

Image Processing

Traitement d'images

Yuliya Tarabalka

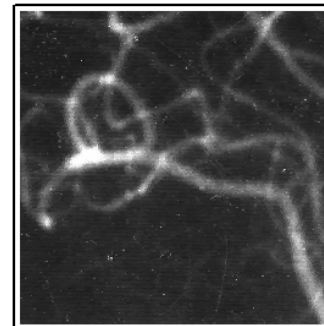
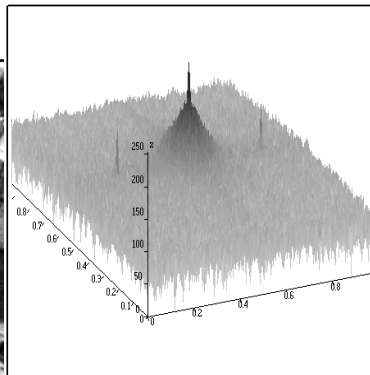
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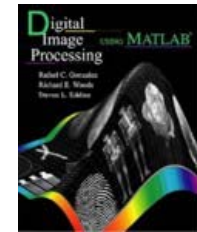
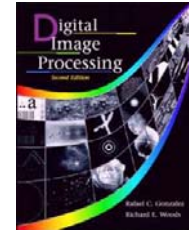
Outline

- Introduction: Digital images
- Histogram modification
- Noise reduction
- Edge detection
- 2D Fourier Transform
- Bases of mathematical morphology
- Examples of image processing



Bibliography

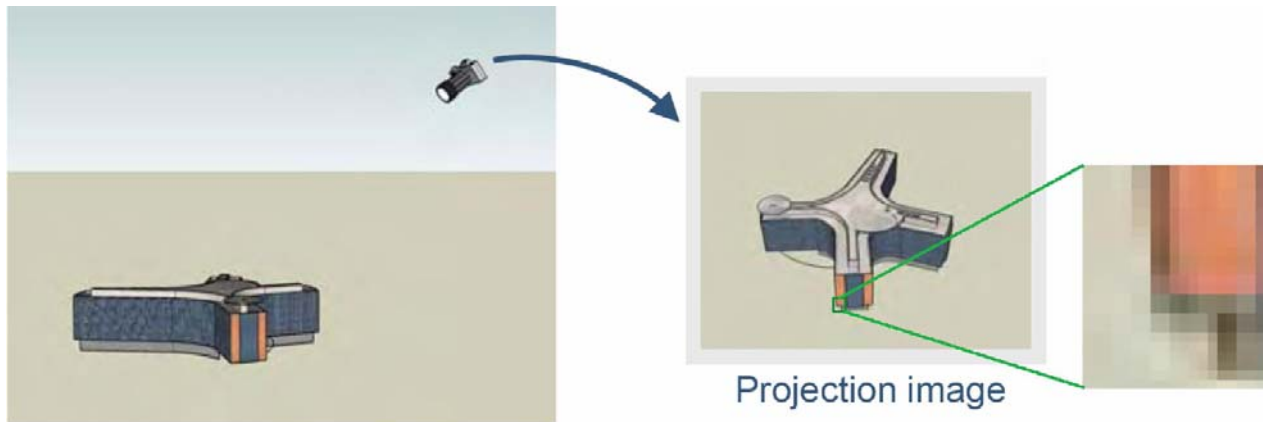
- **Digital Image Processing, 2nd Edition by Gonzalez and Woods Prentice Hall, 2002**
- **Digital Image Processing Using MATLAB by Gonzalez, Woods, and Eddins, Prentice Hall, 2004**
- **Analyse d'images : Filtrage et segmentation By Cocquerez and Philipp, Masson, 1995**
- **Traitement et analyse des images numériques By Bres, Jolion and Lebourgeois, Hermès, 2003**



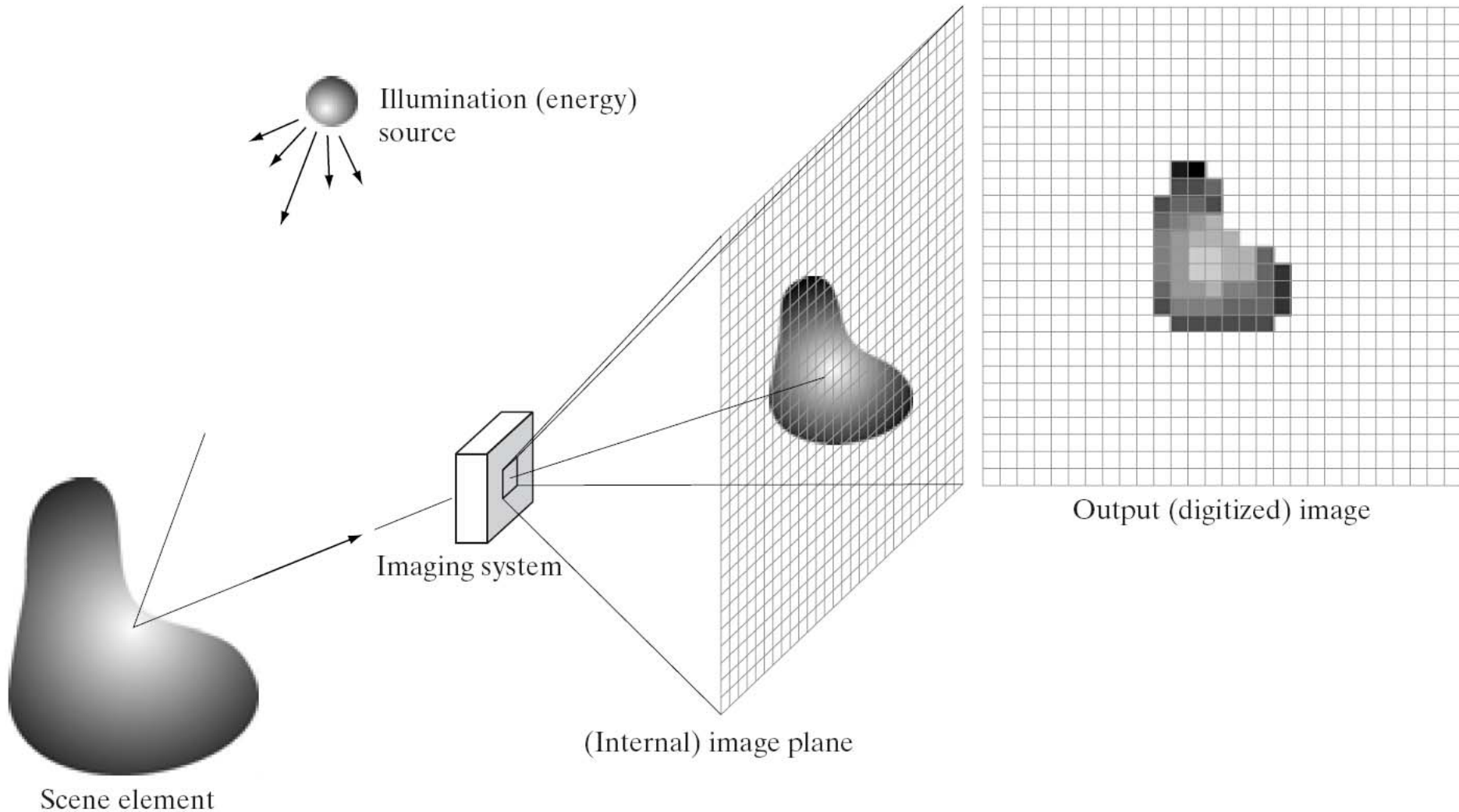
Introduction: Digital images

Digital image is

- A **finite set of pixels** coded by **bits** obtained from spatial sampling
- A matrix or image composed of pixels whose locations hold digital colour and/or brightness information which, when viewed at a suitable distance, form an image
- An image composed of discrete pixels of digitally quantized brightness and color.



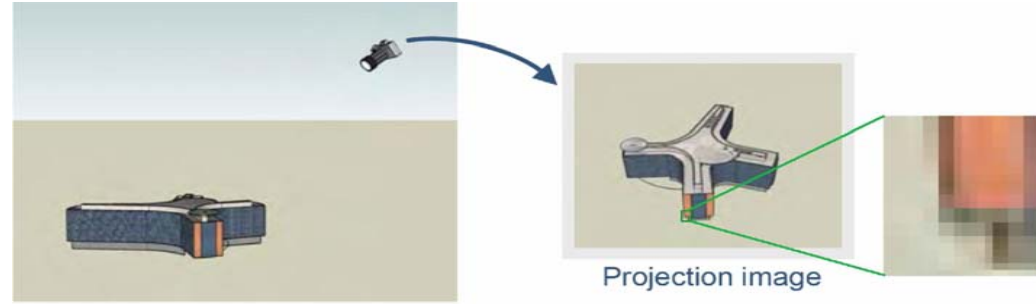
Digital image



Digital image

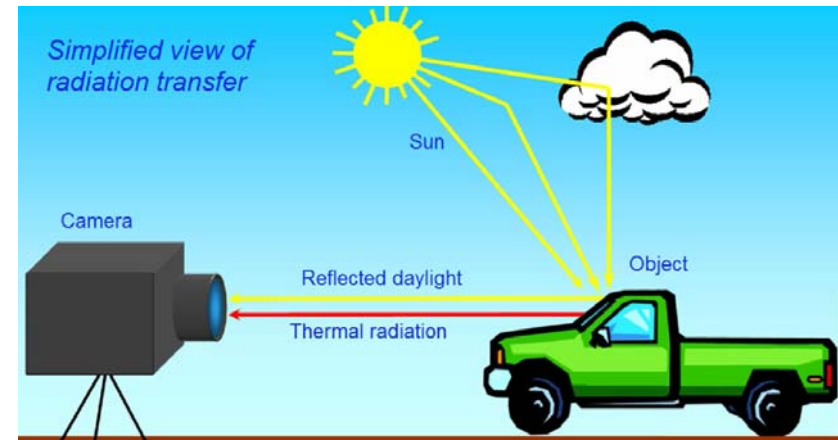
- **Spatial context**

- 2D
- Digital image → composed of pixels



- **Spectral context**

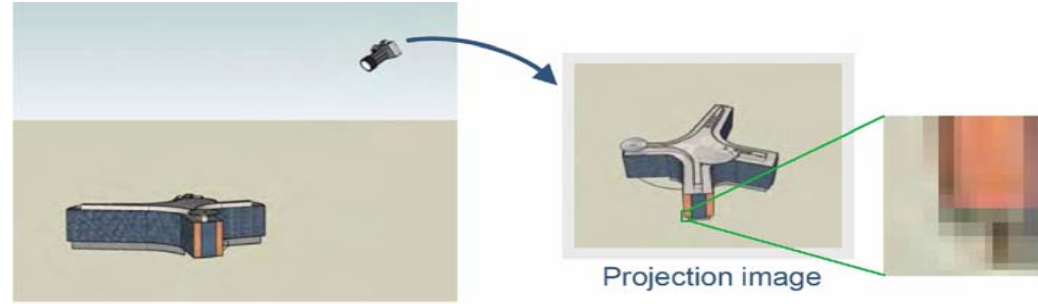
- Measurement of intensity of EM radiations (light)
- For grey-scale images: every pixel is typically coded by 8 bits



Digital image

- **Spatial context**

- 2D
- Digital image → composed of pixels



- **Spectral context**

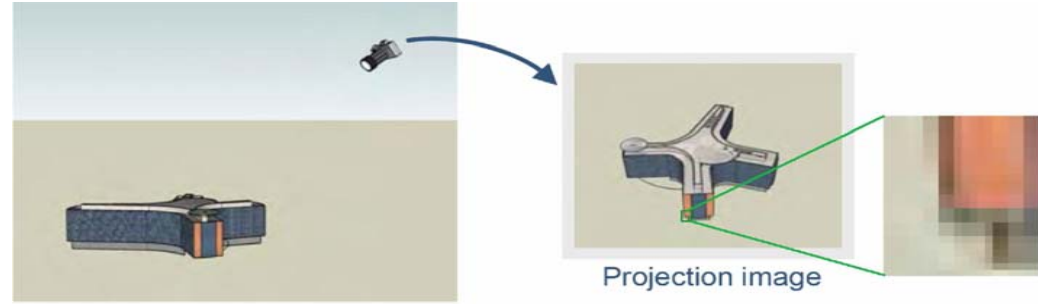
- Measurement of intensity of EM radiations (light)
- For grey-scale images: every pixel is typically coded by 8 bits



Digital image

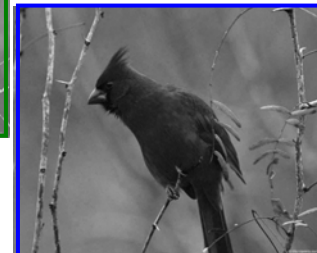
- **Spatial context**

- 2D
- Digital image → composed of pixels



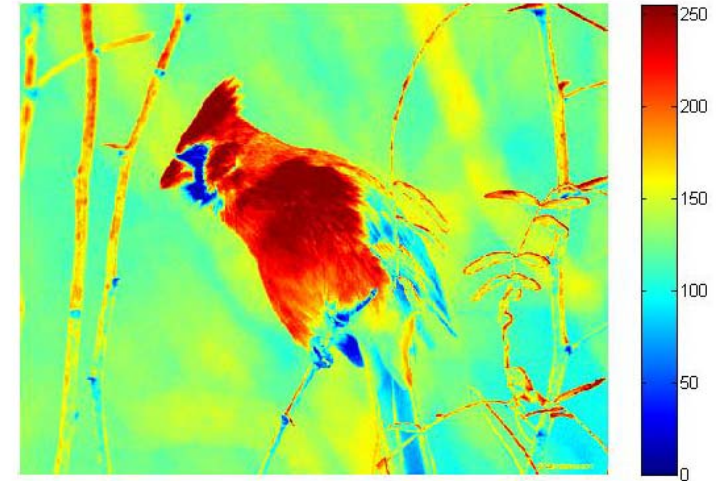
- **Spectral context**

- For grey-scale images: every pixel is typically coded by 8 bits
- For color images: every pixel has 3 components: red, green, blue, each of them coded by 8 bits



Grey levels and look-up table

- Every value of the pixel is associated with one color according to the *color look-up table*



Grey level profile (cut)

- Intensity values along a line path in an image
 - Matlab: *improfile*

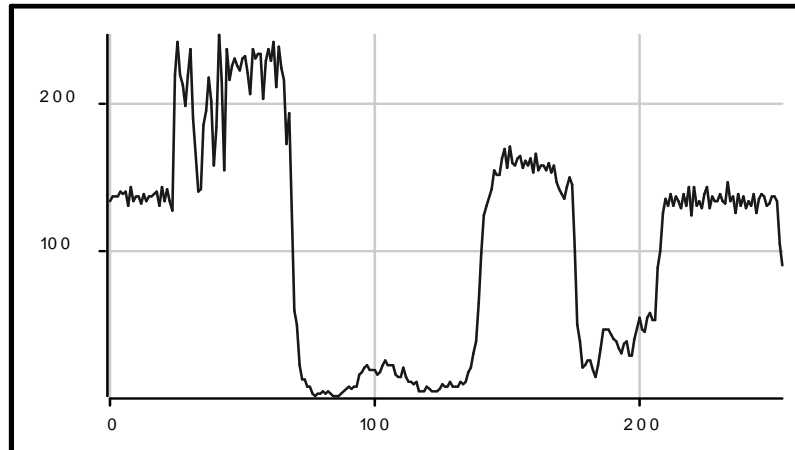


Image sampling and quantization

- **Sampling** means digitizing the coordinate values
- **Quantization** means digitizing the amplitude values

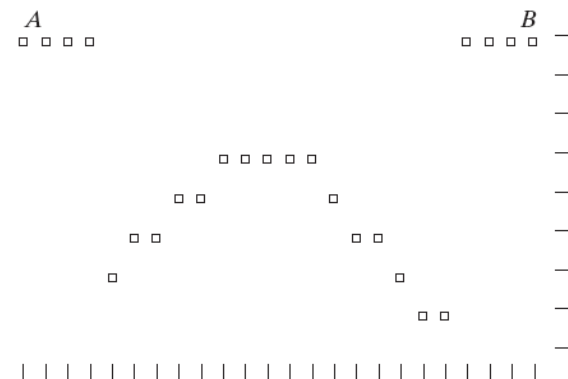
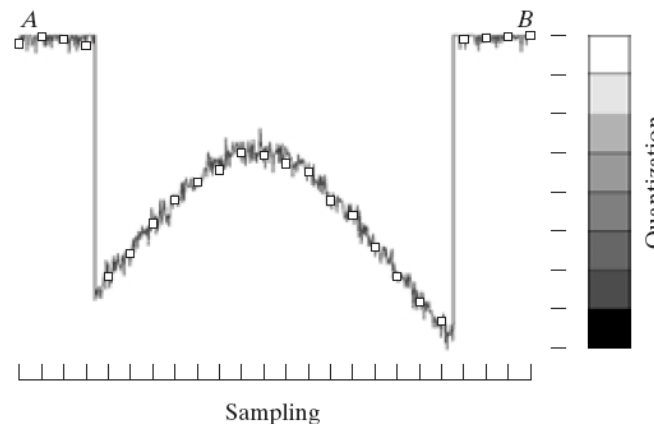
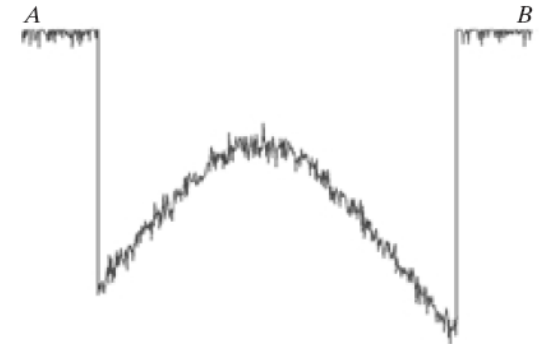
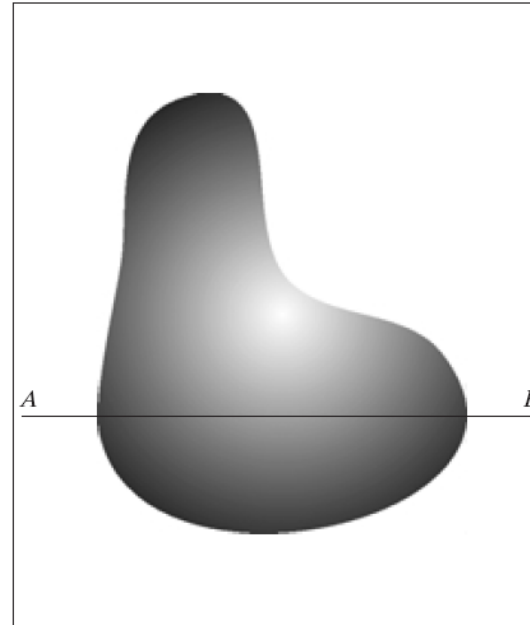
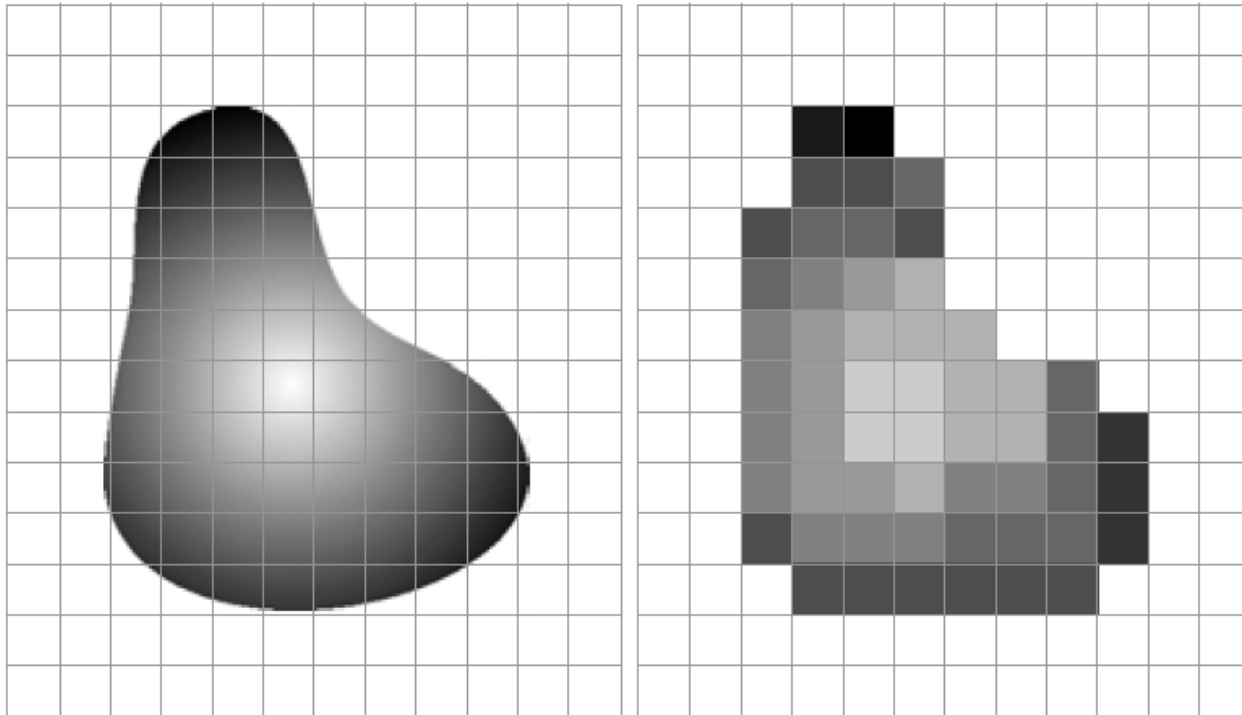


Image sampling and quantization



Quantization

Face:

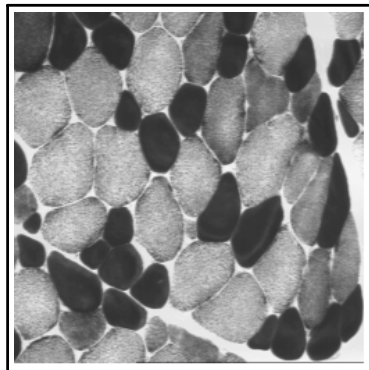


4 bits

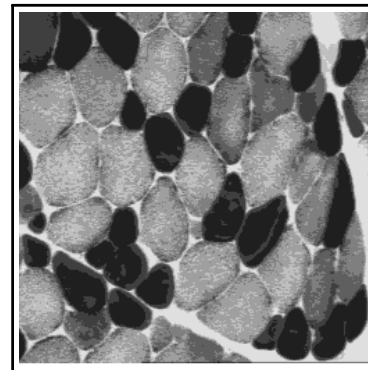


2 bits

Muscle cells:



8 bits



3 bits

Sampling

- Sampling is the principal factor determining the spatial resolution of an image
- Not relevant sampling can result in *image pixelization*



Pixelization is primarily used for censorship

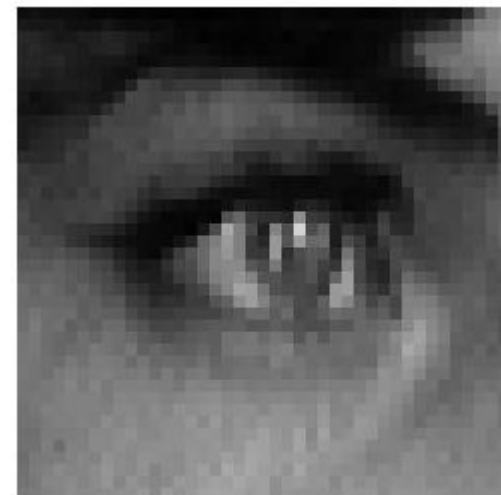
Zoom and interpolation

- The objective of a **zoom** is to enlarge an image

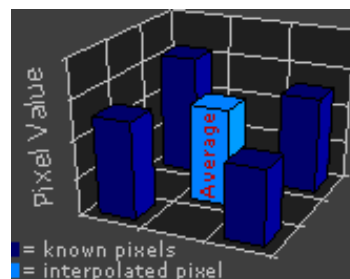


- **Nearest neighbor** interpolation: the color of a pixel in the new image is the color of the nearest pixel of the original image

➤ Matlab: `imresize(, , 'nearest')`



- **Bilinear interpolation**: determines the value of a new pixel based on a weighted average of the 4 pixels in the nearest 2 x 2 neighborhood of the pixel in the original image

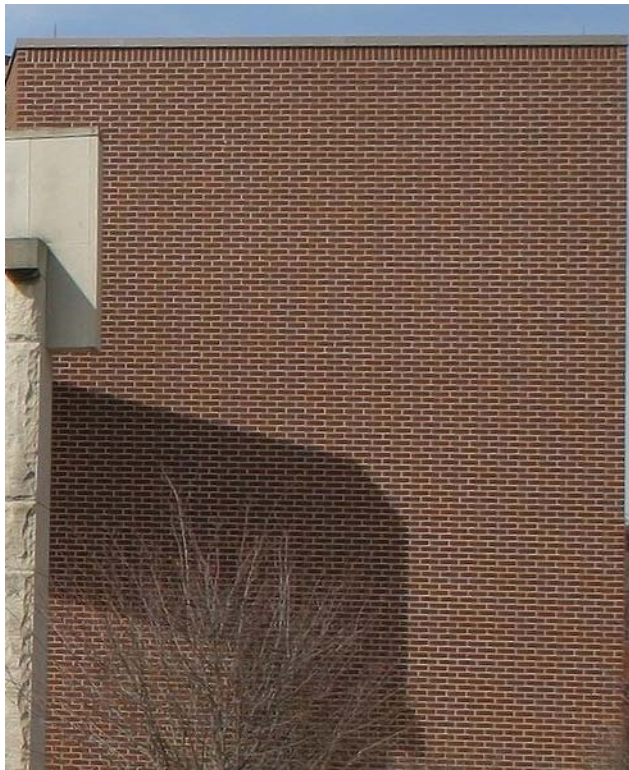


➤ Matlab: `imresize(, , 'bilinear')`



Aliasing

- If the image is undersampled (Shannon sampling theorem requires $F_e < 2 F_{max}$), *aliasing* corrupts the sampled image
- New frequency components can appear
- To avoid aliasing: low-pass filtering prior to sampling



Moiré
patterns

Measuring the difference between images enable INP

- To measure image degradation, a new image can be compared with the original image (using Hamming distance)

- Mean Absolute Error:
$$MAE = \frac{1}{M \cdot N} \sum_{m=1}^M \sum_{n=1}^N |f(m,n) - \tilde{f}(m,n)|$$

- Mean Square Error:
$$MSE = \frac{1}{M \cdot N} \sum_{m=1}^M \sum_{n=1}^N (f(m,n) - \tilde{f}(m,n))^2$$

- Signal to Noise Ratio (dB):
$$SNR = 10 \cdot \log \left(\frac{\frac{1}{M \cdot N} \sum_{m=1}^M \sum_{n=1}^N f^2(m,n)}{\frac{1}{M \cdot N} \sum_{m=1}^M \sum_{n=1}^N (f(m,n) - \tilde{f}(m,n))^2} \right)$$

- Peak Signal to Noise Ratio:
$$PSNR = 10 \cdot \log \left(\frac{255^2}{\frac{1}{M \cdot N} \sum_{m=1}^M \sum_{n=1}^N (f(m,n) - \tilde{f}(m,n))^2} \right)$$

Interest in digital image processing

- 2 principal application areas:

1. Improvement of pictorial information for human interpretation



2. Processing of image data for autonomous machine perception

- For instance, automatic object detection and recognition, detection of object position, text analysis...

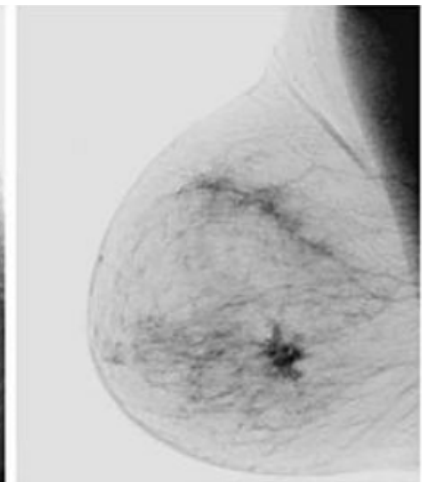
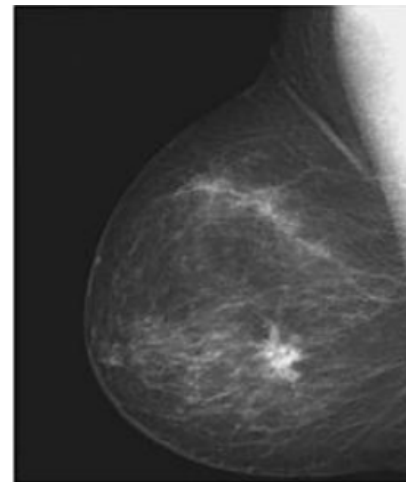
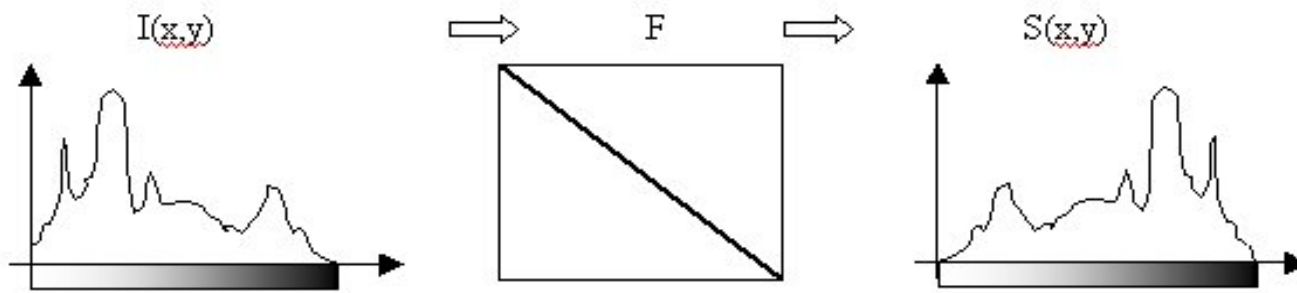
Histogram modification

Image enhancement

- **The objective: to process an image so that the result is more suitable than the original image for a specific application**
- **Image enhancement**
 - In the spatial domain: based on direct manipulation of pixels in an image
 - In the frequency domain: modifying the Fourier transform of an image

Histogram modification

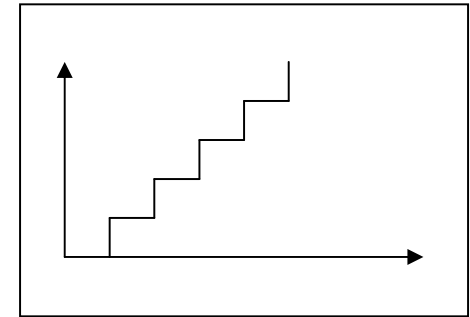
- Grey level transform: Neighborhood is of size 1x1
- Image negative: $v(x,y) = 255 - v(x,y)$



Histogram modification

- **Sub-quantization**

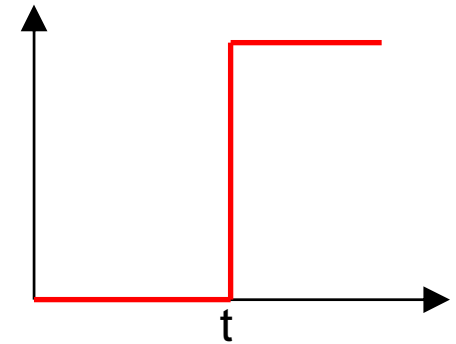
- The number of stairs indicates the number of bits coding an image after transformation



Histogram modification

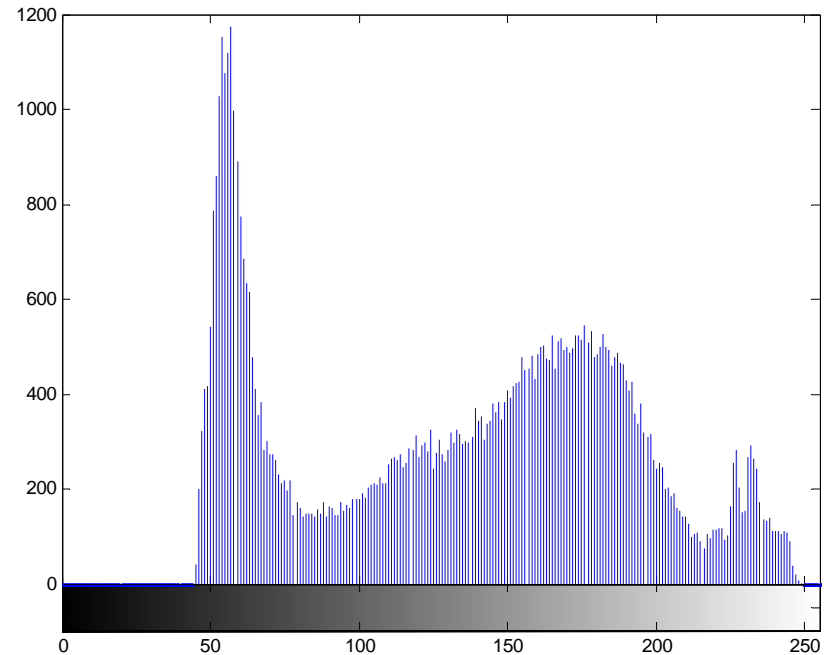
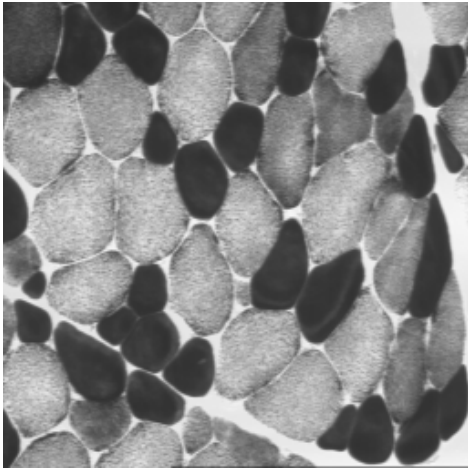
- **Thresholding**

- A particular case of sub-quantization



Histogram

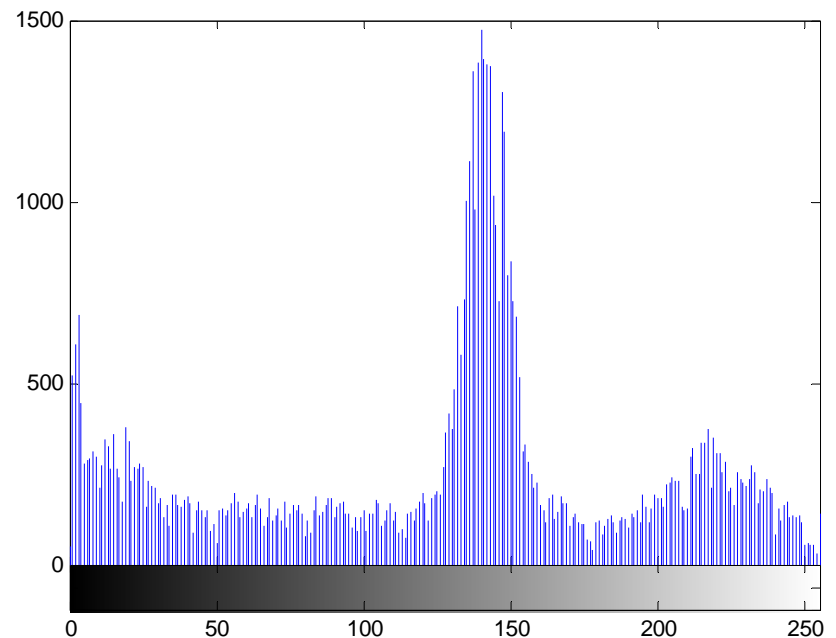
- **Histogram** plots the number of pixels for each grey-level value
 - Matlab: `imhist()`



3 zones of repartition: dark, intermediate and bright

Histogram

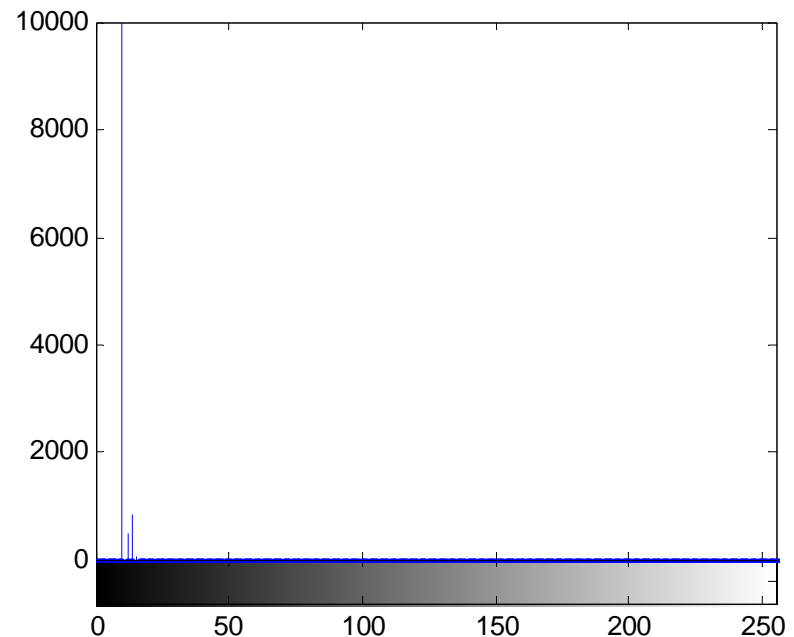
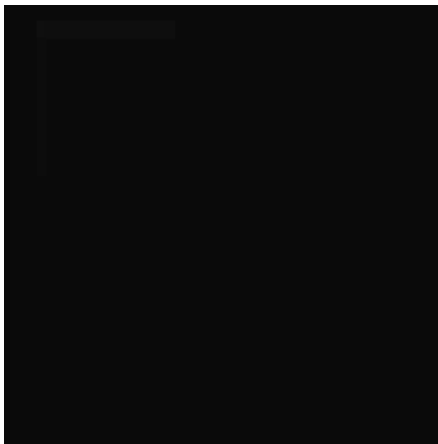
- **Histogram** plots the number of pixels for each grey-level value
 - Matlab: `imhist()`



Almost uniform repartition, except the central peak (meaning that most of the pixels have intermediate grey level)

Histogram

- **Histogram** plots the number of pixels for each grey-level value
 - Matlab: `imhist()`



Though the image seems to be black, the histogram indicates several grey levels in the image

Histograms are the basis for numerous spatial processing techniques

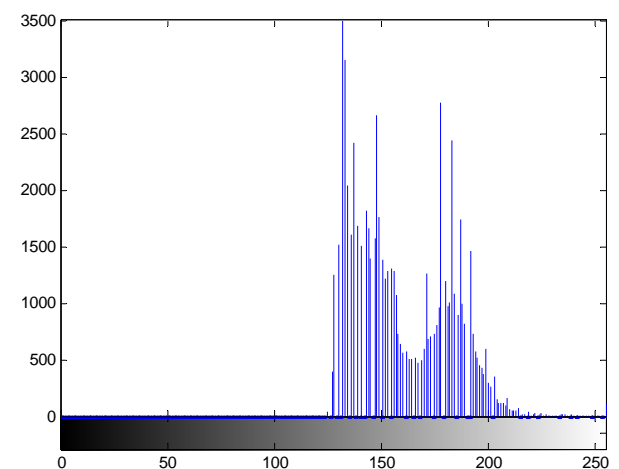
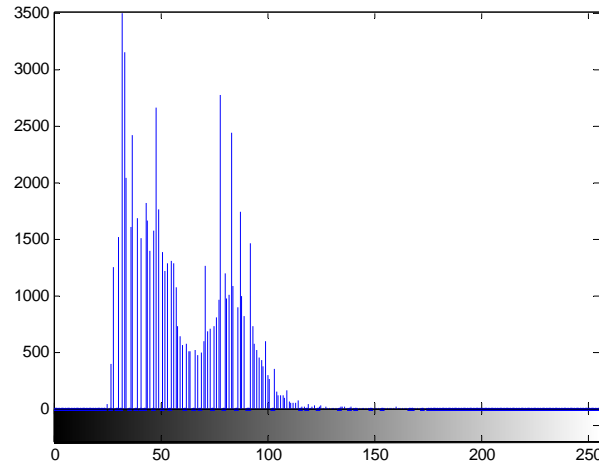
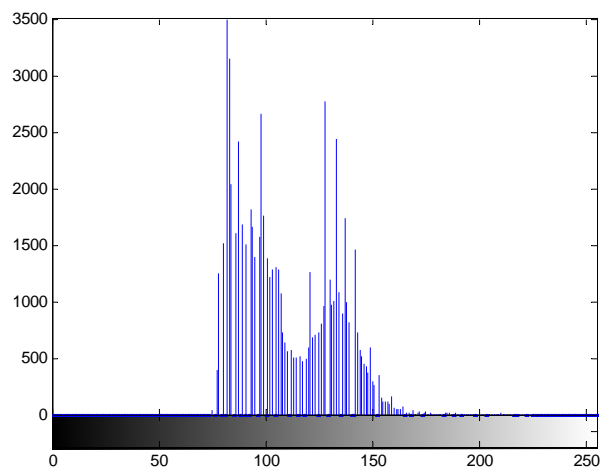
- Image enhancement
- Segmentation

Histogram

Darker image

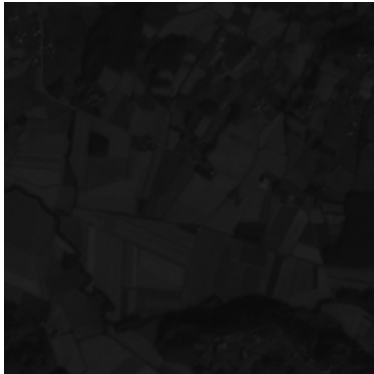


Brighter image

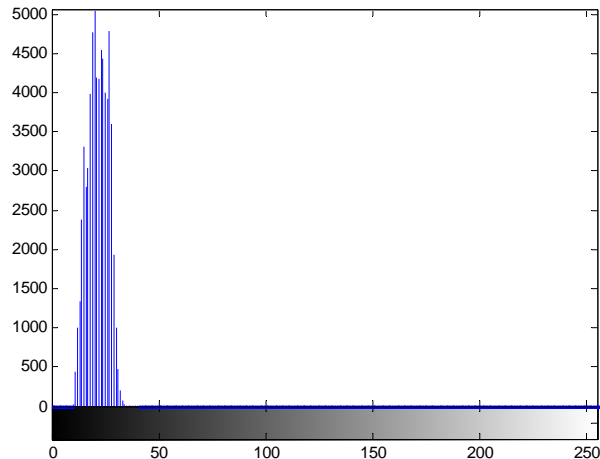


Histogram: Linear rescaling of the range

- The distance between peaks is constant

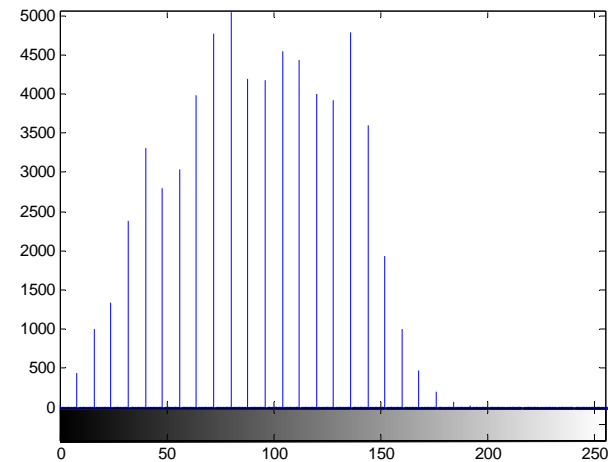
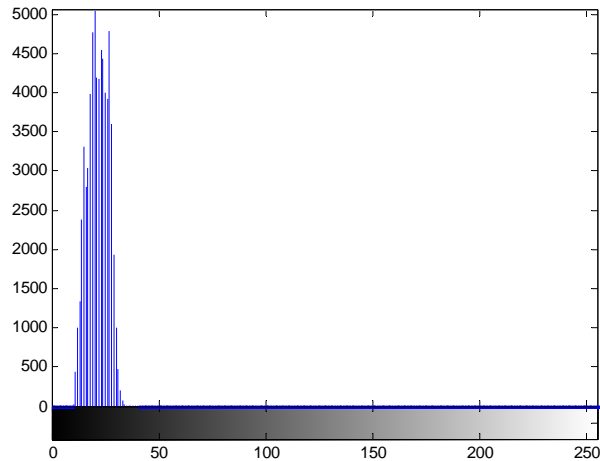
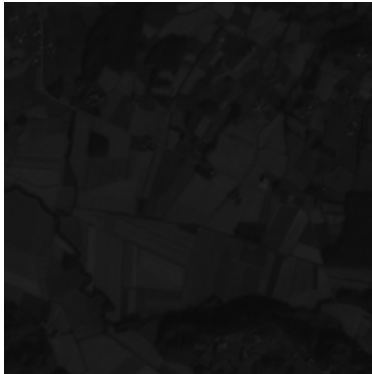


?



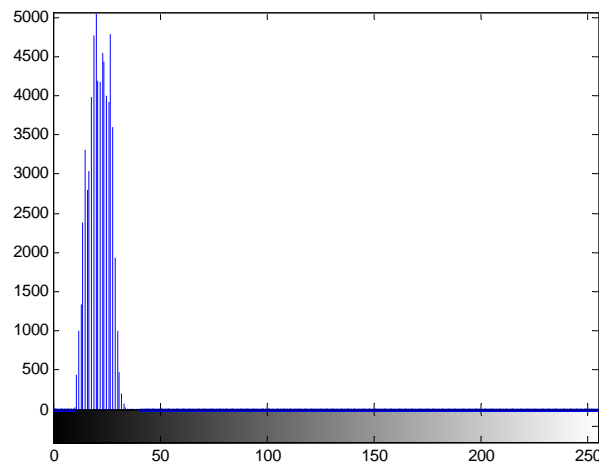
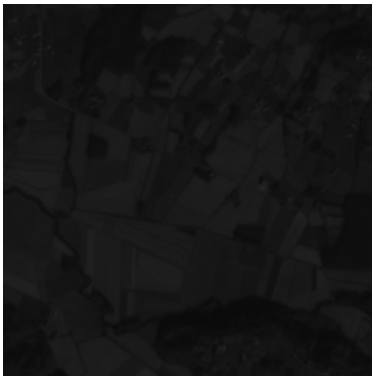
Histogram: Linear rescaling of the range

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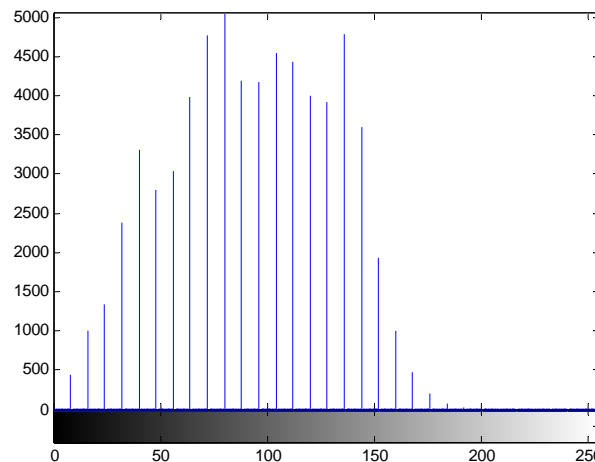


Histogram equalization (Matlab: *histeq()*)

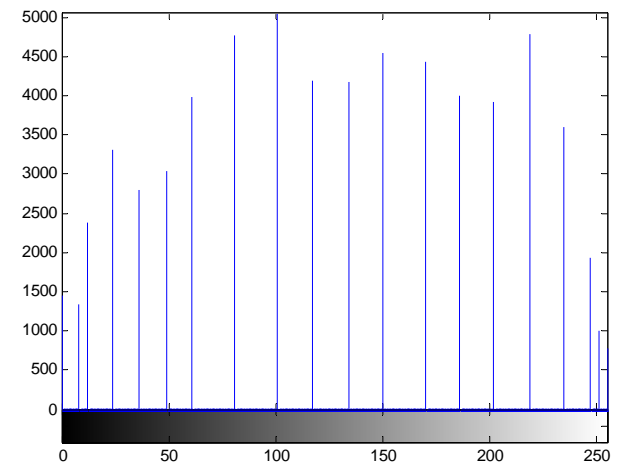
- The distance between peaks is proportional to the height of peaks
- Non-linear transformation → improved contrast



Original image



After linear rescaling



After equalization