Computer Vision and Machine Learning

(Image enhancement)

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Books

1. Digital Image Processing and Analysis, B. Chanda and D. Dutta Majumder, PHI.
2. Image Processing, Analysis and Machine Vision, Milan-Sonka et al., Cengage Learning
3. Computer Vision: Models, Learning and Inference, Simon Prince, Cambridge Univ. Press.
4. Computer Vision: Algorithms & Applications, R. Szeleski, Springer

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.

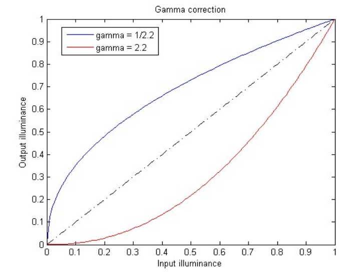
Negative image

Original

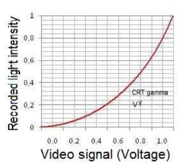
Negative

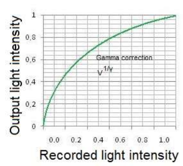
Gamma correction

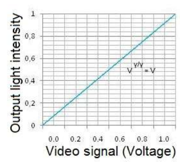
- Response of photosensor to input is non-linear (red curve).
  $B = V^{\gamma}$
- That we may compensate by applying inverse operation (blue curve).
- $I = B^{1/\gamma}$
  $= (V^{\gamma})^{1/\gamma} = \mathrm{V}$ → **linear**



Gamma correction







→ **Gamma Correction** →

White balance

- When looking at a picture on screen or print, we adapt to the illuminant of the room, not to that of the scene in the picture
- When the white balance is not correct, the picture has an unnatural color “cast”.

incorrect white balance

correct white balance

http://www.cambridgeincolour.com/tutorials/white-balance.htm

White balance

- We need to "guess" which pixels correspond to white objects (highest average brightness)!
- Gray world assumption
  - The image average r_{ave}, g_{ave}, b_{ave} is gray
  - Use weights $1/r_{ave}$, $1/g_{ave}$, $1/b_{ave}$
- Brightest pixel assumption
  - Highlights usually have the color of the light source
  - Use weights inversely proportional to the values of the brightest pixels
- Use image statistics, learning techniques

Color balance

Raw image

Color balanced image
(brightest pixels)

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 neighbourhood* 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.

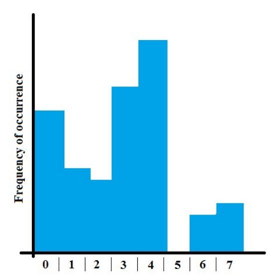
Contrast intensification

- 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

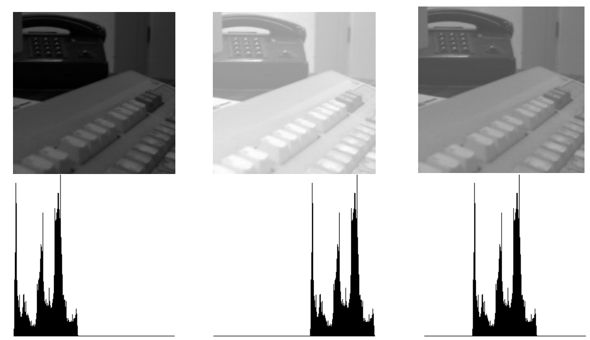
Graylevel histogram

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



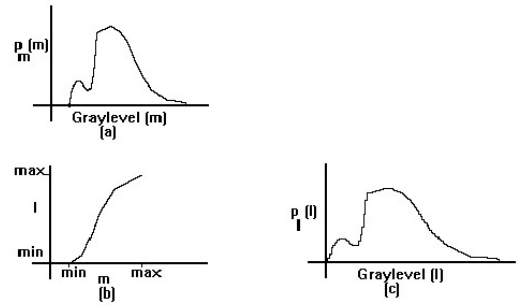
Contrast intensification

Graylevel transformation:

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

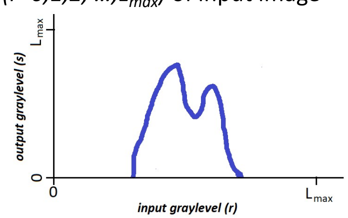
Constraint to be satisfied: $r_i < r_j \Rightarrow \; s_i \leq s_j$

Graylevel transformation



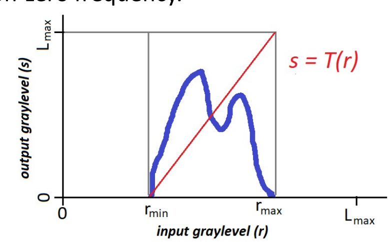
Histogram stretching

- 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
  - $c = 0$



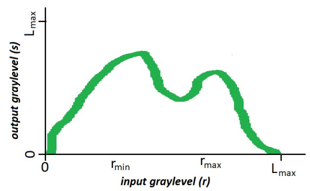
Histogram linear stretching

- Complete definition of transformation at pixel level:

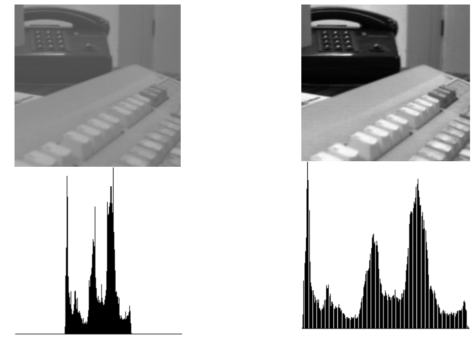
$$f(x,y) = \frac{L_{max}}{r_{max} - r_{min}}[g(x,y) - r_{min}]$$

- 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 $0 \leq r, s \leq 1$.

- 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?