EE657 IMAGE and VIDEO PROCESSING
and
DATA COMPRESSION TECHNIQUES
For Image and Video Coding

Prof. Dr. Hüseyin Abut

Resources:

1. Gonzalez, Woods and Eddins, Digital Image Processing Using Matlab, (2004), Prentice-Hall.
2. Gonzalez & Woods (2002) Digital Image Processing, Prentice-Hall
3. Wang, Ostermann, Zhang, (2002) Video Processing and Communications, Prentice-Hall
4. A. M. Tekalp, *Digital Video Processing*, Prentice-Hall, 1995.

OUTLINE (TBD Soon)

1. Introduction to Digital Imagery and Processing
2. Digital Image Fundamentals
3. Two-Dimensional Signals and Systems and Multi-Dimensional Sampling Theory
4. Image Decimation and Interpolation
5. Multi-Resolution Image Imagery
6. Edge Detection
7. Image Enhancement
8. Linear and Non-Linear Noise Filtering
9. Foundations of Video Coding
10. Still Image Coding Techniques
11. H.261 and MPEG Family Image Coding Techniques
12. Digital Video Standards and Systems

Introduction

Modern digital technology has made it possible to manipulate multi-dimensional signals with systems that range from simple digital circuits to advanced parallel computers. The goal of this manipulation can be divided into three categories:

*** Image Processing** ***image in -> image out***

*** Image Analysis** ***image in -> measurements out***

*** Image Understanding** ***image in -> high-level description out***

We will focus on the fundamental concepts of *image processing*. Further, we will restrict ourselves to two-dimensional (2D) image processing although most of the concepts and techniques that are to be described can be extended easily to three or more dimensions.

We begin with certain basic definitions:

Image: image is considered to be a function of two real variables, for example, $a(x,y)$ with a as the amplitude (e.g. brightness) of the image at the *real* coordinate position (x,y). The amplitudes of a given image will almost always be either real numbers or integer numbers.

ROI: An image may be considered to contain sub-images sometimes referred to as *regions-of-interest*, *ROIs*, or simply *regions*.

This concept reflects the fact that images frequently contain collections of objects each of which can be the basis for a region. Thus one part of an image (region) might be processed to suppress motion blur while another part might be processed to improve color rendition.

Quantization: The latter is usually a result of a quantization process that converts a continuous range (say, between 0 and 100%) to a discrete number of levels. In certain image-forming processes, however, the signal may involve photon counting which implies that the amplitude would be inherently quantized. In other image forming procedures, such as magnetic resonance imaging, the direct physical measurement yields a complex number in the form of a real magnitude and a real phase. For the remainder of this course we will consider amplitudes as reals or integers unless otherwise indicated.

Digital Image: A digital image $a[m,n]$ described in a 2D discrete space is derived from an analog image $a(x,y)$ in a 2D continuous space through a *sampling* process that is frequently referred to as digitization. For now we will look at some basic definitions associated with the digital image. The effect of digitization is shown in Figure 1. The 2D continuous image $a(x,y)$ is divided into N *rows* and M *columns*. The intersection of a row and a column is termed a *pixel*. The value assigned to the integer coordinates $[m,n]$ with $\{m=0,1,2,...,M-1\}$ and $\{n=0,1,2,...,N-1\}$ is $a[m,n]$. In fact, in most cases $a(x,y)$--which we might consider to be the physical signal that impinges on the face of a 2D sensor--is actually a function of many variables including depth (z), color (λ), and time (t). Unless otherwise stated, we will consider the case of 2D, monochromatic, static images in this chapter.

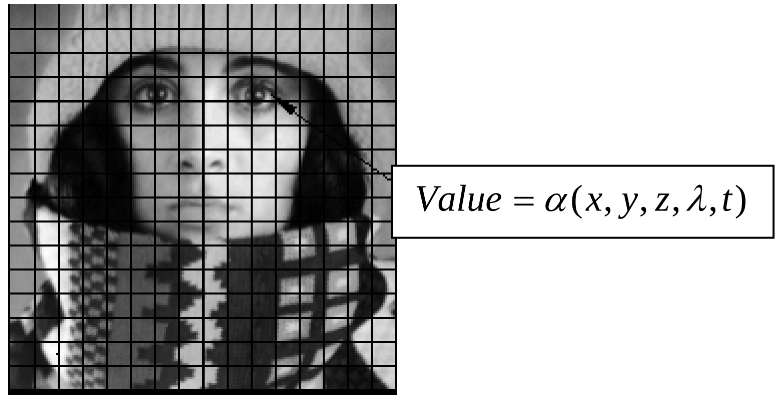
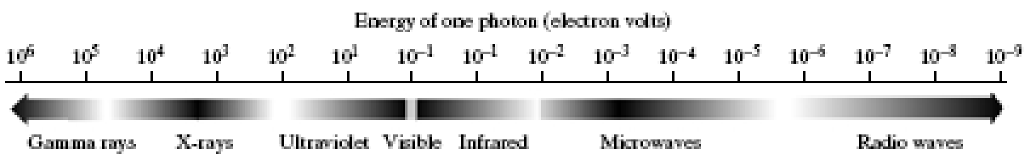


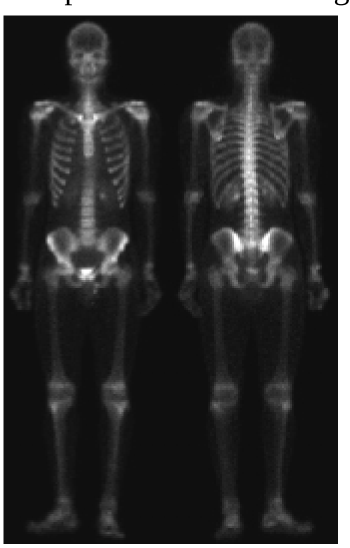
Figure 1: Digitization of a continuous image. The pixel at coordinates [*m*=10, *n*=3] has the integer brightness value 110.

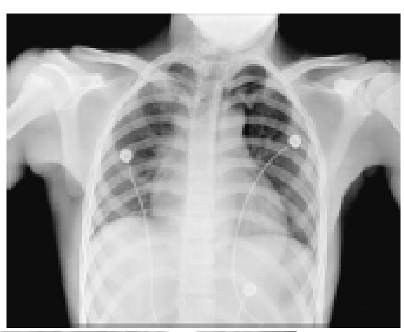
The image shown in Figure 1 has been divided into N = 16 rows and M = 16 columns. The value assigned to every pixel is the average brightness in the pixel rounded to the nearest integer value. The process of representing the amplitude of the 2D signal at a given coordinate as an integer value with L different gray levels is usually referred to as amplitude quantization or simply *quantization*.

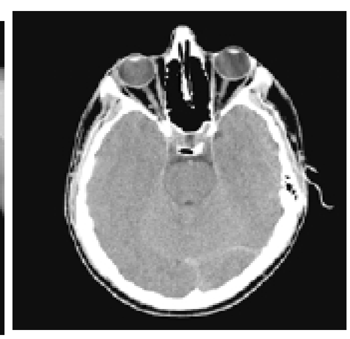
Images are formed from the radiation of electromagnetic (EM) spectrum both in the visual and non-visual bands (Gamma rays through radio waves) as shown below (GW: Figure 1.5.)



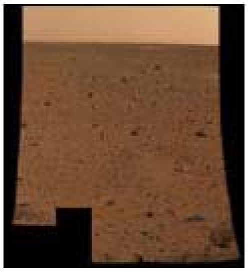
Examples of Different Imagery: Gamma and X-Ray Imagery:







Some infrared images from Mars Rover “Spirit”, which are used for aligning the landing trajectory of the vehicle (Images are downloaded form the NASA/JPL Website.)

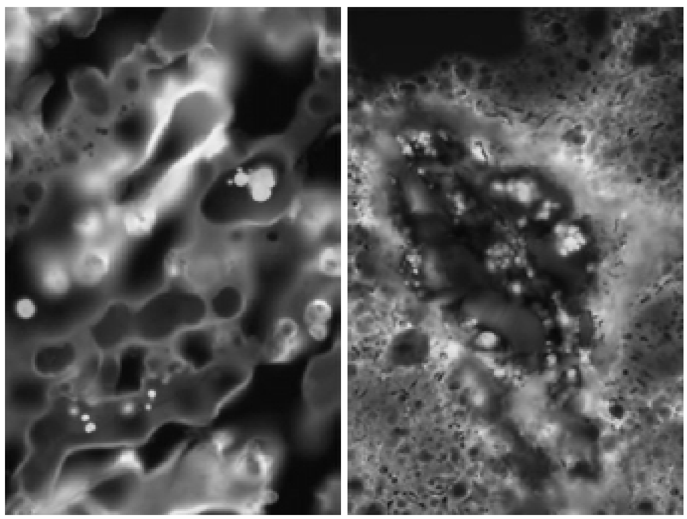


Color mosaic image
Of Mars surface

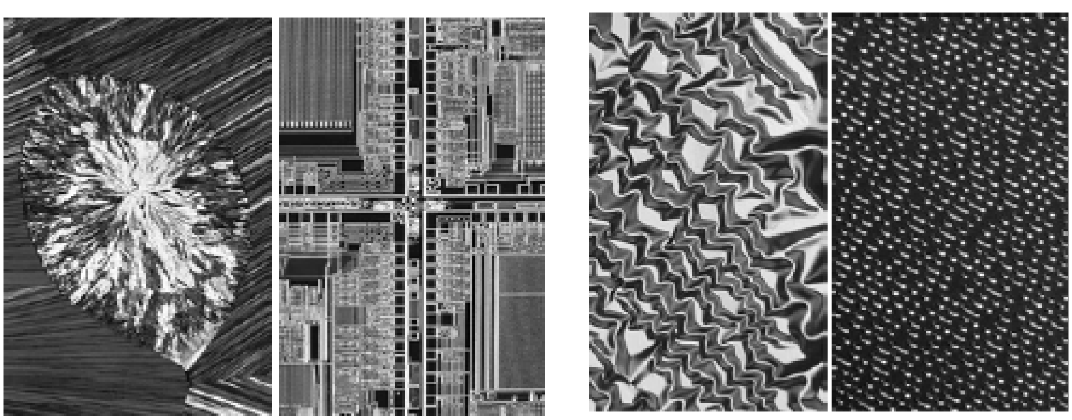
taken by
Mars Global Surveyor

taken by
Rover’s descent imaging motion estimation (DIME) system

Ultraviolet Imaging used in many industrial inspections, microscopy and biological imaging: Normal and smut infected corn.



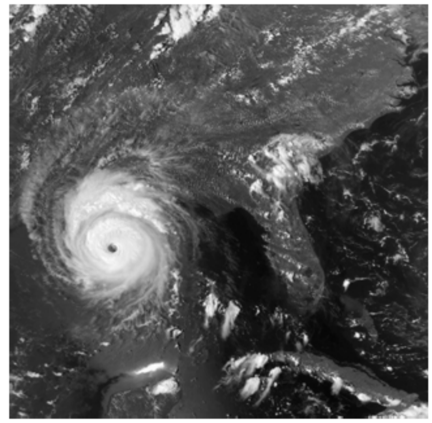
Visible and Infrared Imagery:



From left : Cholestrol(40x); Microprocessor (60x); Audio CD surface(1750x); Organic superconductor(450x).

Thematic Imagery from Landsat Satellite Imaging. There are seven thematic bands used by NASA ranging from 0.45 μm (visible blue) to 12.25 μm thermal infrared, used in many applications.

Band No.	Name	Wavelength (μm)	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping



Seven Thematic Bands and Multi-band imagery of the eye of Hurricane Andrew.

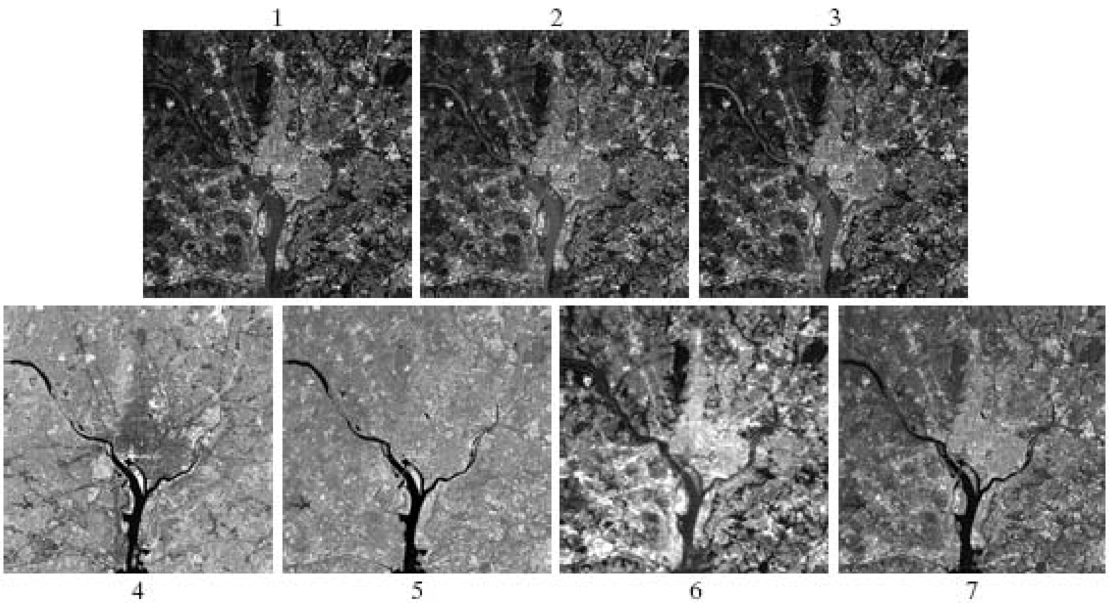
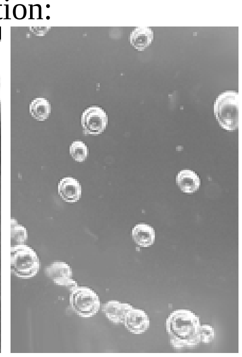
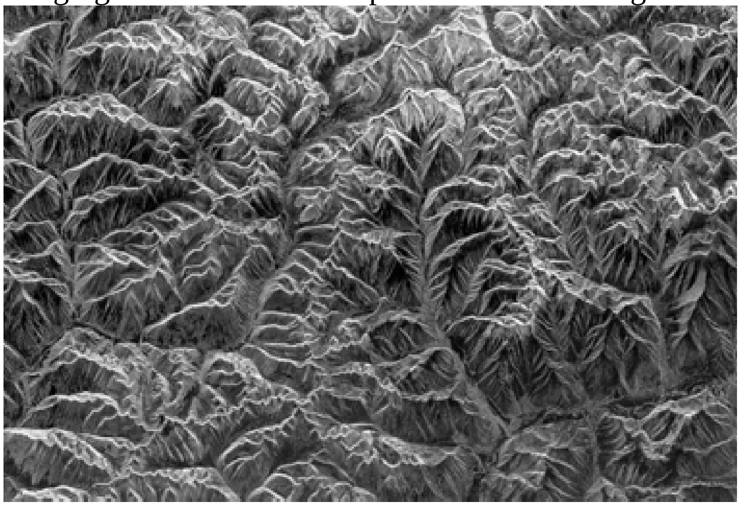


FIGURE 1.10 LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

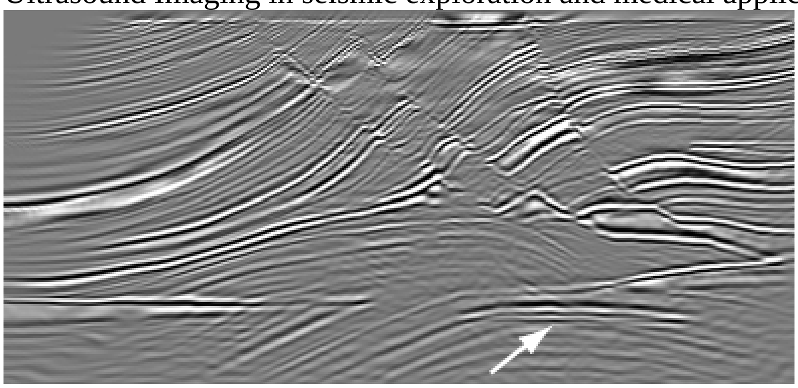
Industrial and Law Enforcement Applications: Bottle and air pocket inspection, fingerprint and licence plate identification:



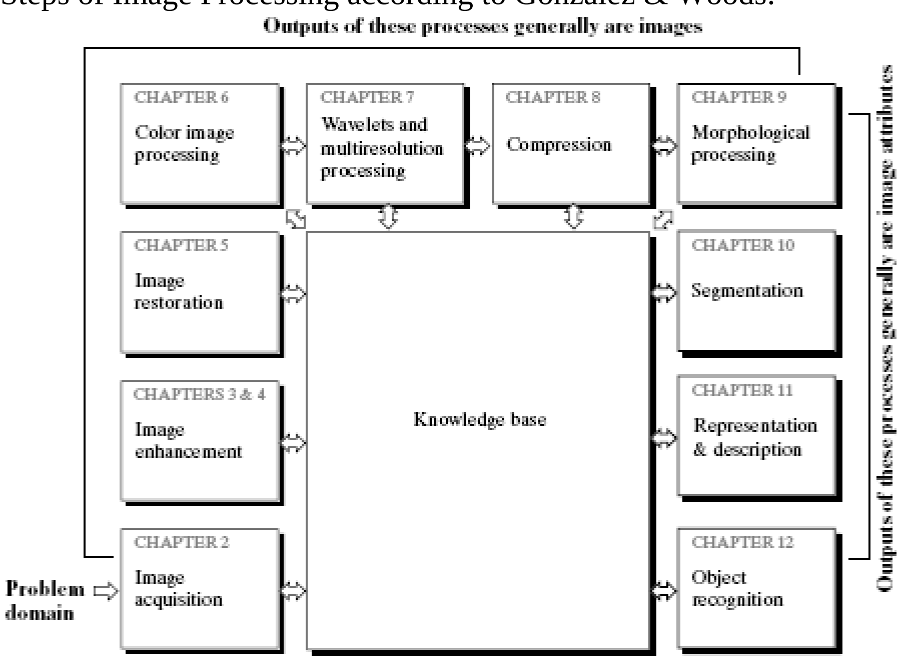
Imaging in the radio band: Spaceborne radar image of Southeast Tibet NS MRI Image of a knee.



Ultrasound Imaging in seismic exploration and medical applications:



Fundamental Steps of Image Processing according to Gonzalez & Woods:



Components of a generic Image Processing System:

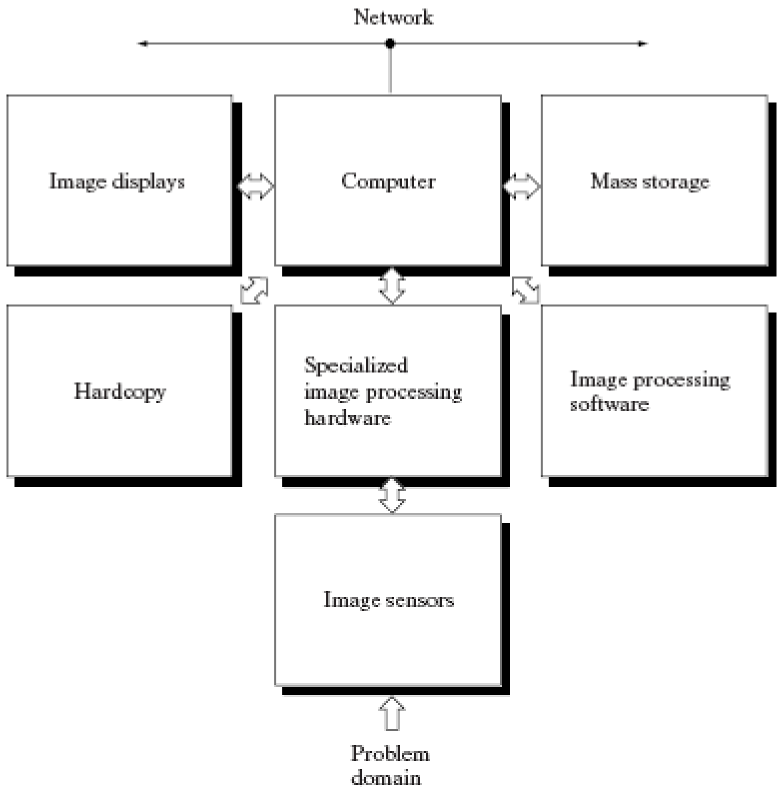


FIGURE 1.24 Components of a general-purpose image processing system.

Common Values encountered in Digital Image Processing:

There are standard values for the various parameters encountered in digital image processing. These values can be caused by video standards, by algorithmic requirements, or by the desire to keep digital circuitry simple. Table 1 gives some commonly encountered values.

Parameter	*Symbol*	*Typical values*
Rows	N	256,512,525,625,1024,1035
Columns	M	256,512,768,1024,1320
Gray Levels	L	2,64,256,1024,4096,16384

Table 1: Common values of digital image parameters

Quite frequently we see cases of $M=N=2^K$ where $\{K = 8,9,10\}$. This can be motivated by digital circuitry or by the use of certain algorithms such as the (fast) Fourier transform (see Section 3.3).

The number of distinct gray levels is usually a power of 2, that is, $L=2^B$ where B is the number of bits in the binary representation of the brightness levels. When $B>1$ we speak of a *gray-level image*; when $B=1$ we speak of a *binary image*. In a binary image there are just two gray levels which can be referred to, for example, as "black" and "white" or "0" and "1".

Characteristics of Image Operations: There is a variety of ways to classify and characterize image operations. The reason for doing so is to understand what type of results we might expect to achieve with a given type of operation or what might be the computational burden associated with a given operation.

Types of operations: The types of operations that can be applied to digital images to transform an input image a[m,n] into an output image b[m,n] (or another representation) can be classified into three categories as shown in Table 2, which is shown graphically in Figure 2.

Operation	**Characterization**	**Generic Complexity/Pixel**
* *Point*	- the output value at a specific coordinate is dependent only on the input value at that same coordinate.	*constant*
* *Local*	- the output value at a specific coordinate is dependent on the input values in the *neighborhood* of that same coordinate.	P^2
* *Global*	- the output value at a specific coordinate is dependent on all the values in the input image.	N^2

Table 2: Types of image operations. Image size = *N* x *N*; neighborhood size = *P* x *P*. Note that the complexity is specified in operations *per pixel*.

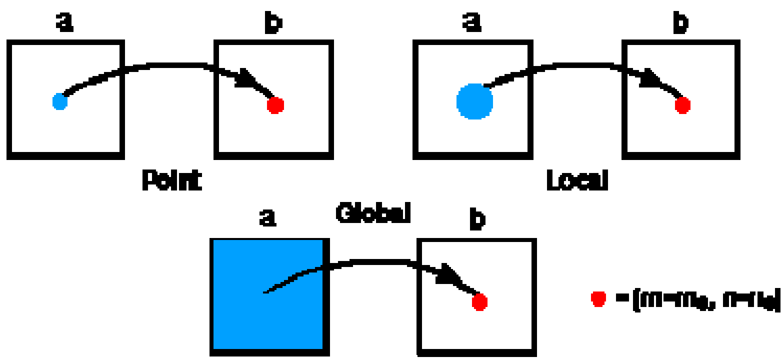


Figure 2: Illustration of various types of image operations