# Computer Vision and Machine Learning

(Image enhancement)

Bhabatosh Chanda
**bchanda57@gmail.com**

## Outline

- Introduction
  - General concept of
  - Different aspects of image quality improvement
- Image contrast stretching
  - Linear stretching
    - Graylevel and colour image
  - Histogram equalization
    - Adaptive histogram equalization



## Types of processing

- Spatial domain processing
  - Directly operates on the pixel values in the spatial domain.
  - Point process
  - Neighbourhood process
    - Most common is convolution operation.
- Frequency domain processing
  - First transforms the image data to frequency domain using an orthogonal transform.
  - Appropriate filtering is applied on transformed data.
  - Inverse transform is applied on filtered data to get back into spatial domain.



## Point process

- A single pixel of input image is processed individually to get the value (colour) at corresponding pixel in the output image.

$$s = T(r)$$

  - $r$ is greylevel in input image, say, $g(x,y)$
  - $s$ is greylevel in output image, say, $f(x,y)$
- Simplest form of point process

$$s = a(r-b) + c$$

  - $a$, $b$ and $c$ are parameters
  - Example, $a = -1$, $b = 0$ and $c=255$ produces negative image.

## Negative image

**Original**

**Negative**



## Neighbourhood process

- Each pixel of input image is processed based on its neighbouring pixels to get the corresponding pixel in the output image.

$$f(x,y) = T_{(u,v)\in N(x,y)}(g(u,v))$$

  - *g(x,y)* is the greylevel in input image
  - *f(x,y)* is the greylevel in output image
  - $N(x,y)$ defines the neighbourhood of the candidate pixel $(x,y)$.
- If the mapping *T* is linear, this may be expressed as convolution:

$$f(x,y) = g(x,y) * h(x,y)$$

  - *h(x,y) is a function defined over the domain similar to the neoghbourhood N.*



## Improvement of image quality

- Image restoration
  - Estimates the original (undegraded) image from the observed image based on the knowledge in terms of model of the degradation process.
- Image enhancement
  - Adhoc process improves the quality of the image using some heuristic designed on the basis of users' experience and application in hand.

## Image enhancement

- Contrast intensification
  - increases discernibility among the regions.
- Smoothing
  - reduces the effect of noise.
- Sharpening or edge crispening
  - reduces ambiguity between regions.

## Contrast intensification

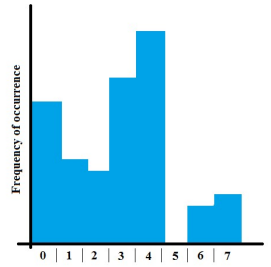
- How to decide
  - Any objective indicator for appearance of image?
  - How to measure contrast?
- What to do
  - Intensify contrast between pixels? Between regions?
- How to do



## Graylevel histogram

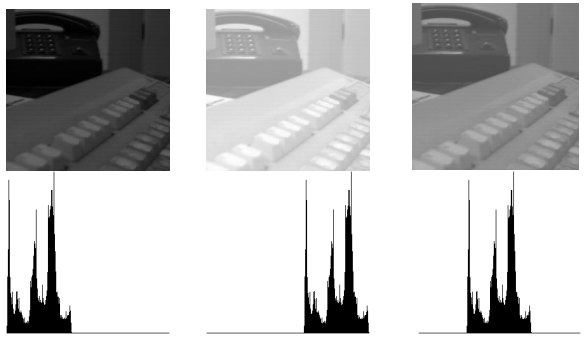
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 4 | 4 | 3 | 3 | 4 | 3 | 6 | 4 |
| 4 | 3 | 6 | 3 | 3 | 6 | 3 | 3 |
| 3 | 3 | 3 | 1 | 1 | 1 | 3 | 4 |
| 3 | 0 | 0 | 2 | 0 | 1 | 0 | 4 |
| 7 | 1 | 0 | 0 | 1 | 2 | 0 | 3 |
| 4 | 0 | 0 | 2 | 0 | 0 | 2 | 7 |
| 4 | 4 | 4 | 1 | 0 | 2 | 2 | 4 |
| 4 | 7 | 4 | 4 | 7 | 4 | 4 | 4 |

| Val. | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|---|
| freq. | 12 | 7 | 6 | 14 | 18 | 0 | 3 | 4 |






## Histogram and appearance





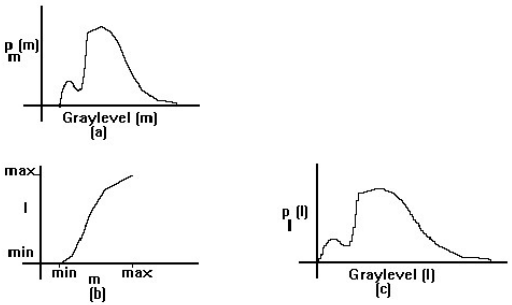
## Contrast intensification

**Graylevel transformation:**

1. Histogram stretching:
   Linear, Piece-wise linear, Non-linear like Logarithmic and Exponential
2. Histogram modification:
   Histogram equalization, specification

**Constraint to be satisfied:** $r_i < r_j \Rightarrow s_i \leq s_j$

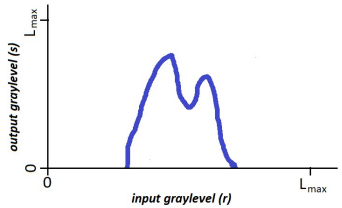
## Graylevel transformation






## Histogram stretching

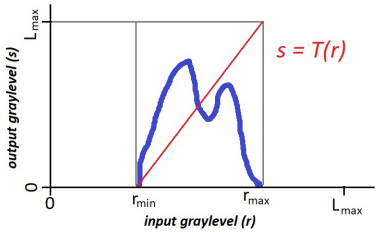
- Increases contrast in image.
- May be implemented efficiently using Look-up table.
- Analyse the greylevel histogram *h(r) (r=0,1,2, …,$L_{max}$)* of input image to decide transformation Function.






## Histogram linear stretching

- Minimum greylevel $r_{min}$ with non-zero frequency.
- Maximum greylevel $r_{max}$ with non-zero frequency.
- *s = T(r) = a.r + b*
  - *a=?, b=?, c=?*
- *For contrast enahancement*
  - $a = \frac{L_{max}}{r_{max} - r_{min}}$,
  - $b = r_{min}$ and
  - $c = 0$





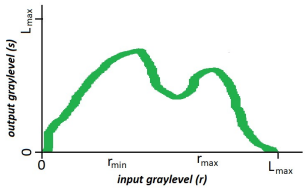

## Histogram linear stretching

- Complete definition of transformation at pixel level:

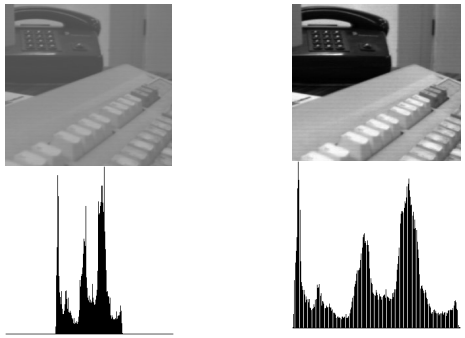
$$f(x,y) = \frac{L_{max}}{r_{max} - r_{min}}[g(x,y) - r_{min}]$$

- Greylevel histogram of output image occupies full range.
- Two conditions are satisfied:

$$\sigma_s \geq \sigma_r \text{ and } \frac{dT}{dr} \geq 1$$



## Histogram and appearance





## Non-linear stretching

- Logarithmic transformation

$$s_i = \frac{L_{max}}{log(r_{max} - r_{min} + 1)} \log(r_i - r_{min} + 1)$$

- Exponential transformation

$$s_i = \frac{L_{max}}{e - 1}\left(\exp\left(\frac{r_i - r_{min}}{r_{max} - r_{min}}\right) - 1\right)$$

## Colour histogram stretching

- Colour image comprises three channels, i.e.,

$$f(x, y) = [f_R(x, y), f_G(x, y), f_B(x, y)]$$

- Corresponding histograms are $h_R(i), h_G(i)$ and $h_B(i)$
- Stretching each histogram independently would change the hue or the colour type.
  - Multiplying factor for each channel may be different.
  - Addition (or subtraction) of some constant.
- Two approaches:
  - Use brightness or value channel only.
  - Determine common parameters of all three histograms.



## Colour histogram stretching

- First approach to colour image histogram stretching:
  - Convert RGB to other colour triplets,
  - apply histogram stretching on value or brightness channel,
  - then convert back to RGB.

## Colour histogram stretching

**Original** **Enhanced**



## Colour histogram stretching

- Second approach to colour image histogram stretching:
  - Find $r_{c,\,min}$ and $r_{c,\,max}$ *(c = R,G,B)* from $h_c(r)$
  - $r_{min} = \min\{r_{R,\,min}, r_{G,\,min}, r_{B,\,min}\}$
  - $r_{max} = \min\{r_{R,\,max}, r_{G,\,max}, r_{B,\,max}\}$
  - then compute linearly stretched colour channels as

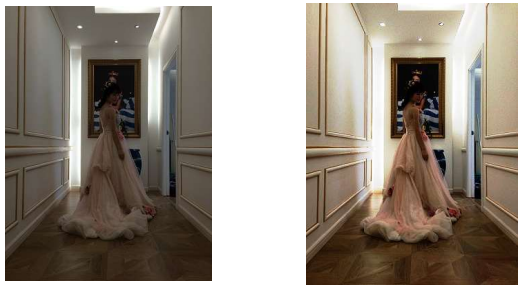
$$f_c(x,y) = \frac{L_{max}}{r_{max} - r_{min}}[g_c(x,y) - r_{min}]$$

for *c = R, G, B*.



## Colour histogram stretching

**Original** **Enhanced**





## Histogram equalization

- Transfer function: $s = \int_{-\infty}^{r} p_r\,(\alpha)d\alpha$
- Assuming both *r* and *s* are continuous, and $0 \le r, s \le 1$.

- In discrete domain: $s_j = L_{max} \sum_{i=0}^{j} p_{r_i}$

where $p_{r_i} = \frac{n_{r_i}}{N}$ and $n_{r_i}$ is the frequency of occurrence of *i*-th levele $r_i$.

## Colour histogram equalization

**Original** **Enhanced**




# Thank you!

## Any question?