of this matrix (SVD is learnt from Introduction to Linear Algebra with MATLAB)

Thank you