Digital Image Processing Fundamentals

What is Image ?

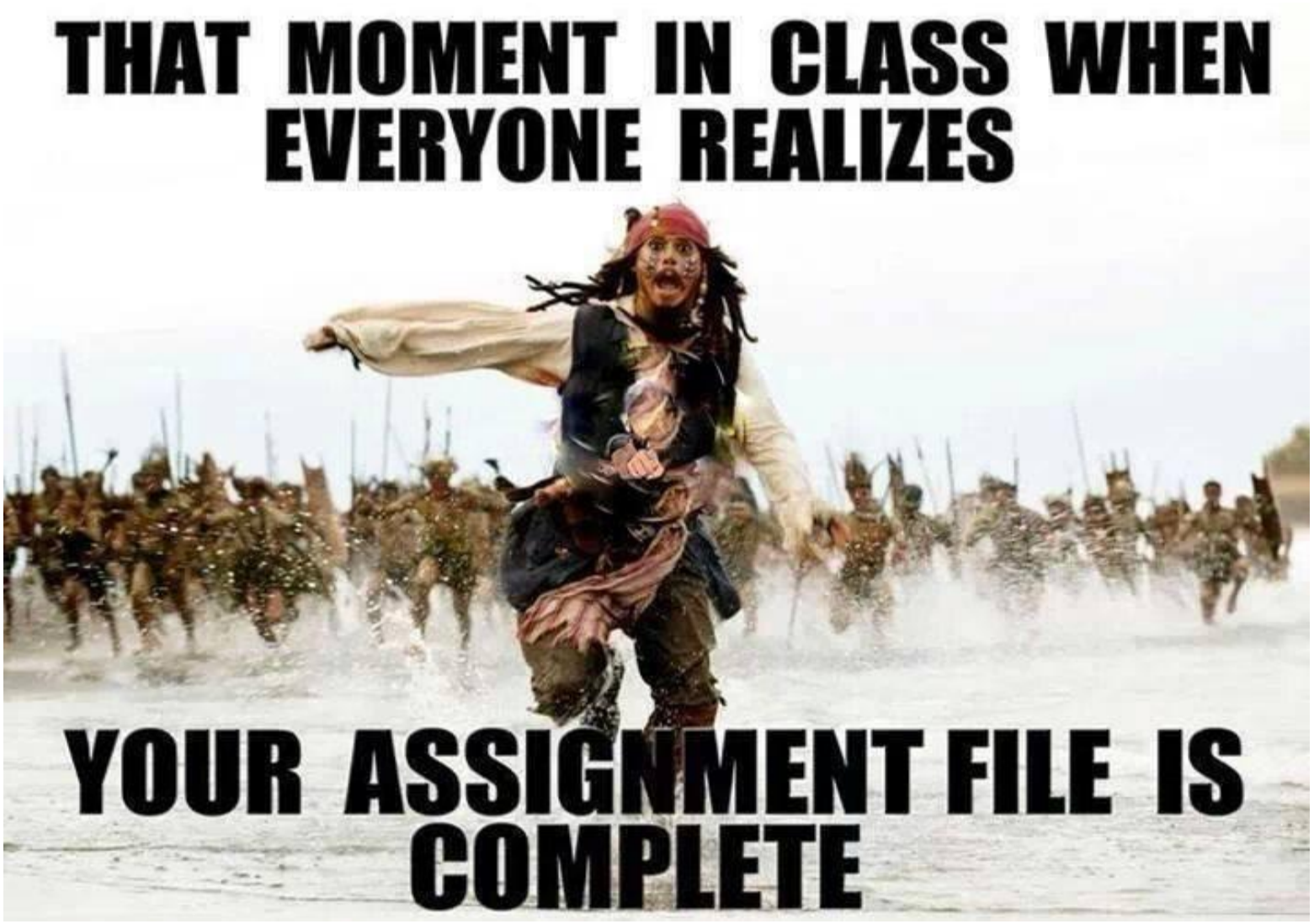
- An image is a spatial representation of a two-dimensional or three-dimensional scene.
- An image is an array, or a matrix pixels (picture elements) arranged in columns and rows.

What is Image Processing

What is Image Processing

What is Image Processing

What is Image Processing



One picture is worth more than thousands of words.

WHY…..digital image processing…???

- Interest in digital image processing methods stems from two principal application areas:

1. Improvement of pictorial information for human interpretation

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

What Is Digital Image Processing?

DIP Definition:

A Discipline in Which Both the Input and Output of a Process are Images.

What Is Digital Image ?

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

- **Digital Image:**

  When x, y and the intensity values of f are all finite, discrete quantities, we call the image a digital image.

- **Color Image:**

$$f(x, y) = \begin{bmatrix} r(x, y) \\ g(x, y) \\ b(x, y) \end{bmatrix}$$

The field of digital image processing refers to processing digital images by means of a digital computer.

What Is Digital Image ?

An Image:

$g(x, y)$

Discretization

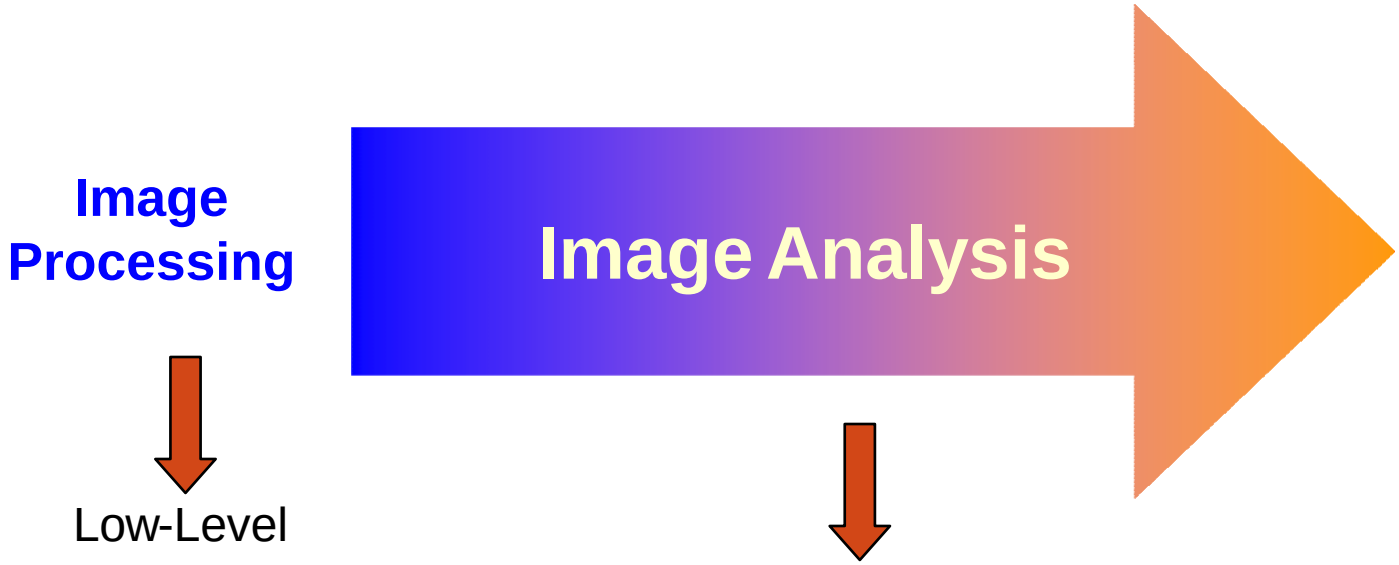
$g(i, j)$

Quantization

$f(i, j)$ Digital Image

$f(i_0, j_0)$: Picture Element, Image Element, Pel, Pixel

What Is Digital Image Processing?



- Reduce Noise
- Contrast Enhancement
- Image Sharpening

- Segmentation
- Classification

Making Sense of an Ensemble of Recognized Objects

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 York.

- Introduction of the Bartlane cable picture transmission system in the early 1920s reduced the time required to transport a picture across the Atlantic from more than a week to less than three hours.

A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces.

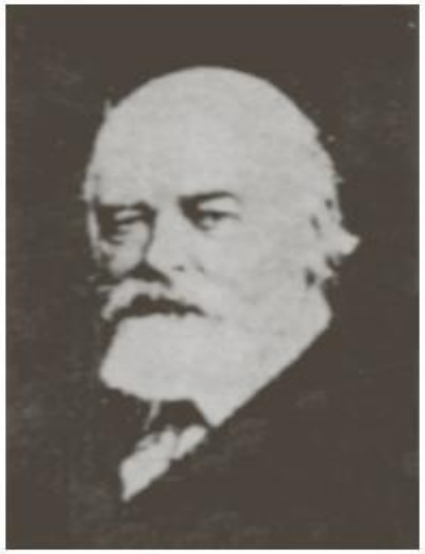


FIGURE 1.2 A digital picture made in 1922 from a tape punched after the signals had crossed the Atlantic twice. (McFarlane.)

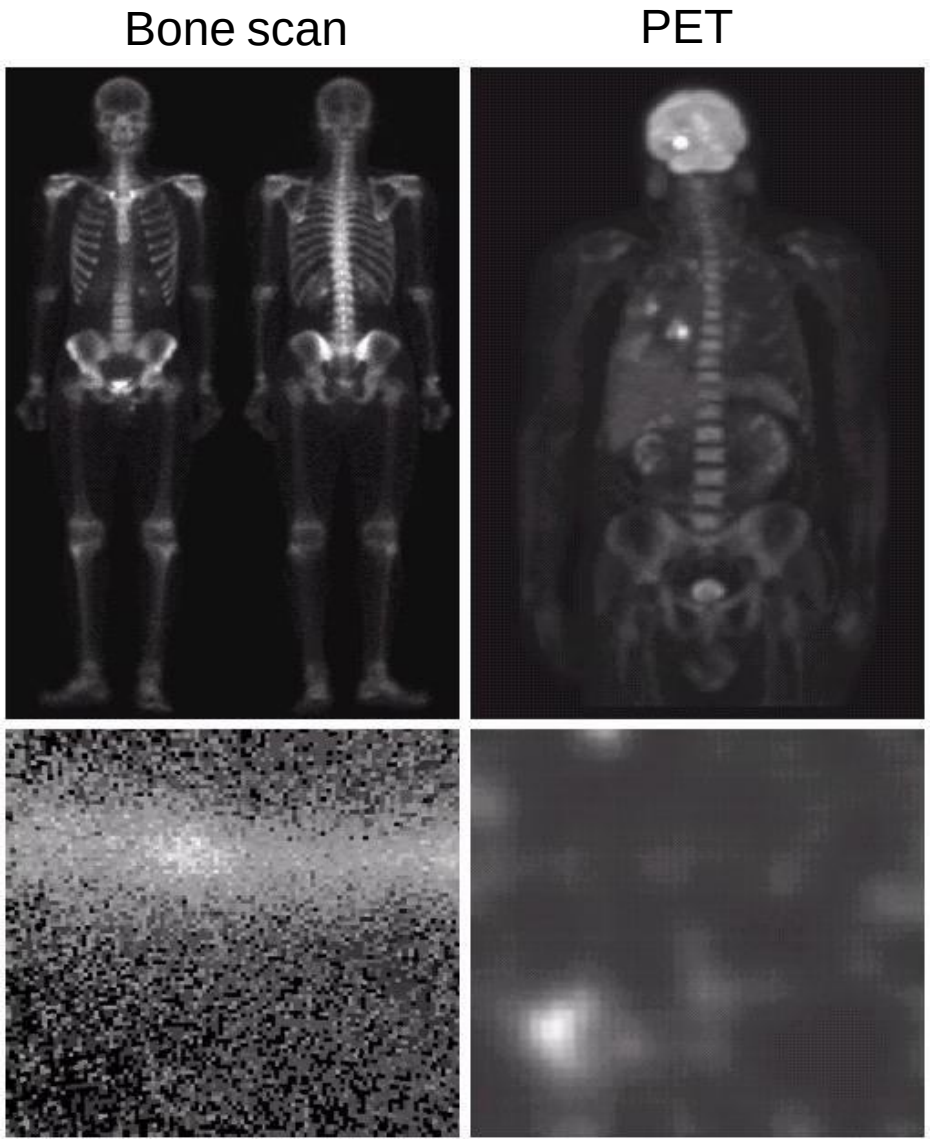
Fields that Use Digital Image Processing

- Today, there is almost no area of technical endeavor that is not impacted in some way by digital image processing.

- Gamma-Ray Imaging
- X-Ray Imaging
- Imaging in the Ultraviolet Band
- Imaging in the Visible and Infrared Bands
- Imaging in the Microwave Band
- Imaging in the Radio Band

Gamma-Ray Imaging

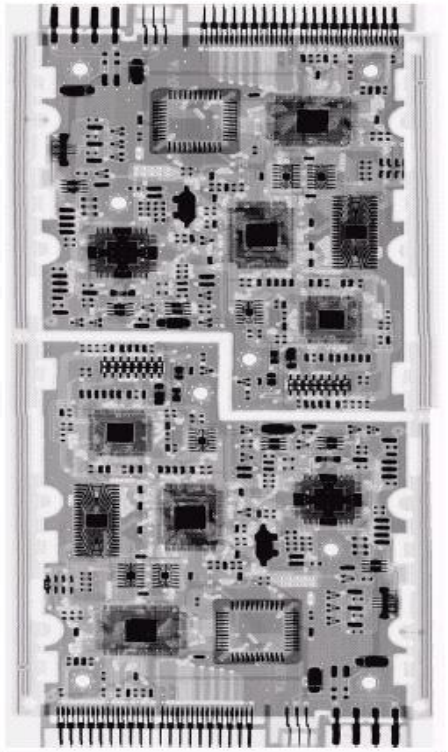
- Major uses of imaging based on gamma rays include nuclear medicine.
- In nuclear medicine, the approach is to inject a patient with a radioactive isotope that emits gamma rays as it decays.
- Images are produced from the emissions collected by gamma ray detectors.



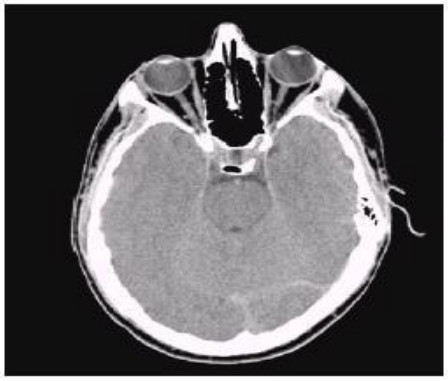
X-Ray Imaging

Chest X-Ray

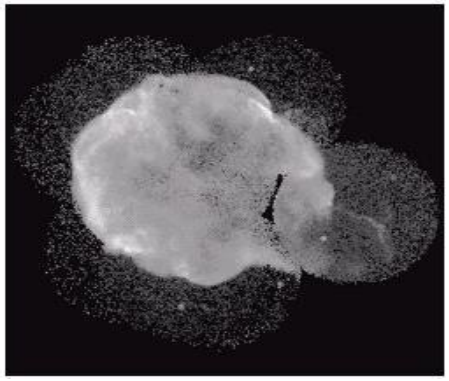
PCB



Angiogram



Head CT

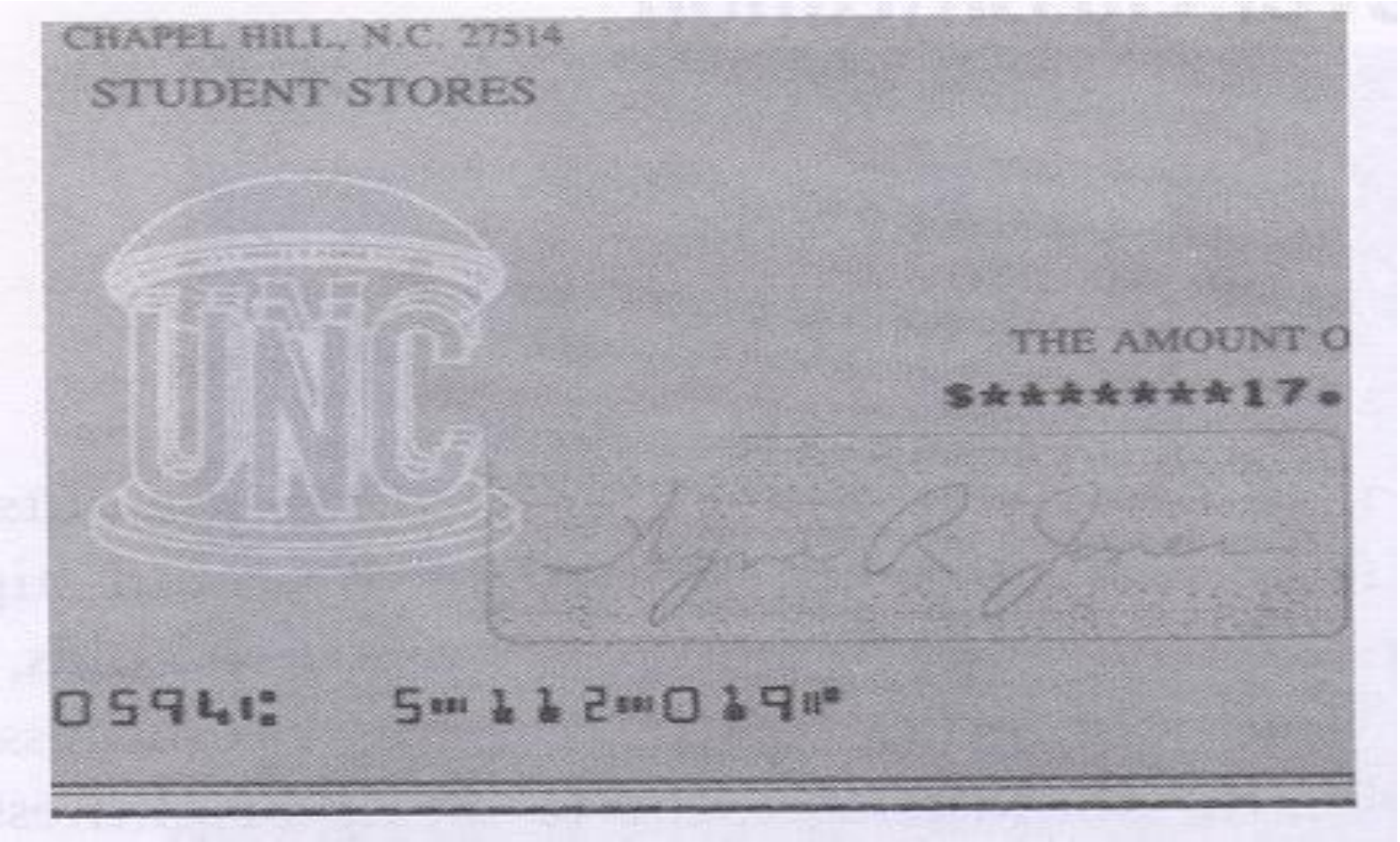


Cygnus loop

Applications and Research Topics

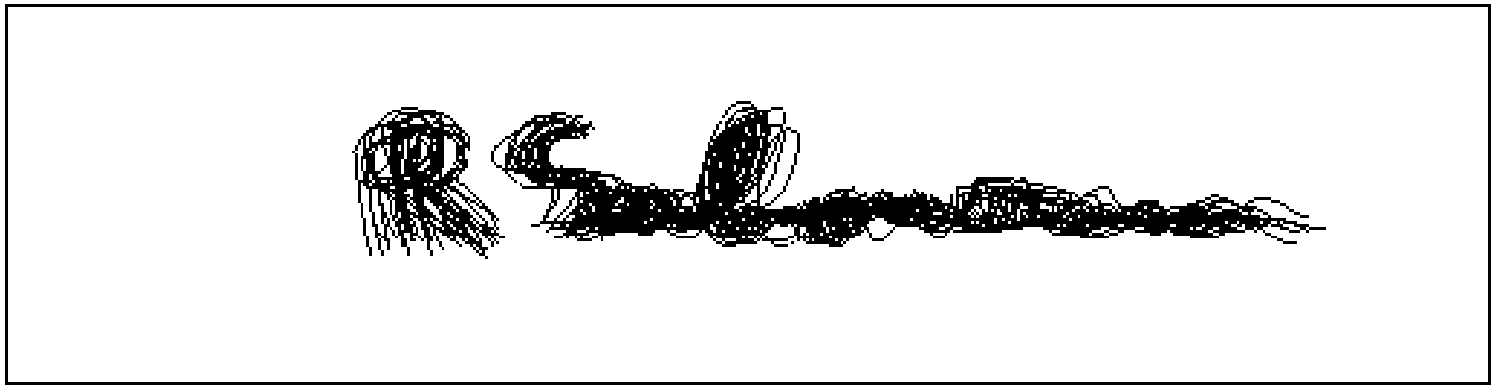
Applications and Research Topics

- Document Handling



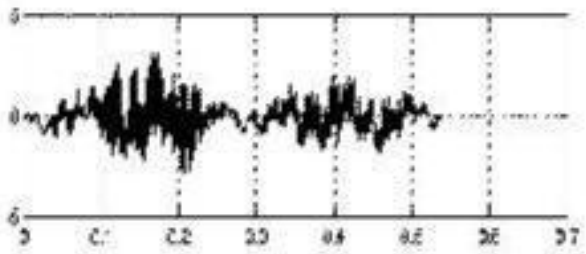
Applications and Research Topics

- Signature Verification



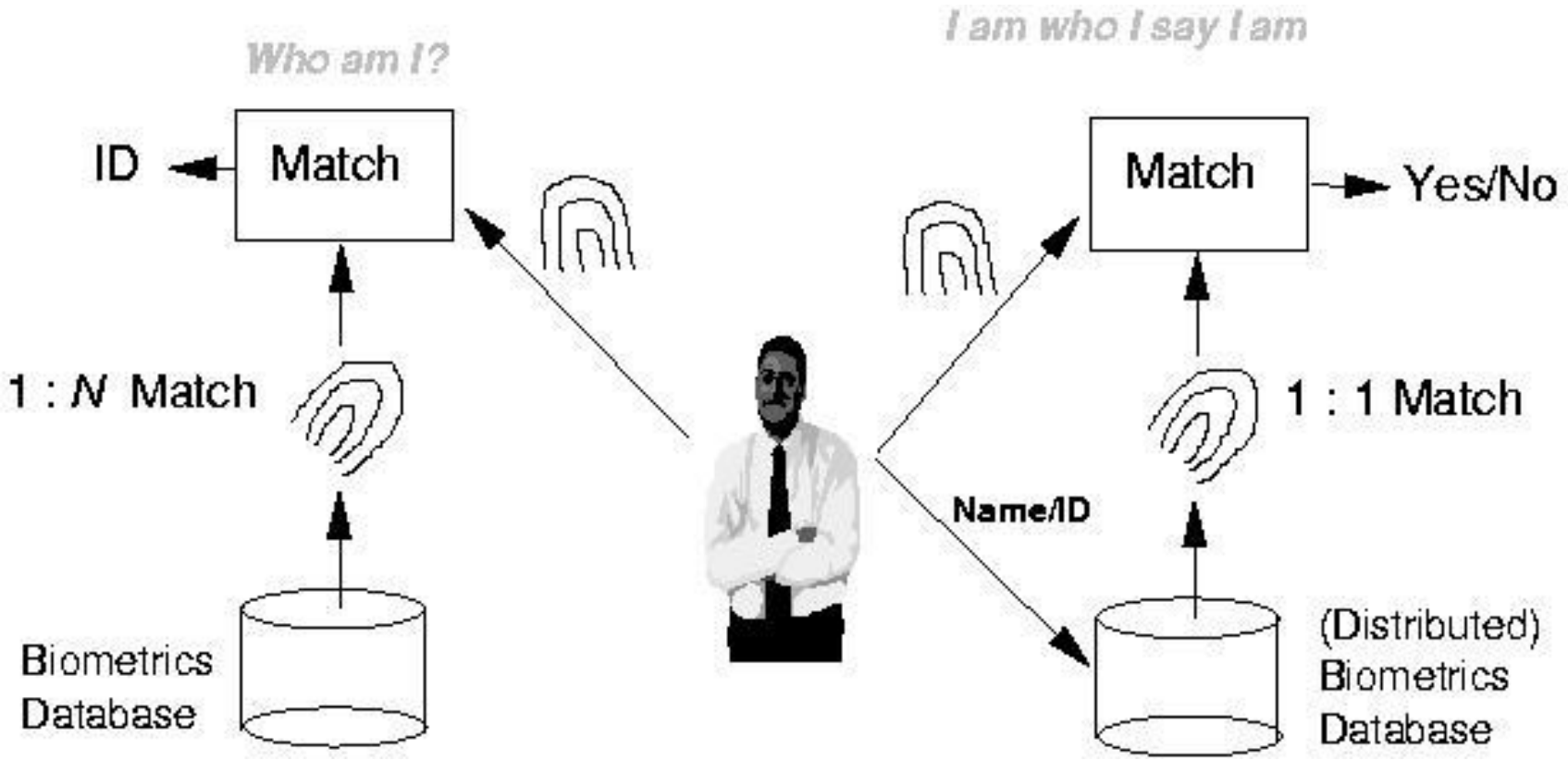
Applications and Research Topics

- Biometrics



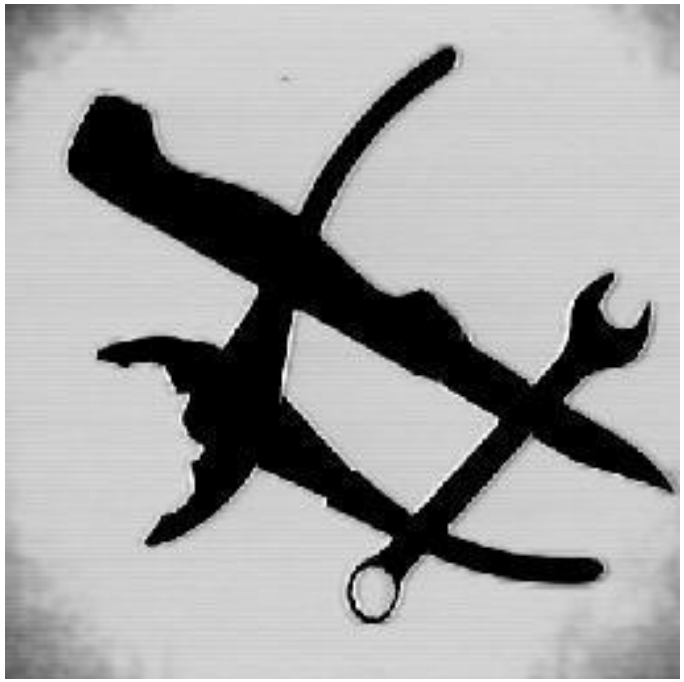
Applications and Research Topics

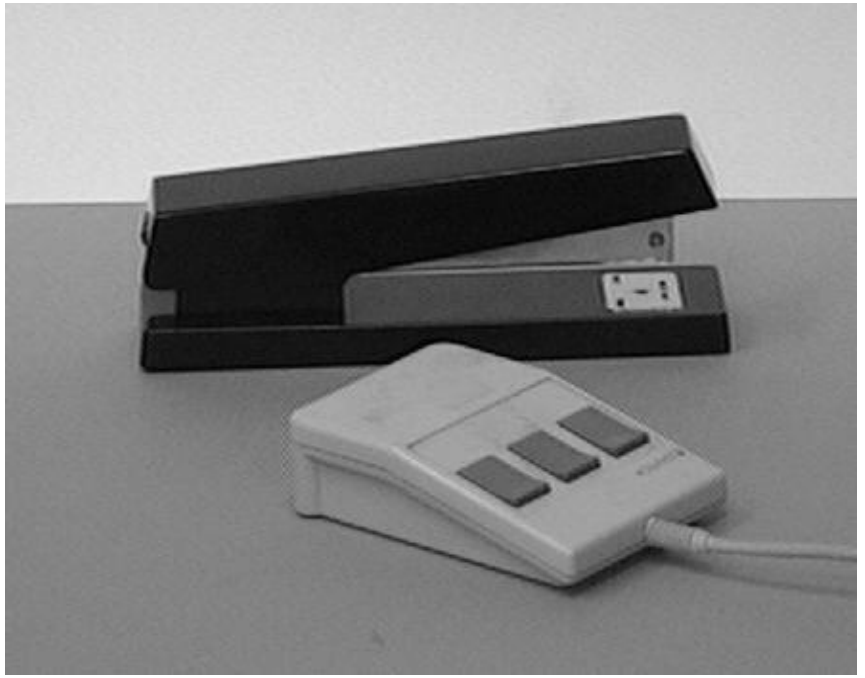
- Fingerprint Verification / Identification



Applications and Research Topics

- Object Recognition

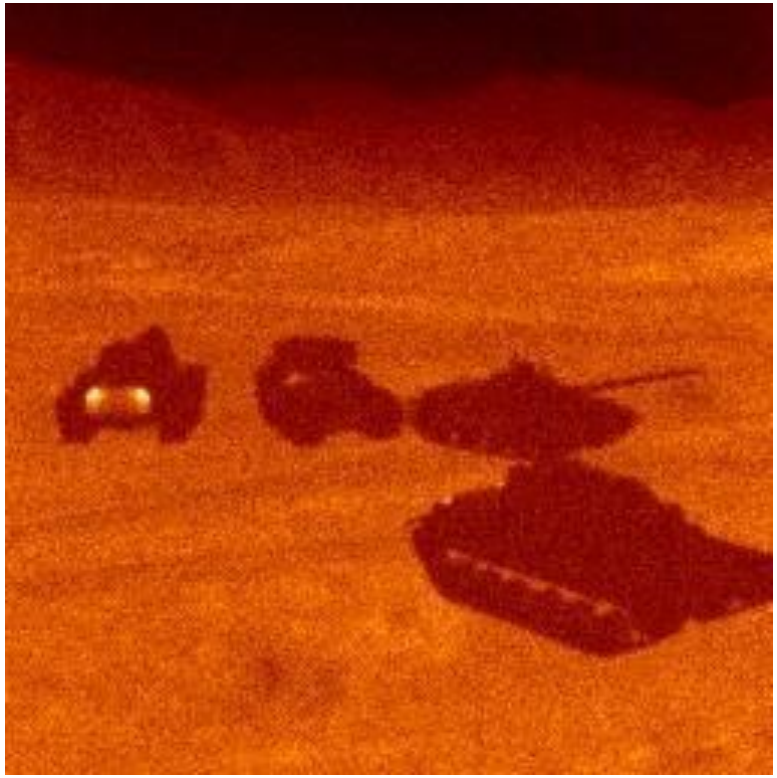




Applications and Research Topics

- Target Recognition

  Department of Defense (Army, Air force, Navy)



Applications and Research Topics

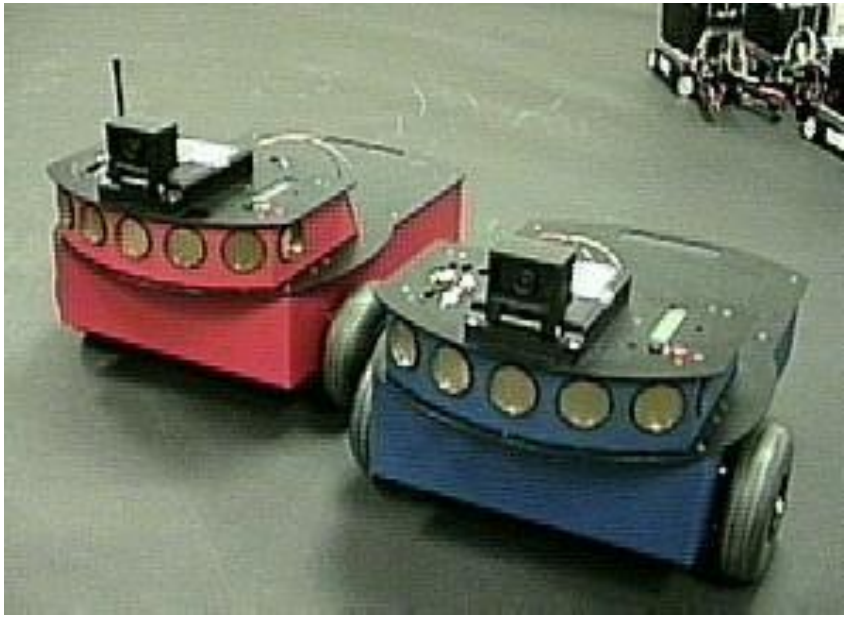
- Interpretation of Aerial Photography

  Interpretation of aerial photography is a problem domain in both computer vision and registration.

Applications and Research Topics

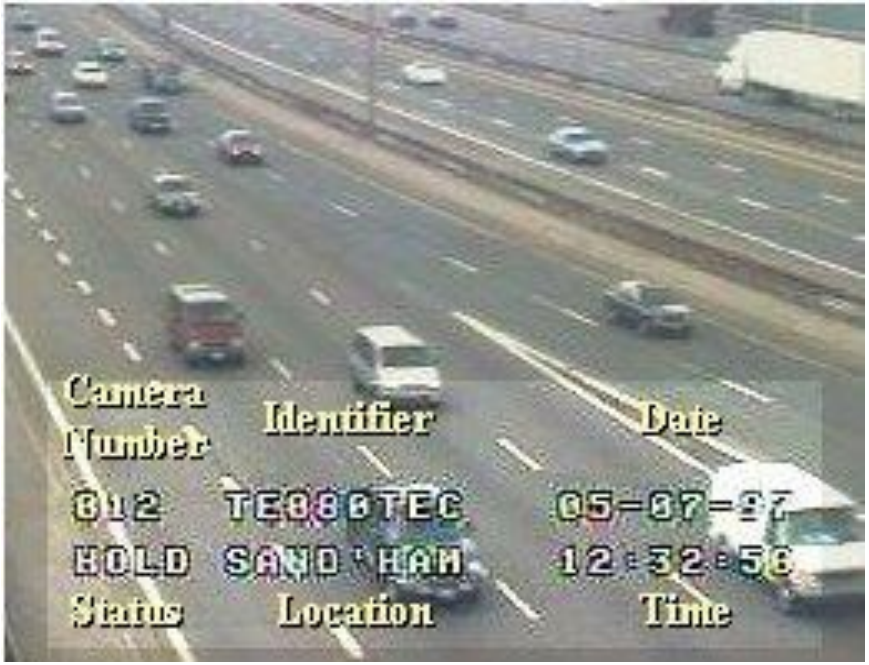
- Autonomous Vehicles

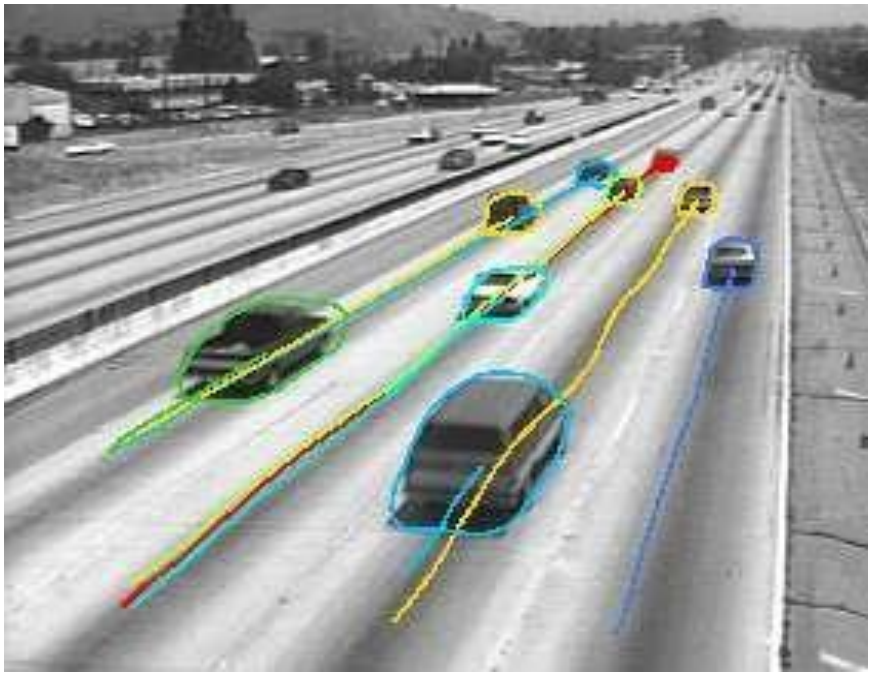
  Land, Underwater, Space



Applications and Research Topics

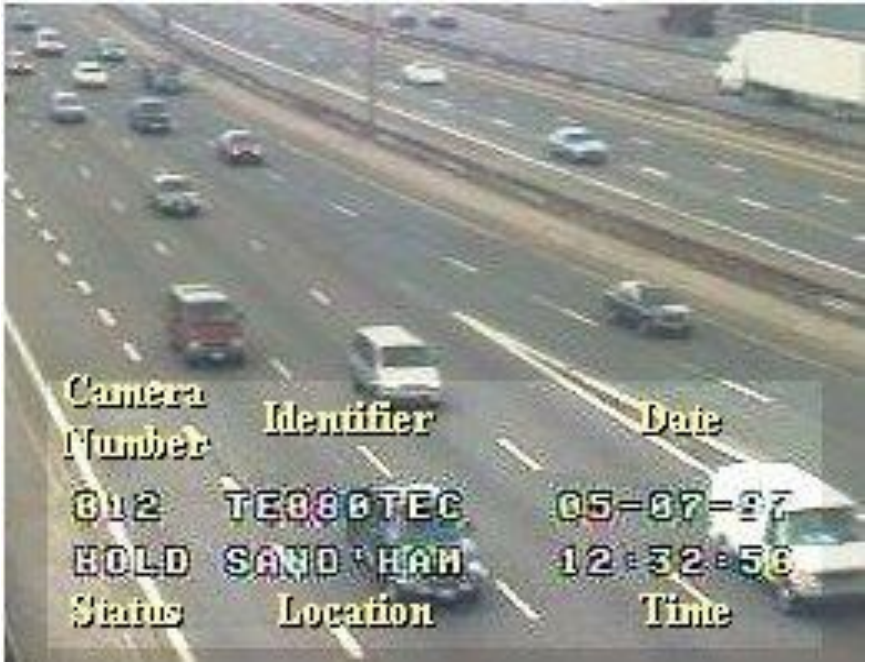
- Traffic Monitoring

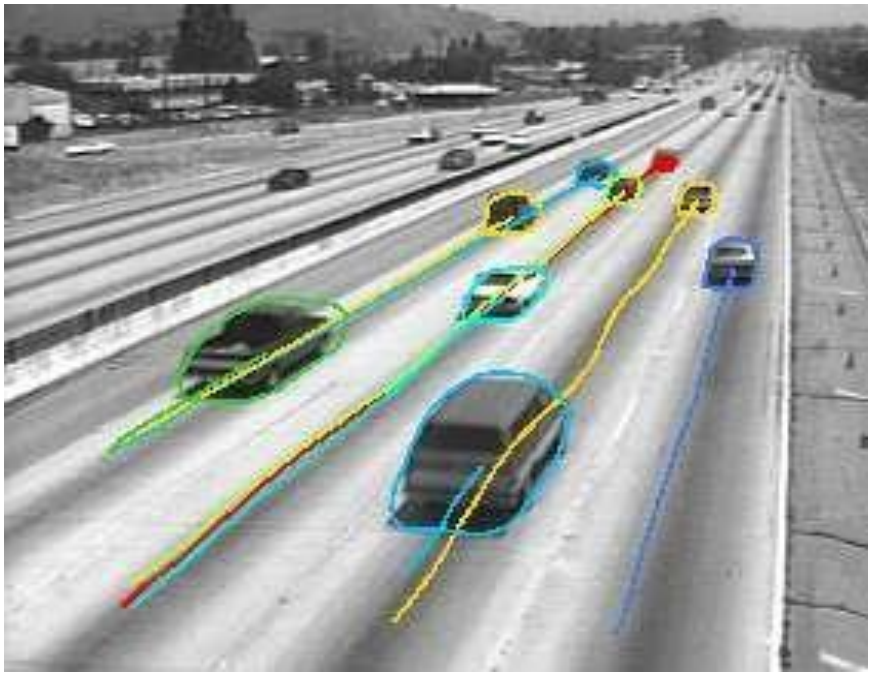




Applications and Research Topics

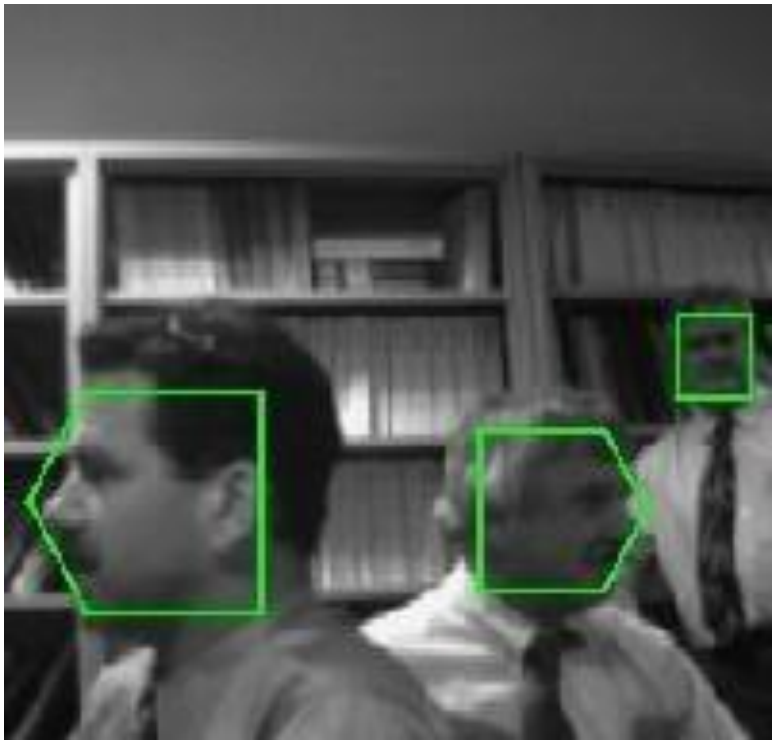
- Traffic Monitoring





Applications and Research Topics

- Face Detection

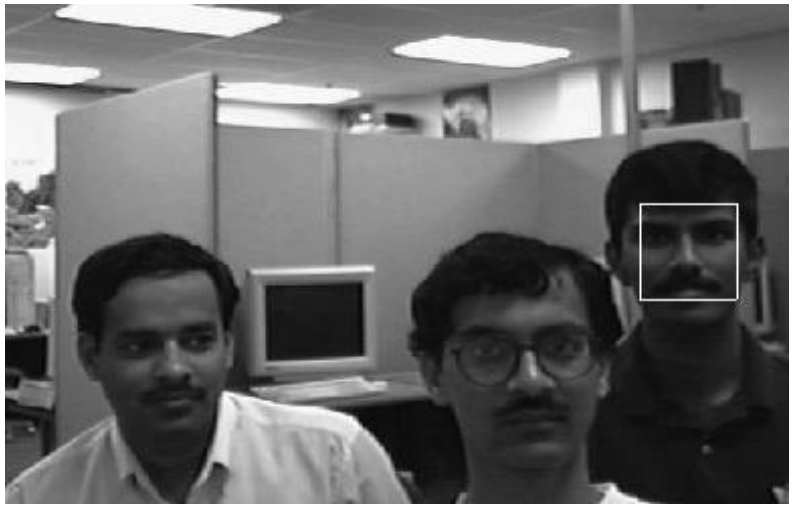


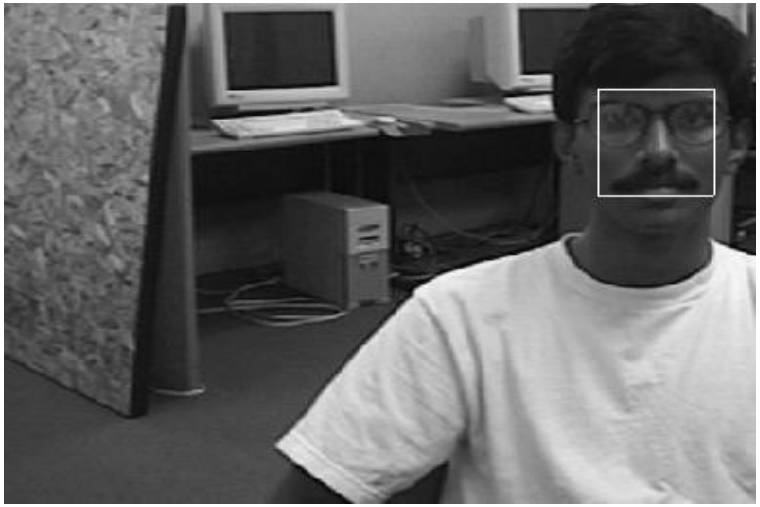
Applications and Research Topics

- Face Recognition

Applications and Research Topics

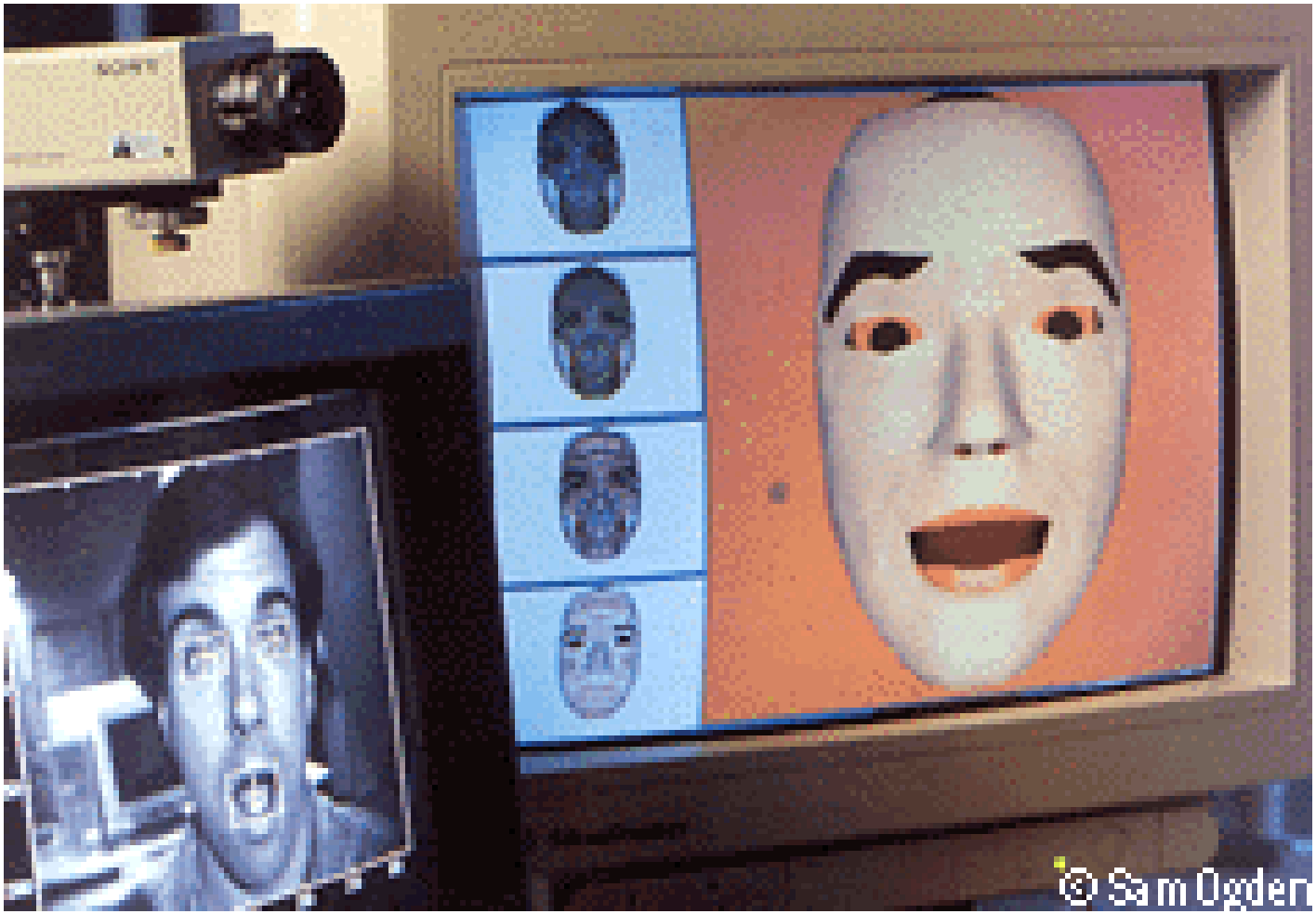
- Face Detection/Recognition Research





Applications and Research Topics

- Facial Expression Recognition

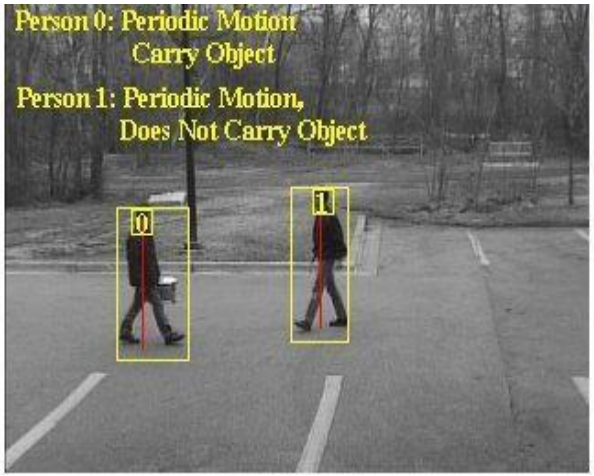


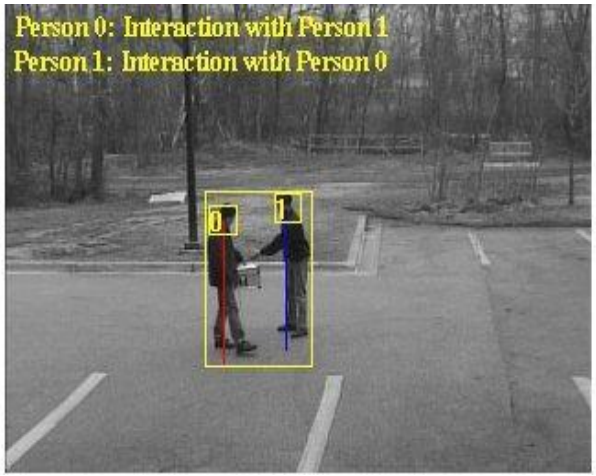
Applications and Research Topics

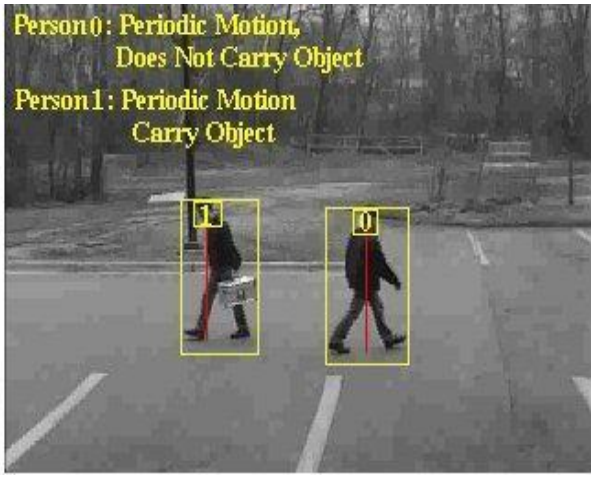
- Hand Gesture Recognition
  - Smart Human-Computer User Interfaces
  - Sign Language Recognition

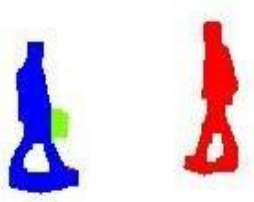
Applications and Research Topics

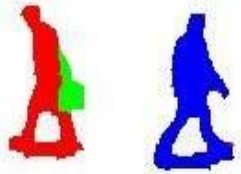
- Human Activity Recognition







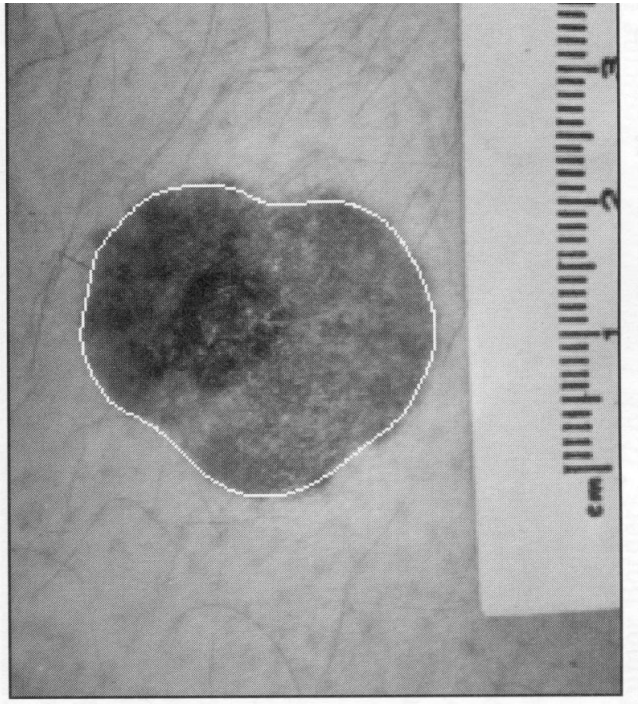




Applications and Research Topics

- Medical Applications

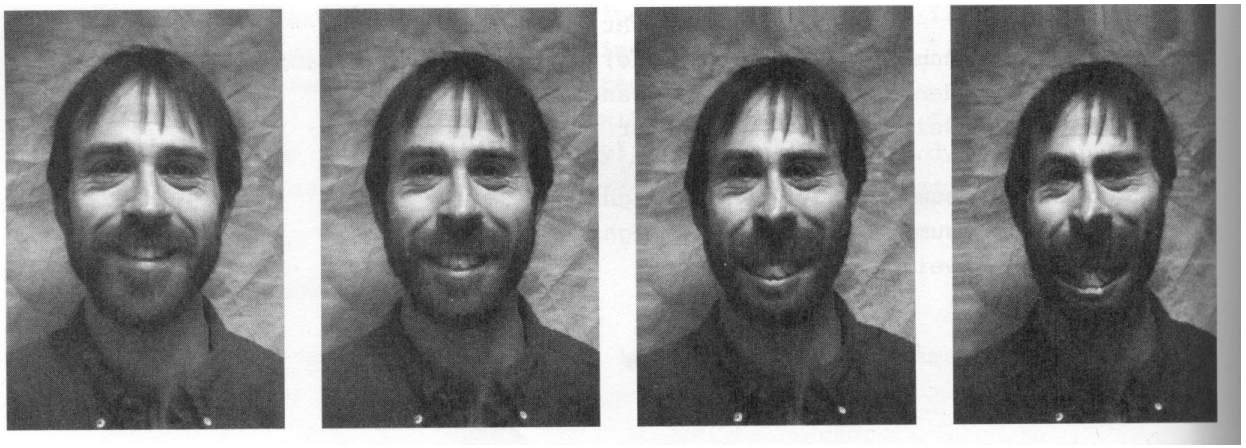
skin cancer

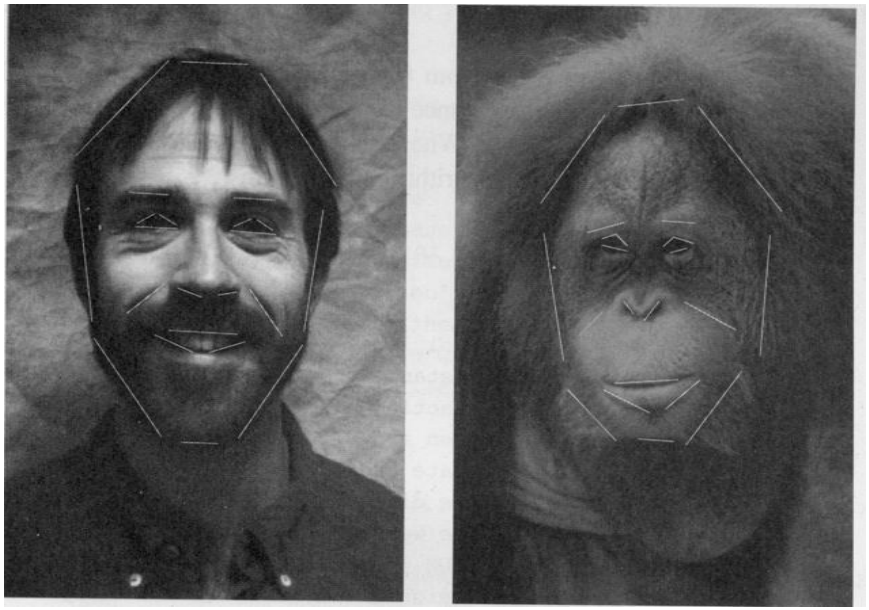


breast cancer

Applications and Research Topics

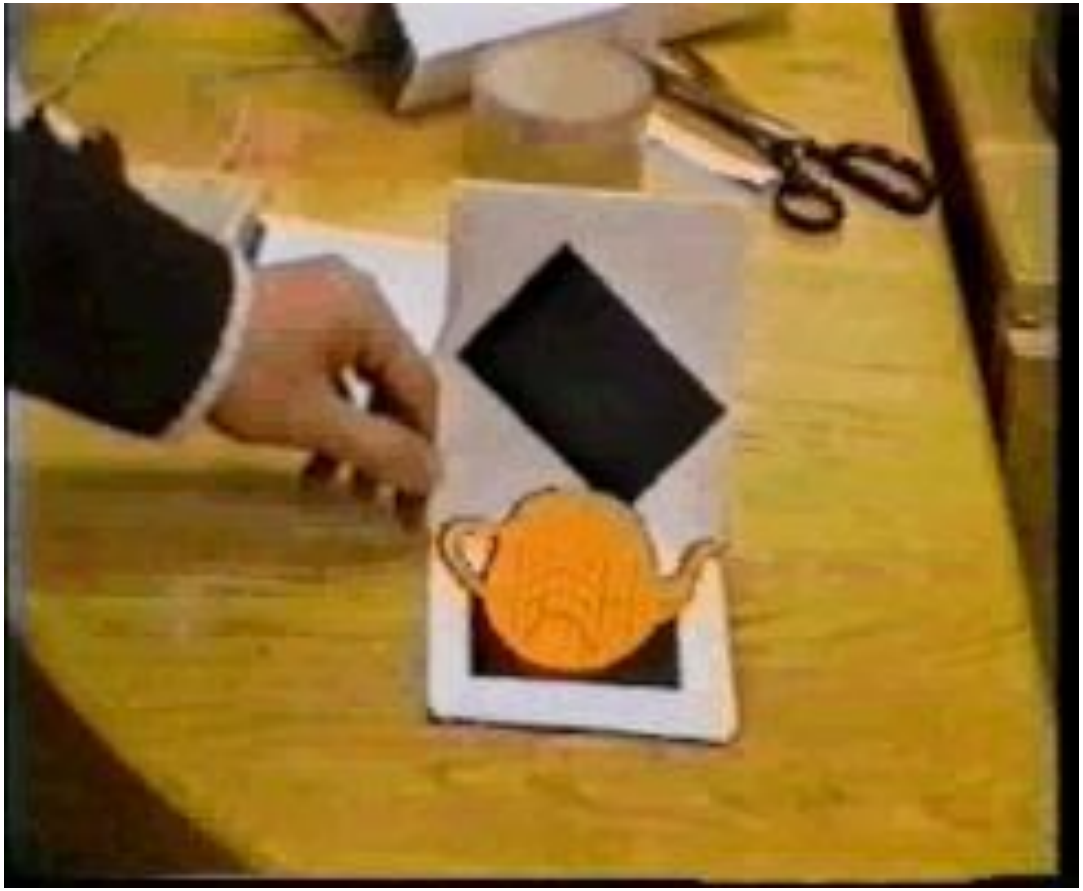
- Morphing





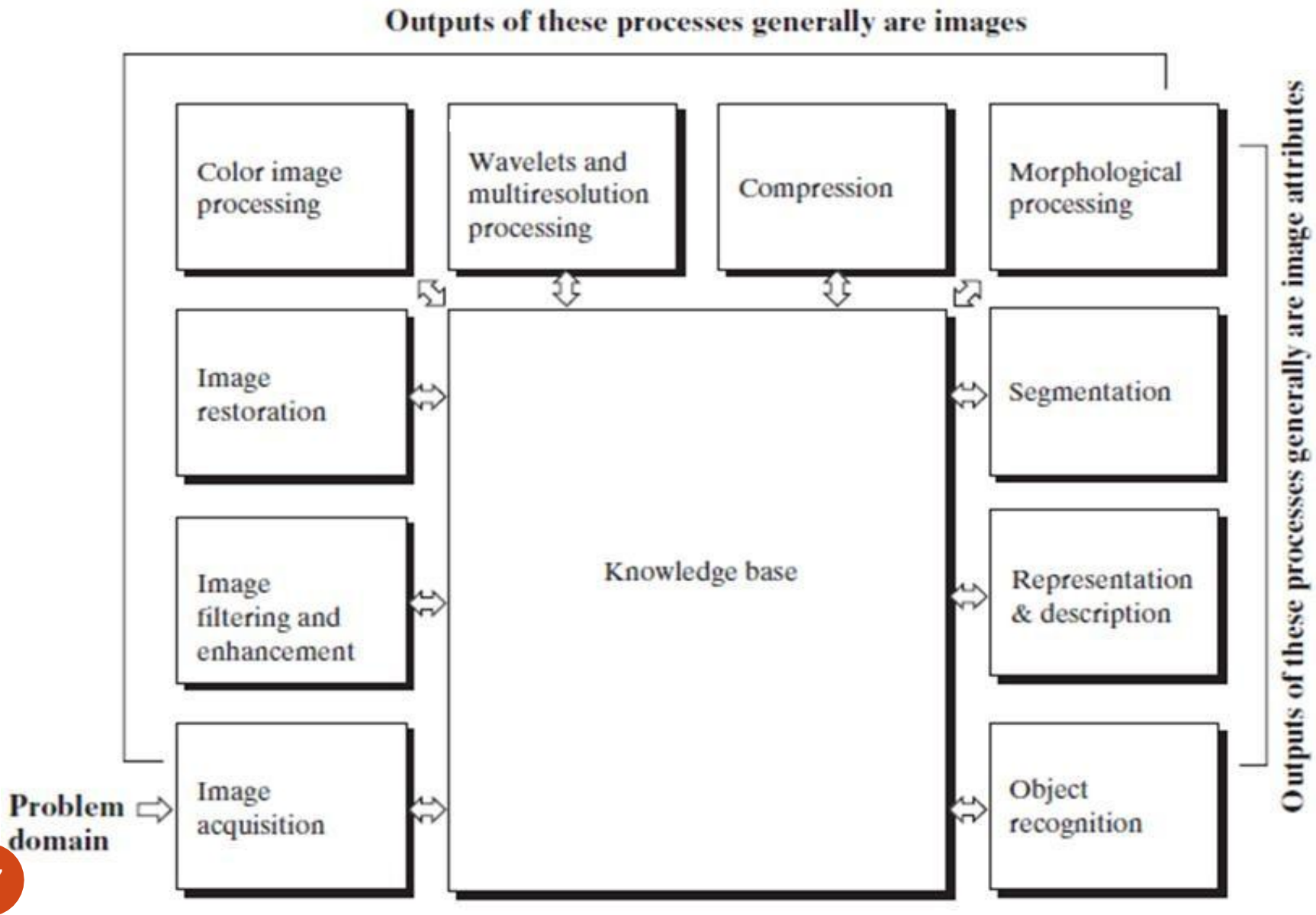
Applications and Research Topics

- Inserting Artificial Objects into a Scene



Fundamental Steps in Digital Image Processing

Fundamental Steps in Digital Image Processing



Fundamental Steps in Digital Image Processing

Essential steps when processing digital images:

Acquisition

Enhancement

Restoration

Color image restoration

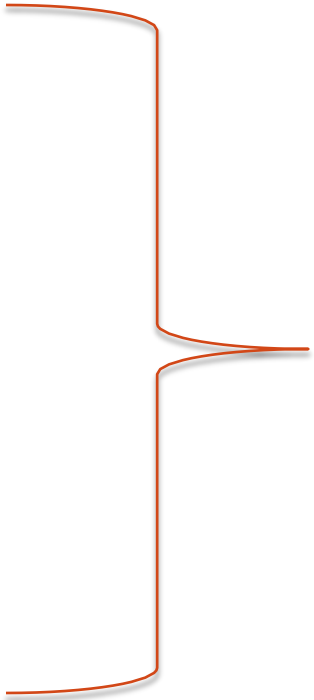
Wavelets

Morphological processing

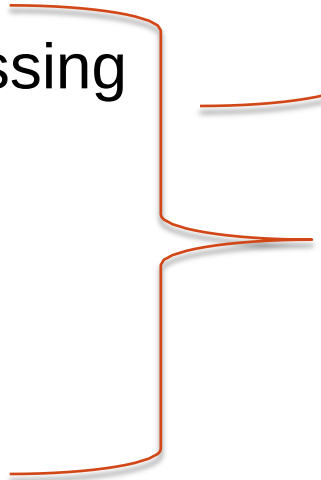
Segmentation

Representation

Recognition



Outputs are digital images

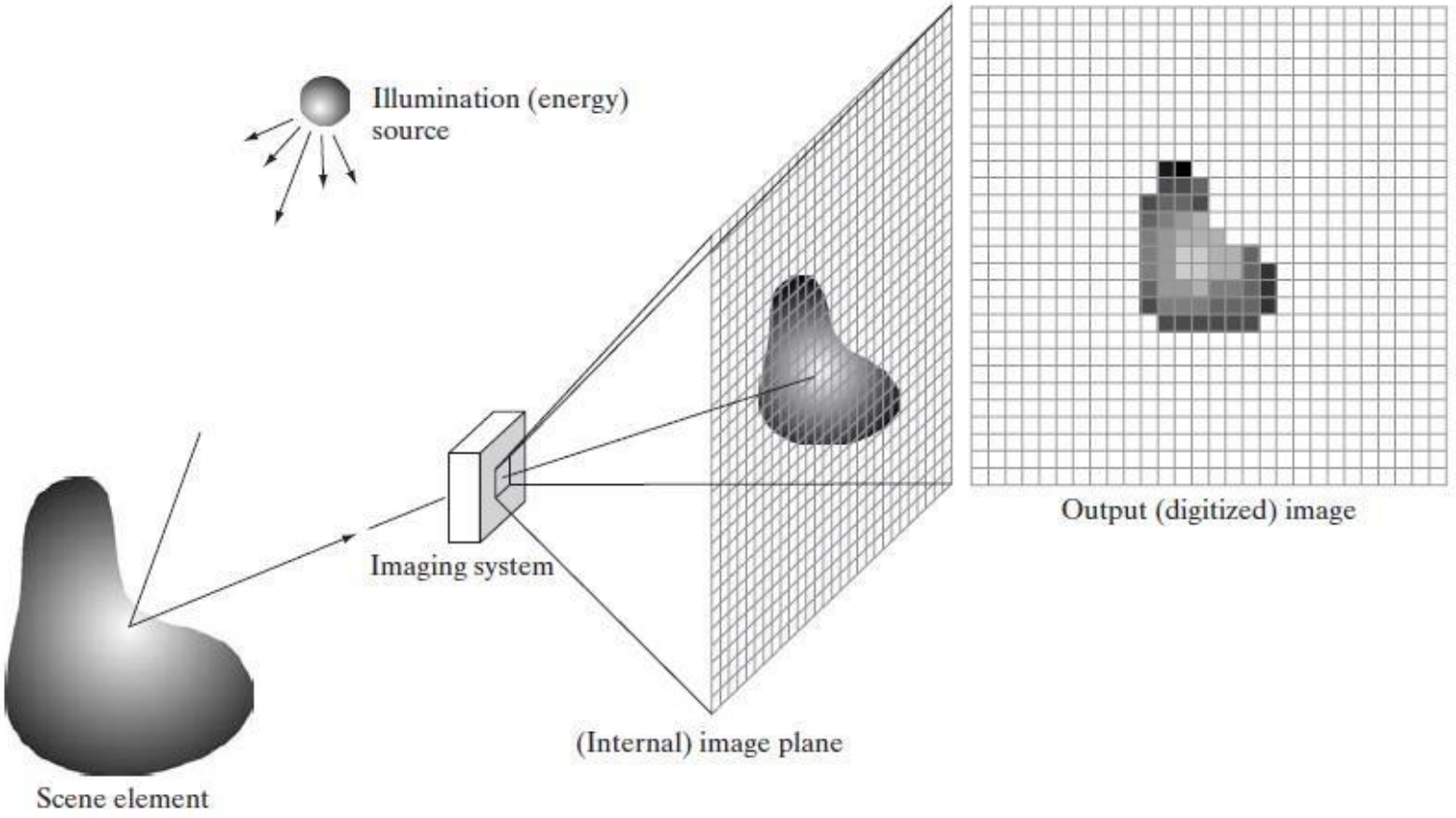


Outputs are attributes of the image

Fundamental Steps in Digital Image Processing

- ***Image acquisition*** is the first process.

  Generally, the image acquisition stage involves preprocessing, such as scaling.



Fundamental Steps in Digital Image Processing

- ***Image enhancement*** is the process of manipulating an image so that the result is more suitable than the original for a specific application.

  There is no general "theory" of image enhancement.

  When an image is processed for visual interpretation, the viewer is the ultimate judge of how well a particular method works.

lack of contrast

image enhancement

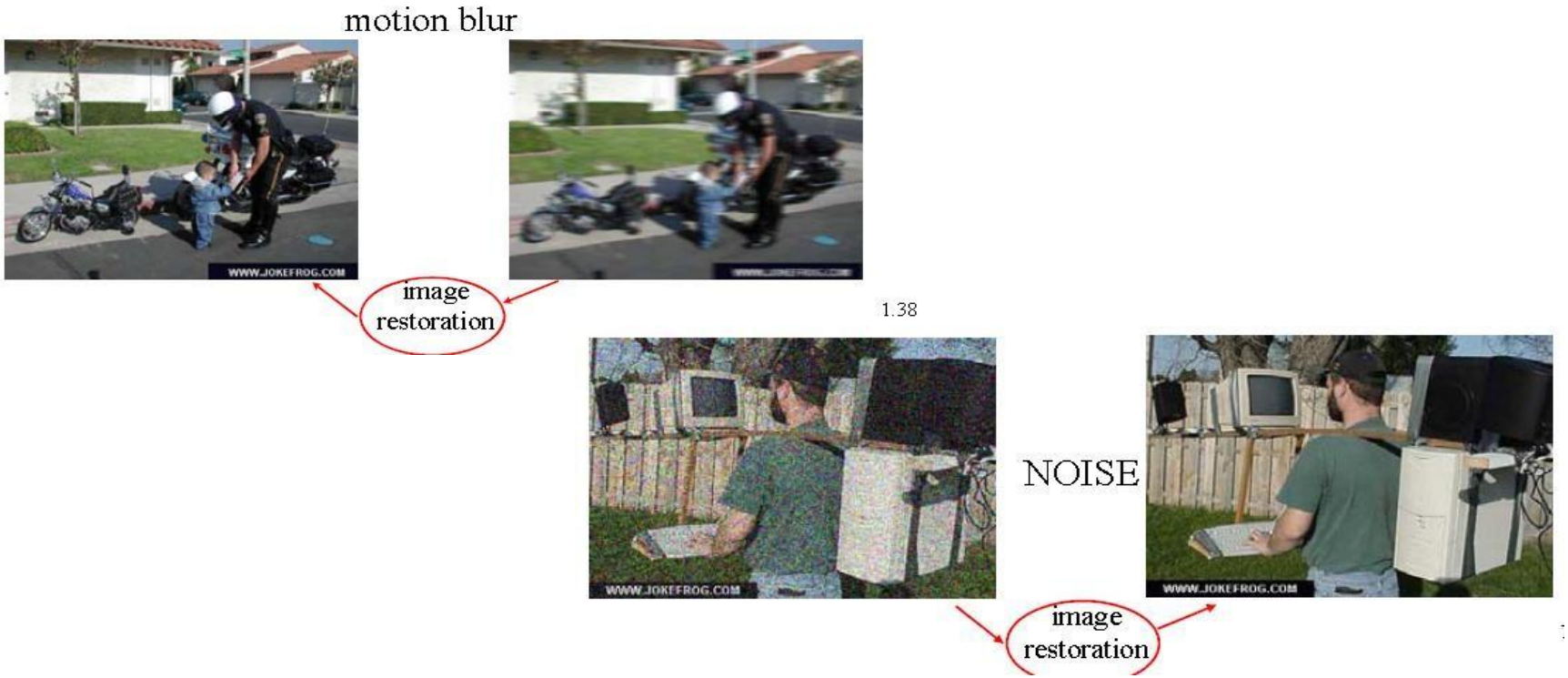
BLURRING

image enhancement

Fundamental Steps in Digital Image Processing

- ***Image Restoration*** is an area that also deals with improving the appearance of an image.

  However, unlike enhancement, which is subjective, image restoration is objective, in the sense that restoration techniques tend to be based on mathematical or probabilistic models of image degradation.



Fundamental Steps in Digital Image Processing

- ***Color Image Processing*** is an area that has been gaining in importance because of the significant increase in the use of digital images over the Internet.

- ***Wavelets*** are the foundation for representing images in various degrees of resolution.

Fundamental Steps in Digital Image Processing

- ***Compression***, as the name implies, deals with techniques for reducing the storage required to save an image, or the bandwidth required to transmit it. This is true particularly in uses of the Internet.

Fundamental Steps in Digital Image Processing

- ***Morphological processing*** deals with tools for extracting image components that are useful in the representation and description of shape.

- ***Segmentation*** procedures partition an image into its constituent parts or objects.

  A segmentation procedure brings the process a long way toward successful solution of imaging problems that require objects to be identified individually.

  In general, the more accurate the segmentation, the more likely recognition is to succeed.

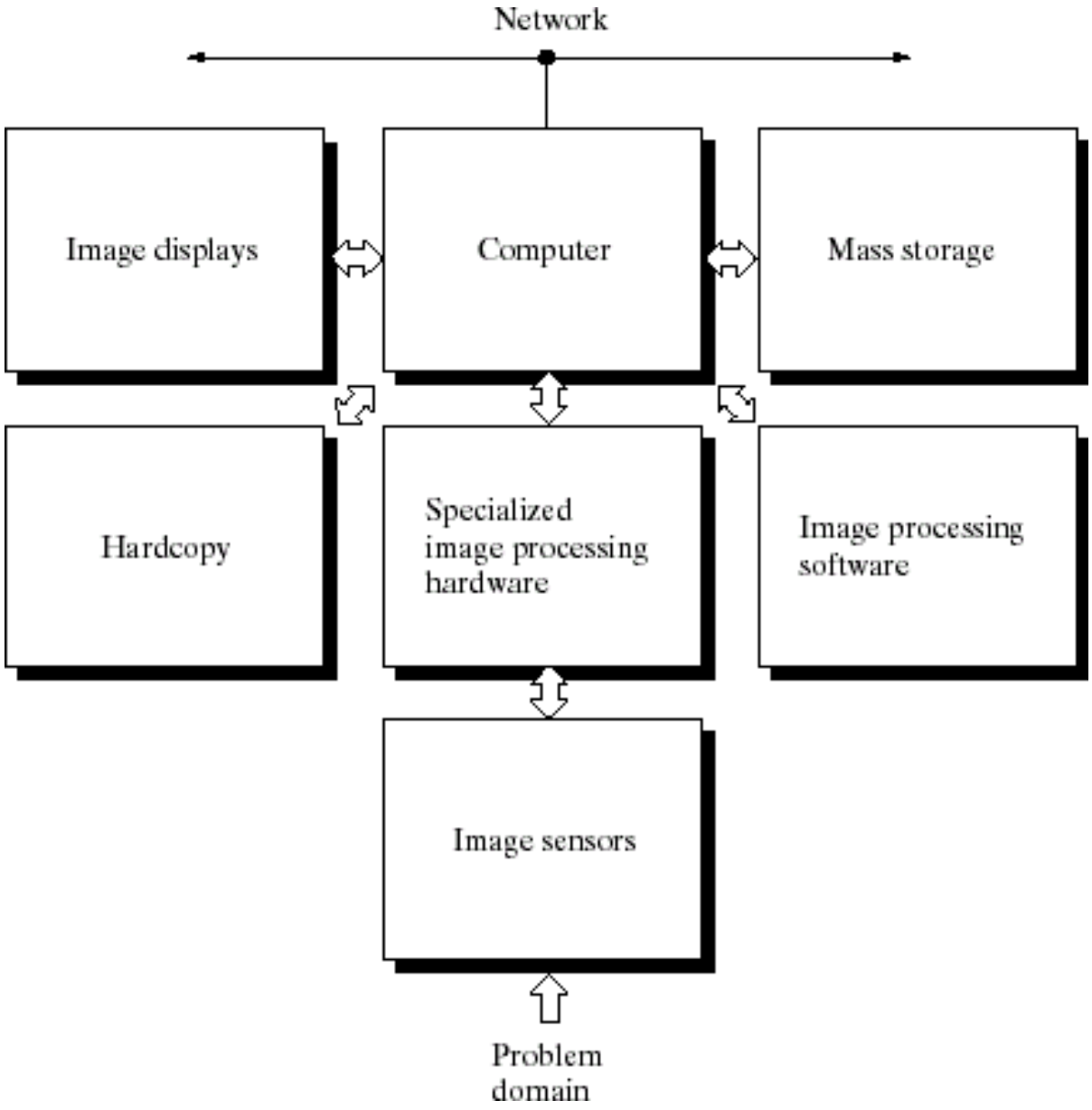
Fundamental Steps in Digital Image Processing

- **Representation and description** almost always follow the output of a segmentation stage, which usually is raw pixel data.
  - Boundary representation is appropriate when the focus is on external shape characteristics, such as corners and inflections.
  - Regional representation is appropriate when the focus is on internal properties, such as texture or skeletal shape.

  Description, also called feature selection, deals with extracting attributes that result in some quantitative information of interest or are basic for differentiating one class of objects from another.

- ***Recognition*** is the process that assigns a label (e.g., "vehicle") to an object based on its descriptors. Digital image processing with the development of methods for recognition of individual objects.

General Purpose Image Processing System



General Purpose Image Processing System

- ***Specialized image processing hardware*** usually consists of the digitizer, plus hardware that performs other primitive operations, such as an arithmetic logic unit (ALU), that performs arithmetic and logical operations in parallel on entire images.

- This type of hardware sometimes is called a *front-end subsystem,* and its most distinguishing characteristic is speed.

General Purpose Image Processing System

- The ***Computer*** in an image processing system is a general-purpose computer and can range from a PC to a supercomputer.

- In dedicated applications, sometimes custom computers are used to achieve a required level of performance, but our interest here is on general-purpose image processing systems.

- In these systems, almost any well-equipped PC-type machine is suitable for off-line image processing tasks.

General Purpose Image Processing System

- ***Software*** for image processing consists of specialized modules that perform specific tasks.

- More sophisticated software packages allow the integration of those modules and general-purpose software commands from at least one computer language.

General Purpose Image Processing System

- ***Mass storage*** capability is a must in image processing applications.
- An image of size 1024 * 1024 pixels, in which the intensity of each pixel is an 8-bit quantity, requires one megabyte of storage space if the image is not compressed.
- Digital storage for image processing applications falls into three principal categories:
  - Short-term storage for use during processing,
  - On-line storage for relatively fast recall, and
  - Archival storage, characterized by infrequent access.
- Storage is measured in:
  - bytes,
  - Kbytes,
  - Mbytes,
  - Gbytes, and

General Purpose Image Processing System

- ***Image displays*** in use today are mainly color (preferably flat screen) TV monitors.
- Monitors are driven by the outputs of image and graphics display cards that are an integral part of the computer system.
- In some cases, it is necessary to have stereo displays, and these are implemented in the form of headgear containing two small displays embedded in goggles worn by the user.

General Purpose Image Processing System

- ***Hardcopy devices*** for recording images include laser printers, film cameras, heat-sensitive devices, inkjet units, and digital units, such as optical and CDROM disks.

- ***Networking*** is almost a default function in any computer system in use today.

  In dedicated networks, this typically is not a problem, but communications with remote sites via the Internet are not always as efficient.

Image Processing Basics

Image Representation

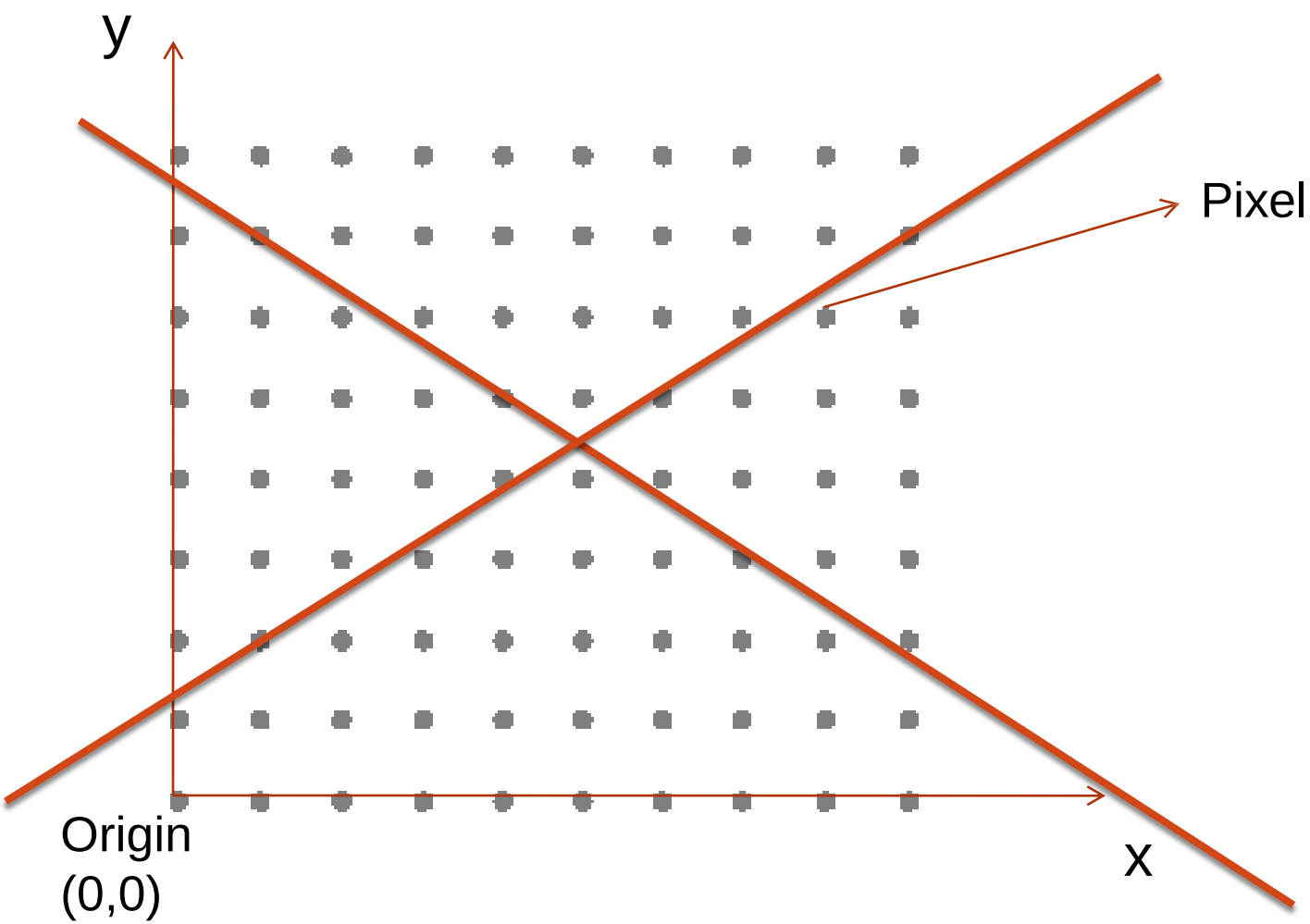
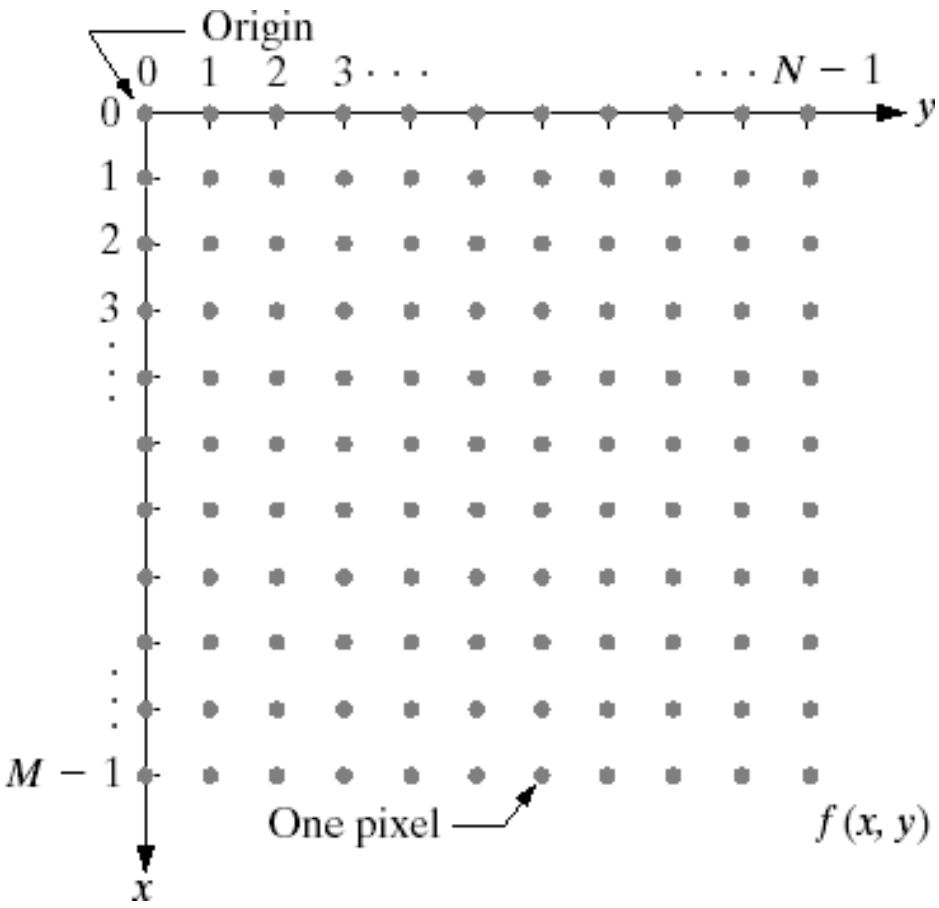
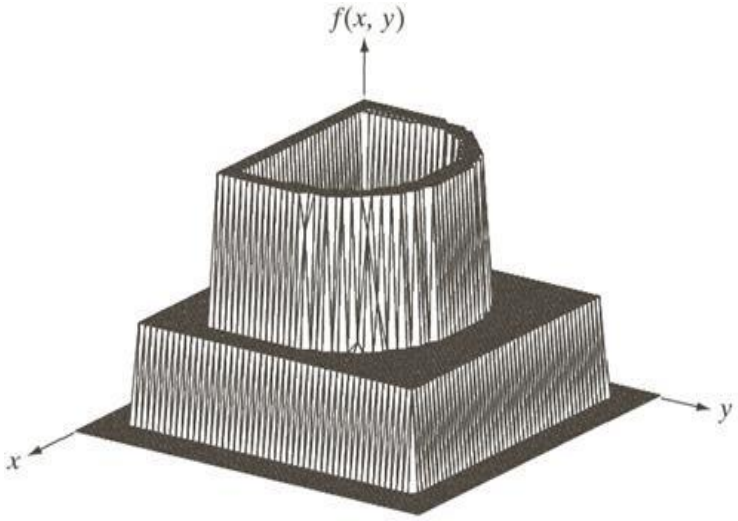


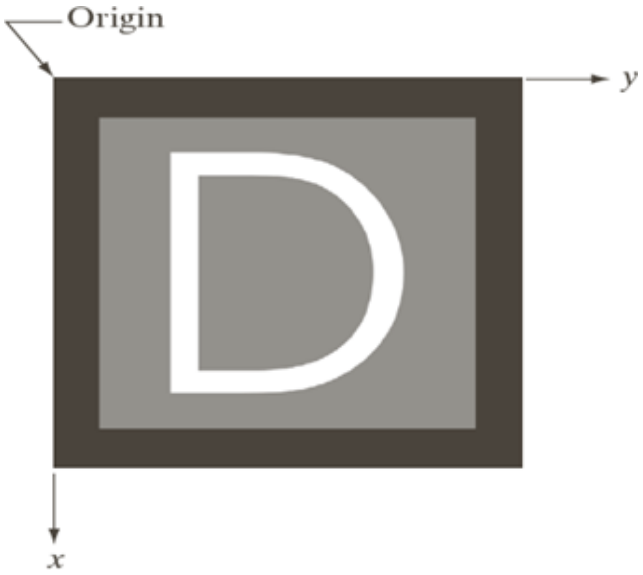
Image Representation



- A digital image is composed of M rows and N columns of pixels each storing a value
- Pixel values are most often grey levels in the range 0-255(black-white)
- We will see later on that images can easily be represented as matrices.

Image Representation





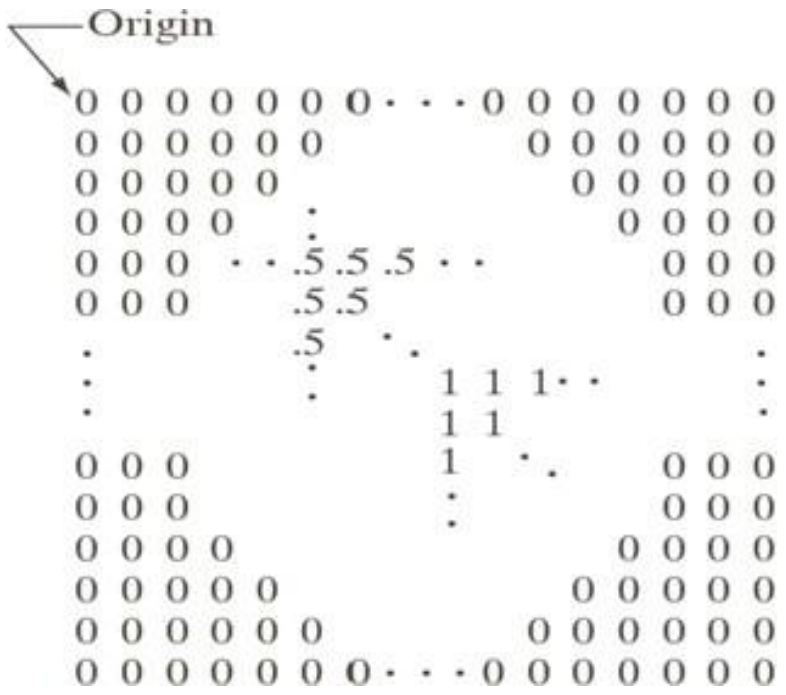
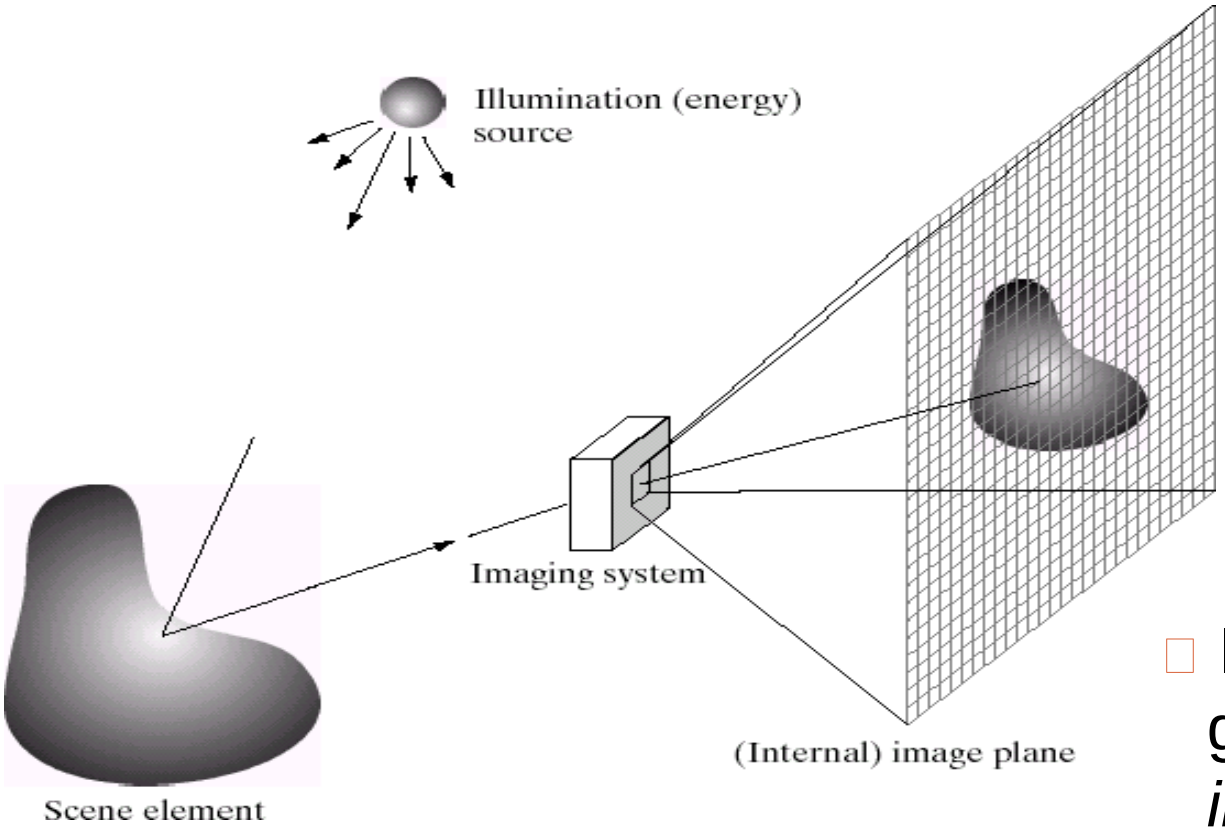
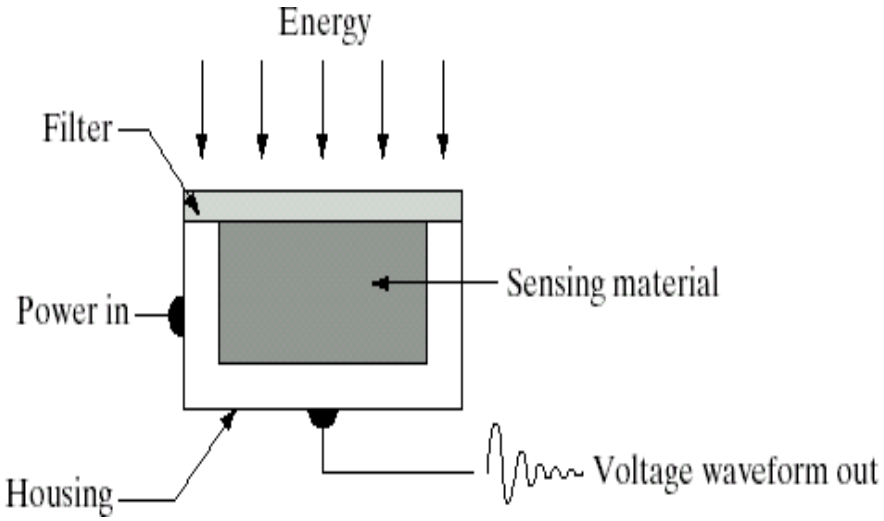


Image Acquisition

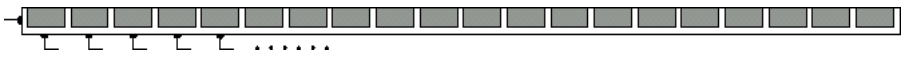


- Images are typically generated by *illuminating* a *scene* and absorbing the energy reflected by the objects in that scene

Image Sensing

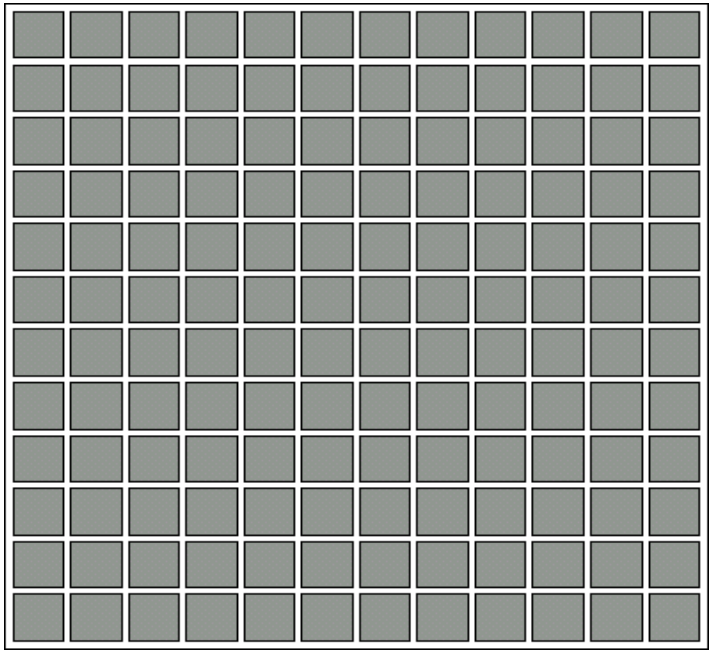


Imaging Sensor



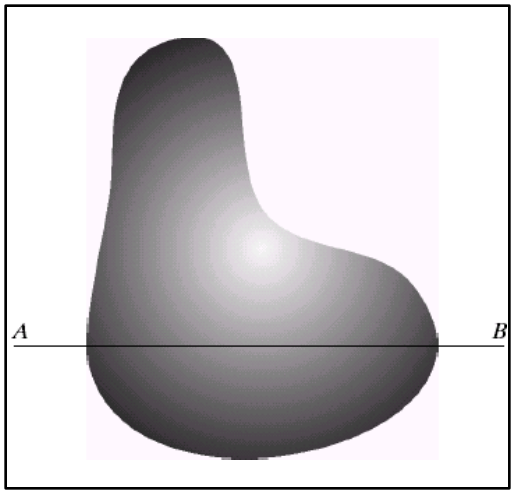
Line of Image Sensors

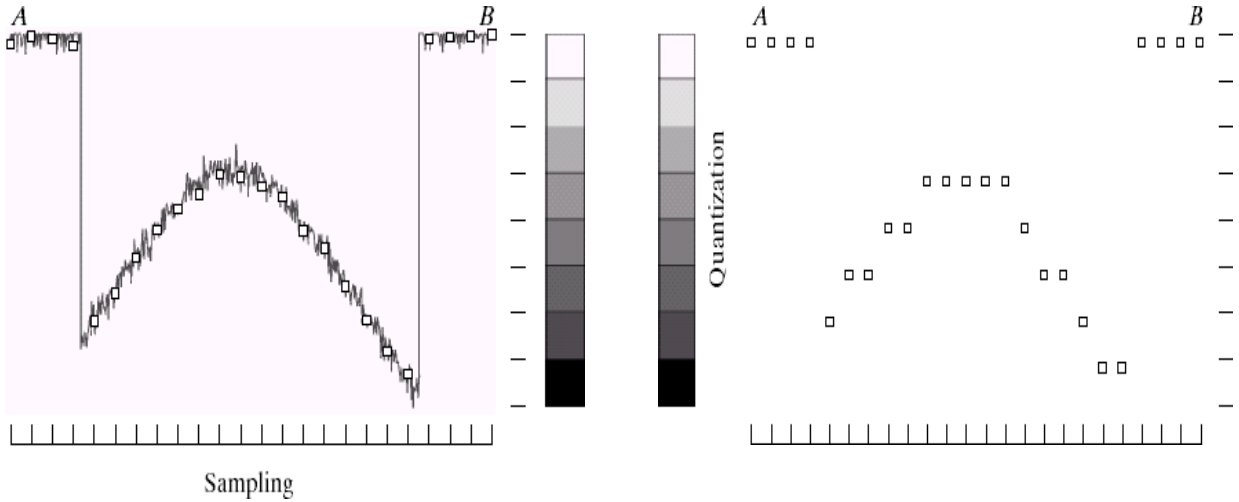
- Incoming energy lands on a sensor material responsive to that type of energy and this generates a voltage
- Collections of sensors are arranged to capture images



Array of Image Sensors

Image Sampling And Quantization

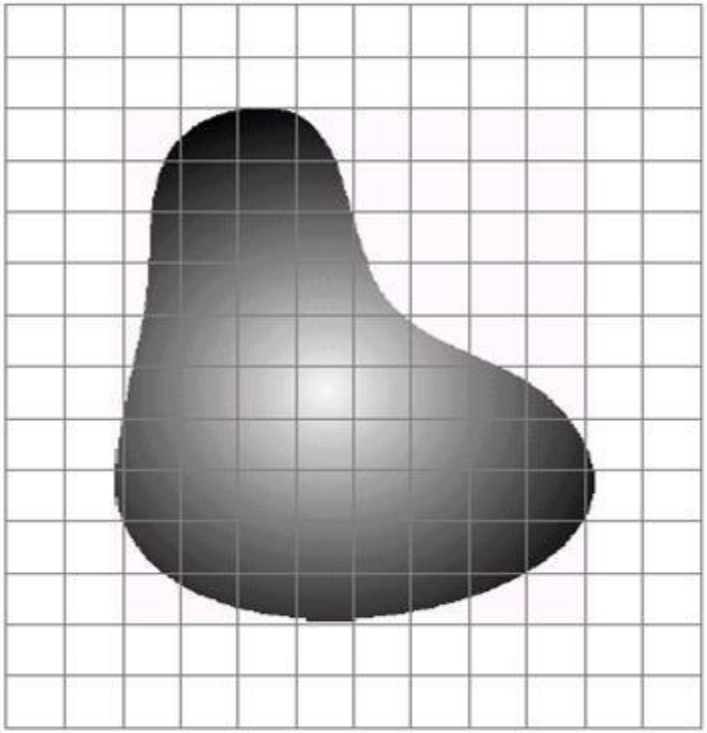


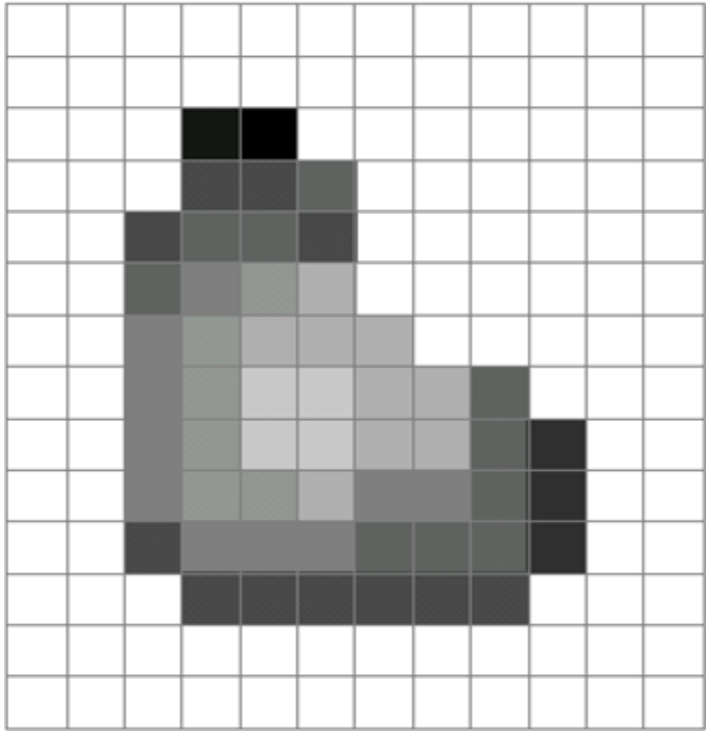


- A digital sensor can only measure a limited number of **samples** at a **discrete** set of energy levels
- *Quantisation* is the process of converting a continuous **analogue** signal into a digital representation of this signal

Image Sampling And Quantization

- Remember that a digital image is always only an **approximation** of a real world scene.

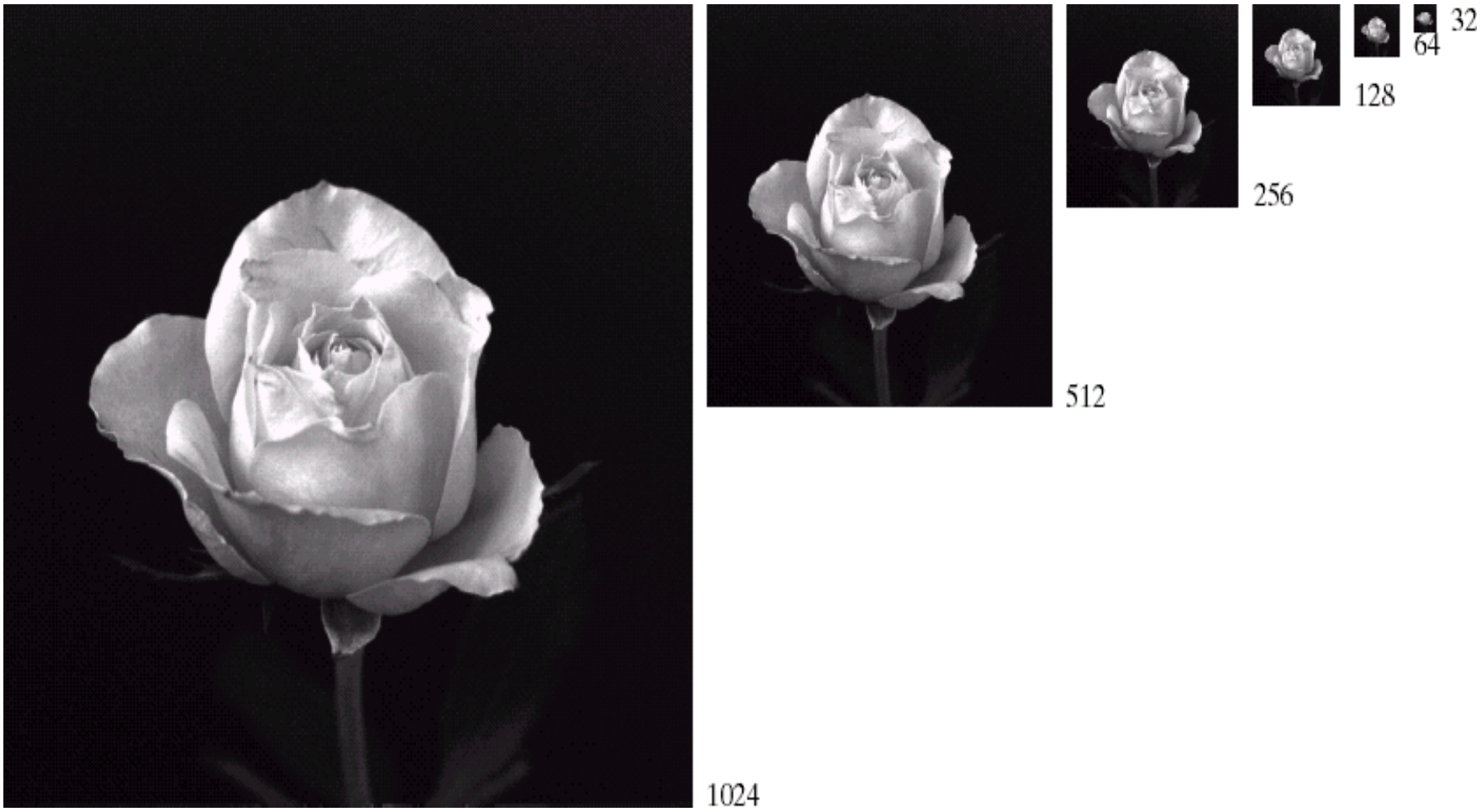




Spatial Resolution

- *The spatial resolution* of an image is determined by how sampling was carried out
- Spatial resolution simply refers to the smallest discernable detail in an image
  - Vision specialists will often talk about pixel size
  - Graphic designers will talk about *dots per inch* (DPI)

Spatial Resolution



Vision specialists will often talk about pixel size

Spatial Resolution

1024 * 1024

512 * 512

256 * 256

128 * 128

64 * 64

32 * 32

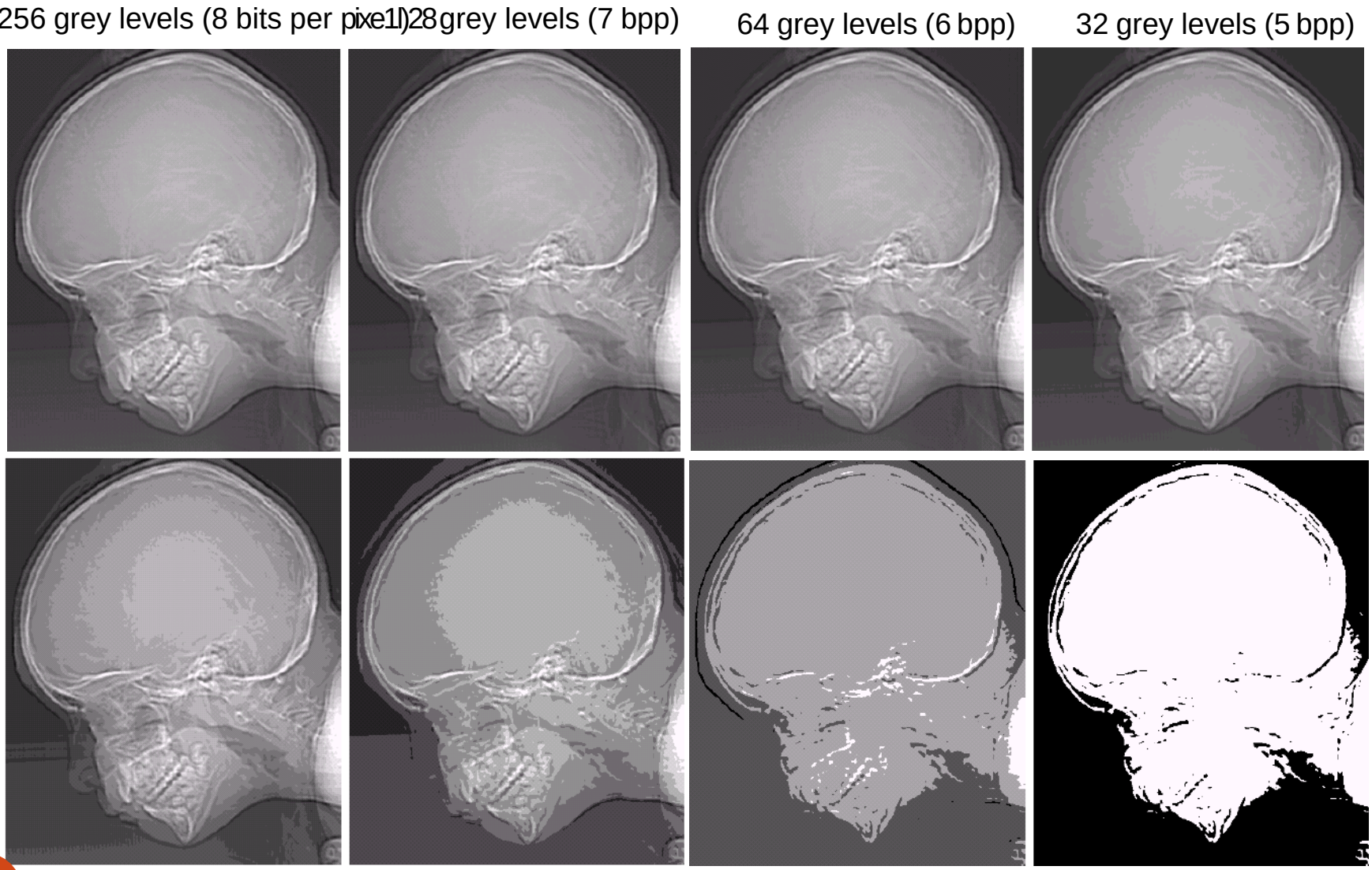
Graphic designers will talk about *dots per inch*

Intensity Level Resolution

- *Intensity level resolution* refers to the number of intensity levels used to represent the image
  - The more intensity levels used, the finer the level of detail discernable in an image
  - Intensity level resolution is usually given in terms of the number of bits used to store each intensity level

Number of Bits	Number of Intensity Levels	Examples
1	2	0, 1
2	4	00, 01, 10, 11
4	16	0000, 0101, 1111
8	256	00110011,
16	65,536	1010010101010101010

Intensity Level Resolution



Resolution: How Much Is Enough?

- The big question with resolution is always *how much is enough*?
  - This all depends on what is in the image and what you would like to do with it
  - Key questions include
    - Does the image look aesthetically pleasing?
    - Can you see what you need to see within the image?

- The picture on the right is fine for counting the number of cars, but not for reading the number plate