(1)

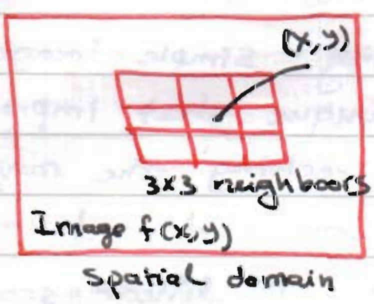
Lect 6

"Intensity Transformation and spatial filtering"

Definition: Image enhancement is the process that improves the quality of the image for a specific application.

Image enhacement methods:

- spatial domain methods (image plane):
  techniques are based on direct manipulation of pixels in ~~an~~ image.
- Frequency domain methods:
  Techniques are based on modifying the fourier transform of the image.
- Combinations methods:
  There are some enhancement techniques based on various combinations of methods from the two first categories.



procedures that operate directly on pixels (spatial domain) can be denoted by the expression:

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

where: $f(x,y)$ is the input image,
$g(x,y)$ is the processed (output) image

T- is an operator on $f(x,y)$ defined over some neighborhood of (x,y).

Mask / filter: neighborhood of a point (x,y) can be used, by using a square / rectangular (common used) or circular sub image area centered at (x,y).
The center of the subimage is moved from pixel to pixel starting at the top of the corner.

- point processing:
  - Neighborhood : 1 x 1 pixel.
  - g depends on only the value of f at (x,y).

and T becomes an intensity transformation function (gray-level or mapping function) of the form:

$$S = T(r)$$

where: r = gray level of $f(x,y)$

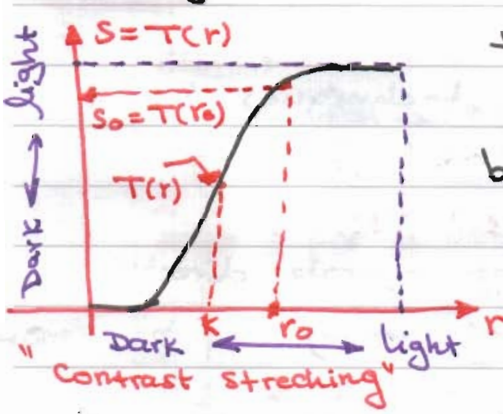
s = gray level of $g(x,y)$

T- is a function that maps r to S

examples:

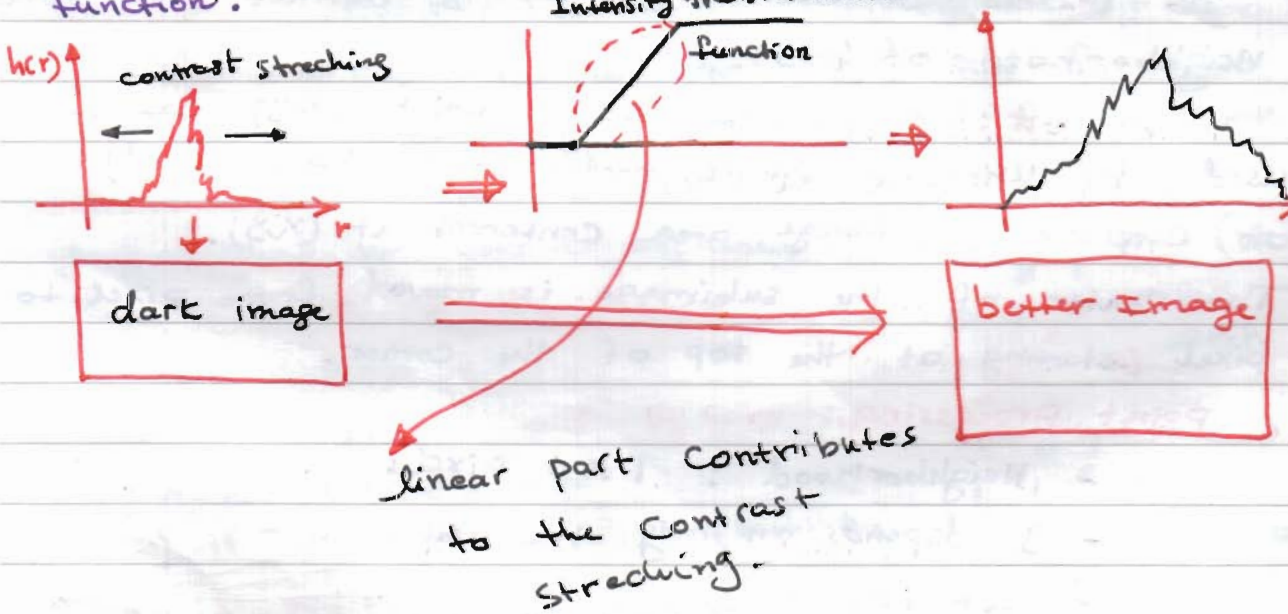
(1.) Contrast streching: (normalization)

if $T(r)$ has the form as shown in figure, the effect of applying the transformation to every pixel of f to generate the corresponding pixels in g whould:

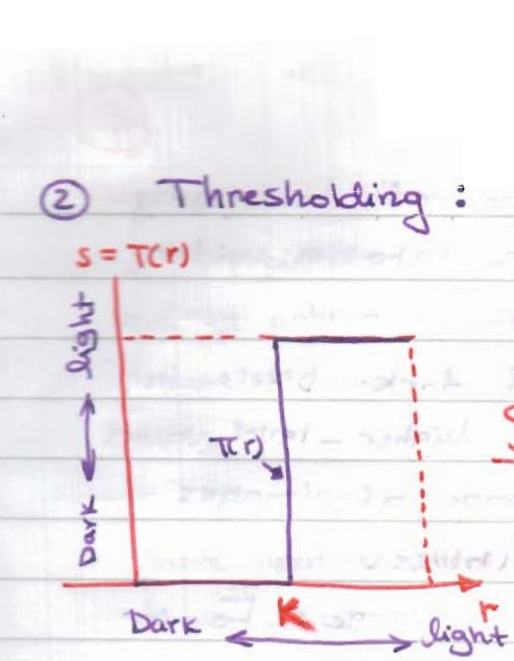


- produce higher contrast than the original by:
  - * darkening the Levels below $\underline{K}$ in the original image.
  - * brightening the levels above $\underline{K}$ in the original image.

Contrast streching: Simple image enhancement technique that improves the contrast in an image by 'streching' the range of intensity values it contains to span a desired range of values. Typically, it uses a linear scaling function.



② **Thresholding:** Produce a two-level (binary) Image, a mapping of this form called thresholding function.



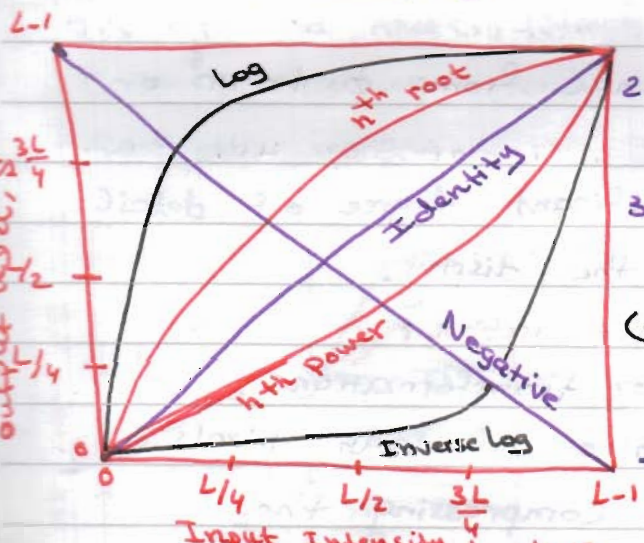
Some Basic Intensity Transformation Functions

three basic types of functions used frequently for image enhancement:

1- linear functions: negative and Identity transformations.

2- Logarithmic: Log and Inverse Log transformations.

3- Power-Law functions (n^{th} power and n^{th} root transformations.



(as shown in figure):

① **Identity function:**

- output intensities are identical to input intensities.
- Is included in the graph only for completeness.

② **Image negatives:**

The negative of an image with gray level in the range [0, L-1], where $L = 2^n$, $n = 1, 2, \ldots$ is obtained by using the negative transformation's expression:

$$s = L - 1 - r.$$

that reverses the intensity levels of an input image.

• The negative transformation is suitable for enhacing white or gray detailed embedded in dark regions of an image, especially when the black area are dominant in size.

③ **Log Transformation:**

The general form of the log transformation:

$$S = c \cdot \log(1 + r).$$

c is a constant, and $r \geq \emptyset$.

- Log Curve maps a narrow range of low gray-level values in the input image into a wider range of the output levels.
- Used to expand the values of dark pixels in an image while compressing the higher-level values.
- it compresses the dynamic range of images with large variations in pixel values.
- Example of image with dynamic range: Fourier spectrum image.
- it can have intensity range from $\emptyset$ to 10^6 or higher.
- We can't see the significant degree of detail as it will be lost in the display.

④ Inverse Logarithm Transformation:

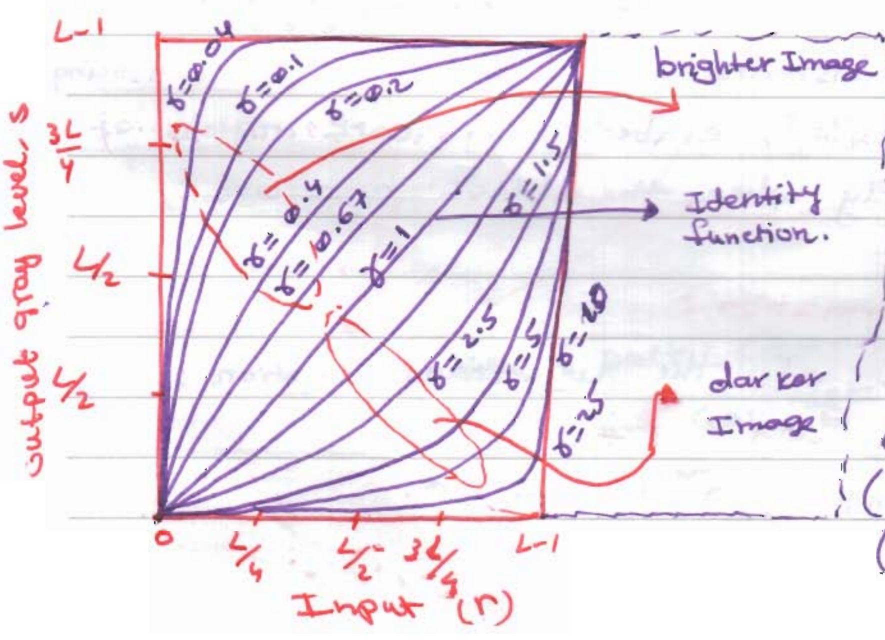
- Do opposite to the log transformations.
- Used to expand the values of high pixels in an image ~~which~~ while compressing the darker-level values.

⑤ power-law (Gamma) Transformation:

The general form of the power-law transformation:

$$S = c \cdot r^{\gamma}, \text{ where } c \text{ and } \gamma \geq \emptyset.$$

- different transformations curves are obtained by varying γ (gamma).



Many Image capturing, printing and display devices use gamma correction, which enhances the given images by power-law response phenomena.

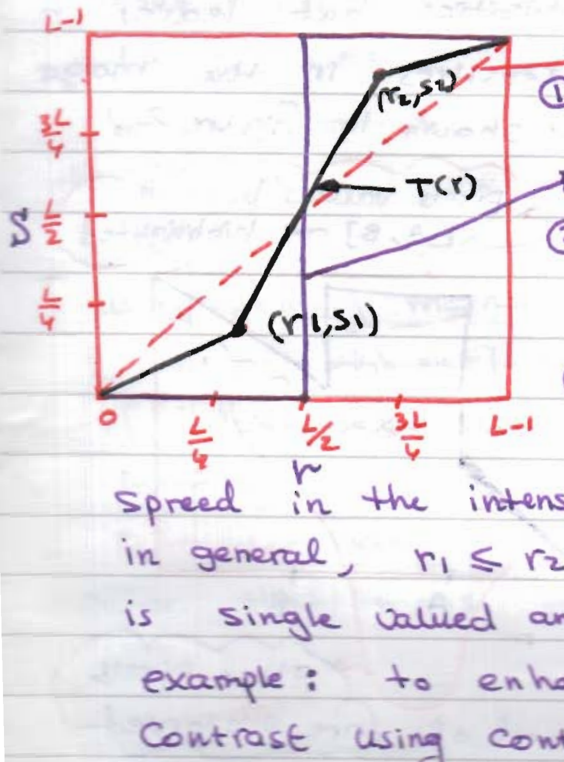
for example: CRT device (Cathode Ray tube) (γ = 1.8 – 2.5)

Piecewise - linear Transformation Functions :

- pricipal advantage : the form of piecewise function can be arbitrarily complex (More options to design), some important transformations can be formulated only as piecewise functions.
- The pricipal disadvantage : their specification requires more user input.

1) Contrast streching :

one of the most (simplest) piecewise function is the Contrast streching, which is used to enhance the low contrast images.



① $s_1 = r_1$ and $s_2 = r_2$ (Identity transformation) (No changes in the image).

② $r_1 = r_2$, $s_1 = \emptyset$, and $s_2 = L-1$ (thresholding function - Image converted to black & white).

③ Intermediate values of (r_1, s_1) and (r_2, s_2) produces various degree of spreed in the intensity levels of the output image, in general, $r_1 \le r_2$ and $s_1 \le s_2$, so the function is single valued and monotonically increasing.

example : to enhance an 8-bit image with low contrast using contrast streching, and obtained by setting :

$(r_1, s_1) = (r_{min}, 0)$ and $(r_2, s_2) = (r_{max}, L-1)$

where r_{min} & r_{max} denote the minimum and the maximum intensity levels in the image → so the transformation function streches the levels linearly from their original range to the full range $[0, L-1]$.

2) Gray-Level slicing (Intensity-level slicing).

This technique is used to highlight a specific range of gray levels in a given image, The process, often called intensity-level slicing, and can be implemented in several way

a- Display all values in the range of interest in one value (say, white), and all other intensities in another value (say, black). as shown in figure 1., this transformation produces a binary image.

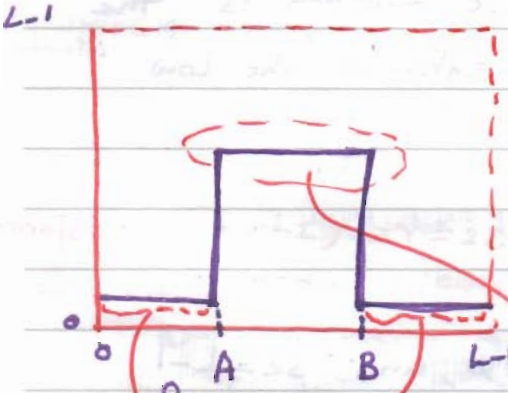
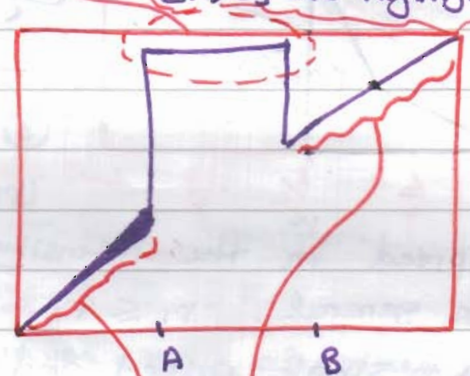


figure 1.

This transformation highlights range [A, B] of gray levels and reduces all others to a contrast level, other pixels are darkened.

B- The second approach. brigthens (or darkens) the desired range of intensitres but leaves all other intensitres in the image Unchanged, as shown in figure 2.



3) Bit-plane slicing:

pixels are digital number composed of bits, Instead of high lighting intensity-level range, we could highlighting the contribution made by each bit, this method is useful and used in image compression.

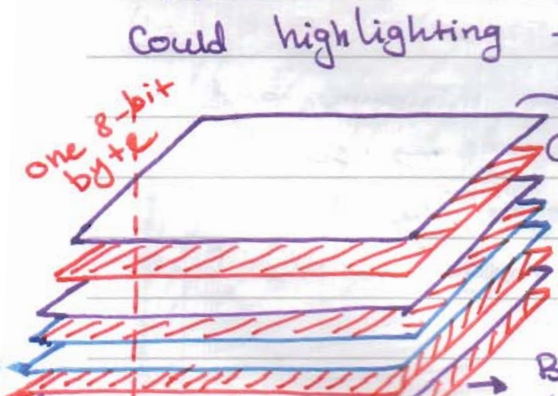


figure : Bit-plane representation of an 8-bit image

most significant bits contains the majority of the visually significant data