Fundamentals of Image Processing

Lecture 06

Histogram Equalization
and Other Non-Linear Transformations

Non-Linear Transformations

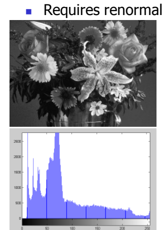
- Examples
  - Histogram Equalization
  - Logarithmic Transformations (and inverses)
  - Power Transformations (and inverses)
    - Gamma correction

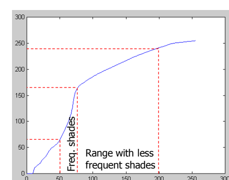
Histogram Equalization

- Automatic, non-linear mapping whose goal is to produce optimal image contrast
- The transformation is specific for each image
- More shades are reserved to regions of the histogram containing more pixels
- Increases the "spacing" (distance) among shades in the regions of the histogram with largest concentrations of pixels
- Seeks to "flatten" the frequency distribution of shades along the entire histogram

Cumulative Histogram

- Prefix sum of the histogram
- An appropriate function for performing equalization
  - Requires renormalization





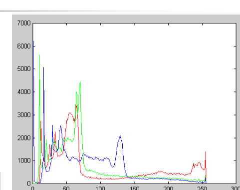
Graph of the function *Cumulative Histogram*

Histogram Equalization - Algorithm

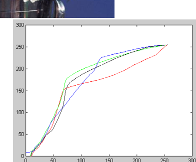
```
Histogram_equalization (image f, image * g)
{   //  f: original image;
    //  g: output image (i.e., equalized)
   int histogram[256],                            // histogram
       hist_cum[256];                             // cumulative histogram
   float α = 255.0 / number of pixels in the image;   // scaling factor
//
//   computes the (renormalized) cumulative histogram
   compute_histogram(f, &histogram);
   hist_cum[0] = α * histogram[0];
   for i = 1 to 255
        hist_cum[i] = hist_cum[i-1] + α * histogram[i];
//
//  use the renormalized cumulative histogram as the equalization function
   for x = 1 to width of image f do
        for y = 1 to height of image f do
             g(x,y) = hist_cum[f(x,y)];        // save new shade of gray
}
```


Histogram of the RGB channels

Reference image



Histogram of the R, G, B channels



Cumulative histogram for the R,G, B and luminance channels

Color images should be mapped to a color space, such as Lab ou Luv, and the equalization applied to the L channel

Histogram Equalization – Color Images

original

after equalization

Histogram Equalization - Exemplos

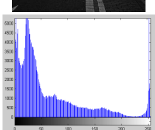
original

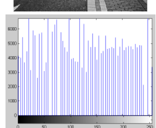
after equalização

Histogram Equalization - Exemplos

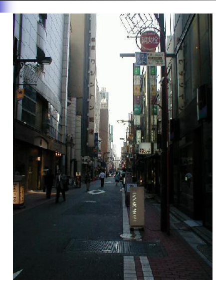
original

after equalization

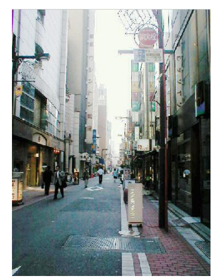




Histogram Equalization – Color Images



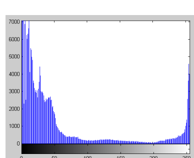
original



after equalization

Histogram Equalization – Example: Low contrast image

before equalization

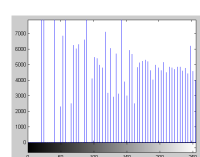


Histogram Equalization – Result for a low-constrast image

Noise

The original (dark) image had a low signal-to-noise ratio (SNR)

after equalization



Histogram Equalization
– Example: Low contrast color image

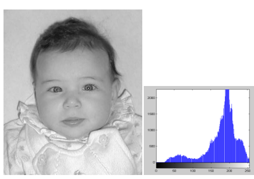
Original image

Histogram Equalization
– Result for a low-constrast color image

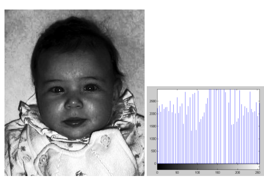
After equalization

Histogram Equalization
– Not always appropriate

- Does not always produce good results
  - Ex.: The photograph on the left contains just a few dark pixels, but that is a good representation for the scene



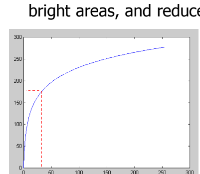
before equalization



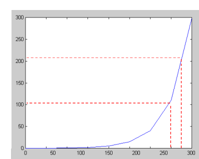
after equalization !!!

Logaritmic and Exponential Transformations

- Represented by $g(x,y) = c*log(1 +f(x,y))$
  - Increases the contrast in dark areas, and reduces it in bright areas
  - The exponencial function (log inverse) increases contrast in bright areas, and reduces it in dark areas



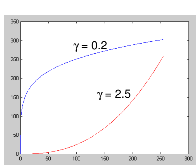
g(x) = 50*log(1 + x)



g(x) = exp(x)/10

Power Transformations

- Represented by $g(x,y) = c*f(x,y)^{\gamma}$
  - c and γ are positive constants
  - $0 < \gamma < 1$ increase the contrast in dark areas
  - Large values of γ increase contrast in bright areas



Gamma Correction

- CRTs have non-linear intensity-to-voltage response
  - Defined by a power function, with approx. $1.8 \leq \gamma \leq 2.5$
    - If pixel should have an intensity p, the CRT will actually display it with intensity p^{γ}
  - Since intensity values are normalized to [0,1]
    - The displayed pixel is darker than desired (*i.e.*, $p^{\gamma} < p$)
  - Solution
    - Encode (correct) the intensities for the gamma value of the display, using $p^{(1/\gamma)}$ instead of p, as $(p^{(1/\gamma)})^{\gamma} = p$
    - The result then becomes linear

Gamma Correction

- Example of gamma function and its inverse for $\gamma = 2.2$

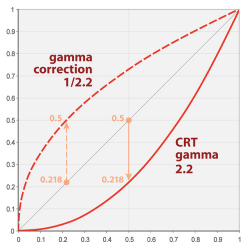
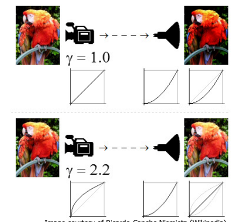


Image courtesy of Jurohi (Wikipedia)

Gamma Correction

- Standard NTSC $\gamma = 2.2$
  - Digital cameras capture, and TV stations broadcast, signals in gamma-encoded form, anticipating the standardized gamma of the TV sets



- For compatibility, LCD displays also use a gamma decoding similar to the one found in CRTs

Image courtesy of Ricardo Cancho Niemietz (Wikipedia)