CSE-404 Digital Image Processing:

- About the course

  Digital image manipulation, enhancement and restoration techniques. Two-dimensional digital filters and their application. Color image processing. Brief coverage of image compression and segmentation methods.

- http://groups.yahoo.com/group/dip2013

Grading Policy

- Assignments, quizzes, project
  - Assignments: 7%
  - Quizzes: 12%
  - Project: 6%
- Mid term: 25%
- Final term: 50%

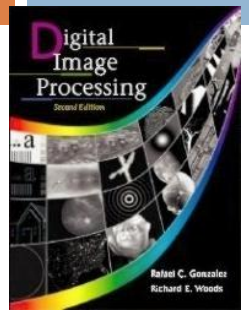
Assignments, quizzes

- Assignments, quizzes
  - Assignments: 7%
    - Total 4
      - 2 before Midterm
      - 2 after Midterm
  - Quizzes: 12%
    - Total 8
      - 4 before Midterm
      - 4 after Midterm

Project

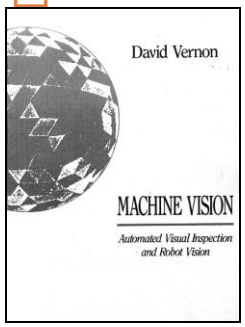
- Project: 6% (Total 100 Marks)
  - Selection of Project:
    - Before 4Th March 2013
      - Submit Project proposal 10 Marks
    - Mid report
      - Submit Before 25th March 2013 30 Marks
    - Final report
      - Submit Before 20th May 2013 40 Marks
    - Final Presentation
      - From 20th May 2013 20 Marks
    - Bonus 10 Marks for some implementation work!

References



"Digital Image Processing", Rafael C. Gonzalez & Richard E. Woods, Addison-Wesley, 2002

- Much of the material that follows is taken from this book



"Machine Vision: Automated Visual Inspection and Robot Vision", David Vernon, Prentice Hall, 1991

Available online at:

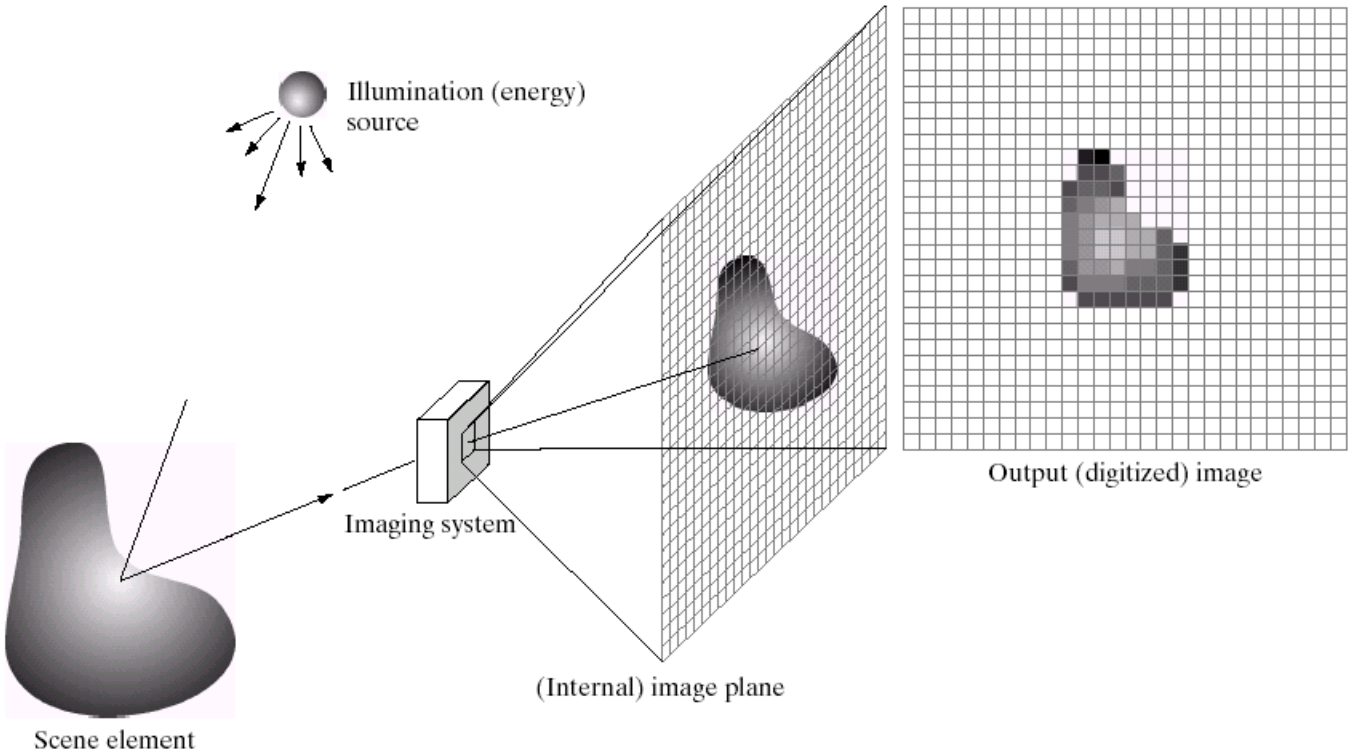
homepages.inf.ed.ac.uk/rbf/BOOKS/VERNON/

Contents

- This lecture will cover:
  - What is a digital image?
  - What is digital image processing?
  - History of digital image processing
  - State of the art examples of digital image processing
  - Key stages in digital image processing

What is a Digital Image?

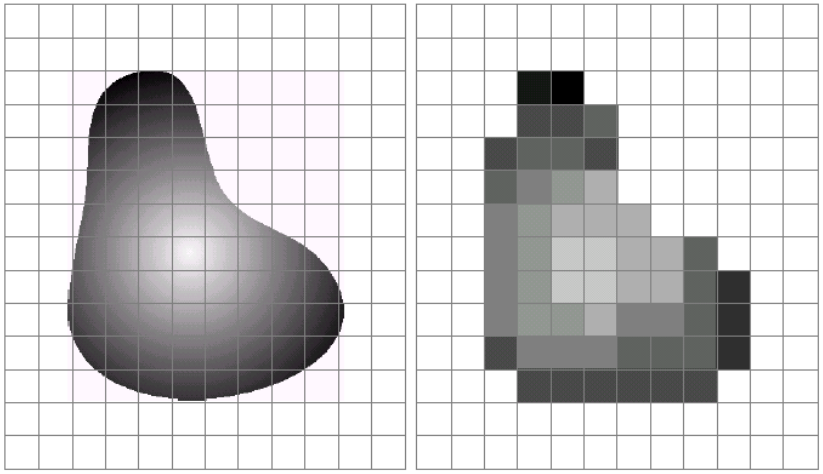
- A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels

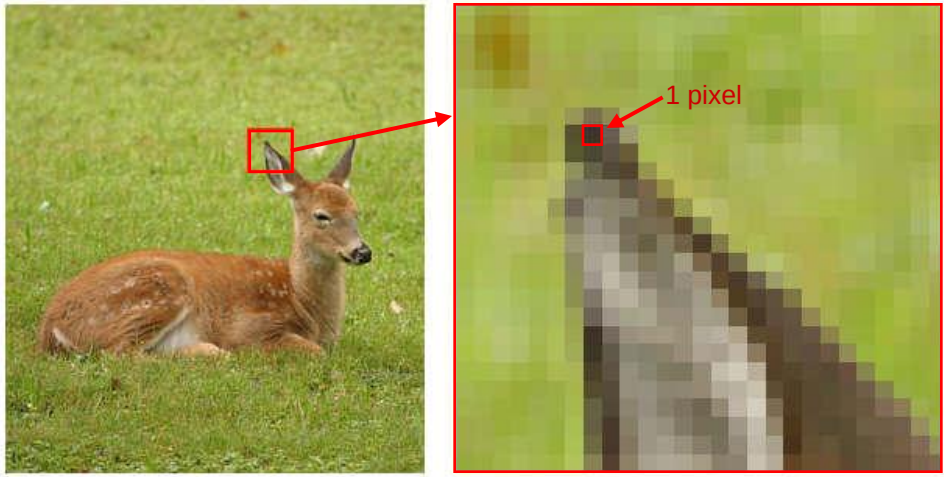


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

What is a Digital Image? (cont…)

- Pixel values typically represent gray levels, colours, heights, opacities etc
- **Remember** *digitization* implies that a digital image is an *approximation* of a real scene





What is a Digital Image? (cont…)

- Common image formats include:
  - 1 sample per point (B&W or Grayscale)
  - 3 samples per point (Red, Green, and Blue)
  - 4 samples per point (Red, Green, Blue, and "Alpha", a.k.a. Opacity)



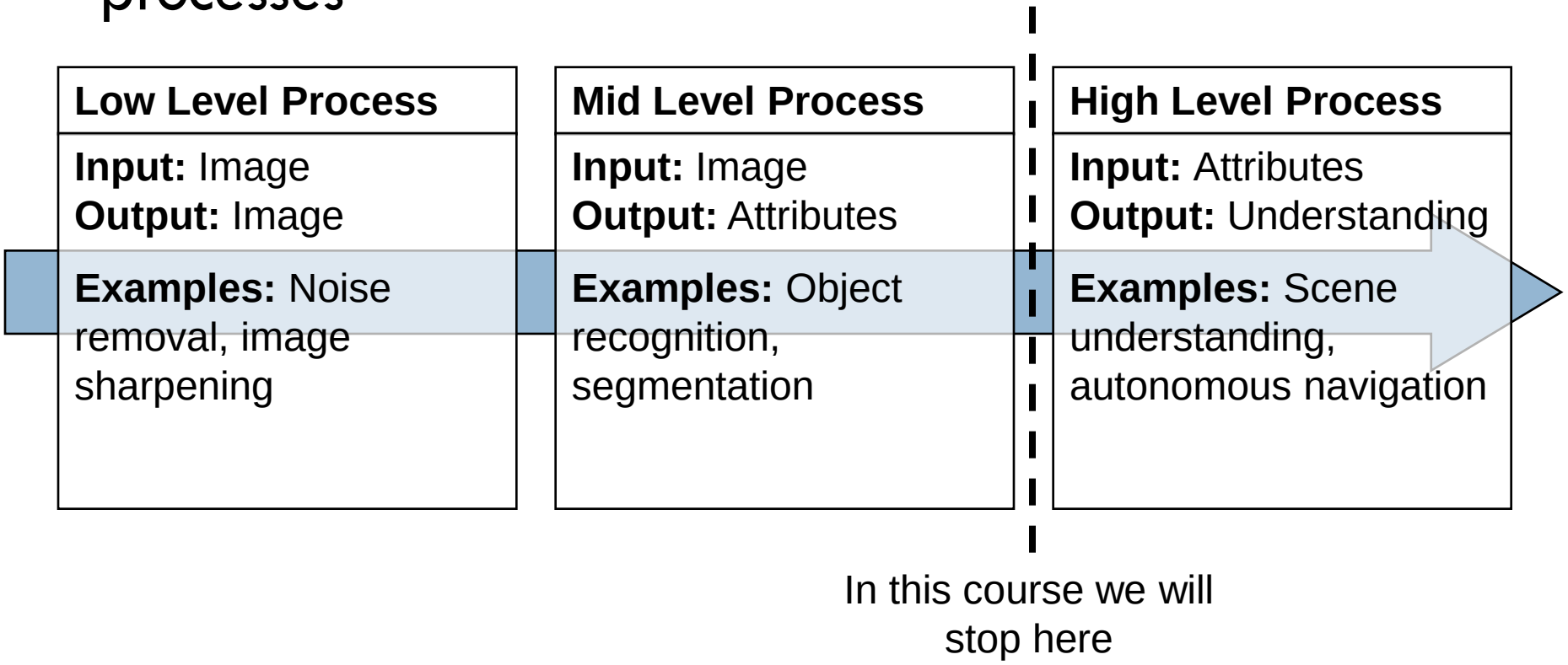
- For most of this course we will focus on grey-scale images

What is Digital Image Processing?

- 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

What is DIP? (cont…)

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



History of Digital Image Processing

- **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

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

History of DIP (cont…)

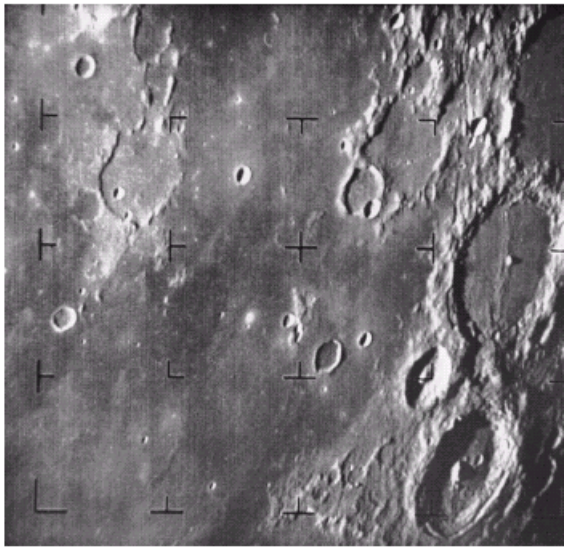
- **Mid to late 1920s:** Improvements to the Bartlane system resulted in higher quality images
  - New reproduction processes based on photographic techniques
  - Increased number of tones in reproduced images

Improved digital image

Early 15 tone digital image

History of DIP (cont…)

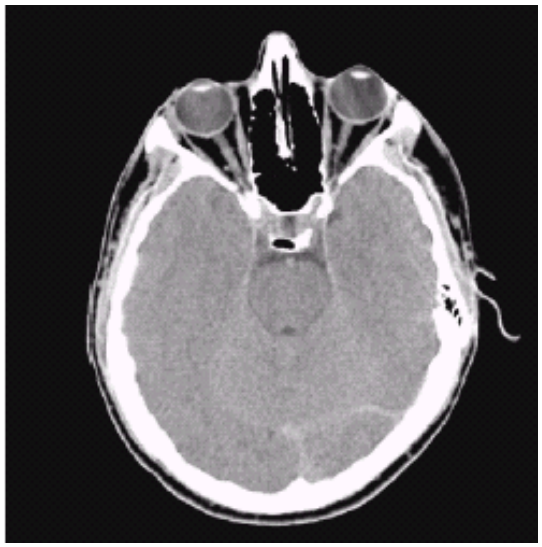
- **1960s:** Improvements in computing technology and the onset of the space race led to a surge of work in digital image processing
  - **1964:** Computers used to improve the quality of images of the moon taken by the *Ranger 7* probe
  - Such techniques were used in other space missions including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



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

History of DIP (cont…)

- **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

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

History of DIP (cont…)

- **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

Applications of Digital Image Processing

- **Applications of Digital Image Processing (DIP) include**:
- 1)Biological Research: e.g. DNA typing and matching; automatic counting and classification of cell structures in bone and tissue.
- 2) Defence and Intelligence: e.g. Reconnaissance photo-interpretation of objects in satellite images; target acquisition and missile guidance.
- 3) Document Processing: e.g. Scanning, archiving and transmission (fax); automatic detection and recognition of printed text (postal sorting office, tax return processing, banking cheques).
- 4) Factory Automation: e.g. Visual quality inspection, defect detection and process monitoring.

Applications of Digital Image Processing …

- 5) Law Enforcement Forensics: e.g. Photo-ID kits, criminal photo-search, automatic fingerprint matching and DNA matching.
- 6) Materials Research: e.g. Automatic counting and classification of object characteristics such as impurities and grain size; surface and structural defect analysis (x-ray analysis for aircraft wing cracks)
- 7) Photography: e.g. Retouching defects, altering colours, zooming; adding and subtracting objects to a scene; special effects such as blending and warping.
- 8) Publishing: e.g. Layout composition, inserting pictures, generating graphics; colour separation for 4-colour printing (cyan, magenta, yellow and black)

Applications of Digital Image Processing …

- 9) Remote Sensing: e.g. Land cover analysis (water, roads, cities and cultivation), vegetation features (water content and temperature) and crop yield analysis; 3-D terrain rendering from satellite or aircraft data (road and dam planning); fire and smoke detection.

- 10) Space exploration and Astronomy: e.g. Image compression for transmission, correction of detector deficiency; automatic satellite navigation and altitude control using star positions.

- 11) Video and Film Special Effects: Animation, dangerous stunts (explosions) and special effects (Star Wars).
- 12) Other examples/areas ??

EM Spectrum

EM waves = propagating sinusoidal waves of varying wavelength
Or stream of massless particles, each travelling in a wave like pattern
And moving at a speed of light.
Each particle with a bundle of energy = photon

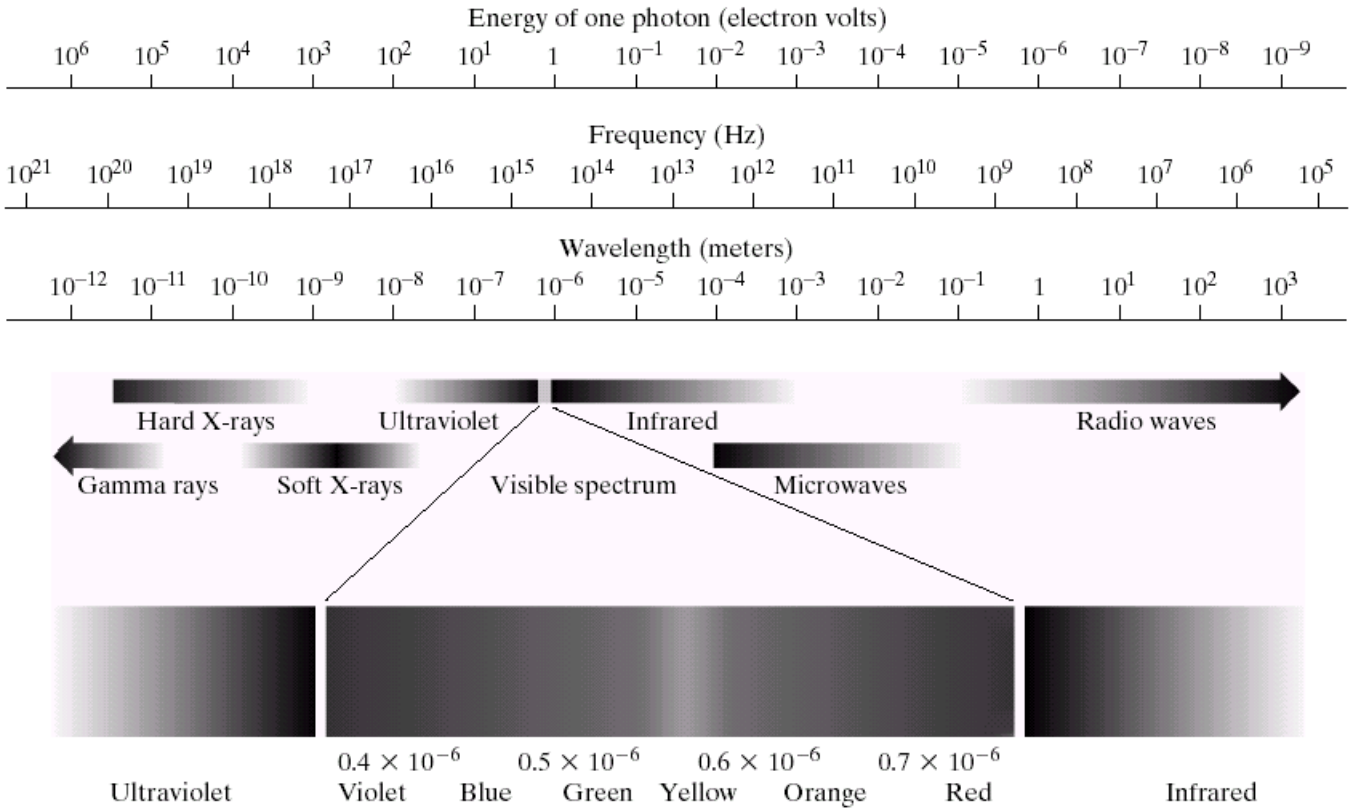
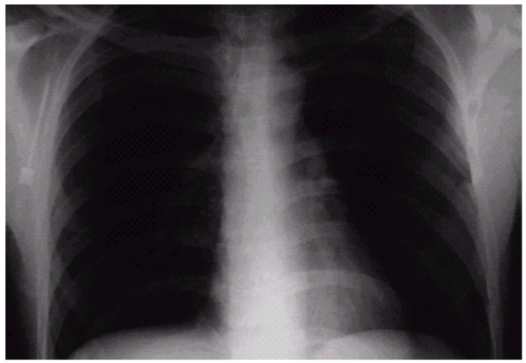
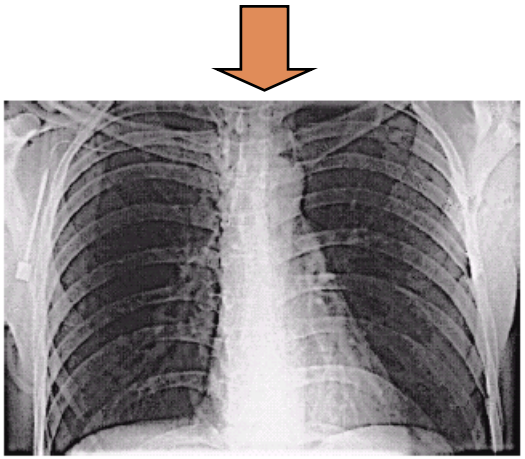


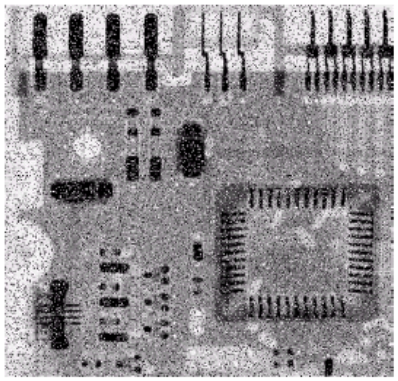
FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

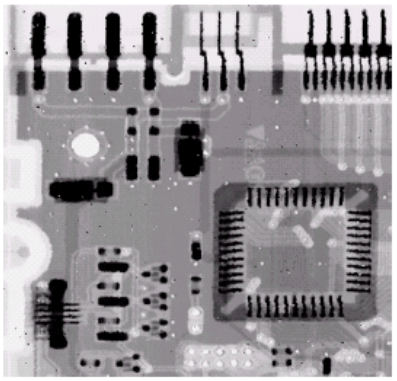
Examples: Image Enhancement

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





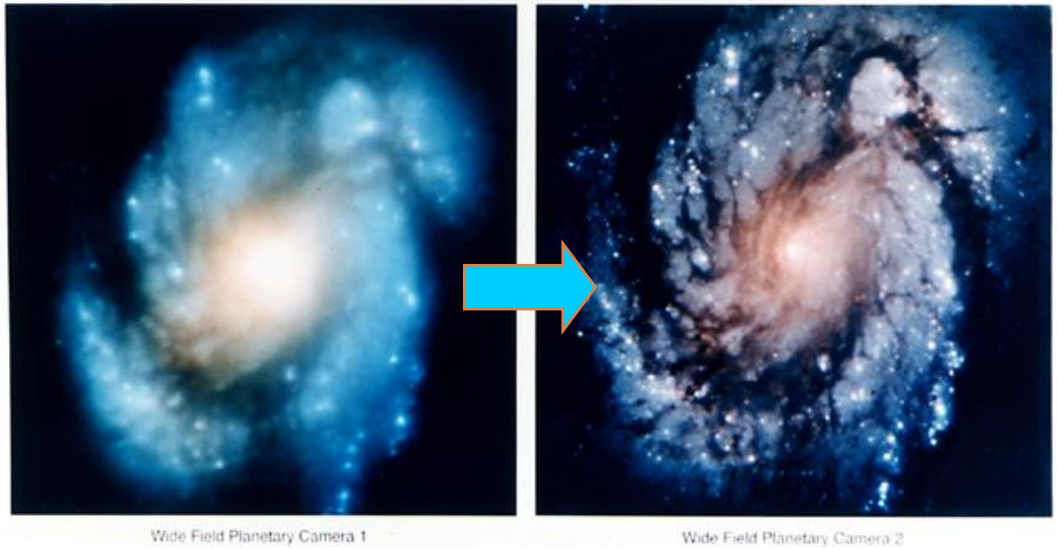




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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

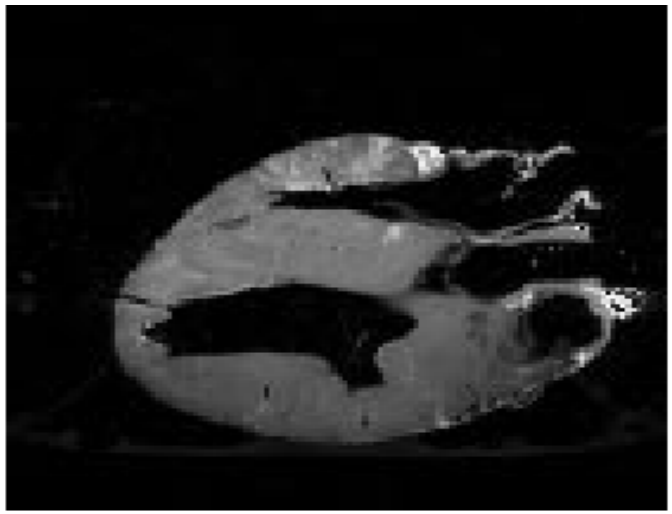


Examples: Artistic Effects

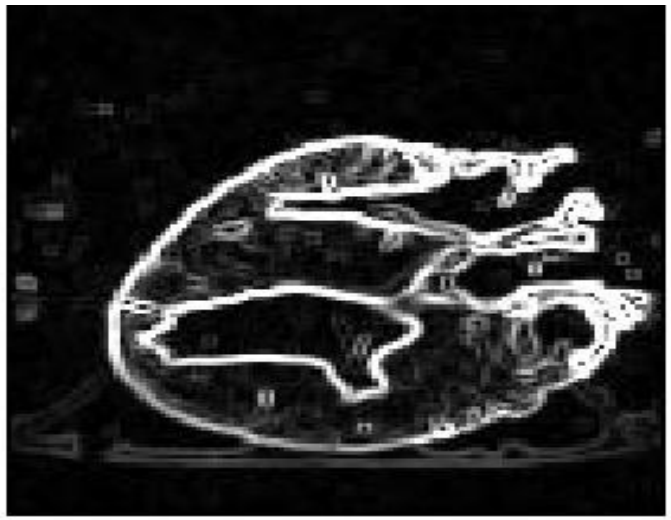
- Artistic effects are used to make images more visually appealing, to add special effects and to make composite images

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

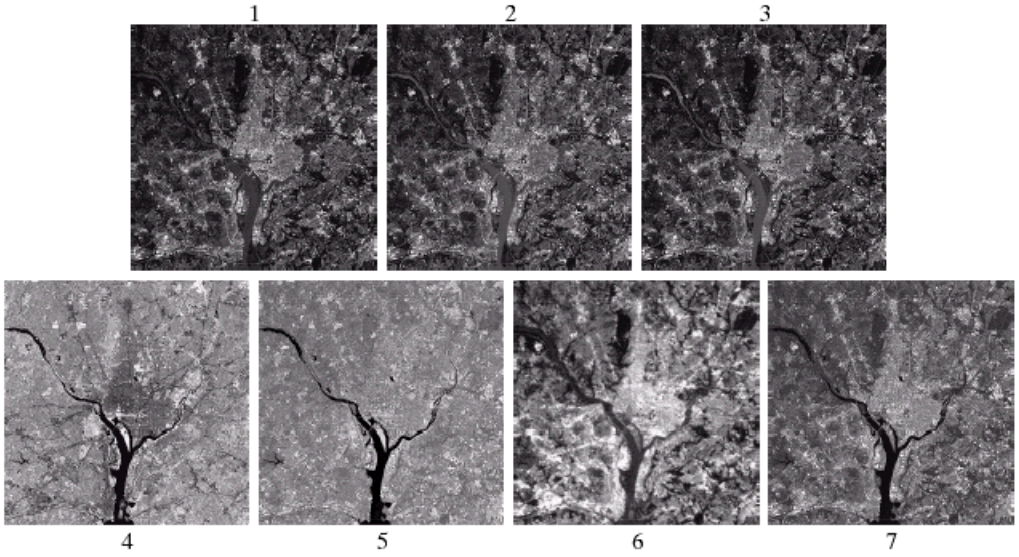


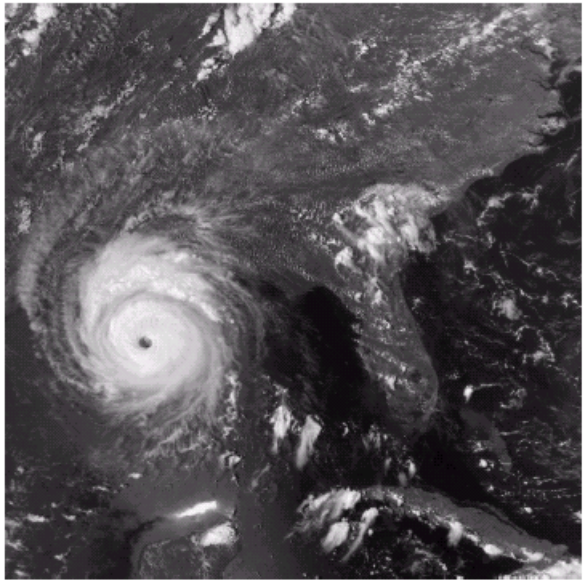
Edge Detection Image

Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Examples: GIS

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

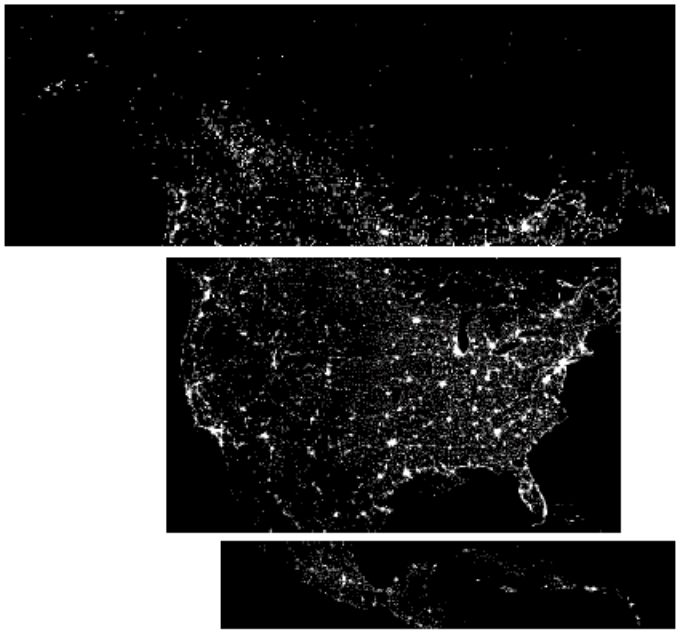




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Examples: GIS (cont…)

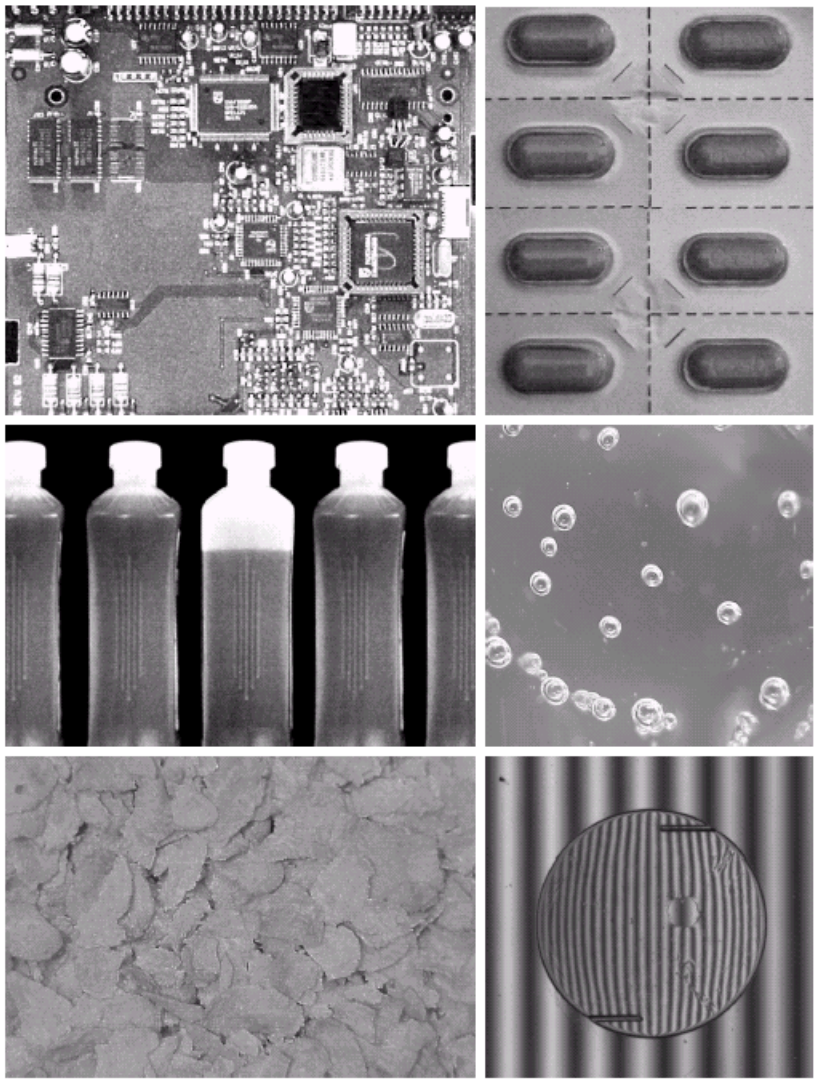
- *Night-Time Lights of the World* data set
  - Global inventory of human settlement
  - Not hard to imagine the kind of analysis that might be done using this data



Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Examples: Industrial Inspection

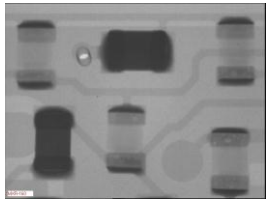
- Human operators are expensive, slow and unreliable
- Make machines do the job instead
- Industrial vision systems are used in all kinds of industries
- Can we trust them?

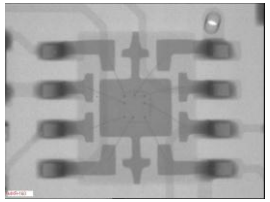


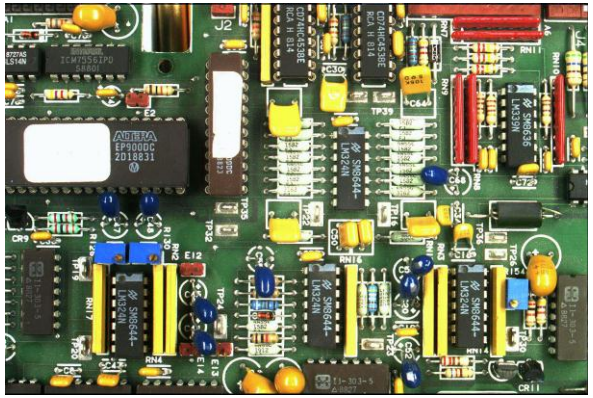
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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

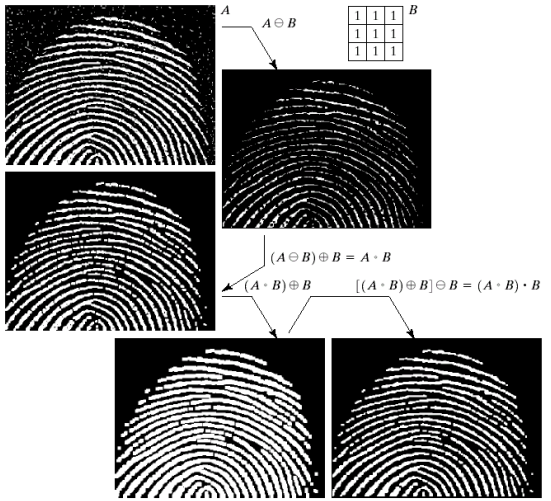






Examples: Law Enforcement

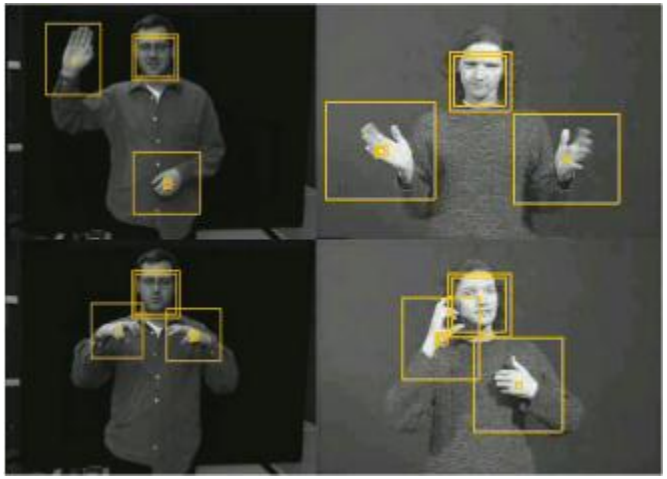
- Image processing techniques are used extensively by law enforcers
  - Number plate recognition for speed cameras/automated toll systems
  - Fingerprint recognition
  - Enhancement of CCTV images

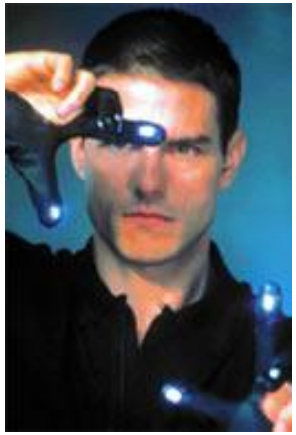


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Examples: HCI

- Try to make human computer interfaces more natural
  - Face recognition
  - Gesture recognition
- These tasks can be extremely difficult





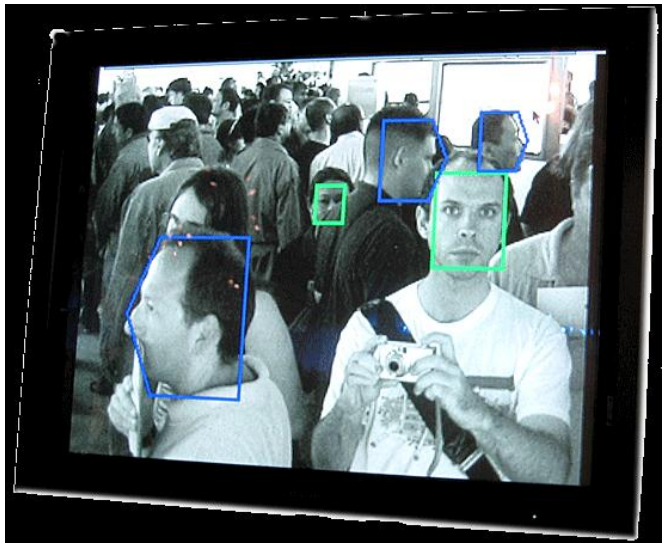


Image Processing Steps

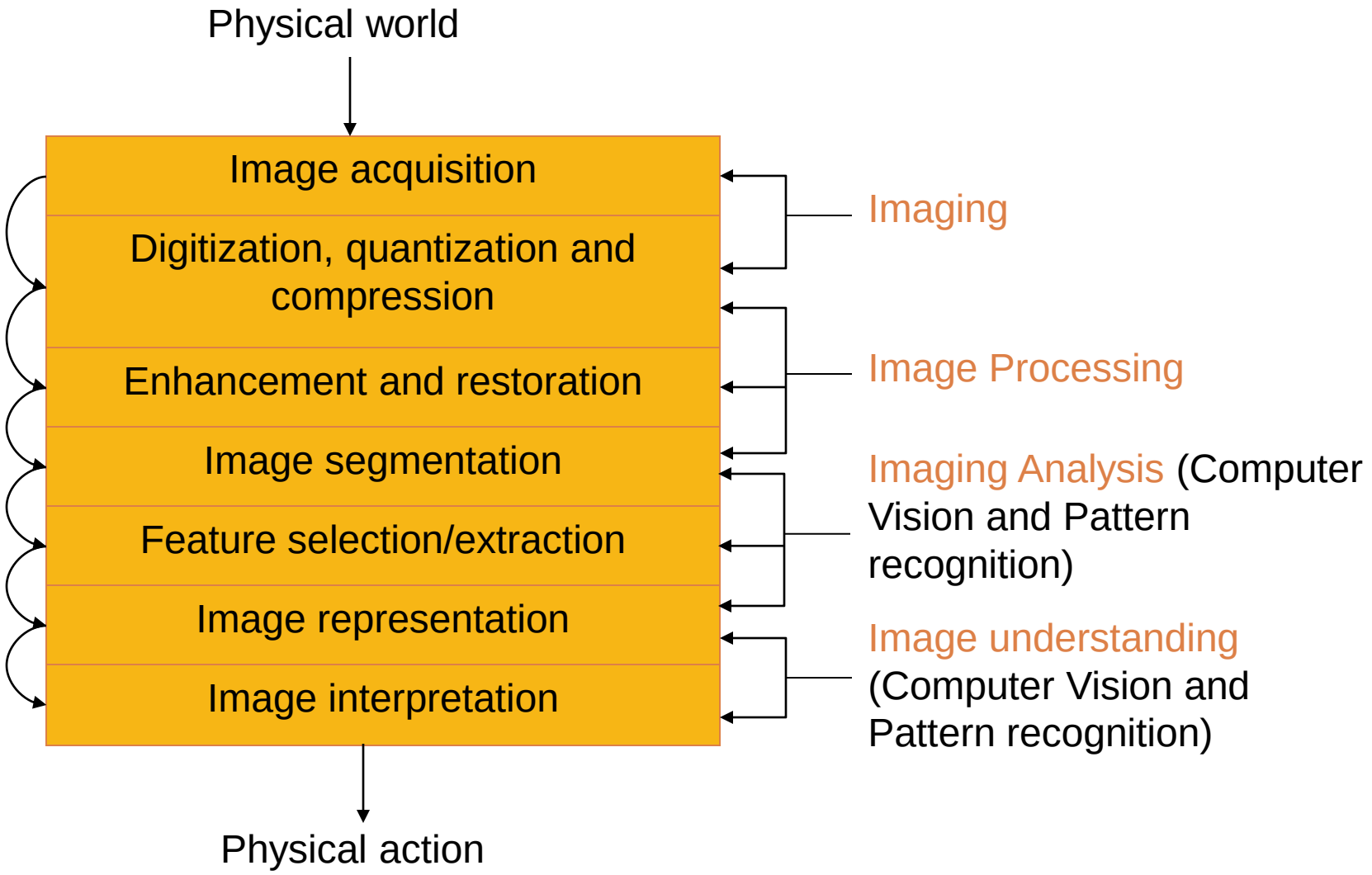
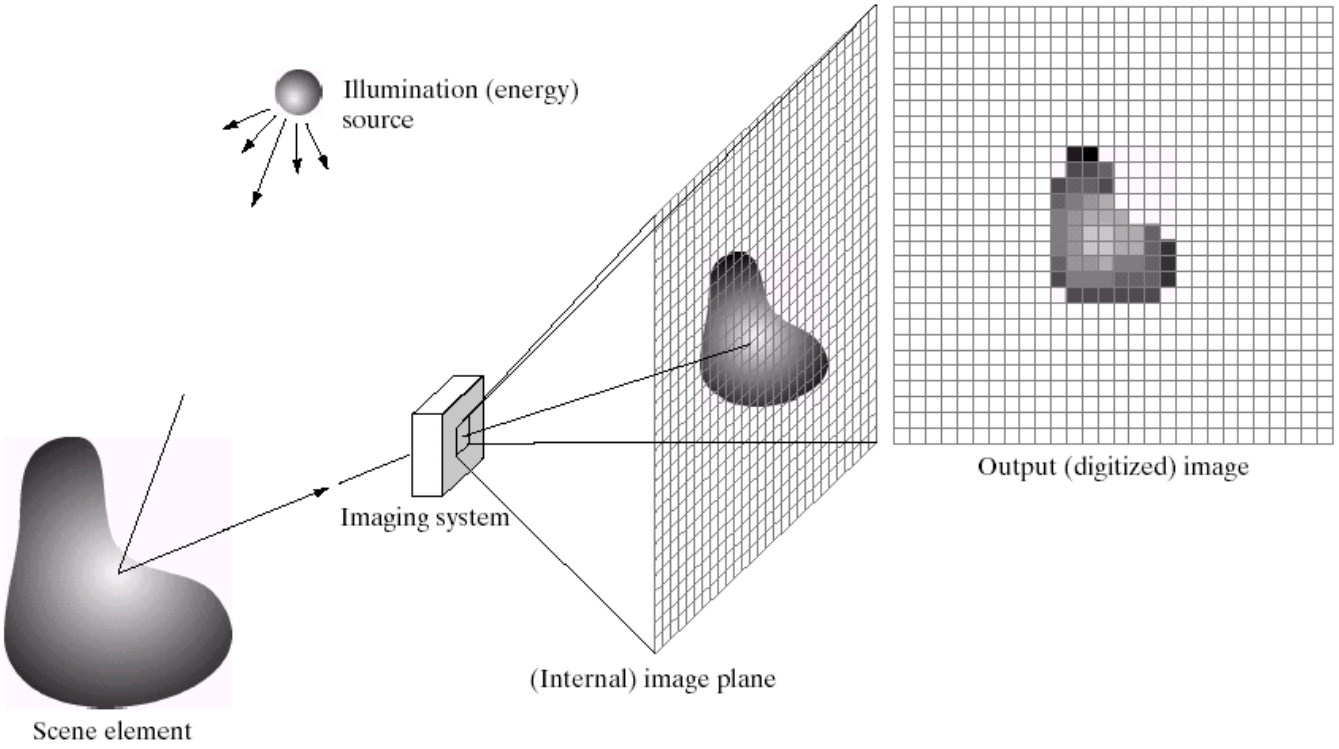


Image acquisition is the first process shown in the previous slide

- Note that acquisition could be as simple as being given an image that is already in digital form. Generally, the image acquisition stage involves pre-processing, such as scaling etc

Image Acquisition



a
b c d e

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.

Image description

$f(x,y)$: intensity/brightness of the image at spatial coordinates (x,y)

$0 < f(x,y) < \infty$ and determined by 2 factors:

illumination component $i(x,y)$: amount of source light incident

reflectance component $r(x,y)$: amount of light reflected by objects

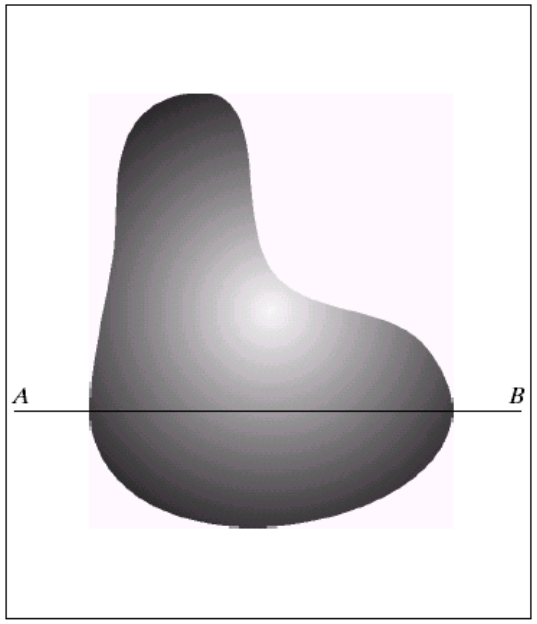
$$f(x,y) = i(x,y)\, r(x,y)$$

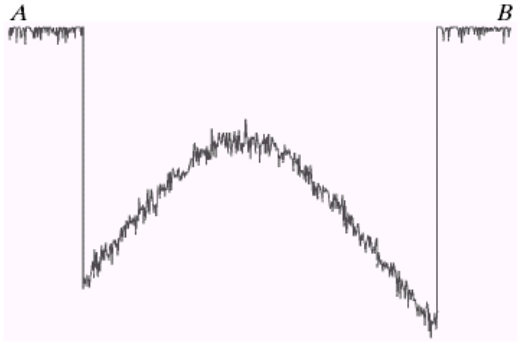
where

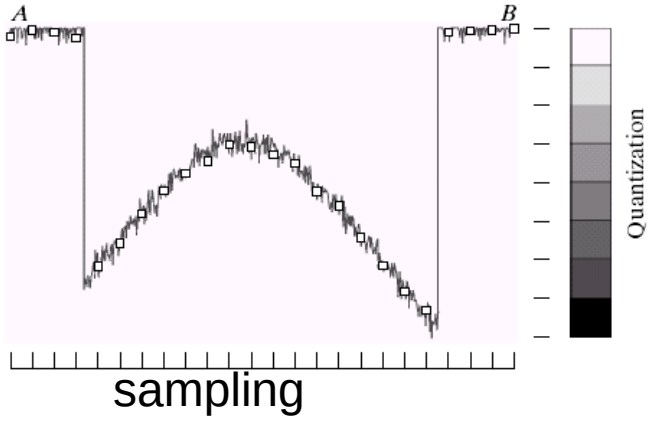
$0 < i(x,y) < \infty$: determined by the light source

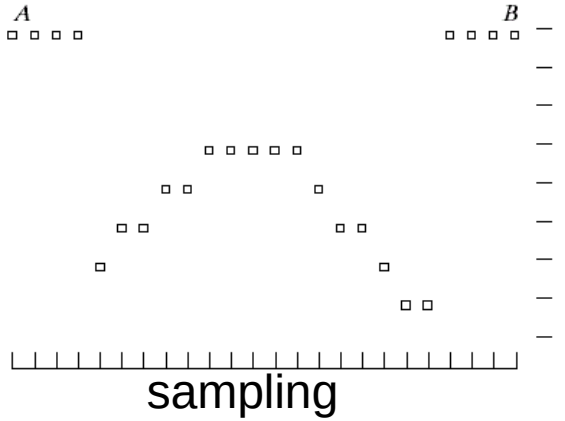
$0 < r(x,y) < 1$: determined by the characteristics of objects

Sampling and Quantization









quantization

Sampling and Quantization

Sampling: Digitization of the spatial coordinates (x,y)

Quantization: Digitization in amplitude (also called *gray-level quantization*)

8 bit quantization: $2^8 = 256$ gray levels (0: black, 255: white)

Binary (1 bit quantization): 2 gray levels (0: black, 1: white)

Commonly used number of samples (resolution)

Digital still cameras: 640x480, 1024x1024, up to 4064 x 2704

Digital video cameras: 640x480 at 30 frames/second
1920x1080 at 60 f/s (HDTV)

Sampling and Quantization

An M x N digital image is expressed as

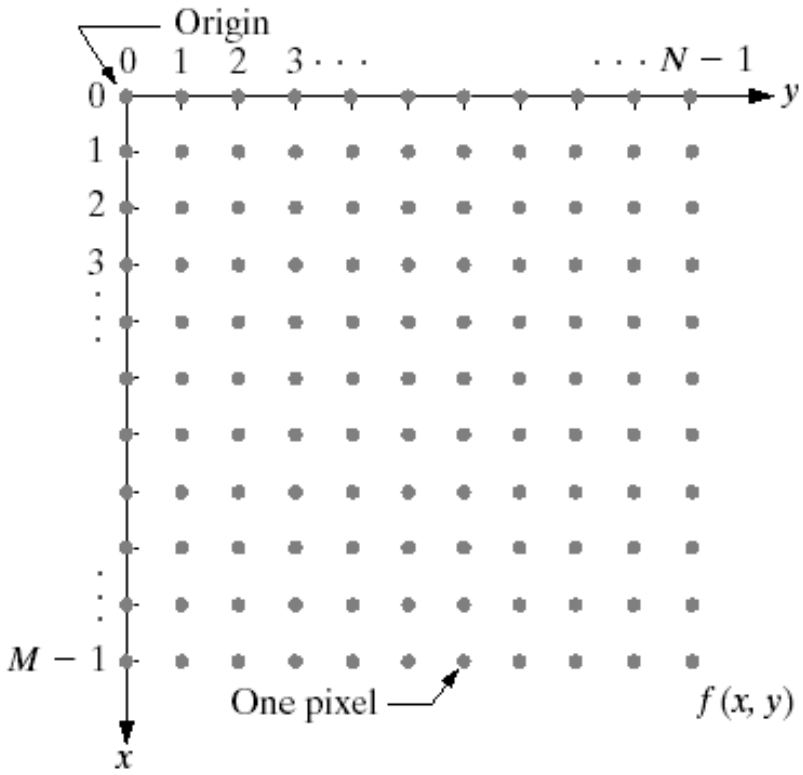
Columns

Rows

$$\begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & \cdots & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}$$

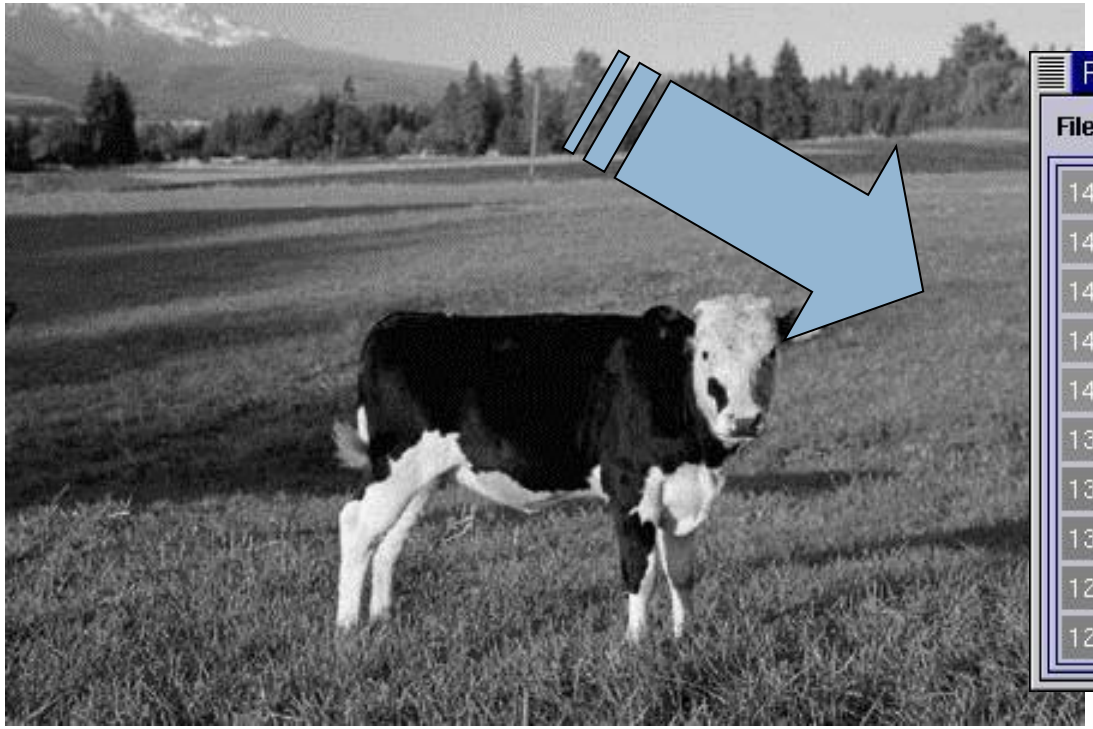
N : No of Columns

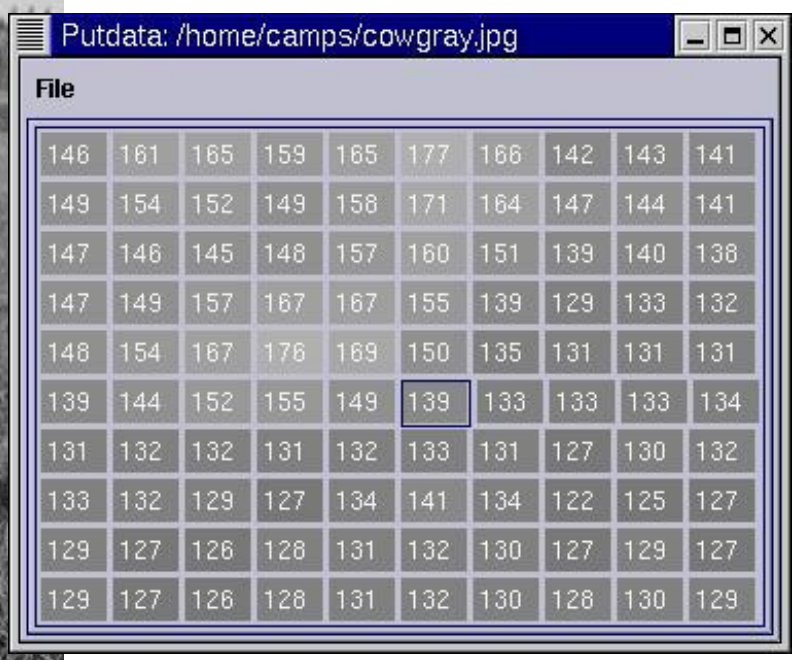
M : No of Rows



Digital Images

Digital images are 2D arrays (matrices) of numbers:





Sampling

1024

512

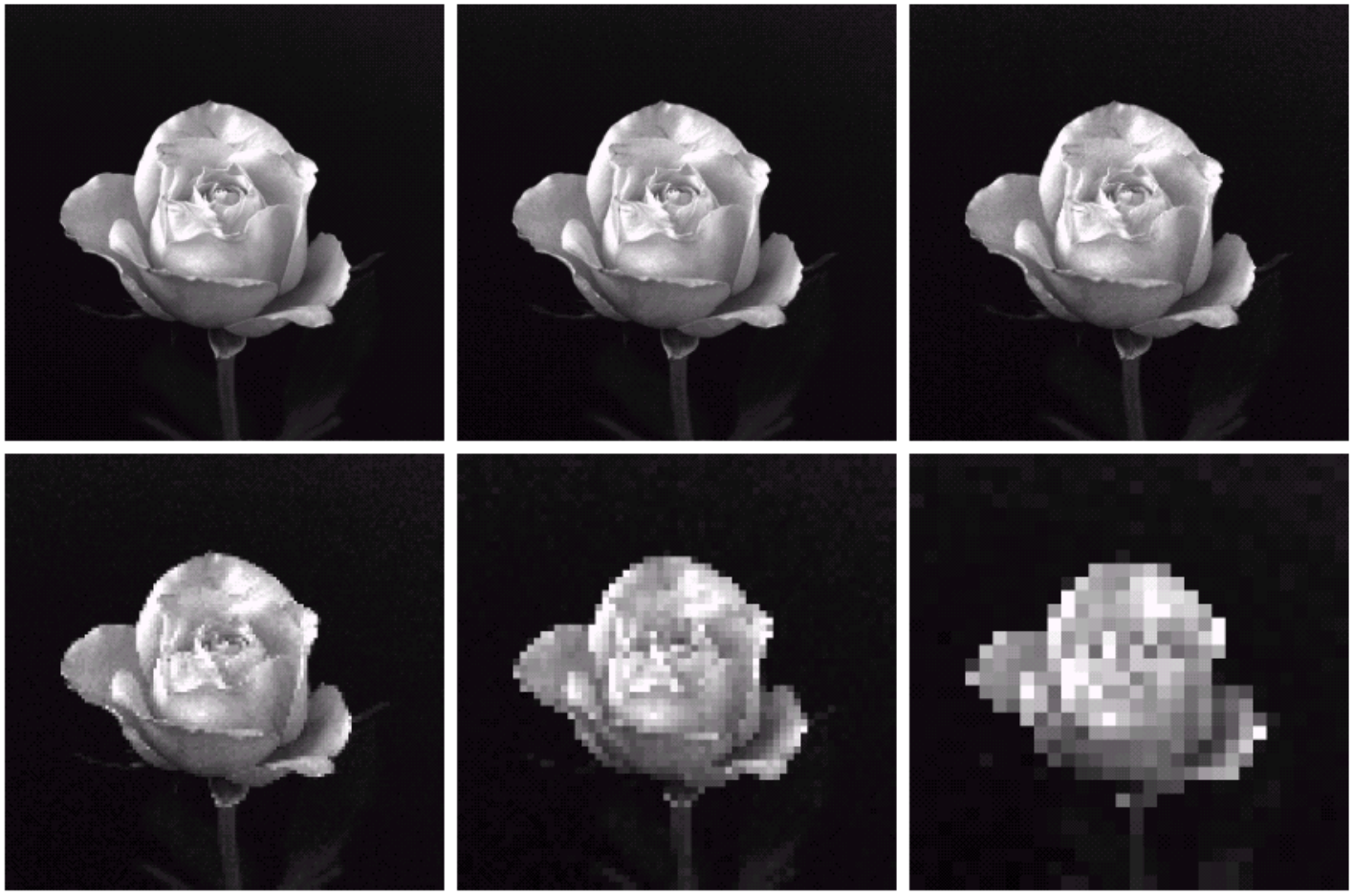
256

128

64

32

Sampling



a b c
d e f

FIGURE 2.20 (a) 1024 × 1024, 8-bit image. (b) 512 × 512 image resampled into 1024 × 1024 pixels by row and column duplication. (c) through (f) 256 × 256, 128 × 128, 64 × 64, and 32 × 32 images resampled into 1024 × 1024 pixels.

Effect of Sampling and Quantization

250 x 210 samples
256 gray levels

125 x 105 samples

50 x 42 samples

25 x 21 samples

16 gray levels

8 gray levels

4 gray levels

Binary image

Image enhancement

- *Image enhancement is* the simplest and most appealing areas of digital image processing. Basically, the idea behind enhancement techniques is to bring out detail that is obscured, or simply to highlight certain features of interest in an image. A familiar example of enhancement is when we increase the contrast of an image because "it looks better."

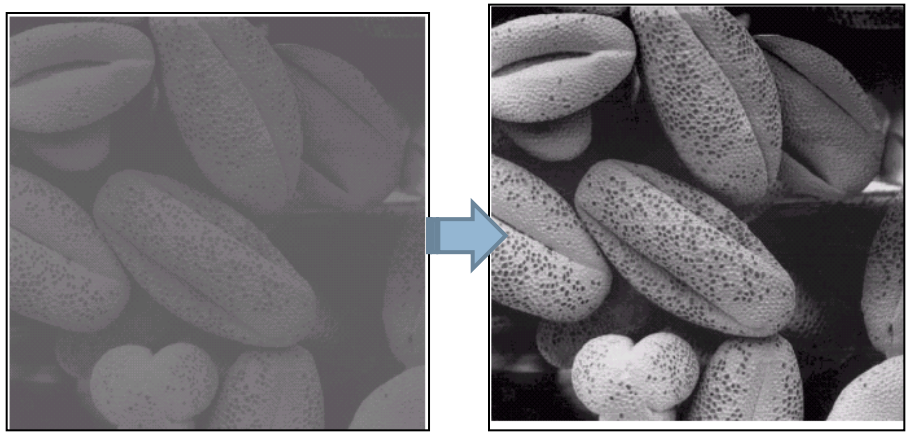
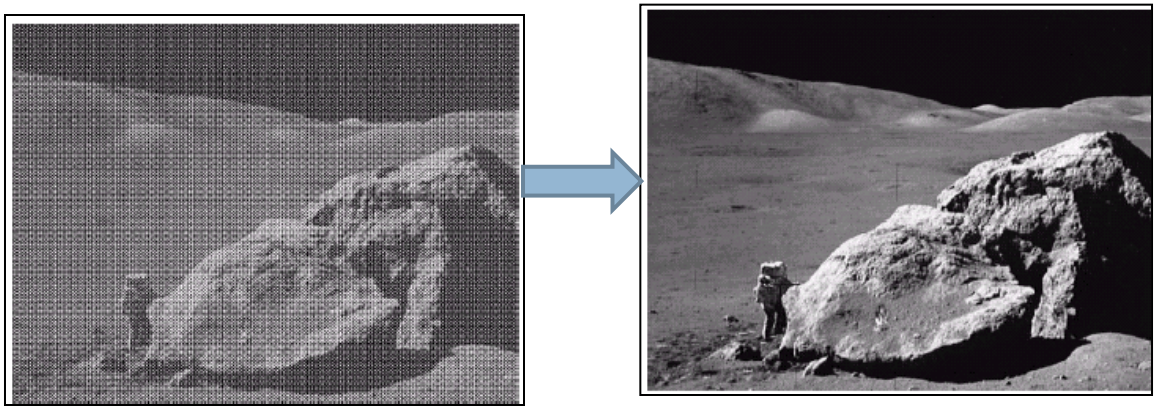
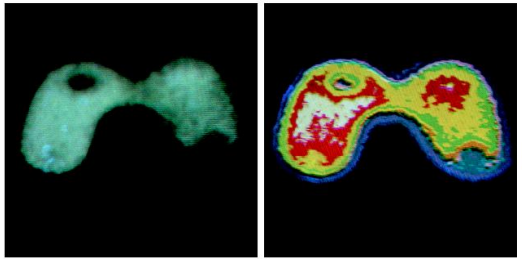


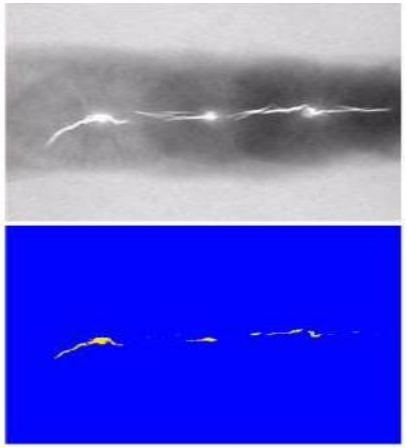
Image restoration

- *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. Enhancement, on the other hand, is based on human subjective preferences regarding what constitutes a "good" enhancement result.



- *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.

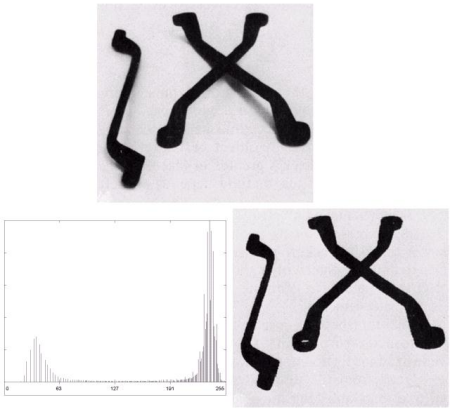




A weld crack is more clearly visible in colored image

- *Compression, as the name implies, deals with techniques for reducing the* storage required to save an image, or the bandwidth required to transmit it.

- *Segmentation procedures partition an image into its constituent parts or objects.* In general, autonomous segmentation is one of the most difficult tasks in digital image processing



- *Representation and description almost always follow the output of a segmentation* stage
- *Recognition is the process that assigns a label (e.g., "vehicle") to an object* based on its descriptors.

Summary

- We have looked at:
  - What is a digital image?
  - What is digital image processing?
  - History of digital image processing
  - State of the art examples of digital image processing
  - Key stages in digital image processing
- Next time we will start to see how it all works…