University of Al-Hamdaniya
Computer Science Department
Digital image processing

Piece-Wise Linear Transformation

Lec-8

By

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Image enhancement

Piece-Wise Linear Transformation

- Complementary approach to gray level transformation.
- **Advantage :** can be arbitrarily complex thus achieve many transformation results using linear functions.
- **Disadvantage** – require more user input

Based on Piece-Wise Linear Transformation

1. Contrast stretching,
2. Clipping and thresholding
3. Gray-level slicing
4. Bit-plane slicing
5. Range Compression

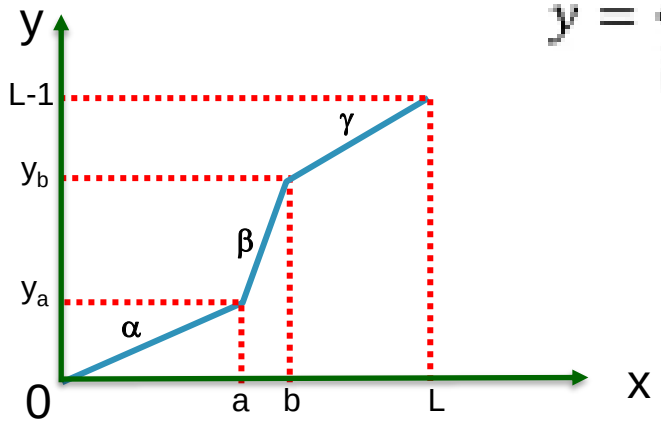
1- Contrast Stretching

The idea behind contrast stretching is to increase the dynamic range of the gray levels in the image being processed.

Produces an image of higher contrast than the original which is given by the expression:

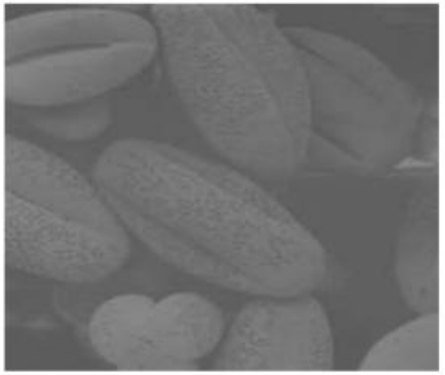
$$y = \begin{cases} \propto x & 0 \leq x < a \\ \beta(x-a) + y_a & a \leq x < b \\ \gamma(x-b) + y_b & b \leq x \leq L \end{cases}$$

$$\alpha, \beta, \gamma = \frac{y2 - y1}{x2 - x1}$$

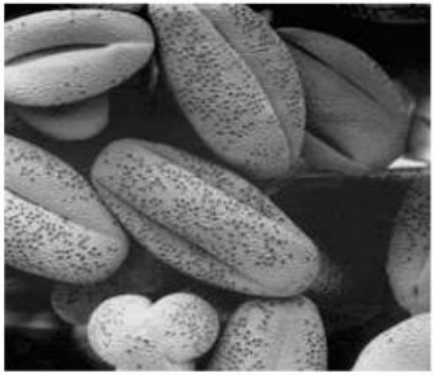


Dotted line - Identity transformation

Solid line - Contrast Stretching



Original Image



Contrast Enhanced Image

1- Contrast Stretching

Example: *Enhance the image contrast for the following image :*

$$I = \begin{matrix} 10 & 51 & 25 \\ 125 & 100 & 1 \\ 201 & 250 & 250 \end{matrix}$$

$a = 50,\quad b = 150,\quad \propto = 5,\quad \beta = 2, \gamma = 0.5,\quad y_a = 10,\quad y_b = 100$

$$y = \begin{cases} \propto x & 0 \le x < a \\ \beta(x-a) + y_a & a \le x < b \\ \gamma(x-b) + y_b & b \le x \le L \end{cases}$$

$$y(1,1) = \propto x \quad (0 \le x < a) \Rightarrow y(1,1) = 5(10) = 50$$

$$y(1,2) = \beta(x-a) + y_a \quad (a \le x < b)$$

$$\Rightarrow y(1,2) = 2 * (51-50) + 10 = 2 * (1) + 10 = 12$$

1- Contrast Stretching

$$y(1,3) = \propto x \quad (0 \le x < a) \Rightarrow y(1,1) = 5\,(25) = \mathbf{125}$$

$$y(2,1) = (x - a) + y_a \quad (a \le x < b)$$

$$\Rightarrow y(2,1) = 2 * (125 - 50) + 10 = 2 * (75) + 10 = 160$$

$$y(2,2) = (x - a) + y_a \quad (a \le x < b)$$

$$\Rightarrow y(2,2) = 2 * (100 - 50) + 10 = 2 * (50) + 10 = 110$$

$$y(2,3) = \propto x \quad (0 \le x < a) \Rightarrow y(2,3) = 5(1) = 5$$

1- Contrast Stretching

$$y(3,1) = \gamma(x - b) + y_b \quad (b \leq x < L)$$

$$\Rightarrow y(3,1) = 0.5 * (201 - 150) + 100 = 0.5 * (51) + 100 = 125.5$$

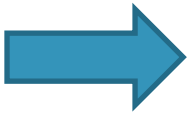
$$y(3,2) = \gamma(x - b) + y_b \quad (b \leq x < L)$$

$$\Rightarrow y(3,2) = 0.5 * (250 - 150) + 100 = 0.5 * (100) + 100 = 150$$

$$y(3,2) = \gamma(x - b) + y_b \quad (b \leq x < L)$$

$$\Rightarrow y(3,2) = 0.5 * (250 - 150) + 100 = 0.5 * (100) + 100 = 150$$

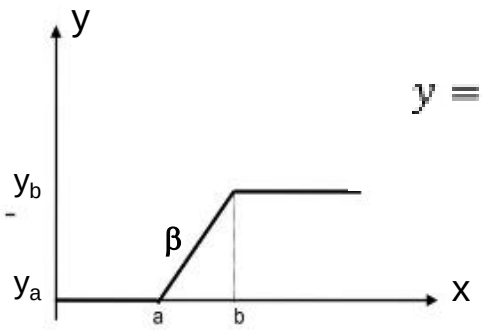
$$I = \begin{matrix} 10 & 51 & 25 \\ 125 & 100 & 1 \\ 201 & 250 & 250 \end{matrix}$$



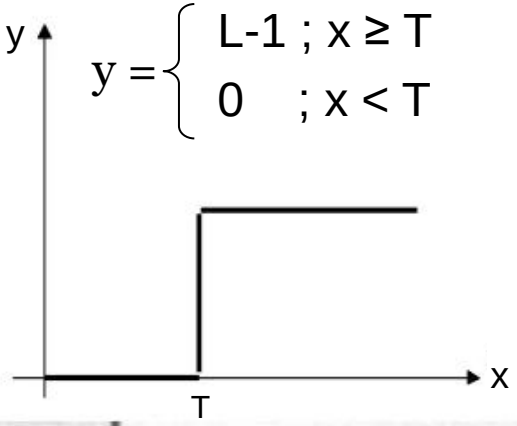
$$T = \begin{matrix} 50 & 12 & 125 \\ 160 & 110 & 5 \\ 125 & 150 & 150 \end{matrix}$$

2- Clipping and Thresholding

- Clipping is a special case of contrast stretching, where $\alpha = \gamma = 0$
- Useful for noise reduction when the input signal is known and the range is [a, b] i.e. valley between the peaks of the histogram.
- It is used for binary or other images that have bimodal distribution of gray levels.
- **Thresholding** is extreme contrast stretching where a = b = t and the output comes as binary. F



$$y = \begin{cases} 0 & 0 \le x < a \\ \beta(x-a) + y_a & a \le x < b \\ y_b & b \le x \le L \end{cases}$$



Clipping

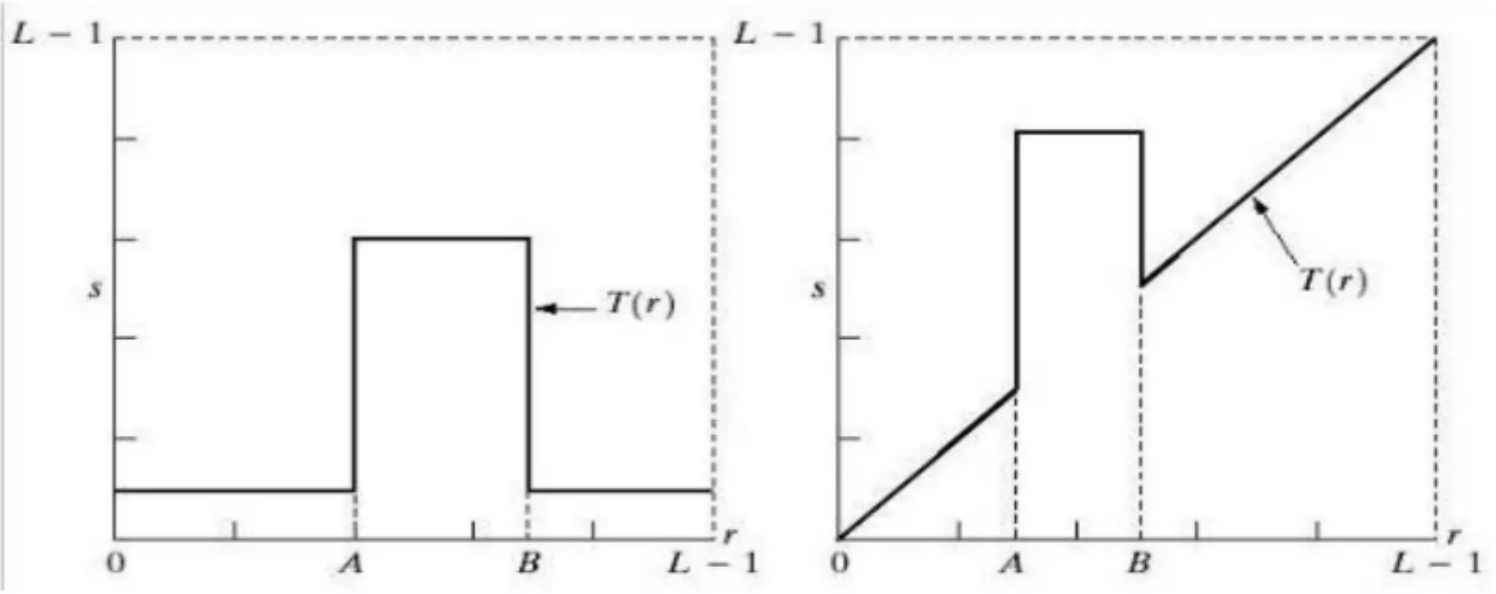
Thresholding

3- Gray-Level Slicing

- Permit segmentation of certain gray level regions from the rest of the image.

$$v = \begin{cases} L, & a \le u \le b \\ 0, & otherwise \end{cases}$$

$$v = \begin{cases} L, & a \le u \le b \\ u, & otherwise \end{cases}$$

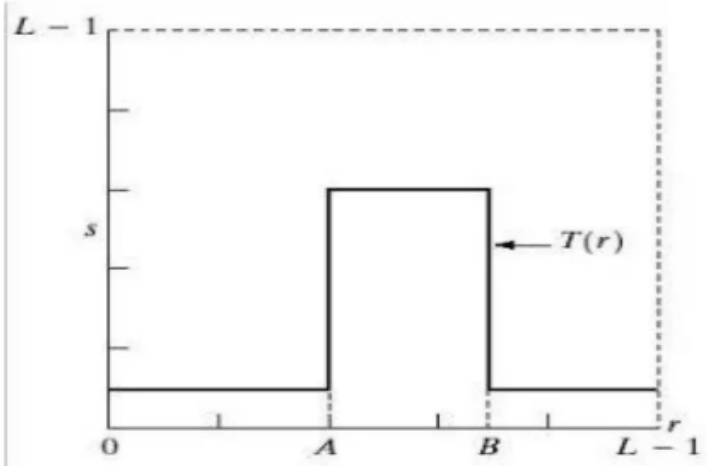


- Transformation highlights range [A, B] of gray levels and reduces all others to a constant level.
- Transformation highlights range [A, B], but preserves all other level.

3- Gray-Level Slicing

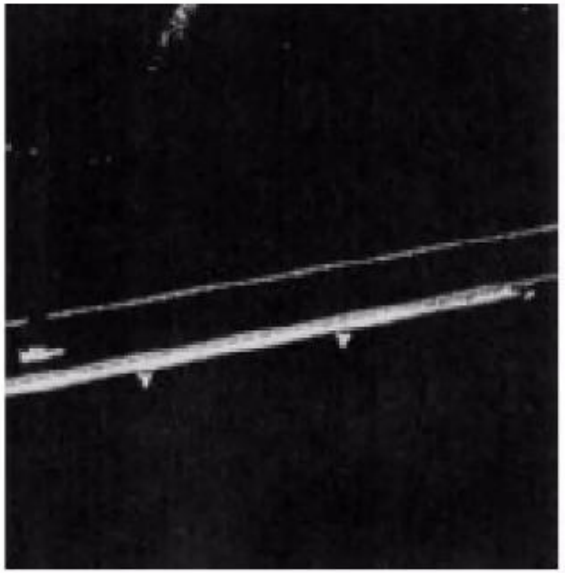
- This technique is used to highlight a specific range of gray levels in a given image.
- It can be implemented in several ways, but the two basic themes are:
  - **One approach** is to **display a high value for all gray levels in the range of interest and a low value for all other gray levels.** This transformation, shown in Fig 3.11 (a), produces a binary image.
  - **The second approach**, based on the transformation shown in Fig 3.11 (b), **brightens the desired range of gray levels but preserves gray levels unchanged**.
  - Fig 3.11 (c) shows a gray scale image, and fig 3.11 (d) shows the result of using the transformation in Fig 3.11 (a).

3- Gray-Level Slicing



(a) Approach one

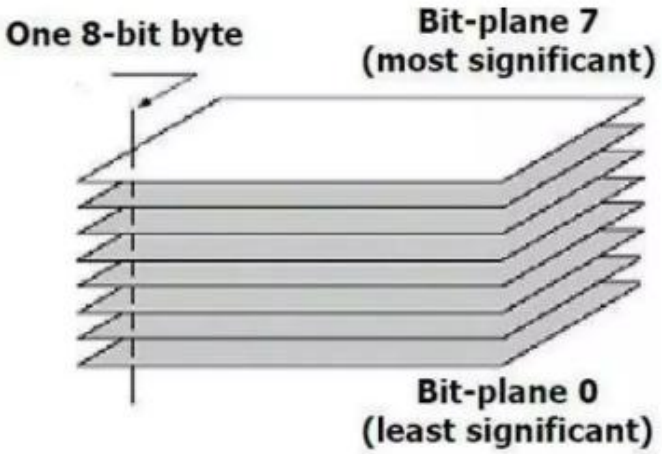
(b) An image



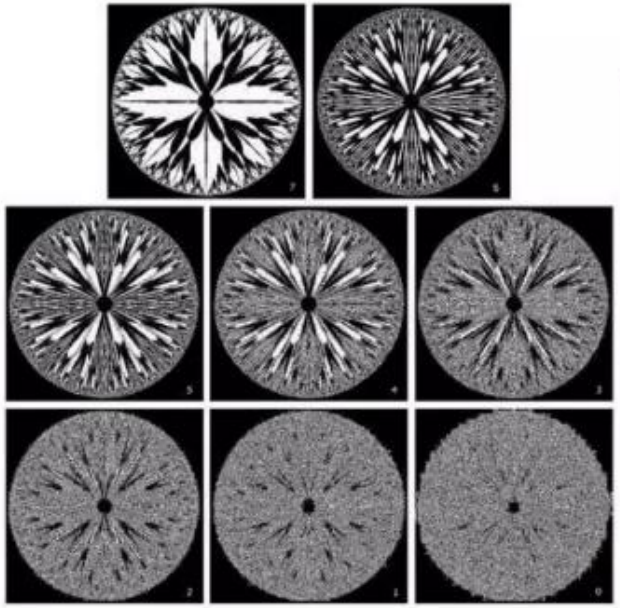
(c) Result of using transformation in (a)

4- Bit (extraction) Level Slicing

- This transformation is useful in determining the number of visually significant bits in an Image.
- Suppose each pixel is represented by 8 bits it is desired to extract the n^{th} most significant bit and display it .
- Higher-order bits contain the majority of the visually significant data



8-bit plane image

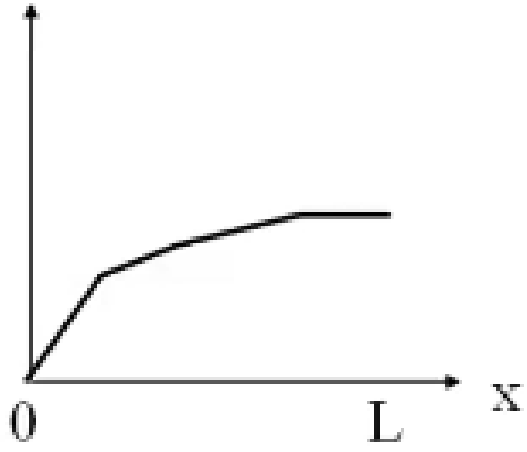


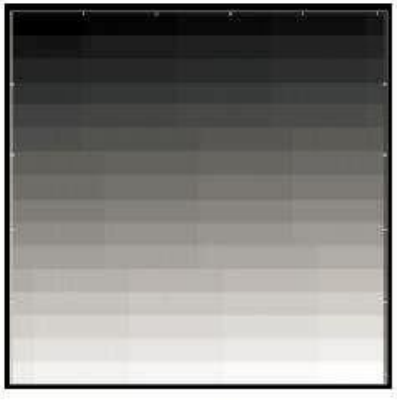
Bit-plane 7	Bit-plane 6	
Bit-plane 5	Bit-plane 4	Bit-plane 3
Bit-plane 2	Bit-plane 1	Bit-plane 0

5- Range Compression

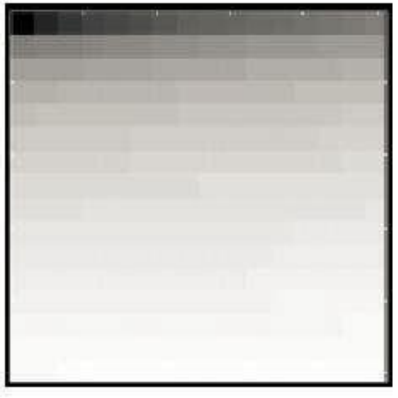
- Sometimes the dynamic range of a processed image far exceeds the capability of the display device, in which case only the brightest parts of the images are visible on the display screen.

$$y = c \log_{10}(1 + x)$$





Original



Processed output

C=100

End of Lecture