Image Processing with Applications-CSCI567/MATH563

Instructor Dr. Nikolay Metodiev Sirakov

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Lecture #1:

P1. **Intro to Image Processing (IP)- Definitions**
P2 **Main IP Problems**
P3 **New Technologies and Applications**
P4 **Image Modalities**
P5 **Visual Perception**

To efficiently handle images, we need to understand what images really are mathematically.

Image Definition: many times depends on modalities/applications.
Image we call a function f(x,y), with domain $(x,y) \in I$,
where I is a rectangular grid, whereas $f(x,y) \in [0, L-1]$
and L is an intiger number.

Math Definition of an Image

Three major classes of image modeling and representation:

- **Random Fields Modelling (RFM)-** images are modelled by Gibson/Markovian random fields. The statistical properties of the fields are often established through filtering techniques and learning theory.

- **RFM is the ideal approach for describing natural images with reach texture pattern – grass and mountains.**

- **Wavelet Representation – the image is acquired from the responses of sensors. The theory is still under development considering geometric wavelets.**

Math Definition of an Image.

Regularity Spaces- an image I is considered to be in the Sobolev space. It works well for homogenous regions, but it is insufficient for global image model.

Two models have been introduced to recognize existing of edges:

1) Mumford Shah – 1989: Object Edge Model;

2) Rubin, Osher and Fatemi – 1992: BV image model.

1) assumes that an ideal image I consists of disjoint homogenous object patches $[I_k, \Omega_k]$, with $I_k \in H^1(\Omega_k)$ and regular boundaries $\partial\Omega_k$.

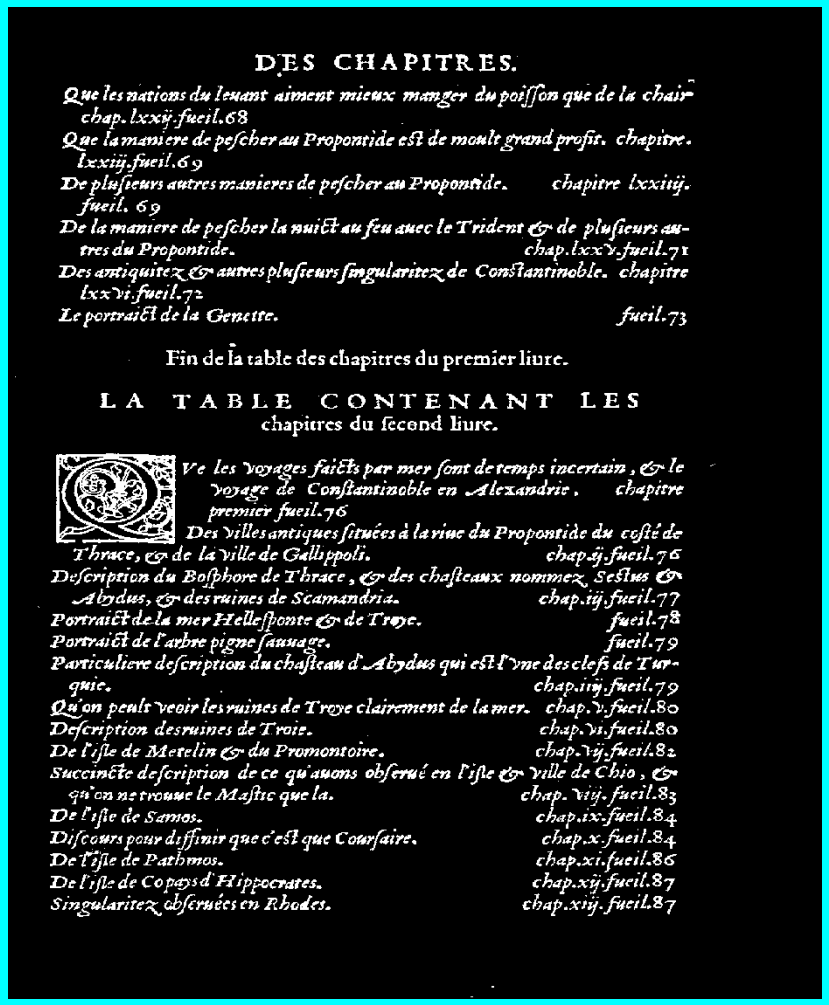
Free boundary model $$E|I,\Gamma| = \int_{\Omega\setminus\Gamma} |\nabla I|^2 dx + \beta H^1(\Gamma)$$

Definition of the scientific field Image Processing (IP).

Low level operations: Image Acquisition noise reduction; contrast enhancement; sharpening.

Mid level operations: image segmentation to objects or regions; description;

High level operations: “making sense”- recognition; relations between objects; events.



DES CHAPITRES.

Fin de la table des chapitres du premier liure.

LA TABLE CONTENANT LES chapitres du ſecond liure.

Figure1. A digital copy of a page from an ancient book.

(the image is from EU Project DEBORA, DGXIII/Telematics Program/LB-5608/A)

Main IP Problems

Image Acquisition – preprocessing, such as zooming

Image Enhancement – to bring out some details that are obscured, to highlight some image features subject of user interest. To increase the contras, the brightness.

Fourier Transforms, Local Statistics, Laplacian, Gradient are very good approaches to solve such kind of problems.

Image Restoration – is IP topic to deal with the above features but from objective point of view. It means we improve image features as a result of mathematical method.

Maim IP Problems

Color Image Processing – to form digital colors we use three channels “R”, “G” and “B” - 2^{24} colors could be generated.

$$f_R(x,y),\ f_G(x,y),\ f_B(x,y)$$

Other color models are CMY, HSI.

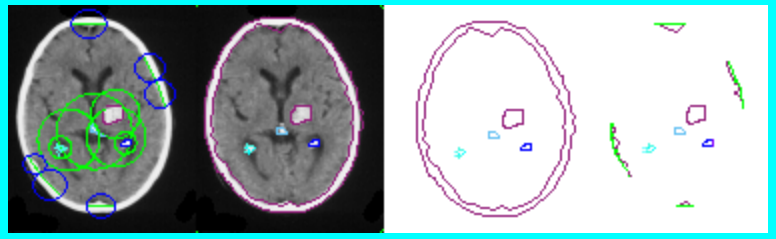
WAVELETS: small waves (functions) of varying frequency and limited duration, unlike Fourier transforms, whose basic functions are sinusoidal .

COMPRESSION: is a sub-field that develops approaches capable of image size reduction. Application – image storage and transmission.

Main IP Problems

Mathematical Morphology: well developed field, Matheron 1960, Serra early 1980. Main application in geology, Mining and oil industry. Main operations: **erosion, dilation** .

Segmentation: to partition an image to set of regions. A definition of region is needed? A set of pixels where the image function has one and the same rate of change.



a) b) c) d)

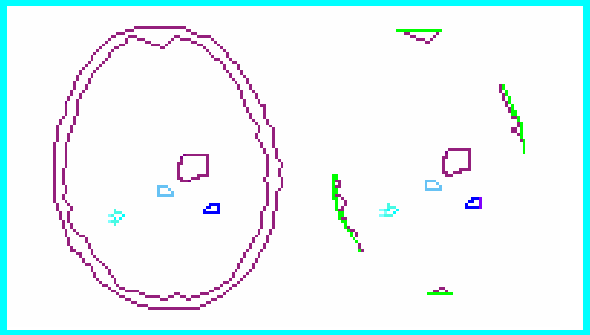
Figure2. a) A section of brain with hemorrhages. The active contours; b) – d) Segmentation of the image to brain and hemorrhages.

Sirakov, N.M., 2007, Monotonic Vector Forces and Green's Theorem For Automatic Area Calculation, Proc. IEEE ICIP2007, San Antonio, Sep. 2007, Vol. IV, pp 297-300. *IEEE Xplore Digital Library*, IEEE Catalog No.: 07CH37925C ISBN:1-4244-1437-7

Main IP Problems

REPRESENTATION

- as a boundary; region. The latter is useful to study internal properties such as texture or skeleton.



a) b)

Figure3. a) Boundary representation of the regions from Fig.2 (b); **b)** extracted hemorrhages and concavities.

DESCRIPTION of an image/objects in terms of extracted features.

New Technologies and Applications

CONTEND BASED IMAGE RETRIEVAL – new emerging area of research and industrial interest.

Automatic Tracking of Objects
Human Activities Recognition
Geographical Information Systems

Forensics – to distinguish images captured by digital camera from computer generated.

Other areas of applications: Medicine, Agriculture, Geology, Astronomy, GIS.

Lavel of Complexity and Classification

IP -> Image Analysis->Computer Vision ->
Artificial Intelligence

Images Classification with respect to:

- the modalities used to obtain the images;
- the image format- .bmp, .jpg, .png, .tiff etc.
- the field of application.

Image Modalities

Gamma Ray Imaging: Astronomy, Medicine

Images of this kind are used to locate bones pathology.

Position Emission Tomography (PET)

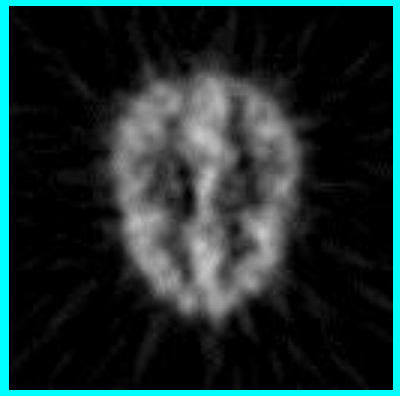


Fig.4. Example of a PET image containing a brain section

X-ray Imaging – some of the oldest sources of electromagnetic radiation.

Application to medical diagnostic.

Figure 5. An example of X-ray image.

Image Modalities

Imaging in the visible and infrared band- applications to satellite imagery, weather observation and prediction, automated visual inspection of manufactured goods.

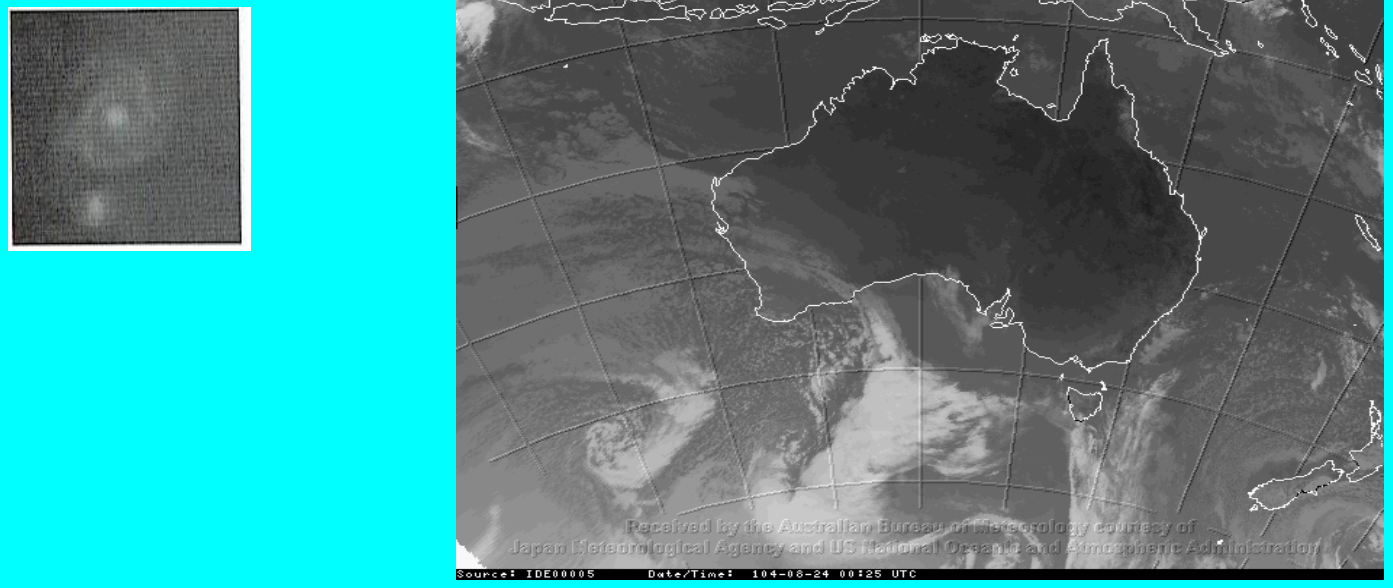


Figure 6. Left) Galaxy; **Right)** Earth map**.**

Imaging in the Ultraviolet Band – very useful for lithography, biological imaging, astronomy

Figure 7. Vales Marineris Canyon – Mars, taken by a spaceship, launched by European Space Agency, from an altitude 275 km, Resolution 12 m per pixel. The greatest Canyon in the Solar System – 4000 km long,
10 km deep

Magnetic Resonance Imaging (MRI) – applications to medicine

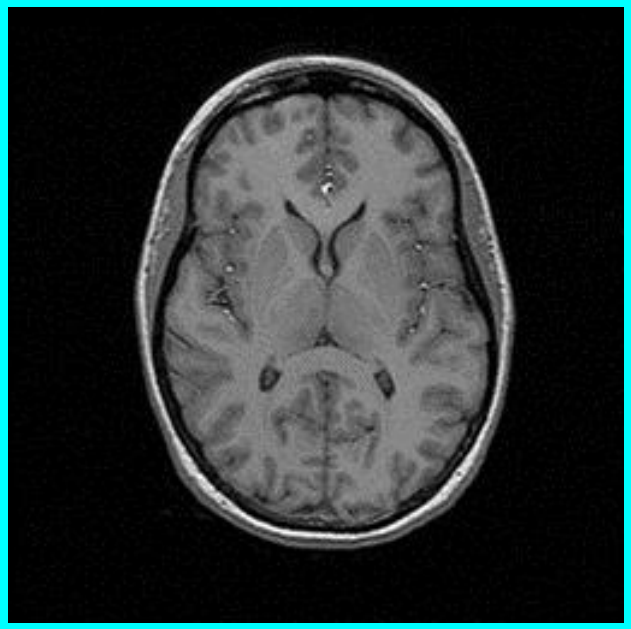


Figure 8. MRI image of a brain section.

Computerized Axial Tomography (CAT) – 3D capabilities because set of slices could be taken from the object.

Figure 9. Four sections of human torso**.**

Image Modalities

Sound Imaging – applications to geology and medicine

Geological Image Processing – minerals, ore, and oil exploration industry.

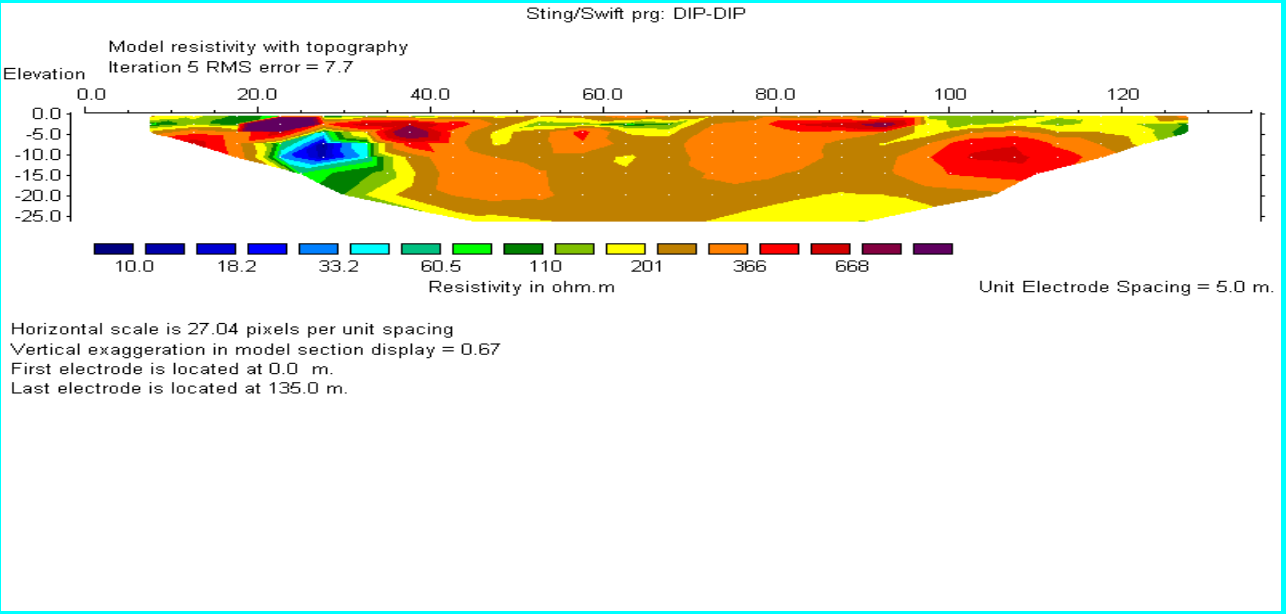


Figure 10. Vertical section of a gravel deposit.

How Images are formed in the human eye?
Limitations of the human eye?

Resolution: is the real length that corresponds to two pixels in an Image.

Brightness, Discrimination:
Experimental evidence show that the subjective brightness is a logarithmic function of the light intensity incident on the eye.

Visual Perception

Multi-resolution study for images that combine small/large, low/high contrast objects.

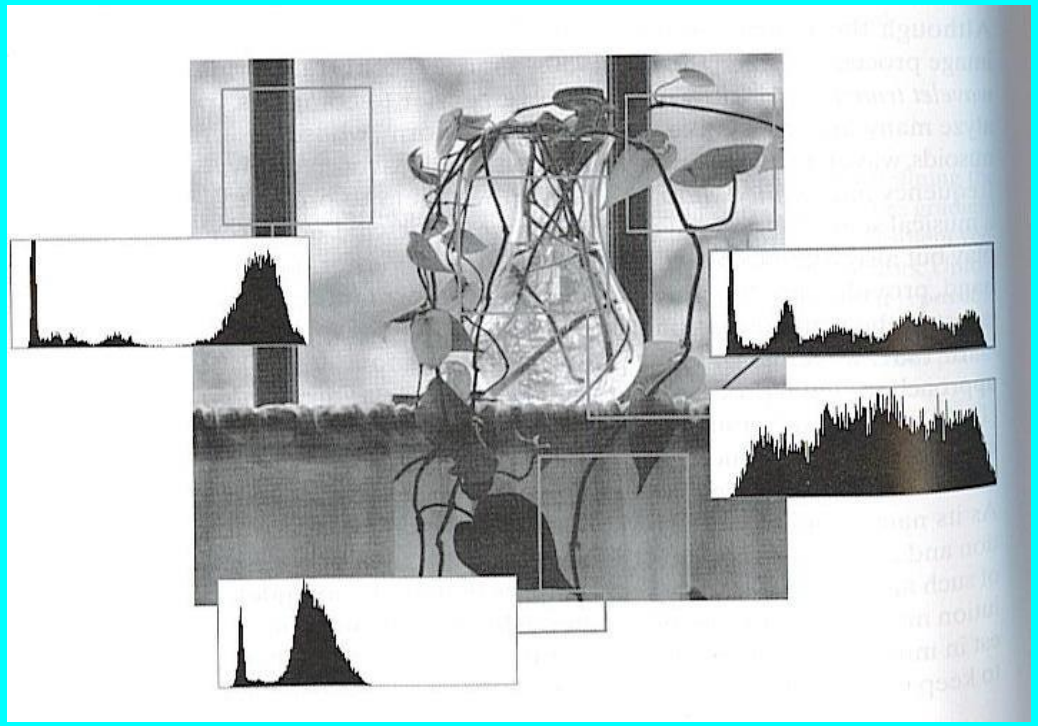


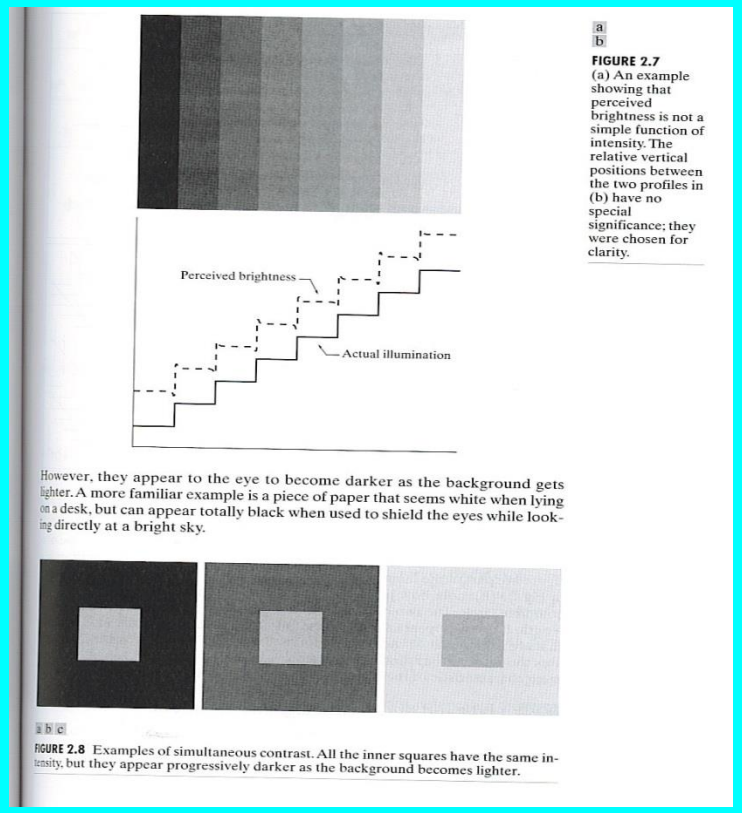
Figure 11. Low/high contrast objects.
(Digital Image Processing, 2nd E, by Gonzalez, Richard).

Visual Perception

Phenomena 1. The visual system tends to undershoot or overshoot around the boundary of regions of different intensity;

Phenomena 2: A region perceived brightness does not depend simply on its intensity.

Visual Perception



a
b

FIGURE 2.7
(a) An example showing that perceived brightness is not a simple function of intensity. The relative vertical positions between the two profiles in (b) have no special significance; they were chosen for clarity.

However, they appear to the eye to become darker as the background gets lighter. A more familiar example is a piece of paper that seems white when lying on a desk, but can appear totally black when used to shield the eyes while looking directly at a bright sky.

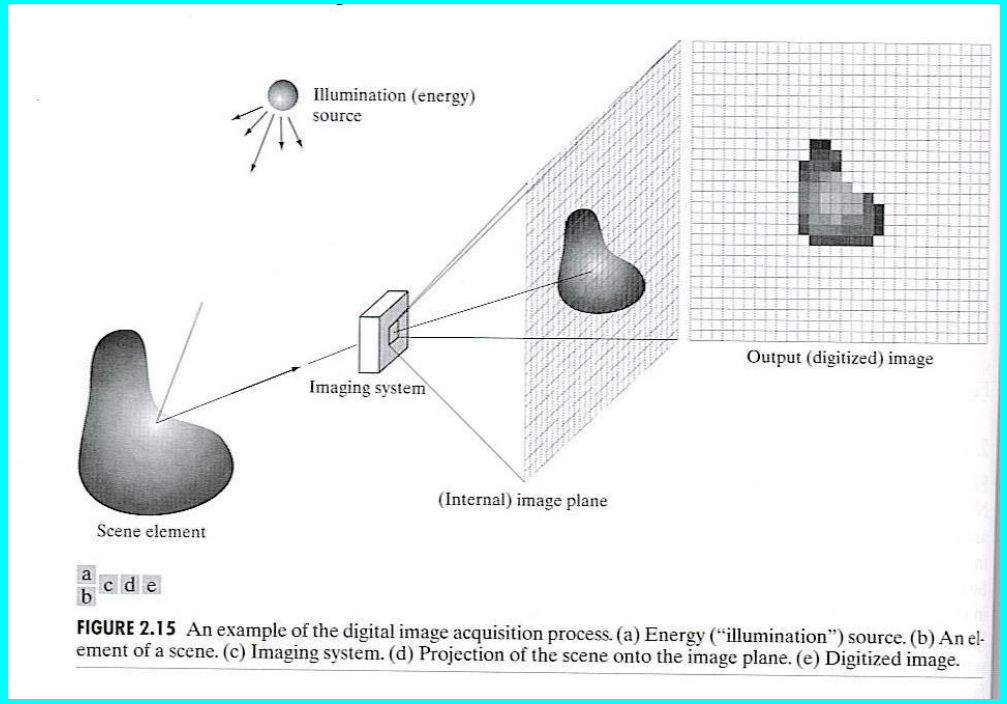
a b c

FIGURE 2.8 Examples of simultaneous contrast. All the inner squares have the same intensity, but they appear progressively darker as the background becomes lighter.

Figure 12. All inner squares have the same intensity but they appear progressively darker as the background becomes lighter. (Digital Image Processing, 2nd E, by Gonzalez, Richard).

Image Formation Model

Continuous to digital image



a b c d e

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.

Figure 13. Digital Image creation.

(Digital Image Processing, 2nd E, by Gonzalez, Richard).

Quantization

a)

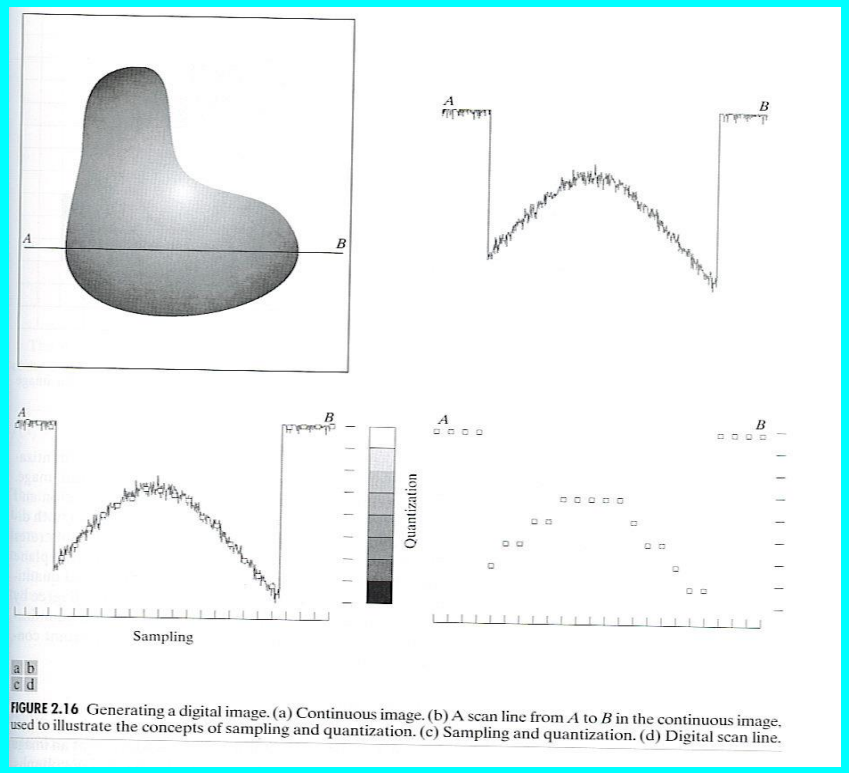


FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from *A* to *B* in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

b)

Figure 14. Quantization the image intensity using **a)** sixteen intervals (gray levels); **b)** 256.
The lighter the gray level the higher the number describing this.

(Digital Image Processing, 2nd E, by Gonzalez, Richard).