IMA 4509

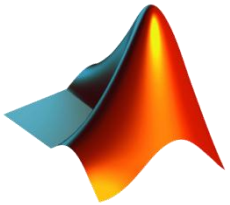
Visual content analysis

Image processing & analysis with MATLAB: an overview

Nicolas ROUGON

ARTEMIS Department

Motivations



- **MATLAB: an industry standard for rapidly testing new ideas & prototyping applications**
  - Interpreted programming language ► (rather) slow
  - Easy-to-program: untyped C-like syntax operating on matrices
  - Powerful API thanks to dedicated toolboxes
  - C/C++ code generation (C/MEX files)
    > compiled MATLAB routines
    > standalone applications

    ► faster execution
  - Extensive online resources: documentation, tutorials, examples, source code repository (MATLAB CENTRAL)
  - Huge literature:
    > MATLAB references
    > Scientific books using MATLAB as simulation language

Motivations

- **The Image Processing Toolbox for MATLAB**
  - Image display & exploration
  - Spatial transformations & image registration
  - Color space conversion
  - Image statistics & arithmetic
  - Basic image analysis
  - Image enhancement & restoration
  - Image filtering & transforms
  - Mathematical morphology
  - GUI tools
  - Online documentation:

    www.mathworks.fr/help/toolbox/images

Local MATLAB versions

- **2 releases available on TSP Unix servers**
  - MATLAB 2010a — **/opt/matlab-disi-R2010a**
    - > main routine — /usr/local/bin/matlab
    - (default) -> /opt/matlab-disi-R2010a/bin/matlab
  - MATLAB 2015a — **/opt/matlab-disi-R2015a**
    - > main routine — /opt/matlab-disi-R2015a/bin/matlab
    - > to be used in this course

(re)Initializing MATLAB

- **Clear display:** close all

```
> close all          // close all figure windows
```

- **Clear worskspace:** clear

```
> clear              // clear all variables
> clear all          // clear all variables, functions, CMEX files…
> clear A1 A2 A3     // clear designated variables
```

Image IOs

- **Loading an image:** imread()

```
> I = imread('the_image.jpg')                          // filename
> I = imread('http://the_server.fr/the_image.jpg')     // URL
```

  - Supported image formats: BMP, GIF, JPEG, JPEG-2000, PBM/PGM/PPM, PNG, TIFF…

- **Writing an image:** imwrite()

```
> imwrite(I, 'the_image.jpg',…)          // get format from extension
> imwrite(I, 'the_image', format,…)      // specify format
```

  - Additional arguments: format-specific parameters

Getting image information

- **From file:** **imfinfo()**

  > imfinfo('the_image.jpg')

  - Returns:
    - file name
    - format
    - modification date
    - size (in bytes)
    - image dimensions
    - # of bits per pixel
    - image type (truecolor | grayscale | indexed)

- **From variable:** **whos**

  > whos

  - Returns:
    - size (in bytes)
    - storage class
    - image dimensions

DICOM images

- **Getting metadata from file:** dicominfo()

  > info = dicominfo('the_image.dcm')

- **Loading an image:** dicomread()

  > I = dicomread('the_image.dcm') // from a DICOM file
  > I = dicomread(info) // from DICOM metadata

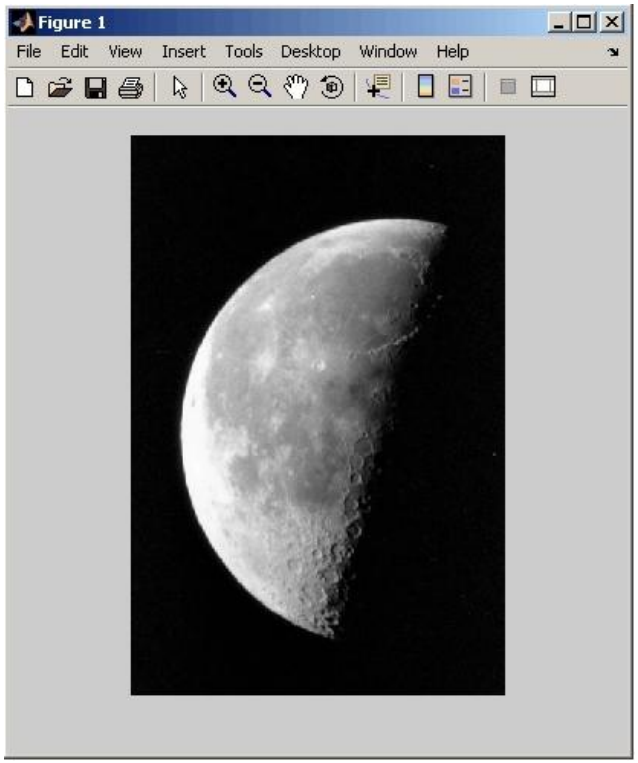
- **Writing an image:** dicomwrite()

  > dicomwrite(I, 'the_image.dcm') // save image data only
  > dicomwrite(I, 'the_image.dcm', info) // save image & metadata

Displaying images

- **In a figure window:** imshow()

```
> I = imread('the_image.jpg');
  imshow(I)
```

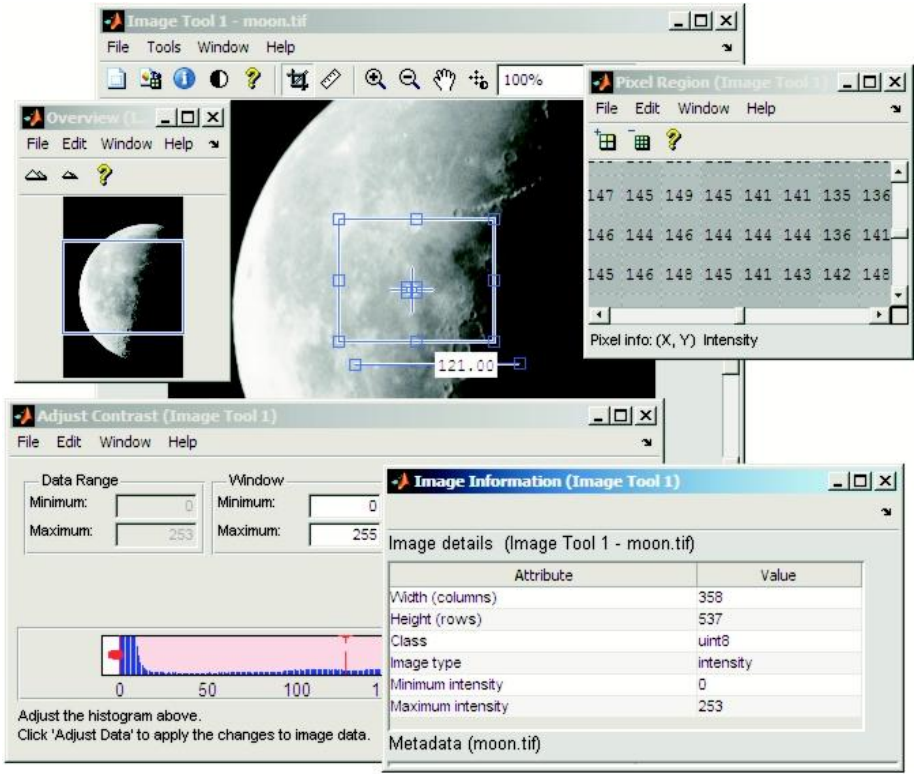


Displaying images

- **An integrated image viewer:** imtool()

  > I = imread('the_image.jpg');
  imtool(I)

  - Image information
  - Current pixel value
  - Region pixel values
  - Zoom / Pan
  - Crop
  - Global contrast transform
  - …



Displaying images

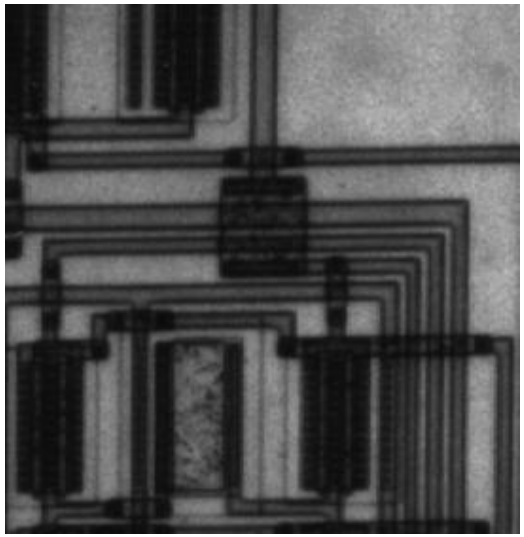
- **As a topographic surface:** surf()

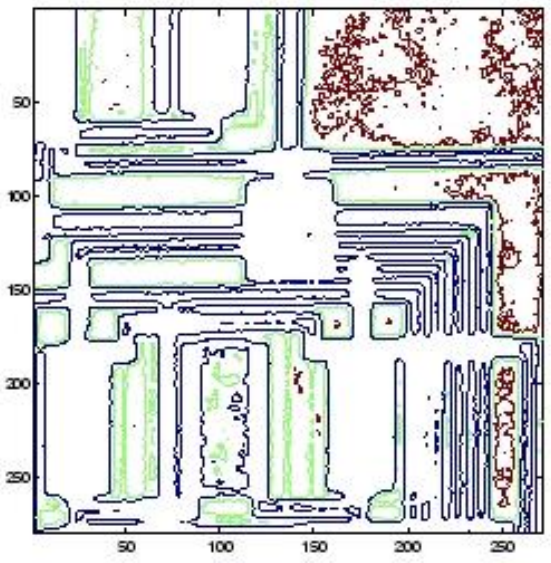
```
> I = imread('the_image.jpg');
  figure, surf(double(I(1:8:end,1:8:end))), zlim([0,255]);
  set(gca, 'ydir', 'reverse');
```

  - surf() operates on double data
  - surf() uses a reference frame with origin at the upper-left corner and upward-pointing *y*-axis
  - zlim() sets *z*-axis limits

Displaying images

- **Image level lines:** imcontour()
  - > imcontour(I)
  - > imcontour(I, nb_lines) // equally spaced values
  - > imcontour(I, values) // specified values





> I = imread('circuit.tif');
imcontour(I,3)

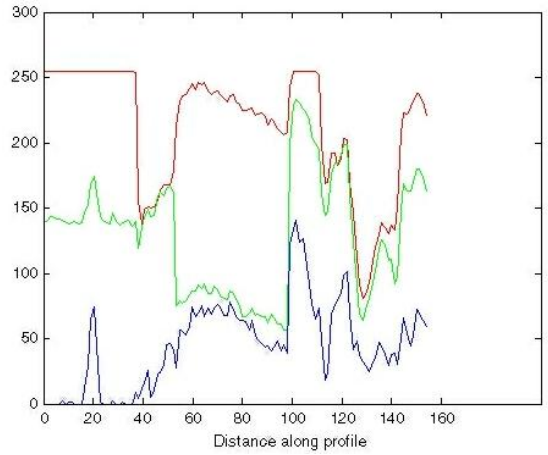
Displaying images

- **Line intensity profile:** improfile()

```
> improfile                    // interactive line definition
> improfile(I, xi, yi)         // line definition from end points
```

  - Arguments

    xi, yi: vectors of *x*,*y* coordinates of end points
    (*n* lines ► 2*n*-dimensional vectors)

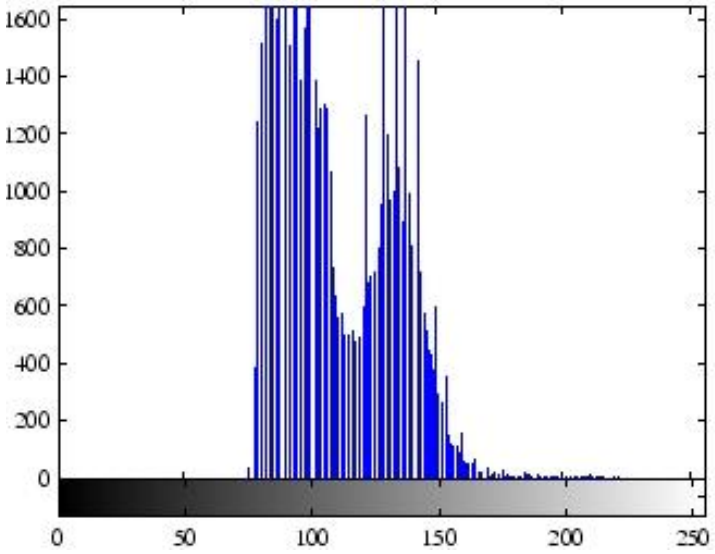



```
> I = imread('peppers.png');
  imshow(I)
  improfile
```

Image histogram

- **Display image histogram:** imhist()

```
> imhist(I)
> imhist(I, nb_bins)          // specify # of bins (default: 64)
> [counts, x] = imhist(I)     // get histogram counts & bin locations
```




```
> I = imread('pout.tif');
  imshow(I);
  figure, imhist(I)
```

Image histogram

- **(Robust) histogram stretching:** imadjust()

```
> J = imadjust(I)      // 1% of data saturated at lower/upper bounds
> J = imadjust(I, [low_in,high_in],[low_out,hight_out])
                       // input/output intensity ranges in [0,1]
```

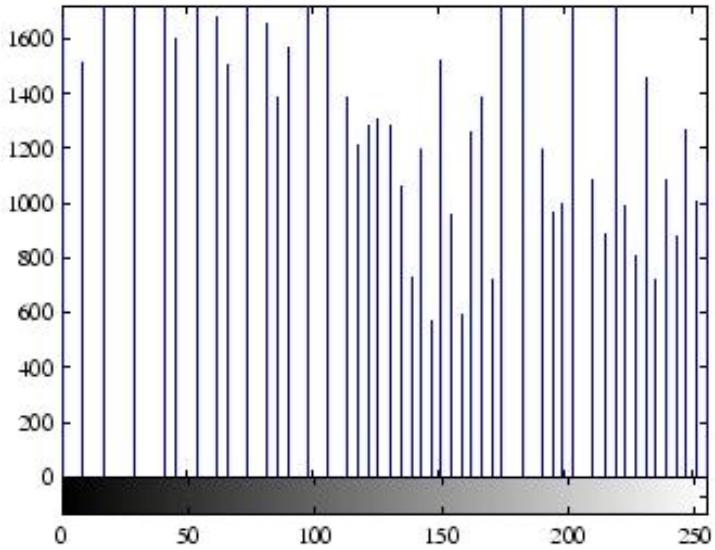
```
> I = imread('pout.tif');
  imshow(I);
  J = imadjust(I);
  figure, imshow(J)
```

Histogram transforms

- **Histogram equalization:** histeq()

  > J = histeq(I)

  > J = histeq(I, nb_bins) // predefined # of bins




```
> I = imread('pout.tif');
  J = histeq(I);
  imshow(J);
  figure, imhist(J);
```

Histogram transforms

- **Histogram specification:** histeq()

```
> hJ = imhist(J)
  I_J = histeq(I, hJ)                    // specified target histogram
```

  - Optional arguments: # of bins

Image threshold

- **Image binarization:** **im2bw()**

  > BW = im2bw(I, level)

  - Arguments

    I : grayscale / color image
    (color images are first converted to grayscale)

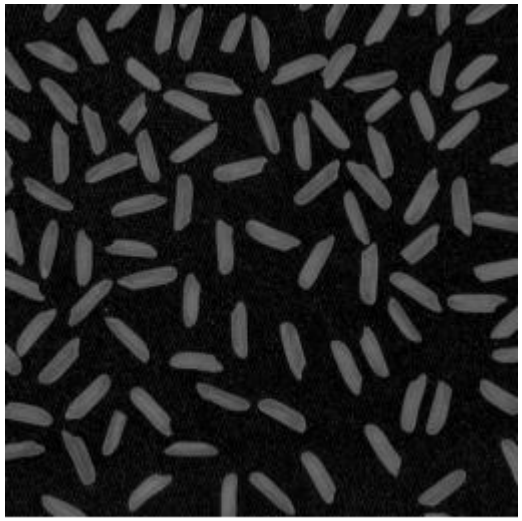
    level : normalized threshold in [0,1]

Histogram-based segmentation

- **Histogram threshold:** graythresh()

```
> level = graythresh(I)
```

// normalized threshold in [0,1]
// using Otsu's method



```
> I = imread('rice.png')
```

```
> J = imadjust(I)
```

```
> level = graythresh(J);
  BW = im2bw(J,level)
```

Image quantization

- **Image quantization:** **imquantize()**

  > J = imquantize(I, levels)

  > J = imquantize(I, levels, values)

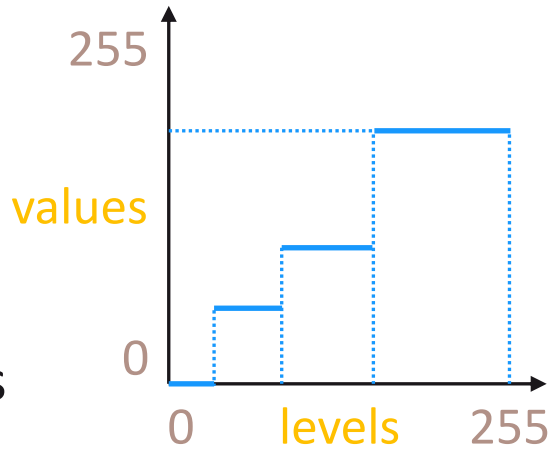
  - Arguments

    I : grayscale / color image

    levels : (1xN)-vector of quantization levels

    values : (1xN)-vector of quantization values

    default: [1..N+1]



Label map visualization

- **Label to RGB map conversion:** label2rgb()

  > I = label2rgb(L)

  > I = label2rgb(L, map)

  - Arguments

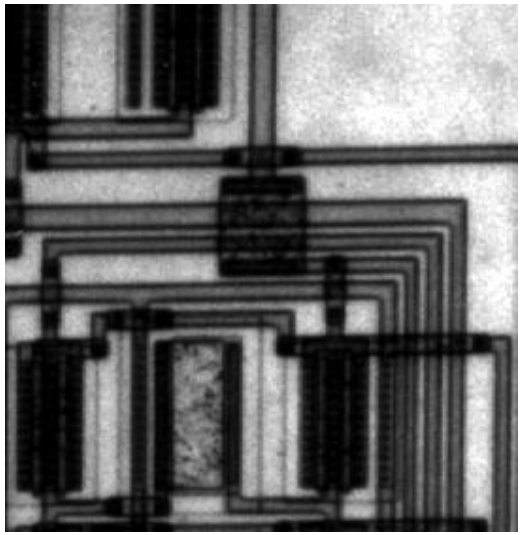
    L : label matrix

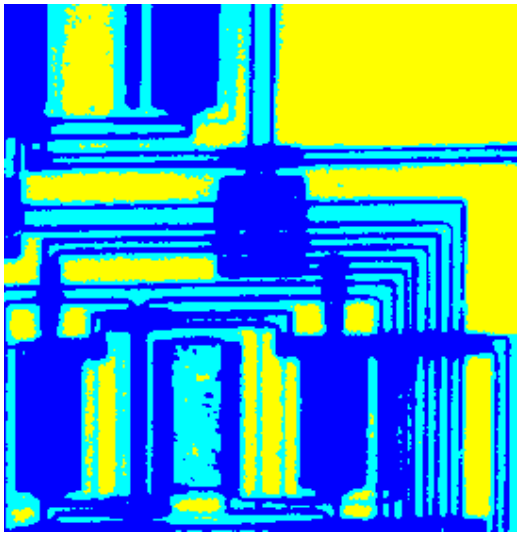
    map : (Nx3) matrix | MATLAB predefined colormap (*see* colormap)

Histogram-based segmentation

- **Multilevel histogram threshold:** multithresh()

```
> levels = multithresh(I, N)      // (1xN)-vector of thresholds
                                  // using multilevel Otsu's method
```





```
> I = imread('circuit.png');
  imshow(I);
```

```
> levels = multithresh(I, 2);
  I_seg = imquantize(I, levels);
  RGB = label2rgb(I_seg);
  imshow(RGB);
```

Image type conversions

- **Image to double:** im2double()

```
> J = im2double(I)
```

- **Image to 8-bit integers:** im2uint8()

```
> J = im2uint8(I)          // unsigned integers
```

- **Image to 16-bit integers:** im2int16() im2uint16()

```
> J = im2int16(I)          // signed integers
> J = im2uint16(I)         // unsigned integers
```

Image noise

- **Noisy image synthesis:** imnoise()

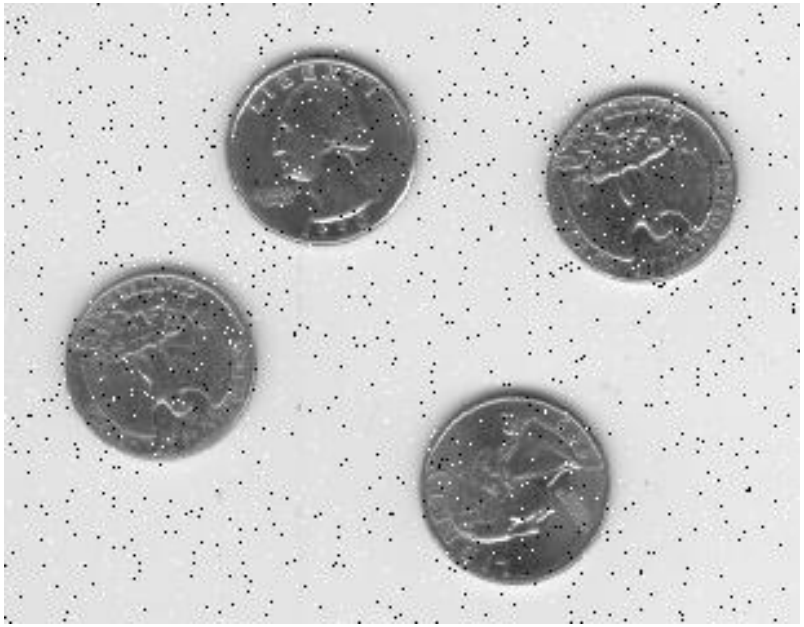
  > J = imnoise(I, type, parameters)

type	parameters	default	
'gaussian'	mean, variance	0, 0.01	
'localvar'	local_variance		// variance map
'poisson'	-	-	
'salt & pepper'	density	0.05	
'speckle'	variance	0.04	

Image noise

- **Noisy image synthesis:** imnoise()

> I = imread('eight.tif');
> imshow(I);



> J = imnoise(I, 'salt & pepper', 0.02);
> figure, imshow(J);

Image linear filtering

- **Create predefined kernel:** fspecial()

```
> H = fspecial(type)
> H = fspecial(type, parameters)        // specify filter parameters
```

type	parameters	default	
'average'	hsize	[3,3]	
'disk'	radius	5	
'gaussian'	hsize, sigma	[3,3] , 0.5	
'laplacian'	alpha	0.2	// (3x3) Laplacian
'prewitt'	-	-	
'sobel'	-	-	
'log'	hsize, sigma	[5,5] , 0.5	

Image linear filtering

- **Apply linear filter:** imfilter()

```
> J = imfilter(I, H)
> J = imfilter(I, H, bcond)        // specify boundary conditions
```

  - Arguments

    H : filter kernel

    bcond = ‘symmetric’ | ‘replicate’ | ‘circular’ | value (default: 0)

Image linear filtering

- **Apply linear filter:** imfilter()

> I = imread('cameraman.tif');
> imshow(I);

> H = fspecial('disk', 10);
> J = imfilter(I,H, 'symmetric');
> figure, imshow(J);

Image nonlinear filtering

- **2D median filter:** **medfilt2()**

```
> J = medfilt2(I)
> J = medfilt2(I, [m n])      // specify neighborhood size
                              // default : [3 3]
```

- **3D median filter:** **medfilt3()**

```
> J = medfilt3(I)
> J = medfilt3(I, [m n q])    // specify neighborhood size
                              // default : [3 3 3]
```

Image nonlinear filtering

- **2D median filter:** medfilt2()

> I = imread('cameraman.tif');
> J = imnoise(I,'salt & pepper',0.02);
> imshow(J);

> K = medfilt2(J);
> figure, imshow(K);

Image nonlinear filtering

- **2D order-statistic filter:** **ordfilt2()**

  > J = ordfilt2(I, order, domain)

  - Arguments

    domain : numeric / logical binary matrix = neighborhood

    e.g. ones (N) | true(N)

    order : index in the sorted neighborhood pixel list

    e.g. domain = true(N)

    order = 1 > minimum

    order = (NxN+1)/2 > median

    order = NxN > maximum

Image enhancement

- **Image sharpening:** **imsharpen()**

  > J = imsharpen(I, Name, Value, …) // unsharp masking

  - Arguments

Name	default Value	
‘Radius’	1	// Gaussian kernel std deviation
‘Amount’	0.8	// sharpening parameter standard range [0 2]

Edge detection

- **Differential edge detection:** edge()

  > BW = edge(I, method, thresh,…) // fixed threshold
  > BW = edge(I, method,…) // adaptive threshold
  > [BW, thresh] = edge(I, method,…) // get threshold value

  - Arguments

    method = ‘roberts’ | ‘prewitt’ | ‘sobel’ | ‘log’ | ‘canny’

    thresh : threshold value / range

  - Optional arguments

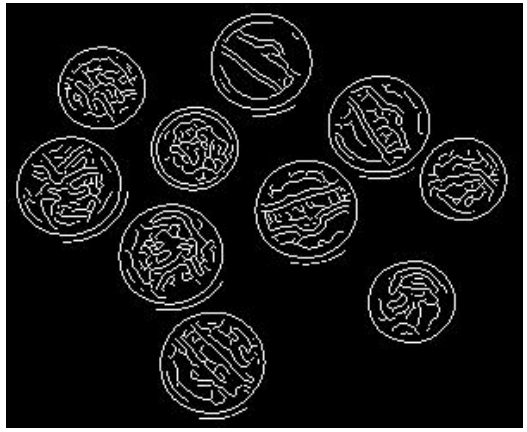
    sigma : variance of LoG filter / Canny-Deriche parameter

    options = ‘nothinning’ | ‘thinning’ (default)

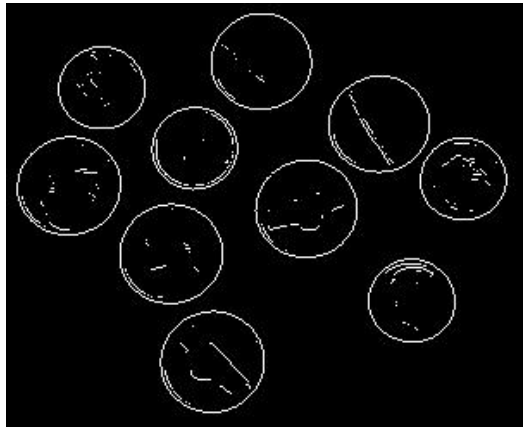
    direction = ‘horizontal’ | ‘vertical’ | ‘both’ (default)

Edge detection

- **Differential edge detection:** edge()



> I = imread('coins.png');
> imshow(I)



> thresh = 40;
> BW = edge(I, 'sobel', thresh);
> figure, imshow(BW)

> thresh = [120,140];
> BW = edge(I, 'canny', thresh);
> figure, imshow(BW)

Corner detection

- **Differential corner detection:** corner()

```
> C = corner(I)
> C = corner(I, method)        // specify corner detector
> C = corner(I, N,…)           // specify maximum # of points
```

  - Arguments

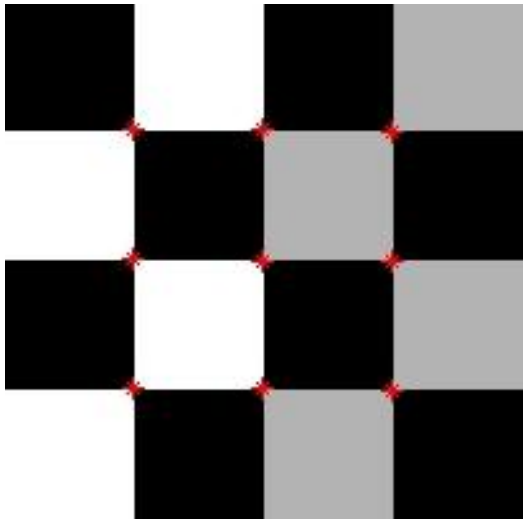
    method = ‘MinimumEigenValue’ | ‘Harris’ (default)

    N : maximum # of corner points (default: 200)

  - Optional arguments: detector-specific parameters

Corner detection

- **Differential corner detection:** corner()



```
> I = checkboard (50,2,2);
  C = corner(I);              // Harris detector (default)
  imshow(I);
  hold on                     // overwrite on image
  plot(C(:,1), C(:,2), 'r*');
```

Active contours

- **Active contour segmentation:** activecontour()

```
> BW = activecontour(I, mask)
> BW = activecontour(I, mask, n)          // specify max # of iterations
> BW = activecontour(I, mask, method) // specify AC method
```

- Arguments

  I : grayscale image

  mask : binary initialization mask

  n : maximum # iterations (default: 100)

  method = ‘Chan-Vese’ (default) | ‘edge’ (geodesic AC)

Active contours

- **Active contour segmentation:** activecontour()

> BW = activecontour(__, Name, Value) // specify hyperparameters

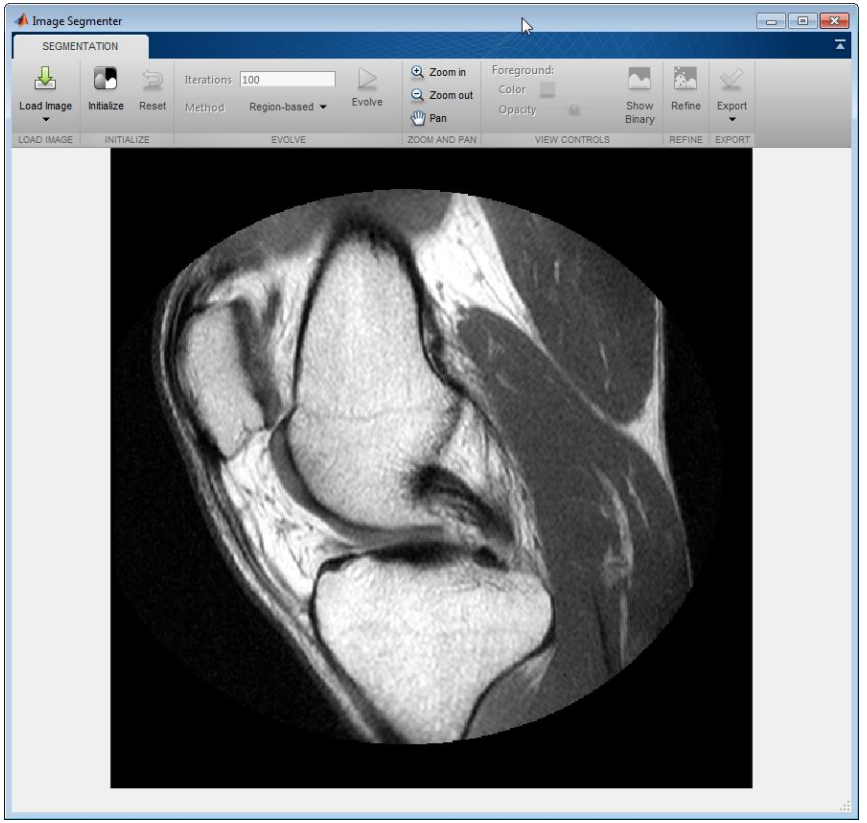
Name	Interpretation	default	
‘ContractionBias’	pressure > 0 shrink | < 0 expand	0	0.3
‘SmoothFactor’	edge map smoothing	0	1.0
		‘Chan-Vese’	‘edge’

Active contours

- **Integrated AC segmentation tool:** imageSegmenter

  > ImageSegmenter

  - Image IOs
  - Initialization (external | interactive | image-based | grid based)
  - GUI for activecontour()
  - Segmentation assessment & post-processing



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