18MIT31C DIGITAL IMAGE PROCESSING

UNIT-I: Introduction:- Digital Image-Digital Image Processing-Origins of Digital Image Processing-Applications of Digital Image Processing-Basic steps in Digital Image Processing. Digital Image Fundamentals: Light and the Electromagnetic Spectrum-Image sensing and acquisition-Image sampling and quantization-Basic relationships between pixels-Linear and non-linear operations.

Textbook :
Gonzalez R C., and Woods R.E., “Digital Image Processing”, Prentice Hall, Third Edition.

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What is a Digital Image ?

A digital image is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels

Digitization implies that a digital image is an approximation of a real scene

Elements of a digital image are the picture elements, image elements, pels or pixels

What is Digital Image Processing ?

Digital image processing is the use of computer algorithms to perform image processing on digital images.

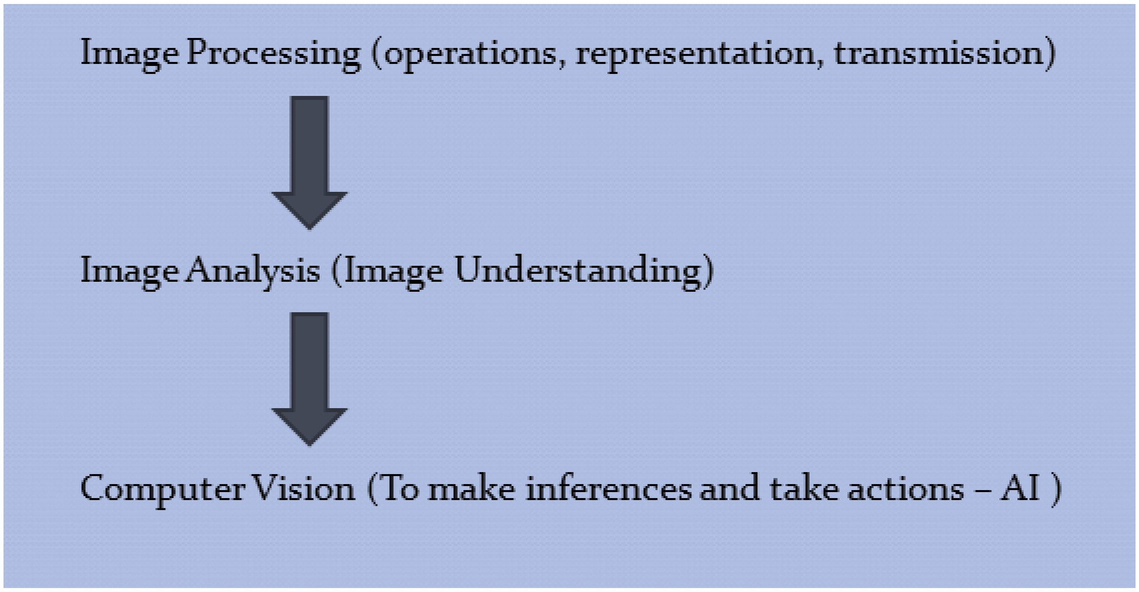
An image f(x, y), where x & y are spatial (plane) coordinates, and the amplitude of f at (x, y) is called the intensity or gray level of the image at that point. When x, y and the intensity values of f are finite, discrete quantities, the image is called a digital image.

Digital image processing focuses on two major tasks

(i) Improvement of pictorial information for human interpretation

(ii) Processing of image data for storage, transmission and representation for autonomous machine perception

The stages in Digital image processing are :



The types of Digital image processing tasks are:

Low Level (primitive operations)

- reducing noise
- contrast enhancement
- image sharpening

Mid Level

- segmentation
- description and classification

High Level

- making sense of the recognised objects

The Origins of Digital Image Processing

* One of the first applications of digital images was in the newspaper industry, when pictures were first sent by submarine cable between London and New Yorks

* Image processing tasks started in early 1960s – Used Satellite images from space probe

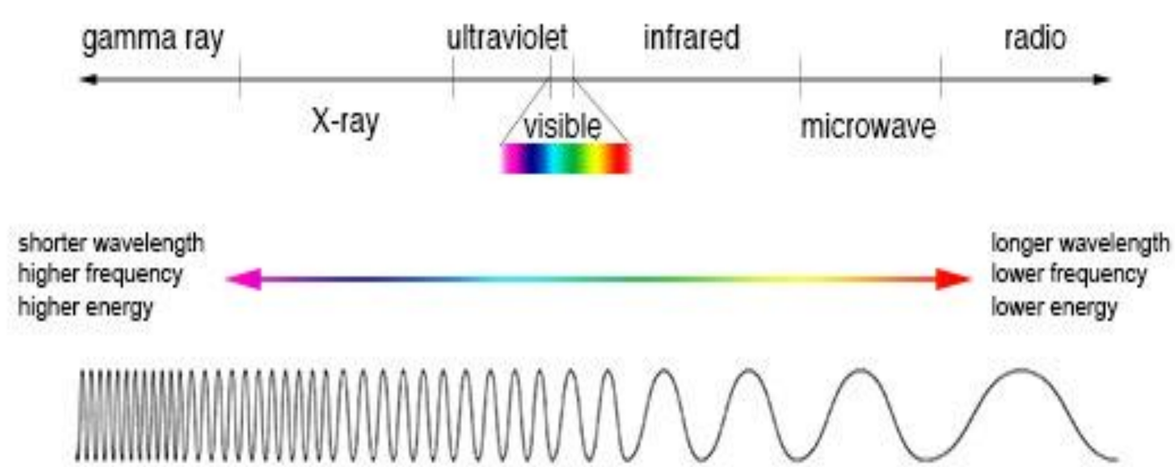
* Late 60s and 70s – used medical imaging, remote earth resources observations and astronomy

Examples of fields that use Digital image processing

*The principal energy source for images is the electro magnetic energy spectrum. Other sources of energy include acoustic, ultrasonic and electronic. Synthetic images are generated by computer

Electro Magnetic Energy Spectrum

* Electro magnetic waves are propagating sinusoidal waves of varying wavelengths, or a stream of massless particles, each traveling in a wavelike pattern and moving at the speed of light. Each massless particle contains a certain amount of energy. Each bundle of energy is called a photon.



The spectrum ranges from gamma ray to radio waves.

*<u>Gamma ray imaging</u>

(i) Images used for Nuclear medicine (by injecting a patient with radioactive isotope that emits gamma rays and images are collected through gamma ray detectors),

(ii) used in bone pathology to detect infections and tumors

(iii) positron emission tomography (PET) – the radioactive isotope emits positrons. When a positron meets an electron, both are annihilated and two gamma rays are emitted → a tomographic image is created.

(iv) Astronomical observations

*<u>X-ray imaging</u>

(i) Medical diagnosis

(ii) Industry → to identify flaws in manufacturing

(iii) Astronomy

(iv) Angiography

In digital radiography, digital images are obtained by (i) digitizing x-ray films, (ii) by passing x-rays on the devices that convert x-rays to light.

*<u>Imaging in the ultra violet band</u>

(i) Lithography

(ii) Industrial inspection

(iii) Microscopy

(iv) Lasers

(v) Biological Imaging

(vi) Astronomical observations

(vii) Fluorescence microscopy

*<u>Imaging in the visible and infrared bands</u>

(i) Light microscopy

(ii) Astronomy

(iii) Remote sensing

(iv) Industry

(v) Law of enforcement

(vi) Weather observation and prediction

*<u>Imaging in the microwave band</u>

(i) Radar →to collect data over virtually any region at any time & to explore inaccessible regions of the Earth's surface.

*<u>Imaging in the radio band</u>

(i) Medicine(MRI)

(ii) Astronomy

*<u>Examples in which Other imaging modalities are used</u>

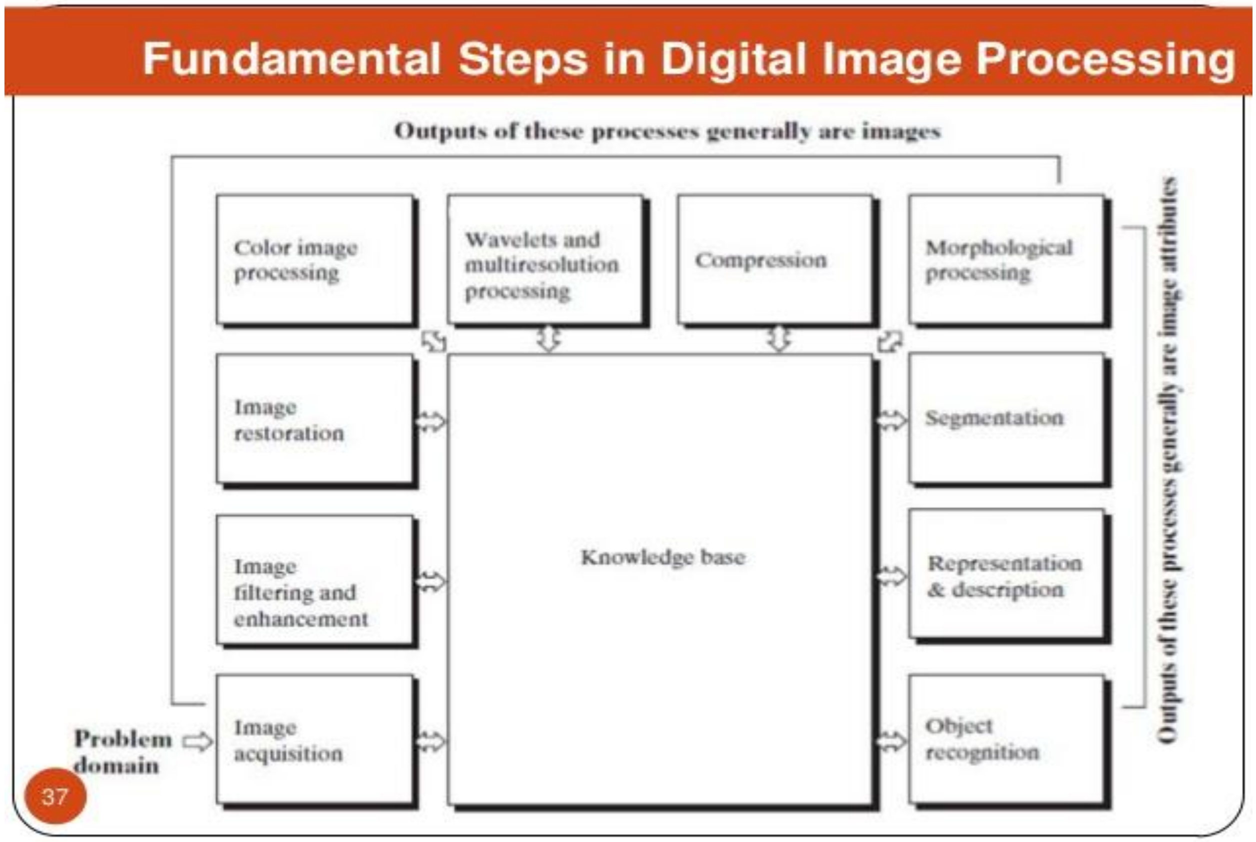
(i) Acoustic imaging→used in geological (mineral & oil) exploration, industry and medicine (hundreds of Hertz)

(ii) Ultrasound(millions of Hz) →used in manufacturing, obstetrics(to scan unborn babies)

(iii) Electron microscopy→a focused beam of electrons are used instead of light

(iv) Fractals →computer generated images

Fundamental steps in Digital image processing



The fundamental steps followed in any digital image processing task are :

*Image acquisition

This is the first process and this involves preprocessing , such as scaling

*Image enhancement

Enhancement is the process of manipulating an image so that it is more suitable for a specific application

*Image restoration

This is used to improve the appearance of an image. Restoration techniques are based on mathematical or probabilistic models of image degradation

*Color image processing

This is the basis for extracting features of interest in an image

*Wavelets

Wavelets are foundation for representing images in various degrees of resolution

*Compression

Compression is used to reduce the storage required to save an image, or the bandwidth required to transmit it

*Morphological processing

This deals with tools for extracting image components that are useful in the representation and description of shape

*Segmentation

This deals with partitioning an image into its constituent parts or objects. Segmentation could be (i) Autonomous (ii) rugged (iii) weak or erratic

*Representation and description

Representation follows the output of the segmentation stage. Here the data may be represented as a (i) Boundary or (ii) a complete region. Boundary representation is used when the focus is on external shape such as corners and inflections. Regional representation is used when the focus is on texture or skeletal shape

Description, also called feature selection, deals with extracting attributes

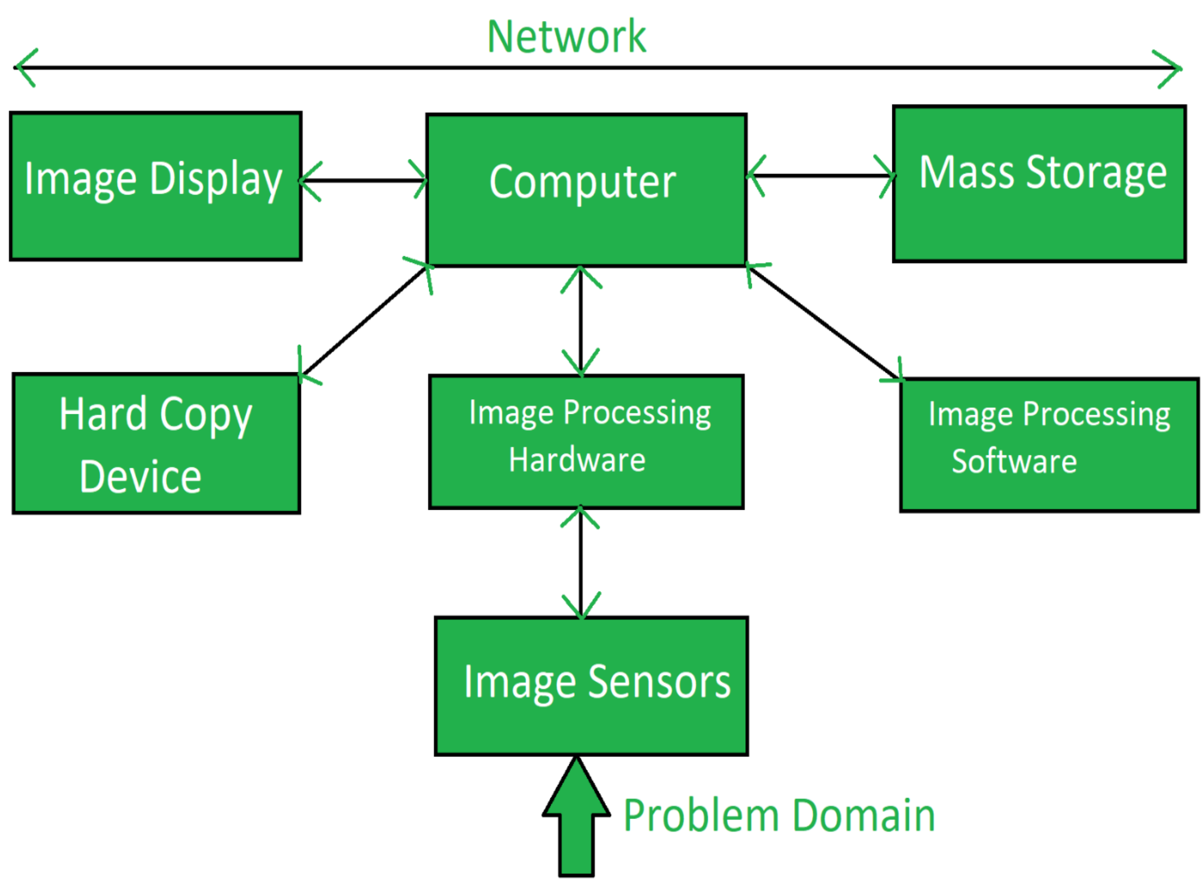
*Recognition

This is the process that assigns a label to an object based on its descriptors

Components of an image processing system

Two elements are required to acquire digital images for sensing and acquiring digital images, i.e., a physical device sensitive to the energy radiated by the object, and a digitizer, for converting the output of the physical sensing device into digital form. For ex., in a digital video camera, the sensors produce an electrical output proportional to light intensity. The digitizer converts this output to digital data.

Specialized image processing hardware consists of the digitizer and ALU. for ex., ALU is used in averaging images, during noise reduction.



The computer is an image processing system. Software consists of specialized modules that perform specific task.

Mass storage capability is a must in image processing applications. Digital storage is of 3 types : (i) short – term storage for use during processing (ii) online storage for fast recall (iii) archival storage, for infrequent access.

Digital Image Fundamentals

Light and the Electromagnetic spectrum

The Electromagnetic spectrum can expressed in terms of wavelength, frequency, or energy. Wavelength (λ) and frequency (ν) are related by the expression $\lambda = c/\nu$, where c is the speed of light (2.998 x 108 m/s). The energy of the Various components of the Electromagnetic spectrum is given by

$E = h\,\nu$, where h is the Planck's constant.

Electromagnetic waves can be visualized as propagating sinusoidal waves with wavelength λ . They are a stream of massless particles ,each traveling in a wave like pattern & moving at the speed of light. Each massless particle contains a certain amount (or bundle) of energy. Each bundle of energy is called a photon.

Since energy is proportional to frequency, a higher-frequency (shorter wavelength) electromagnetic wave carry more energy per photon. Thus, radio waves have photons with low energies, & gamma rays have the maximum energy.

Light is a part of electromagnetic radiation sensed by the human eye. The visible spectrum is divided into six colors (VB GYOR) and each color blends smoothly into the next.

The colors that humans perceive in an object are determined by the nature of the light reflected from the object.

Light that is void of color is called monochromatic or achromatic. The only attribute of monochromatic light is its intensity. The range of measured values of monochromatic light from black to white is called gray scale, and monochromatic images are referred to as gray-scale images.

In addition to frequency, three basic quantities used to describe the quality of chromatic light source are radiance, luminance and brightness

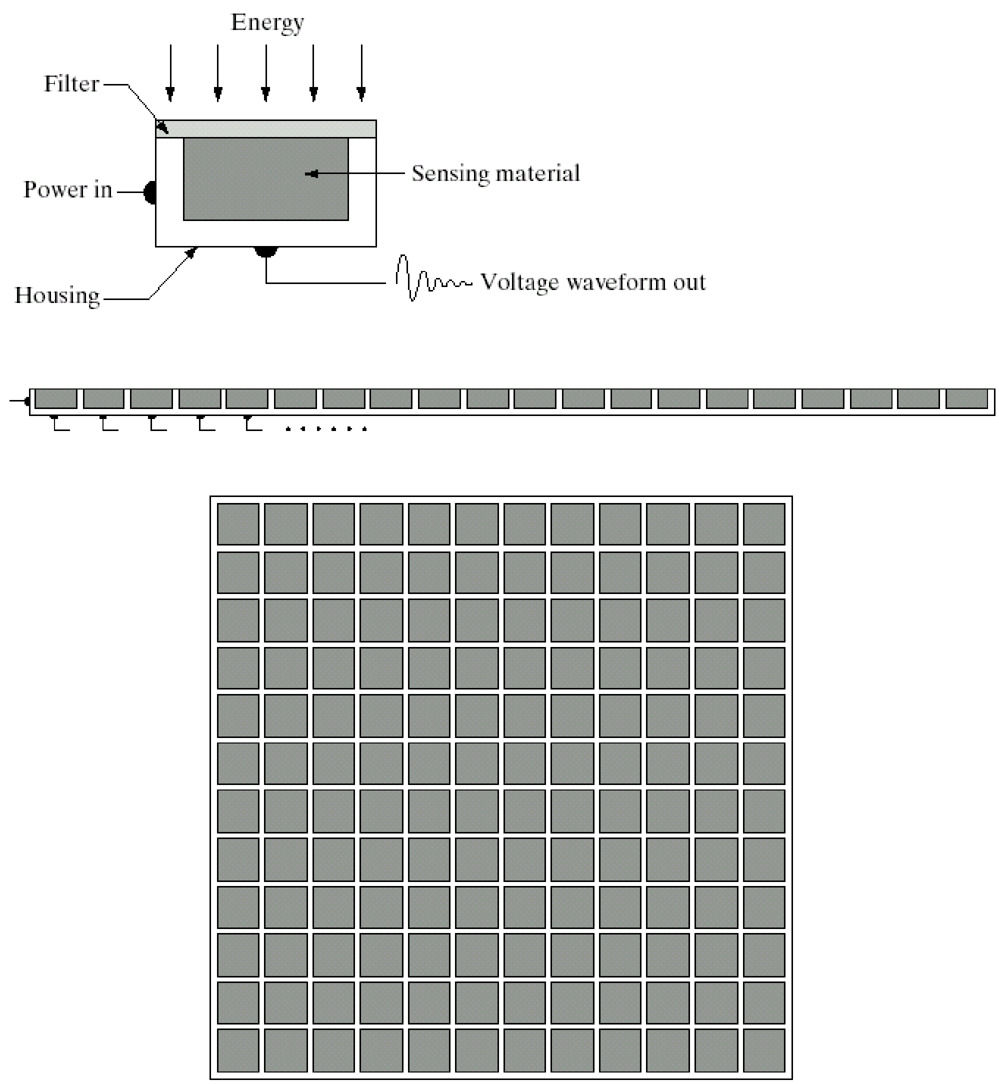
(i) Radiance is the total amount of energy that flows from the light source, measured in watts (w)
(ii) Luminance is the amount of energy an observer perceives from a light source , measured in lumens (lm)
(iii) brightness is the subjective descriptor of light perception

Image Sensing and Acquisition

Images are generated by the Combination of an illumination source and the reflection or absorption of energy from that source by the elements of the scene being imaged.

An illumination may originate from electromagnetic source or ultrasound pattern . Depending on the nature of the source , illumination energy is reflected from or transmitted through objects. (like light reflected from a planar surface or x rays passing through a patient's body)

The reflected or transmitted energy is focused onto a photoconverter (ex., phosphor screen) which converts the energy into visible light



a
b
c

FIGURE 2.12
(a) Single imaging sensor.
(b) Line sensor.
(c) Array sensor.

<u>Image acquisition Using a single sensor</u>

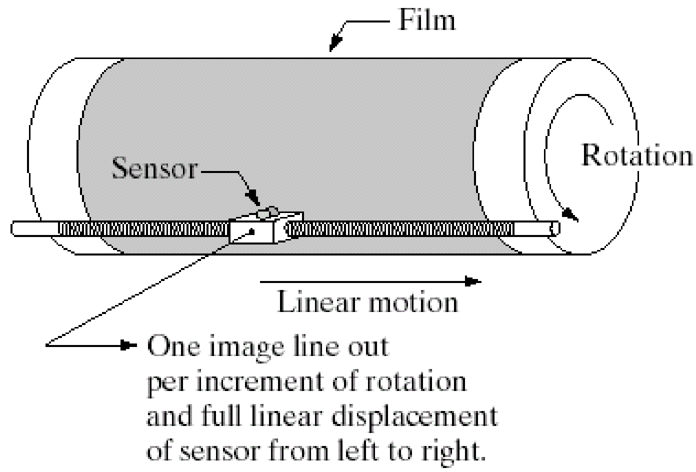


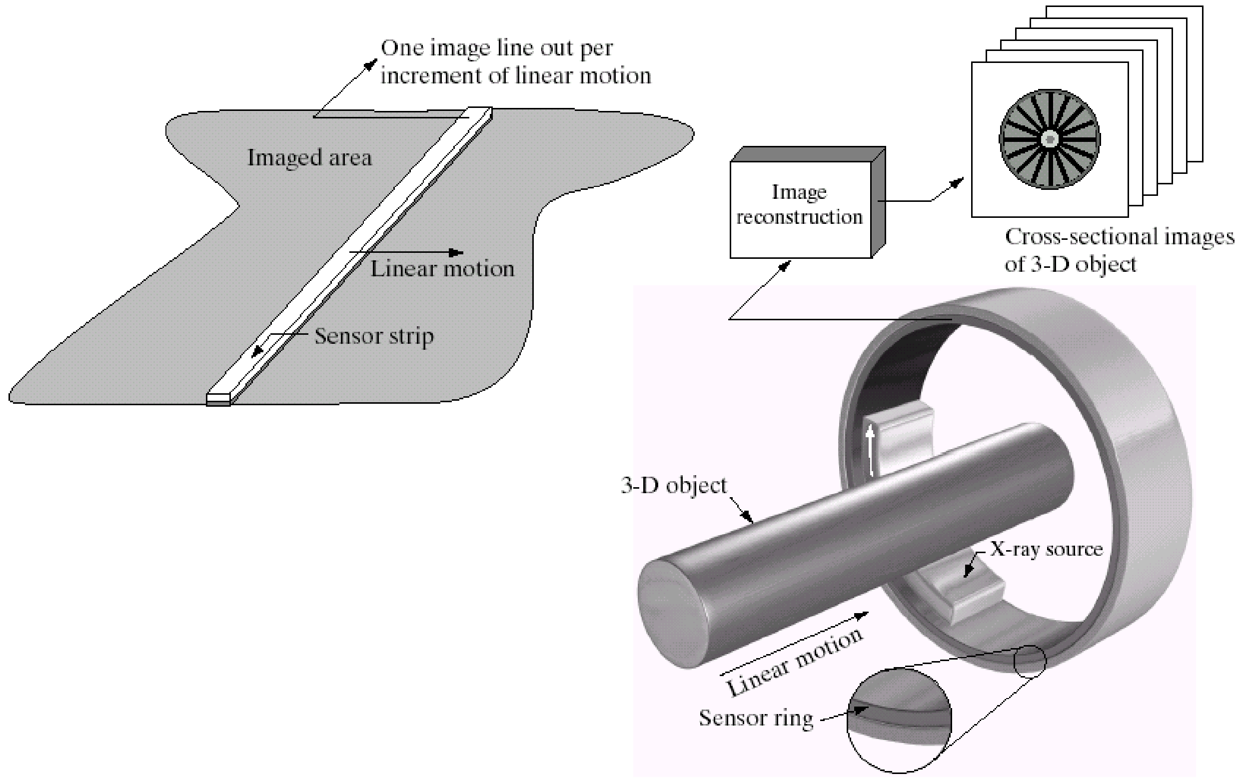
FIGURE 2.13 Combining a single sensor with motion to generate a 2-D image.

A photodiode is used as a sensor, constructed of silicon materials and whose output voltage waveform is proportional to light. The use of filter in front of the sensor improves selectivity. For ex., a green pass filter favors light in the green band of the color spectrum. As a result, the sensor output will be stronger for green light.

In high precision scanning, a film negative is mounted onto a drum whose rotation provides displacement in one dimension. The single sensor mounted provides motion in the perpendicular direction. This is used to obtain high resolution images.

The flat bed mechanical digitizer, with the sensor moving in two linear directions are called as micro-densitometers.

Image acquisition using sensor strips



a b

FIGURE 2.14 (a) Image acquisition using a linear sensor strip. (b) Image acquisition using a circular sensor strip.

This arrangement is used in most flat bed scanners

Sensor strips mounted in a ring configuration are used in medical & industrial imaging to obtain cross sectional images of 3D objects.

A rotating x ray source provides illumination & the sensors opposite to the source collect the x-ray energy that passes through the object. This is the basis for medical & industrial Computerised axial tomography (CAT) imaging.

The output of the sensors must be processed by reconstruction algorithm to transform the sensed data into meaningful cross-sectional images. A set of 3D images are generated as the object is moved in a direction perpendicular to the sensor ring. Ex., Magnetic resonance imaging (MRI) & positron emission tomography (PET)

Image acquisition Using sensor arrays

Individual sensors may be arranged in the form of a 2D –array, electromagnetic and ultrasonic sensing devices, are used as CCD, (Charge Coupled Devices) arrays. CCD sensors of 4000x 4000 elements or more are used. The response of each sensor is proportional to the integral of the light energy projected on to the surface of the sensor.

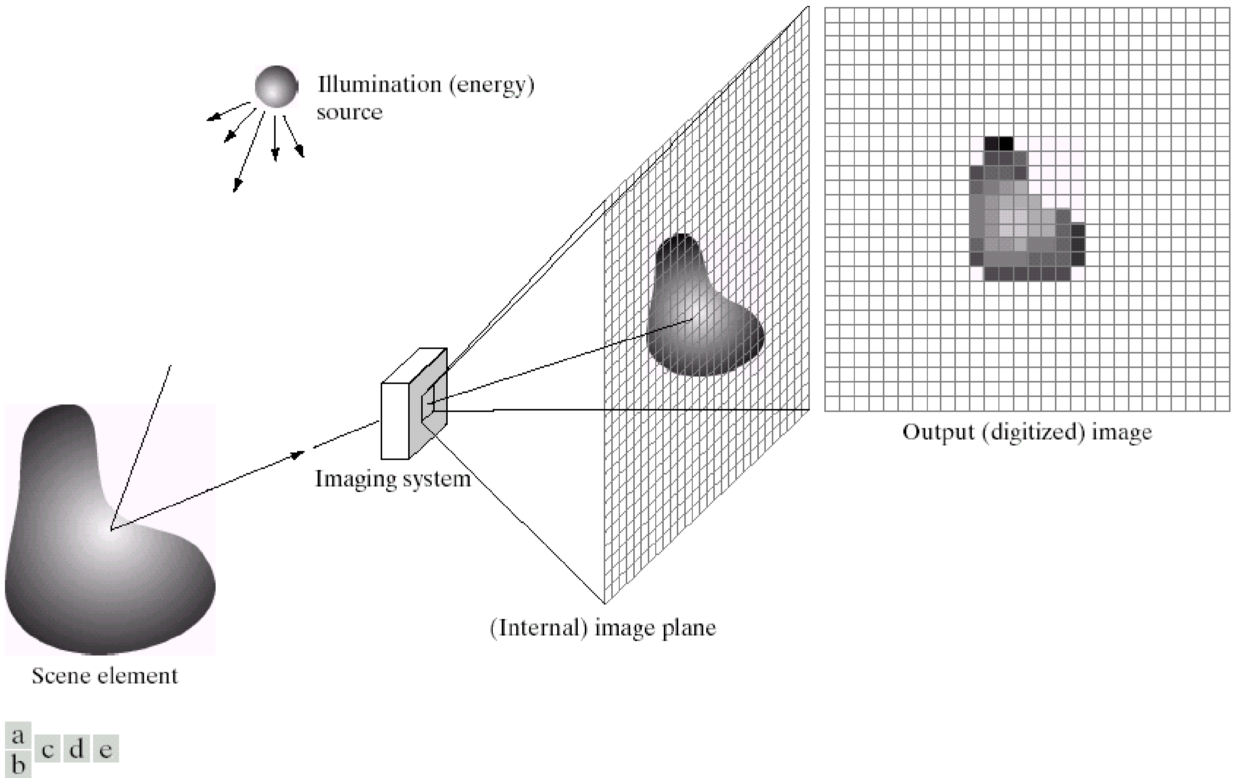


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

The energy from an illumination source is reflected from a scene element. The incoming energy is collected by the imaging system and is focussed onto an image plane. The optical lens at the front end of the imaging system, projects the Viewed scene onto the lens focal plane.

The sensor array, which is coincident with the focal plane, produces output proportional to the integral of the light received at each sensor. Digital & analog circuitry converts them to an analog signal, which is then digitized.

A simple image formation model

Images are denoted by two dimensional functions of the form f(x, f). f(x,y) must be nonzero & finite; that is $0< f(x,y)< \infty$

The function f(x, y) is characterized by two components (i) the amount of source illumination incident on the scene, (ii) the amount of illumination reflected by the objects in the scene

These are called the illumination and reflectance components and are denoted by i(x,y) & r(x,y) respectively.

$f(x,y) = i(x,y) . r(x,y)$

where $0< i(x,y)<\infty$

and $0< r(x,y)<1$

r=0 indicates total absorption & r=1 indicates total reflectance .

i(x,y) is determined by the illumination source, & r(x,y) is determined by the imaged objects.

When the images are formed through transmission of the illumination t hrough a medium (like x- ray), then a transmissivity function is used.

On a clear day, the illumination of Sun is in excess of 90,000 lm/m^2 , i.e., i(x,y). In a commercial office, it is about 1000 lm/m^2 . Typical values of r(x,y) are 0.01 for black velvet , & 0.90 for silver –plated metal

Let the intensity (gray level) of a monochrome image at (x_0, y_0) be

$\rho = f(x_0, y_0)$

$Lmin <= \rho <= Lmax$

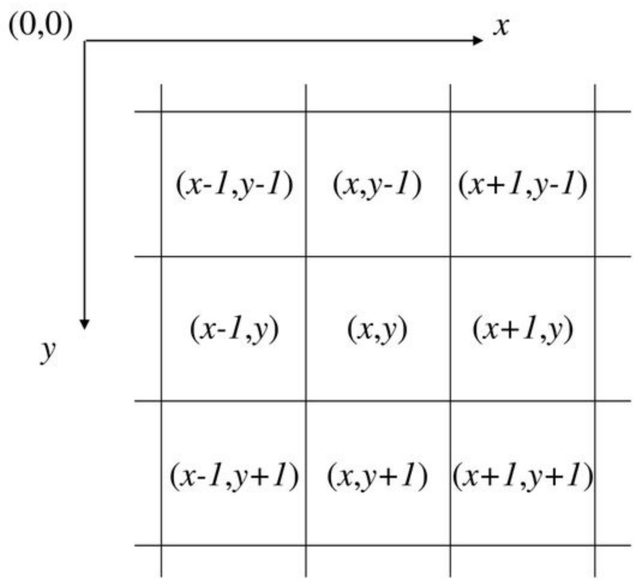
Lmin = imin.rmin & Lmax = imax.rmax

Lmin ≈10 & Lmax ≈ 1000 for indoor values. The interval [Lmin, Lmax] is called the gray scale. The normal values are [0, L-1], ρ=0 is black and ρ=L-1 is white. All intermediate values are shades of gray.

Some basic relationships between pixels

- Neighbors of a pixel
- Adjacency, connectivity , regions and boundaries
- Distance measures

Basic Relationship of Pixels



Conventional indexing method

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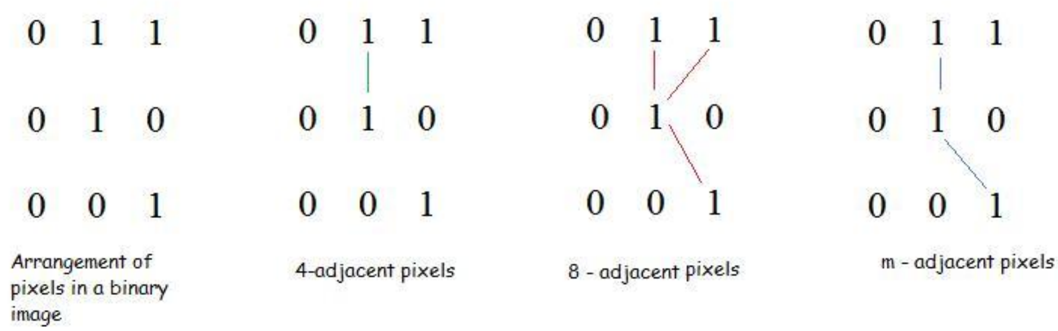
Neighbors of a Pixel

A pixel p at coordinates (x,y) has four horizontal and vertical neighbors whose coordinates are given by: (x+1,y),(x-1,y), (x,y+1), (x,y-1). This set is called the 4-neighbors of p, denoted by $N_4(p)$. Each pixel is a unit distance from (x,y), and some of the neighbor locations of p lie outside the digital image, if (x,y) is on the border of the image. The four diagonal neighbor of p have coordinates: (x+1,y+1),(x+1,y-1), (x-1,y+1), (x-1,y-1), and are denoted by $N_D(p)$. These points together with the 4-neighbors, are called the 8-neighbors of p, denoted by $N_8(p)$. As before , some of the neighbor locations in $N_D(p\ )$and $N_8(p)$ fall outside the image if (x,y) is on the border of the image.

3 types of adjacency

- 4- adjacency: 2 pixels *p* and *q* with values from *V* are 4- adjacent if *q* is in the set $N_4(p)$
- 8- adjacency: 2 pixels *p* and *q* with values from *V* are 8- adjacent if *q* is in the set $N_8(p)$
- *m*- adjacency: 2 pixels *p* and *q* with values from *V* are *m*adjacent if

  1. *q* is in $N_4(p)$, *or*
  2. *q* is in $N_D(p)$ *and* the set $N_4(p) \cap N_4(q)$ has no pixels whose values are from V



A digital path from pixel p with coordinates (x,y) to pixel q with coordinates (s,t) is a sequence of distinct pixels with coordinates (x0,y0), (x1,y1), …, (xn,yn), where (x0,y0)= (x,y) and (xn,yn)=(s,t), and pixels (xi,yi) and (xi-1,yi-1) are adjacent for 1 ≤ i ≤ n.

S: a subset of pixels in an image.

Two pixels *p* and *q* are said to be connected in *S* if there exists a path between them consisting entirely of pixels in *S*.

For any pixel *p* in *S*, the set of pixels that are connected to it in *S* is called a connected component of *S*.

If S has only one connected component, it is called a connected set.

Regions and boundaries

R: a subset of pixels in an image.

R is a region of the image if *R* is a connected set.

The boundary of a region *R* is the set of pixels in the region that have one or more neighbors that are not in *R*.

Distance measures

If we have 3 pixels: p,q,z:

p with (x,y)

q with (s,t)

z with (v,w)

Then:

$D(p,q) = 0$ iff $p = q$

$D(p,q) = D(q,p)$

$D(p,z) \leq D(p,q) + D(q,z)$

Euclidean distance between p and q: $De(p,q) = [(x-s)^2 + (y-t)^2]1/2$

$D4$ distance: $D4(p,q) = |x-s| + |y-t|$

$D8$ distance: $D8(p,q) = \max(|x-s|, |y-t|)$

$D4$ and $D8$ distances between p and q are independent of any paths that might exist between the points.

For *m*-adjacency, *Dm* distance between two points is defined as the shortest *m*-path between the points.