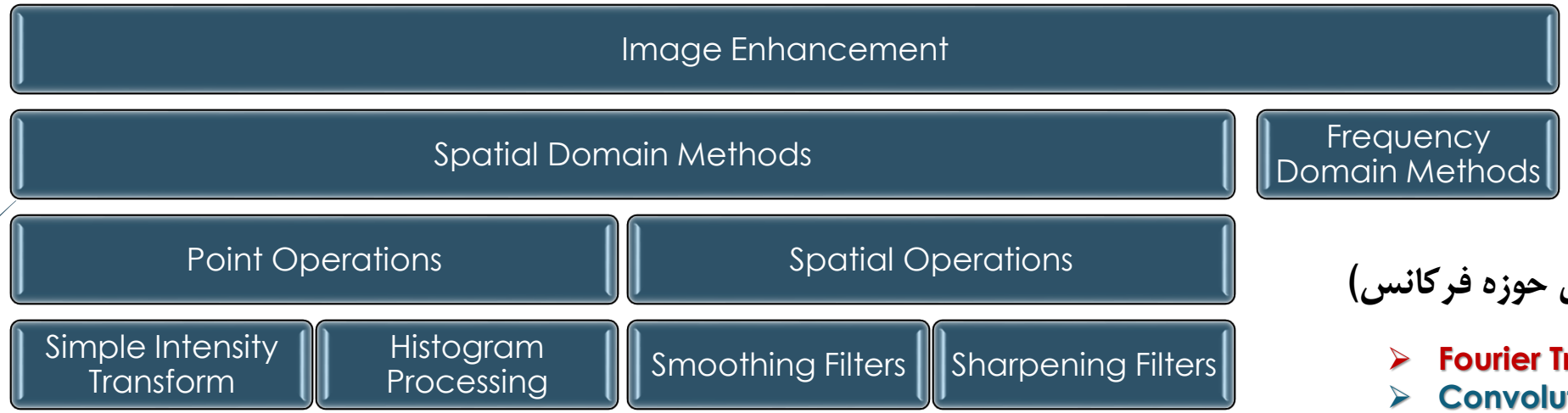
# A Review on Image Enhancement Techniques

By Ariyan Zarei

# Image Enhancement

- Improve perception of information in images
  - For human viewers
  - Provide better input for other Image processing techniques
- Amplifies or sharpens image features such as
  - Edges
  - Boundaries
  - Contrast
- What is a good image enhancement? Which image is good?
  - This problem led the scientists to use fuzzy logic (at the end of the presentation)

# Image Enhancement




(فیلتر گذاری حوزه مکان)

- **Pixels**
- **Neighborhoods**

(فیلتر گذاری حوزه فرکانس)

- **Fourier Transform**
- **Convolution**

# Image Enhancement
## Spatial Domain Methods

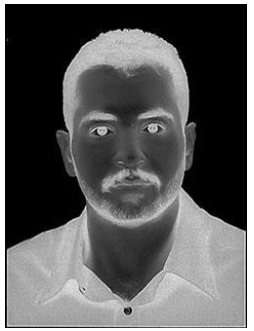
- Direct manipulation of Pixels
- Of the General Form
  - g(x,y) = **T**[f(x,y)]
  - where g is the output, f is the input image and **T** is an operation on f defined over some neighborhood of (x,y) (or the x,y point itself).

- Based only on the intensity of single Pixels
  I. Image Negatives
  II. Contrast Stretching
  III. Compression of Dynamic Range
  IV. Gray Level Slicing

- Useful in many areas such as
  - Medical Imaging
  - Photographing
  - Etc.
- Transform Function
  - T : g(x,y)=255 - f(x,y)
- Matlab Method
  - image2 = imcomplement(image1);

f(x,y)

g(x,y)



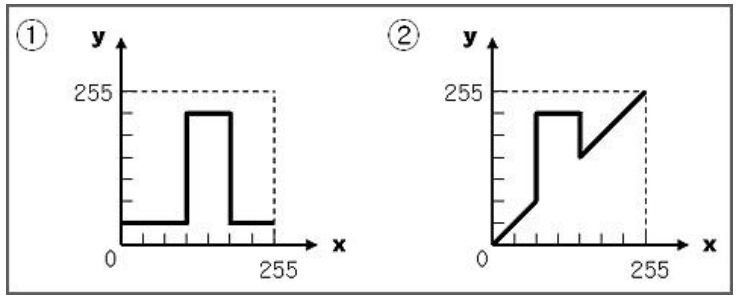
- Low Contrast image can be produced
- Contrast Stretching
  - Increase the dynamic range of gray levels
  - Low Contrast
    - Min = 105 , Max = 190
  - High Contrast
    - Min = 0 , Max = 255 , map each pixel
  - Formula
    - $P_{out} = (P_{in} - c) \times \left(\frac{Max - Min}{d - c}\right) + Min$
    - Where Max = 255 , Min = 0 , d = old Max , c = old Min
  - Matlab Function
    - image2 = imadjust(image1,stretchlim(image1),[]);

Low Contrast

High Contrast

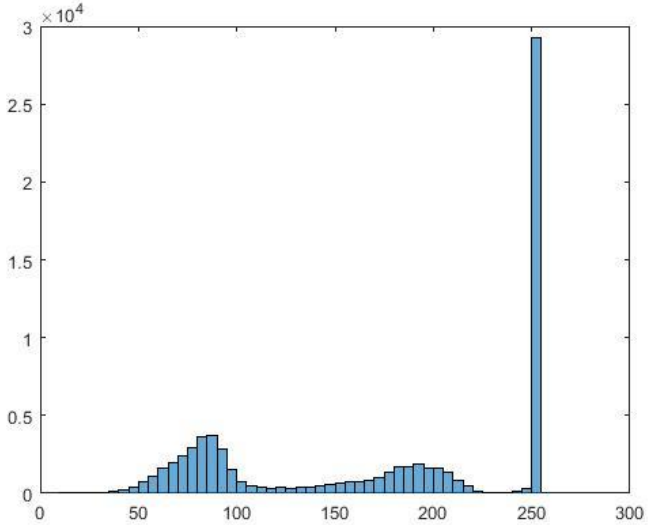
- Range of an image exceeds capability of the display device
  - Only the brightest parts are visible on the screen
- Solution is to
  - Compress the dynamic range of the image using a log function
  - $P_{out} = c \times log(1 + |P_{in}|) + Min$
  - Where c is a scaling constant
- Applications in
  - Images captured in a very light background
  - Sound processing
  - Satellite Imaging
  - Etc.
- In the example, the details of the face in the main image is not clear.

- In order to highlight a specific range in the gray level range of an image
- Something like thresholding

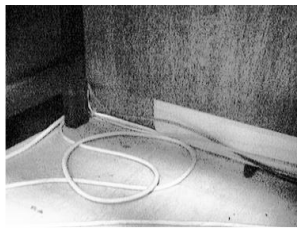



- What is Histogram?
  - Is a discrete function $p(r_k) = \frac{n_k}{n}$ , where $r_k \in [0, L-1]$ is the $k_{th}$ gray level and $n_k$ is the number of pixels with that gray level as their intensities.
  - Shape of the histogram shows a lot of information
  - Narrow histogram → low contrast

- Histogram Processing
  - Histogram Equalization
  - Local Enhancement



- A more sophisticated method that contrast stretching
- R and S are gray levels and T is a Transformation such that
  - S = T(R)
  - It maps a gray level to another
  - It can be a linear or non linear function
  - We may define it as (cumulative frequency)
    - $s = T(r_k) = \sum_{i=0}^{k} \frac{n_j}{n}$
    - It should be discretized for images.
  - If we consider 6 Gray Levels (0 , 0.2 , 0.4 , 0.6 , 0.8 , 1)



| 0 | 0.2 | 0.4 | 0.6 | 0.8 | 1 |
|---|---|---|---|---|---|
| 4/15 | 7/15 | 2/15 | 1/15 | 0/15 | 1/15 |

$$T(r_{0.6}) = \frac{4+7+2+1}{15} = \frac{14}{15} = 1$$

- Matlab function
  - b = histeq(a);

- Enhance details over small areas not in the whole image
- Histogram equalization may result in poor local enhancement
- Solution is so simple
  - Consider a sliding window of any size
  - Move the window on the image on all the pixels
  - Compute the histogram equalization in each step
  - Map the gray levels only for the pixels in the window
  - Repeat for all pixels in the image

- The use of masks or kernels (which we have already seen).
- It uses the 2D convolution.
- Matlab method for convolution
  - Conv2
- Spatial Operations
  - Smoothing Filter
  - Sharpening Filter
  - Etc.

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \quad \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

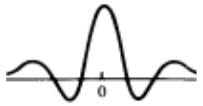
$$\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

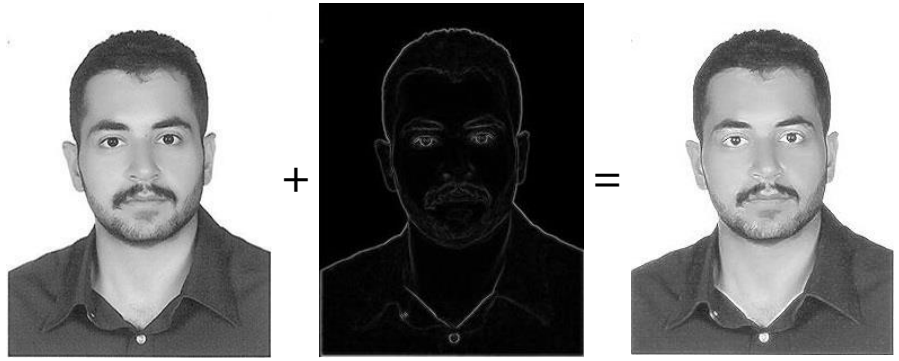
- Used for blurring, Noise Reduction and Details removal
- Low Pass Filtering (positive coefficients)
  - Like averaging , Gaussian blur , etc.
- Median Filtering
  - For noise reduction
  - Non linear
  - Finding the median in each block

$$\frac{1}{9}\begin{bmatrix}1 & 1 & 1\\ 1 & 1 & 1\\ 1 & 1 & 1\end{bmatrix}$$

- Highlight details and edges
- Applications in
  - Medical imaging
  - Object detection
  - Etc.
- Basic high pass spatial filter
  - Positive near center , negative in outer part
- Derivative filters
  - Detect edges using Gradient
  - Highlight edges using the below formula
    - NewImage = Edge + OldImage

$$\frac{1}{9}\begin{bmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$





# Fuzzy Logic

- Fuzzy Logic
  - Classic logic was inadequate in practice for applied problems
  - Prof. Lotfi Zadeh introduced Fuzzy sets
  - Fuzzy Sets
    - Membership is not definite $A = \{(x, M_A(x)) | x \in X\}$ $M_A(x) \in [0,1]$
    - Rules

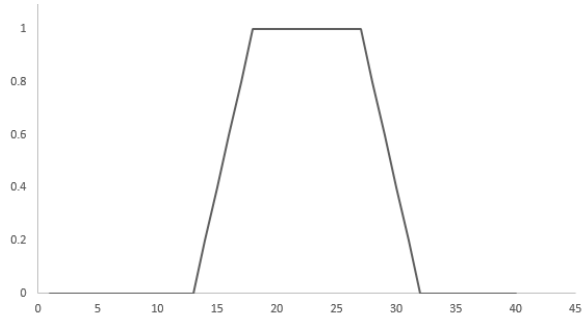
$$\bar{A} = \{(x, M_{\bar{A}}(x)) | M_{\bar{A}}(x) = 1 - M_A(x)\}$$

$$A = B \leftrightarrow \forall_{x \in X} M_A(x) = M_B(x)$$

$$A \subseteq B \leftrightarrow M_A(x) \leq M_B(x)$$

$$M_{\cap} = \min(M_A(x), M_B(x))$$

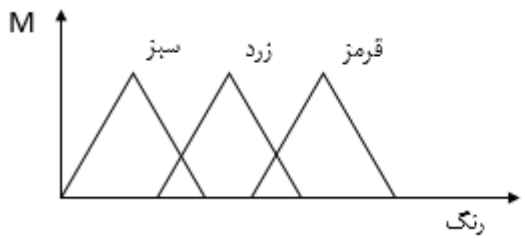
$$M_{\cup} = \max(M_A(x), M_B(x))$$

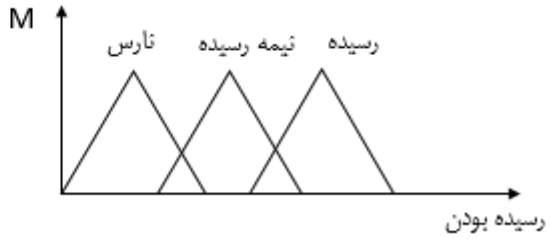


# Fuzzy Logic

- Fuzzy Inference System
  - Rule base

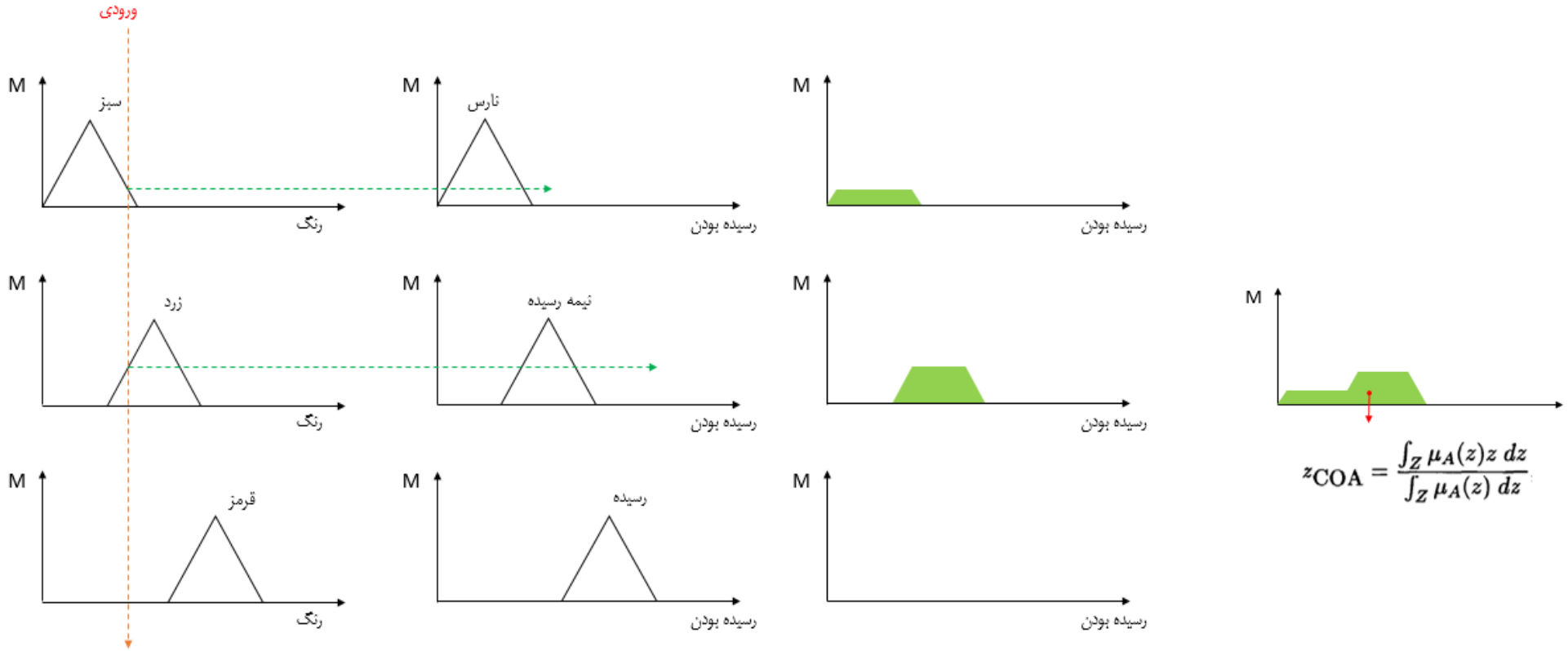
اگر رنگ میوه () سبز است آنگاه از نظر رسیده بودن () میوه نارس است.
اگر رنگ میوه () زرد است آنگاه از نظر رسیده بودن () میوه نیمه رسیده است.
اگر رنگ میوه () قرمز است آنگاه از نظر رسیده بودن () میوه رسیده است.



# Fuzzy Logic

- Fuzzy Inference System (input output)



# Using Fuzzy Logic for Image Enhancement

- Using the below Rule Base and using the method mentioned earlier for Fuzzy Inference Systems.

  - IF the pixel is dark THEN make it darker
  - IF the pixel is gray THEN make it more gray(darker)
  - IF the pixel is light  THEN make it lighter

# Thank you for you time!

You can find this slide and all other resources in my homepage at

**ariyanzarei.com**

References


- Digital Image Processing, Gonzales and Woods.
- CYH Image Enhancement Notes
- http://homepages.inf.ed.ac.uk/rbf/HIPR2/index.htm