Introduction to Medical Imaging (5XSA0)

Digital images in Matlab

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What is a digital image and digital image processing?

- **Digital image is an image for which spatial coordinates x, y and intensity (gray level) $f(x,y)$ are finite, discrete quantities**
  - Digital image is composed of a finite number of elements – picture elements (pixels)
- **Digital image processing is processing digital images by means of a digital computer**

(The slides are based on "Digital Image Processing Using Matlab", R. C. Gonzalez, R. E. Woods, S. L. Eddins)

From image processing to computer vision

- **Low-level: both inputs and outputs are images**
  - Primitive image processing operations: noise reduction, contrast enhancement, image sharpening
- **Mid-level: inputs are images, outputs are attributes extracted from the images (edges, contours)**
  - Segmentation, object recognition
- **Higher-level: "making sense" of an ensemble of recognized objects**

From image processing to computer vision: example from medical imaging – (1)

- **Low-level: both inputs and outputs are images**
  - Primitive image processing operations: noise reduction, contrast enhancement, image sharpening

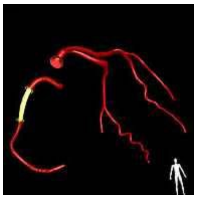
Coronary angiogram

Source: www.heart-valve-surgery.com

From image processing to computer vision: example from medical imaging – (2)

- **Mid-level: inputs are images, outputs are attributes extracted from the images**
  - Segmentation, object recognition

Segment of a coronary artery



Source: http://www.dannyruijters.nl/docs/EMBS_XCT_full.pdf

From image processing to computer vision: example from medical imaging – (3)

- **Higher-level: "making sense" of an ensemble of recognized objects**
  - Automatic volume annotation within volume rendering

Future of full heart modelling

Source: http://incenter.medical.philips.com

MATLAB

* **MATrix LABoratory**
  - High-performance language for technical computing
  - Array – basic data element, does not require dimensioning
  - Toolboxes – application-specific solutions
  - Image Processing Toolbox – for solving digital image processing problems

Matlab desktop

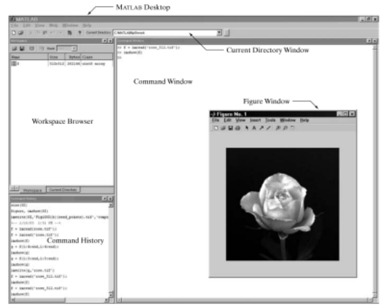


FIGURE 1.1 The MATLAB desktop and its principal components.

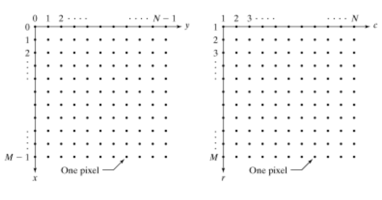
Getting help – (1)

* **Help on Matlab**
  - Click on the question mark symbol (?) on the desktop toolbar
  - Type `helpbrowser` at the prompt in the command window
* **Help on an M-function**
  - Types of help information
    - H1 help – a one-line help
    - Help text block – detailed description

Getting help – (2)

* **Getting help from command window**
  - `help <function_name>`
  - `lookfor <keyword>`
    - displays all H1 lines that contain the keyword
  - `lookfor <keyword> -all`
    - displays H1 lines of all functions that contain the keyword in either the H1 lines or the text block
  - `type <function_name>`
    - displays the text block of the help for the function as well as its code

Digital image representation – (1)



a b
FIGURE 2.1 Coordinate conventions used (a) in many image processing books, and (b) in the Image Processing Toolbox.

Sampling – digitizing the coordinate values
Quantization – digitizing the amplitude (intensity) values

Digital image representation – (2)

$$f = \begin{bmatrix} f(1,1) & f(1,2) & \cdots & f(1,N) \\ f(2,1) & f(2,2) & \cdots & f(2,N) \\ \vdots & \vdots & & \vdots \\ f(M,1) & f(M,2) & \cdots & f(M,N) \end{bmatrix}$$

Example: `f(7,3)` is the element in the 7th row and 3rd column of the matrix (image) `f`.

Reading and displaying images

* **imread('filename')**
  - Example: `f=imread('chestxray.jpg');`
  - **size(f), whos f** display size and additional information respectively
* **imshow(f)**
  - `figure` – creates a new figure window
  - `pixval (impixelinfo)` – shows cursor position and the corresponding intensity

Writing images – (1)

* **imwrite(f,'filename')**
  - Option for a JPEG image – `imwrite(f,'filename.jpg','quality',q)`
  - Obtaining image file details – `imfinfo filename`
    example: `>> imfinfo chestxray.tif`

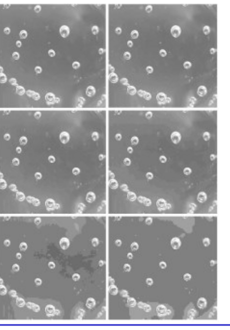
```
ans =
        Filename: 'chestxray.tif'
        FileModDate: '18-Mar-2009 14:55:03'
        FileSize: 297030
        Format: 'tif'
        …
```


Writing images – (2)
some of the image formats supported by **imread** and **imwrite**

Format Name	Description	Recognized Extensions
TIFF	Tagged Image File Format	.tif, .tiff
JPEG	Joint Photographic Experts Group	.jpg, .jpeg
GIF	Graphics Interchange Format[†]	.gif
BMP	Windows Bitmap	.bmp
PNG	Portable Network Graphics	.png
XWD	X Window Dump	.xwd

[†] GIF is supported by imread, but not by imwrite.

Writing images: example



a b
c d
e f

FIGURE 2.4 (a) Original image. (b) through (f) Results of using jpg quality values q = 50, 25, 15, 5, and 0, respectively. False contouring begins to be barely noticeable for q = 15 [image (d)] but is quite visible for q = 5 and q = 0.

Array indexing

```
>> v=[1 3 5 7 9]
v =
     1   3   5   7

>> v(3)
ans =
     5

>> v(2:4)
ans =
     3   5   7
```

```
>> v(1:2:end)
ans =
     1   5   9

>> v(end:-2:1)
ans =
     9   5   1

>> x=linspace(1,10,4)
x =
     1   4   7   10
```


Matrix indexing

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

>> A(2,3)
ans =
     6
```

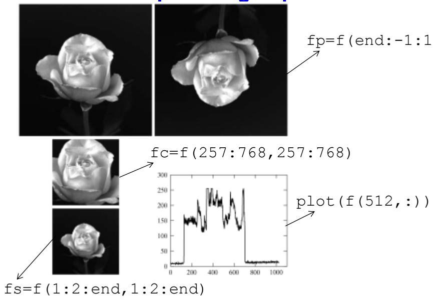
```
>> column3=A(:,3)
column3 =
     3
     6
     9

>> row1=A(1,:)
row1 =
     1   2   3

>> A(2:3,1:2)
ans =
     4   5
     7   8
```

Matrix indexing

Example: image operations



a b
c
d e

FIGURE 2.6 Results obtained using array indexing. (a) Original image. (b) Image flipped vertically. (c) Cropped image. (d) Subsampled image. (e) A horizontal scan line through the middle of the image in (a).

Operators – (1)

Operator	Name	MATLAB Function	Comments and Examples
+	Array and matrix addition	plus(A, B)	a + b, A + B, or a + A.
–	Array and matrix subtraction	minus(A, B)	a – b, A – B, A – a, or a – A.
.*	Array multiplication	times(A, B)	C = A.*B, C(I, J) = A(I, J)*B(I, J).
*	Matrix multiplication	mtimes(A, B)	A*B, standard matrix multiplication, or a*A, multiplication of a scalar times all elements of A.
./	Array right division	rdivide(A, B)	C = A./B, C(I, J) = A(I, J)/B(I, J).
.\	Array left division	ldivide(A, B)	C = A.\B, C(I, J) = B(I, J)/A(I, J).
/	Matrix right division	mrdivide(A, B)	A/B is roughly the same as A*inv(B), depending on computational accuracy.
\	Matrix left division	mldivide(A, B)	A\B is roughly the same as inv(A)*B, depending on computational accuracy.
.^	Array power	power(A, B)	If C = A.^B, then C(I, J) = A(I, J)^B(I, J).
^	Matrix power	mpower(A, B)	See online help for a discussion of this operator.
.'	Vector and matrix transpose	transpose(A)	A.'. Standard vector and matrix transpose.
'	Vector and matrix complex conjugate transpose	ctranspose(A)	A'. Standard vector and matrix conjugate transpose. When A is real A.' = A'.
+	Unary plus	uplus (A)	+A is the same as 0 + A.
–	Unary minus	uminus (A)	–A is the same as 0 – A or –1*A.
:	Colon		Discussed in Section 2.8.

Operators – (2)

TABLE 2.6 Relational operators.

Operator	Name
<	Less than
<=	Less than or equal to
>	Greater than
>=	Greater than or equal to
==	Equal to
~=	Not equal to

TABLE 2.7 Logical operators.

Operator	Name
&	AND
|	OR
~	NOT

TABLE 2.8 Logical functions.

Function	Comments
xor (exclusive OR)	The xor function returns a 1 only if both operands are logically different; otherwise xor returns a 0.
all	The all function returns a 1 if all the elements in a vector are nonzero; otherwise all returns a 0. This function operates columnwise on matrices.
any	The any function returns a 1 if any of the elements in a vector is nonzero; otherwise any returns a 0. This function operates columnwise on matrices.

Flow control

Statement	Description
if	if, together with else and elseif, executes a group of statements based on a specified logical condition.
for	Executes a group of statements a fixed (specified) number of times.
while	Executes a group of statements an indefinite number of times, based on a specified logical condition.
break	Terminates execution of a for or while loop.
continue	Passes control to the next iteration of a for or while loop, skipping any remaining statements in the body of the loop.
switch	switch, together with case and otherwise, executes different groups of statements, depending on a specified value or string.
return	Causes execution to return to the invoking function.
try...catch	Changes flow control if an error is detected during execution.

Introduction to spatial domain techniques – (1)

* **include**
  – Intensity (gray-level) transformations
  – Spatial filtering (or neighborhood processing, or spatial convolution)
* **can be denoted by the expression**

$$g(x, y) = T[f(x, y)]$$

where $f(x,y)$ – input image, $g(x,y)$ – output (processed) image, T – operator defined on a neighborhood around (x,y)

Introduction to spatial domain techniques – (2)

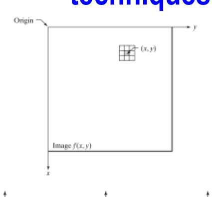
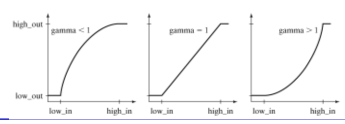


FIGURE 3.1 A neighborhood of size 3 × 3 about a point (x, y) in an image.

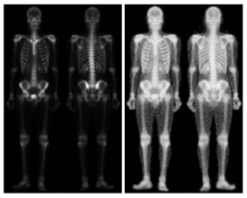


a b c

FIGURE 3.2 The various mappings available in function imadjust.

Intensity transformation functions – (1)

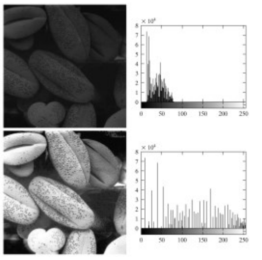
- **`imadjust` – intensity transformations for gray-scale images**
- **logarithmic and contrast-stretching transformations**
- **`gscale` – scale the image to the full maximum range**



a b
FIGURE 3.6 (a) Bone scan image. (b) Image enhanced using a contrast-stretching transformation. (Original image courtesy of G. E. Medical Systems.)

Intensity transformation functions – (2)

- **`imhist` – plot a histogram**
- **`histeq` – histogam equilization, histogram matching**



a b
c d
FIGURE 3.8 Illustration of histogram equalization. (a) Input image, and (b) its histogram. (c) Histogram-equalized image, and (d) its histogram. The improvement between (a) and (c) is quite visible. (Original image courtesy of Dr. Roger Heady, Research School of Biological Sciences, Australian National University, Canberra.)

Spatial filtering

- **Linear spatial filtering**
  - Multiply each pixel in the neighborhood by a corresponding coefficient and sum the results to obtain the response at each point
  - Matrix of coefficients is called filter, mask, filter mask, kernel, template or window
- **Nonlinear spatial filtering**
  - Performs nonlinear operations on neighborhood pixels

Linear spatial filtering – (1)

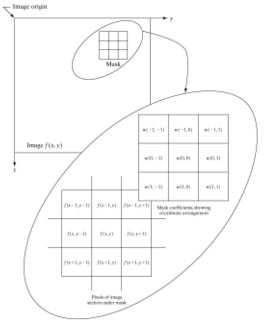


FIGURE 3.12 The mechanics of linear spatial filtering. The magnified drawing shows a 3 × 3 mask and the corresponding image neighborhood directly under it. The neighborhood is shown displaced out from under the mask for ease of readability.

Linear spatial filtering – (2)

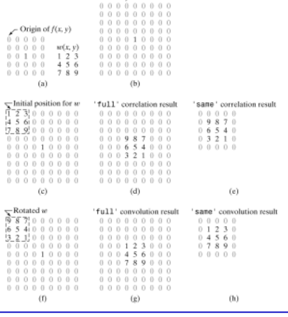


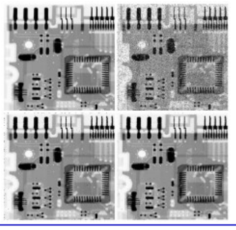
FIGURE 3.14 Illustration of two-dimensional correlation and convolution. The 0s are shown in gray to simplify viewing.

Linear spatial filtering – (3)

- **`imfilter` – linear filtering with a user-defined mask**
  - options – boundary (symmetric, replicate, circular), output size (same or full), correlation or convolution
- **`fspecial` – create predefined 2D filters**
  - types of filters – average, gaussian, laplacian, prewitt, sobel, etc.

Nonlinear spatial filtering

* **`ordfilt2`** **– 2D order-statistic filter**
  - `g=ordfilt2(f,1,ones(m,n))` – min filter
* **`medfilt2`** **– 2D median filter**



a b
c d

FIGURE 3.18 Median filtering. (a) X-ray image. (b) Image corrupted by salt-and-pepper noise. (c) Result of median filtering with `medfilt2` using the default settings. (d) Result of median filtering using the `'symmetric'` image extension option. Note the improvement in border behavior between (d) and (c). (Original image courtesy of Lixi, Inc.)

References

– Rafael C. Gonzalez, Richard E. Woods, Steven L. Eddins, "Digital Image Processing Using Matlab", Pearson Education, 2004
  – Chapter 1
  – Chapter 2
  – Chapter 3