DIGITAL IMAGE PROCESSING-1

Unit 3: Lecture 27-28

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Unit 3: Image Enhancement

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Last Session

- K L Transform
- Singular Value Decomposition (SVD)

Today's Session

- Introduction to Image Enhancement
- Point Operations

- Objective:
  - To process an image so that the result is more suitable than the original image for a *specific* application
  - Techniques are problem/image dependent
    - Methods used for X-ray image enhancement are different from enhancing satellite images
  - One of the most interesting and '***visually appealing'*** areas of image processing

Image Enhancement

- Image enhancement is the process of enhancing the quality of a given image for analysis
    - **Aim is to improve the quality so that image analysis is accurate, leading to an improvement in the reliability of the image processing applications**

Image Enhancement

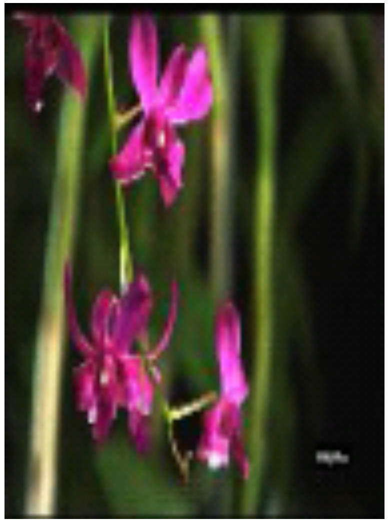
- Very first step in Digital Image Processing
- It is purely subjective
  - It improves subjective qualities of images
- **It is a cosmetic procedure**

Need for Image Enhancement

- Often necessary to extract various features of an image or objects present in image
- Often the quality of acquired image is not satisfactory due to factors such as brightness, contrast, blur, unnatural colours, noise and artefacts

Need for Image Enhancement

- Image is not visually acceptable sometimes



- Reasons:
  - Poor illumination
  - Wrong setting of lens aperture

Types of Enhancement Techniques

- Types (depending on domain):
  - Spatial Domain (Image plane)
  - Frequency Domain(Modifying Fourier transform of image)
  - Joint Spatial-Frequency Domain (eg. Wavelet domain)

Types of Enhancement Techniques

Image Enhancement

Point Operations
- Contrast Stretching
- Noise Clipping
- Window Slicing
- Histogram Modeling

Spatial Operations
- Noise Smoothing
- Median Filtering
- Unsharp Masking
- LP,HP,BP filtering
- Zooming

Transform Operations
- Linear filtering
- Root Filtering
- Homomorphic Filtering

Pseudocoloring
- False Coloring
- Pseudocoloring

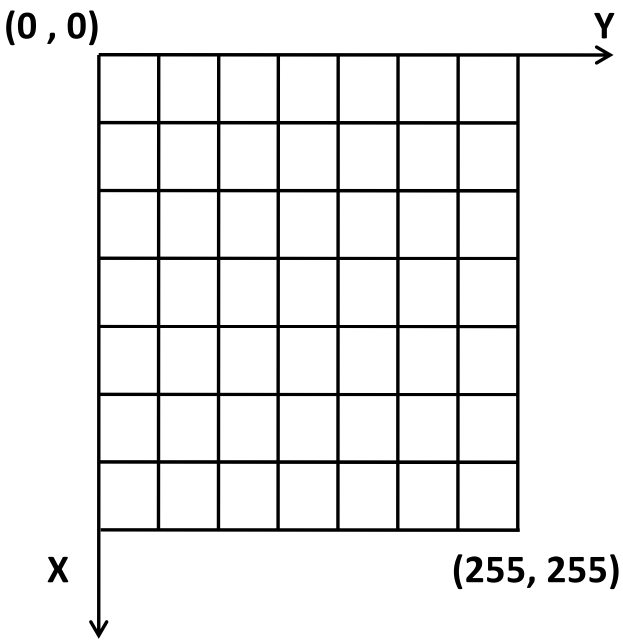
Spatial Domain

Spatial Domain

- Spatial: Working in space i.e.(given image)
- Spatial Domain: Aggregate of pixels composing an image. Working with pixel values or raw data
- Spatial Domain Methods: Methods that operate directly on these pixels

Spatial Domain

- In an image with size 256 x 256, (x, y) can assume any value from (0 , 0) to (255 , 255).



Spatial Domain

- Applying transform modifies the image

  $g(x,y) = T\, f(x,y)$

  where,

  $f(x,y)$ is original image

  T is transformation applied on $f(x,y)$

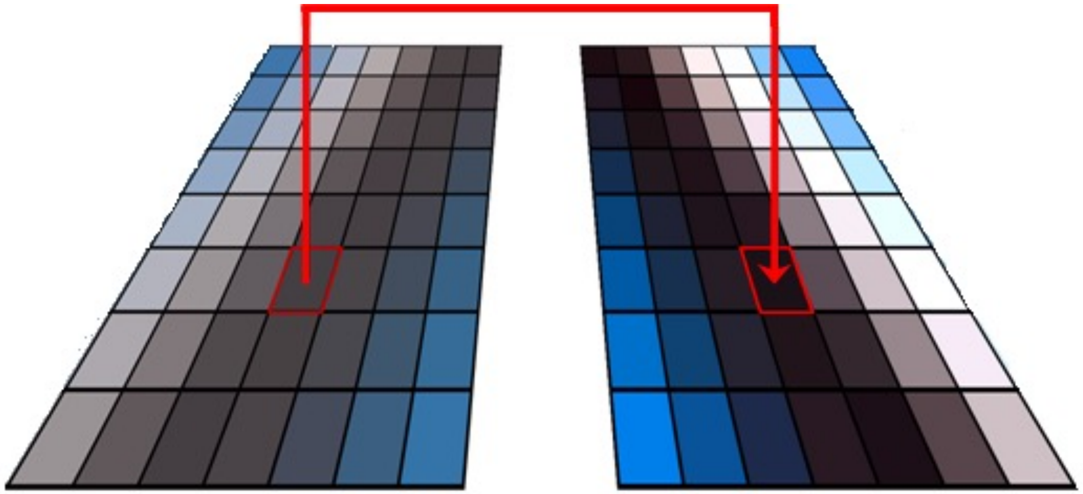
  $g(x,y)$ is new modified image

- In spatial domain techniques it is 'T' that changes
- Spatial domain enhancement is carried out in two ways:
  - ❑Point processing
  - ❑Neighborhood processing (Spatial operations)

Point Processing

- Here, we work on singe pixel i.e. T is 1 x 1 operator

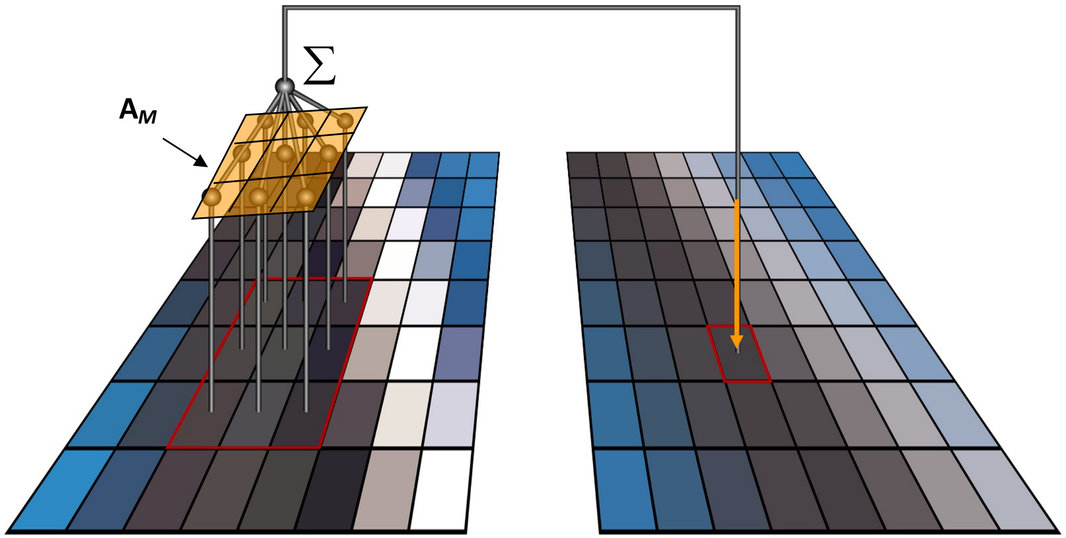
$$g(x, y) = T[f(x, y)]$$



In this case, g depends only on the value of f at a single point (x, y) and T becomes an intensity (also called a gray-level, or mapping) transformation function of the form $s = T(r)$

s and r denote, respectively, the intensity of g and f at any point (x, y)

- Spatial Operations: Each pixel is modified according to values in a small neighborhood called mask(*small matrix whose values are termed as weights*)



Types of Enhancement Techniques

Image Enhancement

Point Operations

- Contrast Stretching
- Noise Clipping
- Window Slicing
- Histogram Modeling

Spatial Operations

- Noise Smoothing
- Median Filtering
- Unsharp Masking
- LP,HP,BP filtering
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Transform Operations

- Linear filtering
- Root Filtering
- Homomorphic Filtering

Pseudocoloring

- False Coloring
- Pseudocoloring

Spatial Domain

Point Processing

- Some important examples of point processing are:
  - Brightness modification
  - Contrast Modification
  - Digital Negative
  - Dynamic range compression
  - Thresholding (noise clipping)
  - Gray level slicing
  - Bit plane slicing
  - Histogram modeling

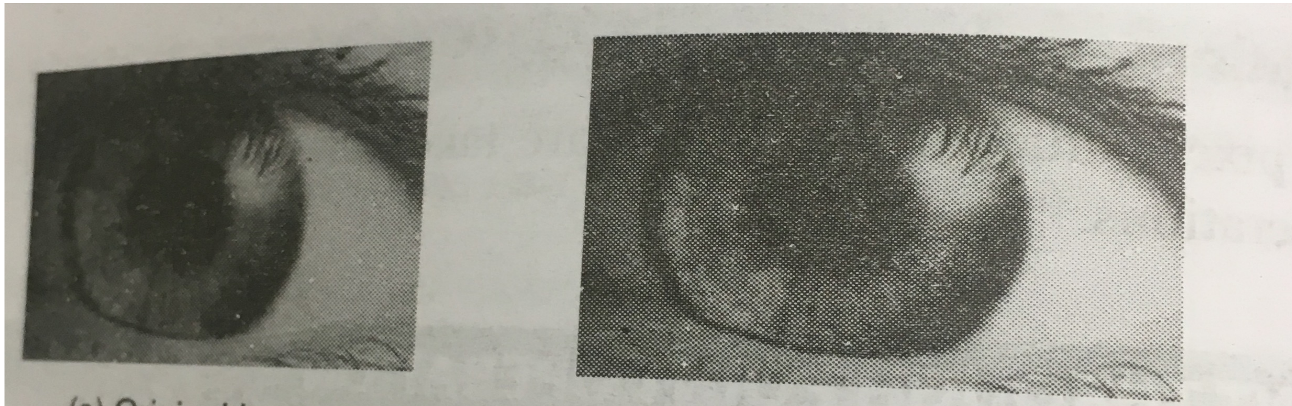
Point Processing

- Some important examples of point processing are:
  - **Brightness modification**
  - Contrast Modification
  - Digital Negative
  - Dynamic range compression
  - Thresholding (noise clipping)
  - Gray level slicing
  - Bit plane slicing
  - Histogram modeling

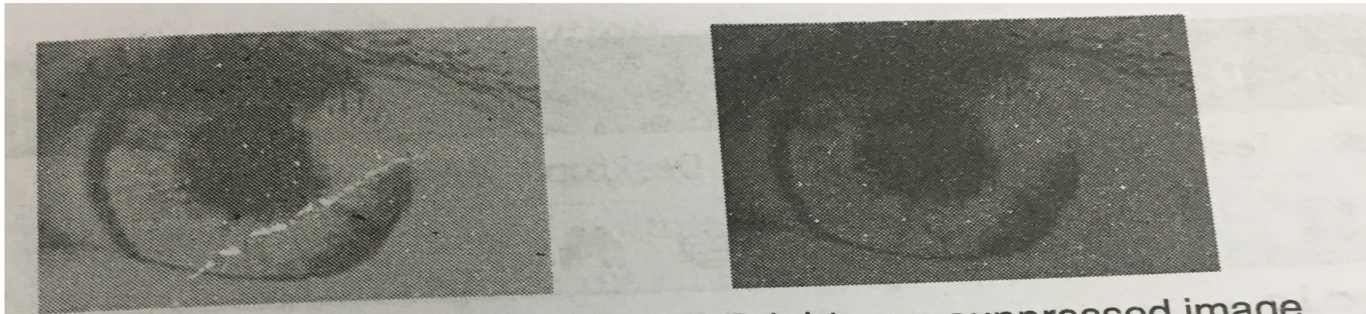
Brightness Modification

- Brightness depends on the values of pixels
- For changing the brightness, a constant is added to (to increase brightness) or subtracted from(to decrease brightness) luminance of all sample values
- Increasing brightness: $g[m,n] = f[m,n] + k$
- Decreasing brightness: $g[m,n] = f[m,n] - k$

Brightness Modification

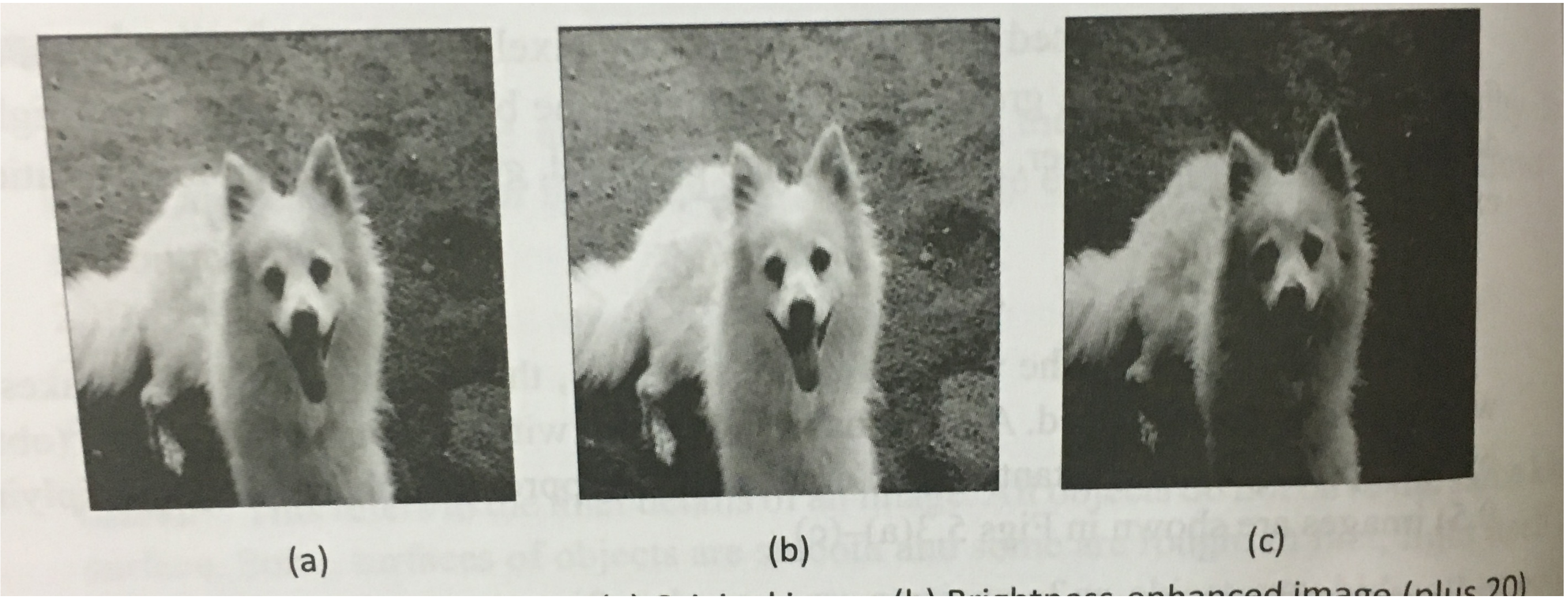


(a) Original image (b) Brightness-enhanced image



(a) Original image (b) Brightness-suppressed image

Brightness Modification



(a) Original image ; (b) Brightness enhanced; (c) Brightness suppressed

Dynamic Range

- The Dynamic Range of an image is the exact subset of gray values {0,1,……,L-1} that are present in the image.
- Dynamic Range refers to how wide a range of values a camera sensor can capture.
- Dynamic range has little to do with contrast (which is primarily a tone curve issue): it is simply a measure of the highest and lowest possible light amounts a camera can capture (technically expressed, it is a ratio of these two values)

Point Processing

- Brightness modification
- ***Contrast Modification***
- Histogram modeling
- Digital Negative
- Dynamic range compression
- Thresholding (noise clipping)
- Gray level slicing
- Bit plane slicing

Contrast

- Contrast: how much differentiation exists between various tones in an image

- Contrast is determined by the difference in the color and brightness of the object and other objects within the same field of view.

What is Contrast Stretching?

- Assume an input image with dynamic range from A to B with gray levels r
- Let A and B be 120 and 220 not using full permissible range
- **Mapping it to range C – D or 0 – 255 is called contrast stretching**
- Linear piecewise function is used for this purpose

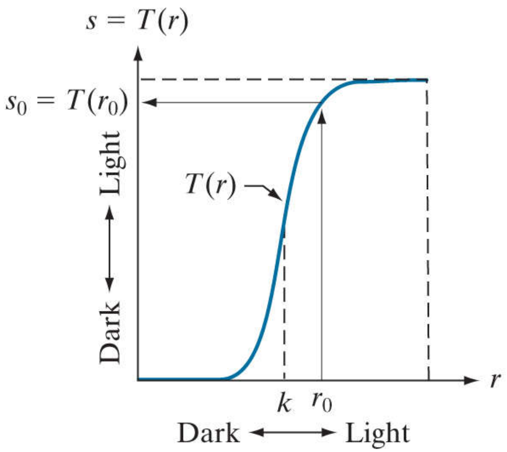
What is Contrast Stretching?

- Low-contrast images can result from poor illumination, lack of dynamic range in the imaging sensor, or even the wrong setting of a lens aperture during image acquisition
- Contrast stretching expands the range of intensity levels in an image so that it spans the ideal full intensity range of the recording medium or display device.

Contrast Stretching

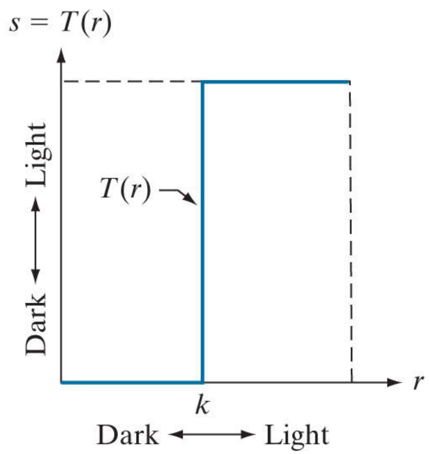
$$g(x,y) = T[f(x,y)]$$
$$s = T(r)$$

- Consider the figure below:



If T(r) has the form as in figure, the result of applying the transformation to every pixel in f to generate the corresponding pixels in g would be to produce an image of higher contrast than the original, by darkening the intensity levels below k and brightening the levels above k

values of r lower than k reduce (darken) the values of s, toward black.
The opposite is true for values of r higher than k. Observe how an intensity value is mapped to obtain the corresponding value
Consider the figure below:



T(r) produces a two-level (binary) image. A mapping of this form is called a thresholding function.

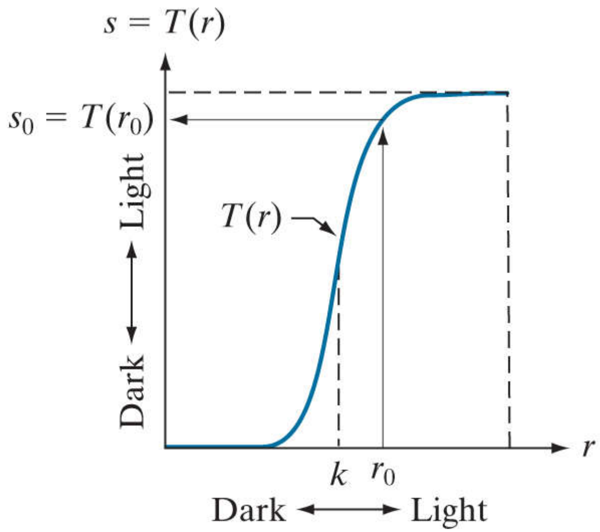
Contrast Stretching

- It is a linear mapping function used to manipulate the contrast of an image

- Contrast stretching is done by scaling all pixels by a constant k;

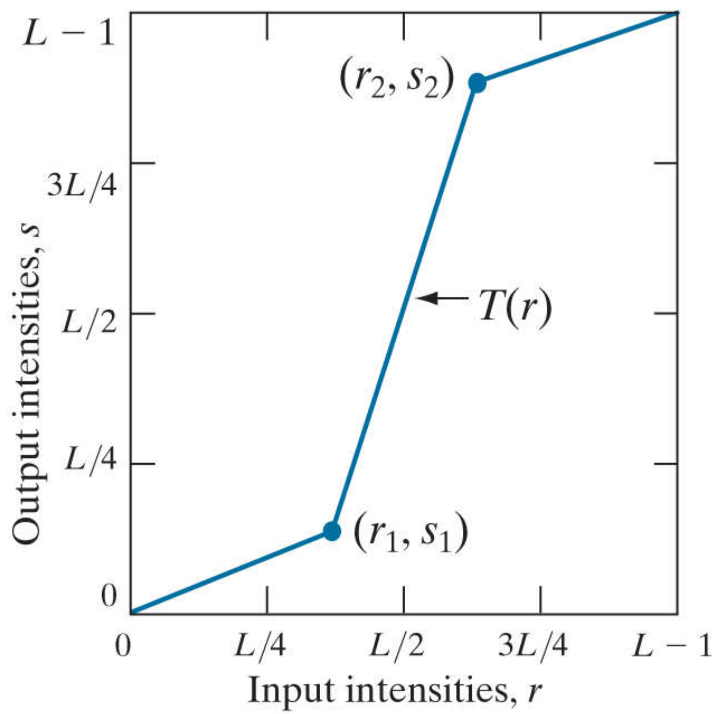
  *g(x,y) = k*f(x,y)*

- By controlling the slope contrast can be controlled



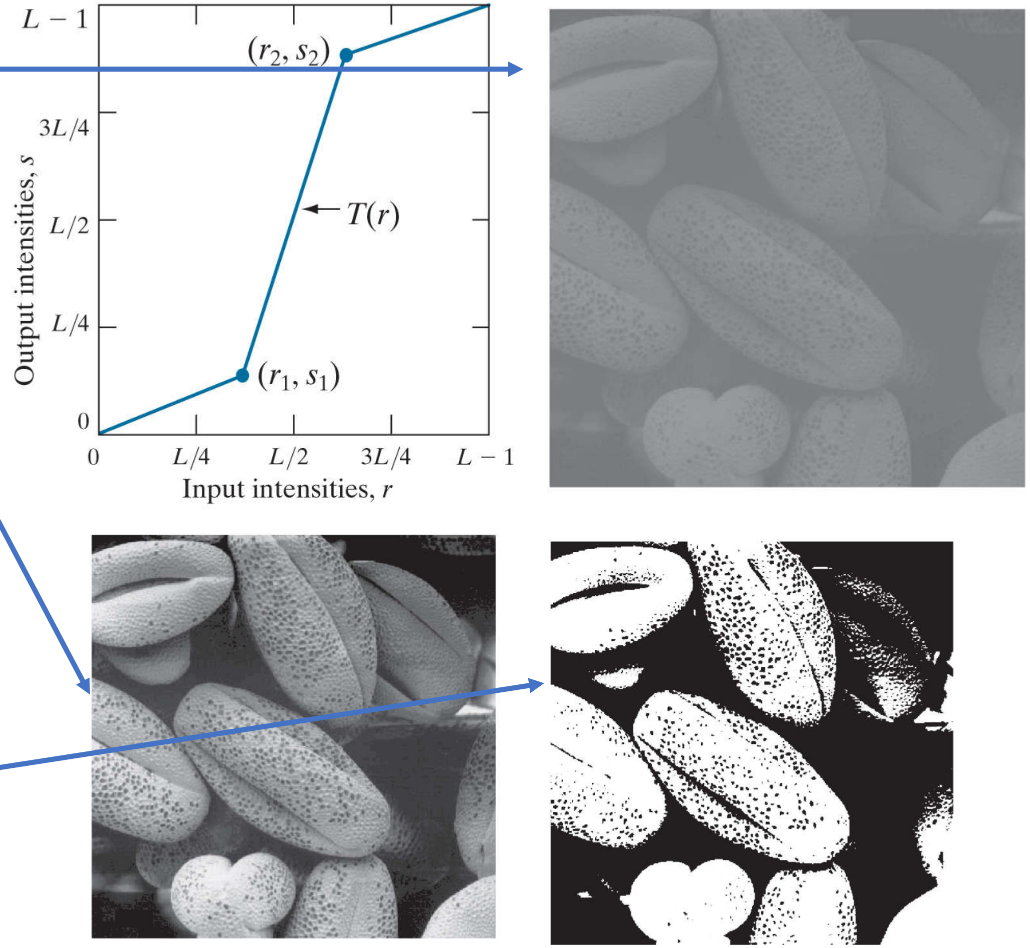
Contrast Stretching Function

- Figure shows a typical transformation used for contrast stretching.
- The locations of points (r_1, s_1) and (r_2, s_2) control the shape of the transformation function.
- If $r_1 = s_1$ and $r_2 = s_2$, the transformation is a linear function that produces no changes in intensity.
- If $r_1 = r_2$ and $s_1 = 0$ and $s_2 = L-1$, the transformation becomes a thresholding function that creates a binary image
- Intermediate values of (r_1, s_1) and (r_2, s_2) produce various degrees of spread in the intensity levels of the output image, thus affecting its contrast
- In general, $r_1 \le r_2$ and $s_1 \le s_2$ is assumed so that the function is valued and monotonically increasing



Contrast Stretching Function

- Figure b shows an 8-bit image with low contrast.
- Figure c shows the result of contrast stretching, obtained by setting $(r_1, s_1) = (r_{min}, s_0)$ and $(r_2, s_2) = (r_{max}, L-1)$ where and r_{min} and r_{max} denote the minimum and maximum intensity levels in the input image, respectively.
  - The transformation stretched the intensity levels linearly to the full intensity range, [0, L− 1] .
- Figure d shows the result of using the thresholding function, with $(r_1, s_1) = (m, 0)$ and $(r_2, s_2) = (m, L-1)$ where m is the mean intensity level in the image.

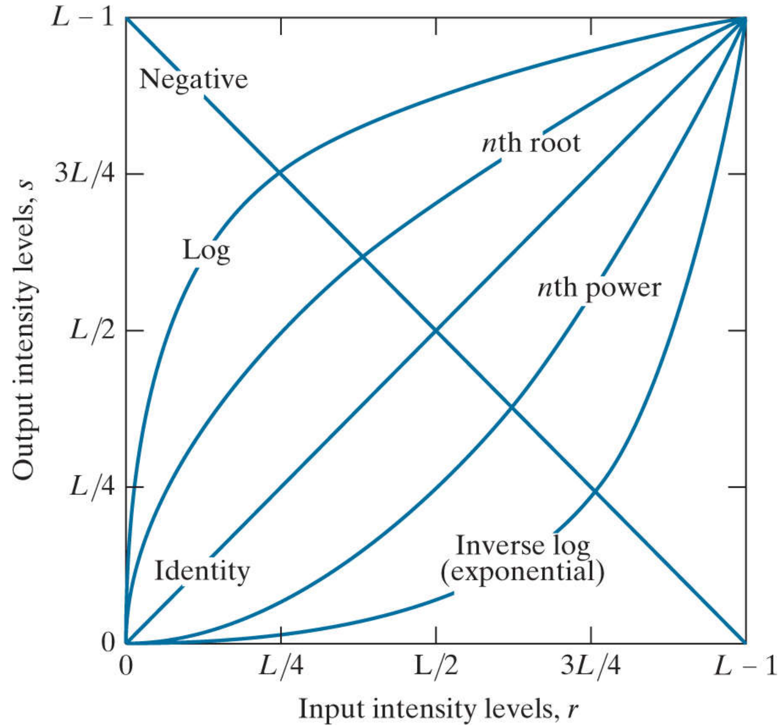


Point Processing

- Brightness modification
- Contrast Modification
- **Digital Negative**
- Dynamic range compression
- Thresholding (noise clipping)
- Intensity level slicing
- Bit plane slicing
- Histogram modeling

Intensity Transformations

- Frequently used intensity transformations are:
  - Linear (negative and identity transformations)
  - Logarithmic (log and inverse-log transformations) and
  - Power-law (nth power and nth root transformations)
- The identity function is the trivial case in which the input and output intensities are identical.



Linear Gray Level Modeling

- A linear transformation of an image is a function that maps each pixel gray level value into another gray level at the same position according to a linear function

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

- Useful in large applications e.g. X-ray images.
- Inverse transformation reverses light and dark

Digital Negative

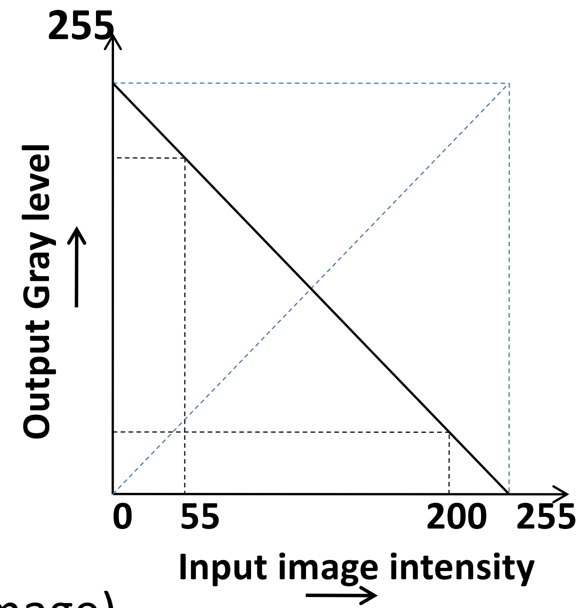
- Digital Negative can be obtained by subtracting each pixel from maximum : $s = L - 1 - r$

g(x,y) = 255 – f(x,y) (where, f_{max} = 255)

when, f(x,y) = 0; g(x,y) = 255
& if g(x,y) = 255; f(x,y) = 0

Generally, g(x,y) = (L-1) – f(x,y)

where, L – total number of gray levels (e.g. 256 for 8-bit image)



Digital Negative

(a) Original image

(digital mammogram)

(b) Negative image

Point Processing

- Brightness modification
- Contrast Modification
- Digital Negative
- **Dynamic range compression**
- Thresholding (noise clipping)
- Intensity level slicing
- Bit plane slicing
- Histogram modeling

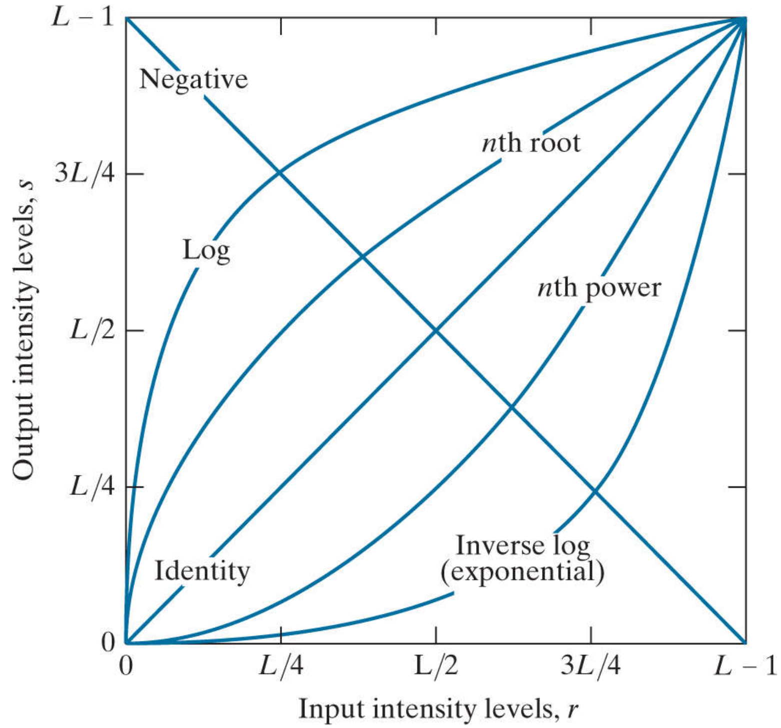
Dynamic Range Compression: Log Transformation

- Log transformations: General form is

$$s = c\log(1 + r)$$

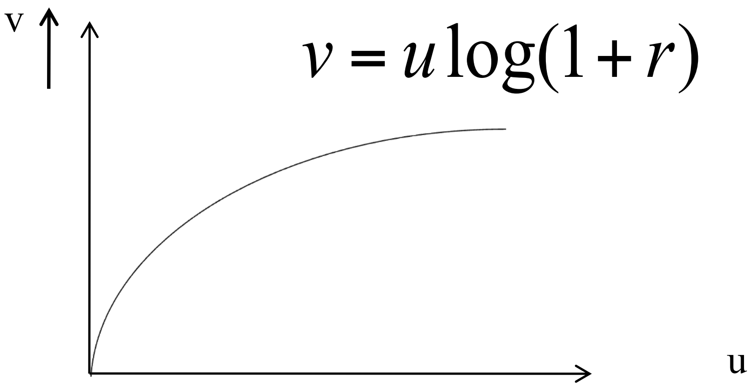
where c is a constant and it is assumed that ≥ 0.

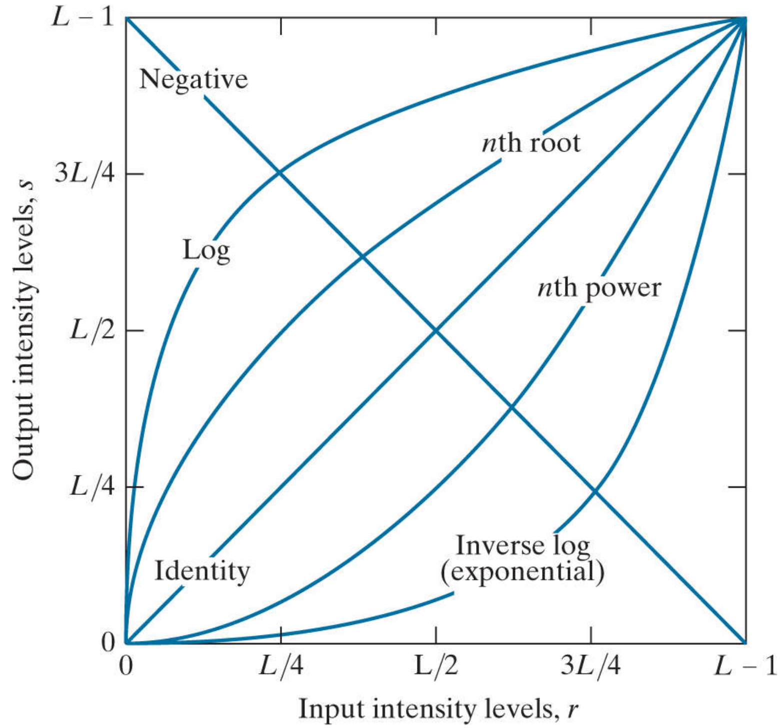
- Figure shows that this transformation maps a narrow range of low intensity values in the input into a wider range of output levels



Dynamic Range Compression

$$v = u\log(1+r)$$

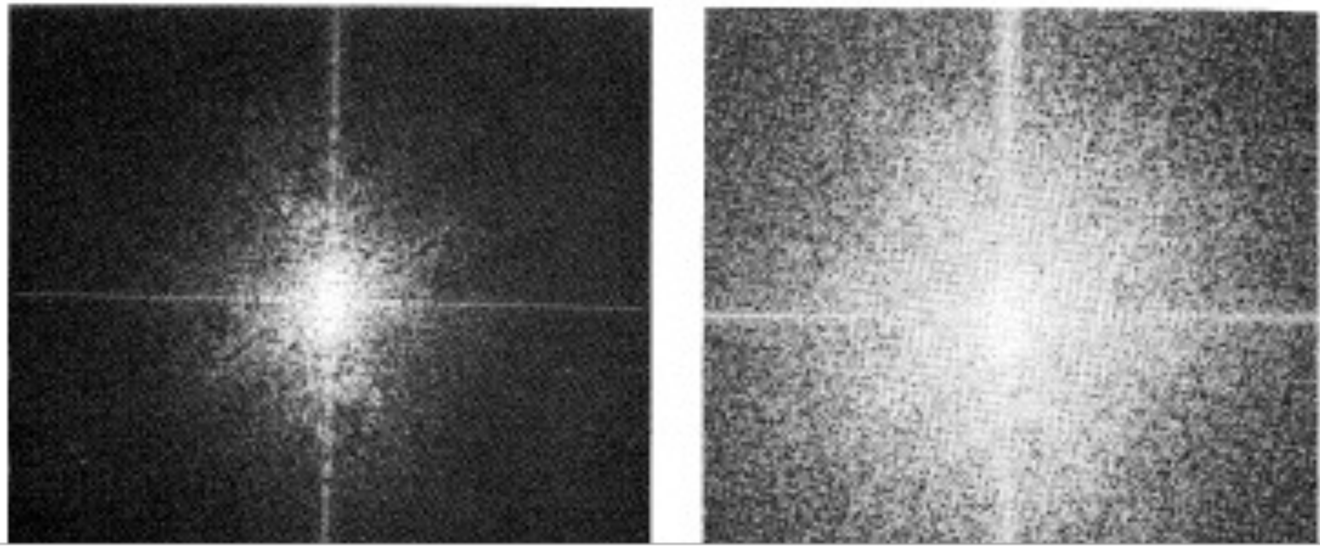




- **At times, dynamic range of image exceeds the capability of display device.**
- **Some pixel values are so large that the other low value pixel gets obscured.**

  E.g. stars in day time are not visible though present due to large intensity of sun.
- **Thus dynamic range needs to be compressed.**

Dynamic Range Compression



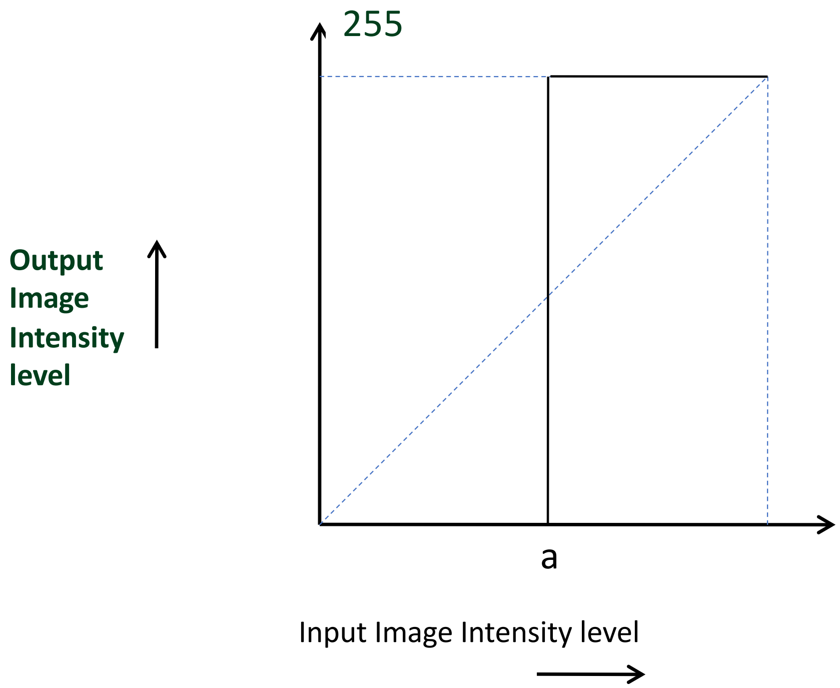
(a) Original (b) log

Point Processing

- Brightness modification
- Contrast Modification
- Digital Negative
- Dynamic range compression
- **Thresholding (noise clipping)**
- Intensity level slicing
- Bit plane slicing
- Histogram modeling

Non Linear Gray Level Transformation

- Hard thresholding:



- **Expression goes as under:**

  v = 0 ; if u ≤ a

  v = L – 1 ; if u >a

  where, L is number of Gray levels.

- **Thresholded image has maximum contrast as it has only BLACK & WHITE gray values.**

Examples

The following matrix represents the pixel values of a 8-bit image (r) , apply thresholding transform assuming that the threshold m=95. Find the resulting image pixel values.

Image (r)

110	**120**	**90**	**130**
91	**94**	**98**	**200**
90	**91**	**99**	**100**
82	**96**	**85**	**90**

Answer::

Image (s)

255	255	0	255
0	0	255	255
0	0	255	255
0	255	0	0

Point Processing

- Brightness modification
- Contrast Modification
- Digital Negative
- Dynamic range compression
- Thresholding (noise clipping)
- **Intensity level slicing**
- Bit plane slicing
- Histogram modeling

Gray Level / Intensity Level Slicing

- At times, we need to highlight a specific range of gray levels.
  eg. X-ray scan, CT scan
- It is similar to thresholding, except that we select a band of gray levels.
- Formulation of Gray level slicing w/o background (Fig.1):

$$v = L-1 \quad ; \quad \text{for } a \le r \le b$$
$$= 0 \quad ; \quad \text{otherwise}$$

- We do not get any background

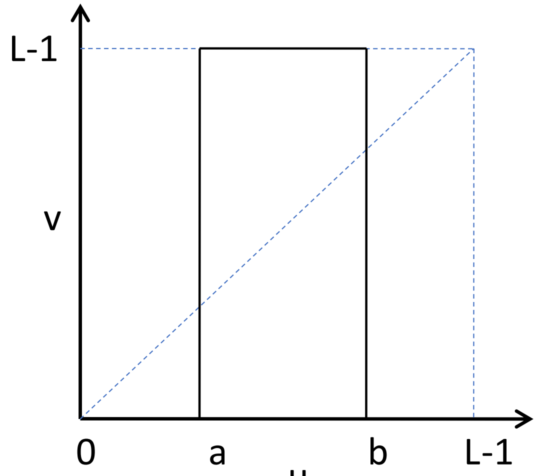


Fig. 1 Slicing w/o background

- Sometimes we may need to retain the background.
- Formulation of Gray level slicing with background (fig. 2):

$$v = L-1 \quad ; \quad \text{for } a \le r \le b$$
$$= u \quad ; \quad \text{otherwise}$$

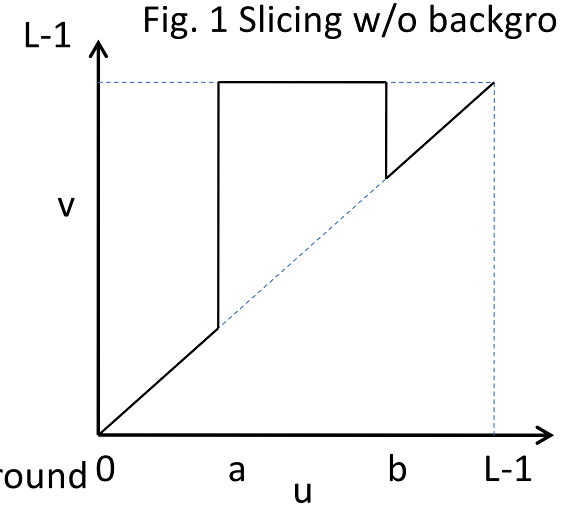


Fig. 2 Slicing with background

Point Processing

- Brightness modification
- Contrast Modification
- Digital Negative
- Dynamic range compression
- Thresholding (noise clipping)
- Intensity level slicing
- **Bit plane slicing**
- Histogram modeling

Bit Plane Slicing

- Here, we find the contribution made by each bit to the final image
- Consider a 256 x 256 image with 256 gray levels i.e. 8-bit representation for each pixel. E.g. BLACK is represented as 00000000 & WHITE by 11111111.
- Consider LSB value of each pixel & plot image. Continue till MSB is reached.
- All 8 images will be binary.

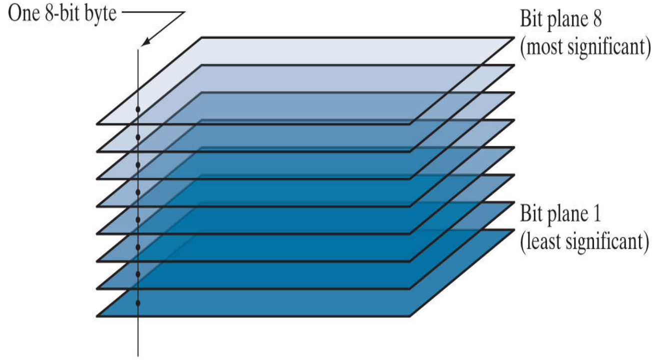


FIGURE 3.13
Bit-planes of an 8-bit image.

Bit Plane Slicing

Ex. Plot bit planes of the given 3 x 3 image.

Max. Intensity is 7 thus use only 3 – bits

1	2	0
4	3	2
7	5	2

001	010	000
100	011	010
111	101	010

1	0	0
0	1	0
1	1	0

LSB plane

0	1	0
0	1	1
1	0	1

Middle Plane

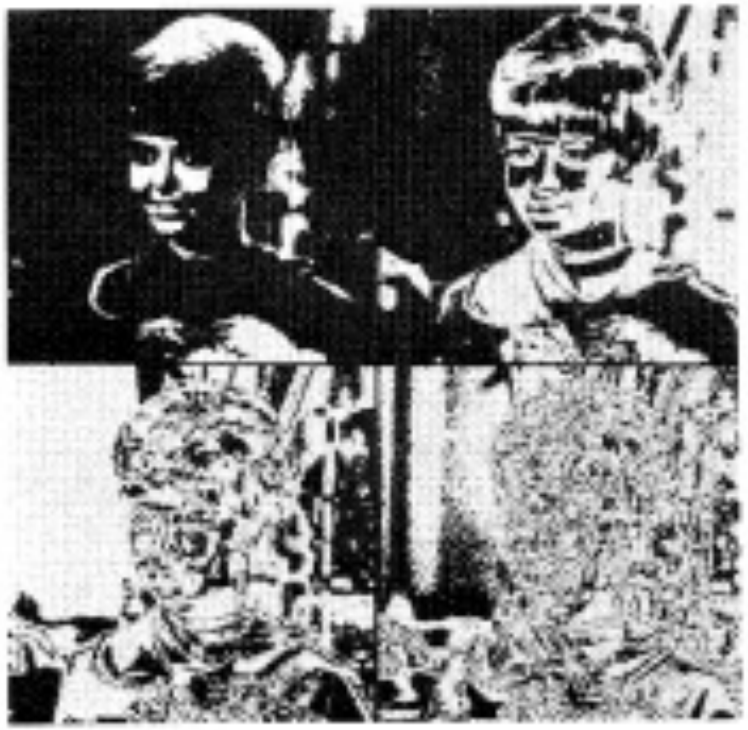
0	0	0
1	0	0
1	1	0

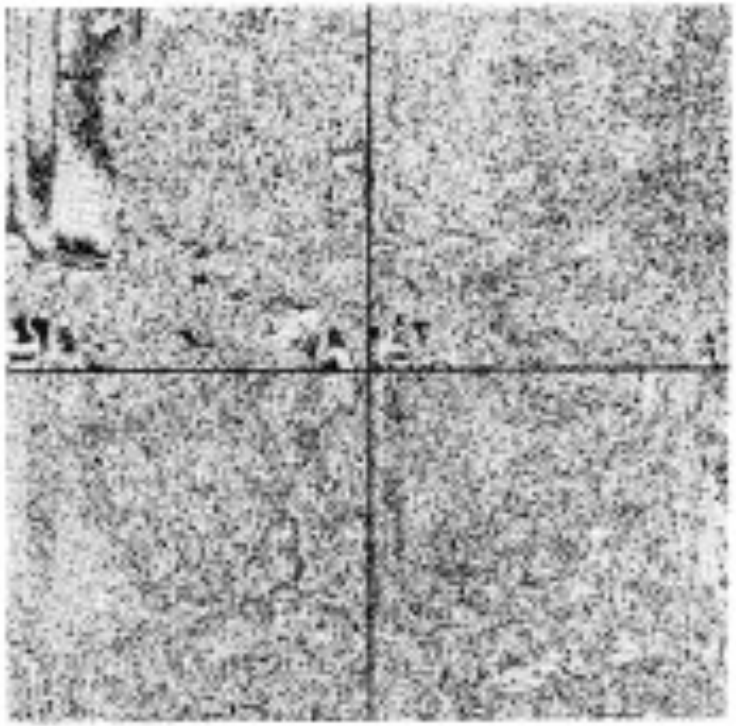
MSB Plane

Bit Plane Slicing

- Observing the images we conclude that
  - Higher order bits contain visually significant data.
  - Lower order bits contain suitable details of image.
- Hence, BPS can be used in Image Compression.
- We can transmit only higher order bits & remove lower order bits.
- E.g. Steganography

Bit Plane Slicing



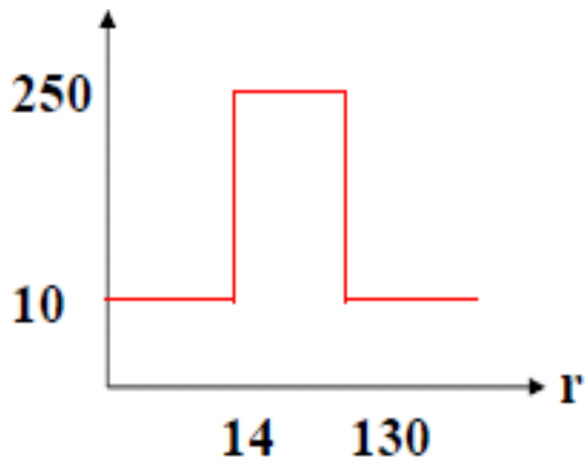


Bit Plane Slicing

Q. A 4x4 image is given as below.

1) The image is transformed using the point transform shown.
Find the pixel values of the output image.
2) What is the 7-th bit plane of this image

17	64	128	128
15	63	132	133
11	60	142	140
11	60	142	138



Bit Plane Slicing

Pixel values of output Image (s)

250	250	250	250
250	250	10	10
10	250	10	10
10	250	10	10

250: 11111010

10: 00001010

7^{th} Bit plane of Image

1	1	1	1
1	1	0	0
0	1	0	0
0	1	0	0

- Brightness modification
- Contrast Modification
- Digital Negative
- Dynamic range compression
- Thresholding (noise clipping)
- Intensity level slicing
- Bit plane slicing
- **Histogram modeling**

Next Session

- **Point Operations**
  - Histogram Processing and Equalization

THANK YOU

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