IE404

Digital Image Processing

Instructor: Manish Khare

Lecture – 1-2

Time Table – IE404

Lecture Timing

- Monday
  - 11:00 – 11:50
- Tuesday
  - 09:00 – 09:50
- Thursday
  - 11:00 – 11:50

Lab Timing

- TBD

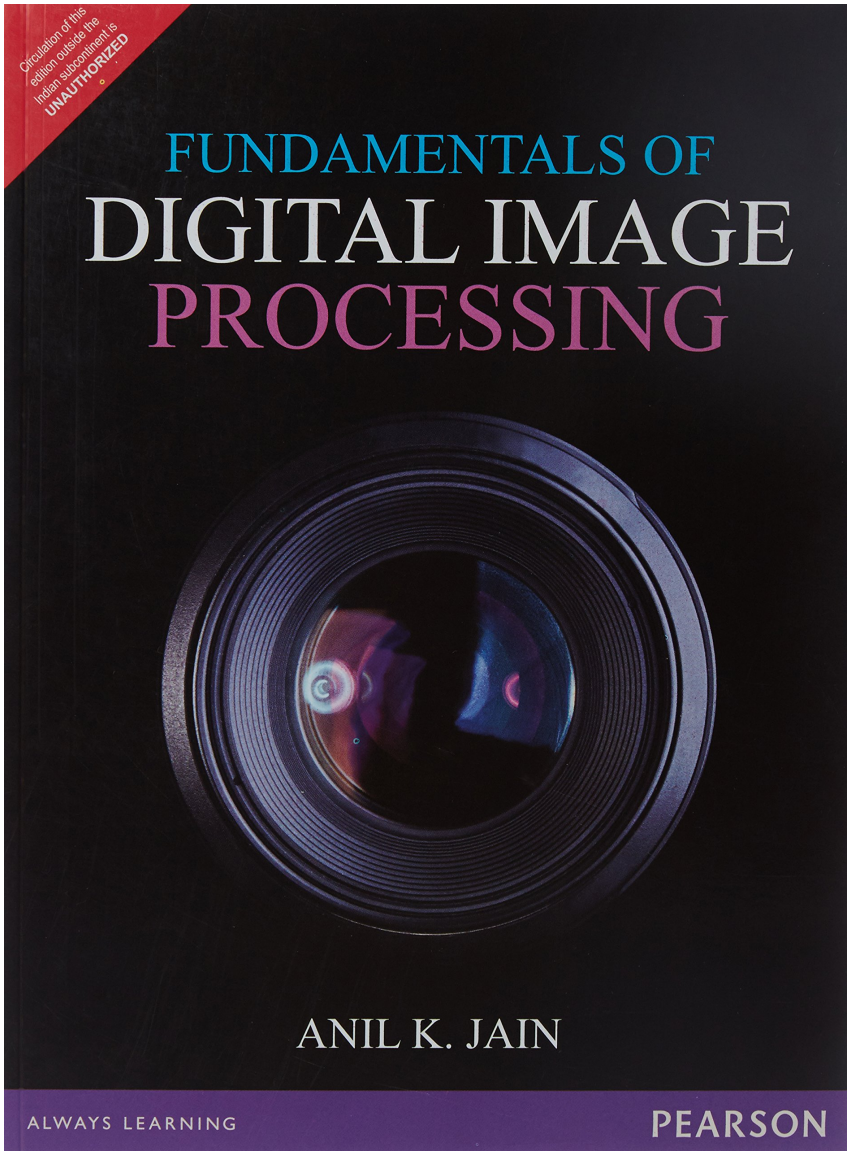
Course Evaluation Plan

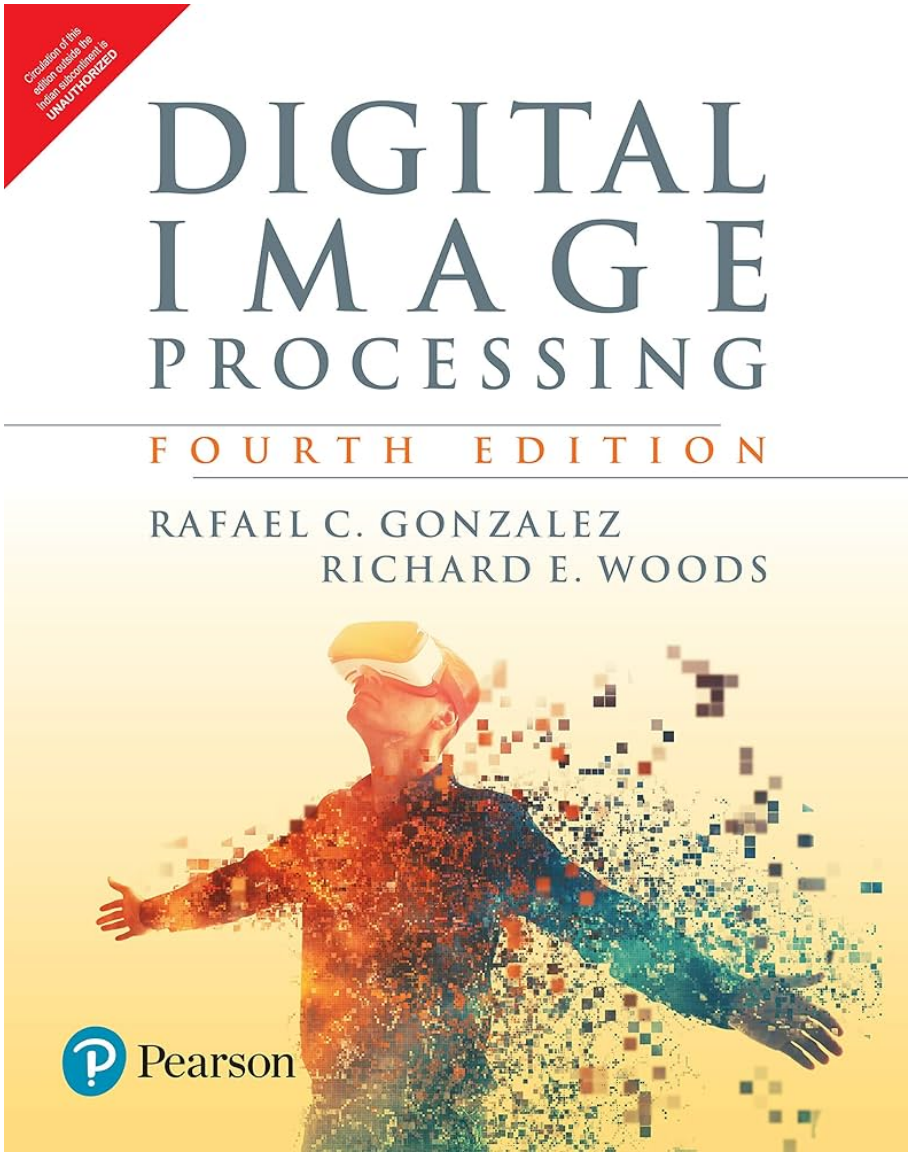
- Credit Structure – 3-Lectures, 0-Tutorials, 2-Lab/Project

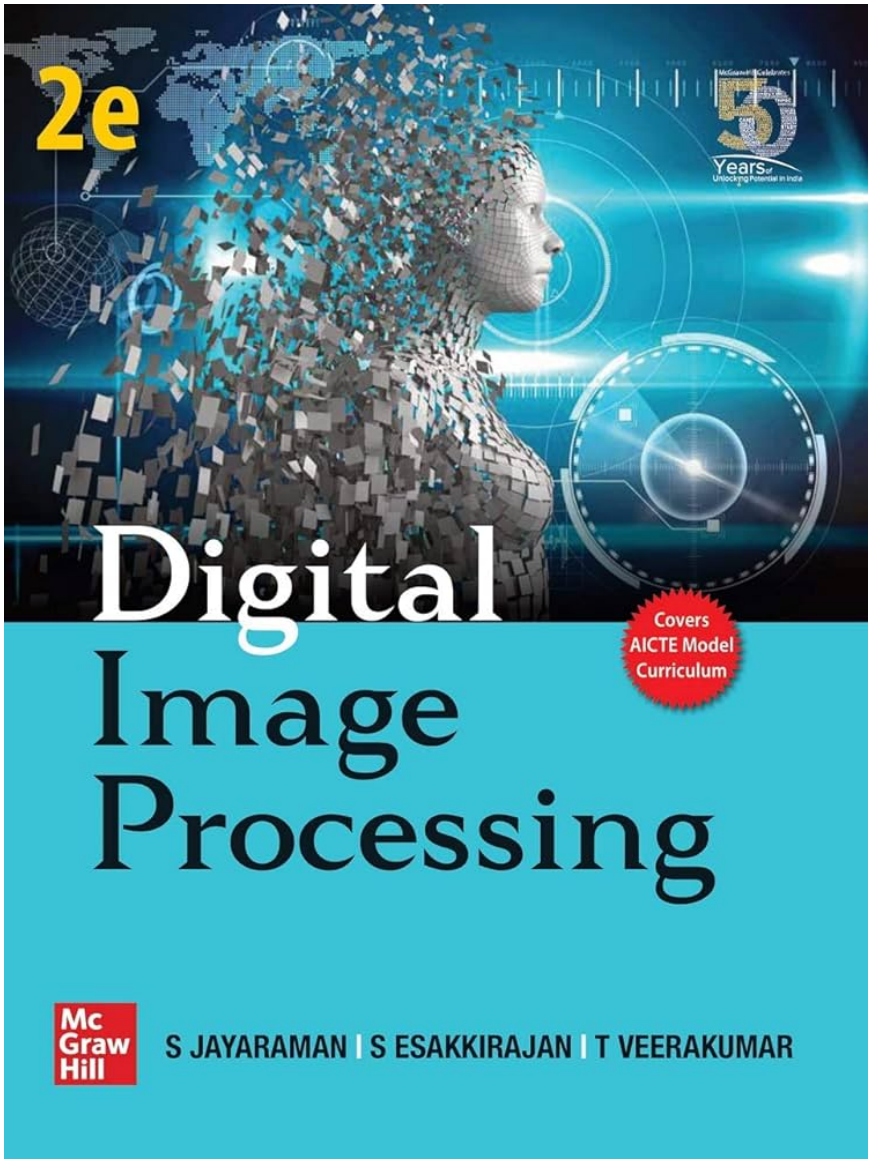
- Total Credits = 4

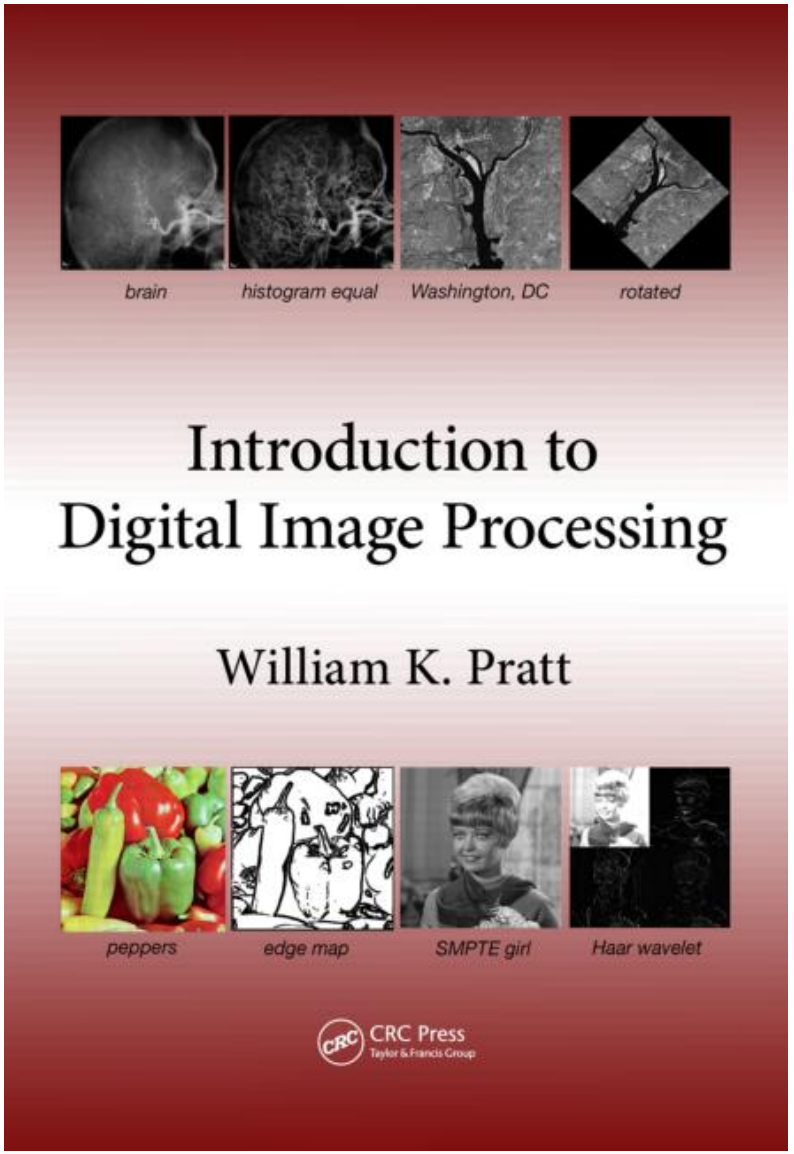
- Evaluation Distribution:
  - In-Semester Exams (1st and 2nd) – 25%
  - End-Semester Exam – 30%
  - Course Project – 20%
  - Class Quizzes, Viva, Lab Assignments and Lab Exam – 25%

Suggested Books/Literatures

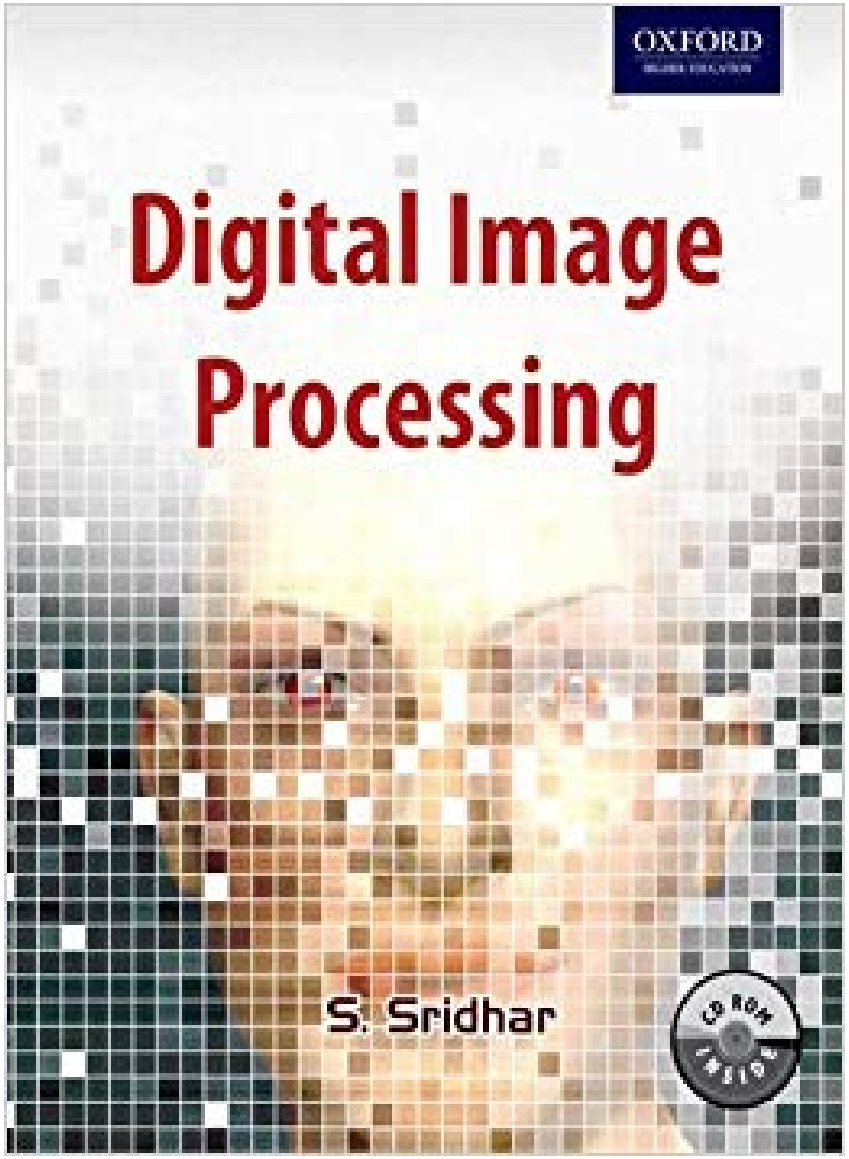


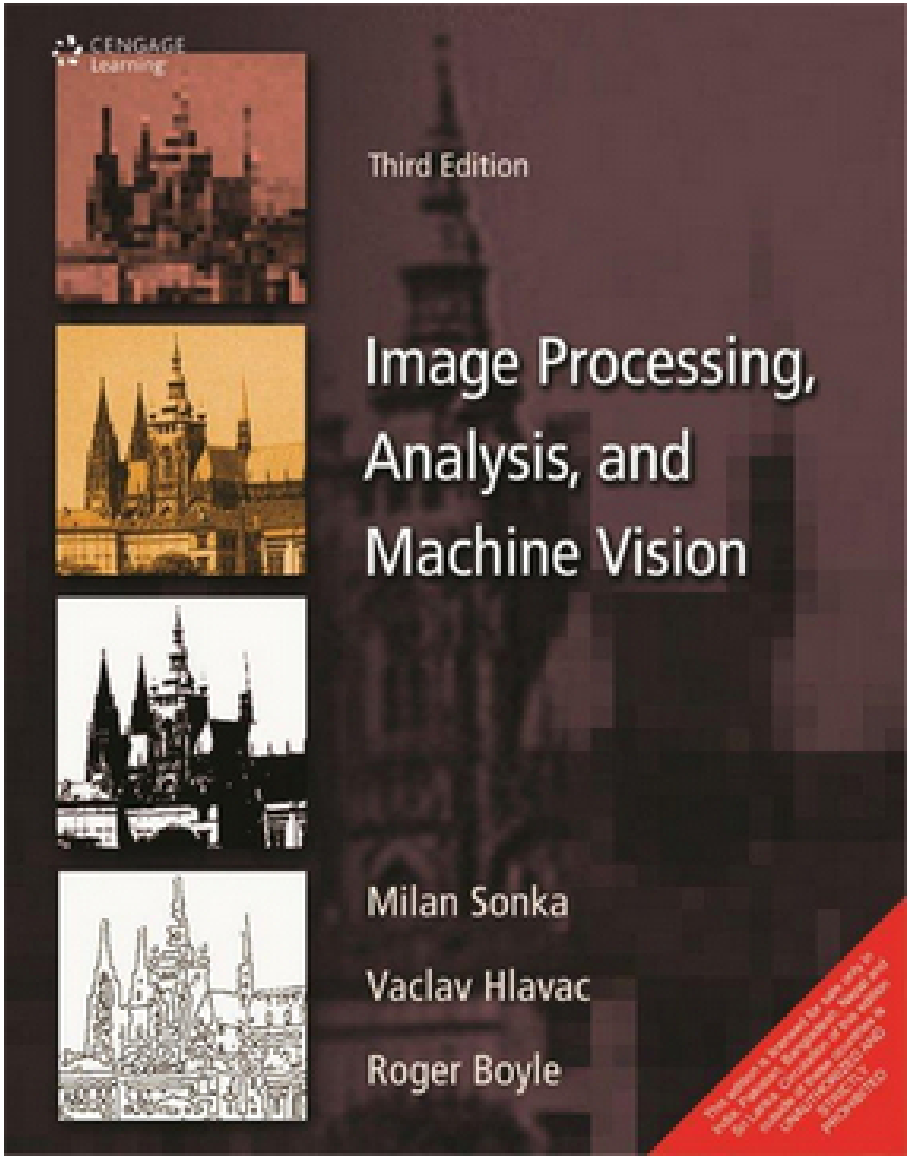



2e
Years
Digital
Image
Processing
Covers
AICTE Model
Curriculum
Mc
Graw
Hill
S JAYARAMAN | S ESAKKIRAJAN | T VEERAKUMAR

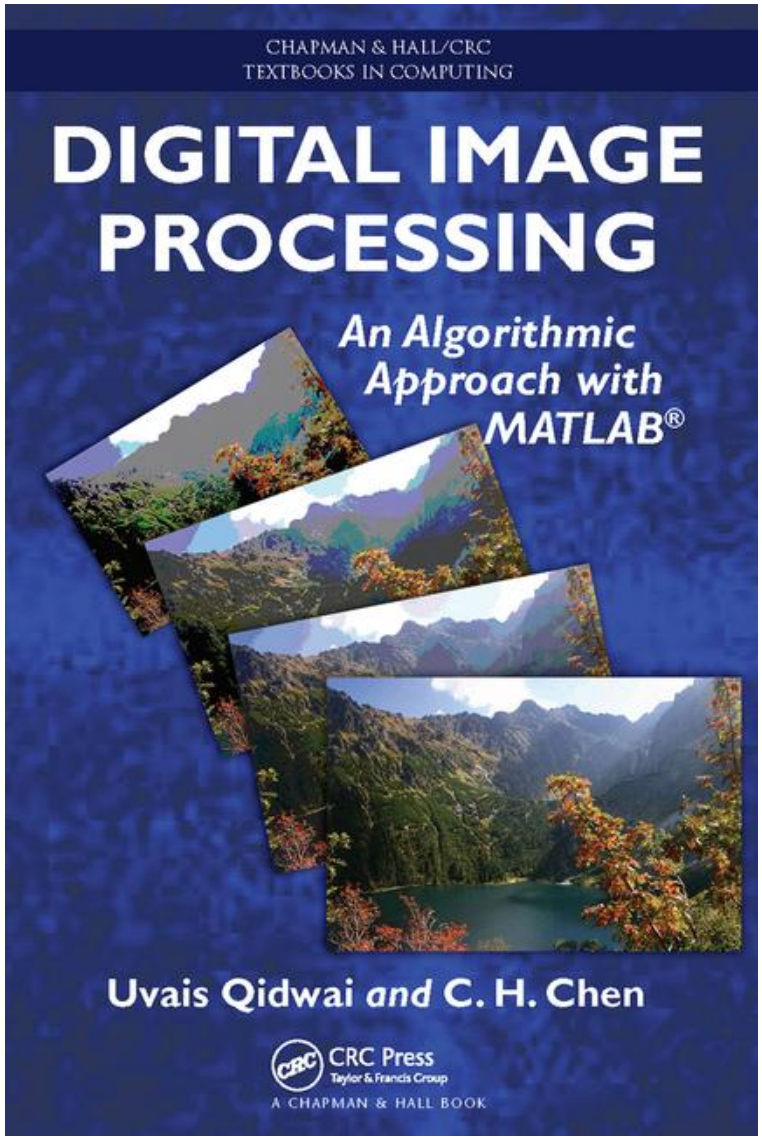

brain
histogram equal
Washington, DC
rotated
Introduction to
Digital Image Processing
William K. Pratt
peppers
edge map
SMPTE girl
Haar wavelet
CRC Press
Taylor & Francis Group

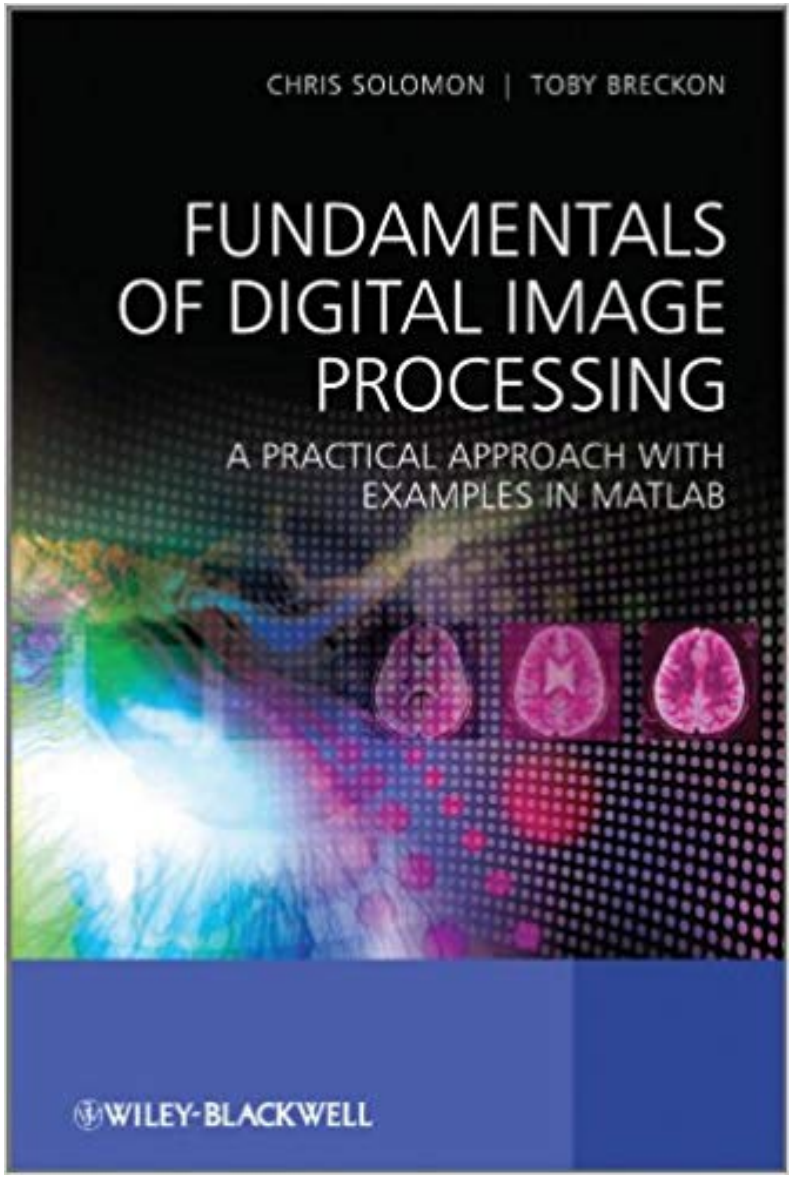
Suggested Books/Literatures





Suggested Books/Literatures





Lab Assignments

- There will be regular lab assignments, usually once a week, 5 - 8 in all.

- Programming Language: MATLAB/Python

Lecture and Lab Material

Classroom Code: foqva3p

Course Outline

- Introduction and Digital Image Fundamentals
- Image Acquisition and Digitization
- Image Transforms
- Image Enhancement in Spatial and Frequency Domain
- Image Restoration
- Color Image Processing
- Image Compression and Encoding
- Morphological Image Processing
- Feature Extraction and Segmentation
- Texture and Motion Analysis

Introduction and Digital Image Fundamentals

- A Picture is more better than 100 words.
- A Video is more than 1000 sentences
- Rich Information from visual data.
- Examples of images around us
  - Natural photographic images
  - Artistic and Engineering drawings
  - Scientific images (satellite, medical, etc.)
- Motion Picture => Video
  - Movie, TV Program, news
  - Family video
  - Surveillance and highway camera

Rodney King incident
(From George Holliday)

Why Do We Process Images?

- Enhancement and Restoration
  - Remove artifacts and scratches from an old photo/movie
  - improve contrast and correct blurred images
- Transmission and Storage
  - Images from oversea via Internet, or from a remote planet
- Information analysis and automated recognition
  - Providing "Human Vision" to machines
- Security and rights protection
  - Encryption and Watermarking

Why Digital?

- "Exactness"
  - Perfect reproduction without degradation
  - Perfect duplication of processing result
- Convenient & Powerful Computer-aided Processing
  - Can perform rather sophisticated processing through hardware or software
  - Even kindergartners can do it!
- Easy Storage and transmission
  - 1 CD can store hundred of family photos!
  - Paperless transmission of high quality photos through network within seconds

What is Digital Image Processing?

- Digital Image
  - is a two-dimensional function
  - x and y are spatial coordinates
  - The amplitude of f is called intensity or gray level at the point (x, y)
- Digital Image Processing
  - process digital images by means of computer, it covers low-, mid-, and high-level processes
    - low-level: inputs and outputs are images
    - mid-level: outputs are attributes extracted from input images
    - high-level: an ensemble of recognition of individual objects
- Pixel
  - the elements of a digital image

Tour Guide

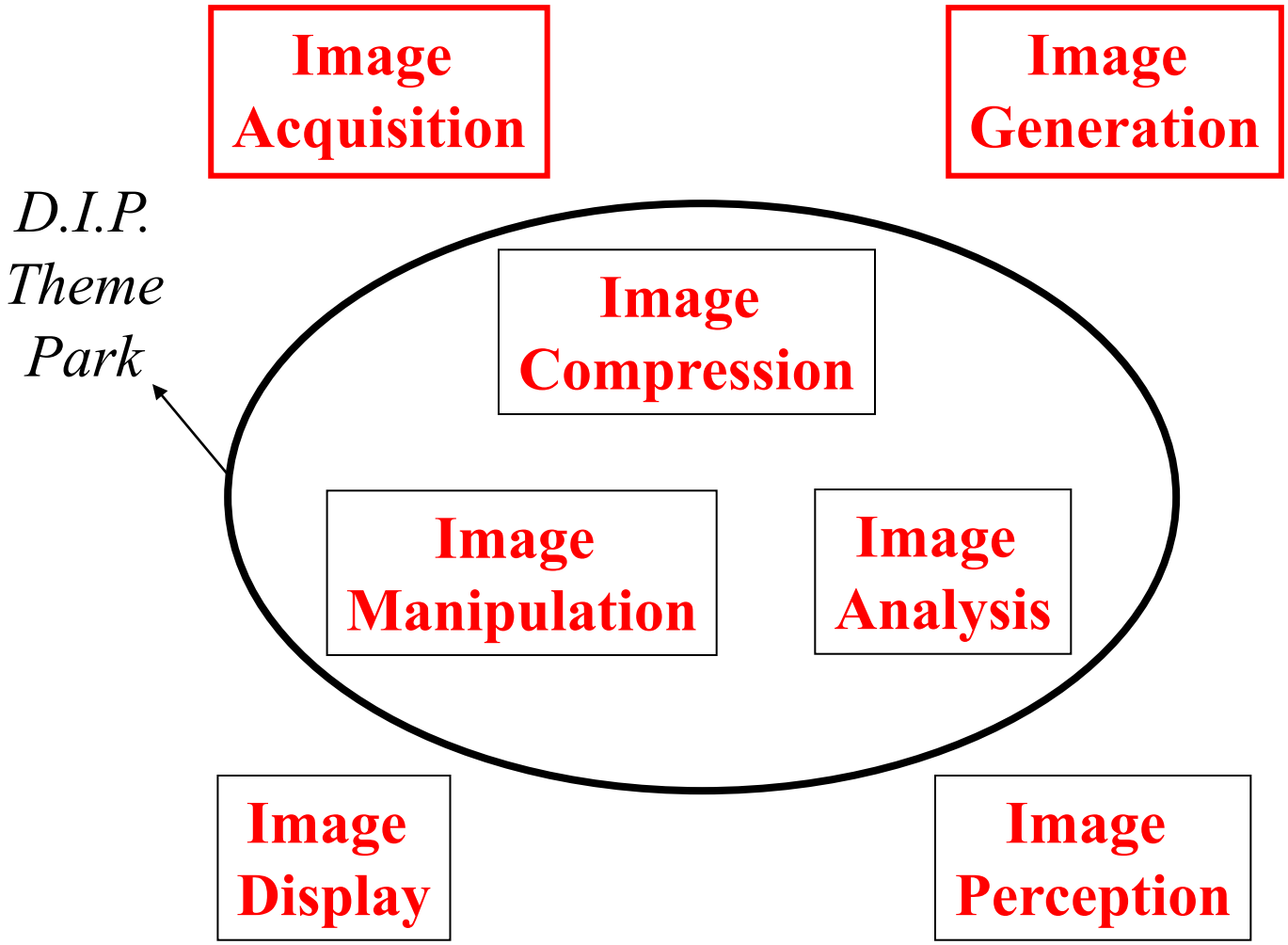


Image Acquisition
Image Generation
D.I.P. Theme Park
Image Compression
Image Manipulation
Image Analysis
Image Display
Image Perception

The first photograph in the world

Joseph Nicéphore Niépce, *View from the Window at Le Gras*, 1826.

A Historical Overview of DIP

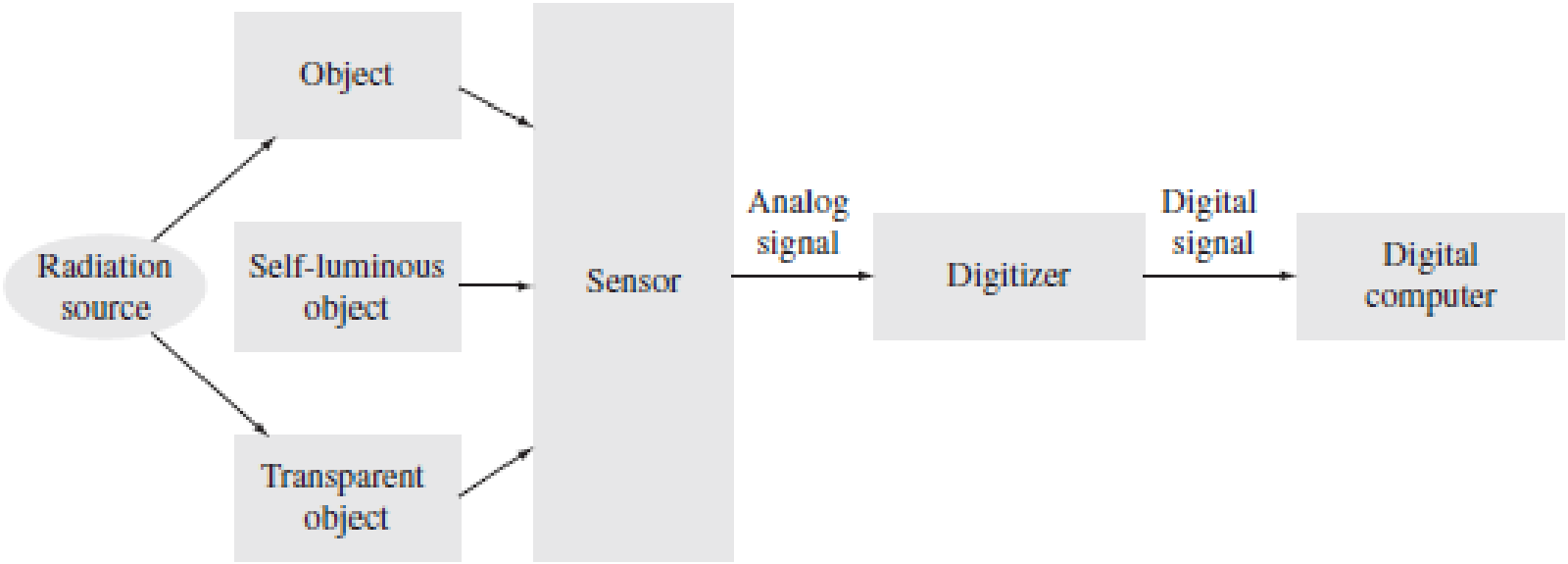
Newspaper industry used Bartlane cable picture transmission system to send pictures by submarine cable between London and New York in 1920s

Nature of Image Processing

- Images are everywhere! Sources of Images are paintings, photographs in magazines, Journals, Image galleries, digital Libraries, newspapers, advertisement boards, television and Internet.

- In image processing, the term ‘image’ is used to denote the image data that is sampled, quantized, and readily available in a form suitable for further processing by digital computers.

IMAGE PROCESSING ENVIRONMENT



Reflective mode Imaging

- *Reflective mode imaging* represents the simplest form of imaging and uses a sensor to acquire the digital image. All video cameras, digital cameras, and scanners use some types of sensors for capturing the image.

Emissive type imaging

- *Emissive type imaging* is the second type, where the images are acquired from self-luminous objects without the help of a radiation source. In emissive type imaging, the objects are self-luminous. The radiation emitted by the object is directly captured by the sensor to form an image. Thermal imaging is an example of emissive type imaging.

Transmissive imaging

- *Transmissive imaging* is the third type, where the radiation source illuminates the object. The absorption of radiation by the objects depends upon the nature of the material. Some of the radiation passes through the objects. The attenuated radiation is sensed into an image.

Image Processing

- *Analog image processing* is an area that deals with the processing of analog electrical signals using analog circuits. The imaging systems that use film for recording images are also known as analog imaging systems.

- *Optical image processing* is an area that deals with the object, optics, and how processes are applied to an image that is available in the form of reflected or transmitted

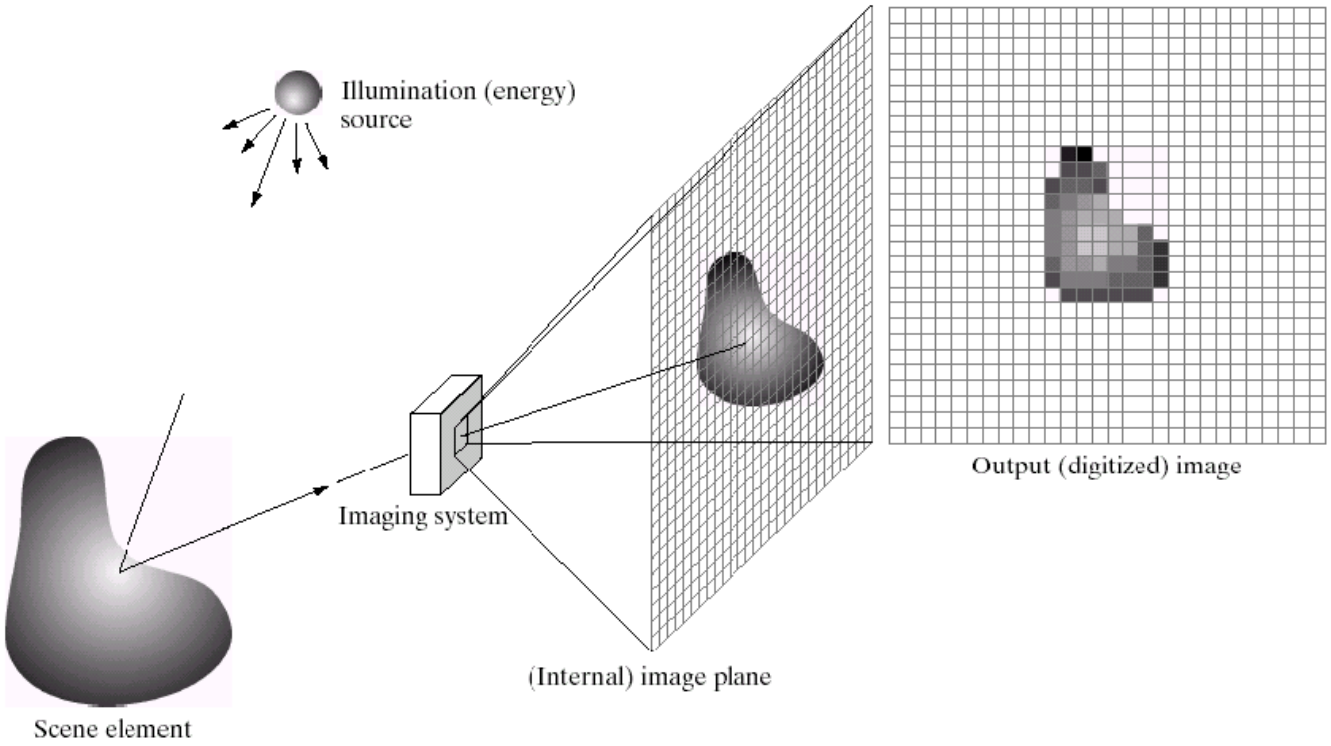
WHAT IS AN IMAGE ?

- A digital image is an array of real or complex numbers represented by a finite no. of bits.

- An image may be defined as a two-dimensional function f(x,y), where x & y are plane coordinates, and the amplitude of f at any pair of coordinates (x,y) is called the intensity or gray levels of the image at that point.

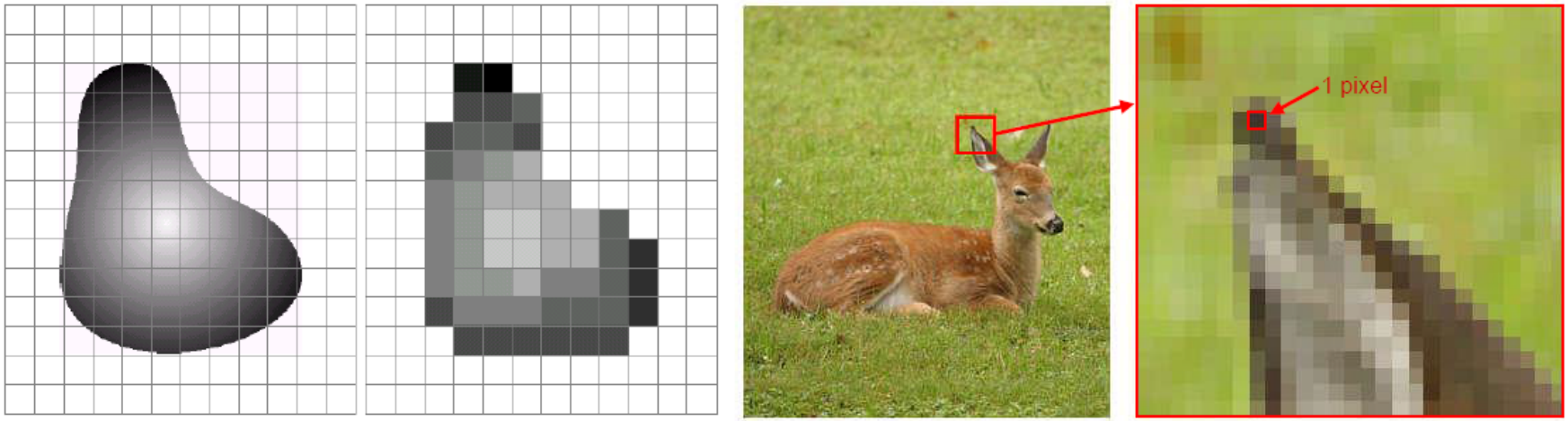
What is Digital Image?

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



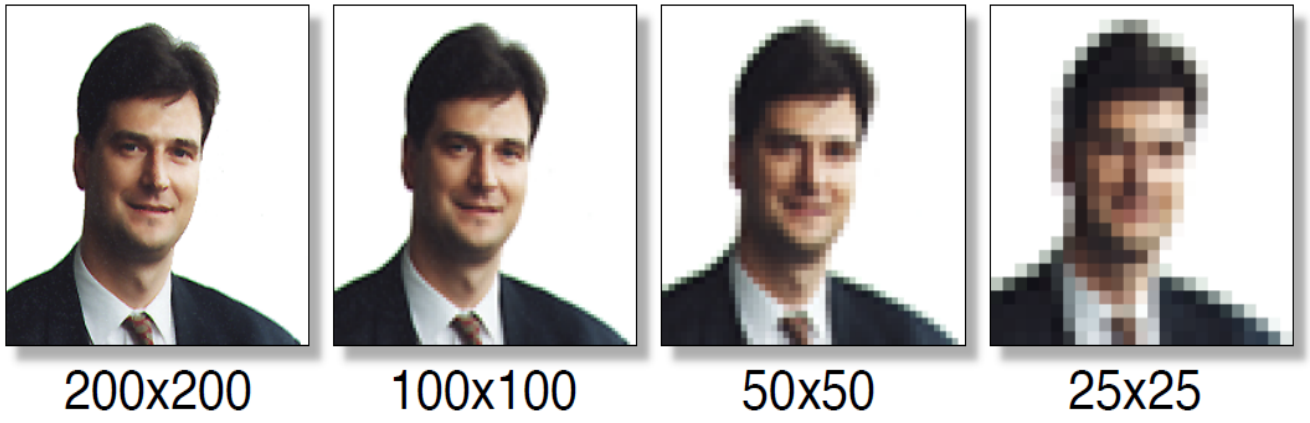
- Pixel values typically represent gray levels, colors, heights, opacities etc.

- Remember, digitization implies that a digital image is an approximation of a real scene



Digital Images and Pixels

- Digital Image: discrete samples *f[x,y]* is representing continuous image *f(x,y)*.
- Each element of the 2-d array *f[x,y]* is called a pixel or pel (picture element)



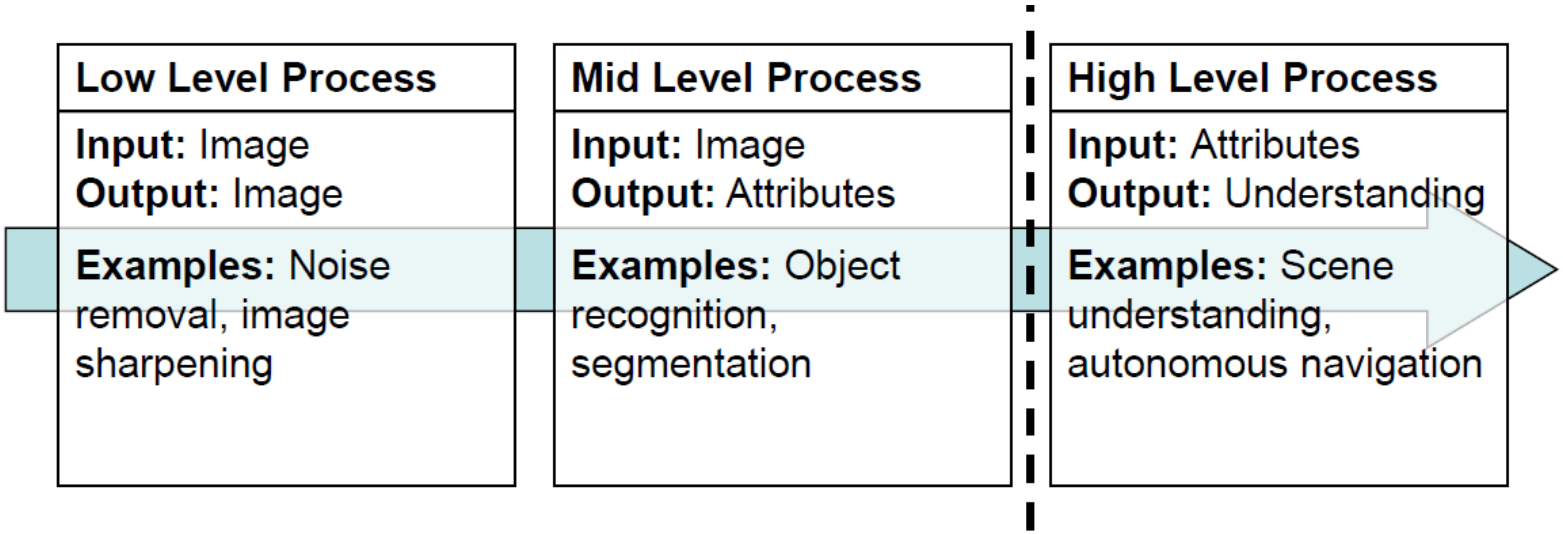
What is Digital Image Processing?

- *Digital image processing* is an area that uses digital circuits, systems, and software algorithms to carry out the image processing operations. The image processing operations may include quality enhancement of an image, counting of objects, and image analysis.

- Digital image processing focuses on two major tasks
  - –Improvement of pictorial information for human interpretation
  - –Processing of image data for storage, transmission and representation for autonomous machine perception.

- Some argument about where image processing ends and fields such as image analysis and computer vision start

- The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes



In this course we will stop here

Why do we process images?

- Acquire an image
  - Correct aperture and color balance
  - Reconstruct image from projections
- Prepare for display or printing
  - Adjust image size
  - Color mapping, gamma-correction, halftoning
- Facilitate picture storage and transmission
  - Efficiently store an image in a digital camera
  - Send an image from space
- Enhance and restore images
  - Touch up personal photos
  - Color enhancement for security screening
- Extract information from images
  - Read 2-D bar codes
  - Character recognition
- Many more....
  - Image processing in ubiquitous







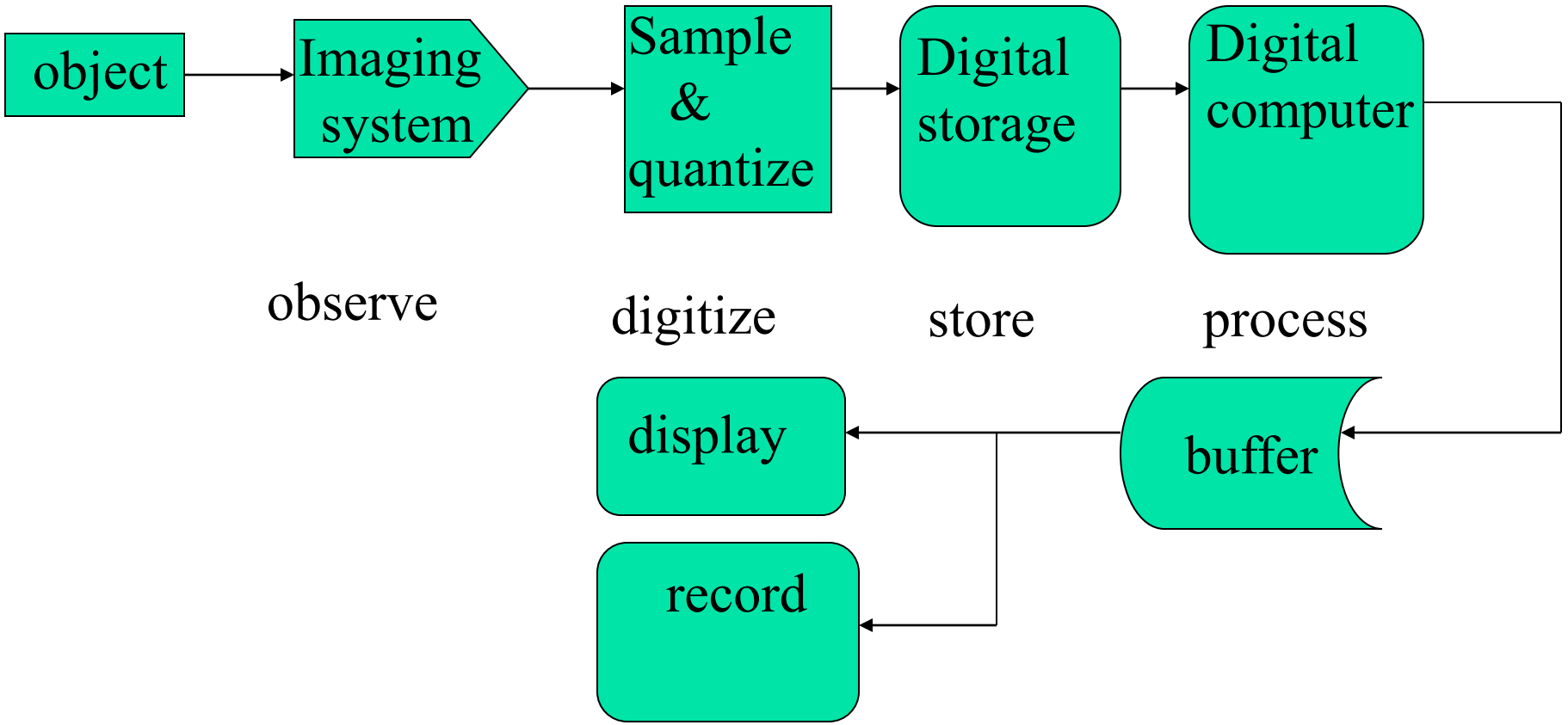


Steps of Digital Image Processing Methods

1. Improvement of pictorial information for human interpretation

2. Processing of image data for storage, transmission, and representation for autonomous machine perception.

Typical digital image processing sequence



History of DIP

- **Early 1920s:** One of the first applications of digital imaging was in the news- paper industry
  - –The Bartlane cable picture transmission service
  - –Images were transferred by submarine cable between London and New York
  - –Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer

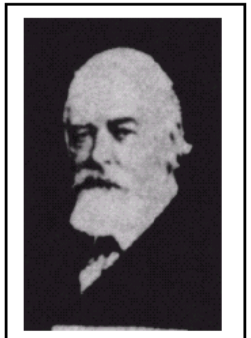
Early digital image

FIGURE 1.1 A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.[†])

Mid to late 1920s:

Improvements to the Bartlane system resulted in higher quality images

- –New reproduction processes based on photographic techniques
- –Increased number of tones in reproduced images



Improved digital image

Early 15 tone digital image

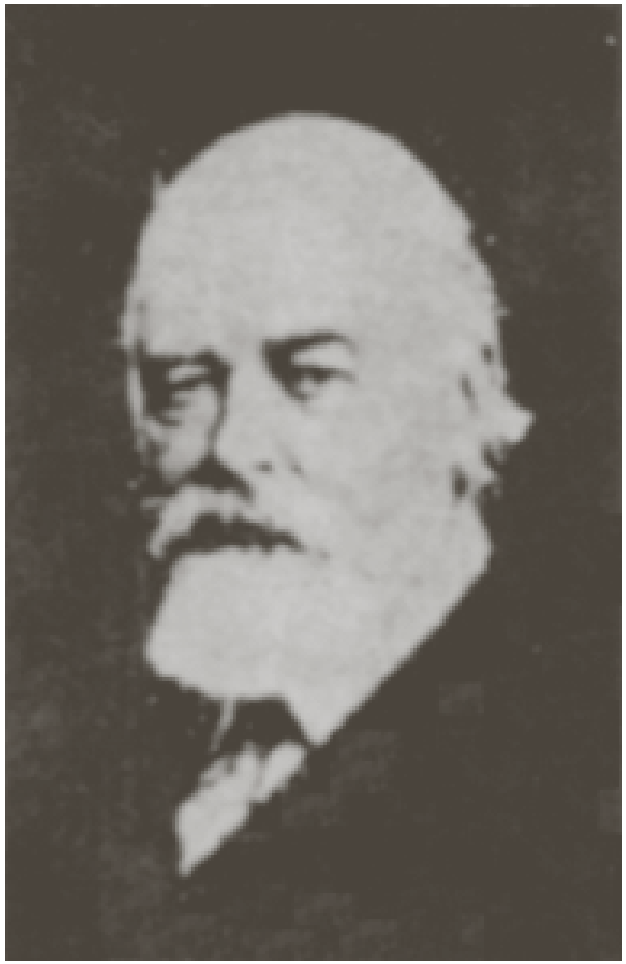
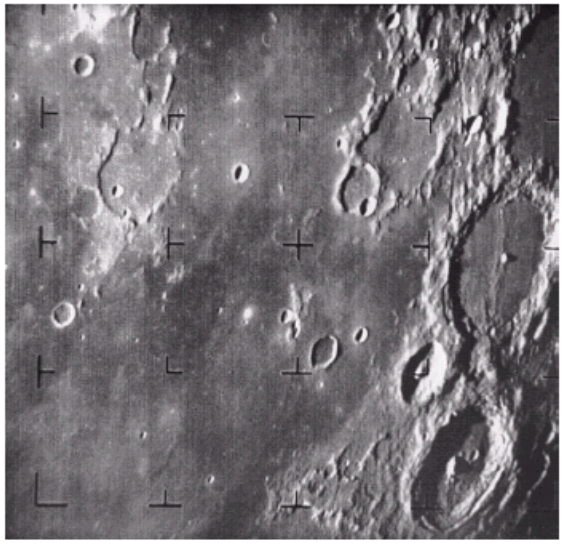


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)

FIGURE 1.3
Unretouched cable picture of Generals Pershing and Foch, transmitted in 1929 from London to New York by 15-tone equipment. (McFarlane.)

- **1960s:** Improvements in computing technology and the onset of the space race led to a surge of work in digital image processing
  - –**1964:** Computers used to improve the quality of images of the moon taken by the *Ranger 7* probe
  - –Such techniques were used in other space missions including the Apollo landings



A picture of the moon taken by the Ranger 7 probe minutes before landing

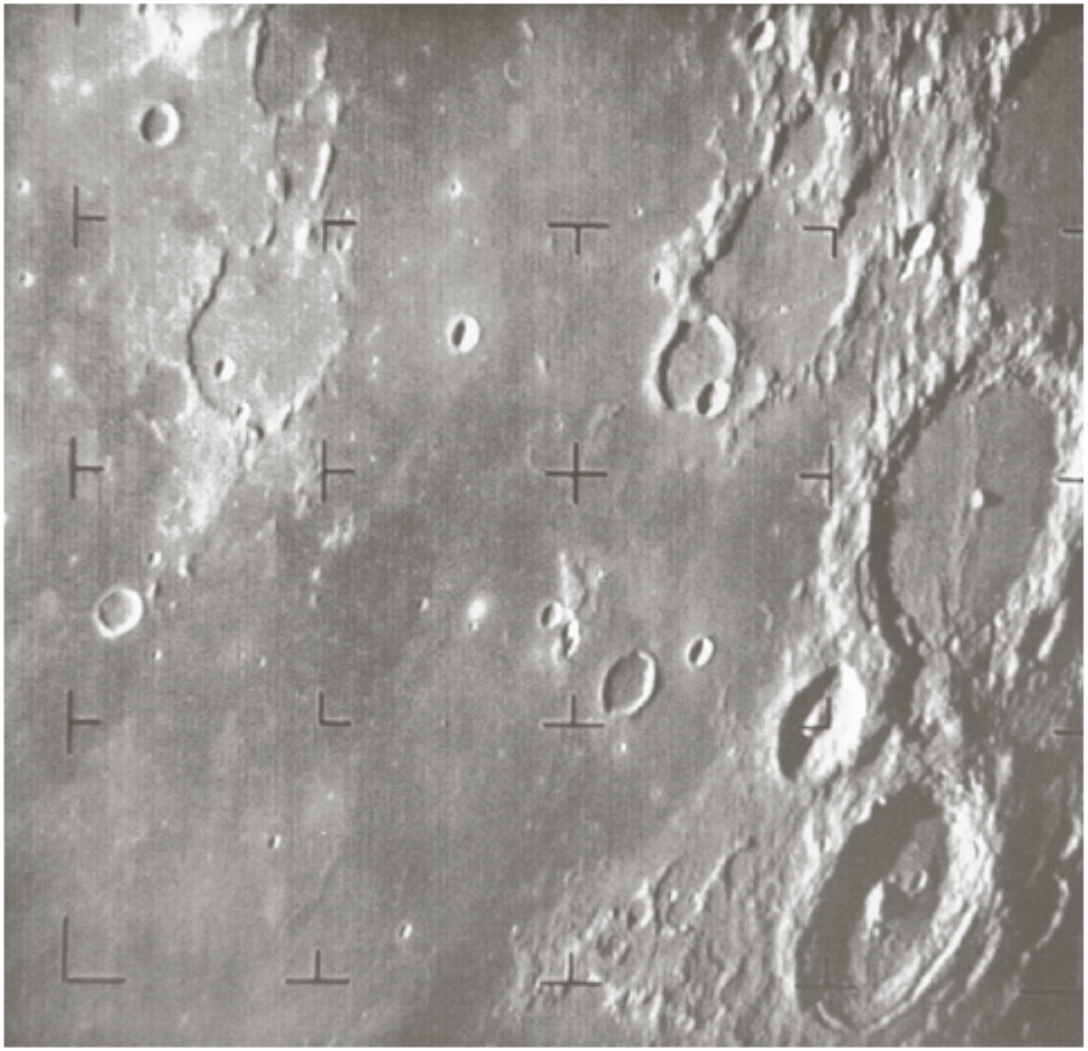


FIGURE 1.4 The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9 : 09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

- **1970s:** Digital image processing begins to be used in medical applications
  - **–1979:** Sir Godfrey N. Hounsfield & Prof. Allan M. Cormack share the Nobel Prize in medicine for the invention of tomography, the technology behind Computerised Axial Tomography (CAT) scans

Typical head slice CAT image

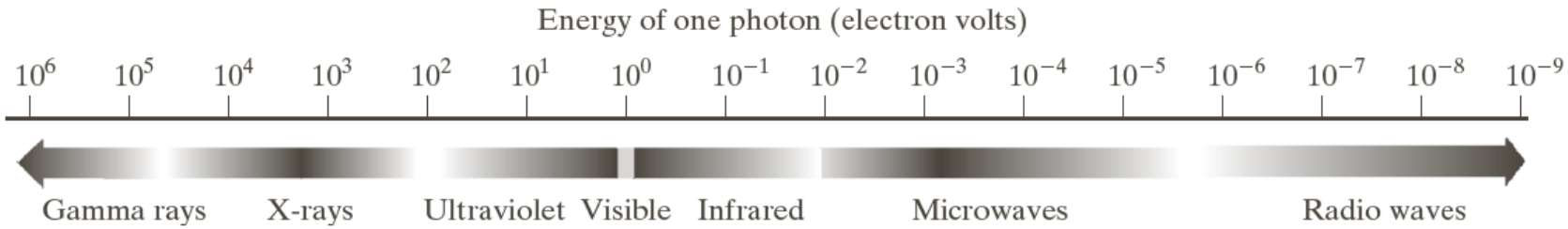
- **1980s - Today:** The use of digital image processing techniques has exploded and they are now used for all kinds of tasks in all kinds of areas
  - Image enhancement/restoration
  - Artistic effects
  - Medical visualisation
  - Industrial inspection
  - Law enforcement
  - Human computer interfaces

The Boom of Digital Images in the Last 20 Years

- Acquisition
  - Digital cameras, scanners
  - MRI and Ultrasound imaging
  - Infrared and microwave imaging
- Transmission
  - Internet, satellite and wireless communication
- Storage
  - CD/DVD, Blu-ray
  - Flash memory, Phase-change memory
- Display
  - Printers, LCD monitor, digital TV
  - Portable DVD player, PDAs, cell-phone

A Physical Perspective of Image Acquisition

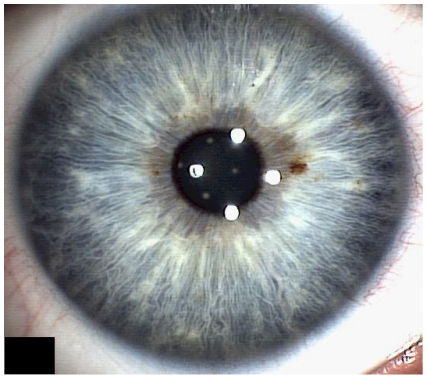
- Extend the capabilities of human vision systems
  - From visible spectrum to non-visible electromagnetic power spectrum
  - From close-distance sensing to remote sensing



Visible (I): Photography

Visible (II): Motion Pictures

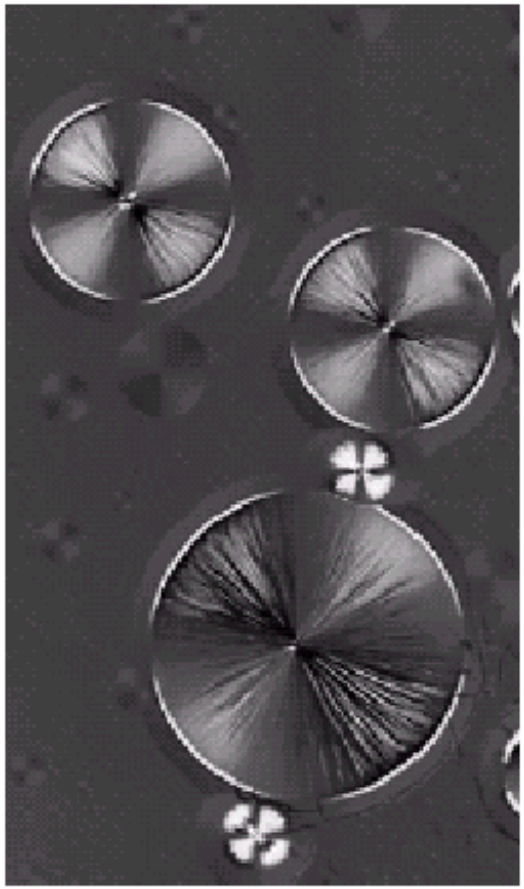
Visible (III): Biometrics and Forensics



You=ID

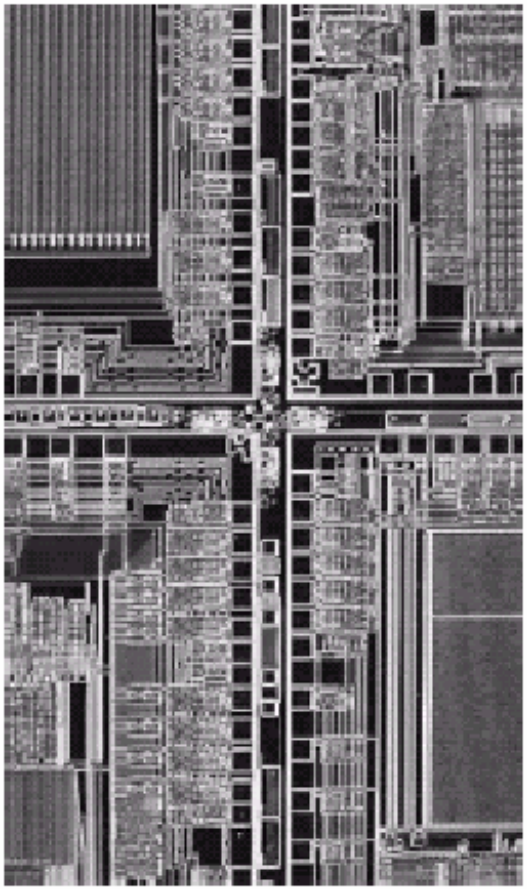
Real or PS?

Visible (IV): Light Microscopy



Taxol (250×)

Cholesterol (40×)



Microprocessor (60×)

Visible (V): Remote Sensing

Earth at night (Only Asia/Europe shown)

Visible (VI): Mobile Imaging

http://en.wikipedia.org/wiki/FingerWorks

Visible (VII): Light Field Camera

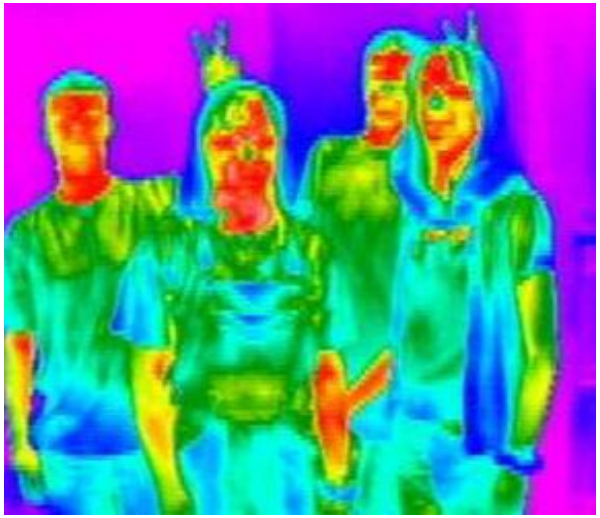
https://www.lytro.com/camera

In-Class Discussions

- Do you know how a smartphone camera works (e.g., CCD vs. CMOS)?
- How to acquire a large view in the physical world (e.g., 360-view of a room or grand canyon)?
- How to acquire a photo under low illumination conditions (e.g., dark theatre)?

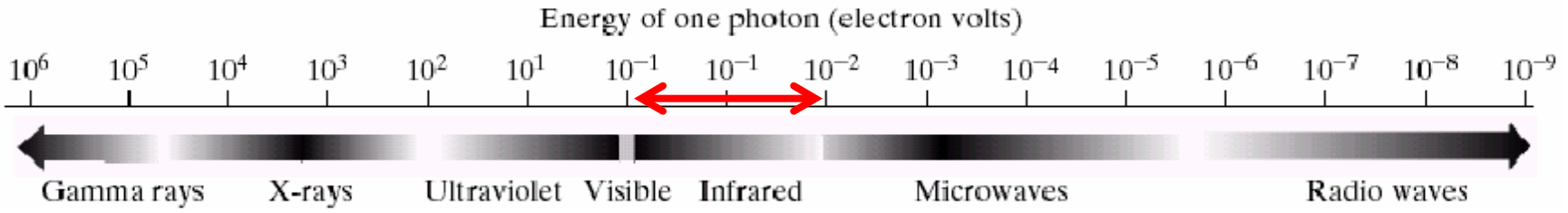
Beyond Visible (I): Thermal Images

Operate in infrared frequency



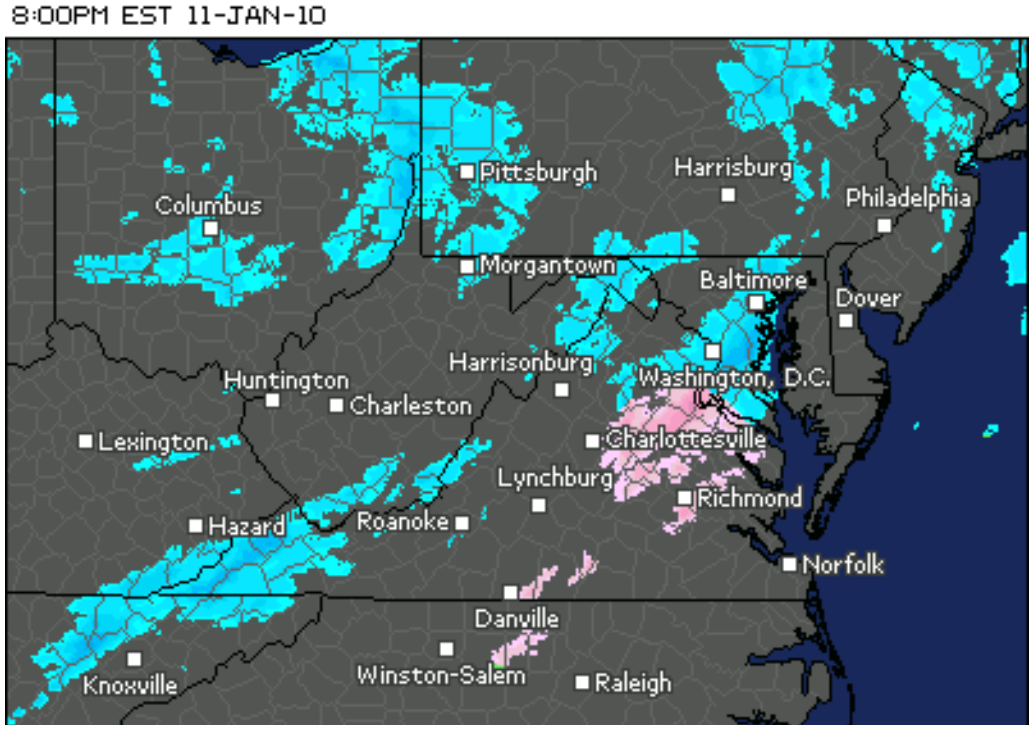
Human body disperses heat (red pixels)

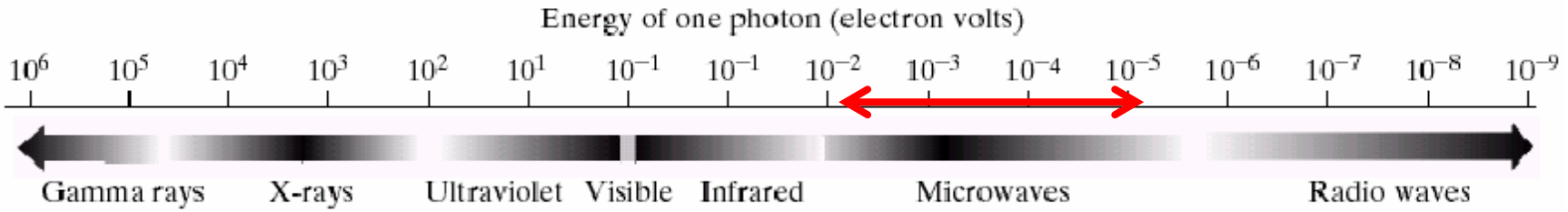
Autoliv's night vision system on the BMW 7 series



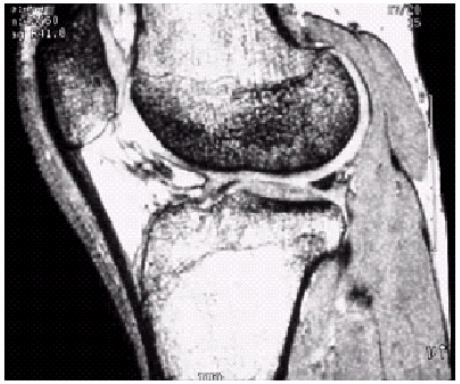
Beyond Visible (II): Radar Images

Operate in microwave frequency



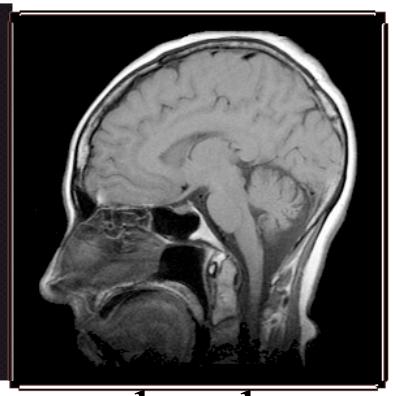


Beyond Visible (III): MRI and Astronomy

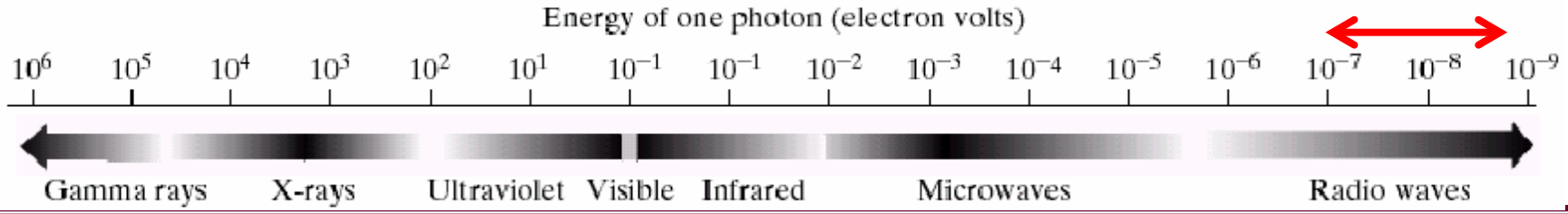


knee

spine



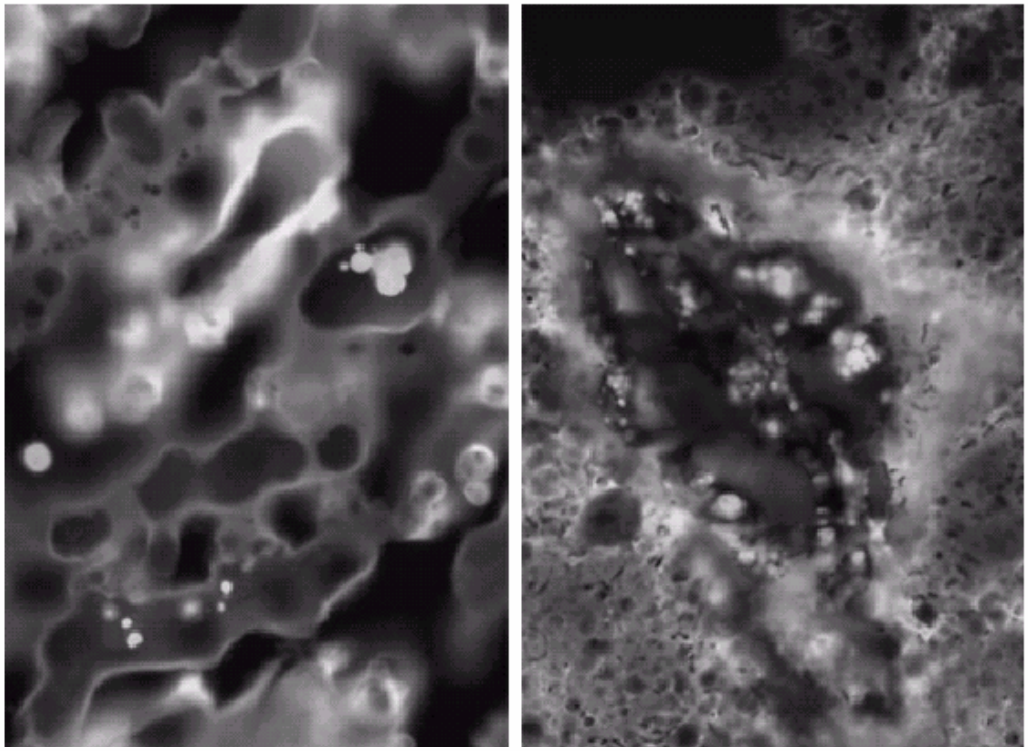
head



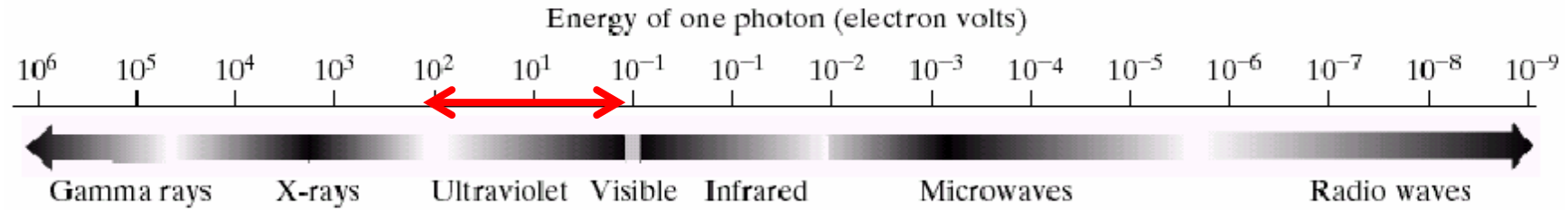
Beyond Visible (IV): Fluorescence Microscopy

Operate in ultraviolet frequency

normal corn

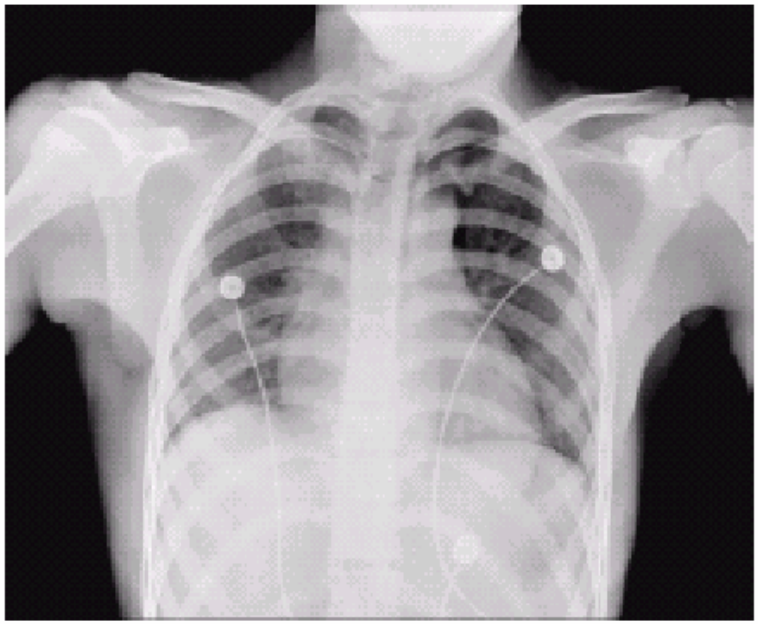


smut corn

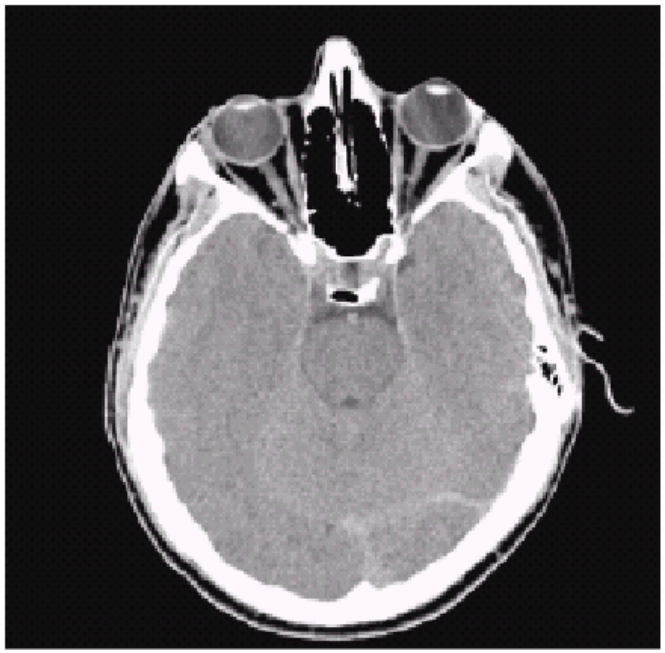


Beyond Visible (V): Medical Diagnostics

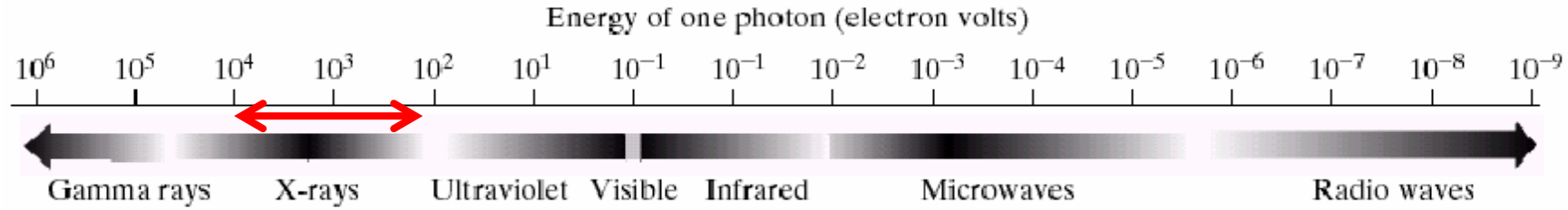
Operate in X-ray frequency



chest



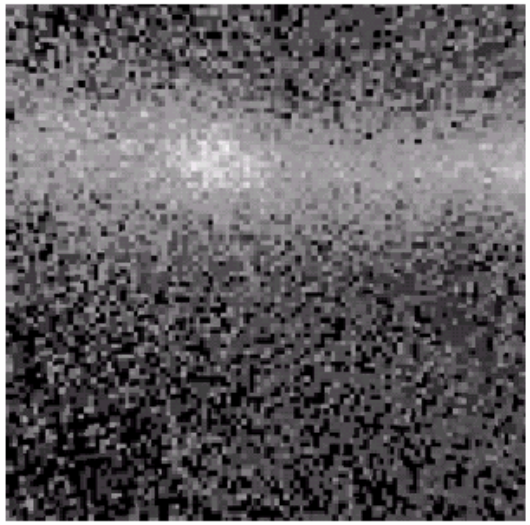
head



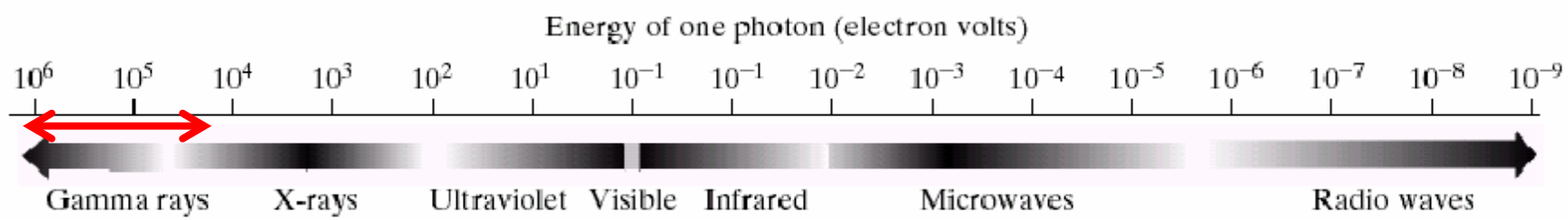
Beyond Visible (VI): PET and Astronomy

Operate in gamma-ray frequency

Positron Emission Tomography



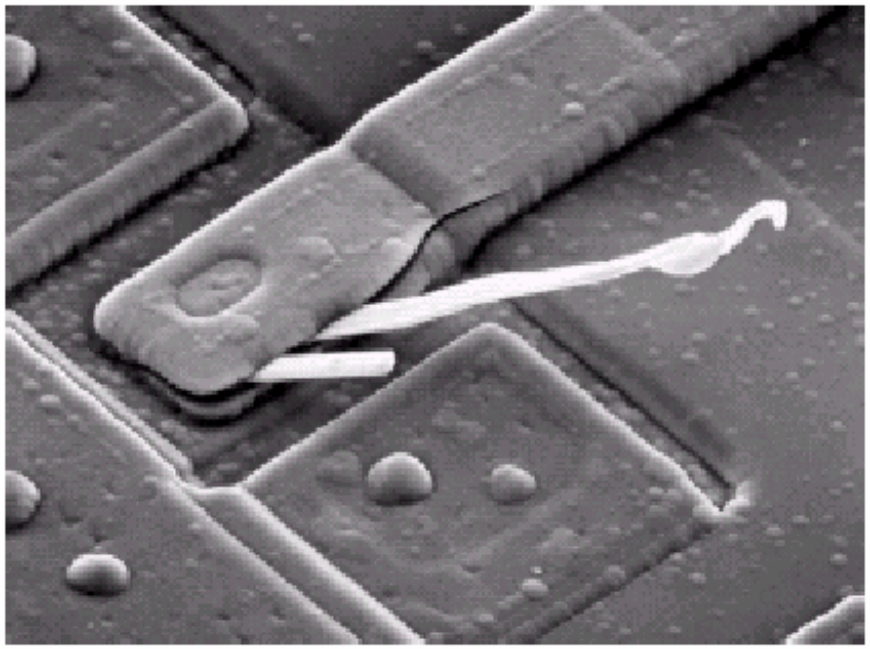
Cygnus Loop in the constellation of Cygnus



Other Non-Electro-Magnetic Imaging Modalities

- Acoustic imaging
  - Translate “sound waves” into image signals
  - Ultrasound imaging
- Electron microscopy
  - Shine a beam of electrons through a specimen
  - Transmission electron microscopy (TEM) vs. scanning electron microscopy (SEM)
- Synthetic images in Computer Graphics
  - Computer generated (non-existent in the real world)

Electron Microscope



2500× Scanning Electron Microscopy (SEM) image of damaged integrated circuit
(white fibers are oxides resulting from thermal destruction)

http://physics.unt.edu/stm-sem-and-afm

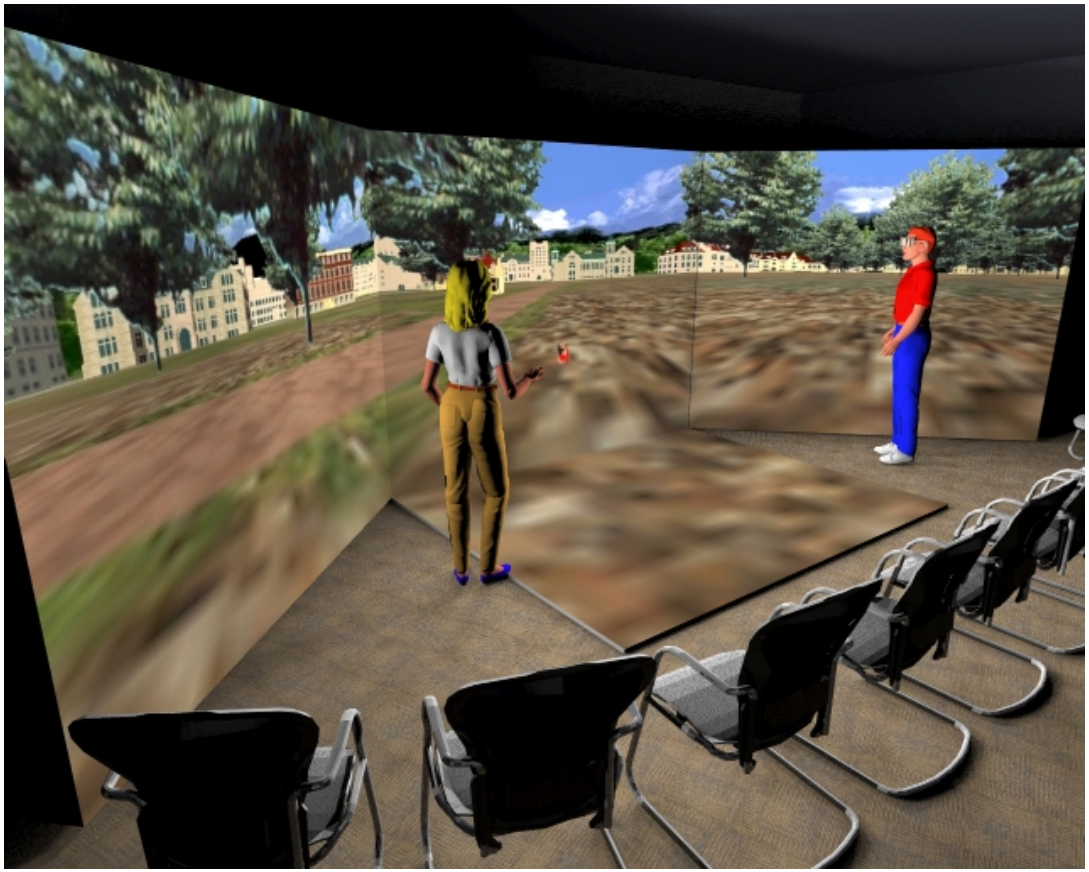
Cartoon Pictures (Non-photorealistic)

Hayao Miyazaki'2008

Synthetic Images in Gaming

League of Legends (MOBA)

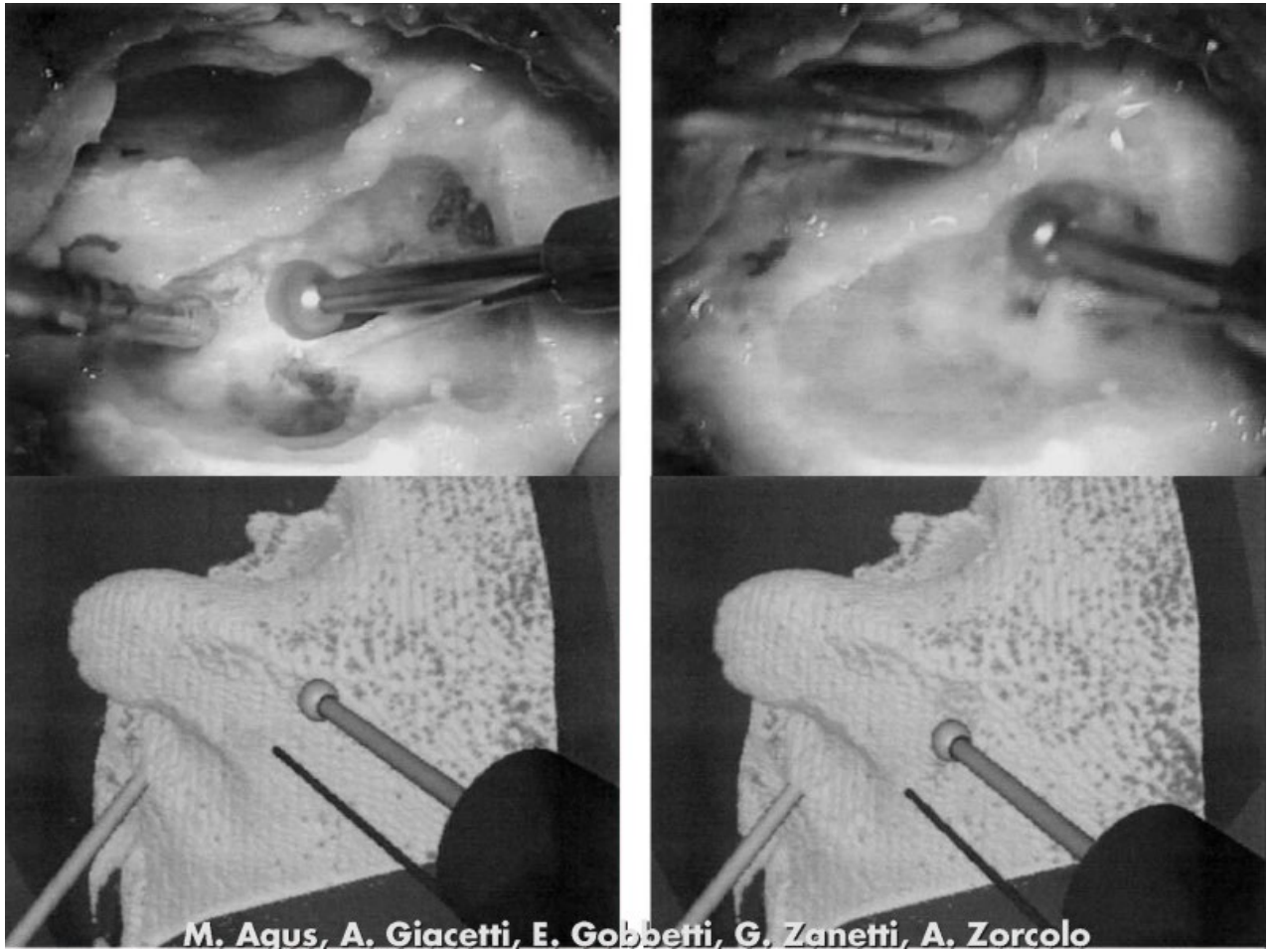
Virtual Reality (Photorealistic)



Graphics in Art

What is wrong with this picture?

Graphics in Medicine



Virtual surgery (surgery simulator)

Mixture of Graphics and Photos

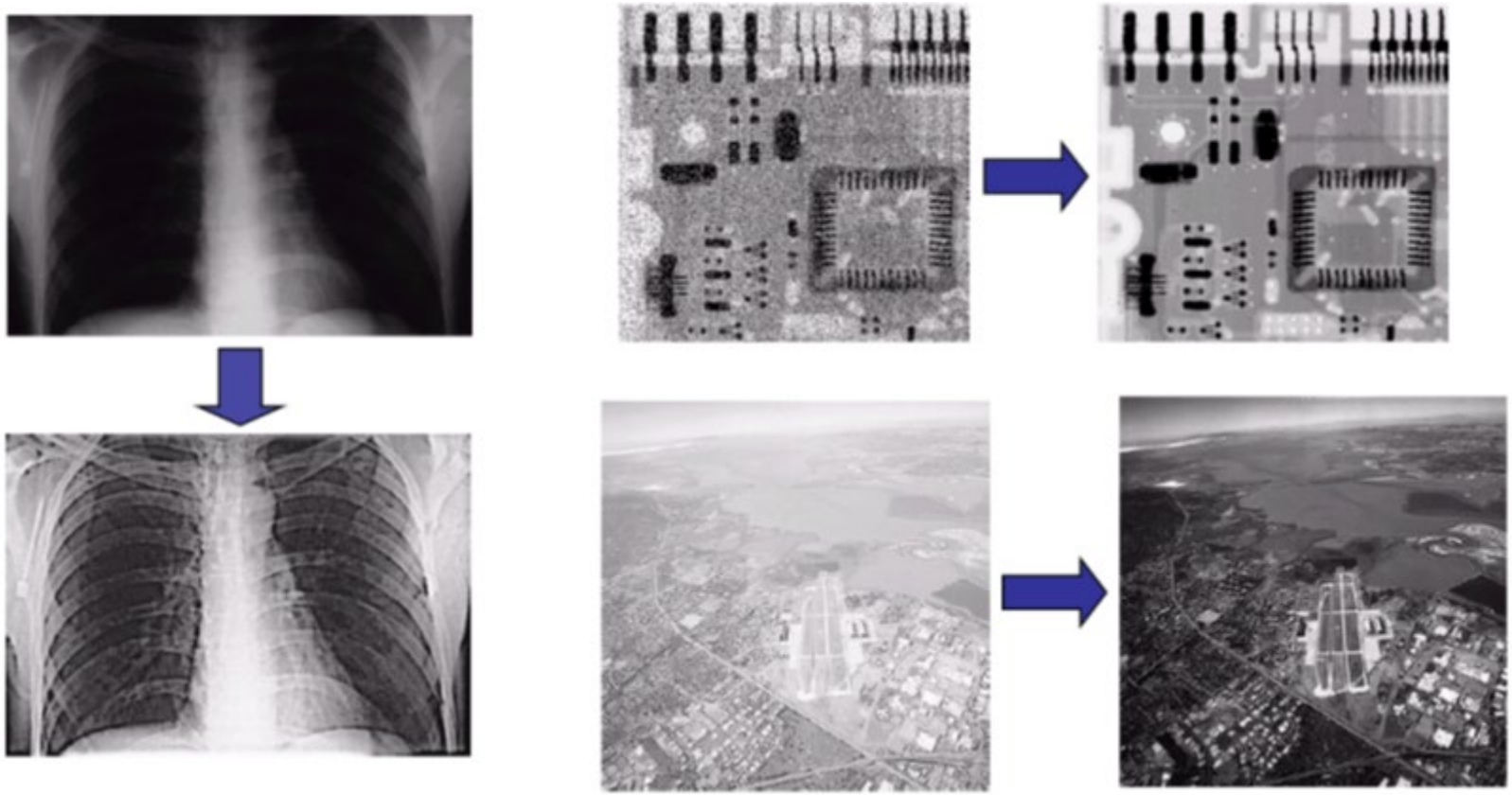
Morgantown, WV in Google Map

Application of DIP

- Some of the major fields in which digital image processing is widely used are mentioned below
  - Image sharpening and restoration
  - Medical field
  - Remote sensing
  - Transmission and encoding
  - Machine/Robot vision
  - Color processing
  - Pattern recognition
  - Video processing
  - Microscopic Imaging
  - Others

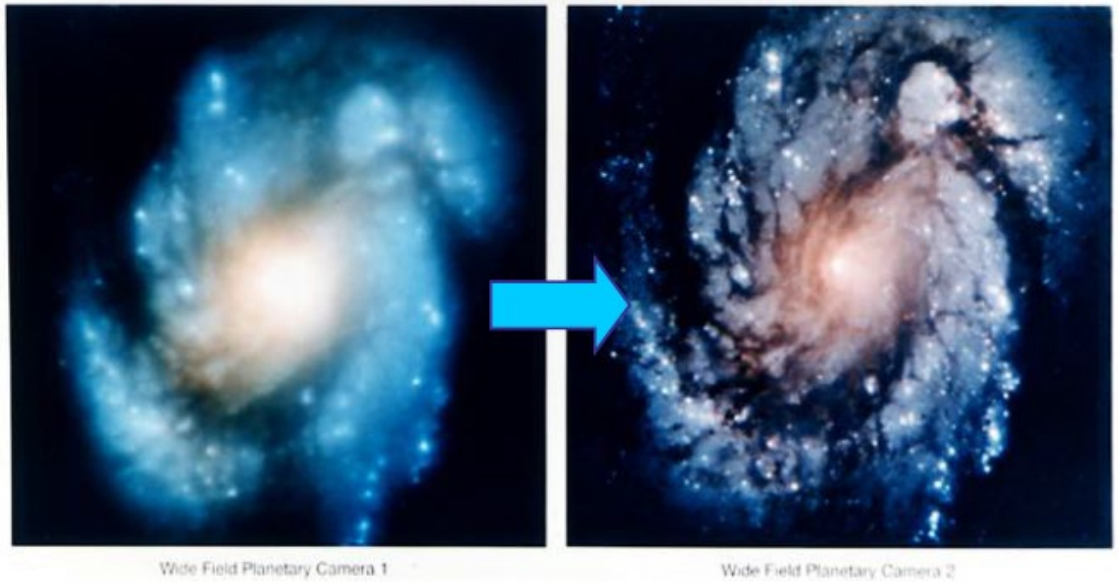
Applications of DIP

- **Image Enhancement**: One of the most common uses of DIP techniques: improve quality, remove noise etc



Applications of DIP

- **The Hubble Telescope**: Launched in 1990 the Hubble telescope can take images of very distant objects However, an incorrect mirror made many of Hubble's images useless then Image processing techniques were used to fix this

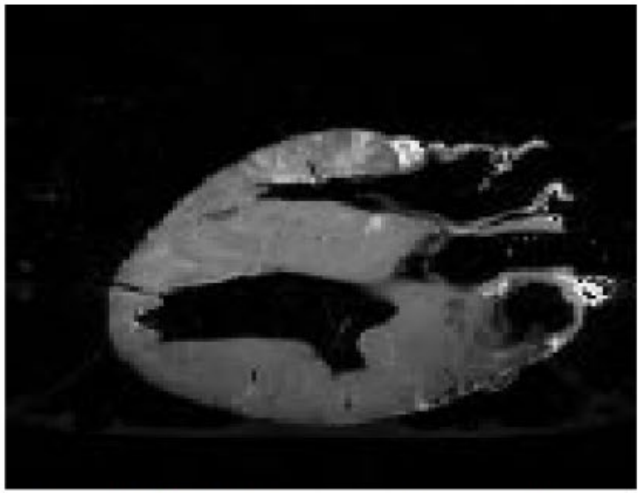


Applications of DIP

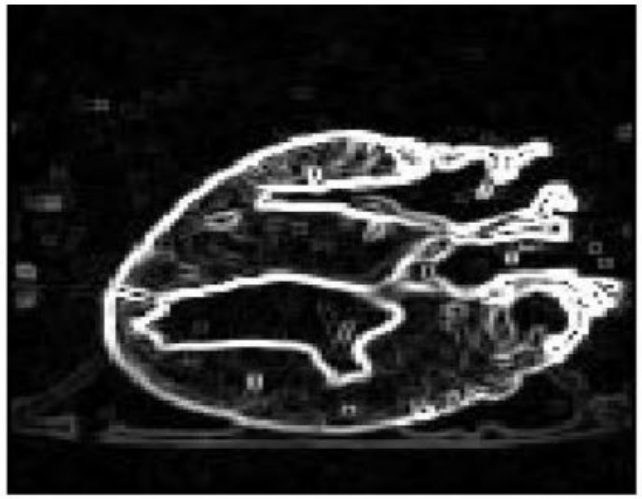
- **Artistic Effects**: Artistic effects are used to make images more visually appealing, to add special effects and to make composite images

Applications of DIP

- **Medicine**: Take slice from MRI scan of canine heart, and find boundaries between types of tissue
  - Image with gray levels representing tissue density
  - Use a suitable filter to highlight edges



Original MRI Image of a Dog Heart



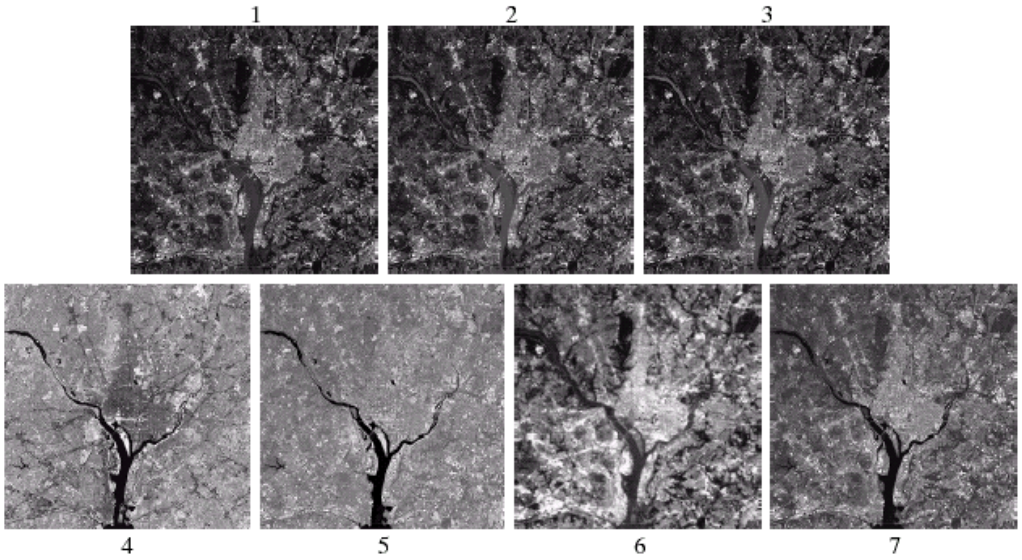
Edge Detection Image

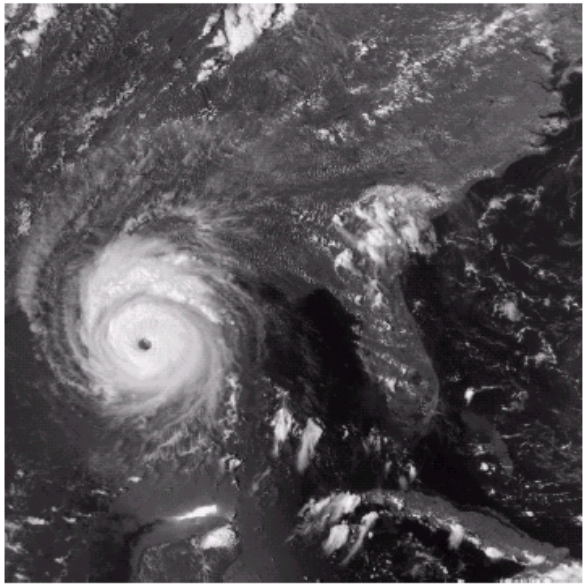
Applications of DIP

- **GIS:**
- Geographic Information Systems
  - Digital image processing techniques are used extensively to manipulate satellite imagery
  - Terrain classification
  - Meteorology

- *Night-Time Lights of the World* data set
  - Global inventory of human settlement
  - Not hard to imagine the kind of analysis that might be done using this data

Applications of DIP

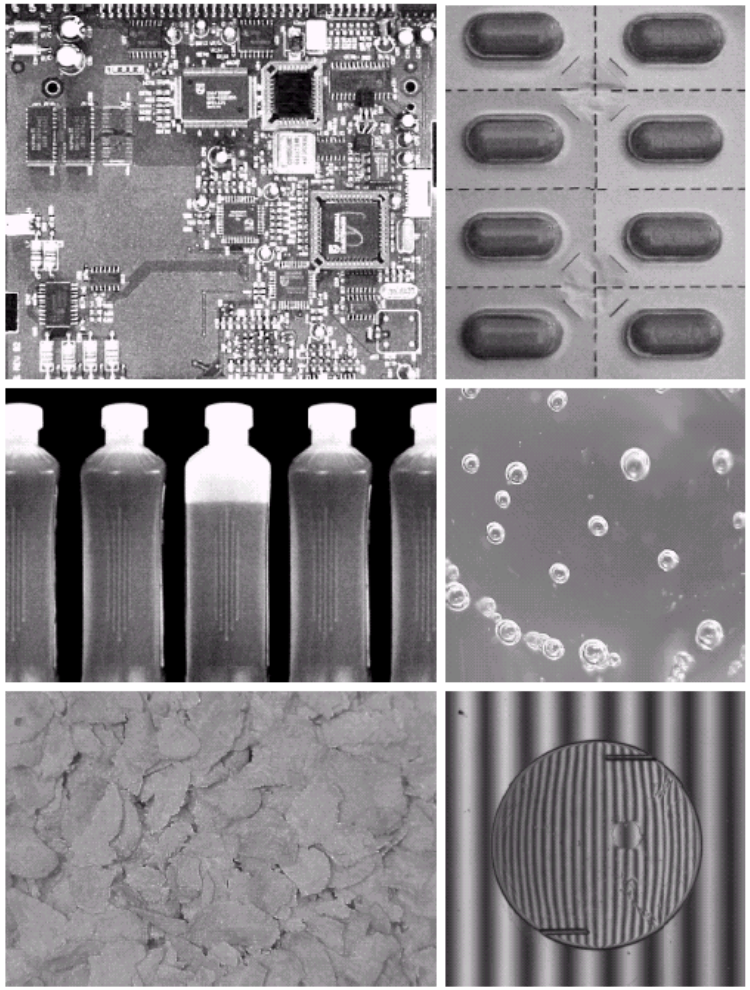




Applications of DIP

Applications of DIP

- Industrial Inspection:

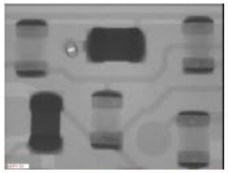


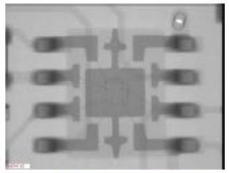
- Human operators are expensive, slow and unreliable Make machines do the job instead Industrial vision systems are used in all kinds of industries

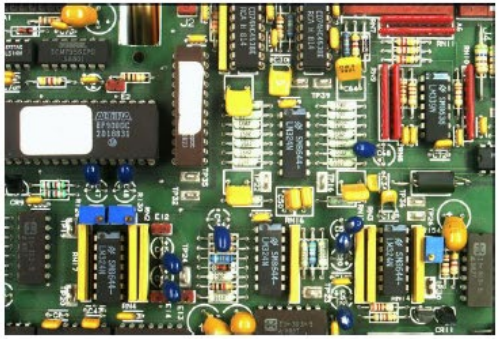
- Can we trust them?

Applications of DIP

- **PCB Inspection**: Printed Circuit Board (PCB) inspection
  - Machine inspection is used to determine that all components are present and that all solder joints are acceptable
  - Both conventional imaging and x-ray imaging







Applications of DIP

- **Law Enforcement:**
- Image processing techniques are used extensively by law enforcers
  - Number plate recognition for speed cameras/automated toll systems
  - Fingerprint recognition
  - Enhancement of CCTV images

Applications of DIP

- HCI:
- Try to make human computer interfaces more natural
  - Face recognition
  - Gesture recognition

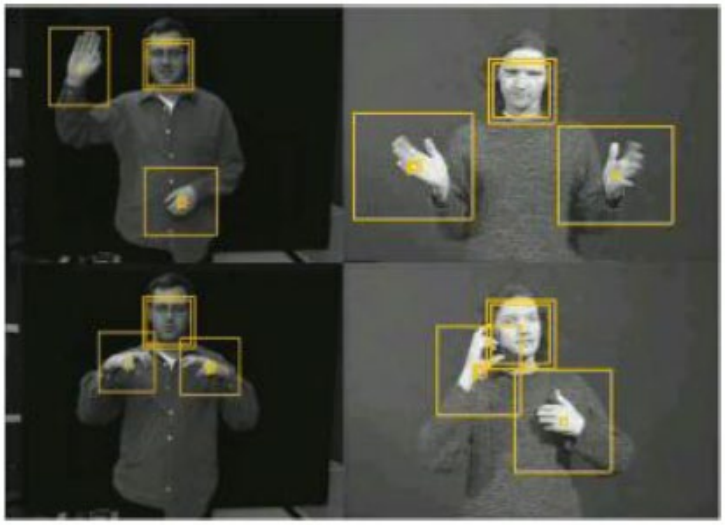
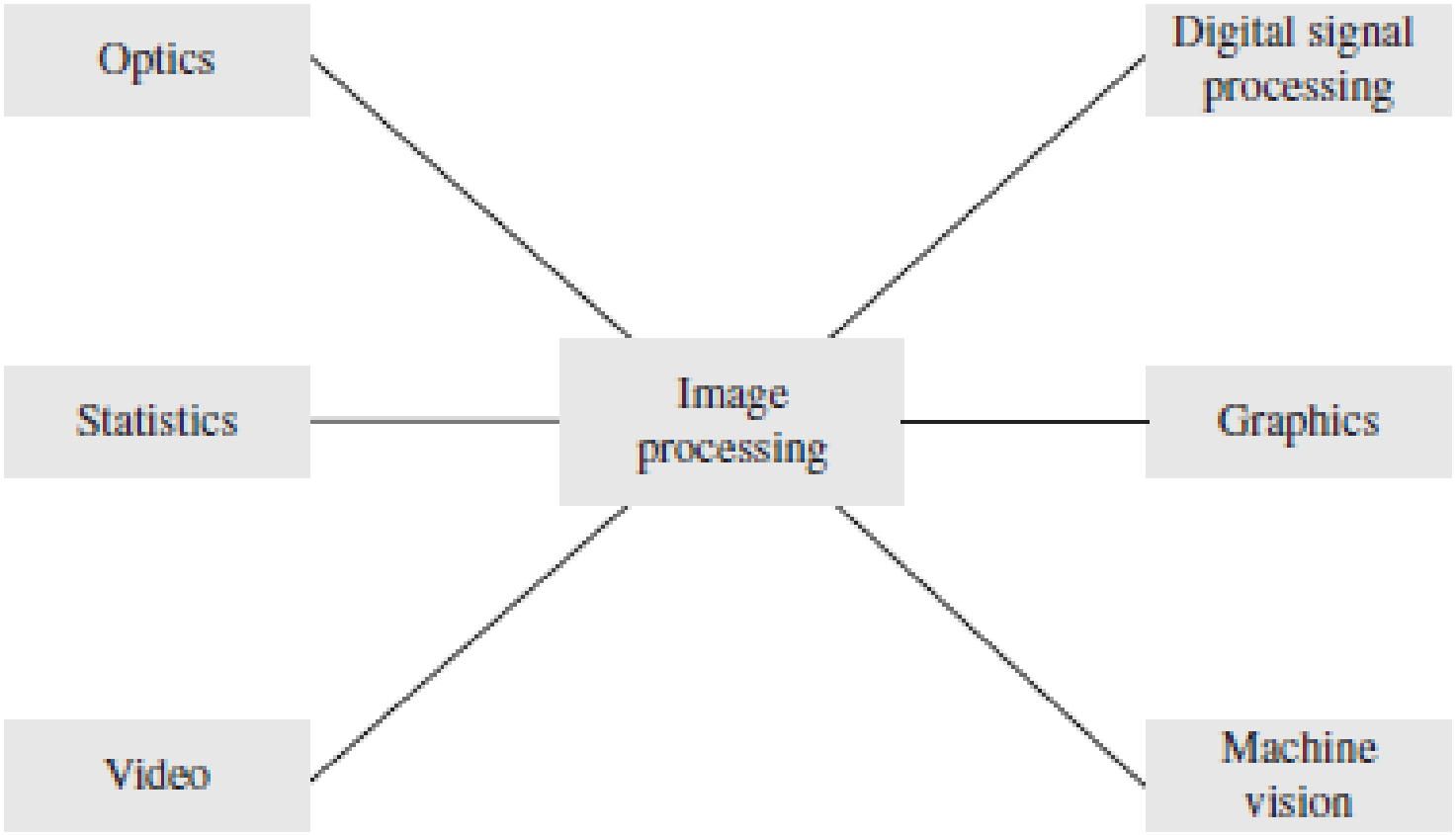


Image Processing and Related Fields



Relations with other branches

- Image processing deals with raster data or bitmaps, whereas computer graphics primarily deals with vector data.

- In digital signal processing, one often deals with the processing of a one-dimensional signal. In the domain of image processing, one deals with visual information that is often in two or more dimensions.

Relations with other branches

- The main goal of machine vision is to interpret the image and to extract its physical, geometric, or topological properties. Thus, the output of image processing operations can be subjected to more techniques, to produce additional information for interpretation.

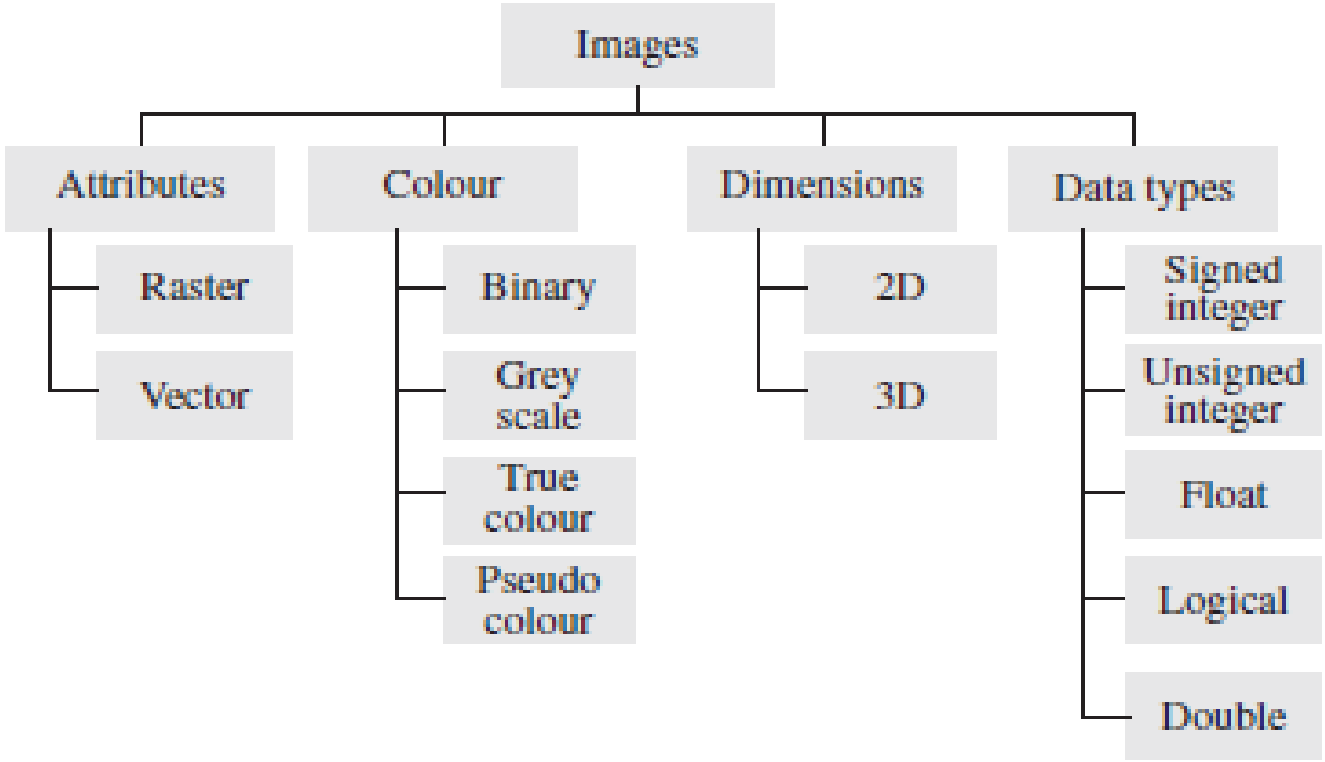
- Image processing is about still images. Thus, video processing is an extension of image processing. In addition, images are strongly related to multimedia, as the field of multimedia broadly includes the study of audio, video, images, graphics, and animation.

Relations with other branches

- Optical image processing deals with lenses, light, lighting conditions, and associated optical circuits. The study of lenses and lighting conditions has an important role in the study of image processing.

- Image analysis is an area that concerns the extraction and analysis of object information from the image. Imaging applications involve both simple statistics such as counting and mensuration and complex statistics such as advanced statistical inference. So statistics play an important role in imaging applications.

Types of Images



Types of Images Based on Colour

- Grey scale images are different from binary images as they have many shades of grey between black and white.

- These images are also called monochromatic as there is no colour component in the image, like in binary images.

- *Grey scale* is the term that refers to the range of shades between white and black or vice versa.

Binary Images

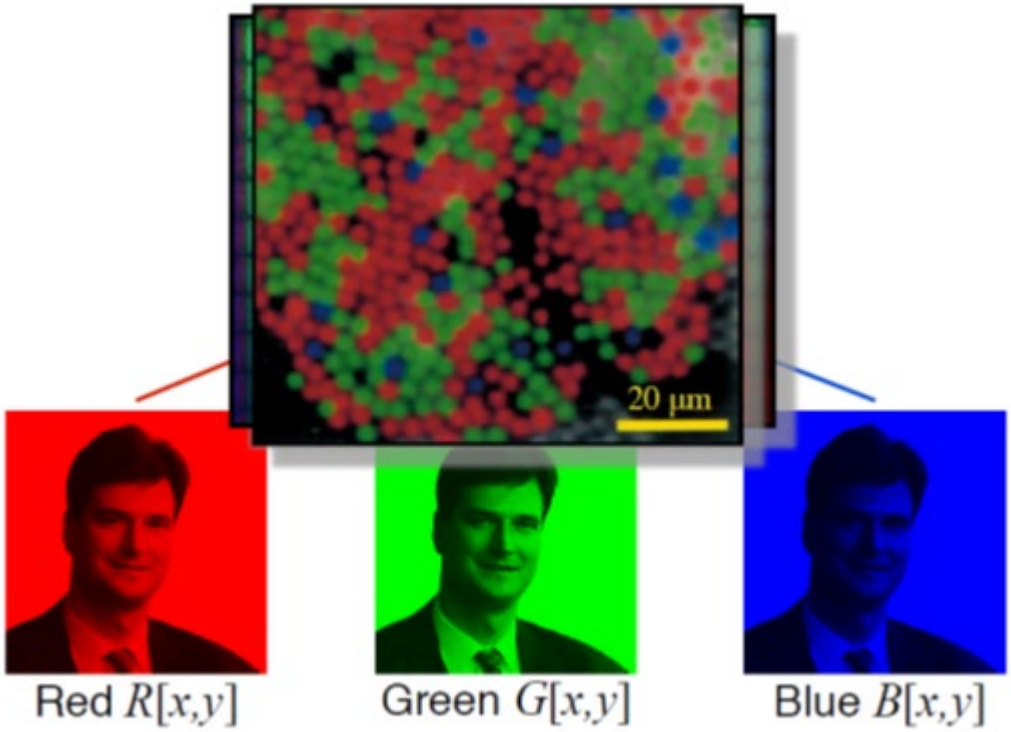
- In binary images, the pixels assume a value of 0 or 1. So one bit is sufficient to represent the pixel value. Binary images are also called bi-level images.

True Colour Images

- In true colour images, the pixel has a colour that is obtained by mixing the primary colours: red, green, and blue. Each colour component is represented like a grey scale image using eight bits. Mostly, true colour images use 24 bits to represent all the colours.

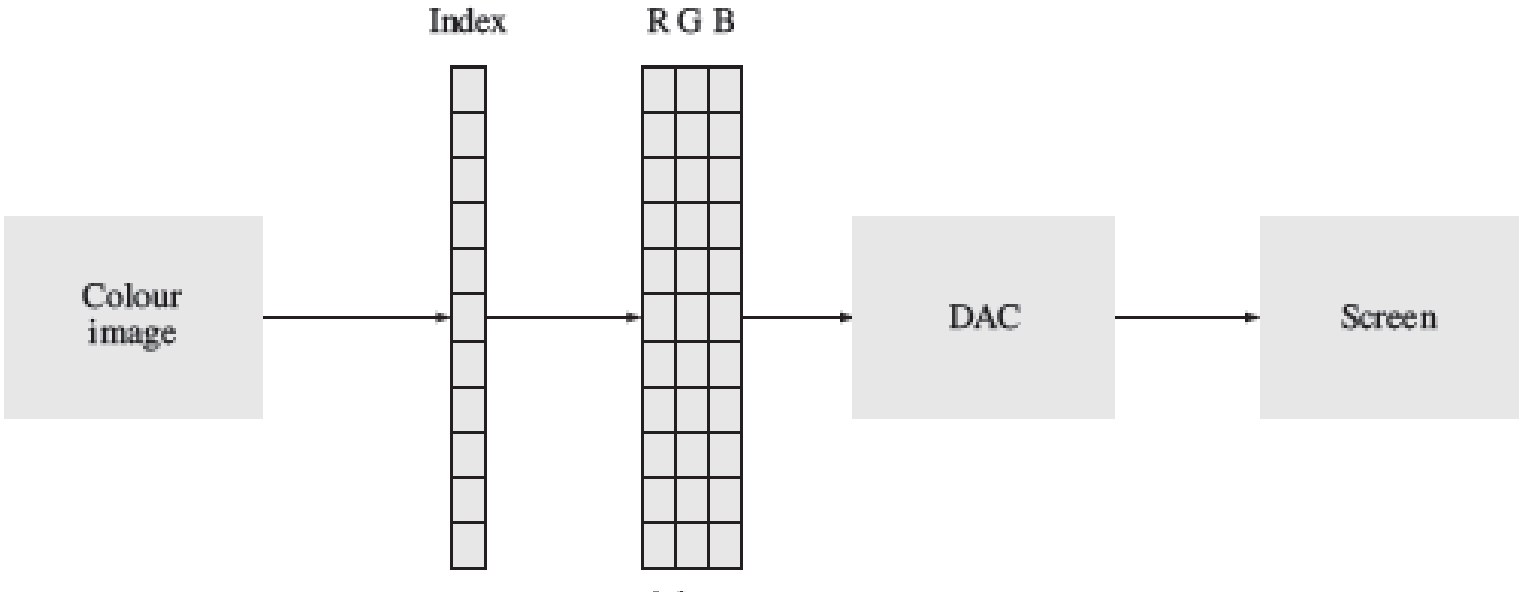
Monochrome image

$R[x,y] = G[x,y] = B[x,y]$



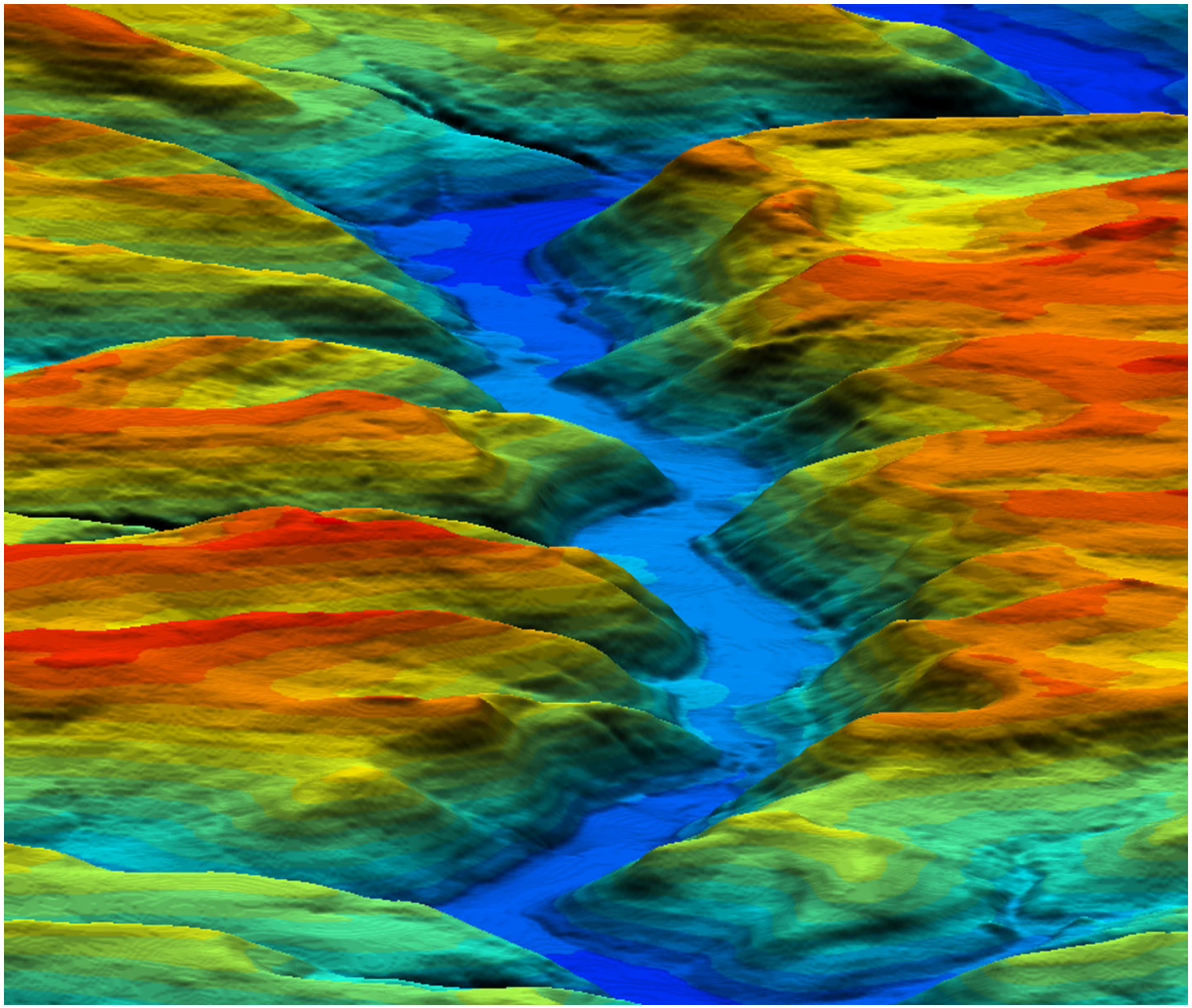
Indexed Image

- A special category of colour images is the indexed image. In most images, the full range of colours is not used. So it is better to reduce the number of bits by maintaining a colour map, gamut, or palette with the image.


Index
R G B
Colour image
DAC
Screen

Pseudocolour Image

- Like true colour images, Pseudocolour images are also used widely in image processing. True colour images are called three-band images.
- However, in remote sensing applications, multi-band images or multi-spectral images are generally used. These images, which are captured by satellites, contain many bands.
- A typical remote sensing image may have 3-11 bands in an image, and this information is beyond the human perceptual range.



Types of Images based on Dimensions

- **Types of Images Based on Dimensions**
  - 2D and 3D

- **Types of Images Based on Data Types**
  - Single, double, Signed or unsigned.