The Course

Digital image processing field deals with manipulation of images through computers, which takes images as inputs, applies an efficient algorithm and produces images as output.

- Image Models,
- Image Representation,
- Various Operations,
- Transforms,
- Techniques For Enhancement.
- Restoration,
- Segmentation,
- Morphological Operations,
- Compression
- Image Analysis.

Objectives

- To provide the students a foundation of digital image processing concepts.

- To build up the capability of implementing various image processing algorithms.

Expected Outcome

- Apply principles and techniques of digital image processing in applications related to digital imaging system design and analysis

- Analyze and implement image processing algorithms

Syllabus

Module 1

- **Introduction :** Image Representation and Image Processing Paradigm - Elements of digital image processing - Image model.
- **Digital Image, Its Representations :** Sampling and quantization - Relationships between pixels - Connectivity, Distance measures between pixels - Color image (overview, various Color models) - Various image formats – bmp, jpeg, tiff, png, gif, etc.

Module 2

- **Digital Image Properties :** Topological Properties of Digital Images - Histograms, Entropy , Eigen Values - Image Quality Metrics - Noise in Images – Sources, types.
- **Operations On Digital Images :** Arithmetic operations - Addition, Subtraction, Multiplication, Division - Logical operations – NOT, OR, AND, XOR - Set operators - Spatial operations – Single pixel, neighbourhood, geometric - Contrast Stretching - Intensity slicing - Bit plane slicing - Power Law transforms.

Syllabus

Module 3

- **Image enhancement :** Spatial and Frequency domain - Histogram processing - Spatial filtering -Smoothening spatial filters - Sharpening spatial filters - Discrete Fourier Transform - Discrete Cosine Transform - Haar Transform - Hough Transform - Frequency filtering - Smoothening frequency filters -Sharpening frequency filters - Selective filtering.

Module 4

- **Digital image restoration :** Noise models - Degradation models - Methods to estimate the degradation -Image de-blurring - Restoration in the presence of noise only spatial filtering - Periodic noise reduction by frequency domain filtering - Inverse filtering - Wiener Filtering
- **Digital image registration :** Geometrical transformation - Point based methods - Surface based methods - Intensity based methods.

Syllabus

Module 5

- **Feature Extraction :** Region of interest (ROI) selection - Feature extraction: Histogram based features - Intensity features - Color, Shape features - Contour extraction and representation - Homogenous region extraction and representation - Texture descriptors - Feature Selection: Principal Component Analysis (PCA).

Module 6

- **Image segmentation :** Discontinuity detection - Edge linking and boundary detection – Thresholding -Region oriented segmentation - Histogram based segmentation Object recognition based on shape descriptors
- **Morphological Image Processing :** Dilation and Erosion - Opening and Closing - Medial axis transforms - Objects skeletons - Thinning boundaries.

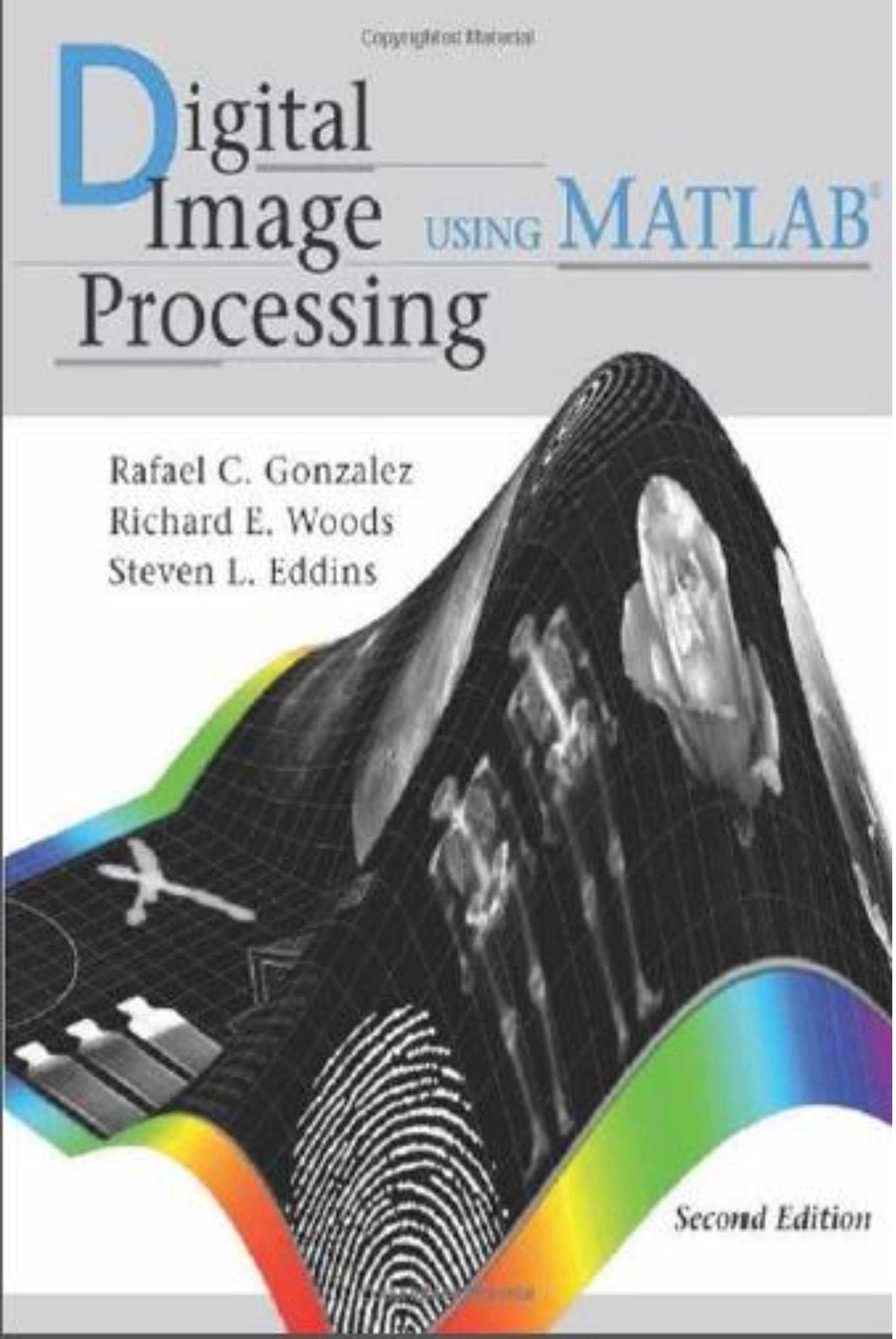
Syllabus

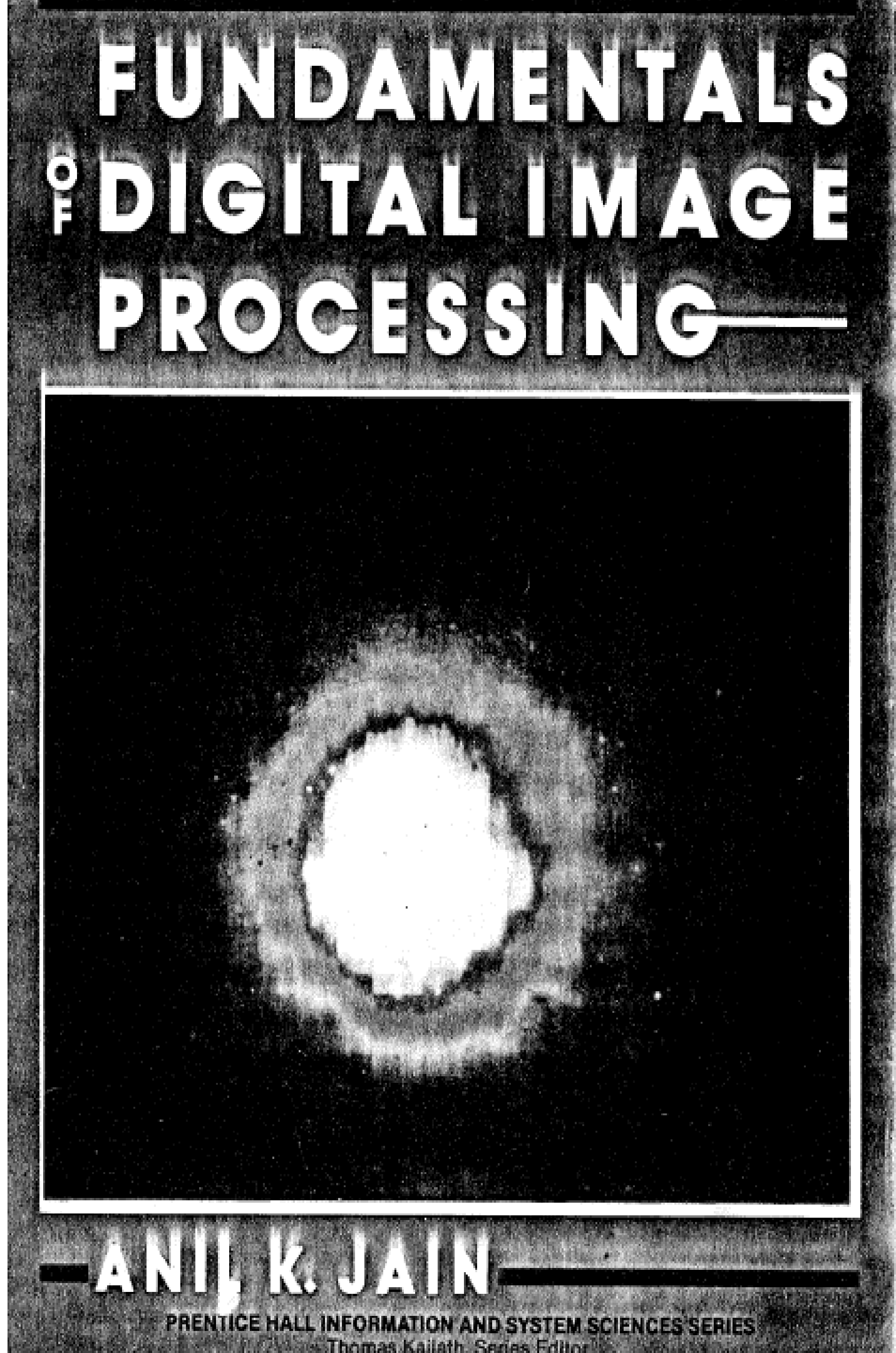
Module 7:

- **Image coding and compression :** Lossless compression versus lossy compression - Measures of the compression efficiency - Hufmann coding - Bitplane coding - Shift codes - Block Truncation coding -Arithmetic coding - Predictive coding techniques - Lossy compression algorithm using the 2-D DCT transform - The JPEG 2000 standard – Baseline lossy JPEG, based on DWT.

Module 8:

Recent Trends in Image Processing


Copyrighted Material
Digital Image Processing
USING MATLAB
Rafael C. Gonzalez
Richard E. Woods
Steven L. Eddins
Second Edition


FUNDAMENTALS OF DIGITAL IMAGE PROCESSING
ANIL K. JAIN
PRENTICE HALL INFORMATION AND SYSTEM SCIENCES SERIES

One picture is worth more than ten thousand words.

What is an Image?

- Some form of representation for visual information.
- Mathematically, a digital image is a matrix of number, or a function on a rectangular domain.
- An image contains rich information with a lot of redundancy.

What is image processing?

Enhance, extract the wanted information, analyze and interpret an image.

Allied Image Processing Fields

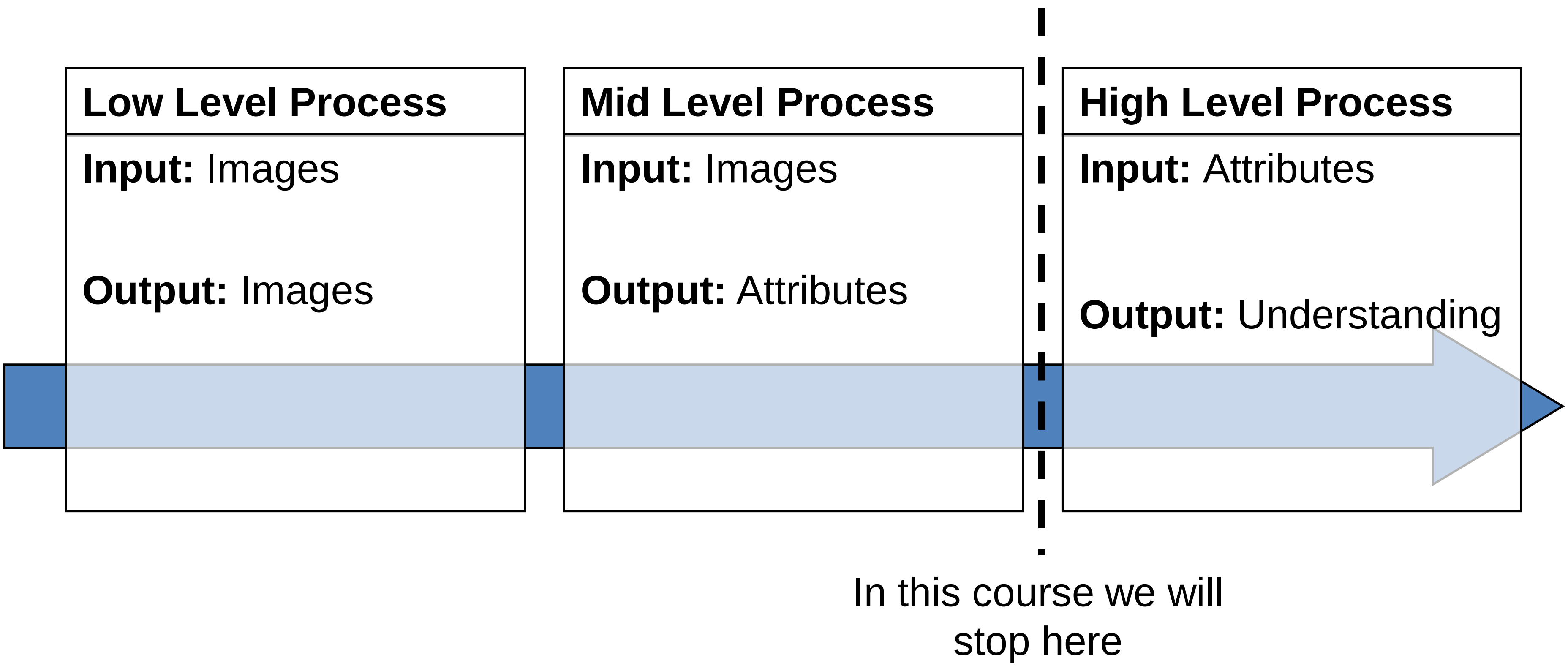
- **Computer Graphics:**
  The creation of images

- **Image Processing:**
  Enhancement or other manipulation of the image

- **Computer Vision:**
  Analysis of the image content

Digital Image Processing

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



Computerized Processes Types

Low-Level Processes:

- **Input** and **output** are images
- **Tasks:** Primitive operations,
  - image processing to reduce noise,
  - contrast enhancement,
  - image sharpening.

Computerized Processes Types

Mid-Level Processes:

- **Inputs**, generally, are images.

- **Outputs** are attributes extracted from those images (*edges, contours, identity of individual objects*)

- **Tasks:**
  - Segmentation (partitioning an image into regions or objects)
  - Classifications of objects

Computerized Processes Types

High-Level Processes:

- Image analysis and computer vision
- Scene Understanding
- Autonomous navigation

What math has to do with digital image processing?

- Mathematical modeling

  Characterize/Quantify features, such as noise, edge, textures, shape, ….

- Mathematical theory

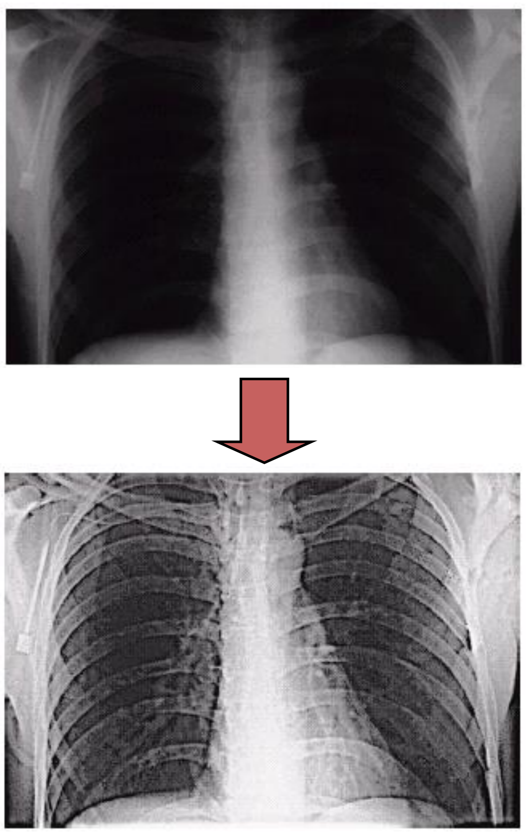
- Efficient numerical algorithms

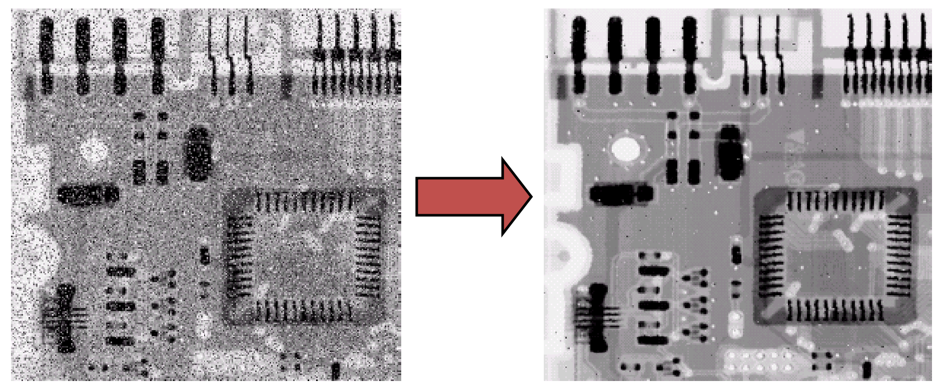
For digital image processing, it is all about numbers and math!

Examples: Image Enhancement

One of the most common uses of DIP techniques:

improve quality, remove noise etc.



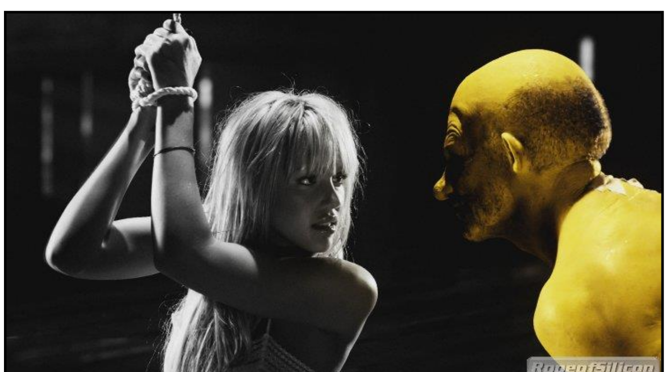


Examples: The Hubble Telescope

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

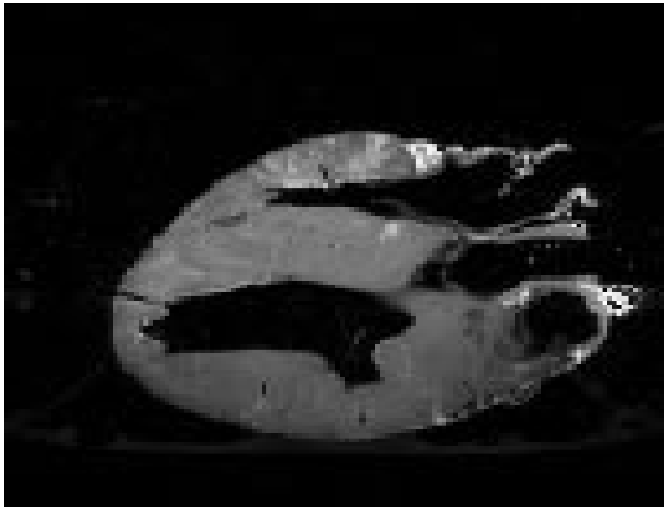
Examples: Artistic Effects

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

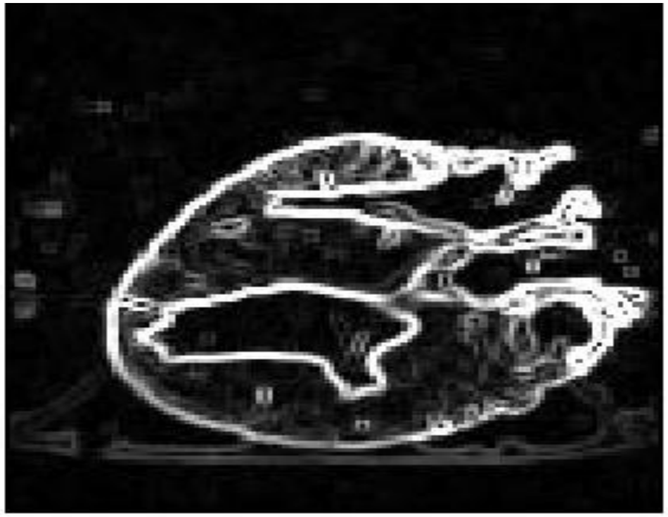


Examples: Medicine

- 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



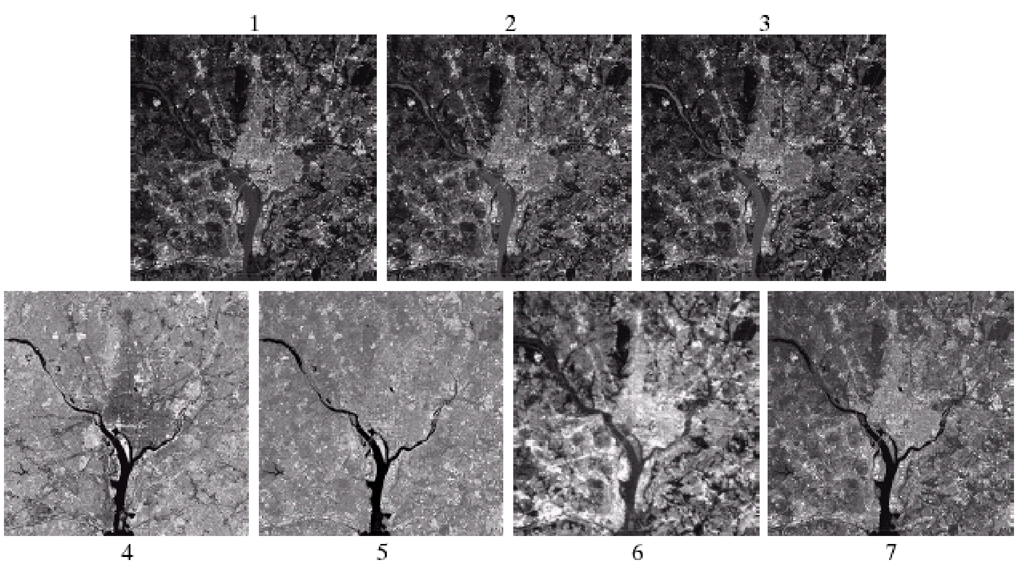
Original MRI Image of a Dog Heart

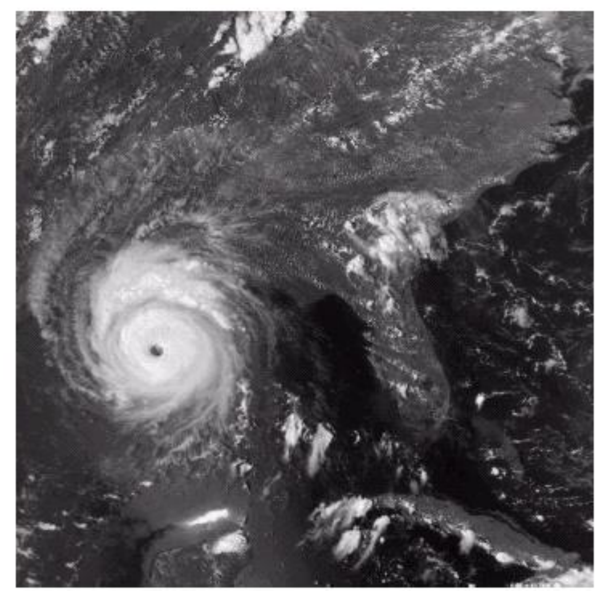


Edge Detection Image

Examples: GIS

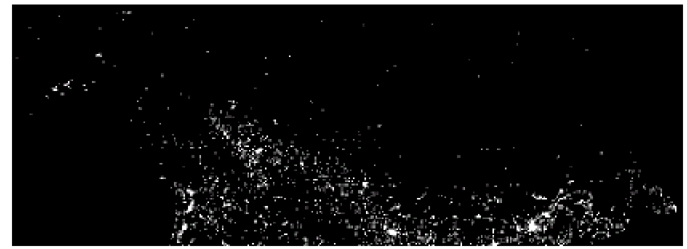
- Geographic Information Systems
  - Digital image processing techniques are used extensively to manipulate satellite imagery
  - Terrain classification
  - Meteorology

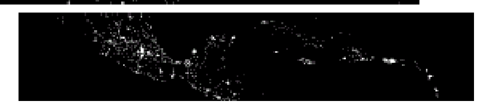




Examples: GIS

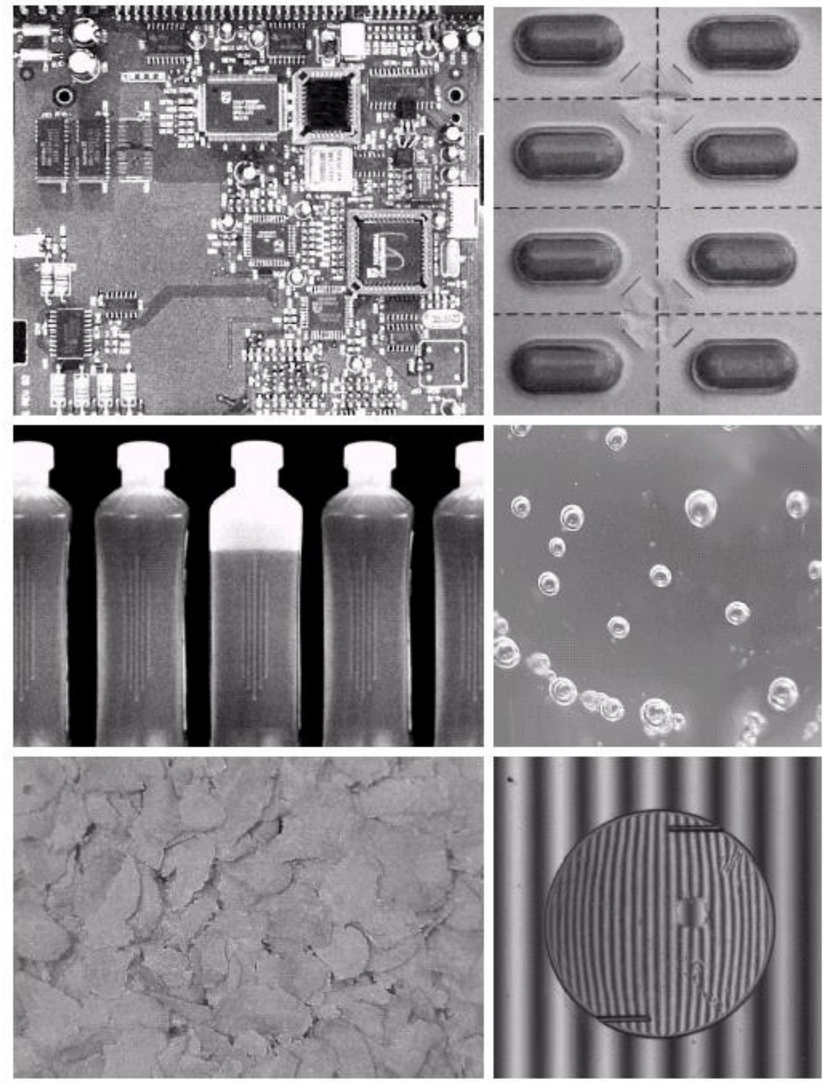
- *Night-Time Lights of the World* data set
  - Global inventory of human settlement
  - Not hard to imagine the kind of analysis that might be done using this data





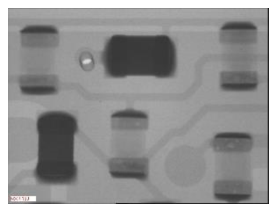
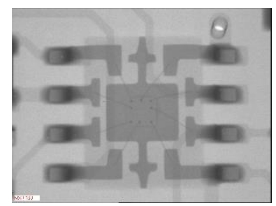
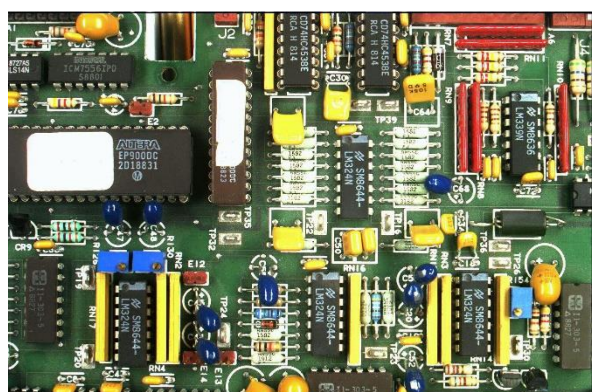
Examples: Industrial Inspection

- 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?



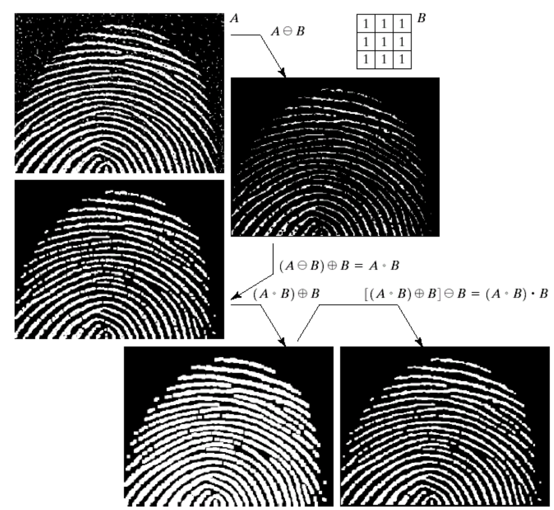
Examples: PCB Inspection

- 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 are used


Examples: 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



Examples: HCI

- Try to make human computer interfaces more natural
  - Face recognition
  - Gesture recognition
- Does anyone remember the user interface from “Minority Report”?
- These tasks can be extremely difficult

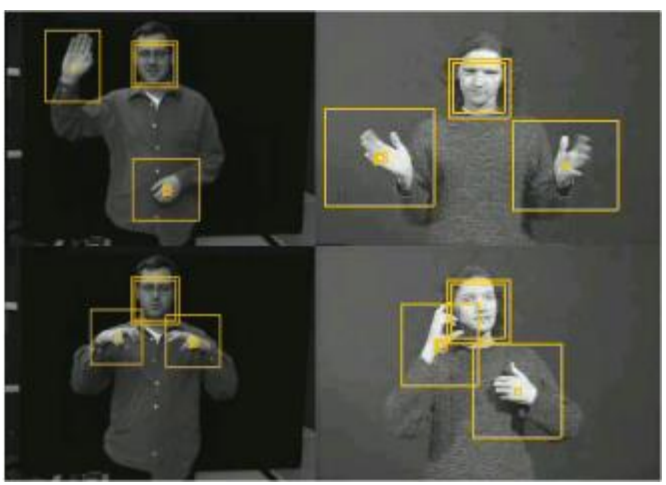
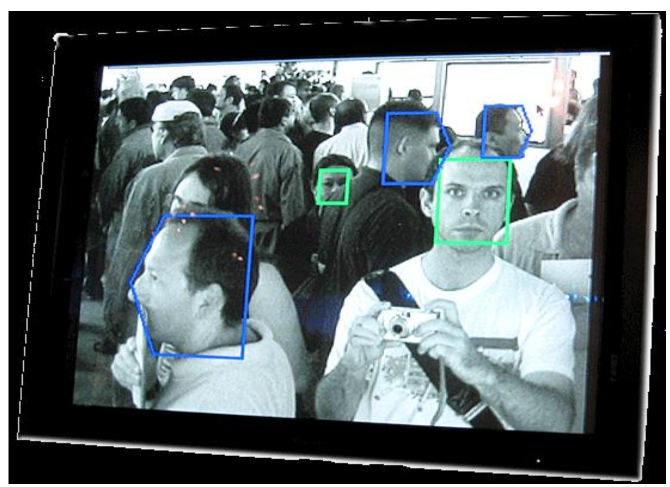
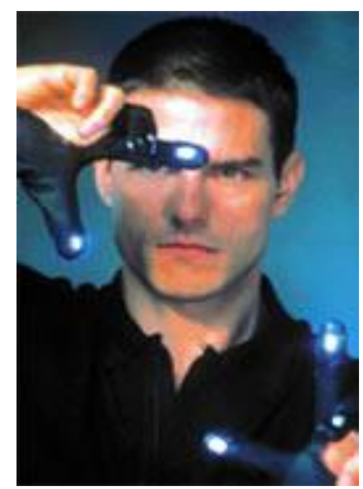
  

Image Formation

- For natural images we need a light source (λ : wavelength of the source)
  - **$E(x,y,z,\lambda)$:** incident light on a point (x,y,z world coordinates of the point)

- Each point in the scene has a reflectivity function.
  - **$r(x,y,z,\lambda)$:**reflectivity function

- Light reflects from a point and the reflected light is captured by an imaging device.
  - **$c(x,y,z,\lambda) = E(x,y,z,\lambda) \cdot r(x,y,z,\lambda)$:** reflected light

$E(x,y,z,\lambda)$

$c(x,y,z,\lambda) = E(x,y,z,\lambda) \cdot r(x,y,z,\lambda)$

$\text{Camera}(c(x,y,z,\lambda)) =$ 

Image Formation

- Optical parameters of the lens
  - lens type / focal length / field of view
- Photometric parameters
  - type, intensity, and direction of illumination
  - reflectance properties of the viewed surfaces
- Geometric parameters
  - type of projections
  - position and orientation of camera in space
  - perspective distortions introduced by the imaging process

Image Formation: Image distortion

Image Formation: Short wavelengths

- Different wavelengths of radiation have different properties.
- The **x-ray** region of the spectrum, it carries sufficient energy to penetrate a significant volume or material.

Image Formation: Long wavelengths

- Abundant quantities of **infrared** (IR) radiation are emitted from warm objects (e.g., locate people in total darkness).

Image Formation: Long wavelengths (cont'd)

- "**Synthetic aperture radar**" (SAR) imaging techniques use an artificially generated source of microwaves to probe a scene.
- SAR is unaffected by weather conditions and clouds (e.g., has provided us images of the surface of Venus).

Image Formation: Sonic images

- Produced by the reflection of sound waves off an object.
- High sound frequencies are used to improve resolution.

Image Formation: CCD cameras

- Tiny **solid state cells** convert light energy into electrical charge.
- The image plane acts as a digital memory that can be read row by row by a computer.

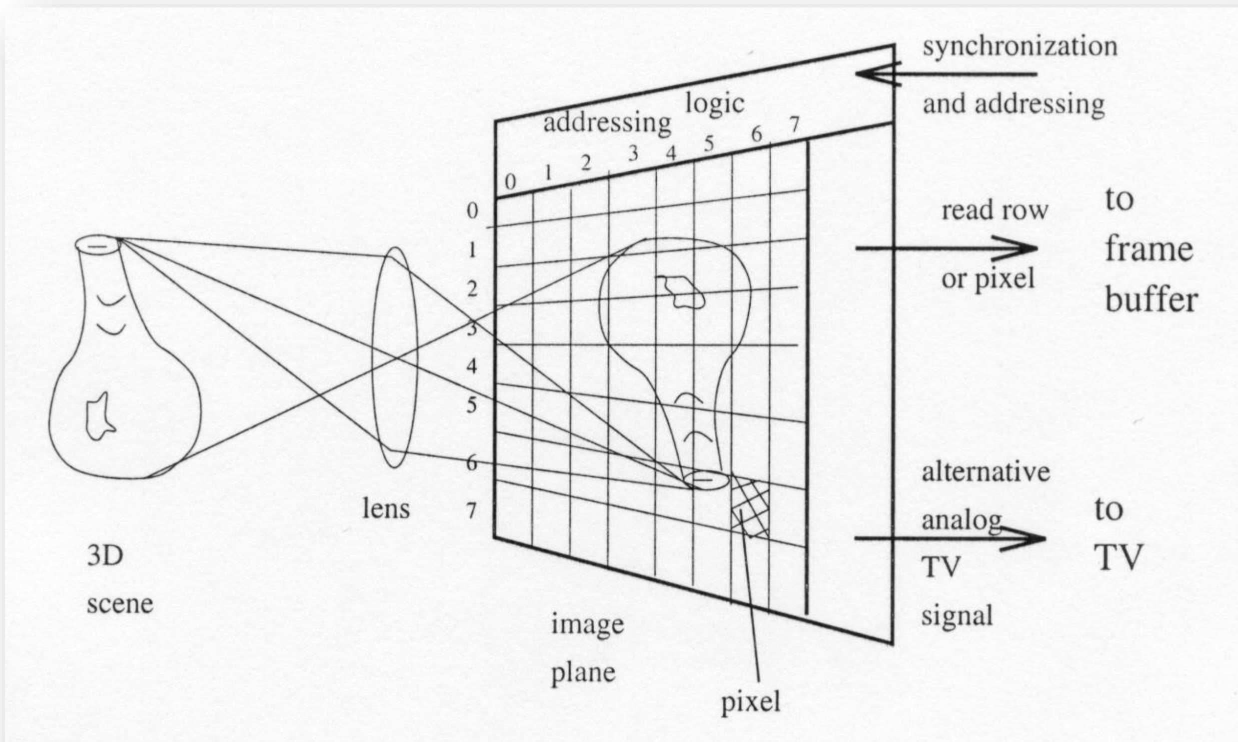
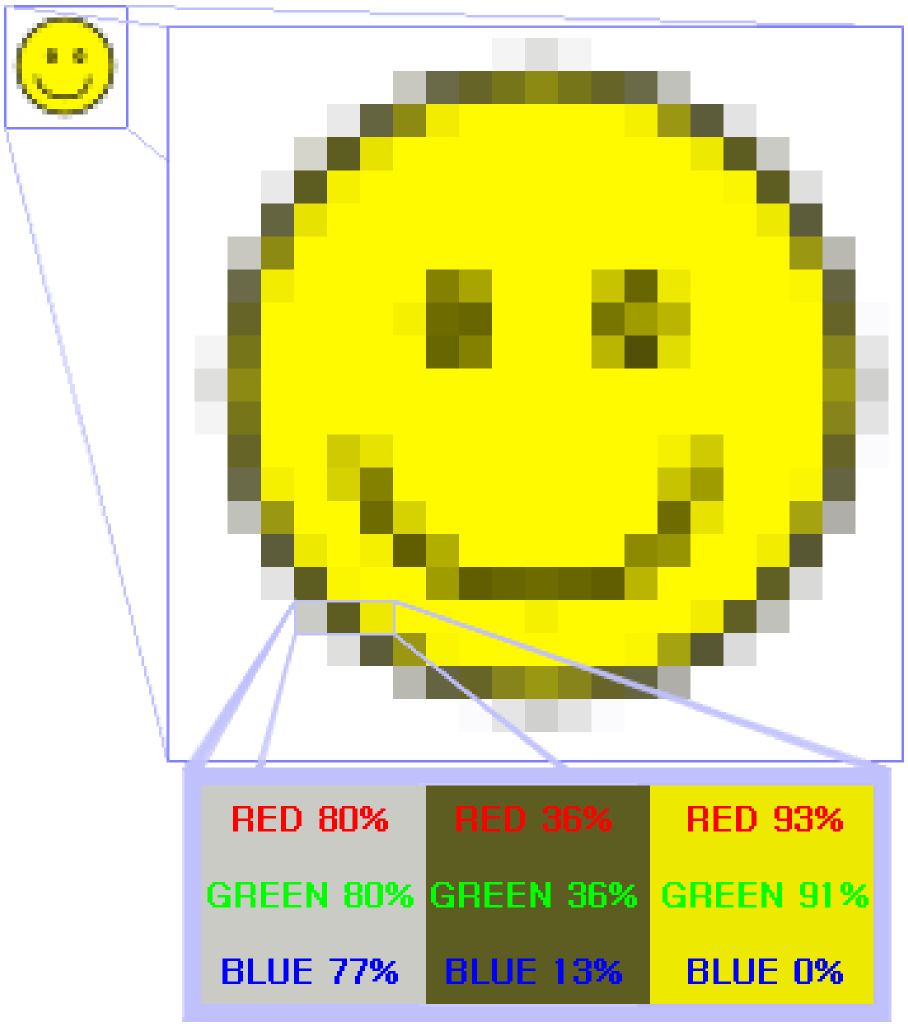


Image Composition: Smiley



Digital Image Definition

- An image can be defined as a two-dimensional function **f(x,y)**
- **x,y:** Spatial coordinate
- **f:** the amplitude of any pair of coordinate x,y, which is called the intensity or gray level of the image at that point.
- ***x,y and f, are all finite and discrete quantities.***

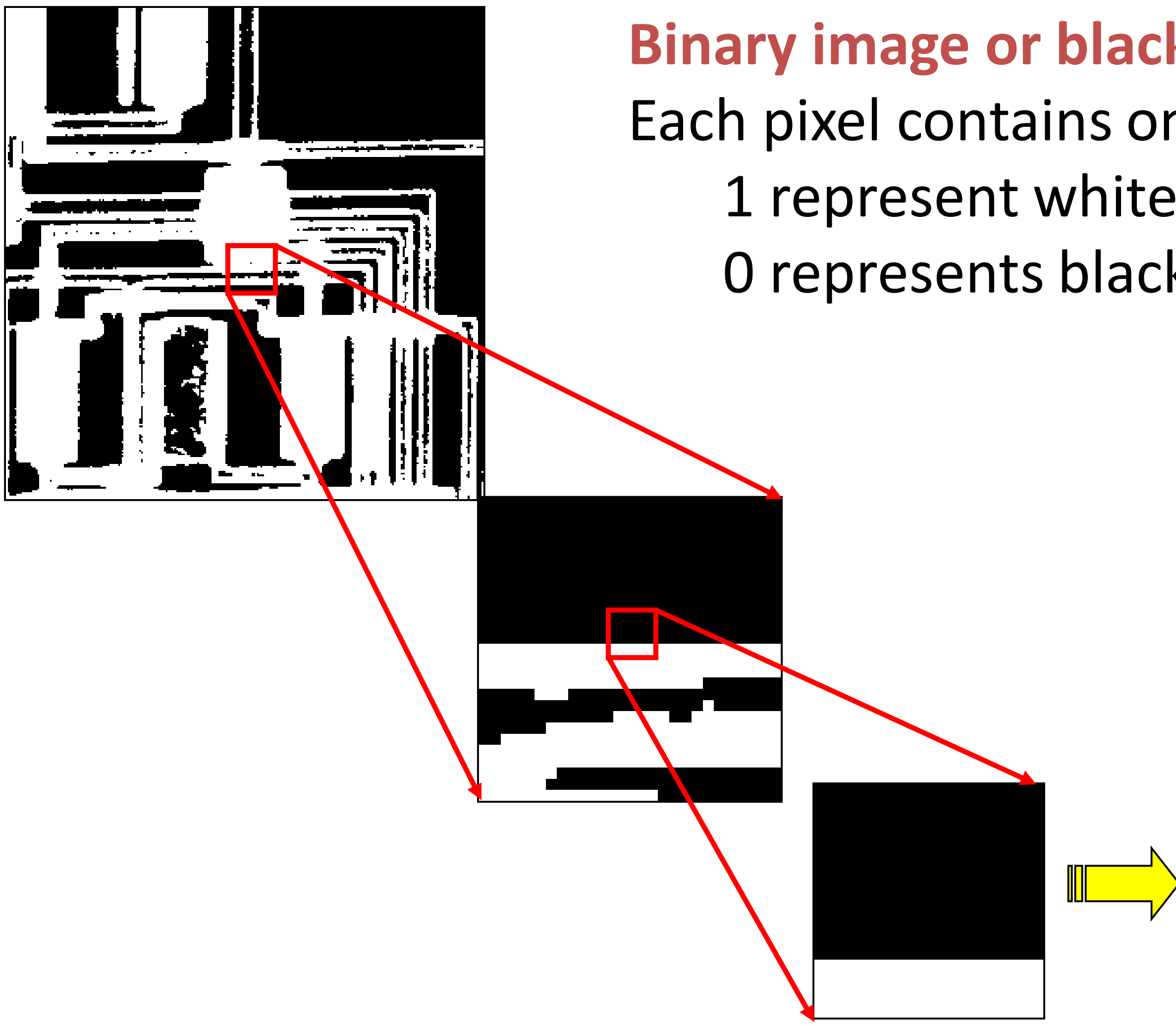
Image Types : Binary Image

Binary image or black and white image

Each pixel contains one bit :

1 represent white

0 represents black



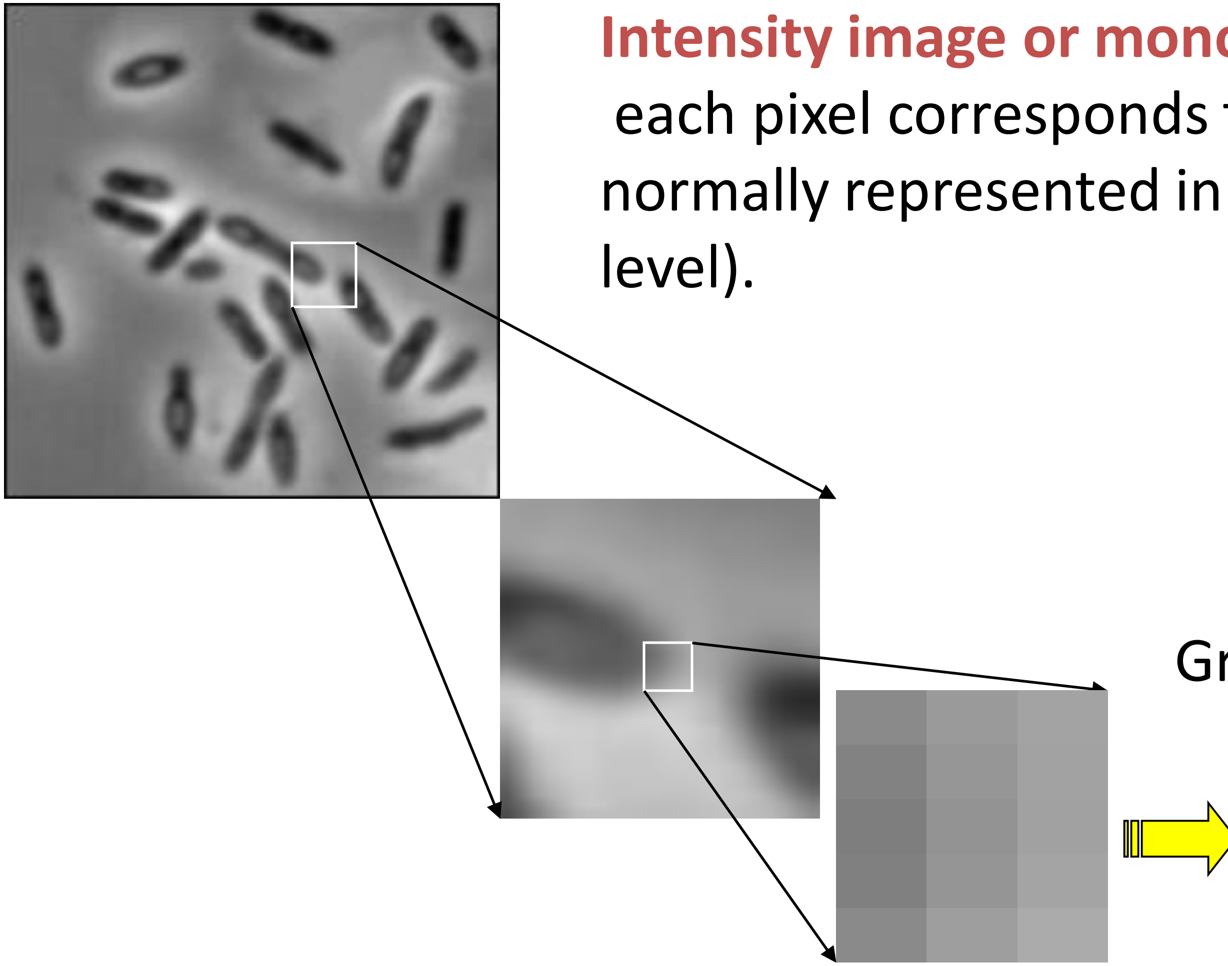
Binary data

$$\begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 \end{bmatrix}$$

Digital Image Types : Intensity Image

Intensity image or monochrome image

each pixel corresponds to light intensity normally represented in gray scale (gray level).



Gray scale values

$$\begin{bmatrix} 10 & 10 & 16 & 28 \\ 9 & 6 & 26 & 37 \\ 15 & 25 & 13 & 22 \\ 32 & 15 & 87 & 39 \end{bmatrix}$$

Digital Image Types : COLOR (RGB) Image

Color image or RGB image: each pixel contains a vector representing red, green and blue components.

RGB components

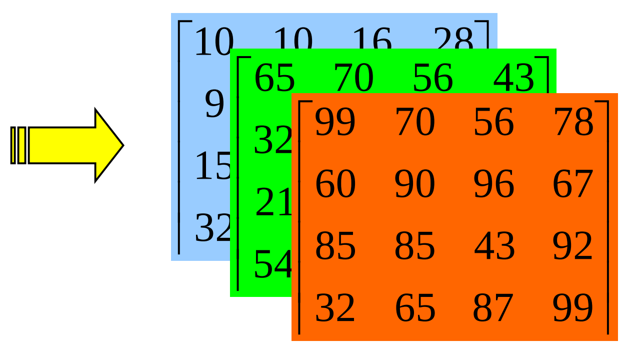
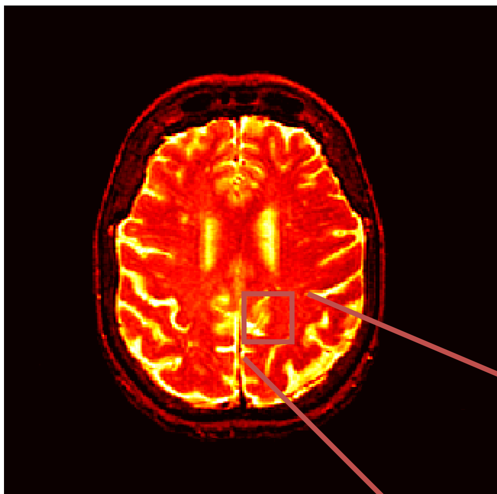


Image Types : Index Image

Index image

Each pixel contains index number pointing to a color in a color table



$$\begin{bmatrix} 1 & 4 & 9 \\ 6 & 4 & 7 \\ 6 & 5 & 2 \end{bmatrix}$$

Index value

Color Table

Index No.	Red component	Green component	Blue component
1	0.1	0.5	0.3
2	1.0	0.0	0.0
3	0.0	1.0	0.0
4	0.5	0.5	0.5
5	0.2	0.8	0.9
…	…	…	…

Image File Formats (1/2)

BMP – Bitmap format from Microsoft uses Raster-based 1~24-bit colors (RGB) without compression or allows a run-length compression for 1~8-bit color depths

GIF – Graphics Interchange Format from CompuServe Inc. is Raster-based which uses 1~8-bit colors with resolutions up to 64,000*64,000 LZW (Lempel-Ziv-Welch, 1984) lossless compression with the compression ratio up to 2:1

Raw – Raw image format uses a 8-bit unsigned character to store a pixel value of 0~255 for a Raster-scanned gray image without compression. An R by C raw image occupies R*C bytes or 8RC bits of storage space

Some Image File Formats (2/2)

- **TIFF** – Tagged Image File Format from Aldus and Microsoft was designed for importing image into desktop publishing programs and quickly became accepted by a variety of software developers as a standard. Its built-in flexibility is both a blessing and a curse, because it can be customized in a variety of ways to fit a programmer's needs. However, the flexibility of the format resulted in many versions of TIFF, some of which are so different that they are incompatible with each other

- **JPEG** – Joint Photographic Experts Group format is the most popular lossy method of compression, and the current standard whose file name ends with ".jpg" which allows Raster-based 8-bit grayscale or 24-bit color images with the compression ratio more than 16:1 and preserves the fidelity of the reconstructed image

- **EPS** – Encapsulated PostScript language format from Adulus Systems uses Metafile of 1~24-bit colors with compression

- **JPEG 2000**