CMPSCI 370: Intro to Computer Vision

Image processing

[quantization, color maps, image enhancement]

University of Massachusetts, Amherst
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Slides credit: Erik Learned-Miller and others

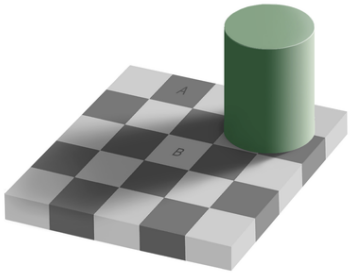
Overview

- Announcements:
  - Homework 1 due today
  - Homework 2 will be posted soon
  - Honors section will meet today at 4pm
- Today's lecture:
  - Review color constancy
  - Image processing
    - signal quantization
    - color representation
    - enhancing images intro

Color constancy

- The ability of the human visual system to perceive color relatively constant despite changes in illumination conditions

We perceive the same color both in shadow and sunlight

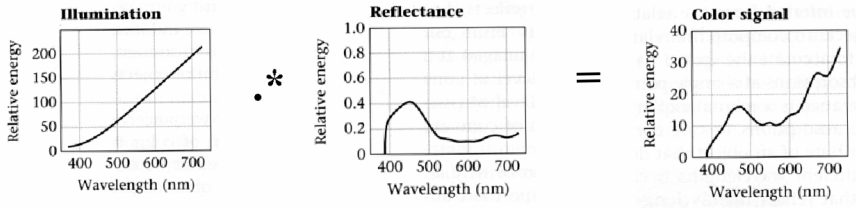


Color constancy causes A and B to look different although the pixel values are the same

http://en.wikipedia.org/wiki/Color_constancy

Color constancy problem

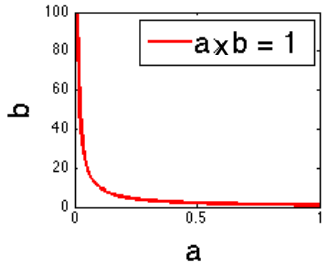
- Reflected color is the result of interaction between the light source spectrum and the reflection surface reflectance

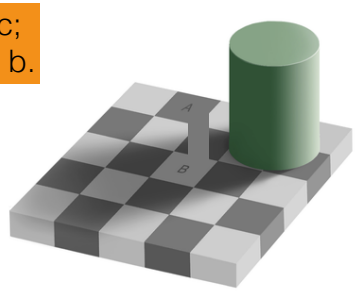


Color constancy

paint light

Mathematically we have a x b = c;
Given c we want to recover a and b.





Color constancy causes A and B to look different although the pixel values are the same

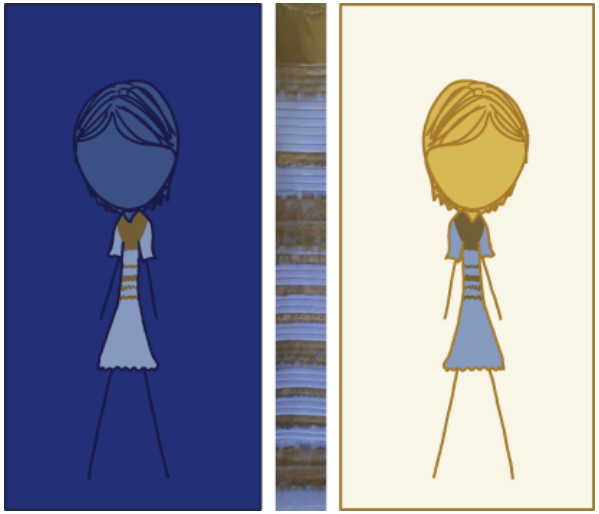
Color constancy

#1 white and gold
or
#2 blue and black

1 light is blue so white is tinted blue and gold doesn't really change

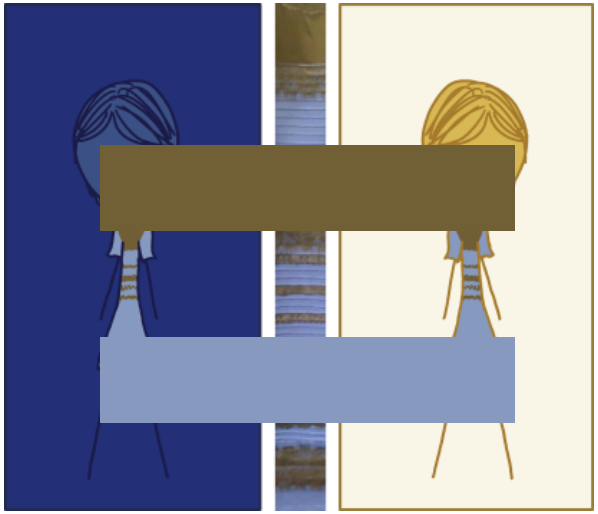
2 light is yellow, so black reflects the yellow and the blue is unaffected

Color constancy



http://xkcd.com/1492/

Color constancy



http://xkcd.com/1492/

Chromatic adaptation

- The visual system changes its sensitivity depending on the luminances prevailing in the visual field
  - The exact mechanism is poorly understood
- Adapting to different brightness levels
  - Changing the size of the iris opening (i.e., the aperture) changes the amount of light that can enter the eye
  - Think of walking into a building from full sunshine
- Adapting to different color temperature
  - The receptive cells on the retina change their sensitivity
  - For example: if there is an increased amount of red light, the cells receptive to red decrease their sensitivity until the scene looks white again
  - We actually adapt better in brighter scenes: This is why candlelit scenes still look yellow

http://www.schorsch.com/kbase/glossary/adaptation.html

White balance

- When looking at a picture on screen or print, our eyes are adapted to the illuminant of the room, not to that of the scene in the picture
- When the white balance is not correct, the picture will have an unnatural color "cast"

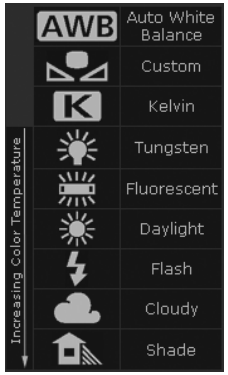
incorrect white balance

correct white balance

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

White balance

- **Film cameras:**
  - Different types of film or different filters for different illumination conditions
- **Digital cameras:**
  - Automatic white balance
  - White balance settings corresponding to several common illuminants
  - Custom white balance using a reference object



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

White balance

- Von Kries adaptation
  - Multiply each channel by a gain factor
- **Best way:** gray card
  - Take a picture of a neutral object (white or gray)
  - Deduce the weight of each channel
    - If the object is recoded as r_w, g_w, b_w use weights $1/r_w$, $1/g_w$, $1/b_w$

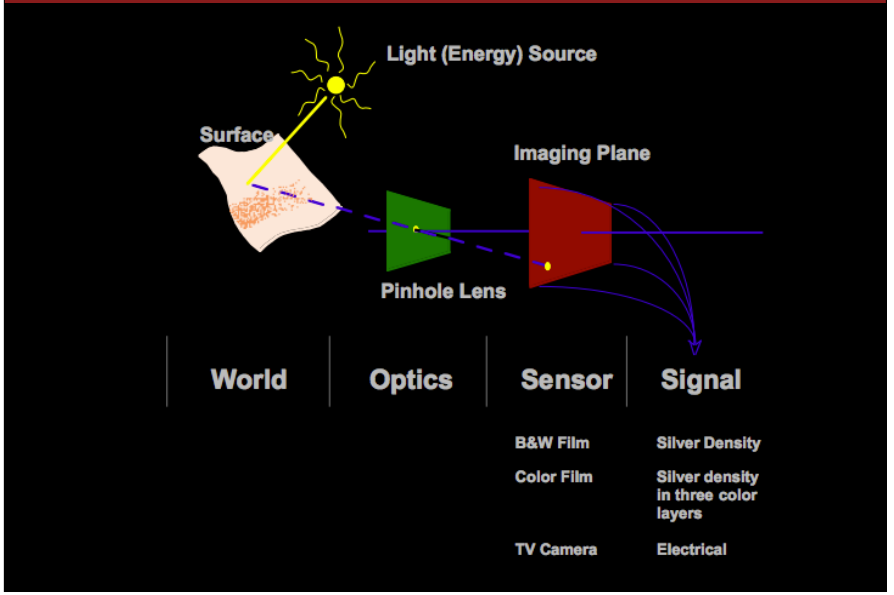
Source: L. Lazebnik

White balance

- Without gray cards: we need to “guess” which pixels correspond to white objects
- 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
- Gamut mapping
  - Gamut: convex hull of all pixel colors in an image
  - Find the transformation that matches the gamut of the image to the gamut of a “typical” image under white light
- Use image statistics, learning techniques

Source: L. Lazebnik

Image formation



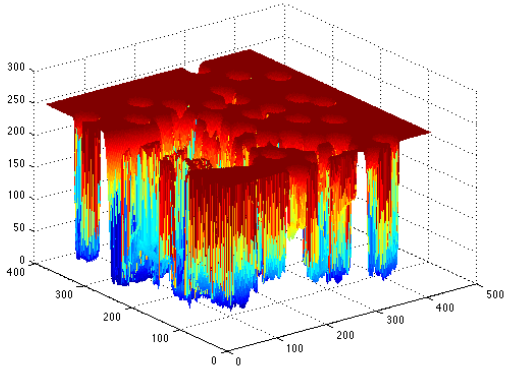
Pre-digitization image

- What is an image before you digitize it?
  - Continuous range of wavelengths
  - 2-dimensional extent
  - Continuous range of power at each point

Brightness images

- To simplify, consider only a brightness image
  - Two-dimensional (continuous range of locations)
  - Continuous range of brightness values
- This is equivalent to a two-dimensional function over a plane

An image as a surface



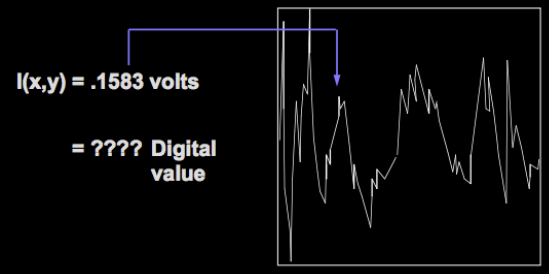
How do we represent this continuous two dimensional surface efficiently?

Discretization

- Sampling strategies
  - Spatial sampling
    - How many pixels?
    - What arrangement of pixels?
  - Brightness sampling
    - How many brightness values?
    - Spacing of brightness values?
  - For video, also the question of time sampling.

Signal quantization

- **Goal:** determine a mapping from a continuous signal (e.g. analog video signal) to one of K discrete (digital) levels.



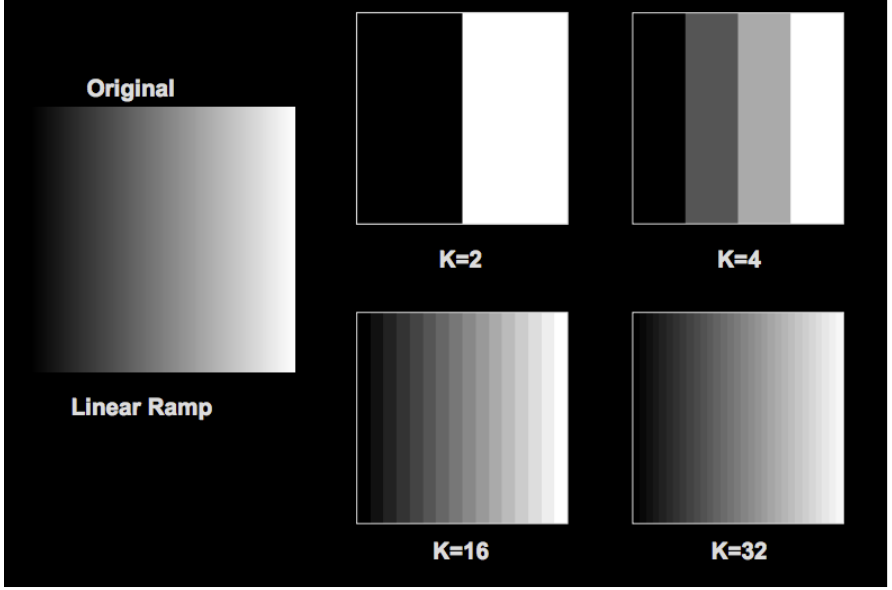
Quantization

- I(x,y) = continuous signal: $0 \le I \le M$
- Want to quantize to K values 0,1,....K-1
- K usually chosen to be a power of 2:

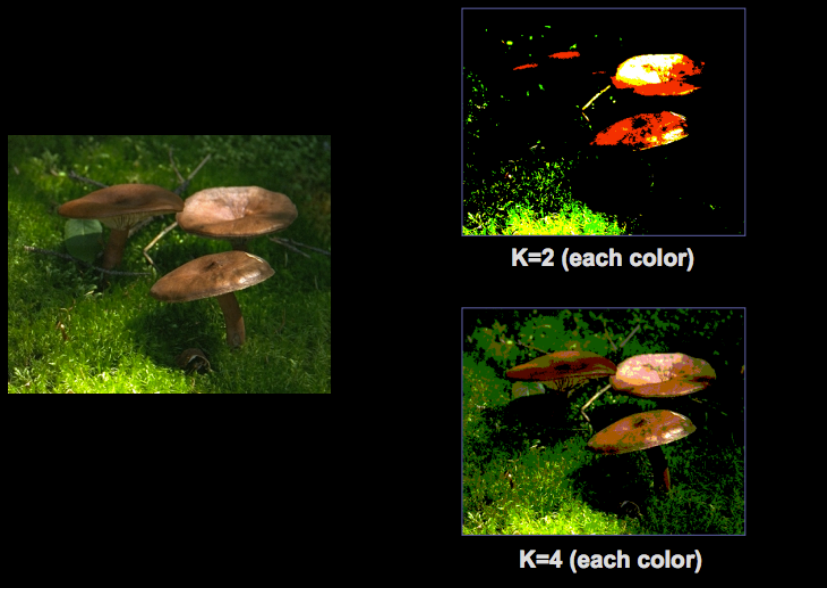
K: #Levels	#Bits
2	1
4	2
8	3
16	4
32	5
64	6
128	7
256	8

- Mapping from input signal to output signal is to be determined.
- Several types of mappings: uniform, logarithmic, etc.

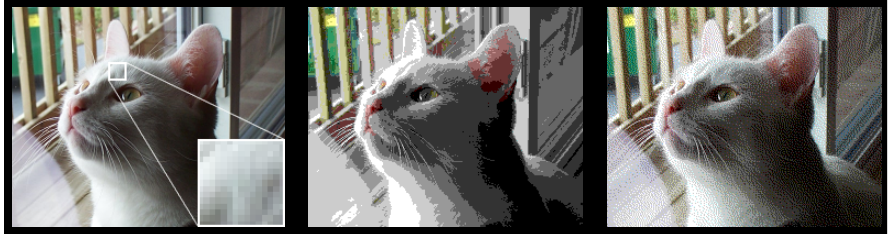
Choice of K



Choice of K



False contours problem



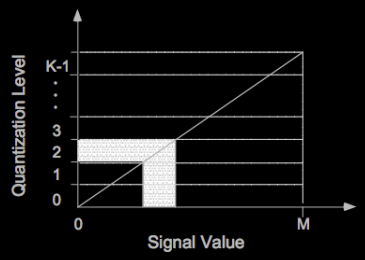
original image 16 colors with random noise

"Dithering" adds random noise to reduce false contours

https://en.wikipedia.org/wiki/Dither

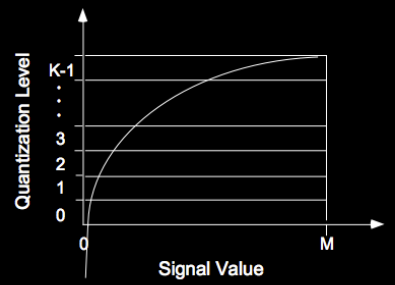
Choice of the function: uniform

- Uniform sampling divides the signal range [0-M] into K equal-sized intervals.
- The integers 0,...K-1 are assigned to these intervals.
- All signal values within an interval are represented by the associated integer value.
- Defines a mapping:



Logarithmic quantization

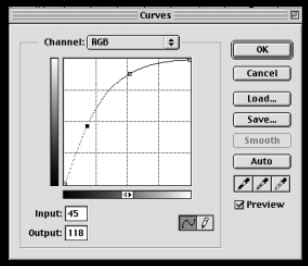
- Signal is: log I(x,y)
- Effect is:



- Detail enhanced in the low signal values at expense of detail in high signal values.

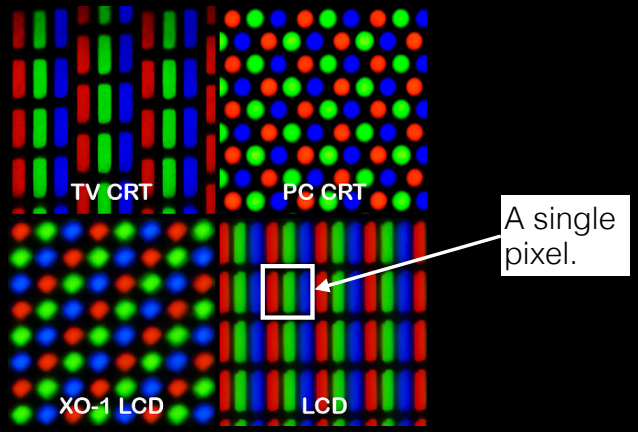
Logarithmic quantization

Quantization Curve



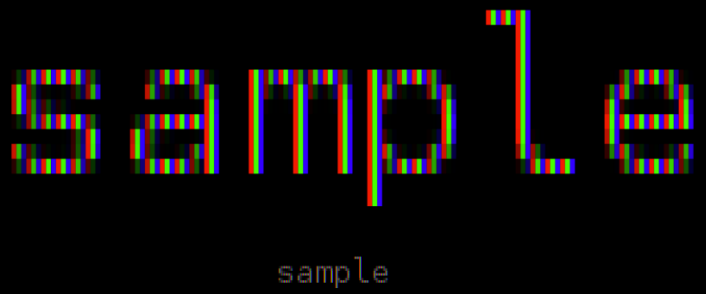
Color displays

- Given a 24 bit color image (8 bits for R, G, B)
  - Turn on 3 subpixels with power proportional to RGB values



https://en.wikipedia.org/wiki/File:Pixel_geometry_01_Pengo.jpg

"White" text on color display



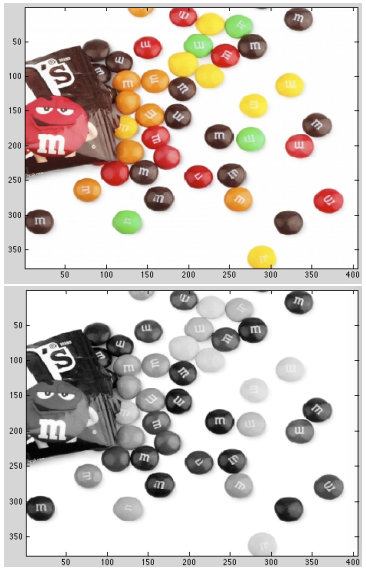
sample

http://en.wikipedia.org/wiki/Subpixel_rendering

Lookup tables

- 8 bit image: 256 different values.
- Simplest way to display: map each number to a gray value:
  - 0 → (0.0, 0.0, 0.0) or (0,0,0)
  - 1 → (0.0039, 0.0039, 0.0039) or (1,1,1)
  - 2 → (0.0078, 0.0078, 0.0078) or (2,2,2)
  - ...
  - 255 → (1.0, 1.0, 1.0) or (255,255,255)
- This is called a **grayscale** mapping.

Lookup tables

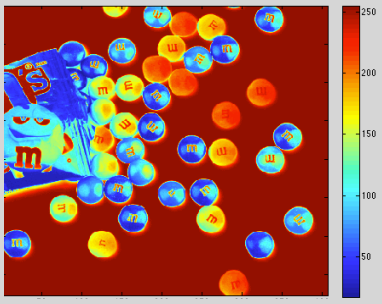


```
>> im = imread('mnms.jpeg');
>> figure;
>> imagesc(im);
>> size(im)

ans =

   376   406     3

>> im8 = rgb2gray(im);
>> size(im8)

ans =

   376   406

>> figure;
>> imagesc(im8); colormap(gray);
>>
```

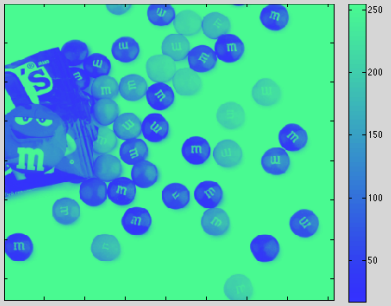

Non-gray lookup tables

- We can also use other mappings:
  - 0 → (17, 25, 89)
  - 1 → (45, 32, 200)
  - ...
  - 255 → (233,1,4)
- These are called lookup tables.

More colormaps

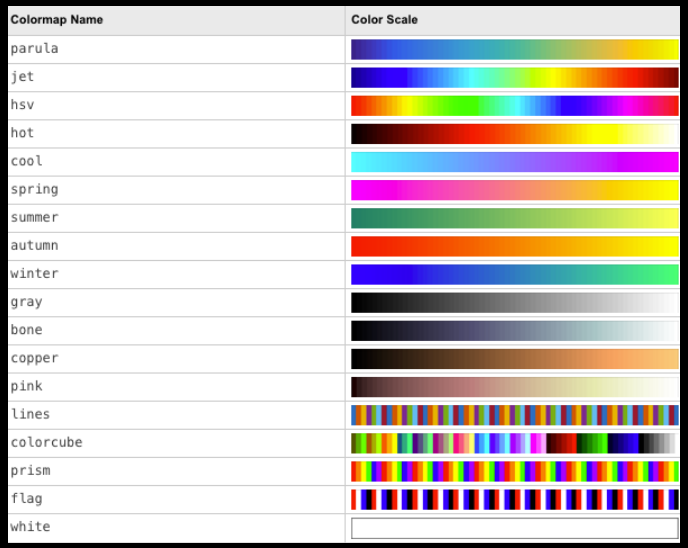


colormap jet;



colormap winter;

Fun with Matlab



Enhancing images

- What can we do to “enhance” an image after it has already been digitized?
  - We can make the information that is there easier to visualize.
  - We can guess at data that is not there, but we cannot be sure, in general.

contrast enhancement

deblurring

Contrast enhancement

- Two methods:
  - Normalize the data (contrast stretching)
  - Transform the data (histogram equalization)

Contrast stretching

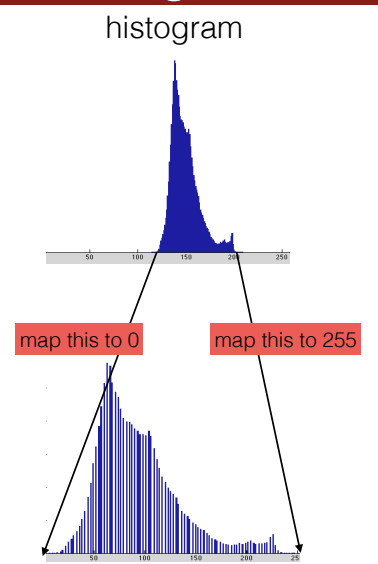
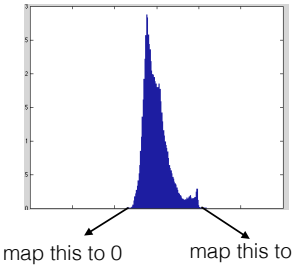


image source: wikipedia

Contrast stretching

- **Basic idea:** scale the brightness range of the image to occupy the full range of values

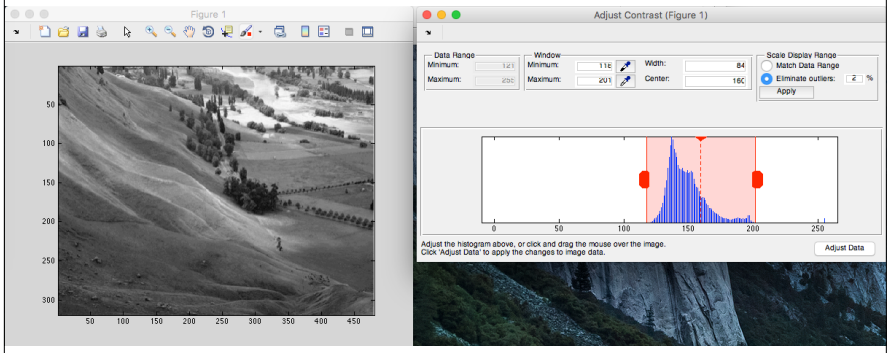


$$I \leftarrow floor\left(\frac{I - \min(I)}{\max(I) - \min(I)} \times 255\right)$$

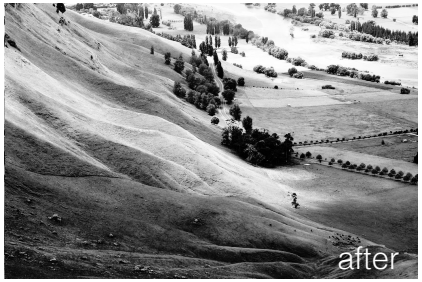
- Issues:
  - What happens if there is one bright pixel?
  - What happens if there is one dark pixel?

Matlab demo

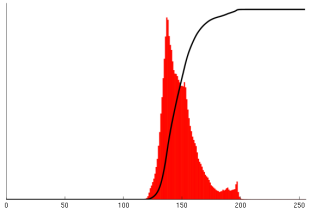
- imcontrast() — contrast stretching



Histogram equalization



histogram



make the distribution close to the uniform distribution