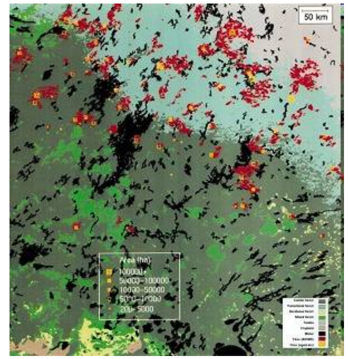
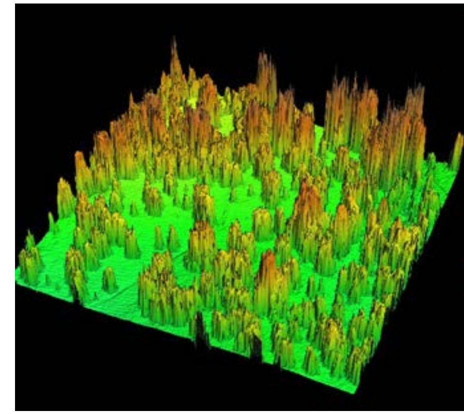
Processing of Remotely Sensed Data:
from a Bunch of Numbers to…

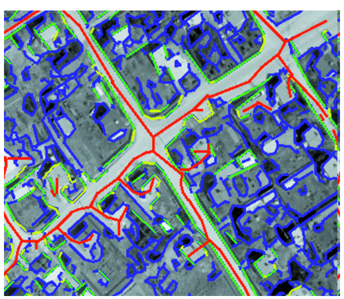
Land Cover Classification



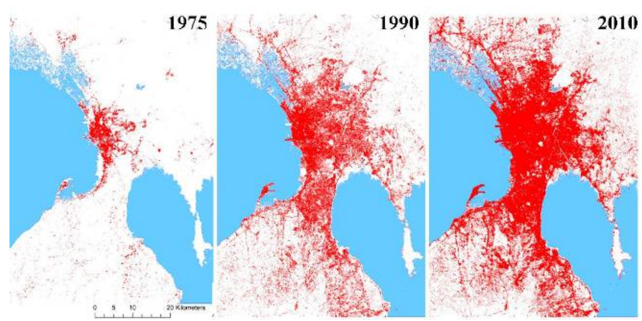
Target Detection
(here: Forest Fires)



3D Surface Modelling

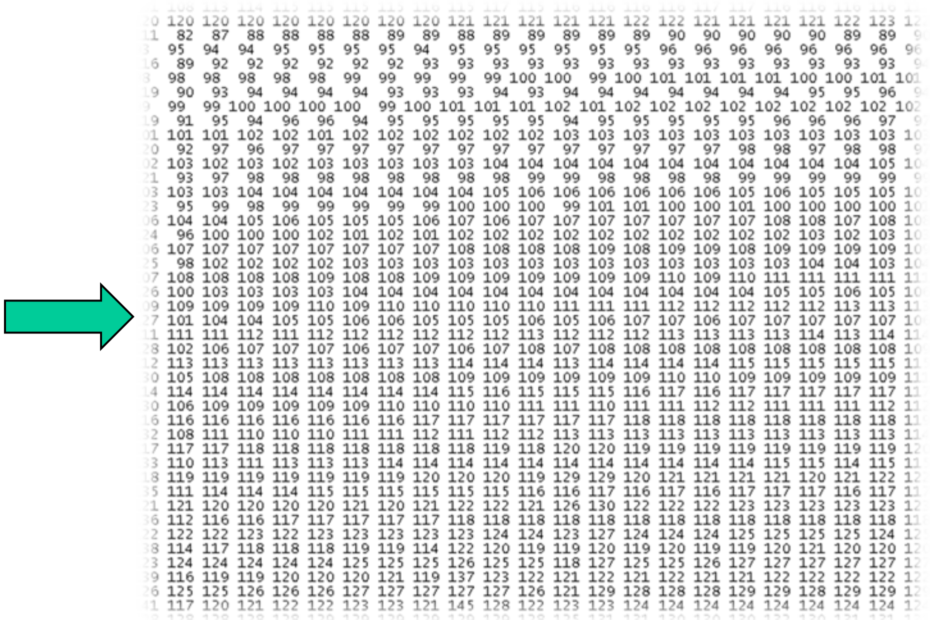


Feature Extraction



Multitemporal Analysis
(here: Urban Sprawl Monitoring)

What the computer gets

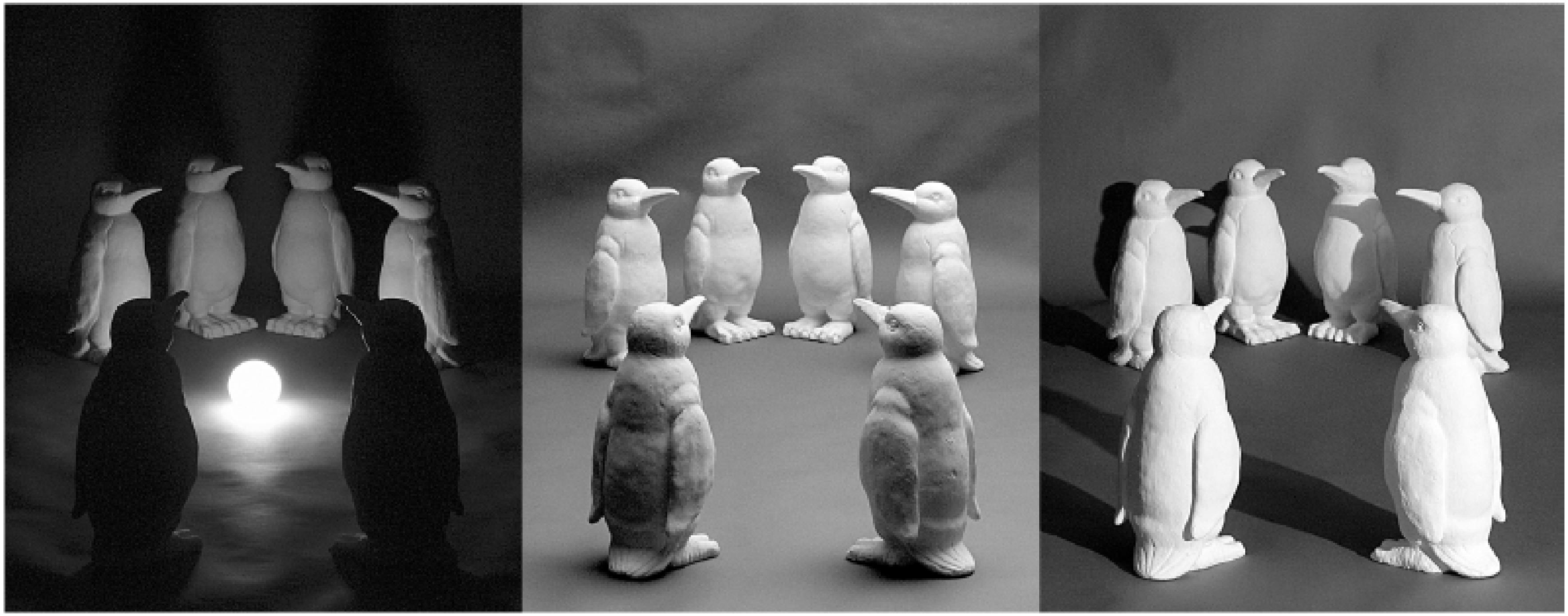


Challenges 1: view point variation

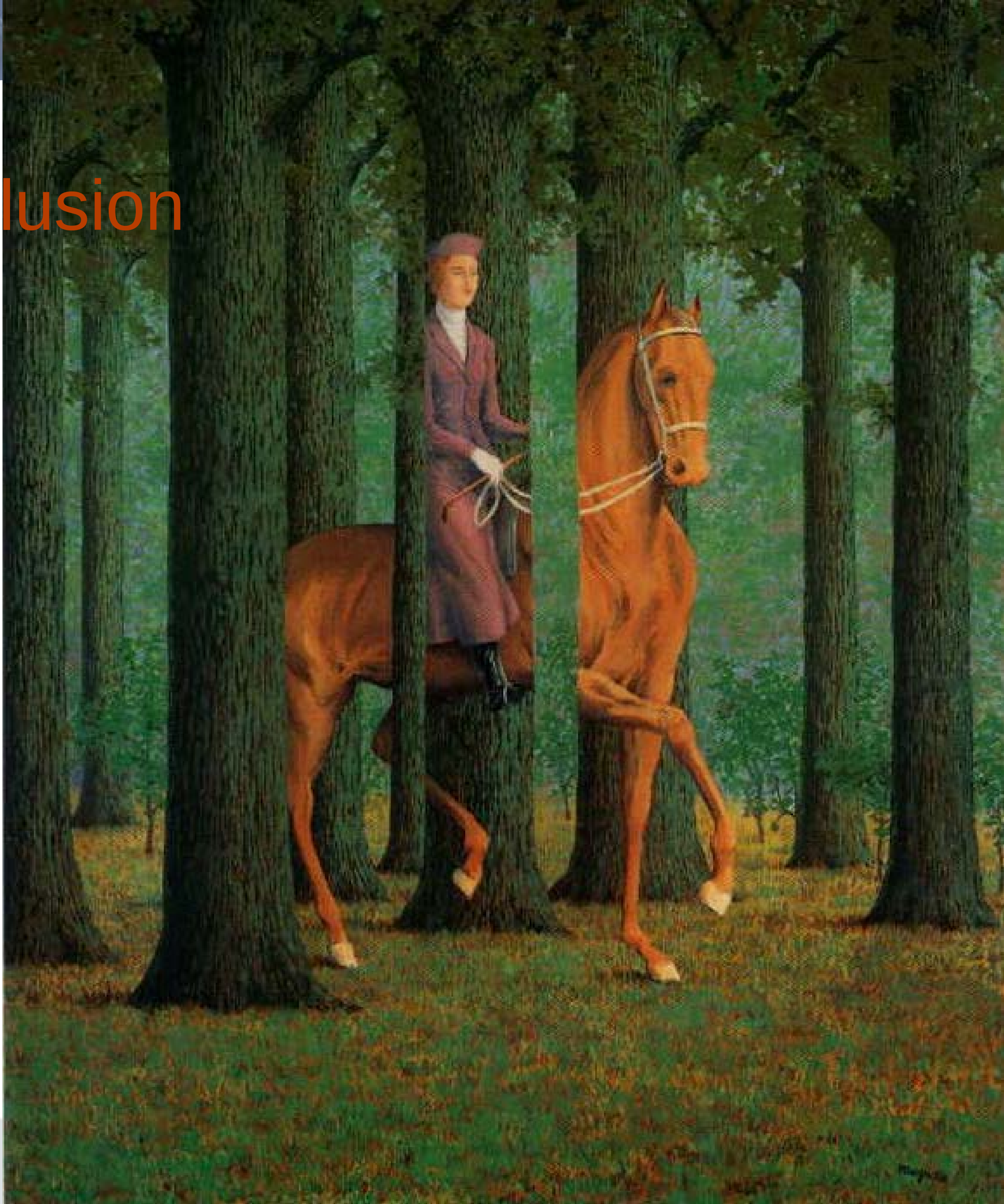
Michelangelo 1475-1564

Adapted from L. Fei-Fei,
R. Fergus, A. Torralba

Challenges 2: illumination



Challenges 3: occlusion



Magritte, 1957

Adapted from L. Fei-Fei,
R. Fergus, A. Torralba

Challenges 4: scale

Challenges 5: background clutter

Challenges 6: intra-class variation

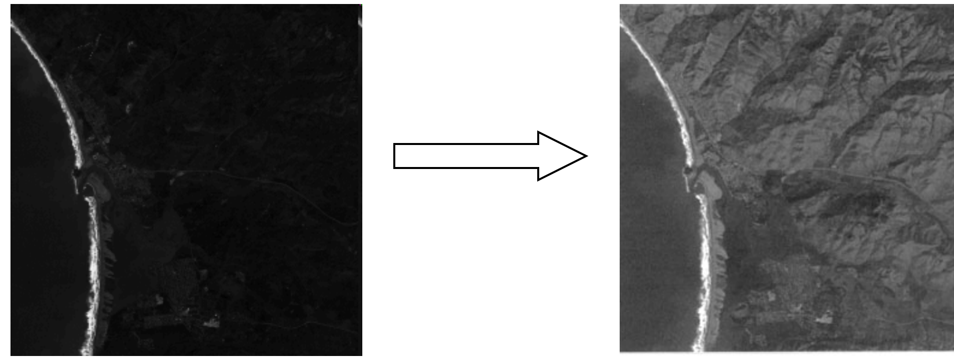




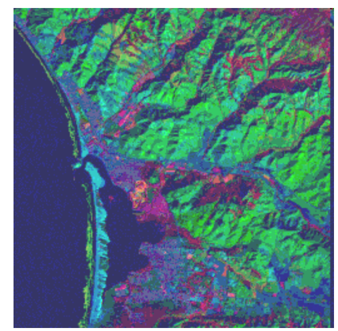

- Image Acquisition & Correction
  - Raw Data→ Raw Image → Image

03	29	38	48
59	96	94	04
05	06	96	97
87	76	75	45

- Low-level Analysis
  - Image → Image
    - Time domain
    - Frequency domain



- Mid-level Analysis
  - Image → Features / Attributes
    - Feature Extraction
    - Clustering / Segmentation



- Beach Bar
- Wave Breakers
- Vegetation1
- Vegetation2
- Golf Course
- Urban Area
- Shadows
- Sea
- Mountains (bright slopes)

- High-level Analysis
  - Features → Recognition
  - Classification

A nice book!

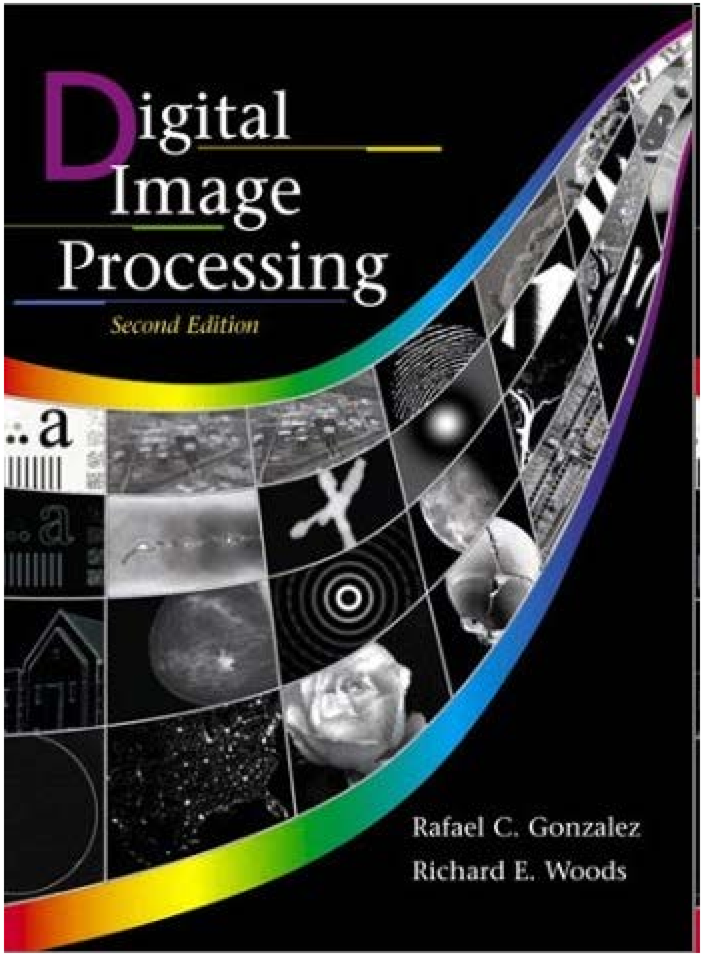

Digital
Image
Processing
Second Edition
Rafael C. Gonzalez
Richard E. Woods

Image Acquisition

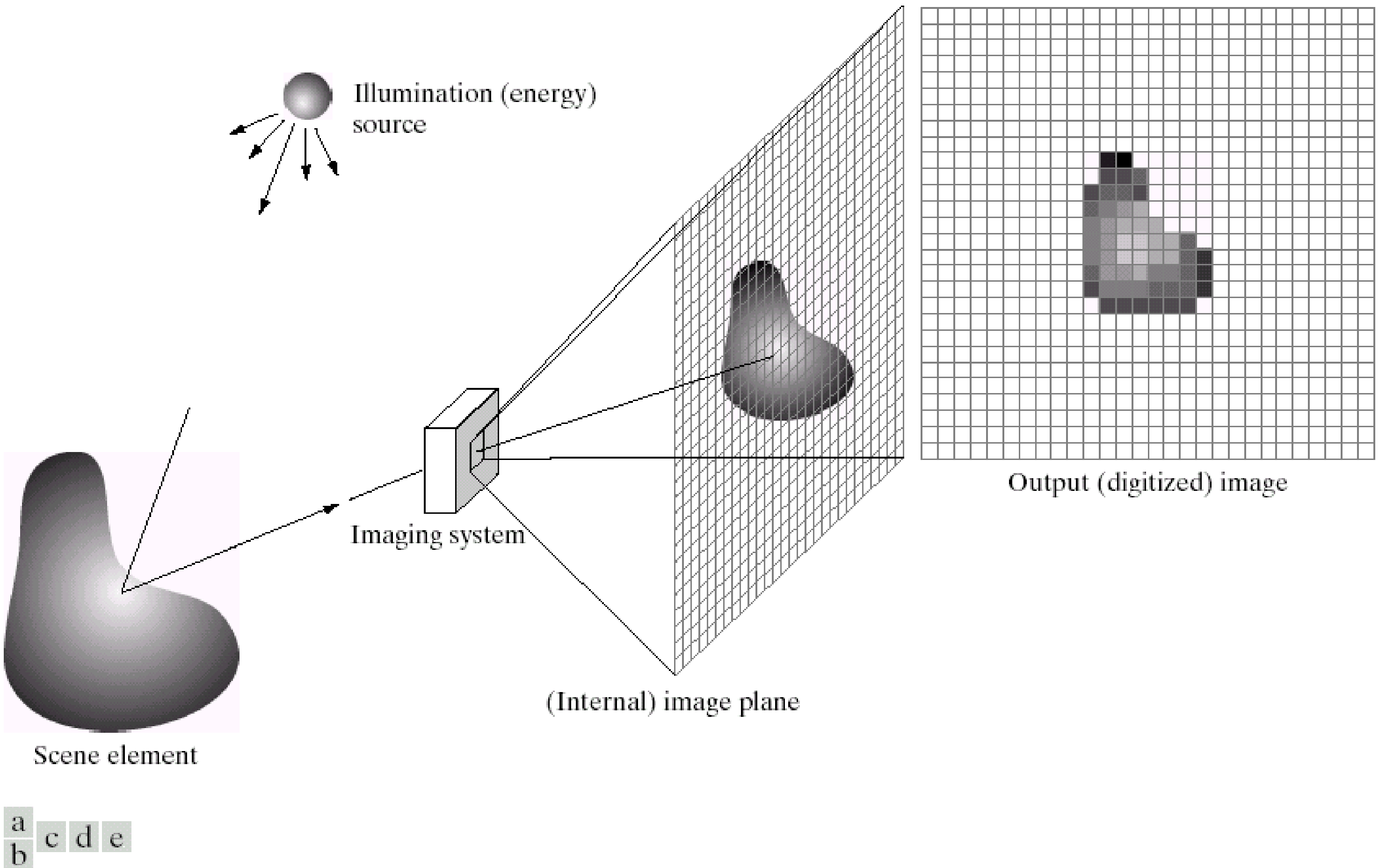
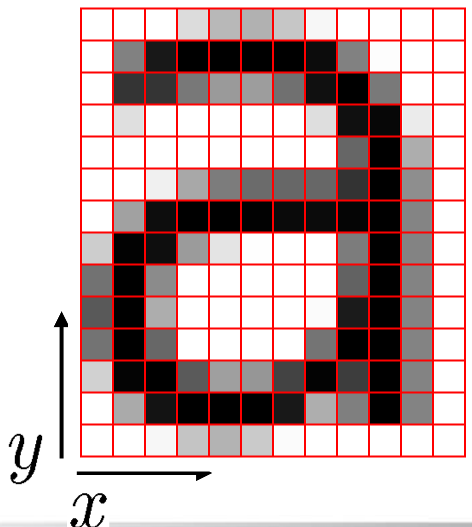


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Image representation

- In a digital image, both the coordinates and the image value become discrete quantities
- Images can be represented as 2D arrays (matrices) of integer values: I[i,j] (or I[r,c])
- The term gray level is used to describe monochromatic intensity

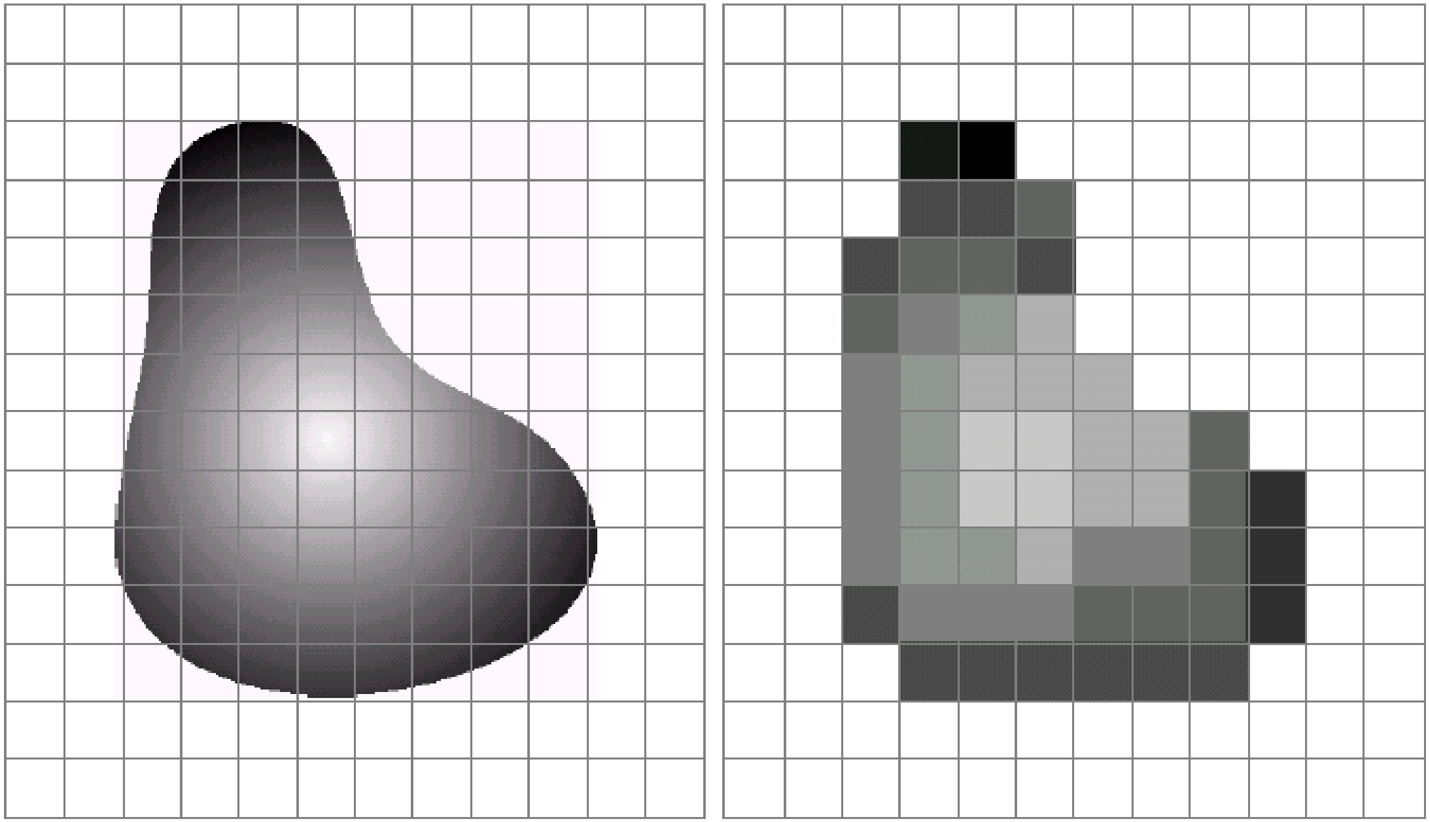
A rasterized form of the letter 'a' magnified 16 times



j →, i ↓

1.0	1.0	1.0	0.9	0.6	0.6	0.6	1.0	1.0	1.0	1.0	1.0
1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0	1.0	1.0
1.0	0.2	0.2	0.5	0.6	0.6	0.5	0.0	0.0	0.5	1.0	1.0
1.0	0.9	1.0	1.0	1.0	1.0	1.0	0.9	0.0	0.0	0.9	1.0
1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0
1.0	1.0	1.0	0.5	0.5	0.5	0.5	0.5	0.4	0.0	0.5	1.0
1.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.0
0.9	0.0	0.0	0.6	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0
0.5	0.0	0.6	1.0	1.0	1.0	1.0	1.0	0.5	0.0	0.5	1.0
0.5	0.0	0.7	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.5	1.0
0.6	0.0	0.6	1.0	1.0	1.0	1.0	0.5	0.0	0.0	0.5	1.0
0.9	0.1	0.0	0.6	0.7	0.7	0.5	0.0	0.5	0.0	0.5	1.0
1.0	0.7	0.1	0.0	0.0	0.0	0.1	0.9	0.8	0.0	0.5	1.0
1.0	1.0	1.0	0.8	0.8	0.9	1.0	1.0	1.0	1.0	1.0	1.0

Sampling and quantization

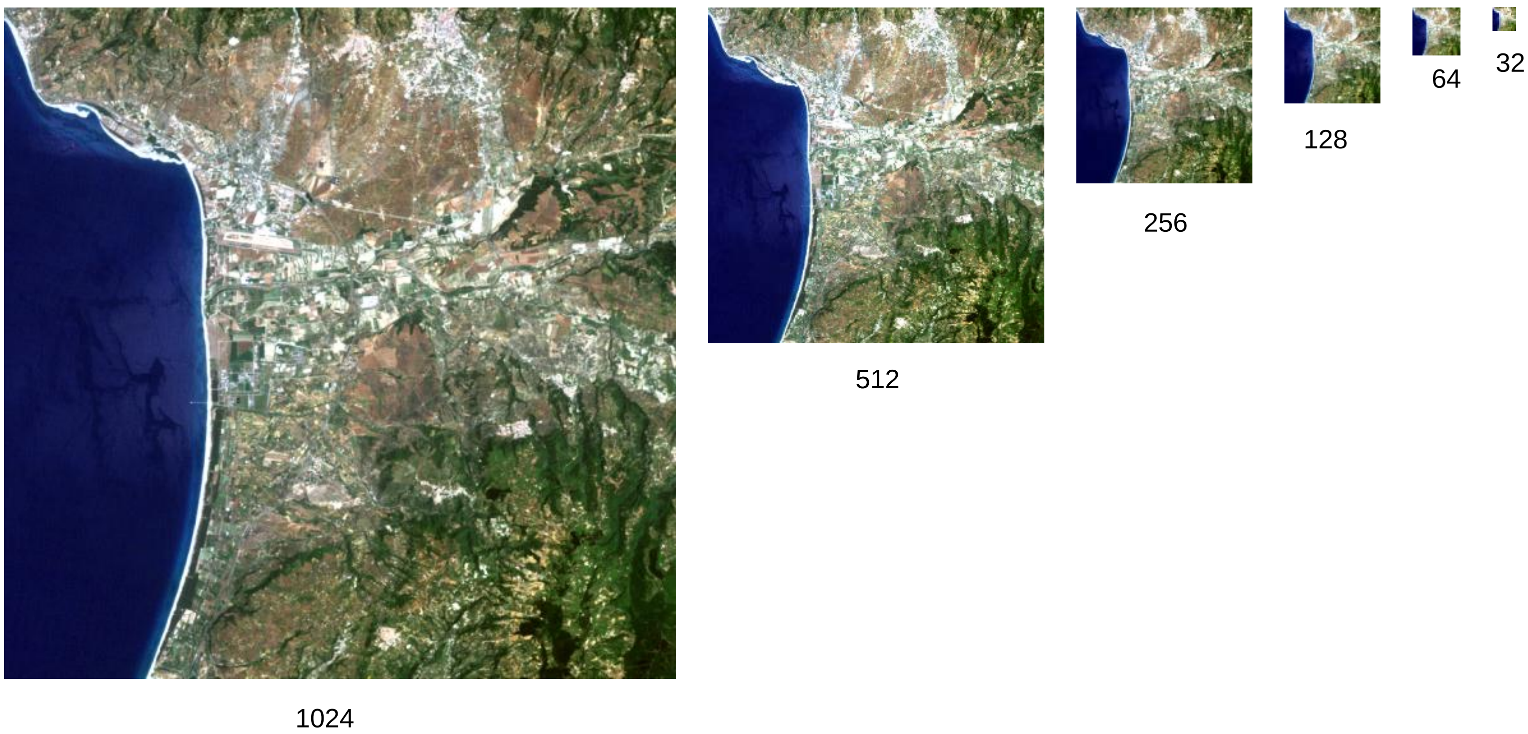


a b

FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Spatial resolution ← Sampling

- Spatial resolution is the smallest discernible detail in an image
- Sampling is the principal factor determining spatial resolution

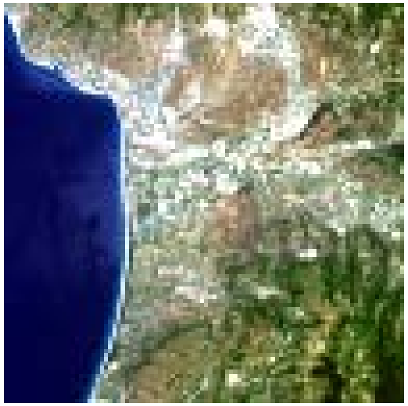


Spatial resolution

1024 x 1024

512 x 512

256 x 256



128 x 128

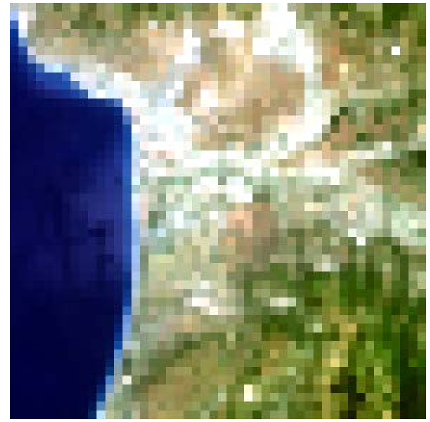
64 x 64

32 x 32

Spatial resolution: Resampling

Resampling without interpolation (nearest-neighbour resampling)

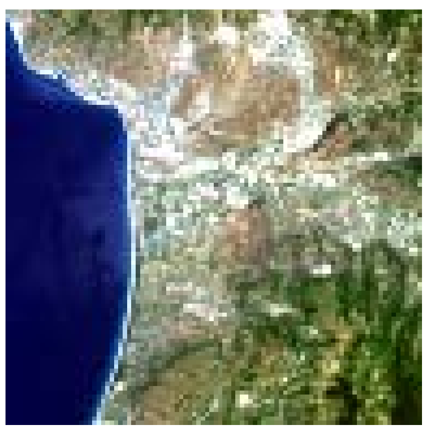
128 x 128



64 x 64

32 x 32

Resampling with interpolation (each pixel is a combination of neighbouring pixels)



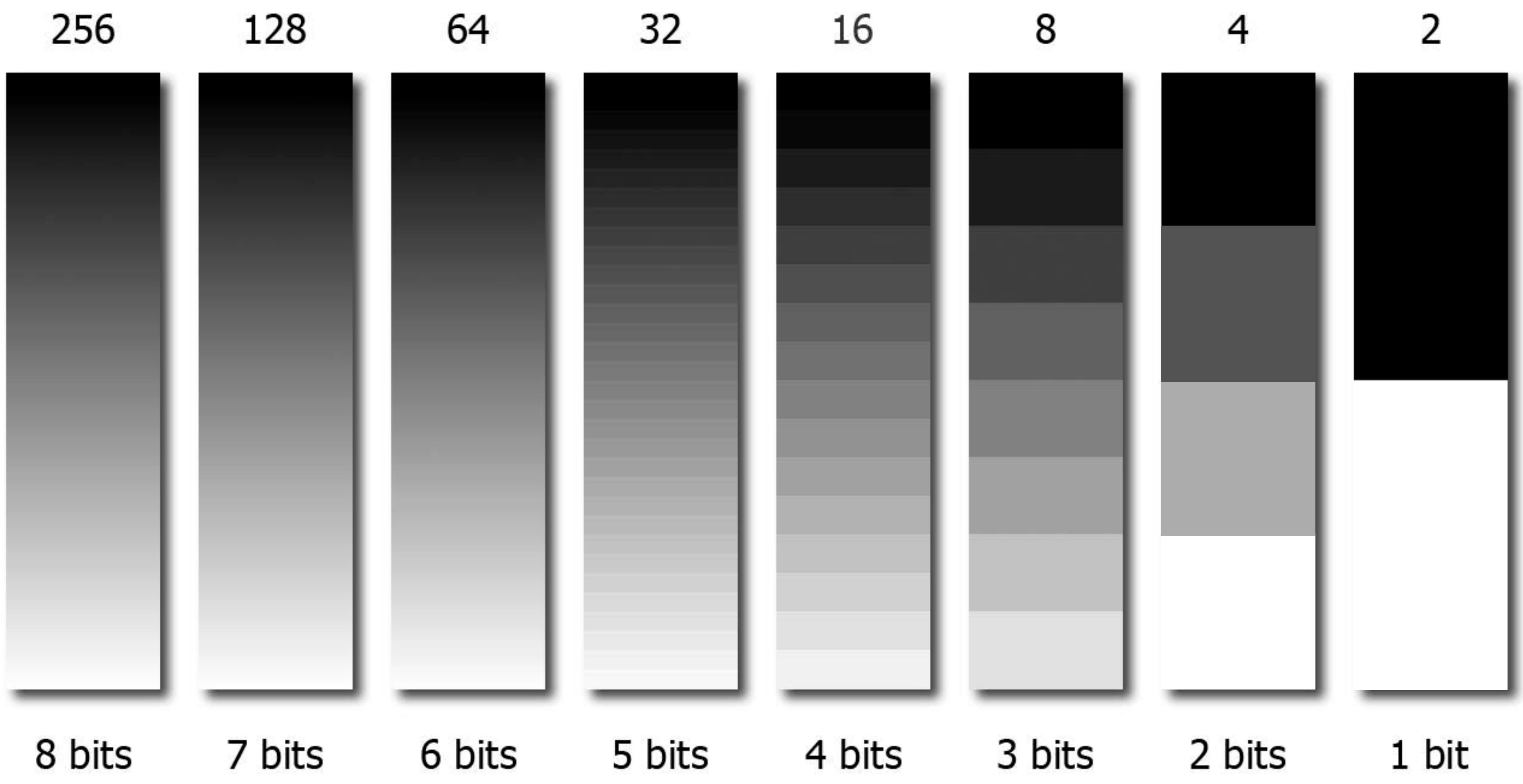
128 x 128

64 x 64

32 x 32

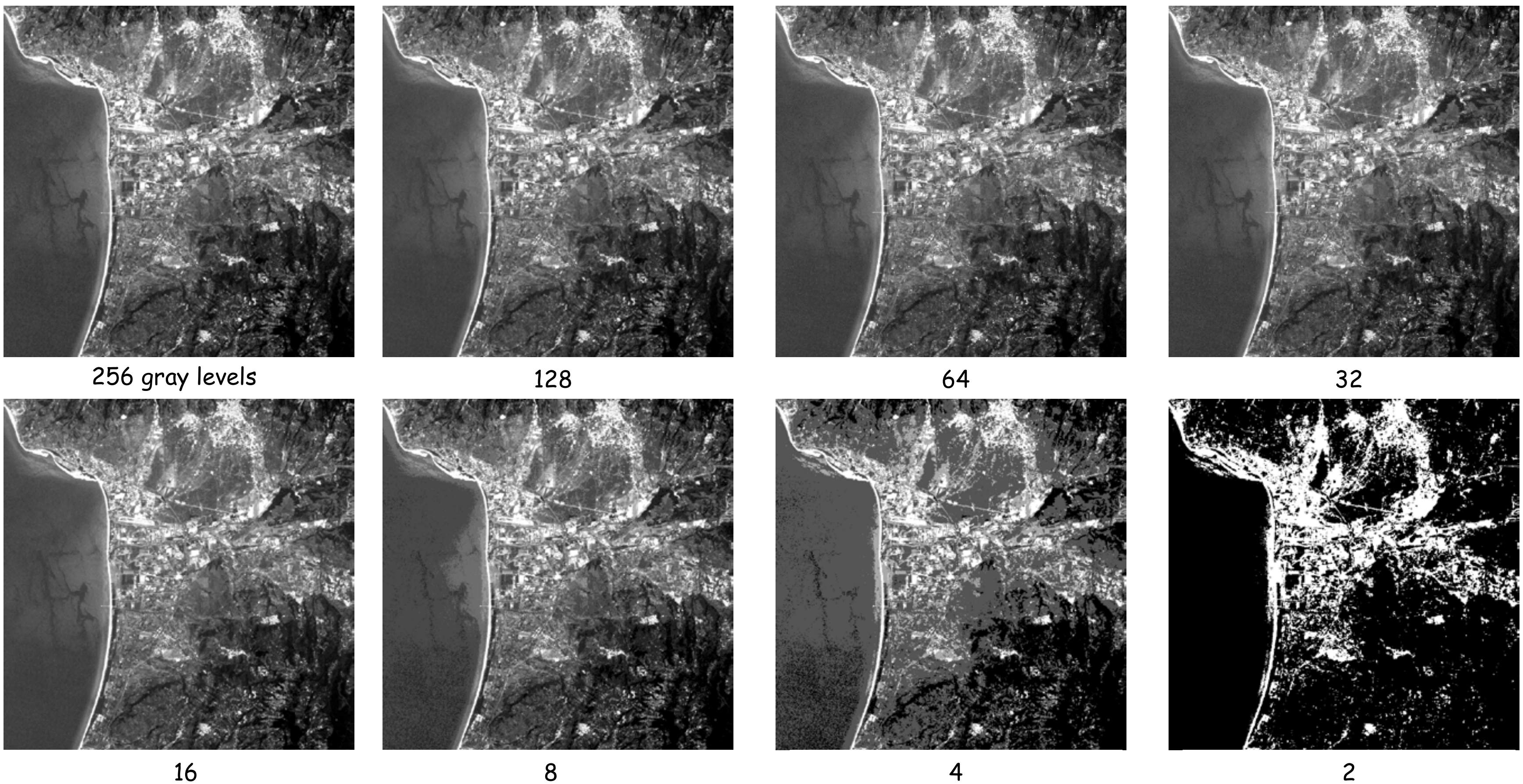
DLR

Radiometric Resolution

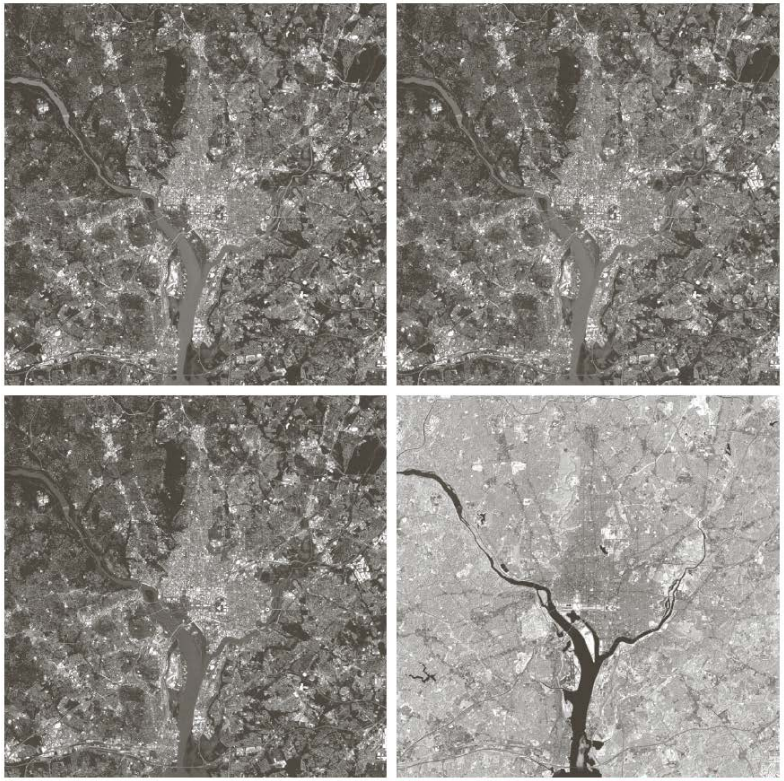


Radiometric resolution ← Quantization

- Radiometric resolution refers to the smallest discernible change in gray level (often power of 2)
- The human eye is inefficient at distinguishing differences in gray levels much beyond the limit of 16 (but to the machine it may make a big difference)

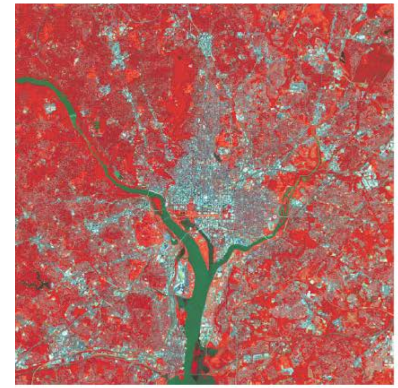


Spectral Resolution & Color Display



R G B

3 2 1



NIR R G

4 3 2

Reflected energy for each pixel in the frequencies Blue, Green, Red & Near Infrared

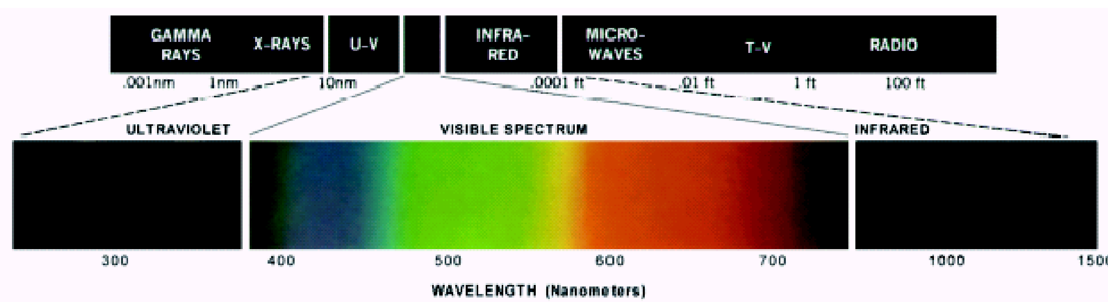


FIGURE 6.2 Wavelengths comprising the visible range of the electromagnetic spectrum. (Courtesy of the General Electric Co., Lamp Business Division.)

Bit planes 10000101

a	b	c
d	e	f
g	h	i

FIGURE 3.14 (a) An 8-bit gray-scale image of size 500 × 1192 pixels. (b) through (i) Bit planes 1 through 8, with bit plane 1 corresponding to the least significant bit. Each bit plane is a binary image.

8-bit gray scale image

Application of Quantization: Steganography

10000101

Pieter Bruegel (the Elder, ca. 1525-69), *The Peasant Dance*, 1568, Oil on oak panel, 114x164 cm, Kunsthistorisches Museum Wien, Vienna

If an image is quantized, say from 8 bits to 6 bits and redisplayed it can be all but impossible to tell the difference between the two.

6-bit-per-band, 3-band, quantized image

Application of Quantization: Steganography

10000101

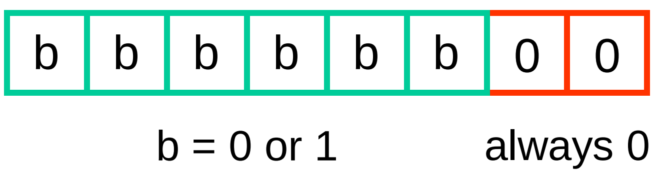
a value from the set {0, 4, 8, … , 252}

Pieter Bruegel (the Elder, ca. 1525-69), *The Peasant Dance*, 1568, Oil on oak panel, 114x164 cm, Kunsthistorisches Museum Wien, Vienna

If an image is quantized, say from 8 bits to 6 bits and redisplayed it can be all but impossible to tell the difference between the two.

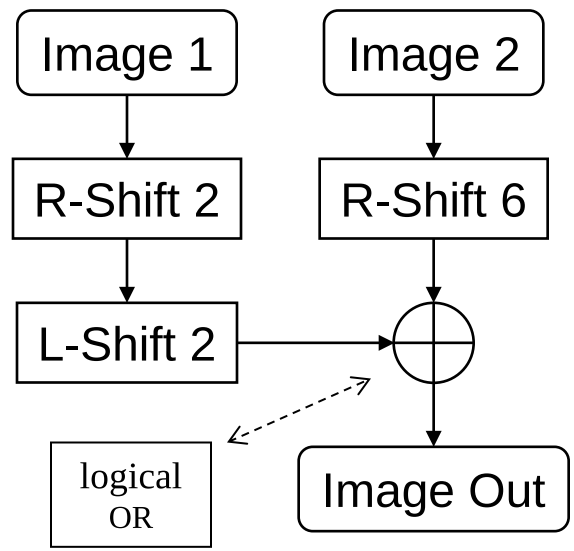
Application of Quantization: Steganography

If the 6-bit version is displayed as an 8-bit image then the 8-bit pixels all have zeros in the lower 2 bits:



This introduces the possibility of encoding other information in the low-order bits.

That other information could be a message, perhaps encrypted, or even another image.



X-Shift *n* = logical left or right shift by *n* bits.

Image 1 in upper 6-bits.
Image 2 in lower 2-bits.

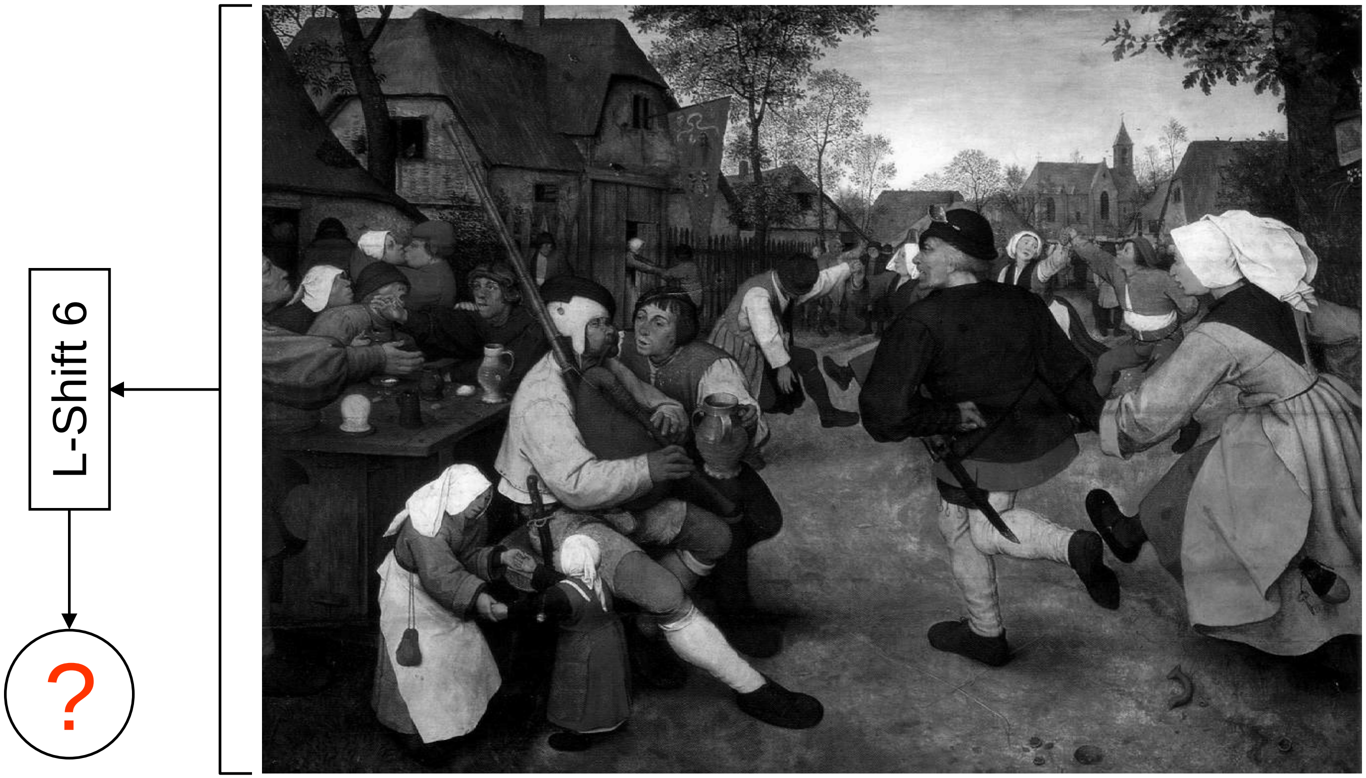
Application of Quantization: Steganography

Pieter Bruegel (the Elder, ca. 1525-69), *The Peasant Dance*, 1568, Oil on oak panel, 114x164 cm, Kunsthistorisches Museum Wien, Vienna

The second image is invisible because the value of each pixel is between 0 and 3. For any given pixel, its value is added to the to the collocated pixel in the first image that has a value from the set {0, 4, 8, … , 252}. The 2^{nd} image is noise on the 1^{st}.

Image 1 in upper 6-bits.
Image 2 in lower 2-bits.

Application of Quantization: Steganography



Pieter Bruegel (the Elder, ca. 1525-69), *The Peasant Dance*, 1568, Oil on oak panel, 114x164 cm, Kunsthistorisches Museum Wien, Vienna

To recover the second image (which is 2 bits per pixel per band) simply left shift the combined image by 6 bits.

Image 2 in upper 2-bits.
Image 1 shifted out

Application of Quantization: Steganography

From the video game, *ZeroWing*, by Toaplan.
See http://en.wikipedia.org/wiki/All_your_base

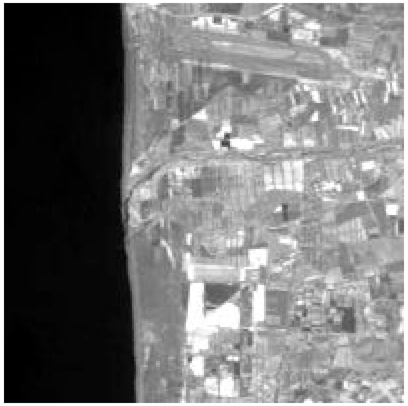
To recover the second image (which is 2 bits per pixel per band) simply left shift the combined image by 6 bits.

Remote Sensing: multiband Images (Landsat)

Band 1

Band 2

Band 3



Band 4

Band 5

Band 7

Remote Sensing: multiband Images

- We can visualize 3 bands at a time: pseudocolor

True Color

R G B

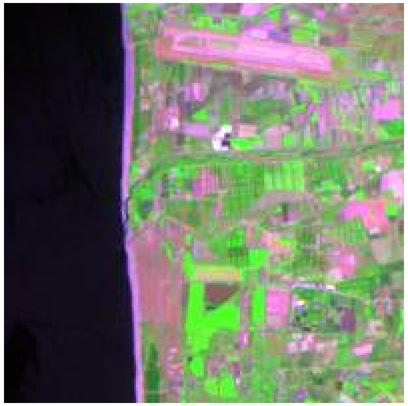
3 2 1

False Color Composite

NIR R G

4 3 2

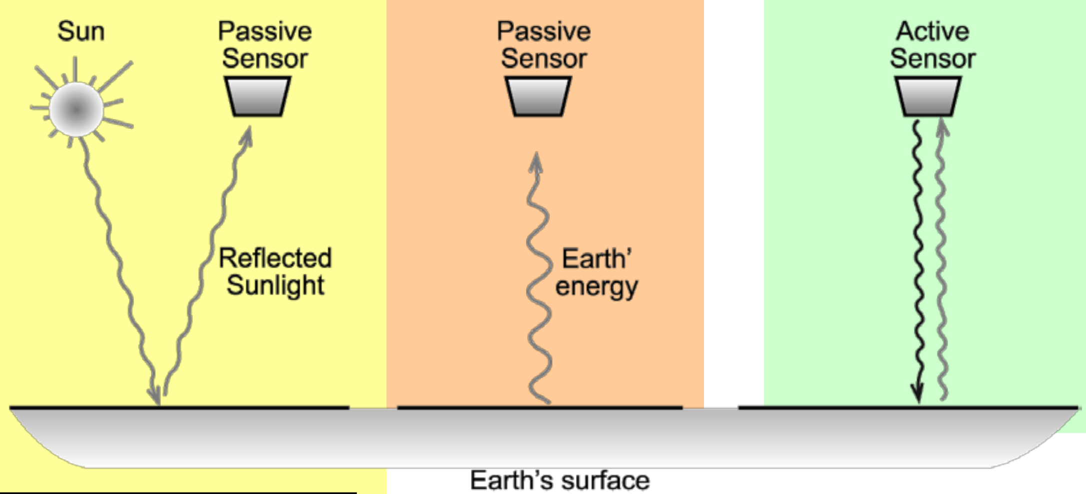
False Color Composite



SWIR NIR R

7 4 3

How many Sensors / kinds of images / datasets in RS?



Optical Passive

- Panchromatic
- Multispectral
- Hyperspectral

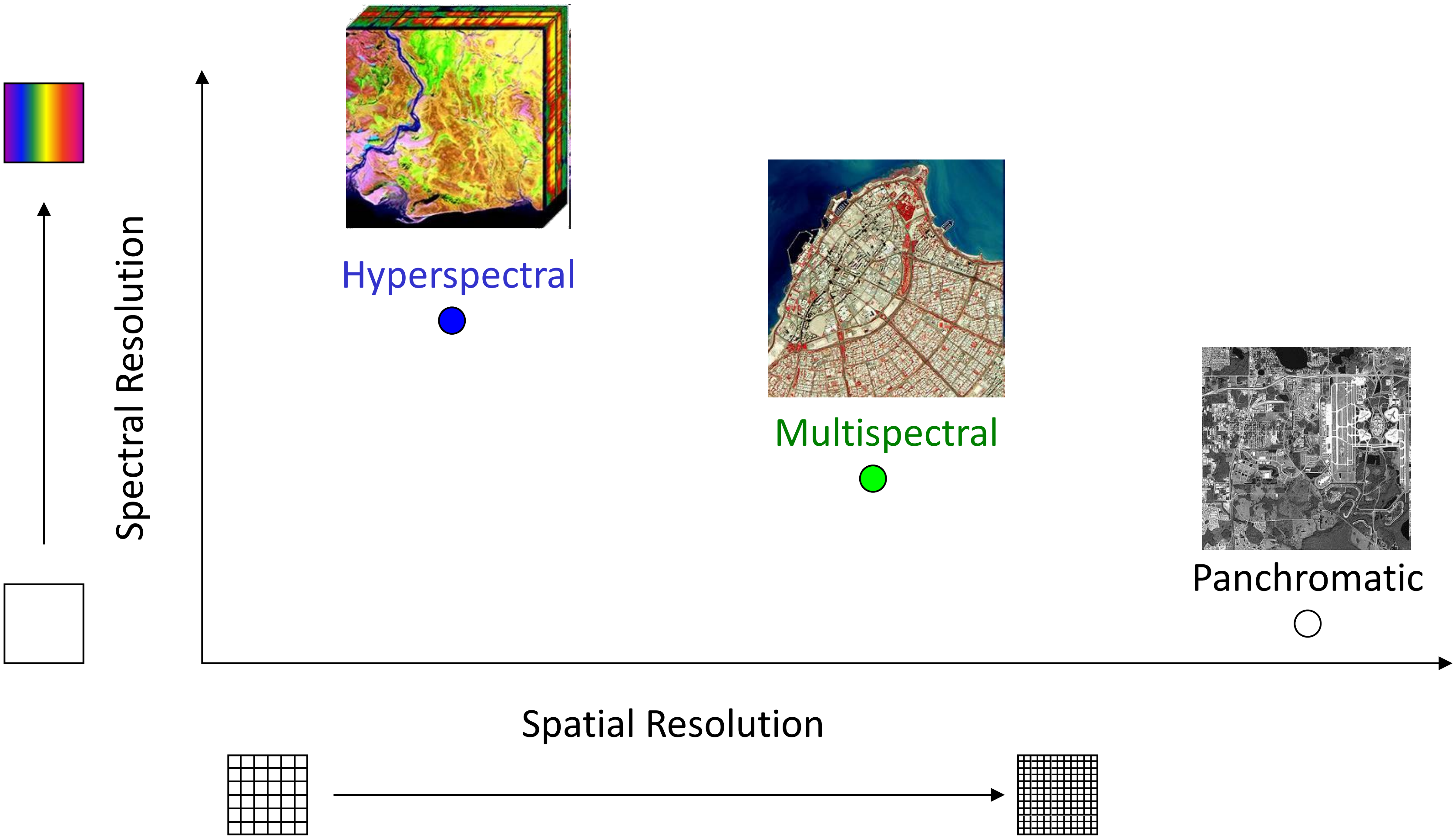
Thermal

Radar (SAR)

Lidar

Sonar

Optical Passive Sensors in Remote Sensing



Why are spatial and ***spectral*** resolution inversely proportional?

Hyperspectral

Buddingtonite

Kaolinite

Alunite

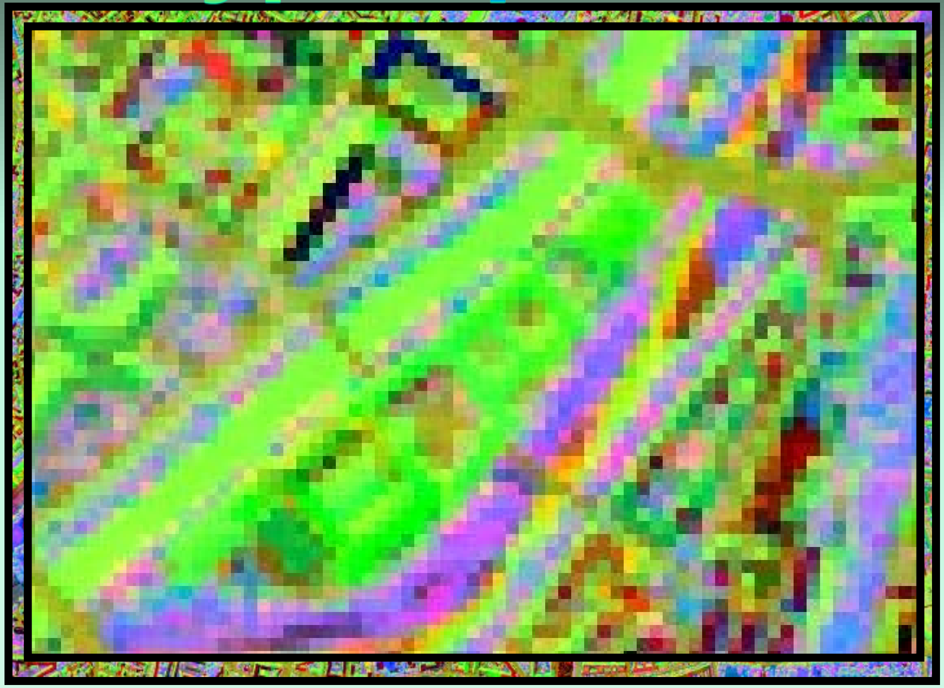
Chalcedony

In the city..

Zoom in!

Panchromatic

Hyperspectral



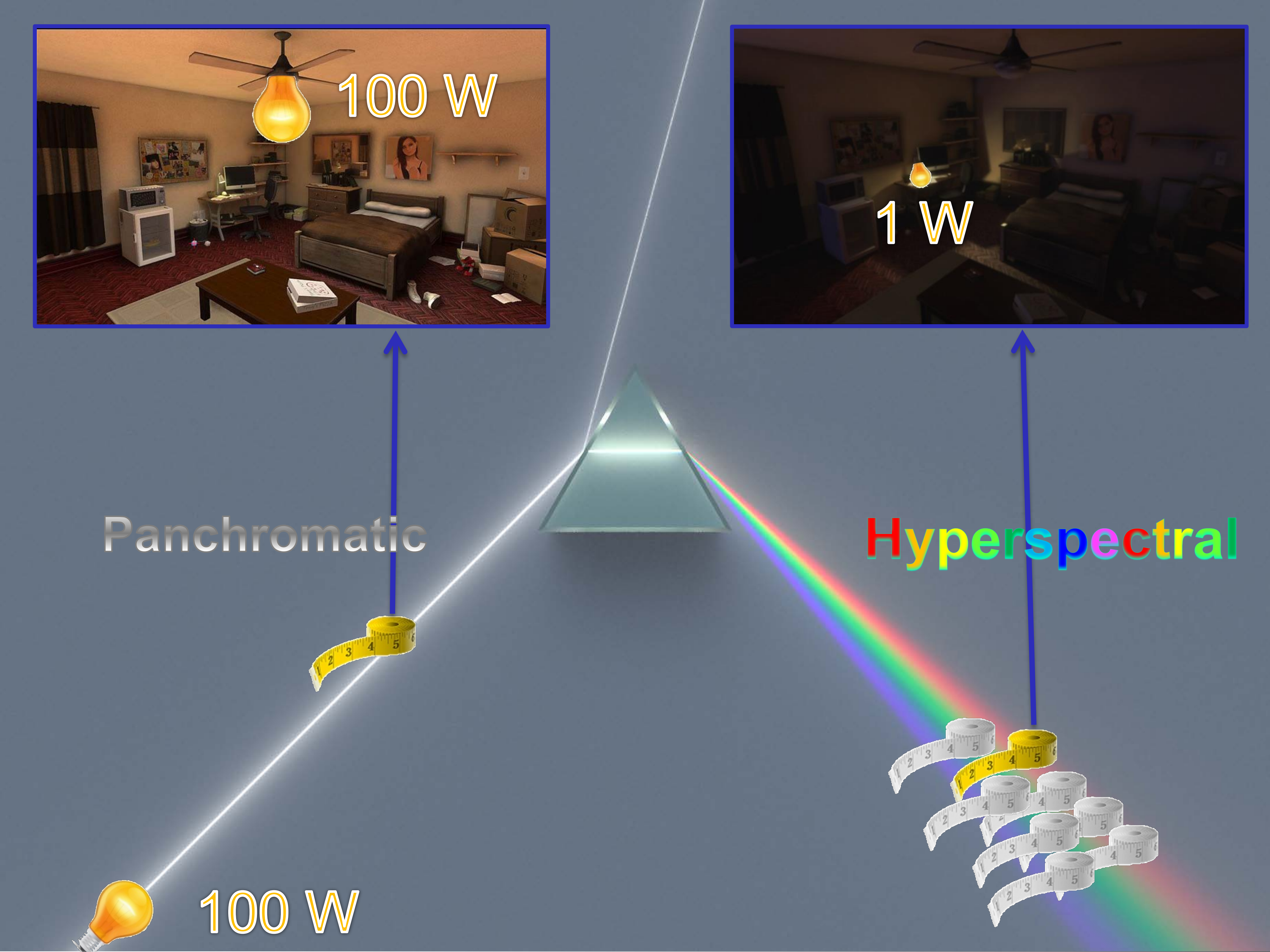
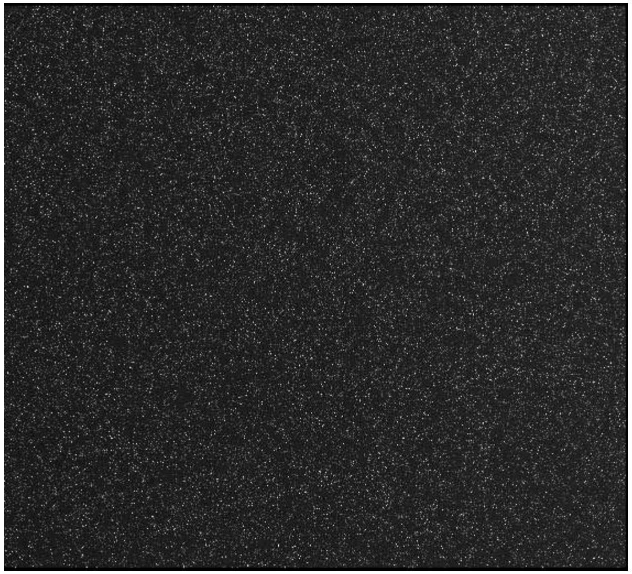

100 W
1 W
Panchromatic
Hyperspectral
100 W

Image Correction

- Raw images are minimally processed images coming directly from the image sensors
- They usually go through several correction steps
- Some important ones are:
  - Dark Signal Correction
  - Non-linearity Correction
  - Odd-even Effect Correction
  - Dead Pixels Flagging

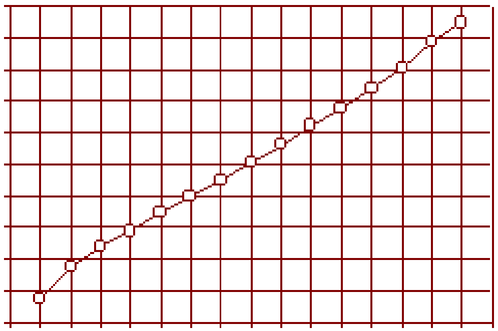
Dark Signal Correction

- Electronic interferences make the recorded signal (a bit) different than it really is
- Dark Signal Measurements
  - Shutter Method
    - Before every take an acquisition is made with the shutter closed. The resulting signal is the „dark current“
  - Deep Space Looking
    - Measures thermal radiation that can affect Dark Signal measurements
  - Dark pixels of the SWIR detector
    - Dark signal depends on the stability of the supplied voltage
    - During image special pixels which stay dark are used as reference



Dark Signal Measurement

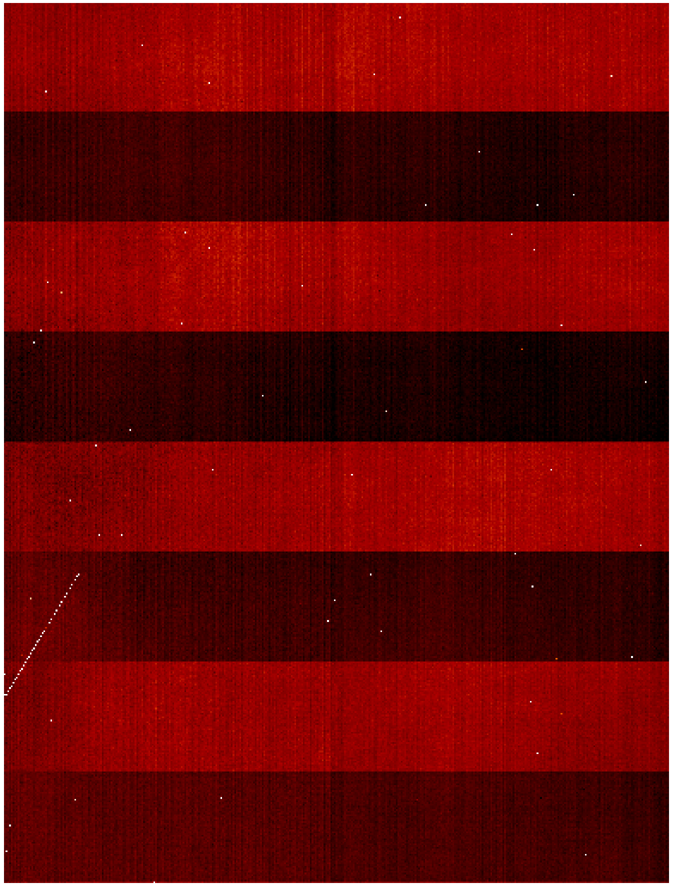
Non-linearity Correction



- The response of a detector as a function of integration time is not linear
- The (non-linear) pixel response is measured at different exposition times and a correction is estimated as a linear function
- During the process dark signal has to be taken into account

Odd-Even Effect

- The odd-even column effect consists of variations of the signal between the columns of the array
  - It is due to differences between sensor arrays
- It is easy to correct
  - Check the difference between the average values of a given column and its neighbouring columns



Raw Image with Odd-even Effect

Dead Pixel Map

- A list of pixels which readings do not have any meaning
- They are declared as „dead“ and ignored (set to 0)
- Different kinds of dead pixels:
    - No response
    - Very large output (hot pixel), saturates easily
    - Flickering pixel (constantly changing output)
    - Constant output

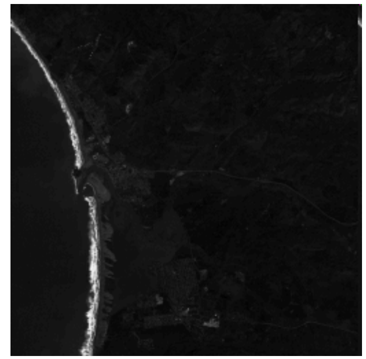
Image Correction

- Once our raw data are corrected, the image is formed and usually undergoes other correction steps….
  - Atmospheric Correction
  - Geometric Correction / Orthorectification..

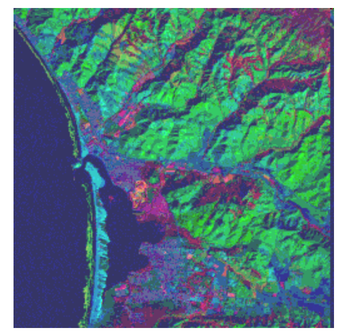
- Image Acquisition & Correction
  - Raw Data → Raw Image → Image

03	29	38	48
59	96	94	04
05	06	96	97
87	76	75	45

- Low-level Analysis
  - **Image → Image**
    - **Time domain**
    - Frequency domain



- Mid-level Analysis
  - Image → Features / Attributes
    - Feature Extraction
    - Clustering / Segmentation



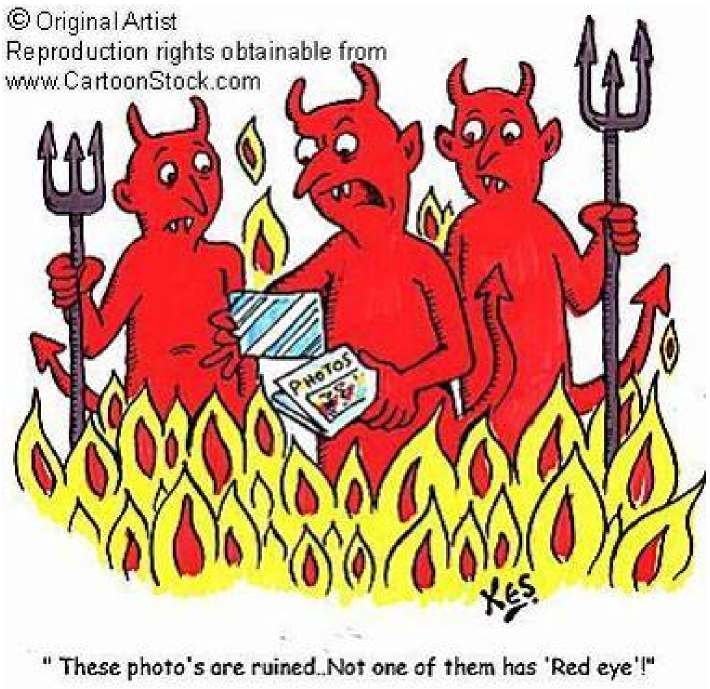
- High-level Analysis
  - Features → Recognition

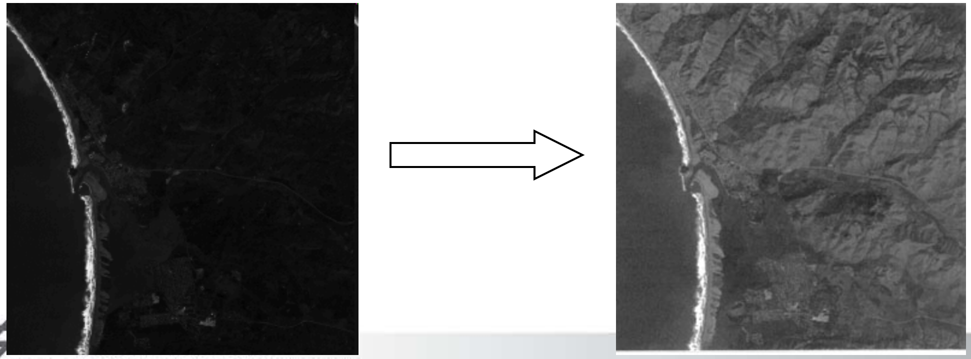
Summary

- Image Acquisition & Characteristics
  - Spatial, radiometric & spectral resolution
  - Image Correction
- Image enhancement
  - Time Domain
    - Global Techniques: Histogram Stretch
    - Local Techniques: Moving Window Transform
  - Frequency Domain
- Sampling & Aliasing
- Image Features
- Image Clustering
- Image Classification

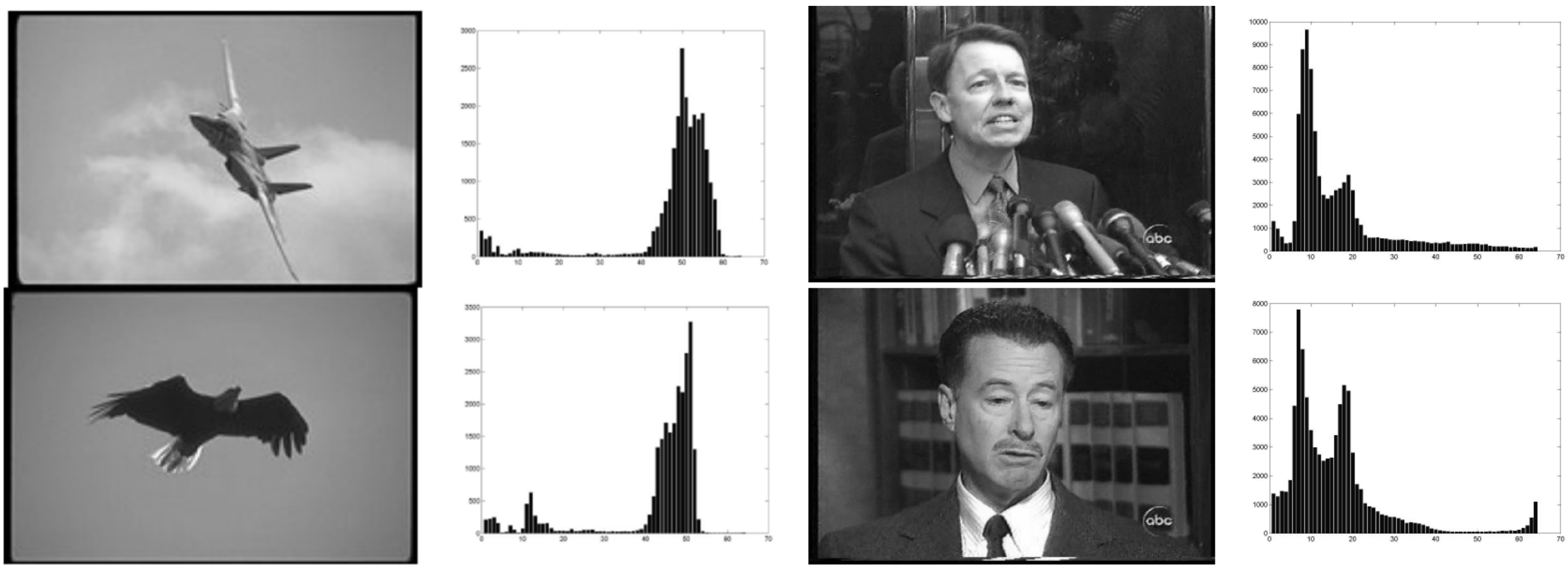
Image enhancement

- *Enhance*: to make greater (as in value, desirability, or attractiveness)
- The principal objective of enhancement is to process an image so that the result is more suitable than the original for a *specific* application
- Enhancement is subjective!
    - A good technique for a given application is not valid for another one

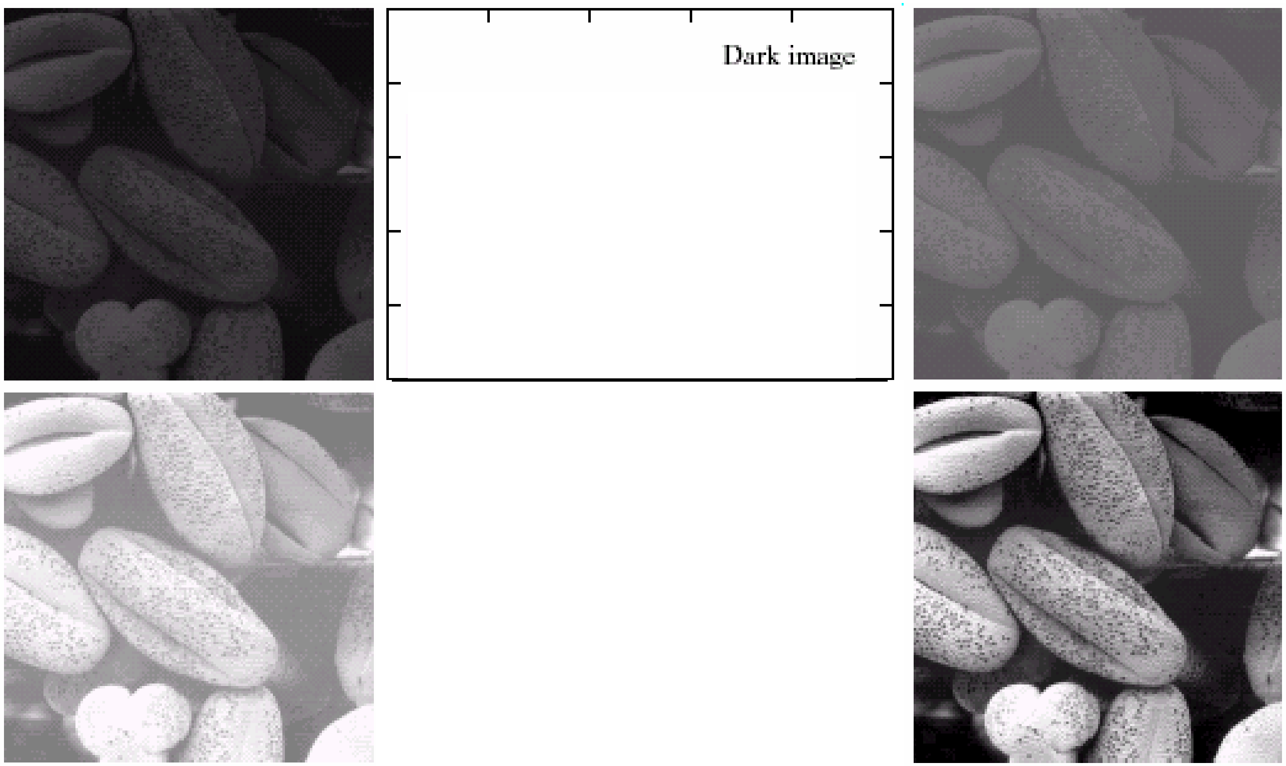




Sample Histograms, Natural Images

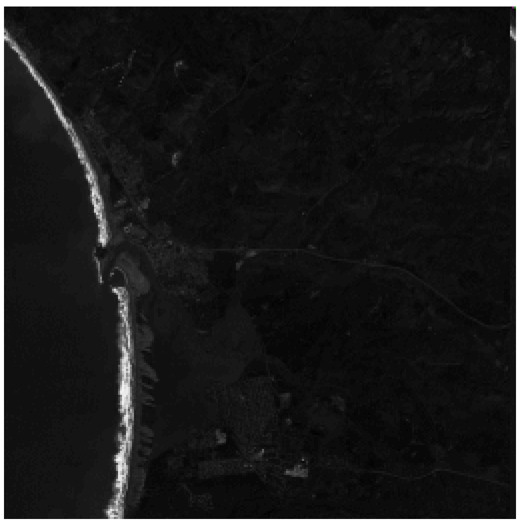


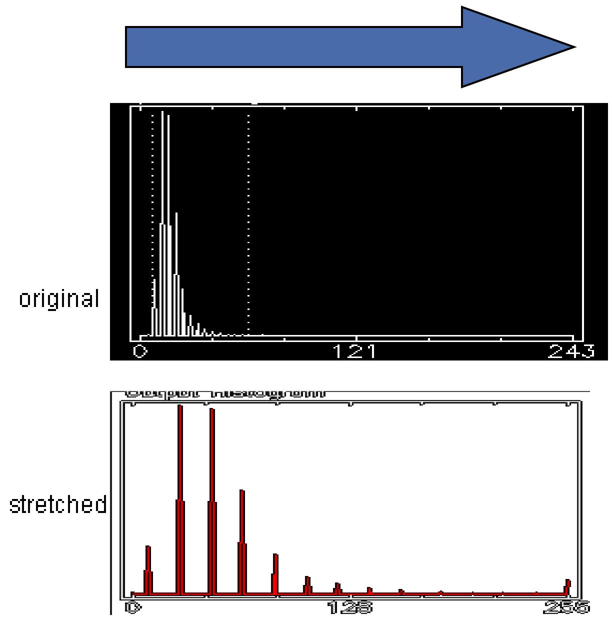
Histogram processing

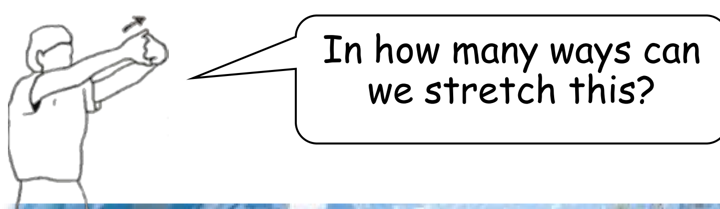


How do you expect the histograms for these pictures?

Histogram Stretching



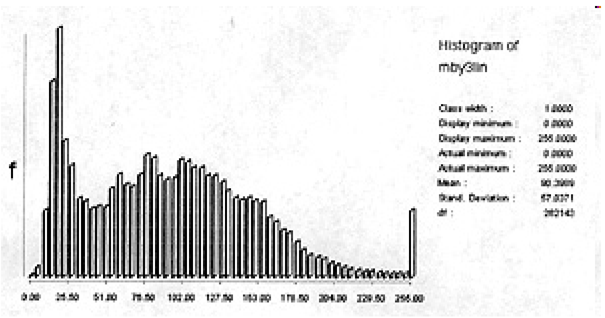




Histogram Stretching

Selective Linear Stretch

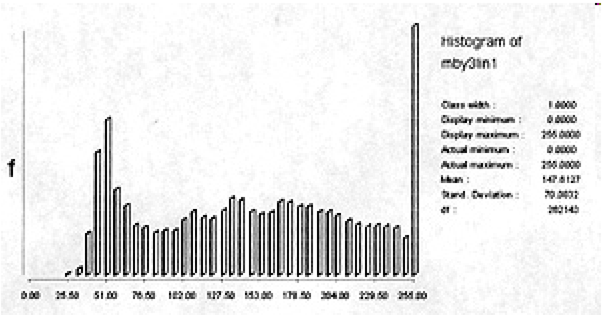
- We take Digital Numbers between 5 and 65
- We expand these from 0 to 255
- All values < 5 are set to 0
- All values > 65 are set to 255
- All values in between are stretched proportionally



Histogram Stretching

Selective Linear Stretch, let us try to get rid of these dark areas!

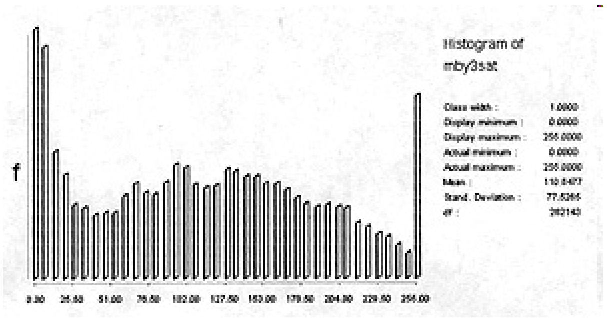
- We take now the DNs between 0 and 45
- We expand these from 0 to 255

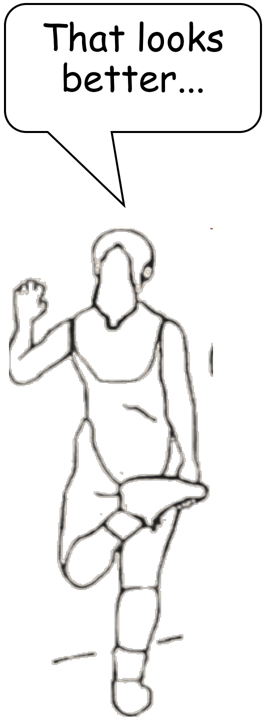


Histogram Stretching

Linear-with-Saturation stretch

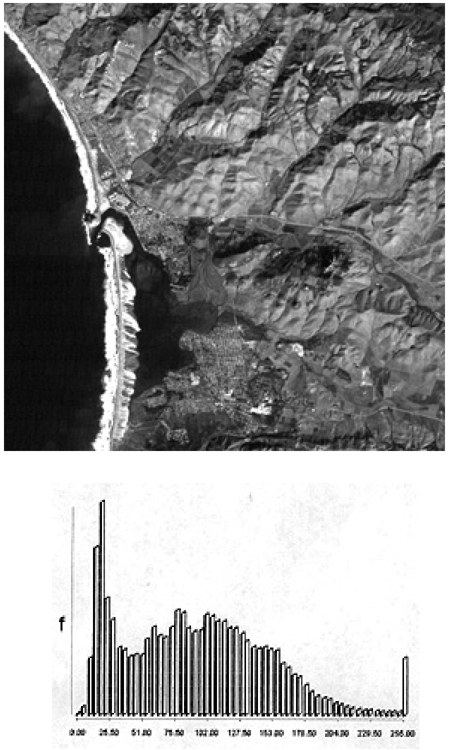
We assign 5% of pixels at each end (tail) of the histogram to single values, and stretch the values in between



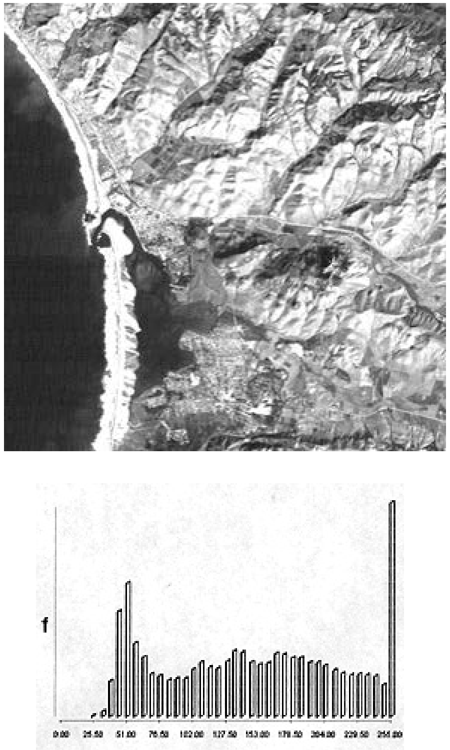


DLR

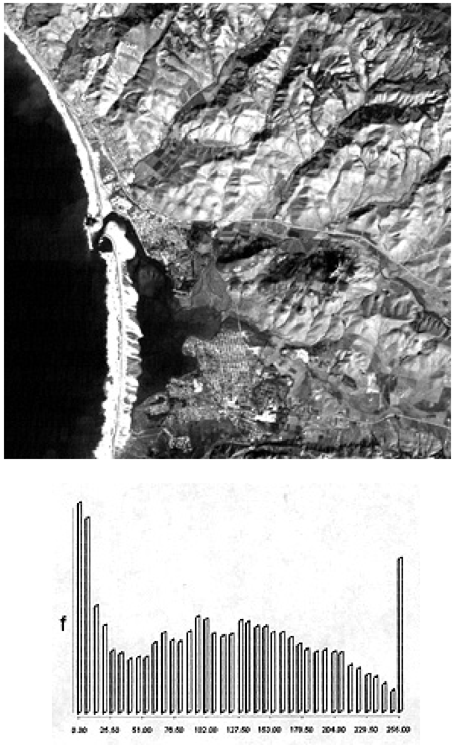
Histogram Stretching: Comparison



Selective Stretch I



Selective Stretch II

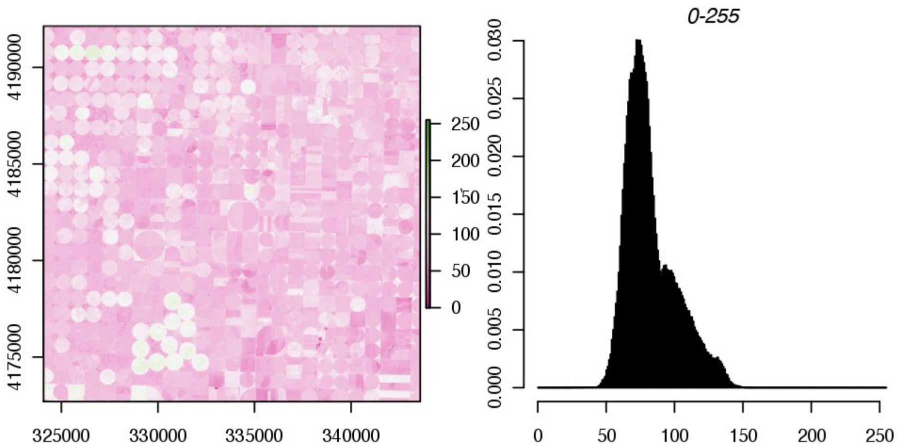


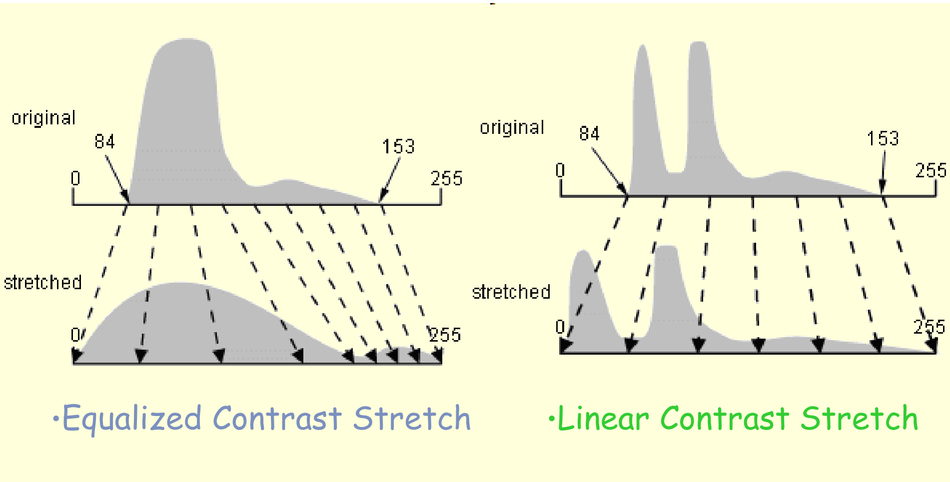
Automatic Linear-with-Saturation

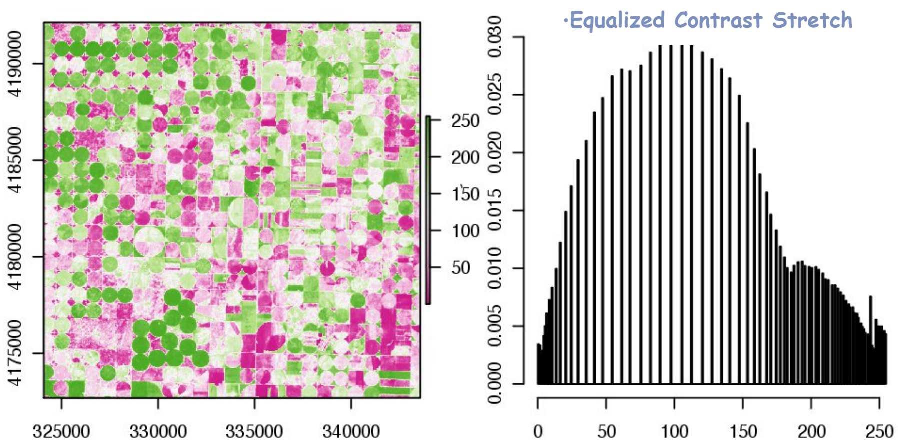
Linear Histogram Equalization

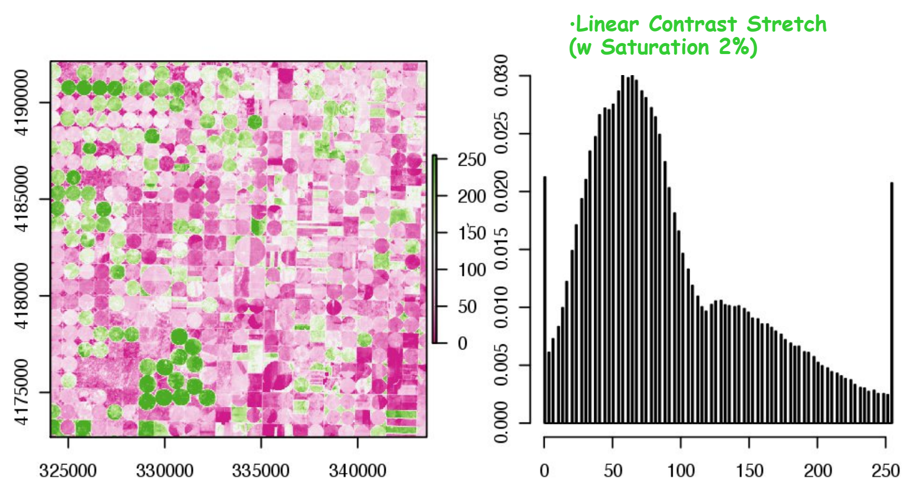
- All 4 images are mapped to a similar output image by applying the same histogram equalization function

Histogram Equalization vs. Linear Stretch









DLR