Scuola Interdipartimentale delle **Scienze**, dell'**Ingegneria** e della **Salute**

DiST — Dipartimento di Scienze e Tecnologie — Università Parthenope

Laurea Magistrale in IA (ML&BD)

Scientific Computing – ACS (part 2 – 6 credits)

prof. Mariarosaria Rizzardi

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Contents

- Introduction to Part 2 of Scientific Computing (SC2)

NEW 2023

Teaching material of SC2

The current teaching material (under construction) can be found on the e-Learning platform at url:

https://elearning.uniparthenope.it

course name

Rizzardi Mariarosaria
SCIENTIFIC COMPUTING - part 2 (EN)

instead of

INFORMATICA APPLICATA (MACHINE LEARNING E BIG DATA)
SCIENTIFIC COMPUTING part 1

On the course page you will find:

1) downloadable files

- Copy of lecture *slides* (pdf files).
- Assigned exercises (pdf files).
- Examples of MATLAB codes (both *m*-files and *mlx*-files).
- Data files (*mat*-files) for examples or exercises.
- Audio files and image files for examples or exercises.

2) and in addition

SCORM package
Moodle is able to display it

- HTML5 with animated slides and some audio explanations (format).

Useful informations

Rizzardi Mariarosaria

SCIENTIFIC COMPUTING - part 2 (EN)

Moodle short course name: SC2-AY2022-23

MS Teams class: SC - part 2 (2023)

MS Teams code: dyf5mhf

Office hours: in order to plan an online meeting, students having some questions about theory and/or exercises must send a mail to mariarosaria.rizzardi@uniparthenope.it.

Meetings will be arranged on the Teams platform.

class name: Ricevimento Mariarosaria Rizzardi

Teams code: dxboq3t

In SC part 2 of the course …

what will the students learn?

what will they acquire?

Problem Solving skills: how to use mathematics to solve problems from a geometrical point of view, … but not only that

Problem Solving: by means of a computer with MATLAB installed

Primary goal: "Computational Mathematics"

Why MATLAB?

MATLAB is a modern programming and numeric computing platform, equipped by several libraries: numerical, graphical, symbolic, audio-video processing and many other tools in specific application areas. It can be used **interactively** (… as a calculator).

MATLAB is free for all the students at Parthenope University.

SC2: course syllabus in short

- Linear Spaces and Subspaces.
- Affine Spaces and Subspaces.
- Inner products and norms.
- Linear and Affine Mappings.
- Conformal Mappings.
- Geometrical Interpretation of Eigenvalues/Eigenvectors.
- Diagonalization of a matrix.
- Principal Component Analysis.
- Best Linear Approximation in Normed Linear Spaces: (1) finite and discrete case (*Least Squares* Solutions), (2) infinite and discrete case, (3) continue case. Brief notes on Hilbert Spaces.
- Discrete Fourier Transform, Fourier Series, Fourier Transform.
- 2D Discrete Fourier Transform, 2D Fourier Series, 2D Fourier Transform.
- Laplace Transform.

All of them will be accompanied by MATLAB examples and exercises, both numerical and symbolic.

Mathematics is the main tool to describe the real world: simple examples of Linear Algebra

Encrypt a message

Text: 'MATLAB stays for MATrix LABoratory.'

M	A	T	L	A	B	
s	t	a	y	s		f
o	r		M	A	T	r
i	x		L	A	B	o
r	a	t	o	r	y	.

7 (columns) × 5 (rows)

ASCII →

77	65	84	76	65	66	32
115	116	97	121	115	32	102
111	114	32	77	65	84	114
105	120	32	76	65	66	111
114	97	116	111	114	121	46

ASCII code is simple to decrypt!

```
T='MATLAB stays for MATrix LABoratory.';
T=reshape(T,7,5)'
T =
    'MATLAB '
    'stays f'
    'or MATr'
    'ix LABo'
    'ratory.'
A=randi(99,5)
A =
    81    10    16    15    65
    90    28    97    42     4
    13    55    95    91    85
    91    95    49    79    93
    63    96    80    95    68
```

ASCII codes

```
double(T)
ans =
    77    65    84    76    65    66    32
   115   116    97   121   115    32   102
   111   114    32    77    65    84   114
   105   120    32    76    65    66   111
   114    97   116   111   114   121    46
```

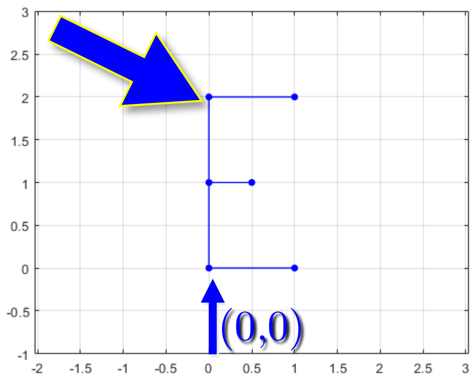
```
C=A*T
C =
  33210  32441  22890  29343  26766  22977  26058
  22937  22065  15248  19304  17355  18761  16930
  25051  24759  16872  21696  20071  18918  19132
  32514  32002  19749  26745  24204  26235  25455
  13448  12276  11834  12579  12300  12107   7579
T1=inv(A)*C; % T1=A^-1 C
T1=char(round(T1));
T1 =
    'MATLAB '
    'stays f'
    'or MATr'
    'ix LABo'
    'ratory.'
```

Mathematics is the main tool to describe the real world: simple examples of Linear Algebra

Make oblique a normal font

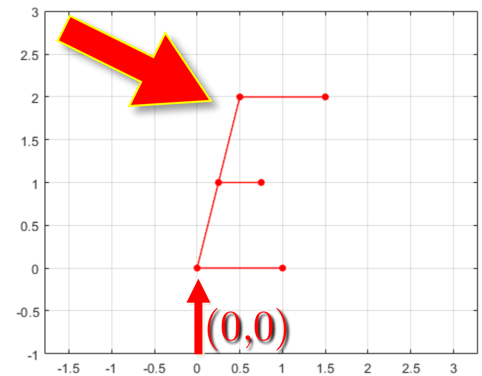
$$\mathbf{P}=\begin{pmatrix}1 & 0 & 0 & 0.5 & 0.5 & 0 & 1\\ 0 & 0 & 1 & 1 & 1 & 2 & 2\end{pmatrix}$$

$$\mathbf{Q}=\mathbf{T}\cdot\mathbf{P}=\begin{pmatrix}1 & 0 & 0.25 & 0.75 & 0.25 & 0.5 & 1.5\\ 0 & 0 & 1 & 1 & 1 & 2 & 2\end{pmatrix}$$

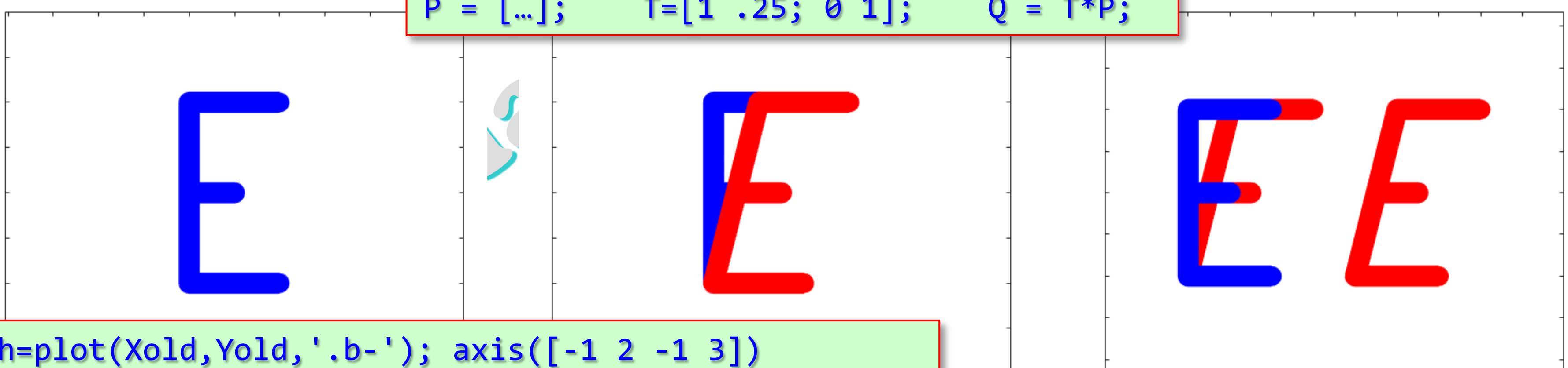


$$\mathbf{T}=\begin{pmatrix}1 & 0.25\\ 0 & 1\end{pmatrix}$$

shear map T




```
P = […];    T=[1 .25; 0 1];    Q = T*P;
```



```
h=plot(Xold,Yold,'.b-'); axis([-1 2 -1 3])
axis equal; set(h,'LineWidth',15,'MarkerSize',48)
set(gca,'XTickLabel',''); set(gca,'YTickLabel','')
```

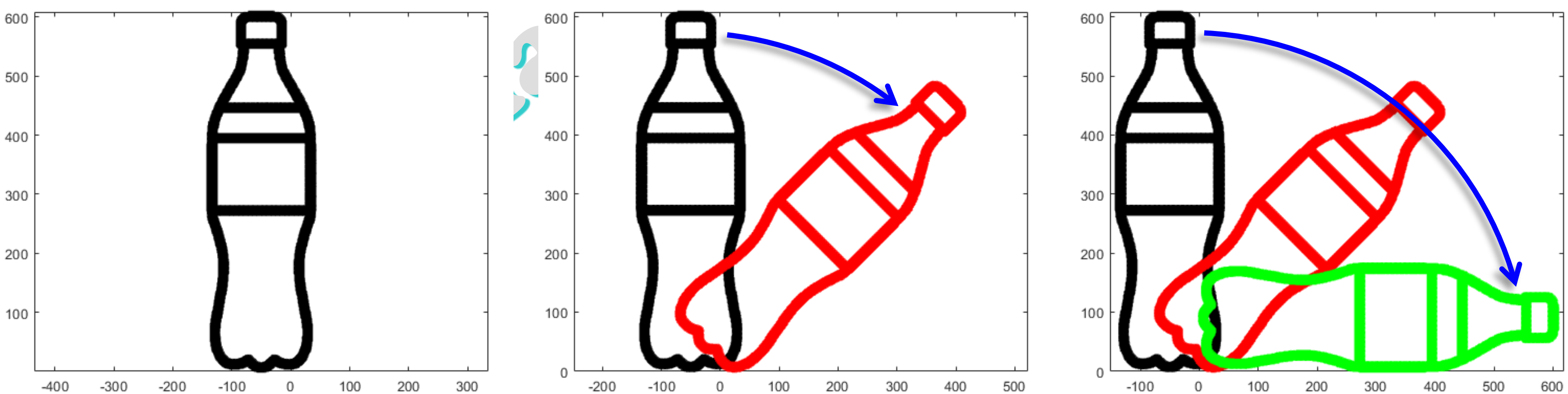
Mathematics is the main tool to describe the real world: simple examples of Linear Algebra

Create an animation

$$R = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix}$$

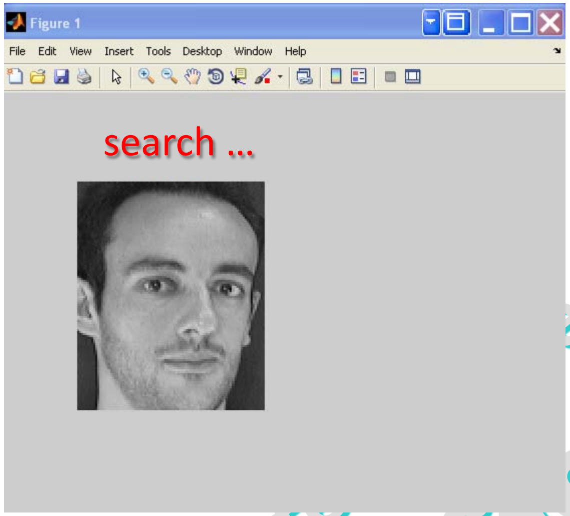
Rotation matrix by an angle θ

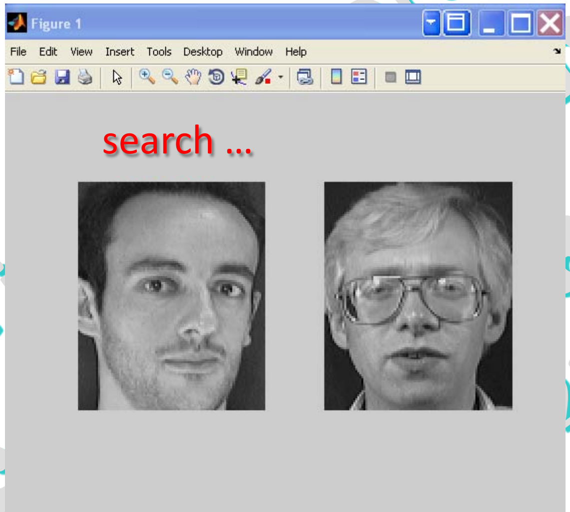
```
load cola % mat data file: P is a matrix of size (2, 22238)
a=-pi/4; R=[cos(a) -sin(a); sin(a) cos(a)]; % rotation matrix
P1=R*P;  % rotated of 45°
P2=R*P1; % rotated of 90°
P1(2,:)=P1(2,:) - min(P1(2,:)); % vertically translated
P2(2,:)=P2(2,:) - min(P2(2,:)); % vertically translated
plot(P(1,:),P(2,:),'.k'); axis equal; hold on;  pause(0.2)
plot(P1(1,:),P1(2,:),'.r');  pause(0.2)
plot(P2(1,:),P2(2,:),'.g')
```

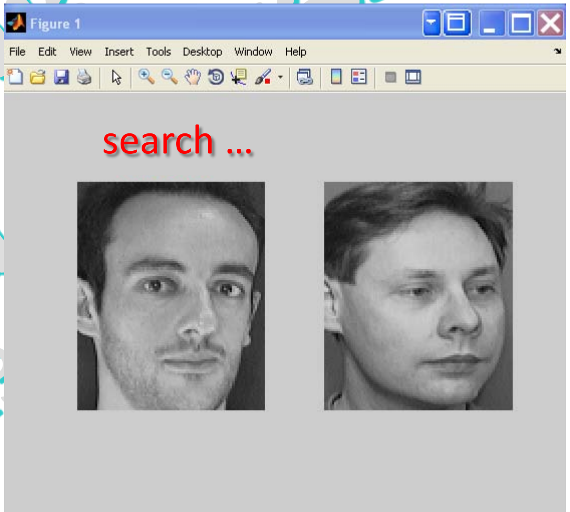


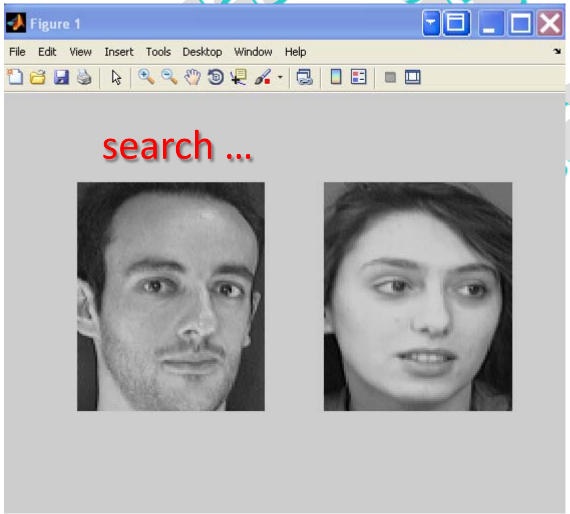
Mathematics is the main tool to describe the real world: simple examples of Linear Algebra

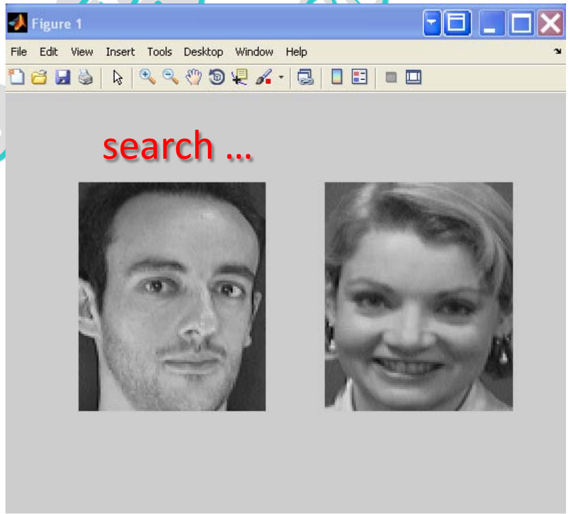
Face recognition: Eigenfaces algorithm

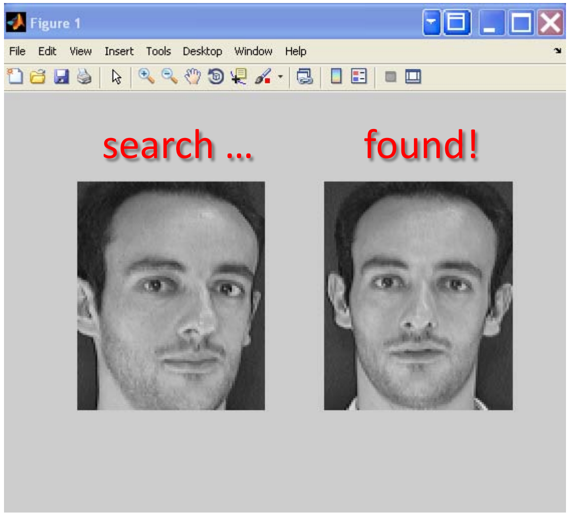












Mathematics is the main tool to describe the real world: simple examples of Linear Algebra

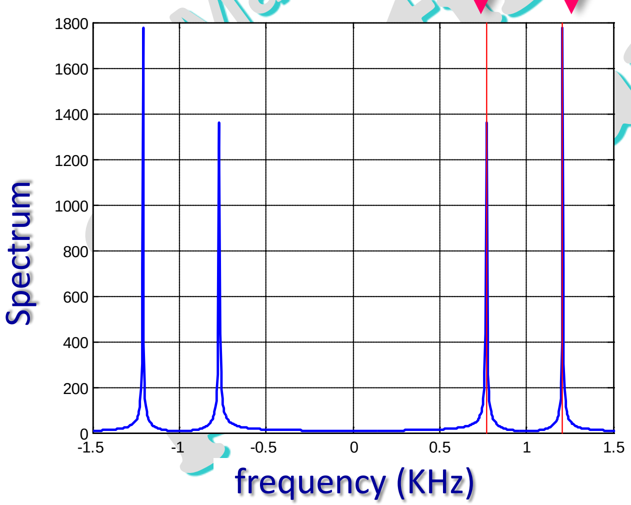
Dual-tone multi-frequency (DTMF) phone keypad

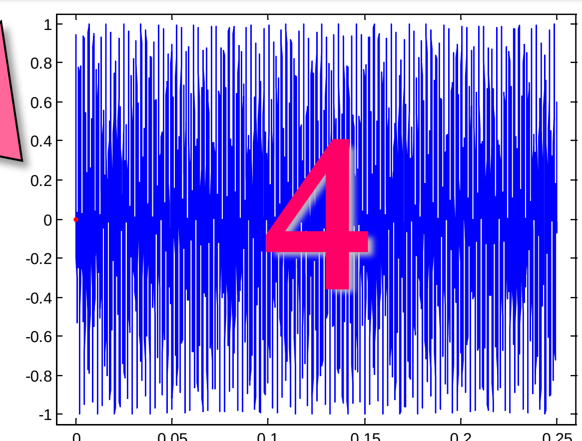
low freq. high freq.

$$y = \frac{\sin(2\pi\phi_{row} t) + \sin(2\pi\phi_{col} t)}{2}$$

Hz	1209	1336	1477	1633
697	1	2	3	A
770	4	5	6	B
852	7	8	9	C
941	*	0	#	D

low frequency 770 Hz
high frequency 1209 Hz





A new computational environment:

symbolic computations

In MATLAB you need to install Symbolic Math Toolbox

The next slides will briefly show some comparisons between numerical and symbolic computations with MATLAB. We'll explore this topic in more detail later.

MATLAB: "numeric" vs "symbolic" code

numeric object

```
a=sqrt(2)
a =
    1.4142
```

it has not to be declared

```
ff=@(x)x.^2 - 4
ff =
  function_handle with value:
    @(x)x.^2-4
s=fsolve(ff,0.5)
s =
     2
s=fsolve(ff,-0.25)
s =
    -2
```

symbolic object

```
syms a
a
a =
a
```

it has to be declared
or converted

```
a=sqrt(sym(2))
a =
2^(1/2)
a=double(a)
a =
    1.4142
```

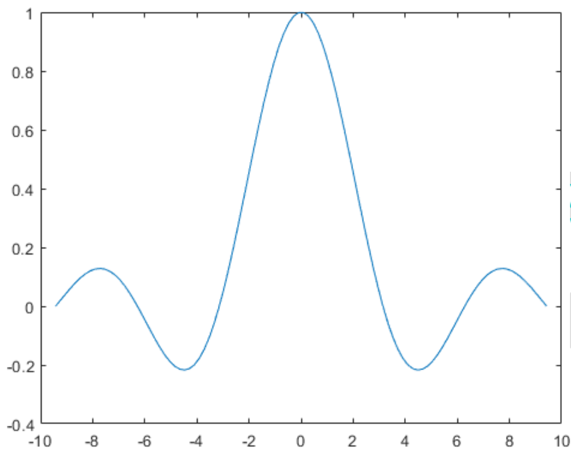
```
syms a b c x real
f=a*x^2+b*x+c
f =
a*x^2 + b*x + c
f1=diff(f,x) % ∂f/∂x
f1 =
b + 2*a*x
ff=subs(f,{a,b,c},{1,0,-4})
ff =
x^2 - 4
s=solve(ff)    s=solve(ff == 0)
s =
-2
 2
```

roots

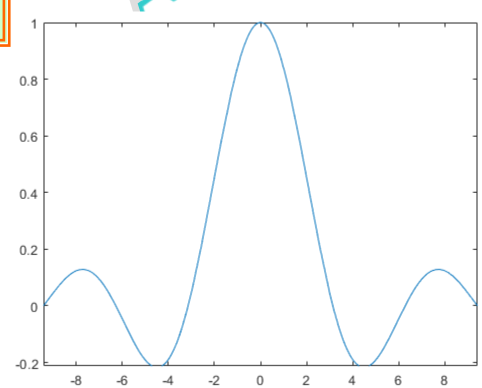
MATLAB: "numeric" vs "symbolic" graphics

numeric

```
x=linspace(-3*pi,3*pi,100);
y=sin(x)./x;  plot(x,y)
```

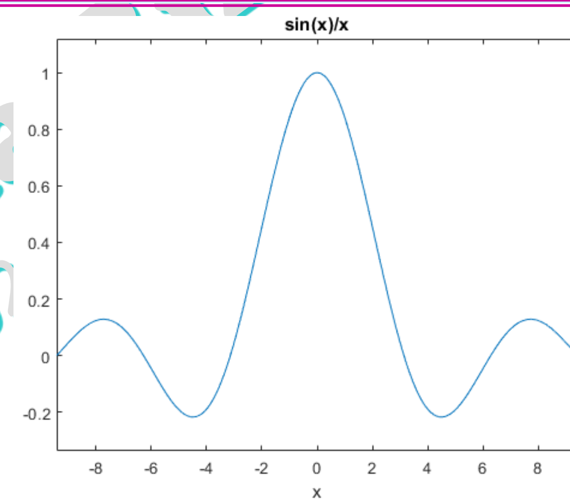


```
f=@(x) sin(x)./x;
fplot(f,[-3*pi,3*pi])
```



symbolic

```
syms x real
y=sin(x)/x;
ezplot(y,[-3*pi,3*pi])
```



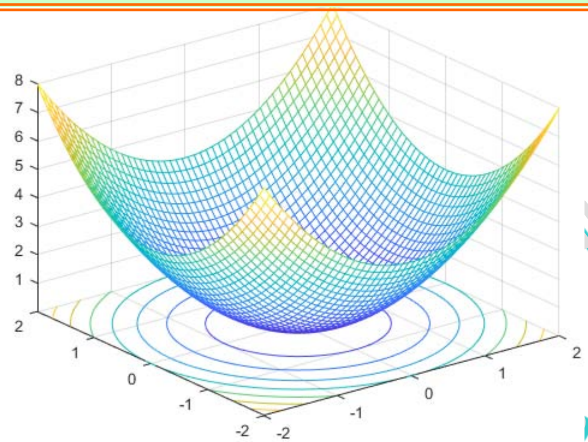

```
fplot(y,[-3*pi,3*pi])
```

2D graphics

MATLAB: "numeric" vs "symbolic" graphics

numeric

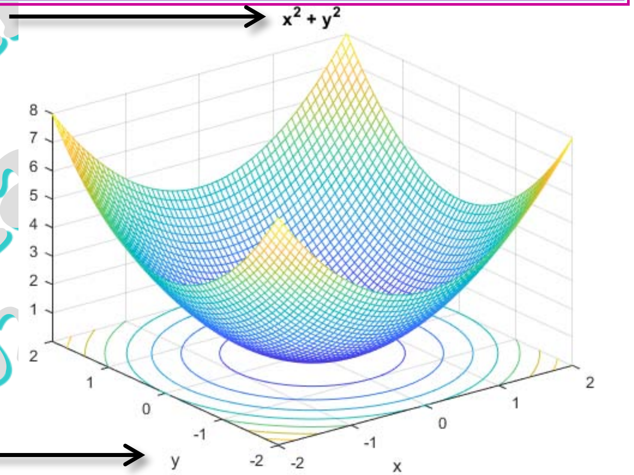
```
[x,y]=meshgrid(linspace(-2,2,50));
z=x.^2 + y.^2; % paraboloid
meshc(x,y,z) % surface and contour plot
```



symbolic

```
syms x y real
z=x^2 + y^2;
ezmeshc(z,[-2,2])
```

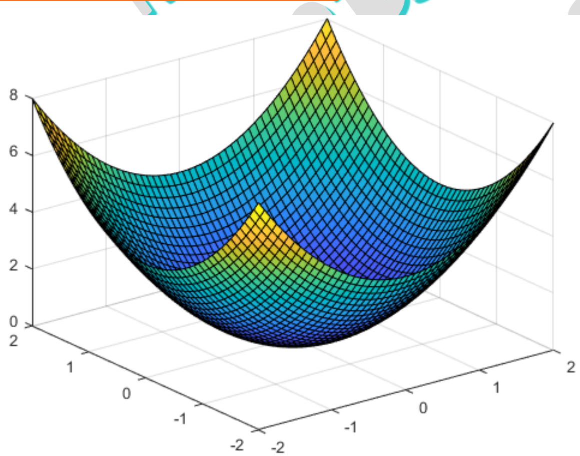
title →



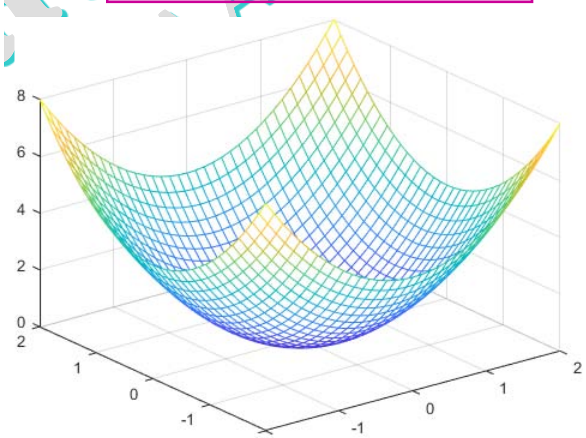
axis labels →

3D graphics

```
surf(x,y,z)
```



```
fmesh(z,[-2,2])
```



```
ezsurfc(z,[-2,2])
```