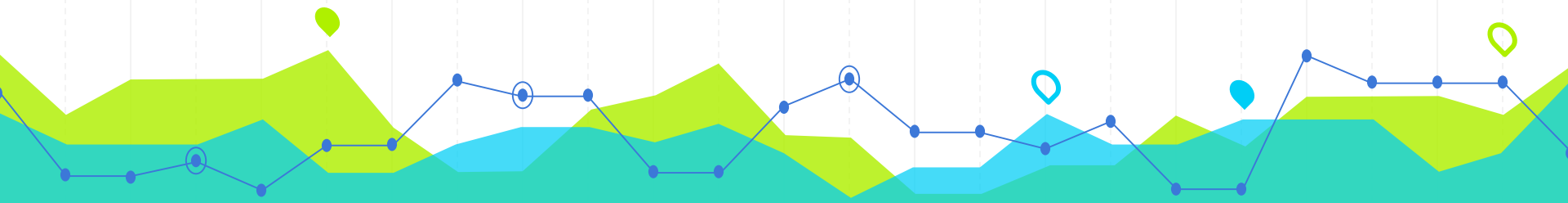


Introduction to Matlab

Presented by Yasaman Sabahi

Outline

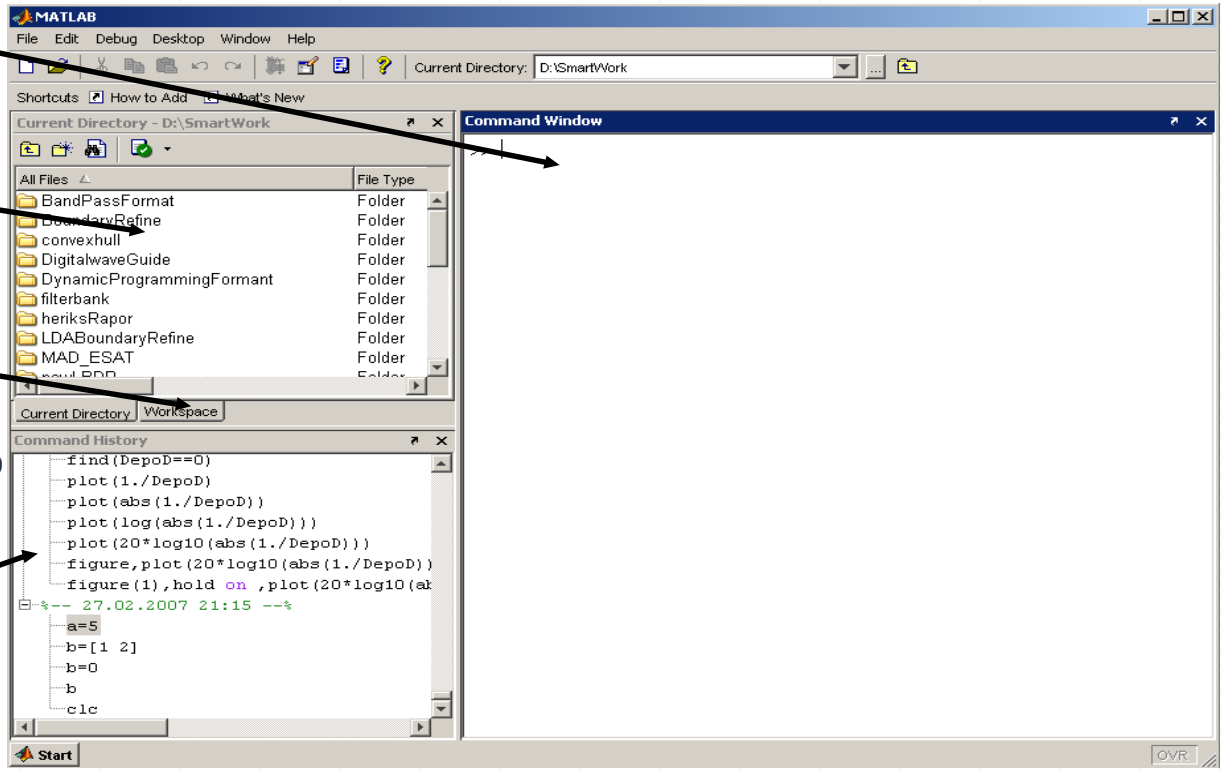
1. Introduction
    1. Overview
    2. Variables
    3. Matrix
    4. Misc.
2. Image Processing with Matlab
3. References

What & Why

- Matrix Laboratory
  - Dynamically typed language
    - Variables require no declaration
    - Creation by initialization (x=10;)
  - All variables are treated as matrices
    - Scalar: 1×1 matrix; Vector: N×1 or 1×N matrix
    - Calculations are much faster
- Advantages
  - Fast implementation and debugging
  - Natural matrix operation
  - Powerful image processing toolbox

Matlab Main Screen

- Command Window
  - type commands
- Current Directory
  - View folders and m-files
- Workspace
  - View variables
  - Double click on a variable to see it in the Array Editor
- Command History
  - view past commands
  - save a whole session using diary



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Variables

Defining variables

```
int a;
a=1;
double b;
b=2+4;
```

C/C++

```
>>a=1;
>>b=2+4;
```

Matlab

```
>> a=1
a =
     1
>> b=2+4
b =
     6
```

Variables are created when they are used

All variables are created as matrices with “some” type (unless specified)

Variables

```
a = 1;
```

a <1x1 double>

	1	2
1	1	
2		

```
>> whos a
  Name        Size                Bytes  Class     Attributes

  a           1x1                     8  double
```

```
b = false;
```

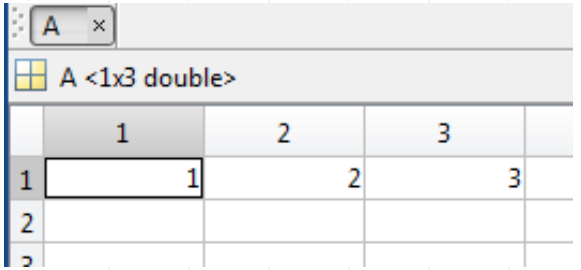
b <1x1 logical>

	1	2
1	0	
2		

Variables

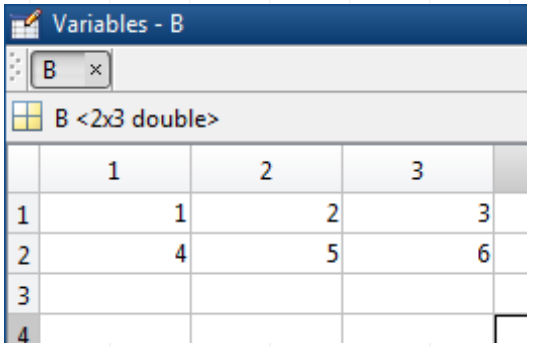
A = [1, 2, 3]

```
>> A=[1 2 3]
A =
     1     2     3
```



B = [1,2,3;4,5,6]

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



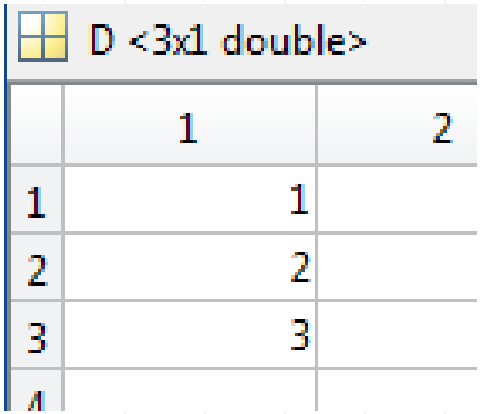
C=[1 2 3;4 5 6;7 8 9]

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

Variables

D=[1 ; 2 ; 3]

```
>> D= [1 ;2 ;3]
D =
     1
     2
     3
```



E=[1 2 3]'

```
>> E=[1 2 3]'
E =
     1
     2
     3
```

Variables

```
>> A=1:10
A =
     1     2     3     4     5     6     7     8     9    10
```

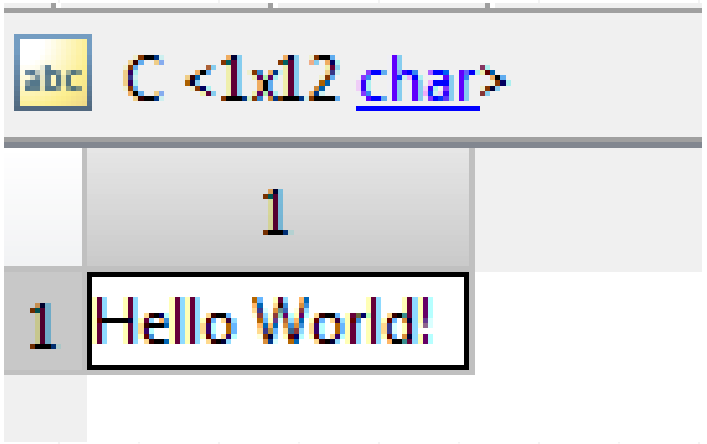
```
>> B= 0:2:10
B =
     0     2     4     6     8    10
```

```
>> 1:0.5:5
ans =
    1.0000    1.5000    2.0000    2.5000    3.0000    3.5000    4.0000    4.5000    5.0000
```

Variables

C = ‘Hello World!';

```
>> C='Hello World!'
C =
Hello World!
```



Variables

```
A = zeros(3);
B = ones(5);
C = rand(100,2);
D = eye(20);
E = sprintf('%d\n',9);
```

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Matrix Index

Matrix indices begin from 1 (not 0!!!)

Matrix indices must be positive integers

```
A =
     1     2     3
     4     5     6
     7     8     9
```

```
>> A(1,3)
ans =
     3
```

```
>> A(1)
ans =
     1
```

```
>> A(2)
ans =
     4
```

Column-Major Order

```
>> A(0)
Subscript indices must either be real positive integers or logicals.
>> A(1,4)
Index exceeds matrix dimensions.
>>
```

Matrix Index

```
A =
     1     2     3
     4     5     6
     7     8     9
```

```
>> A(2,2:3)

ans =

     5     6
```

```
>> A(2,1:end)

ans =

     4     5     6
```

```
>> A(2,:)

ans =

     4     5     6
```

```
>> A(2,1:2:3)

ans =

     4     6
```

```
>> A(2,[1 3])

ans =

     4     6
```

```
>> A(:)

ans =

     1
     4
     7
     2
     5
     8
     3
     6
     9
```

Matrix Index

Accessing Elements

```
A = rand(4);
A(2,3)
A(:,2)
A(end,:)
A([1,2],[1,3])
A(1:2,3:end)
```

http://www.mathworks.com/company/newsletters/articles/matrix-indexing-in-matlab.html

Matrix Operations

+ addition

- subtraction

* multiplication

^ power

' complex conjugate transpose

Matrix Operations

Given A and B:

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

A =

     1     2     3
     4     5     6
     7     8     9
```

```
>> B = [3 5 2; 5 2 8; 3 6 9]

B =

     3     5     2
     5     2     8
     3     6     9
```

Addition

```
>> X = A + B

X =

     4     7     5
     9     7    14
    10    14    18
```

Subtraction

```
>> Y = A - B

Y =

    -2    -3     1
    -1     3    -2
     4     2     0
```

Product

```
>> Z = A * B

Z =

    22    27    45
    55    66   102
    88   105   159
```

Transpose

```
>> T = A'

T =

     1     4     7
     2     5     8
     3     6     9
```

Matrix Operations

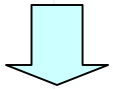
.* element-wise multiplication

./ element-wise division

.^ element-wise power

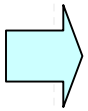
Matrix Operations

```
A = [1 2 3; 5 1 4; 3 2 1]
    A =
          1    2    3
          5    1    4
          3    2   -1
```



```
x = A(1,:)      y = A(3 ,:)

x=              y=
    1   2   3       3  4  -1
```



```
b = x .* y

b=
     3  8 -3
```

```
c = x . / y

c=
   0.33   0.5   -3
```

```
d = x
.^y
d=
       1    16    0.33
```

Matrix Operations

“

A/B Solve linear equation xA=B for x

A\B Solve linear equation Ax=B for x

Matrix Concatenation

X=[1 2], Y=[3 4]

```
>> A=[X Y]
A =
     1     2     3     4
```

```
>> A=[X ; Y]
A =
     1     2
     3     4
```

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Strings

A = ‘vision and geometry’
strfind(A, ‘geometry')
strcmp(A,'computer vision')
B = strcat(A,' 12345')
c = [A,' 12345']
D = sprintf('I am %02d years old.\n',9)
int2str, str2num, str2double

http://www.mathworks.com/help/matlab/ref/strings.html

Cell and Structure

- Cells
  - a = {}; a = cell(1)
  - b = {1,2,3}
  - c = {{1,2},2,{3}}
  - D = {'cat','dog','sheep','cow'}
  - E = {'cat',4}

```
>> D{2}
ans =
dog
```

```
>> E{1}
ans =
cat
>> E{2}
ans =
     4
```

- Structures
  - A = struct('name','1.jpg','height',640,'width',480);
  - b.name = '1.jpg`

http://www.mathworks.com/help/matlab/matlab_prog/cell-vs-struct-arrays.html

Operators

== Equal to

~= Not equal to

< Strictly smaller

> Strictly greater

<= Smaller than or equal to

>= Greater than equal to &

And operator

| Or operator

Flow Control

- if, for, while ....

```
if (a<3)
    Some Matlab Commands;
elseif (b~=5)
    Some Matlab Commands;
end
```

```
while  ((a>3) & (b==5))
    Some Matlab Commands;
end
```

```
for ii=1:100
    Some Matlab Commands;
end
```

```
for j=1:3:200
    Some Matlab Commands;
end
```

```
for k=[0.1 0.3 -13 12 7 -9.3]
    Some Matlab Commands;
end
```

http://www.mathworks.com/help/matlab/control-flow.html

Vectorization

Optimize your code for Matrix operations

Examples

In other languages:

```
tic; i = 0;
for t = 0:.001:1000
    i = i + 1;
    y(i) = sin(t);
end; toc;
```

Elapsed time is 0.509381 seconds.

In MATLAB:

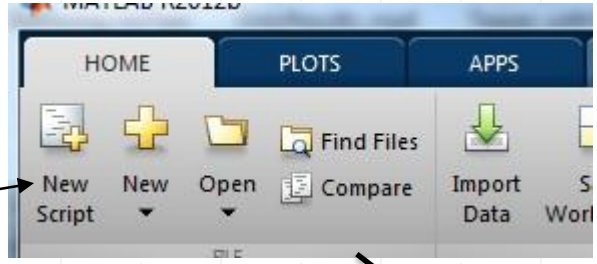
```
tic; t = 0:.001:1000;
y = sin(t); toc;
```

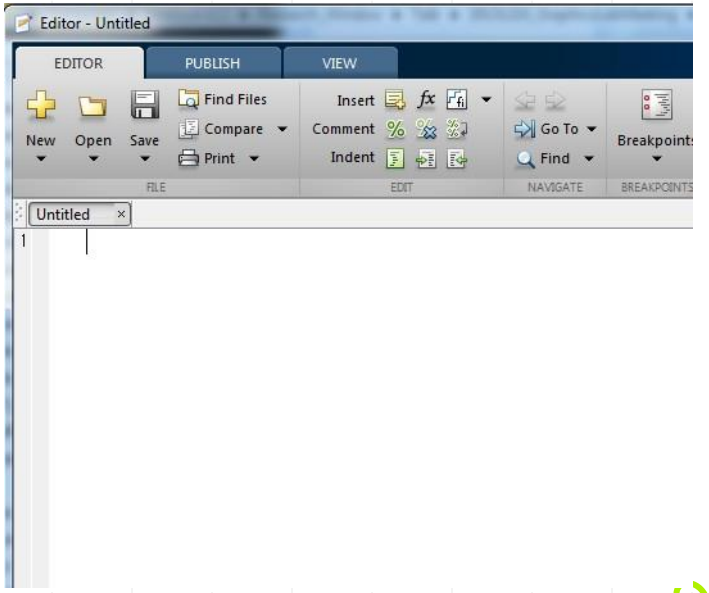
Elapsed time is 0.011212 seconds.

http://www.mathworks.com/help/matlab/matlab_prog/vectorization.html

M-File

Click to create a new M-File





- A text file containing script or function
- Extension ".m"

Functions

For example,

Implement your own function Add3()

B =Add3(A)

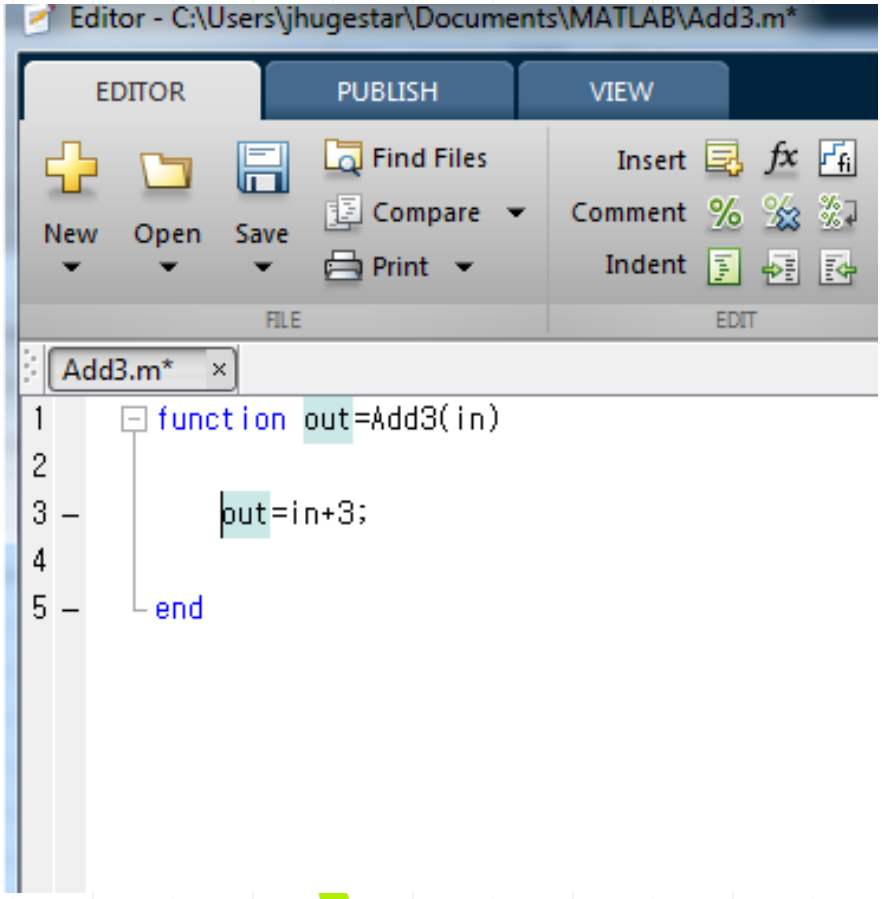
How?

Create a M-file with the function name

Use the function definition at the beginning

```
function out1=functionname(in1)
function out1=functionname(in1,in2,in3)
function [out1,out2]=functionname(in1,in2)
```

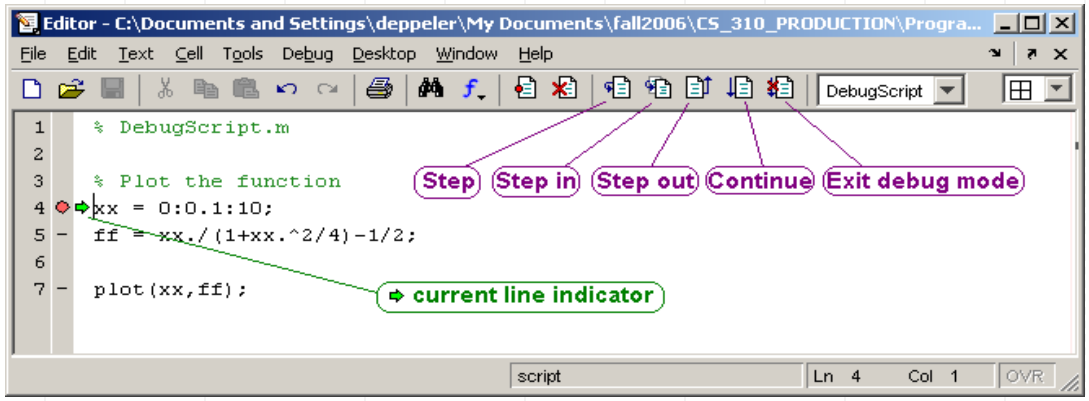
Functions




```
>> a =magic(3)
a =
     8     1     6
     3     5     7
     4     9     2
>> b =Add3(a)
b =
    11     4     9
     6     8    10
     7    12     5
```

Debugging

Breakpoints

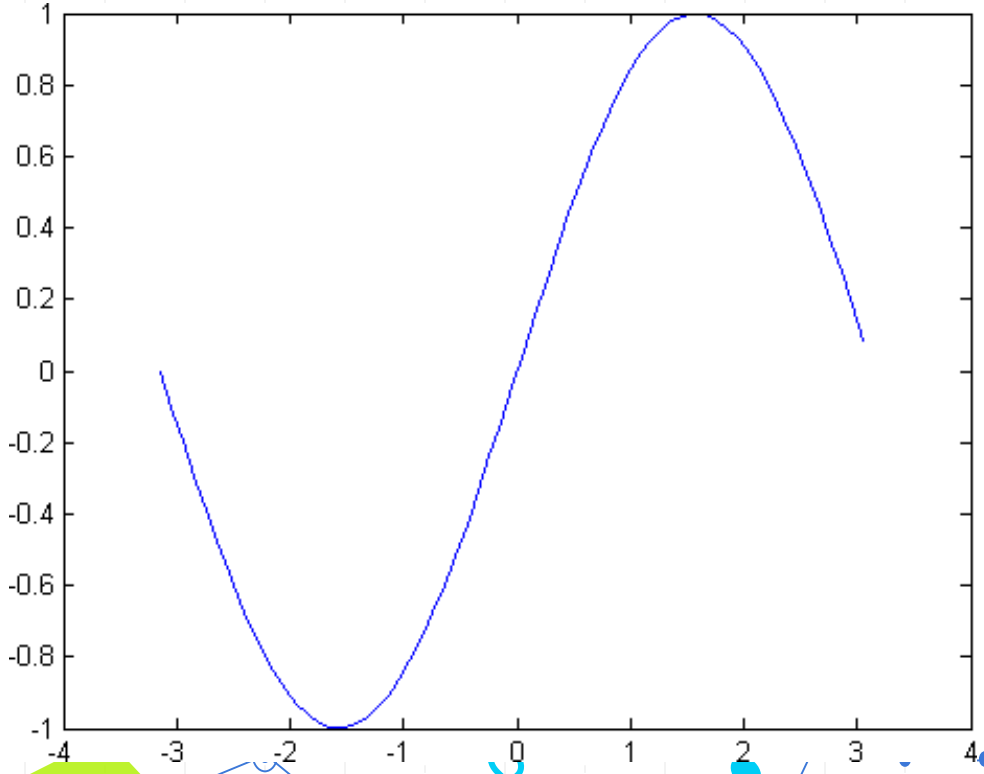


Plotting

Plotting functions

plot, plot3d, bar, area, hist, contour, mesh

```
x = -pi:.1:pi;
y = sin(x);
plot(x,y)
```



Help & Doc

help functionName

doc functionName

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Image Data Structure

- Image as matrices
  - Gray image: m × n
  - RGB image: m × n × 3
- Format:
  - [0, 255] `uint8`
  - [0, 1] `double`

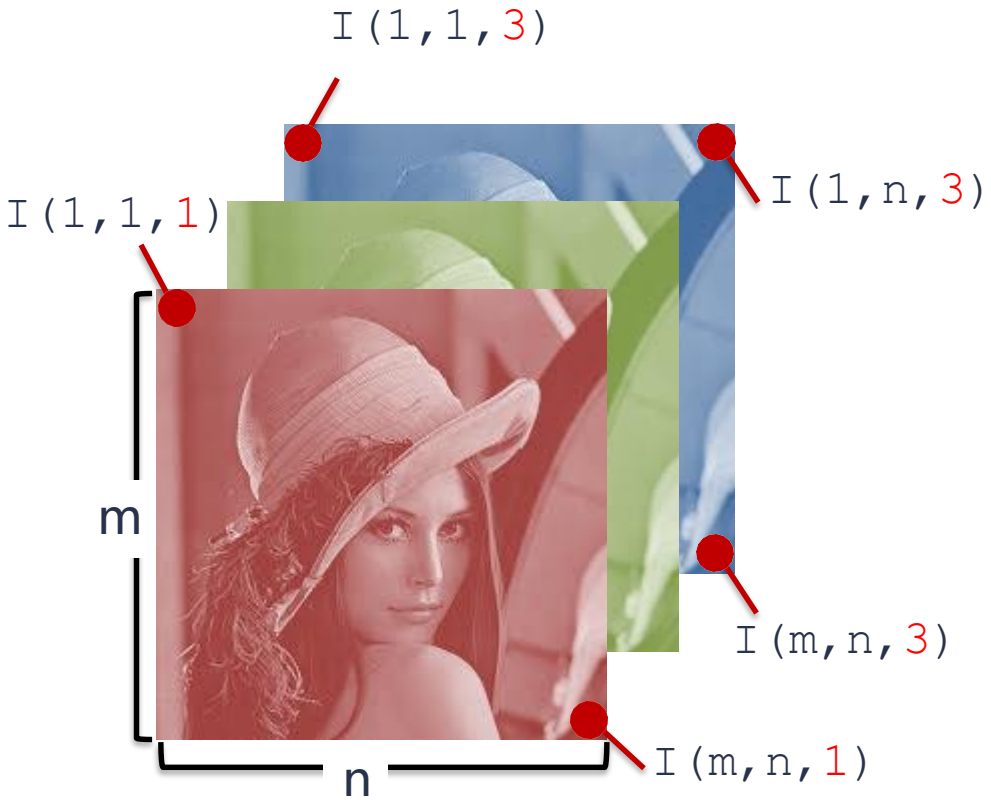


Image I/O/Display

```
% Read image (support bmp, jpg, png, ppm, etc)
I = imread('lena.jpg');

% Save image
imwrite(I, 'lena_out.jpg');

% Display image
imshow(I);

% Alternatives to imshow
   imagesc(I);
   imtool(I);
   image(I);
```

Image Conversions

```
% Type conversion
I1 = im2double(I);
I2 = im2uint8(I);

% Convert from RGB to grayscale
I3 = rgb2gray(I);
```

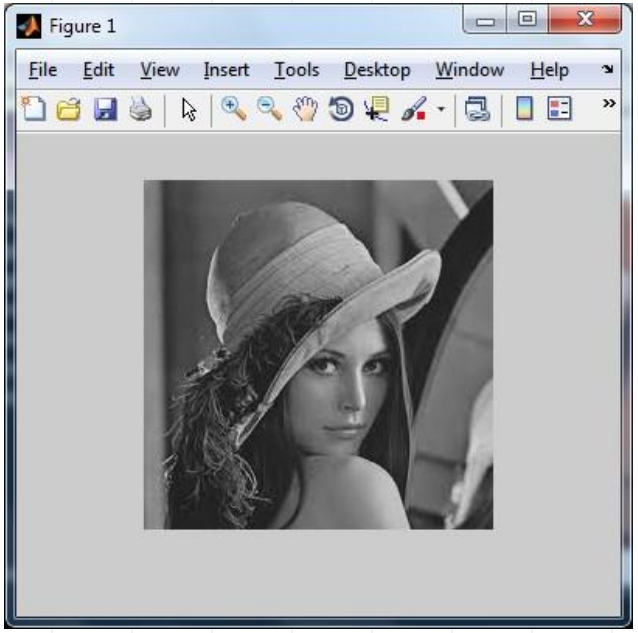


Image Operations

```
% Resize image as 60% smaller
Ires = imresize(I, 0.6);

% Crop image from user's input
imshow(I);
Rect = getrect;
Icrp = imcrop(I, Rect);

% Rotate image by 45 degrees
Irot = imrotate(I, 45);

% Affine transformation
A = [1 0 0; .5 1 0; 0 0 1];
tform = maketform('affine', A);
Itran = imtransform(I, tform);
```

$$\mathbf{p}^i_{warped} = \begin{pmatrix} a & b \\ c & d \end{pmatrix} \mathbf{p}^i_{source} + \mathbf{t}$$

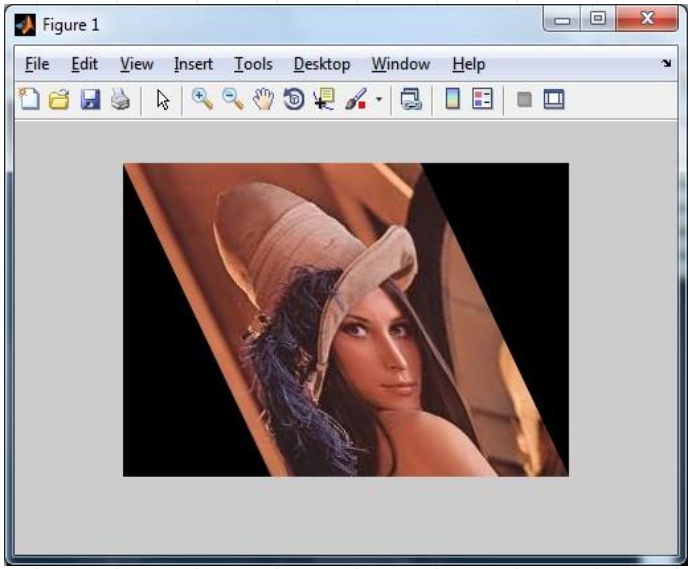
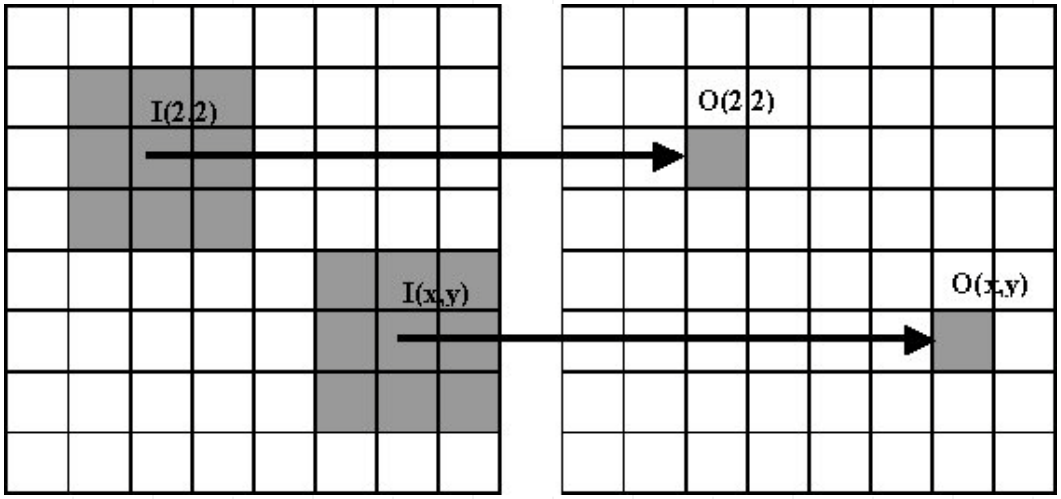
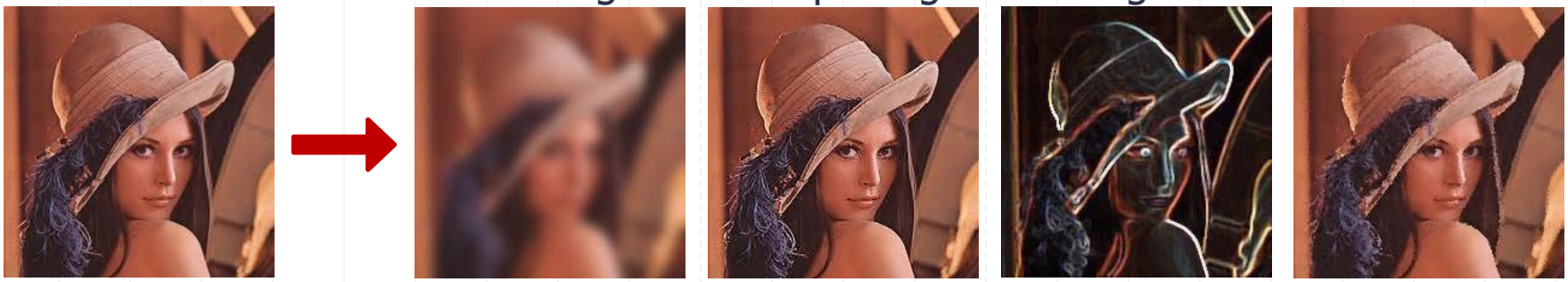


Image Filtering / Convolution

- A filter (or called mask, kernel, neighborhood) is N×N matrix.



- Filters help us perform different kinds of operations:



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References

- More tutorials
  - Matlab course @ ETHZ (http://goo.gl/W2jmZJ)
  - Introductory Digital Processing @ IIT (http://goo.gl/U0osD2)
- Open source CV algorithms with Matlab interface
  - VLFeat (http://www.vlfeat.org/)
  - Piotr Dollar's toolbox (http://vision.ucsd.edu/~pdollar/toolbox/)
  - Mexopencv (http://www.cs.stonybrook.edu/~kyamagu/mexopencv/)

References

- Matlab Documentation
  - http://www.mathworks.com/help/matlab/
- Cheat Sheets
  - http://web.mit.edu/18.06/www/Spring09/matlab-cheatsheet.pdf
  - http://www.geog.ucsb.edu/~pingel/210b/general/matlab_refcard.pdf

THANKS!

Any questions?