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GNR607 Principles of Satellite Image Processing

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Lecture – 2 Contents

- Introduction to Digital Image Processing
- Generation of a digital image
- Sampling and quantization
- Image Processing System
- Image Understanding Methodology
- Applications

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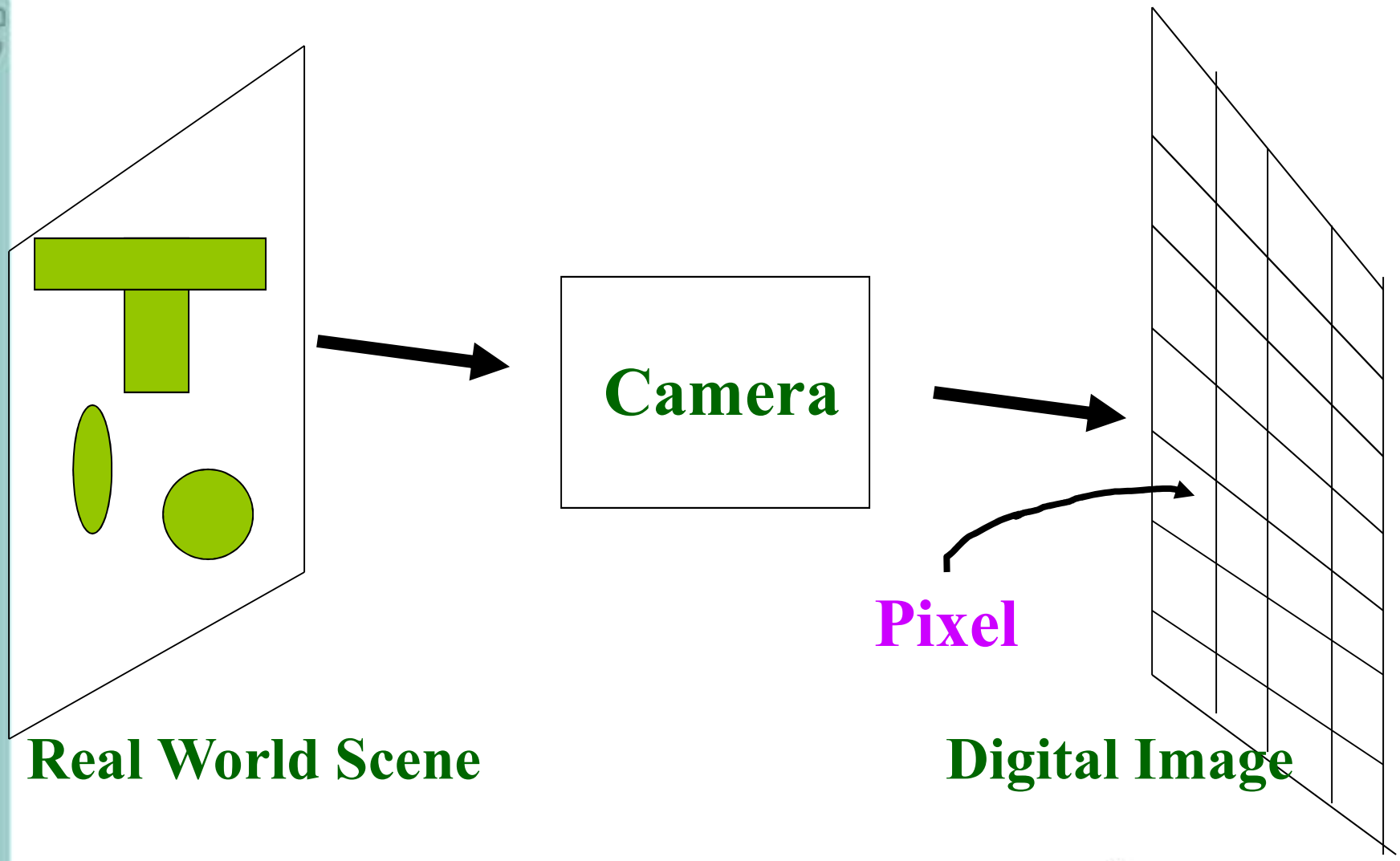
What is a digital image?

- A digital image is a representation of the real world, discretized in space, with energy reflected / emitted / transmitted by the objects in the image quantized to a finite number of levels

Real World to Digital World



Digitization

- Digitization involves three steps:
  - Sampling
  - Quantization
  - Coding

Sampling

- View area divided into cells
- Each cell is a picture element *pixel*
- The image now is a matrix of M rows, and N columns
- M = Length of View area / Length of Cell
- N = Width of View area / Width of Cell
- Smaller cell size → better ability to distinguish between closely spaced objects

Sampling

- In remotely sensed images the sampling is essentially ground sampling – i.e., on the ground a virtual grid is placed and the energy reflected / transmitted / emitted from each grid cell is collected by the sensors and stored as a pixel value
- The grid cell corresponds to a pre-defined area on the ground; e.g., 5.8m x 5.8m as with ISRO's Resourcesat or 50cm x 50cm as in case of WorldView Satellite

Sampling

- Smaller the grid cell area better the details visible in the image
- The grid cell corresponding to a pre-defined area on the ground; e.g., 5.8m x 5.8m
- This is similar to ***dpi*** settings in desktop image scanners. Higher dpi, smaller size of dot, more pixels or cells in the image

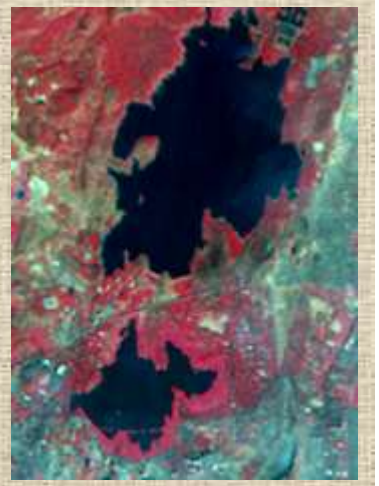
Spatial Resolution

Image Detail and Sampling Size

61cmx61cm resolution
details of individual
buildings

5.8m x 5.8m resolution
An entire settlement block
seen without individual
buildings

23.5m x 23.5m resolution
Vast areas seen without
local details



Example using Desktop Scanner

75dpi scan

150dpi scan

300dpi scan

Increased clarity, reduced distortion with finer sampling

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Impact of Pixel Size

- **Pixel size corresponds to the Instantaneous Field of View (IFOV) of the sensing system**
- **Smaller the IFOV, better is the ability to *resolve* closely spaced objects (RESOLUTION)**
- **Price to pay – larger size of data**
- **Noise sensitivity of the sensor determines the maximum possible resolution**

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Point to Remember!

- **IFOV is 10 metres x 10 metres square does not mean that objects smaller than this size will not be visible**
- **If a smaller object has very high or very low reflectance relative to its background, such object will be visible despite its size being smaller than the pixel's IFOV**

Quantization

- Reflected / transmitted / emitted energy from the object is converted into an electrical signal
- The electrical signal converted to a *digital* signal by an *analog-to-digital* converter (ADC).
- Digital signal takes a range of values according to the specification of the ADC

Quantization

24 bit color

8-bit color

Gray Shades and Levels

Analog to Digital Converter

- 8-bit ADC ➔ 2^8 distinct values, represented in binary as 00000000 – 11111111, or 0 to 255 in decimal form or 00 to FF in hex
- 11-bit ADC ➔ 2^{11} values, 0 to 2047
- The number of levels indicate the number of distinct individually differentiable levels of received energy

Impact of Quantization Levels

Impact of quantization levels

64 levels (6 bit) – more shades visible

4 levels (2 bit) – severe contouring effect

Pixel Size Importance

160 x150

24-bit

80 x 75

24-bit

Pixel Size Importance

160 x150

24-bit

160 x 150

8-bit

Points to Ponder… (1)

- Image of stadium full of people
- Image of interviewer interviewing a VIP

Which image can benefit from high sampling rate and which one from more quantization levels?

Points to ponder… (2)

How does the data volume change with

- More sampling rate?
- More quantization levels?

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Motivation for Digital Image Processing

- **Why Digital Image Processing for Remote Sensing?**
  - Nature of data (inherently digital)
  - Flexibility offered by computers
  - Reducing the bias of human analysts
  - Standardizing routine operations
  - Rapid handling of large volumes of data

Wavelengths Used for Imaging

- Gamma Rays
- X-Rays
- Visible/Infrared
- Microwaves
- Radio waves
- Ultrasound waves
- Seismic waves

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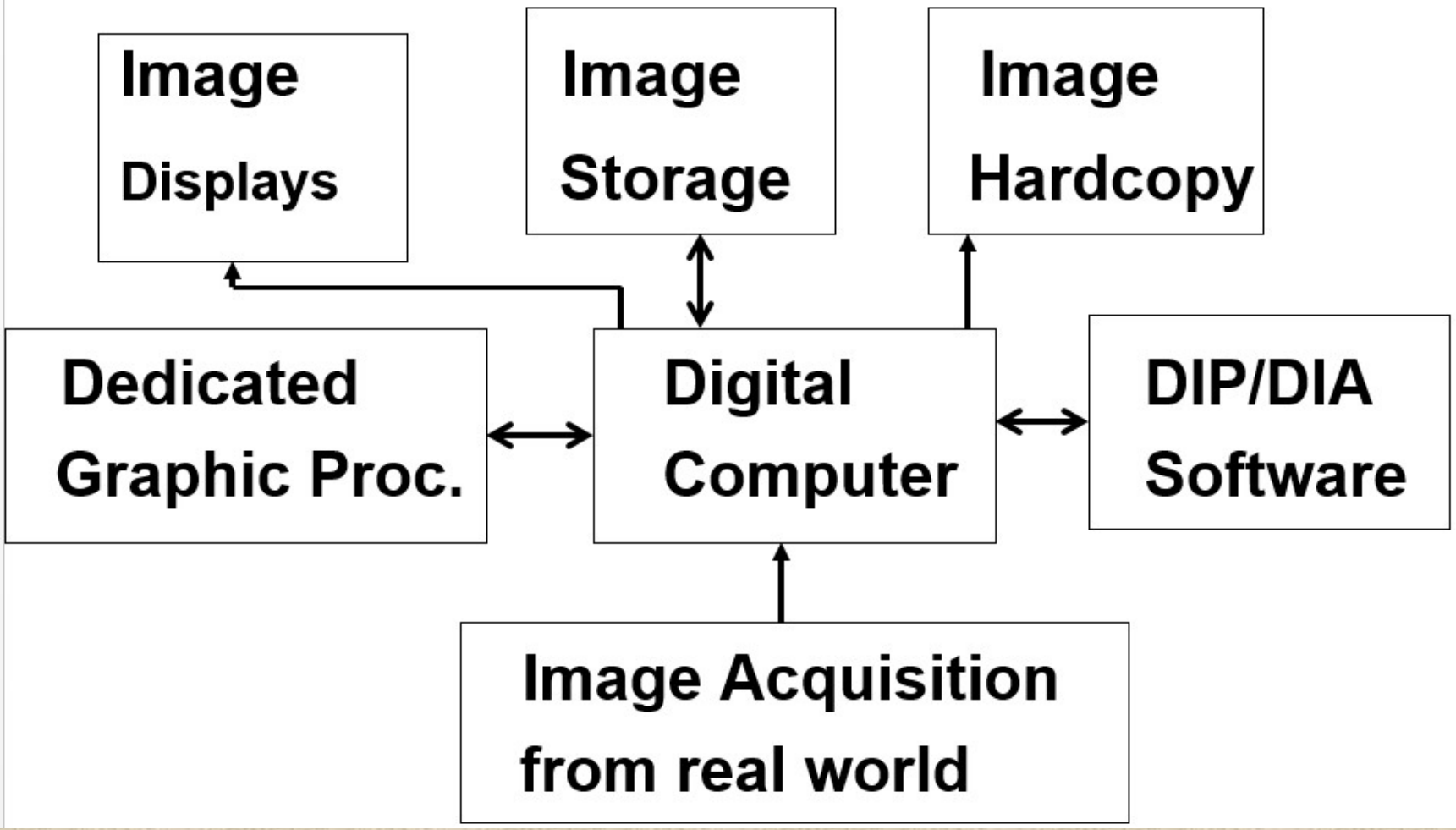
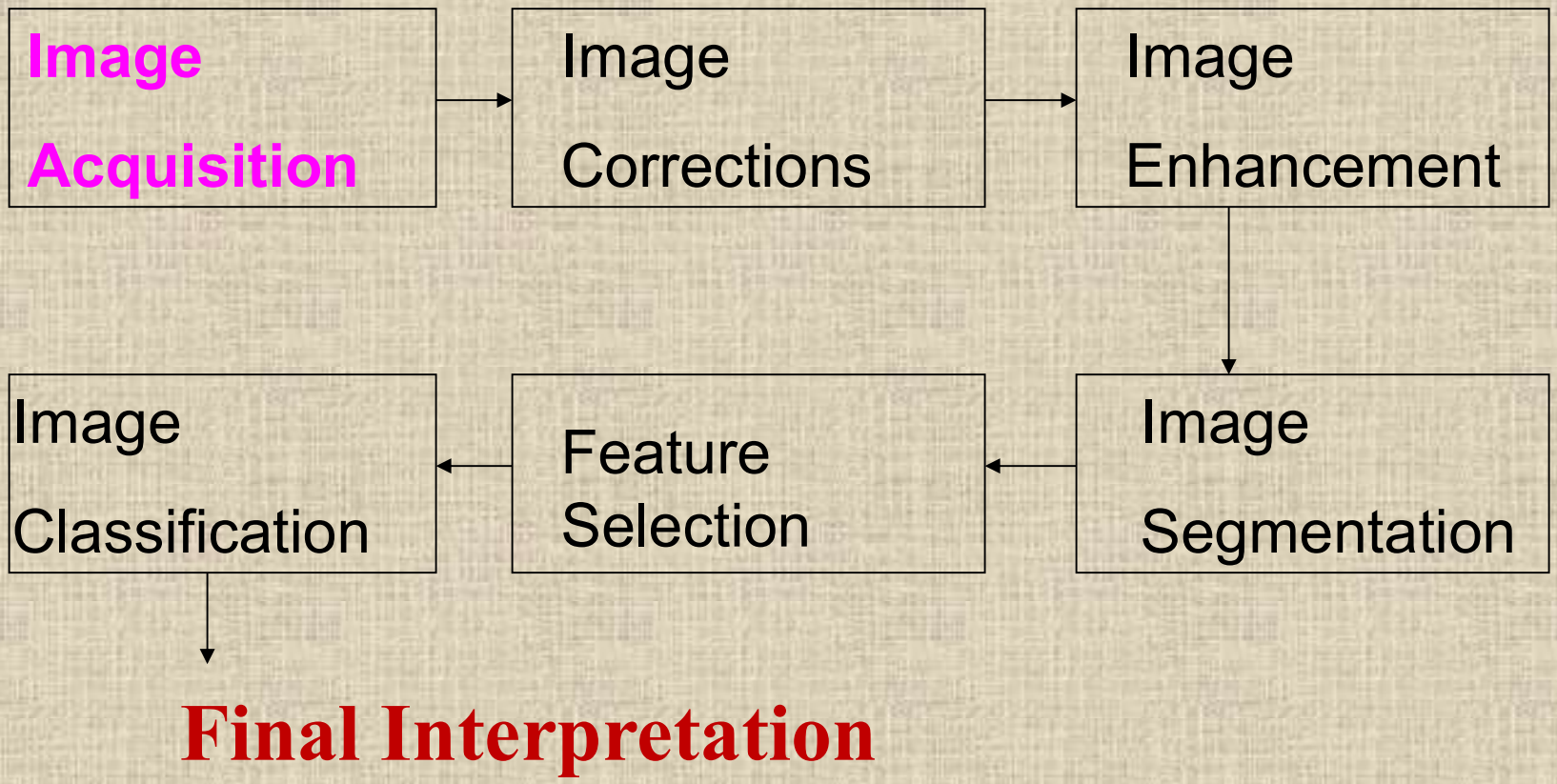
Components of an Image Processing System

- Image Sensors
- Image Display
- Image Storage
- Computer
- Image Processing software
- Special Purpose graphics hardware
- Image printers/plotters

Schematic Diagram



Steps in Digital Image Processing



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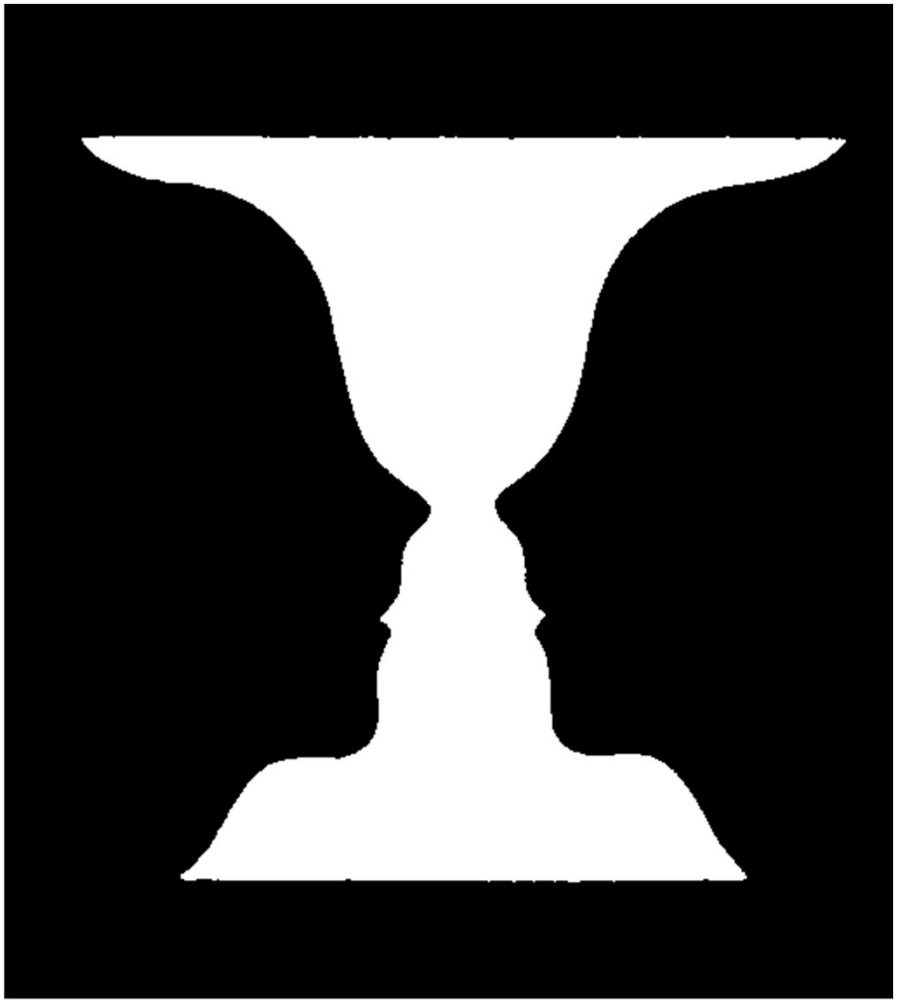
Limitations of Computer Based Image Interpretation

- Lack of access to human intuition
- Ambiguities

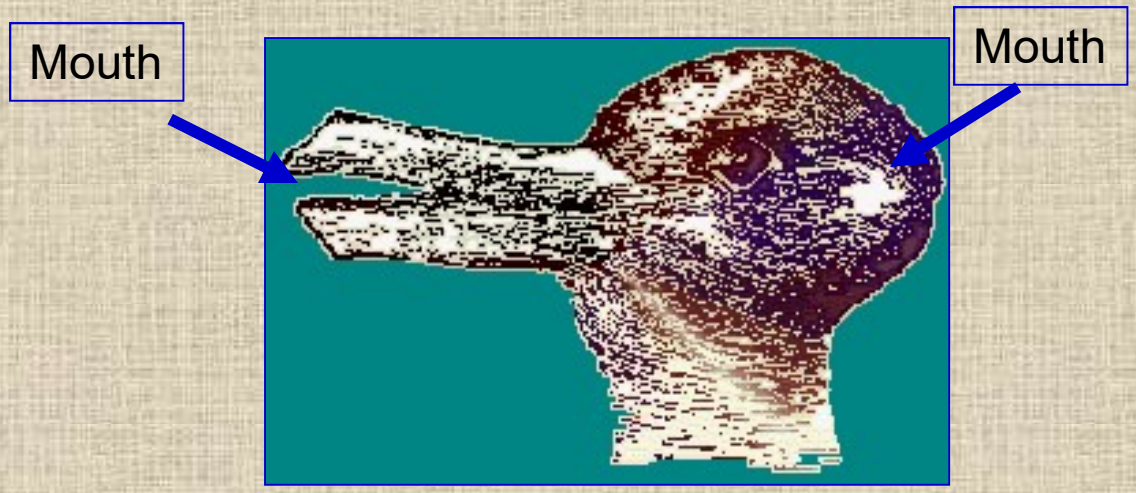
What is the foreground?



Vase? Or …
People?

Illusions

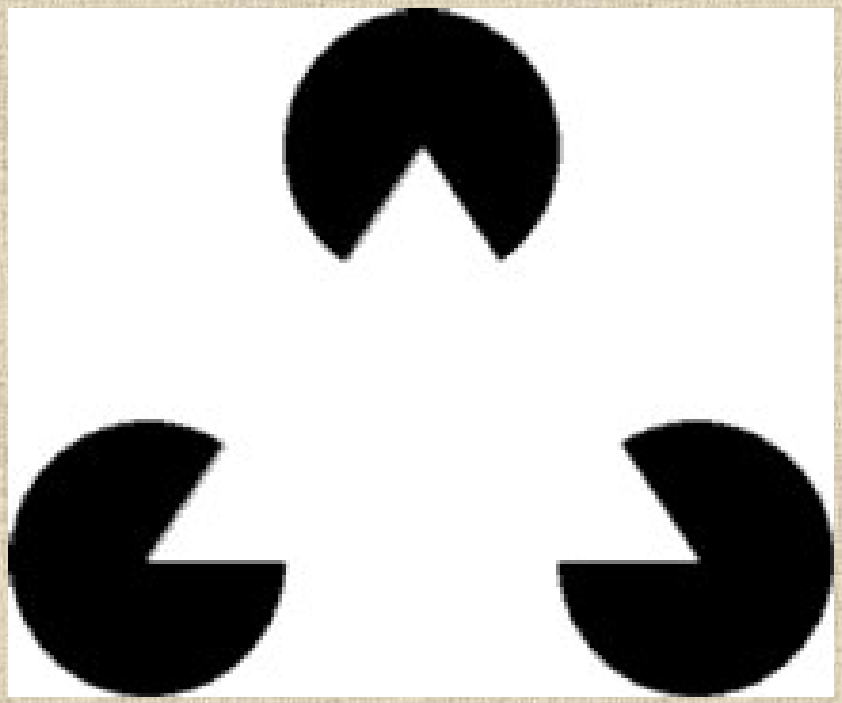
- Which is the mouth?



The Bunny/Duck illusion.

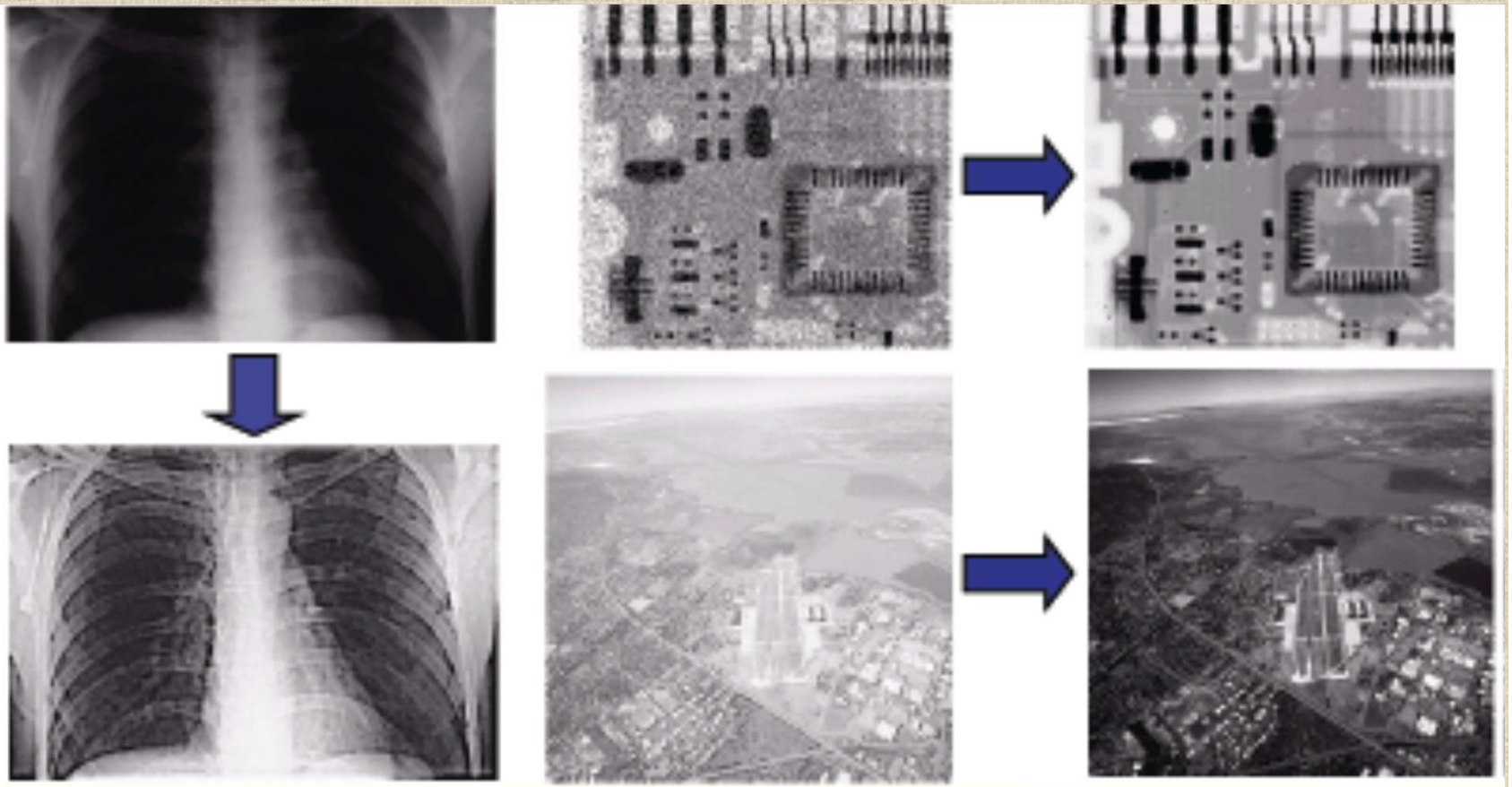
Illusions

- Who drew the triangle?



Some Applications

Quality Improvement

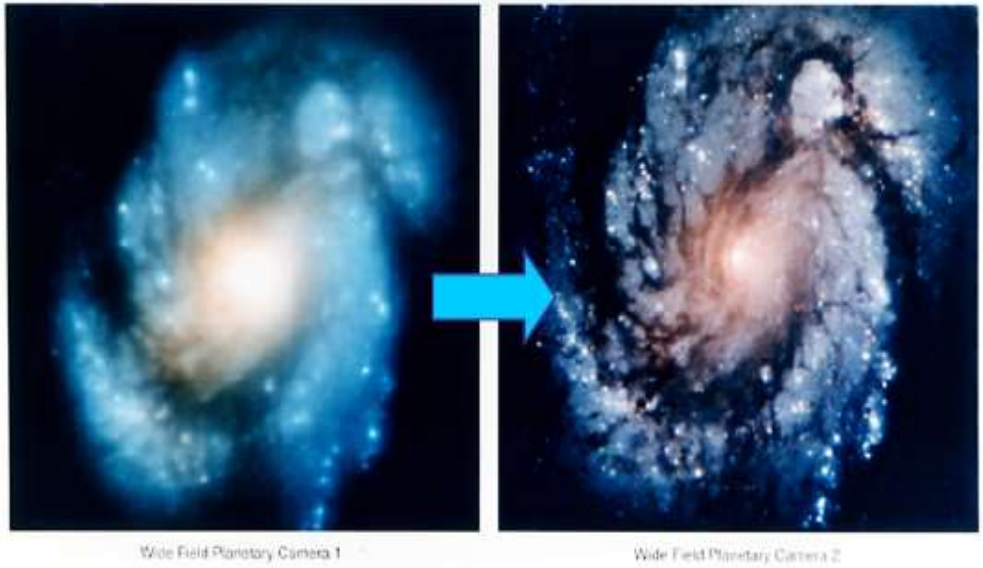


Hubble Telescope

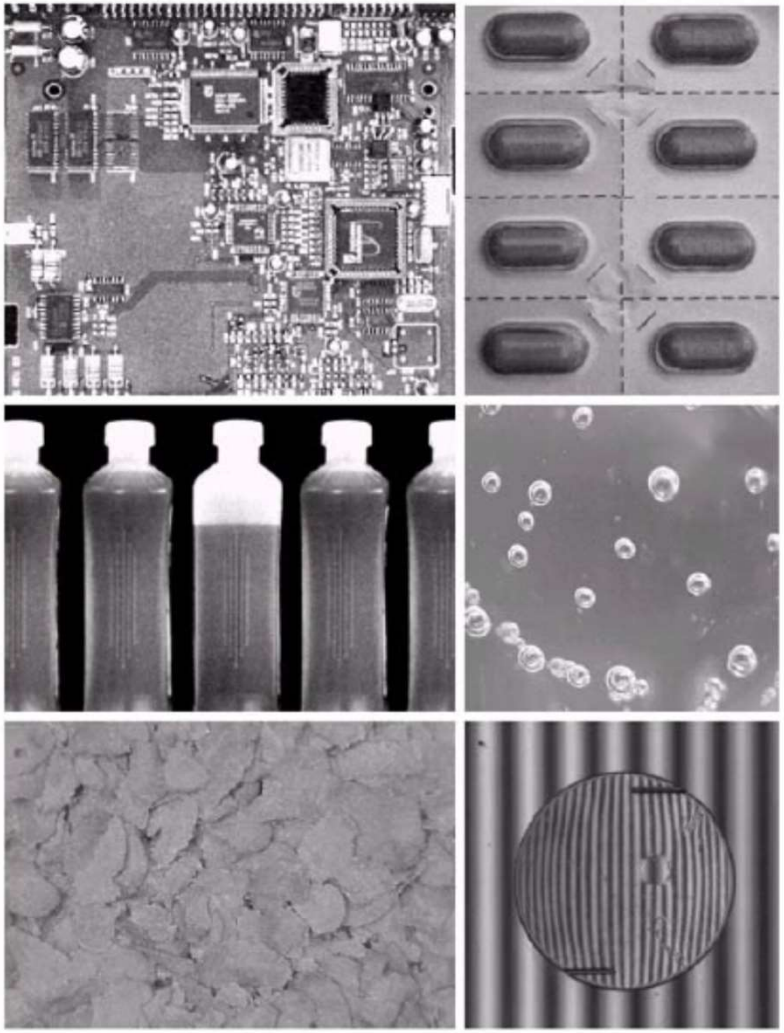
Launched in 1990 the Hubble telescope can take images of very distant objects

However, an incorrect mirror made many of Hubble's images useless

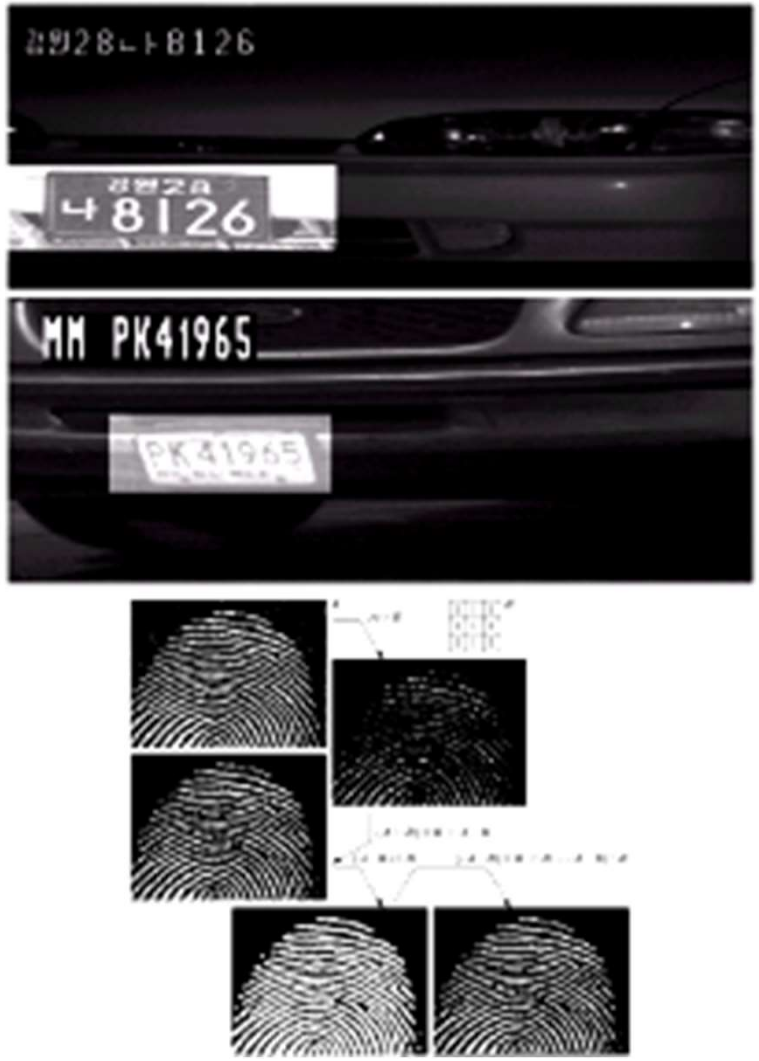
Image processing techniques were used to fix this



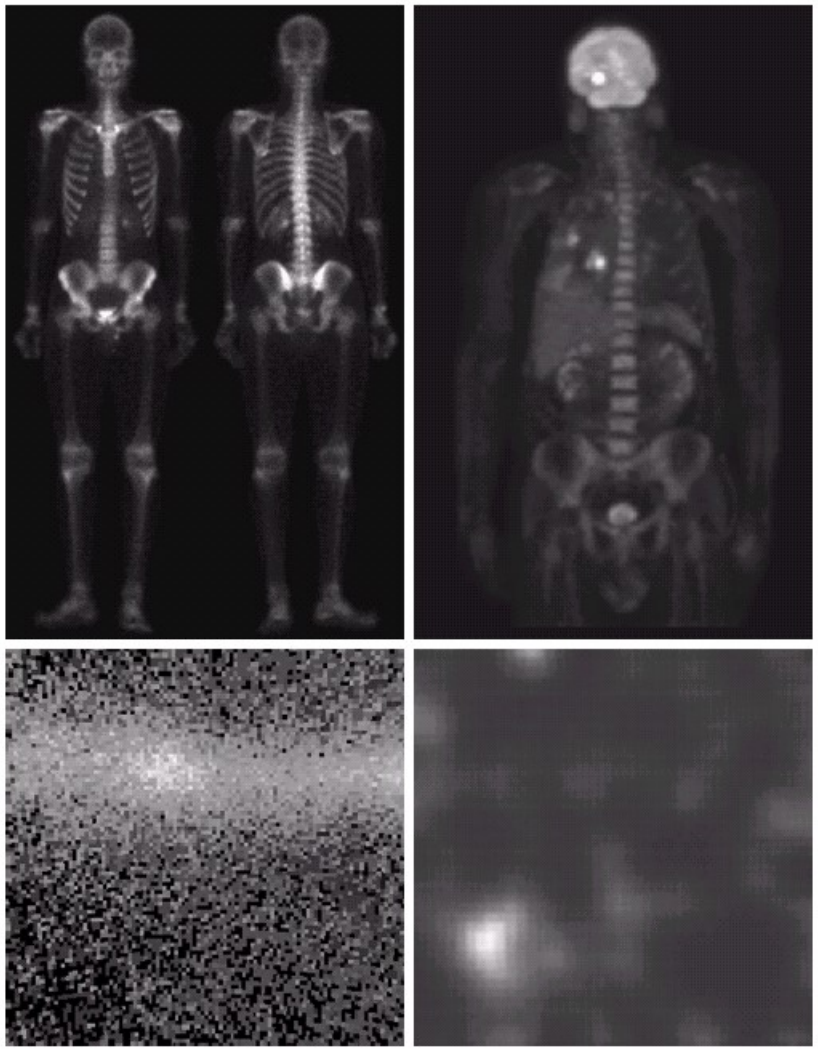
Industrial Quality Inspection



Law Enforcement



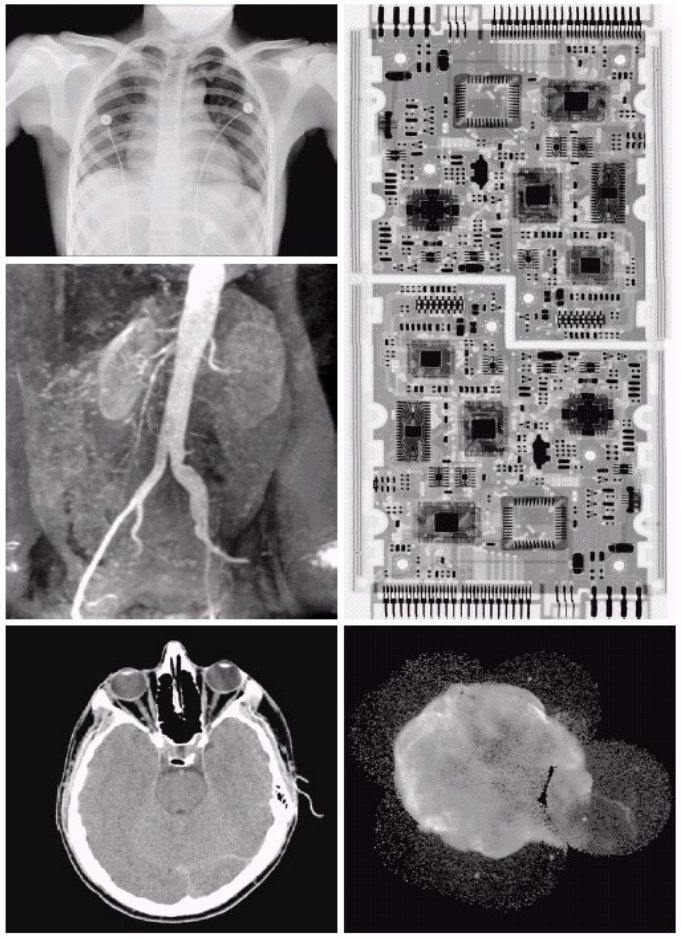
Gamma-Ray Imaging



a b
c d

FIGURE 1.6
Examples of gamma-ray imaging. (a) Bone scan. (b) PET image. (c) Cygnus Loop. (d) Gamma radiation (bright spot) from a reactor valve. (Images courtesy of (a) G.E. Medical Systems, (b) Dr. Michael E. Casey, CTI PET Systems, (c) NASA, (d) Professors Zhong He and David K. Wehe, University of Michigan.)

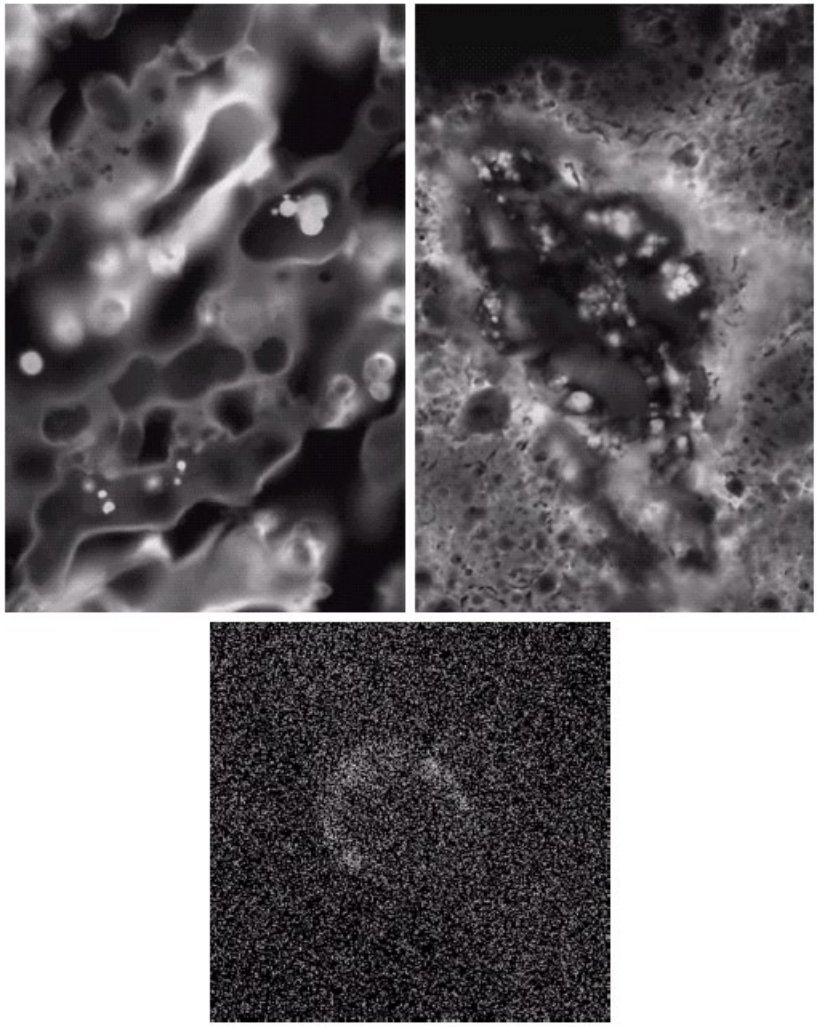
X-Ray Imaging



a b c d e

FIGURE 1.7 Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center, (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, (d) Mr. Joseph E. Pascente, Lixi, Inc., and (e) NASA.)

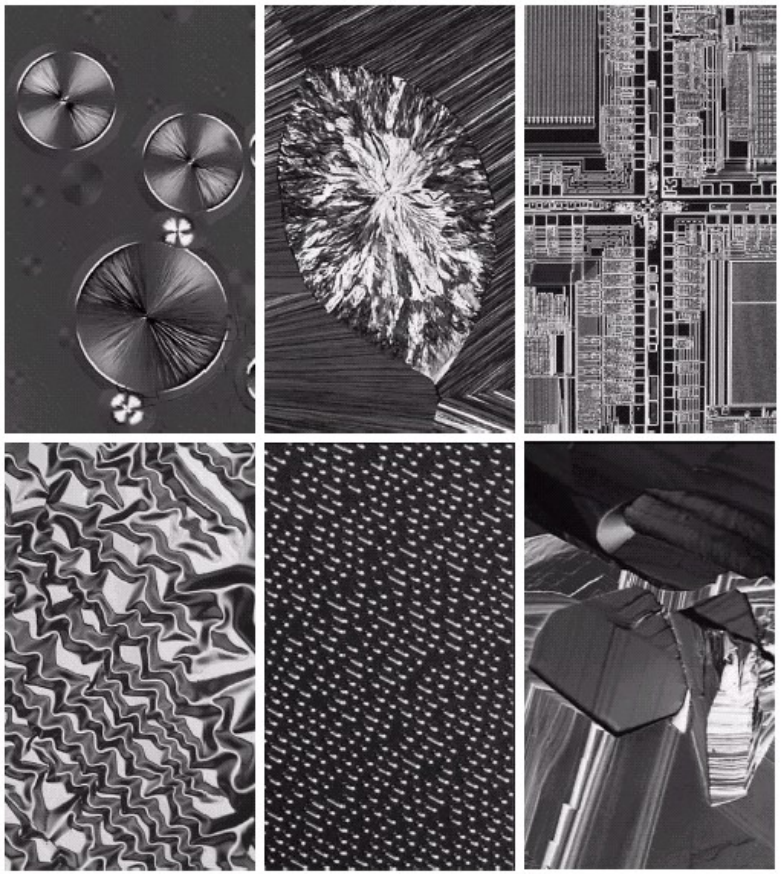
UV Imaging



a b
c

FIGURE 1.8
Examples of ultraviolet imaging.
(a) Normal corn.
(b) Smut corn.
(c) Cygnus Loop.
(Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)

Visible – Infrared Imaging



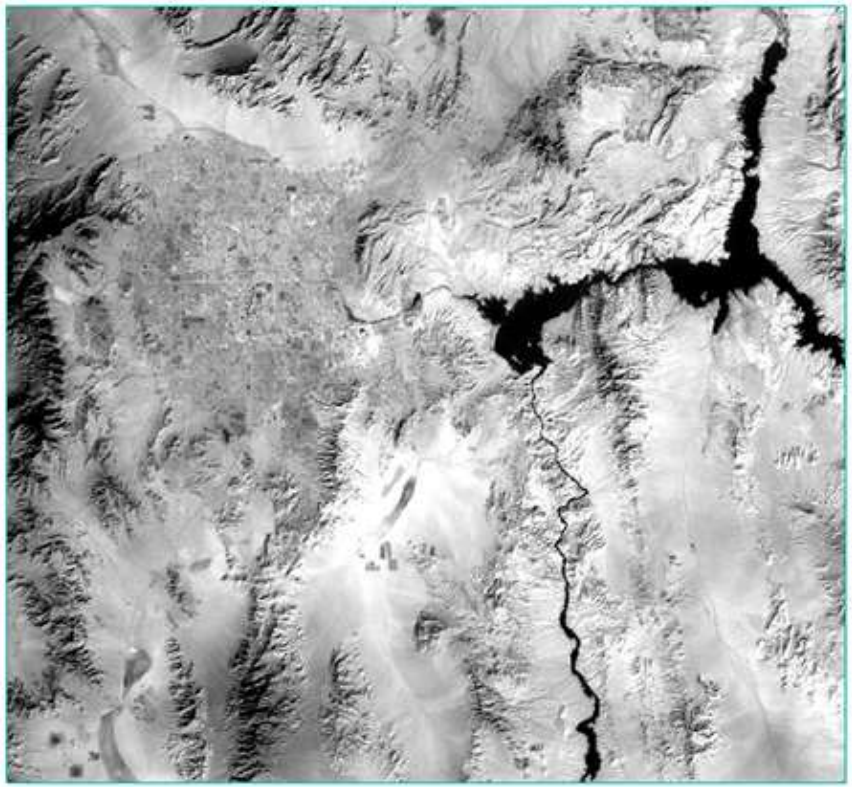
a b c
d e f

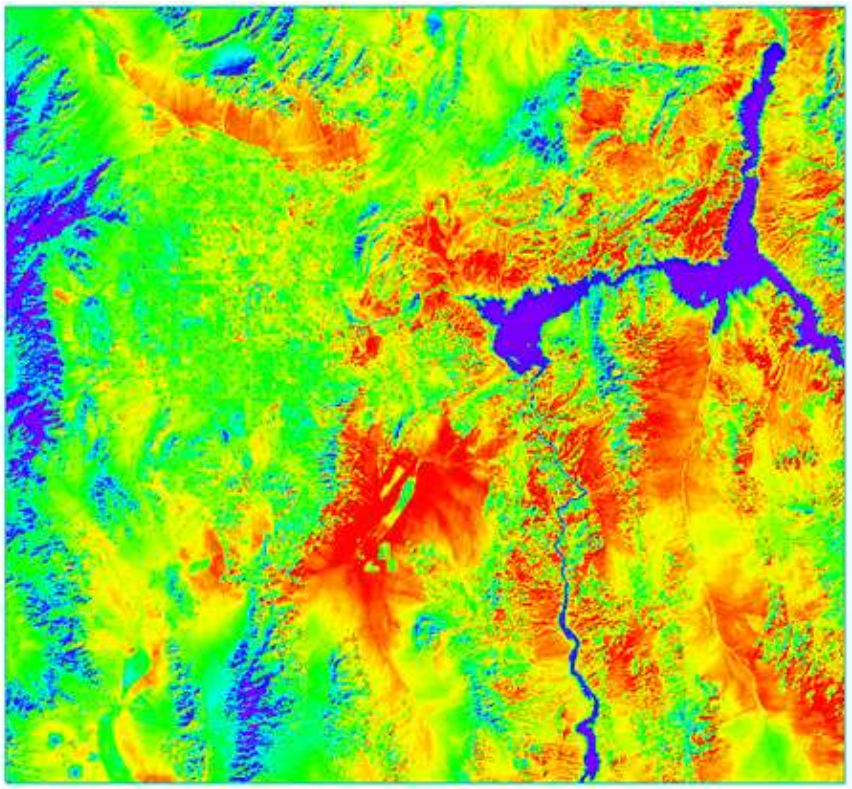
FIGURE 1.9 Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600 ×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

Visible – Infrared Imaging

FIGURE 1.11 Multispectral image of Hurricane Andrew taken by NOAA GEOS (Geostationary Environmental Operational Satellite) sensors. (Courtesy of NOAA.)

Thermal Imaging





http://gsp.humboldt.edu/olm_2015/Courses/GSP_216_Online/lesson8-1/interpreting-imagery.html

Microwave Imaging

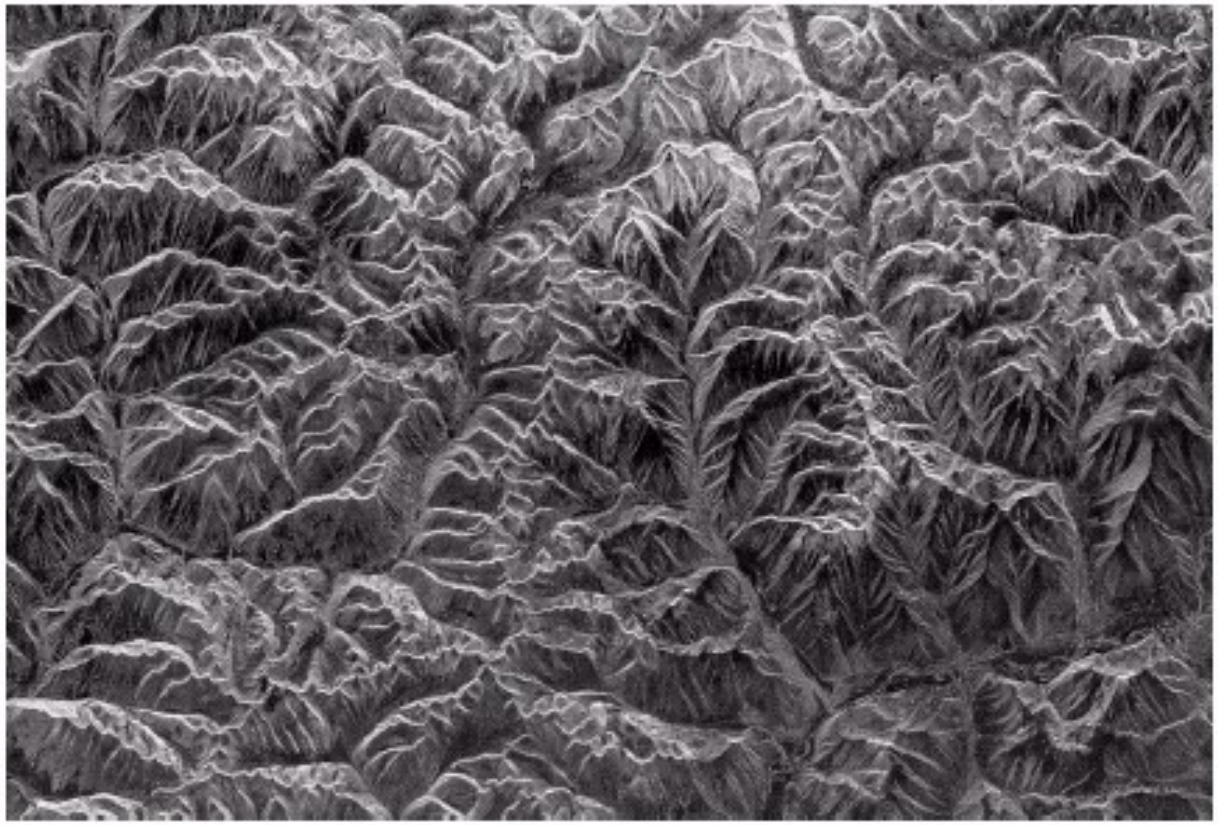
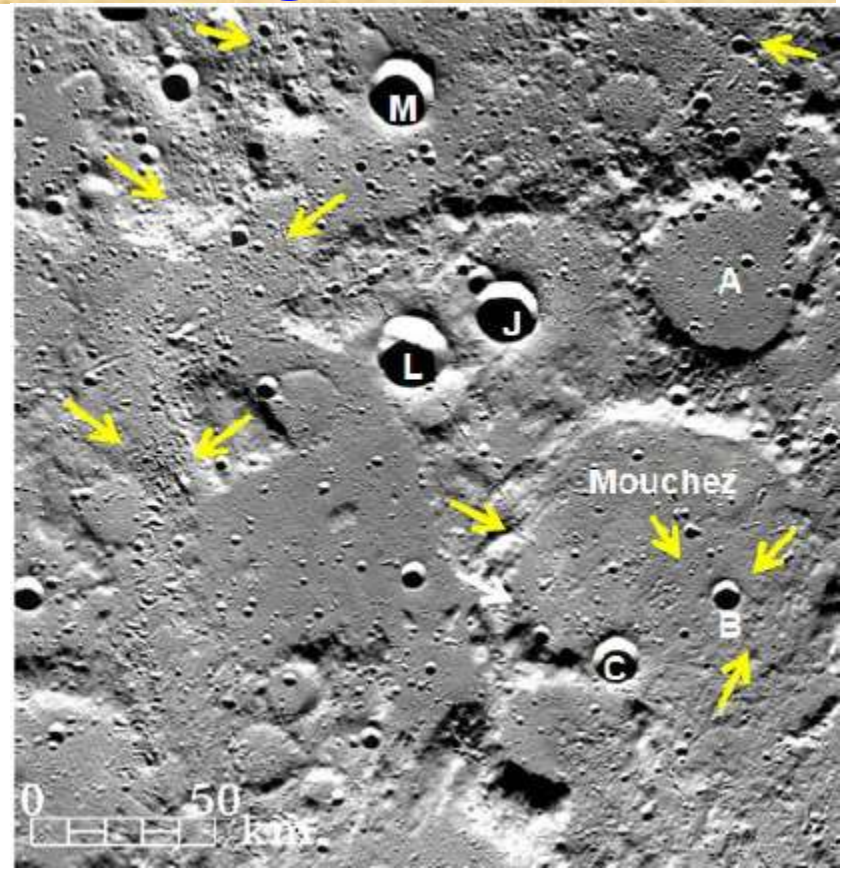


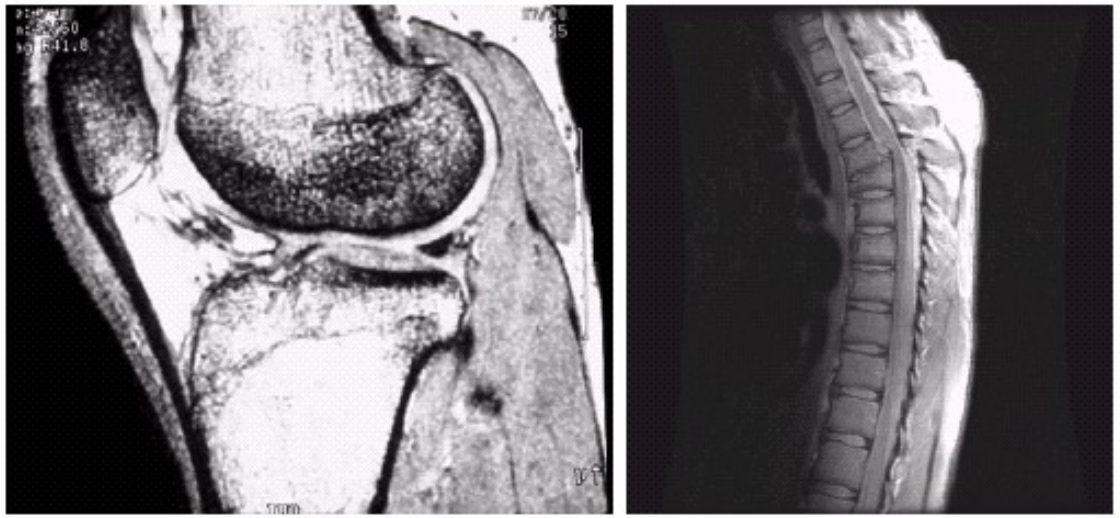
FIGURE 1.16
Spaceborne radar image of mountains in southeast Tibet. (Courtesy of NASA.)

Imaging in RF Region



Mini-RF CPR (colorized and overlaid on backscatter image) image of the Mouchez crater (78.38°N, 26.8°W) region. The radar bright regions with abundant wavelength-scale scatterers are indicated with arrows in both the CPR and WAC (Fig.3) images.

Imaging in the Radio Band



a b

FIGURE 1.17 MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

Seismic Imaging

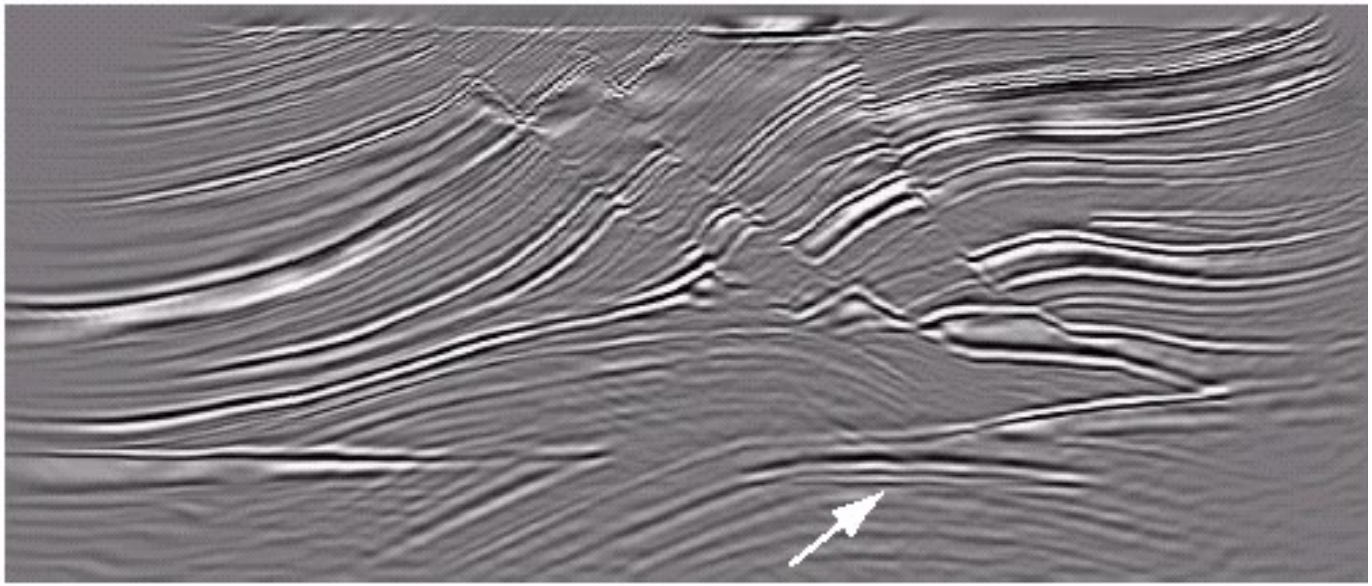
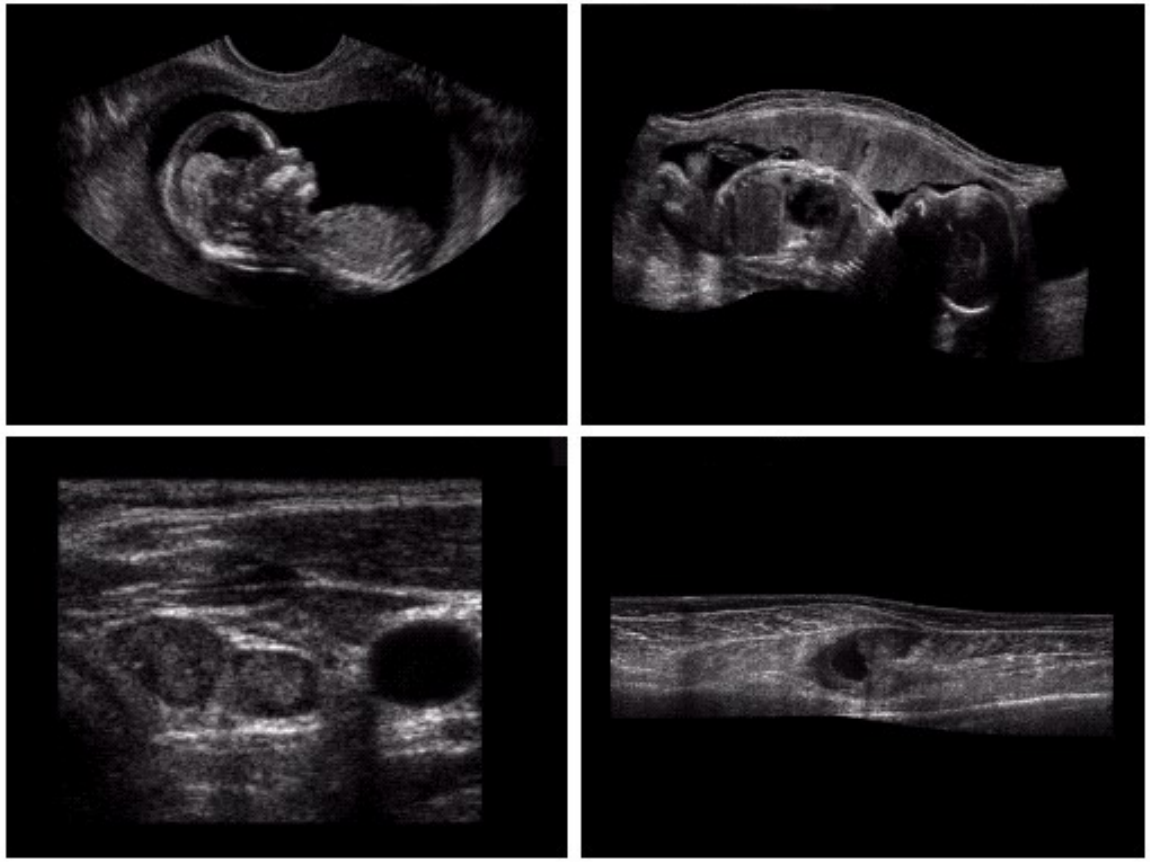


FIGURE 1.19
Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap. (Courtesy of Dr. Curtis Ober, Sandia National Laboratories.)

Ultrasound Imaging



a b
c d

FIGURE 1.20 Examples of ultrasound imaging. (a) Baby. (2) Another view of baby. (c) Thyroids. (d) Muscle layers showing lesion. (Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

Advances in Imaging

- 2-D Still images, only location on ground, no height or depth
- 3-D Still images, with location on ground, location and depth
- 4-D Image location, height/depth and temporal variations
- 6-D Image location, height/depth, 3-D motion of field of view
- Add color/thermal/spectral dimensions…

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Summary

- Images are used in a wide range of applications
- Most part of the electromagnetic spectrum is suitable for imaging for one or the other application

Points to Ponder… (3)

- Some more image based applications not listed in this presentation?

Points to ponder… (4)

What is the reason for some image based applications to become operational – found in mobile phones, laptop and tablet computers…, while some applications require human expertise?

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To be continued …