ज्ञानेन प्रकाशते जगत्
INDUS UNIVERSITY

Image Processing (EC0703)

Unit-1

B.Tech (Electronics and Communication)

Semester-7

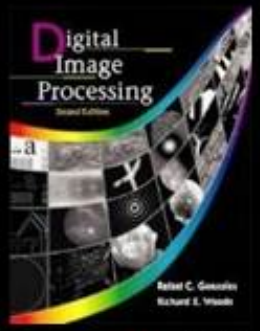
Prof.Hansa Shingrakhia

Academic Year 2019-2020

Introduction

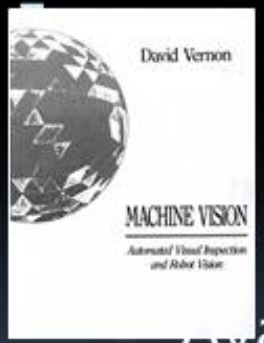
- *"One picture is worth more than ten thousand words"*

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

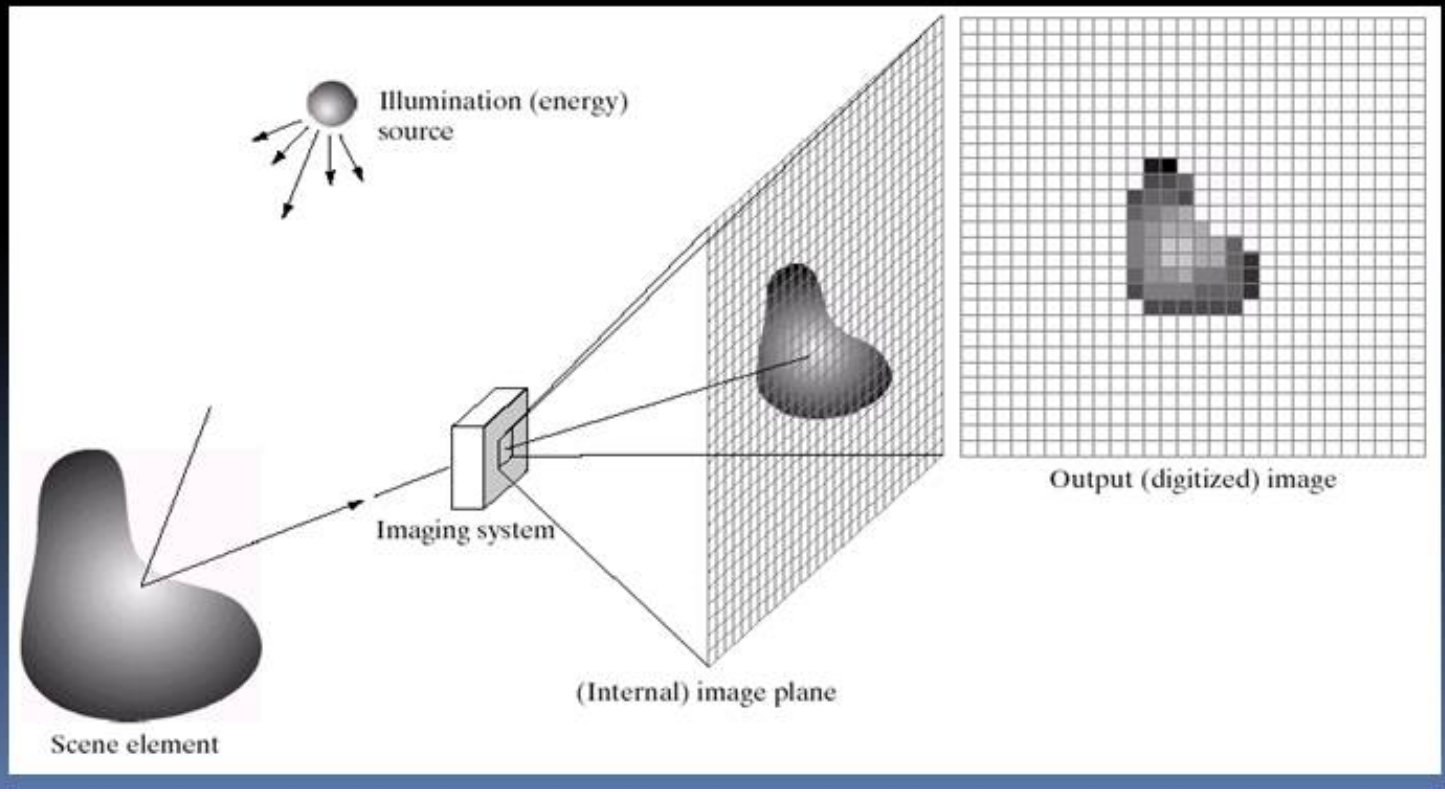
Available online at:
homepages.inf.ed.ac.uk/rbf/BOOKS/VERNON/

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?

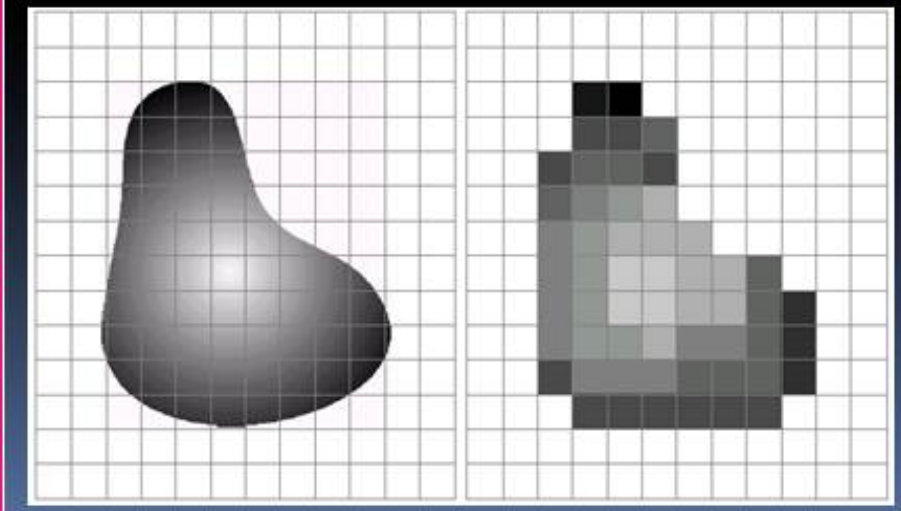
- A **digital image** is a representation of a two-dimensional image as a finite set of digital values, called picture elements or pixels

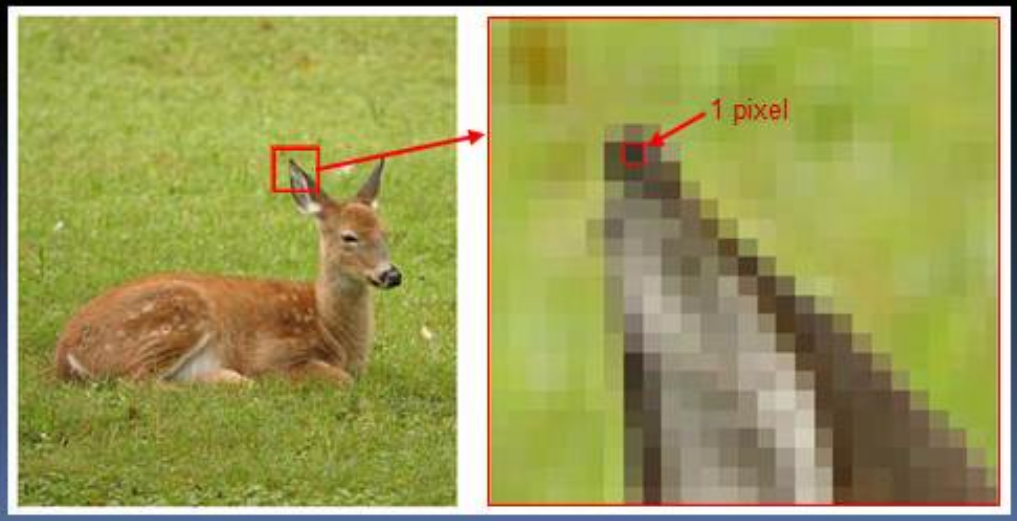


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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

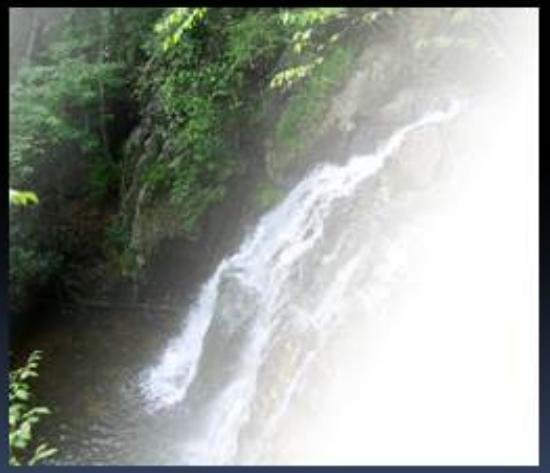




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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

Employ methods capable of enhancing pictorial information for human interpretation and analysis

Typical applications:

- Noise filtering
- Content enhancement
  - Contrast enhancement
  - Deblurring
- Remote sensing

Filtering

Noisy Image

Filtered Image

Image Enhancement

Low contrast Image

Enhanced Image

Low contrast Image

Enhanced Image

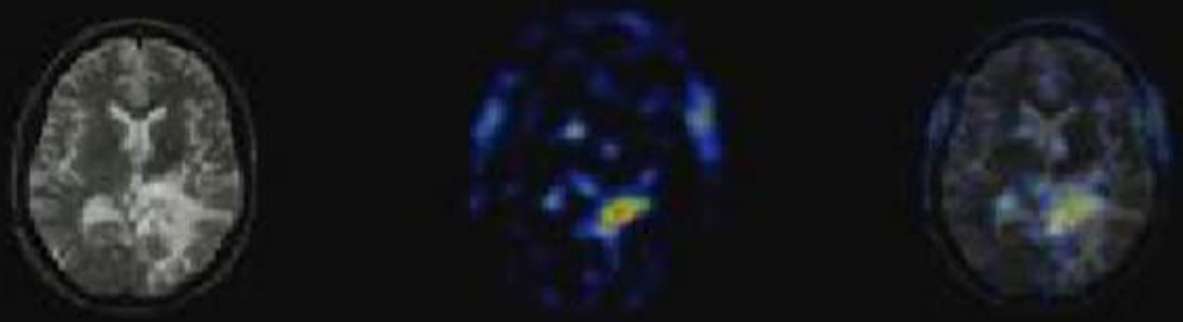
Image Deblurring

Defocused

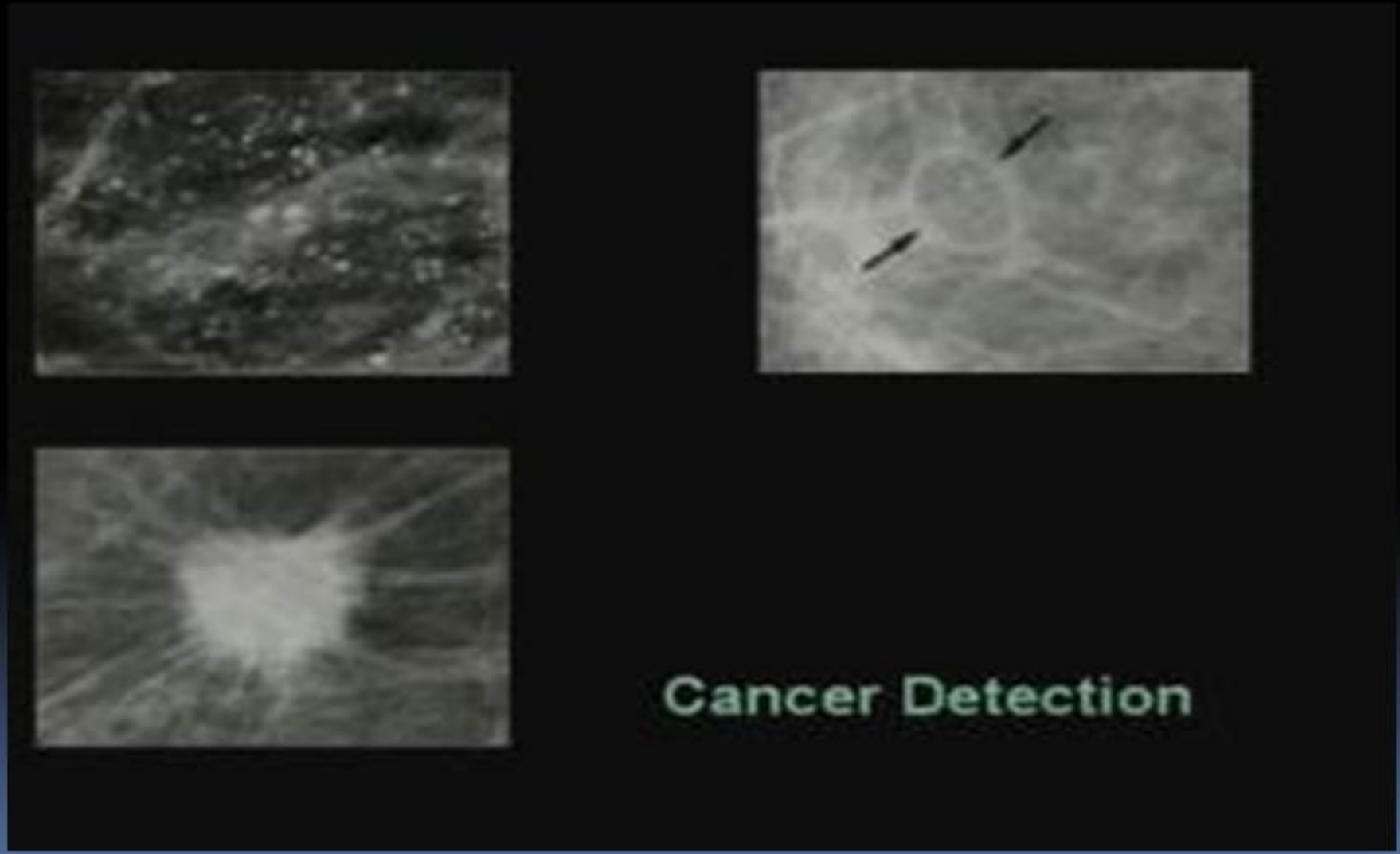
Motion Blurred

Deblurred

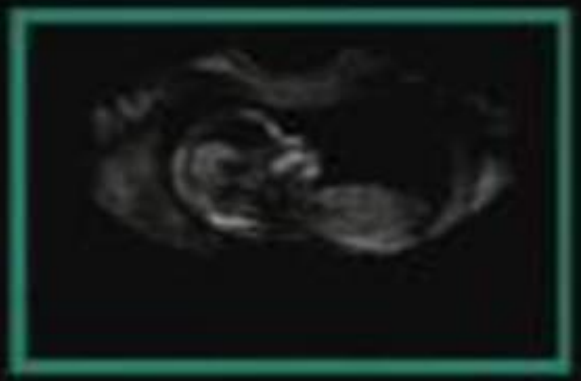
Medical Imaging

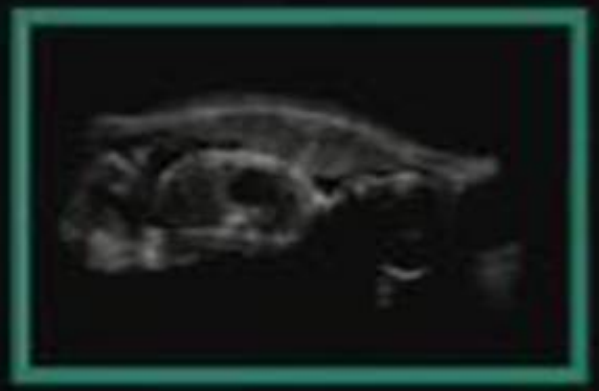


Brain Tumor


Cancer Detection

Medical Imaging

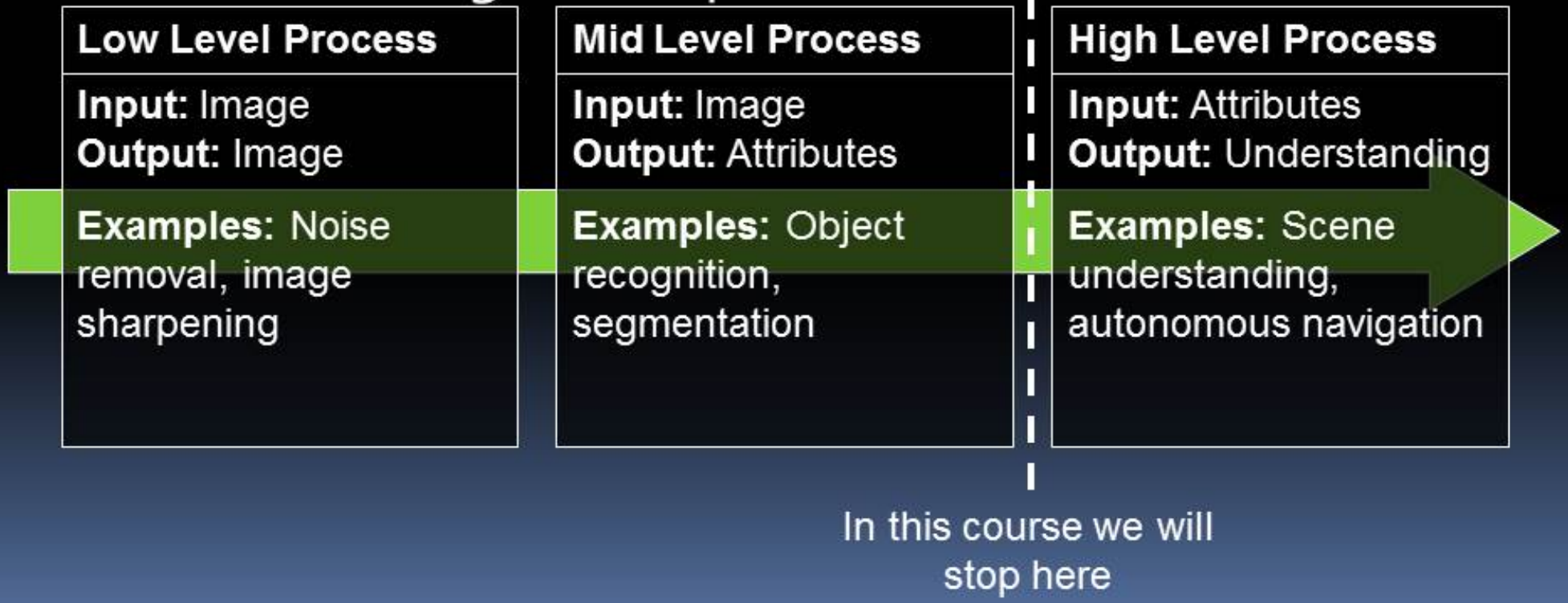




Ultra Sonogram

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

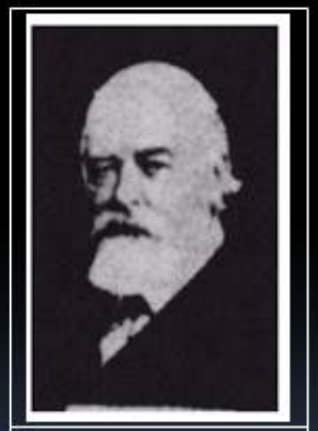
- **Early 1920s:** One of the first appli[illegible] digital imaging was in the news-paper industry
  - The Bartlane cable picture transmission service
  - Images were transferred by submarine cable between London and New York
  - Pictures were coded for cable transfer and reconstructed at the receiving 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



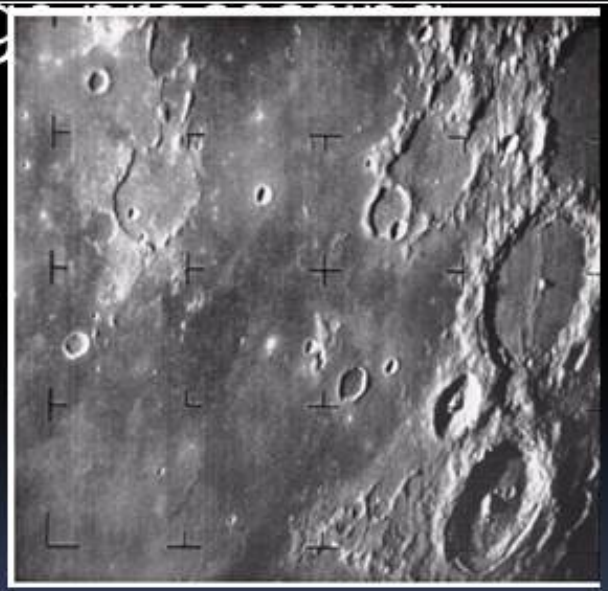
Improved digital image

Early 15 tone digital image

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

History of DIP (cont…)

- **1960s:** Improvements in computing technology and the onset of the space race led to a surge of work in digital imag
  - **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

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

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

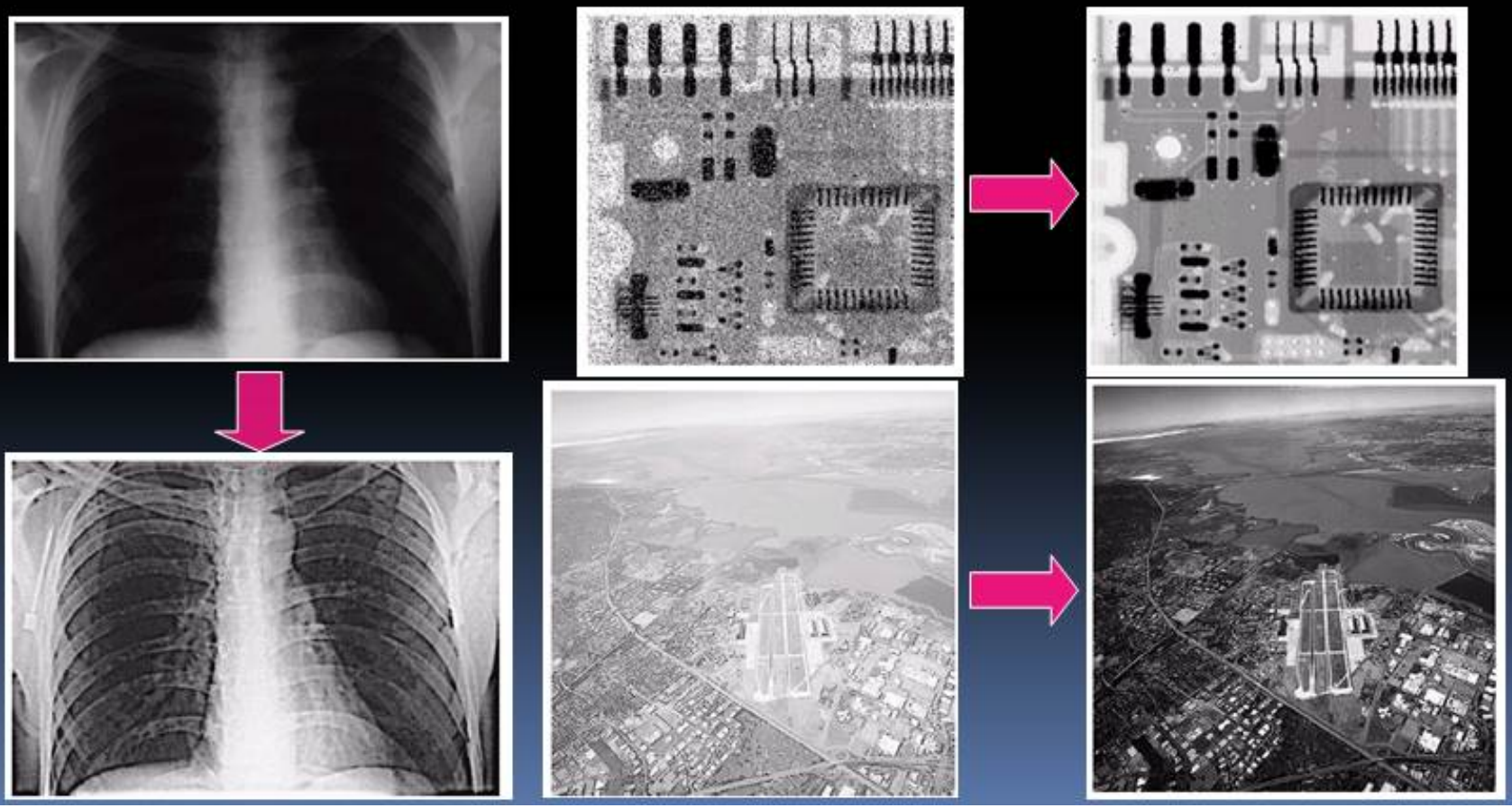
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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

Examples: Image Enhancement

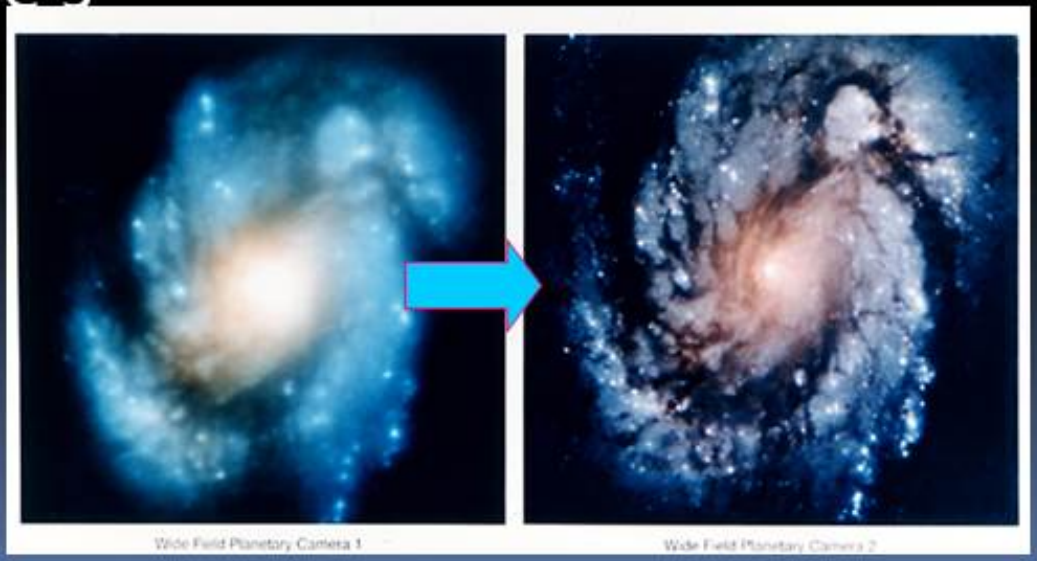
- One of the most common uses of DIP techniques: improve quality, remove noise etc



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

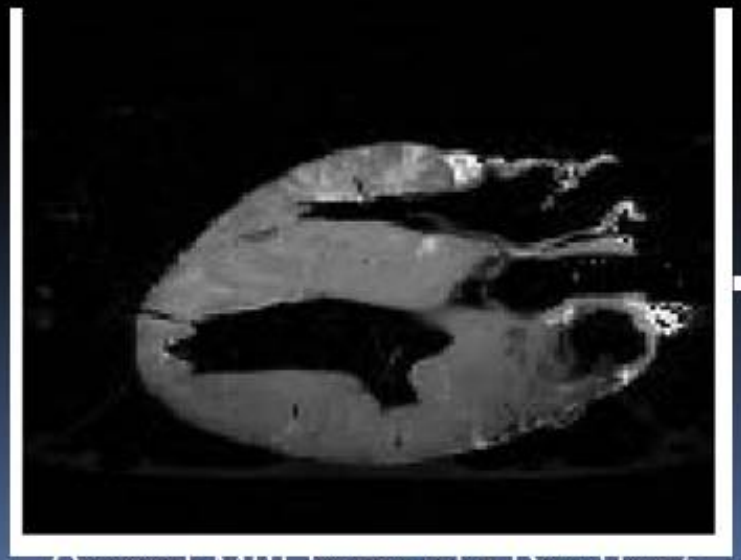


Examples: Artistic Effects

- 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

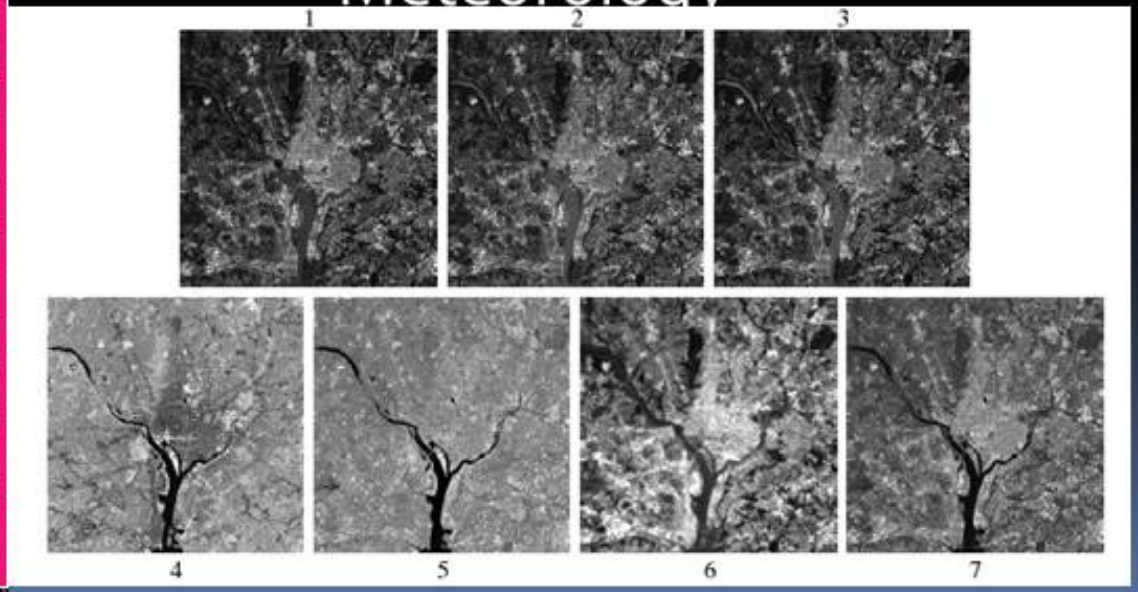
Edge Detection Image

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

Examples: GIS

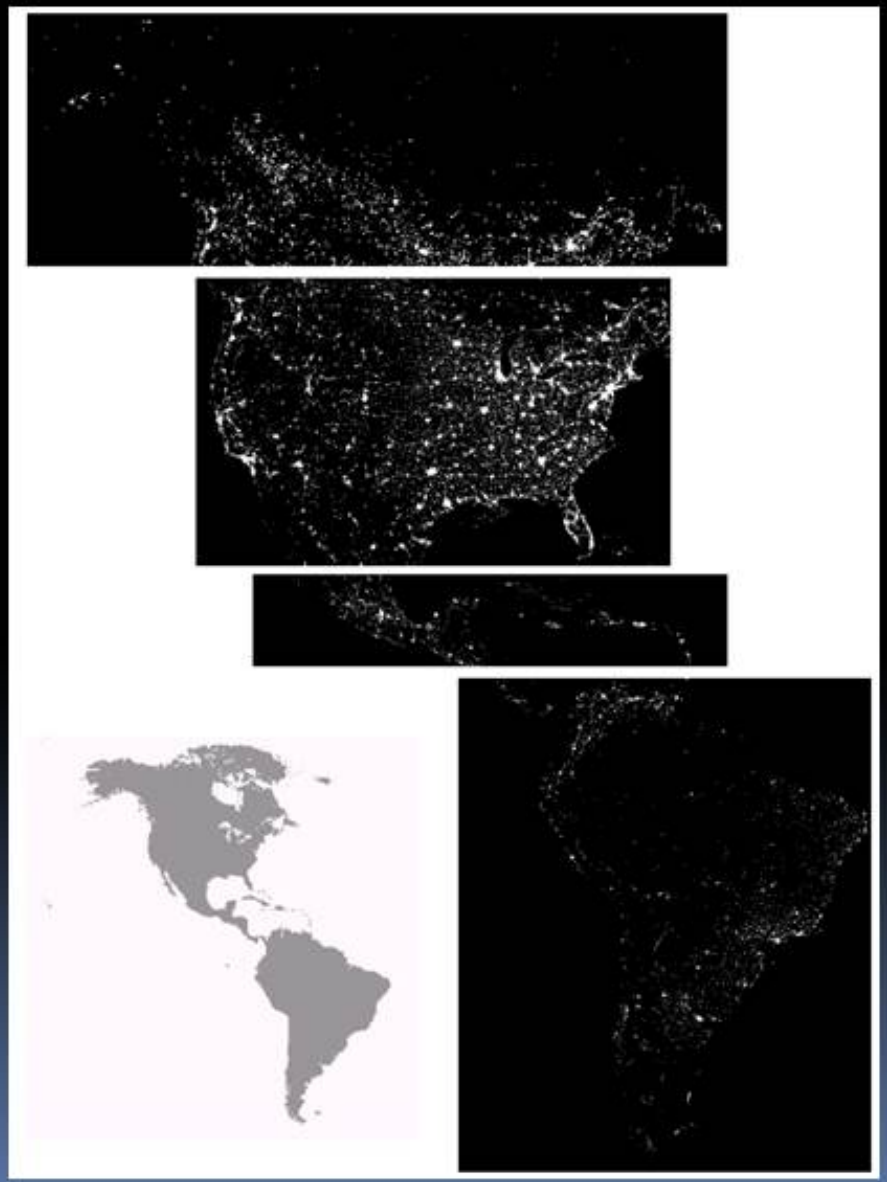
- Geographic Information Systems
  - Digital image processing techniques are used extensively to manipulate satellite imagery
  - Terrain classification
  - Meteorology

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



Examples: GIS (cont…)

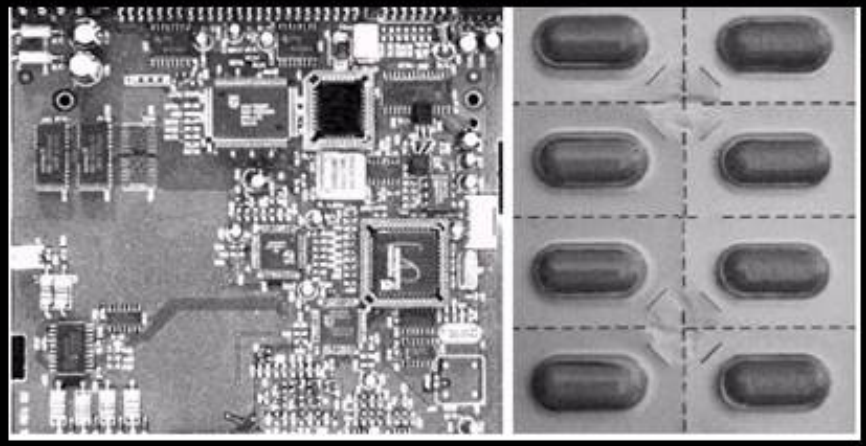
- *Night-Time Lights of the World* data set
  - Global inventory of human settlement
  - Not hard to imagine the kind of analysis that might be done using this data



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

Examples: Industrial Inspection

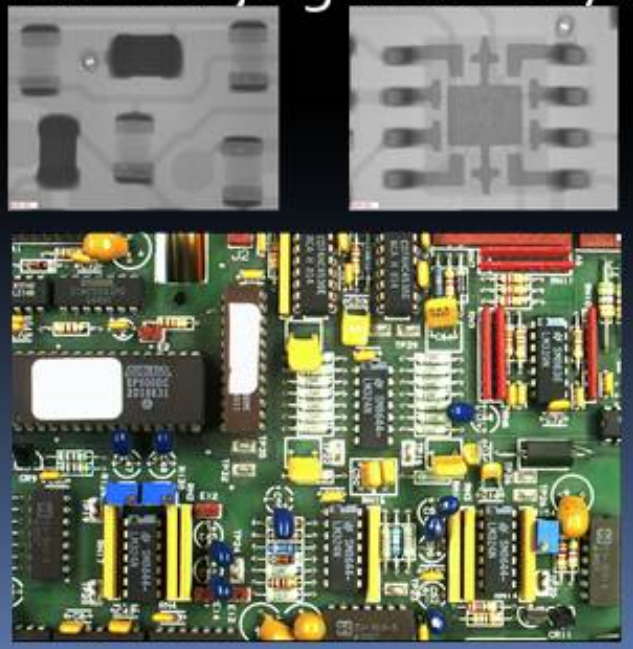
- Human operators are expensive, slow and unreliable
- Make machines do the job instead
- Industrial vision systems are used in all kinds of industries



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

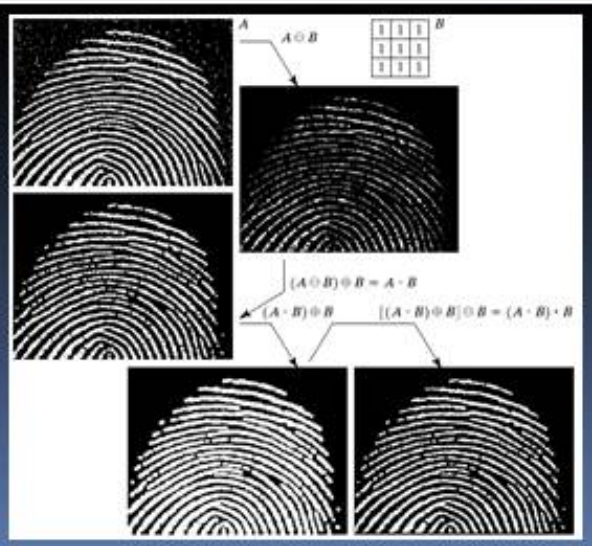
Examples: PCB Inspection

- 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



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



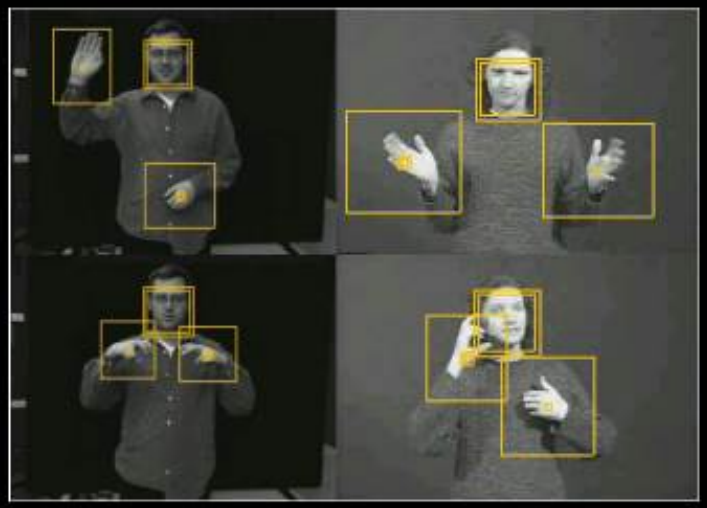
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Boundary Information

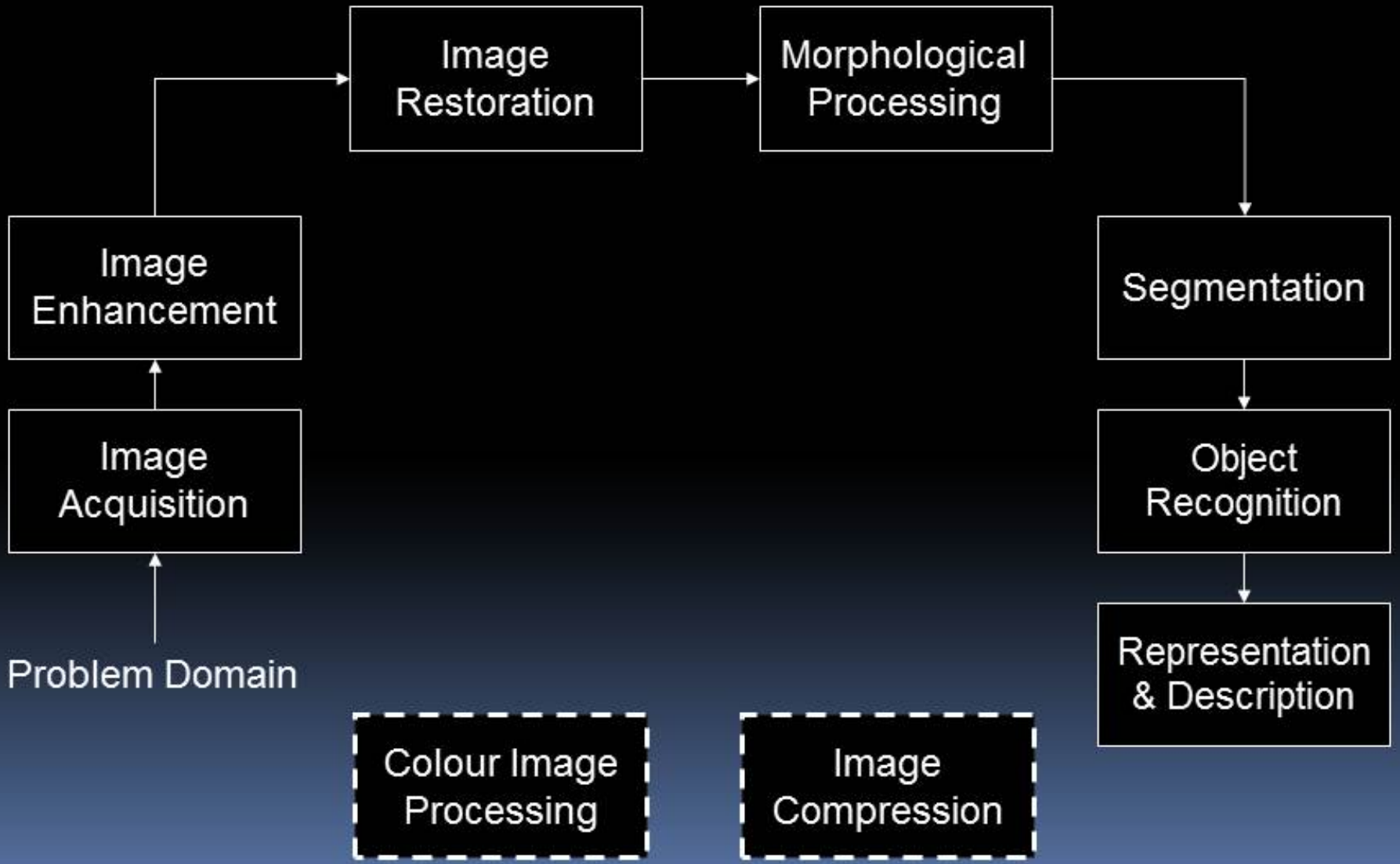
Importance of Boundary Information

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 extre difficult



Key Stages in Digital Image Processing



Key Stages in Digital Image Processing:

Image Restoration

Morphological Processing

Segmentation

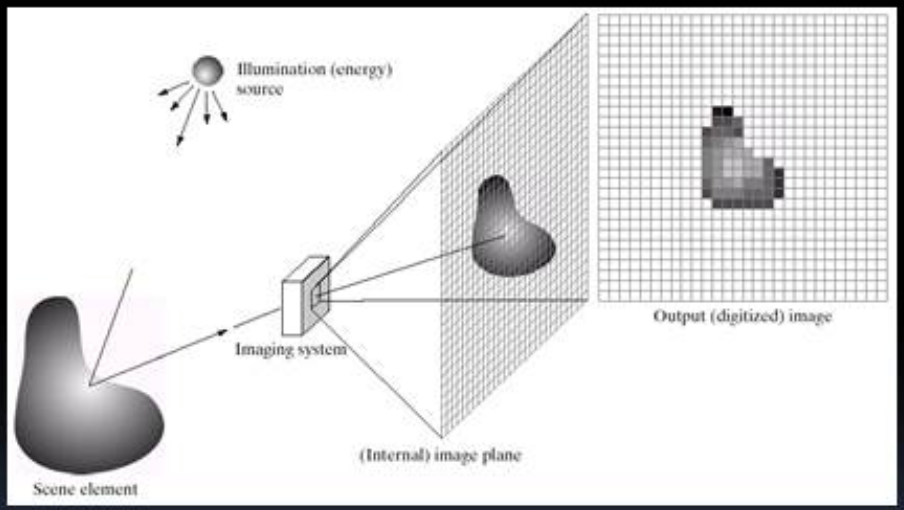
Object Recognition

Representation & Description

Image Enhancement

Image Acquisition

Problem Domain

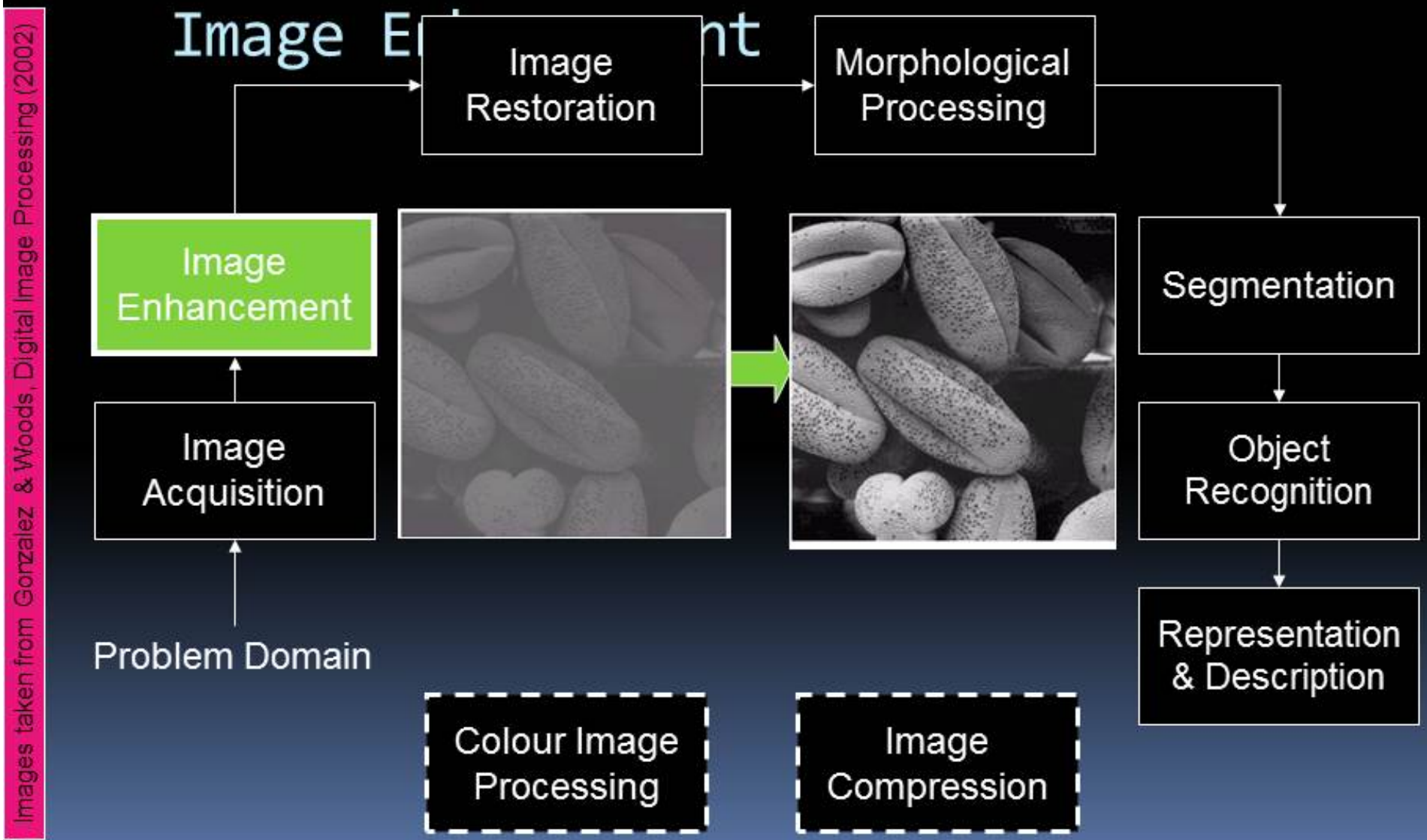


Colour Image Processing

Image Compression

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

Key Stages in Digital Image Processing:



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

Key Stages in Digital Image Processing:

Image R…on

Image Restoration

Morphological Processing

Image Enhancement

Segmentation

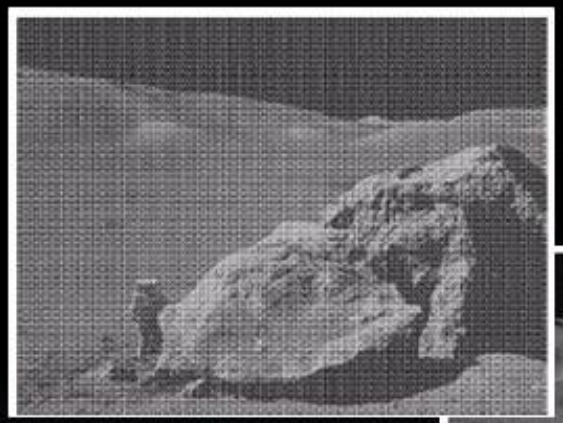


Image Acquisition

Object Recognition

Representation & Description

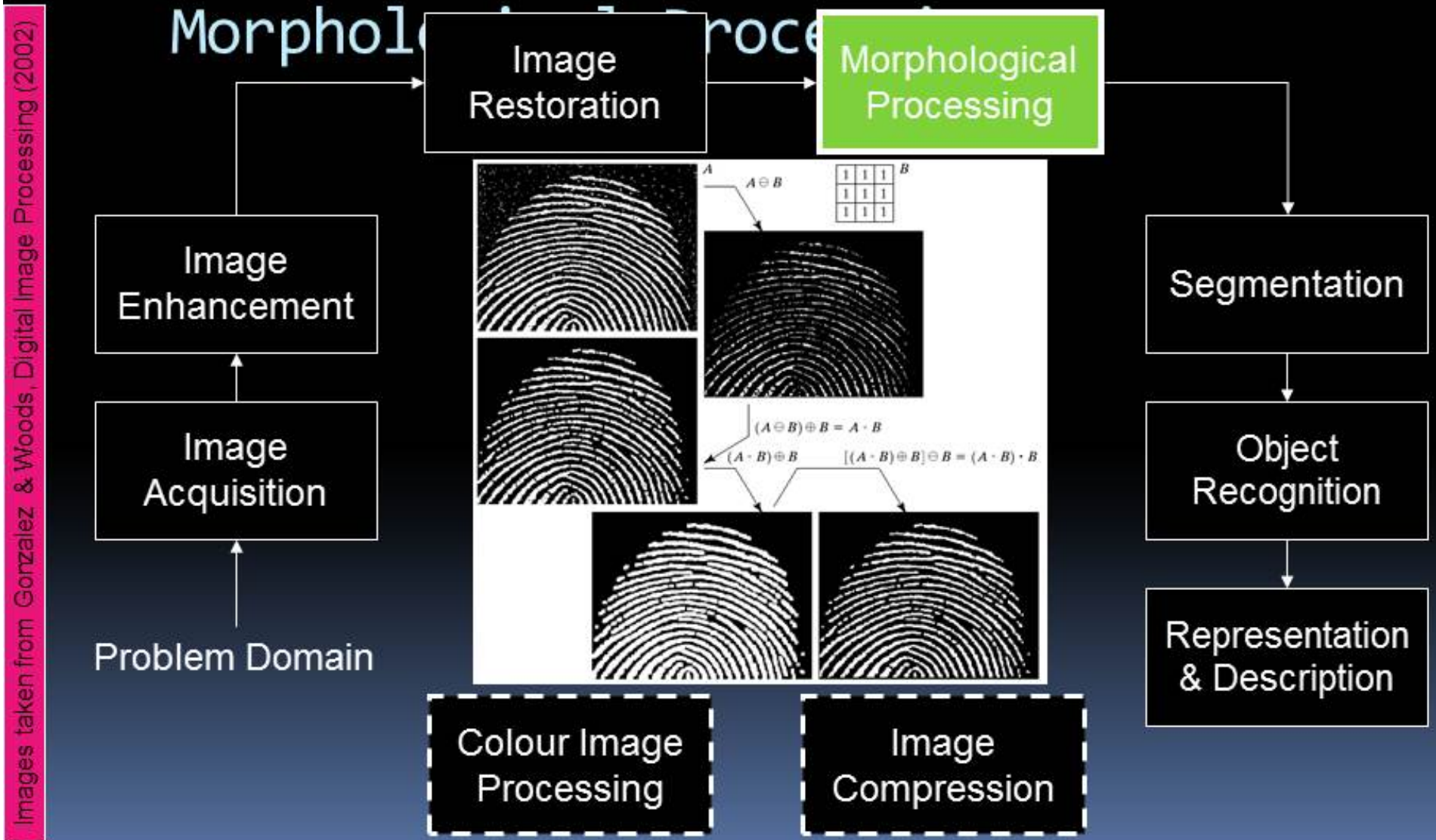
Problem Domain

Colour Image Processing

Image Compression

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

Key Stages in Digital Image Processing:



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

Key Stages in Digital Image Processing:

Image Restoration

Morphological Processing

Segmentation

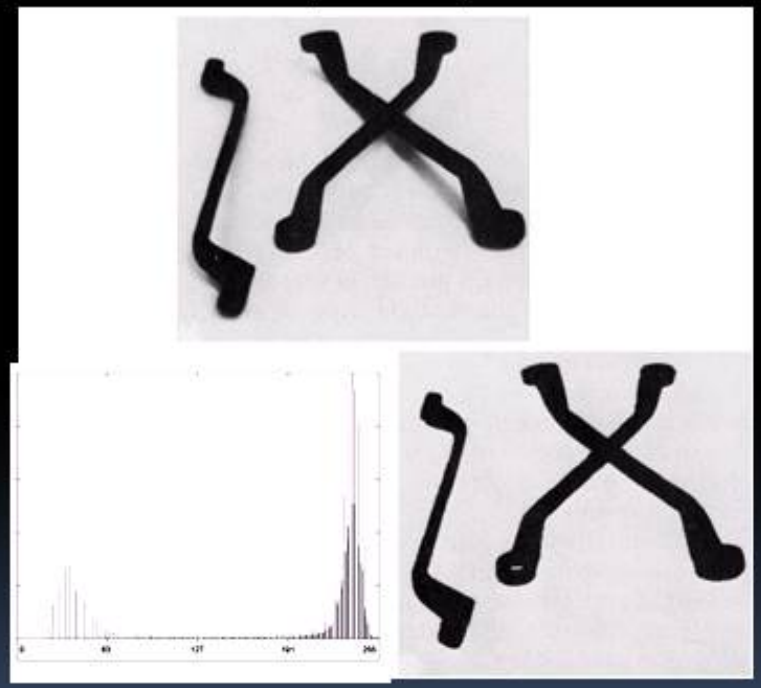
Object Recognition

Representation & Description

Image Enhancement

Image Acquisition

Problem Domain



Colour Image Processing

Image Compression

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

Key Stages in Digital Image Processing: Object [illegible]ion

Image Restoration

Morphological Processing

Image Enhancement

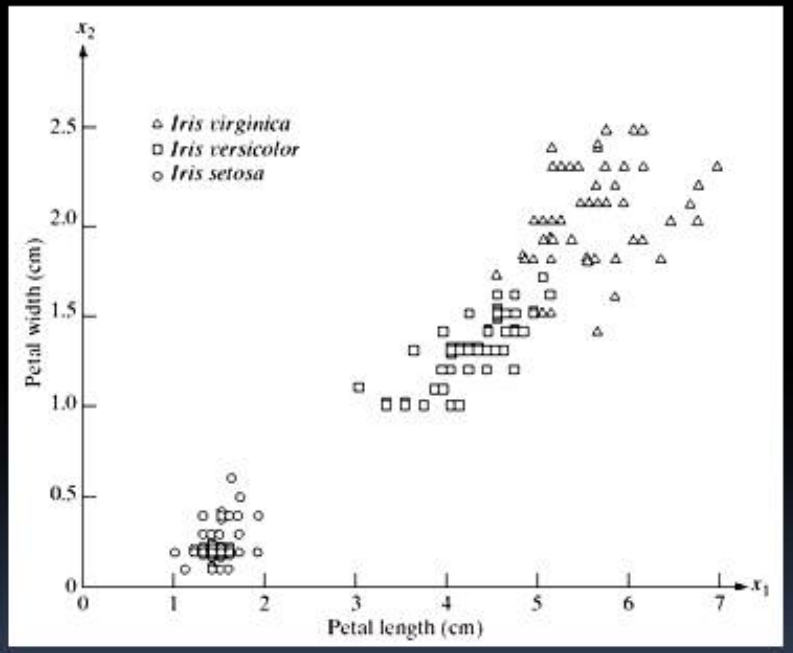
Segmentation

Image Acquisition

Object Recognition

Problem Domain

Representation & Description

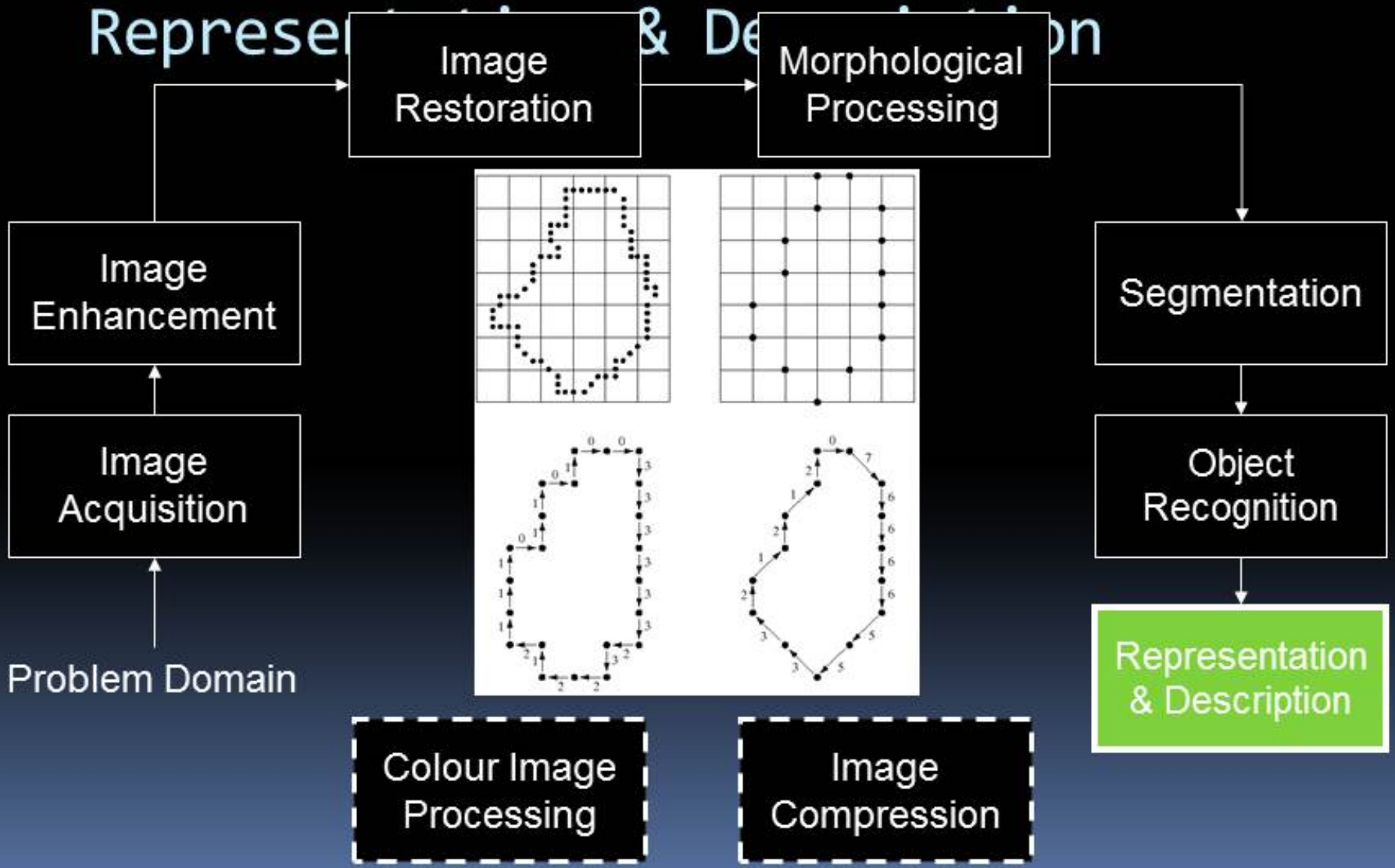


Colour Image Processing

Image Compression

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

Key Stages in Digital Image Processing:



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

Key Stages in Digital Image Processing:
Image C...on

Image Restoration

Morphological Processing

Image Enhancement

Segmentation

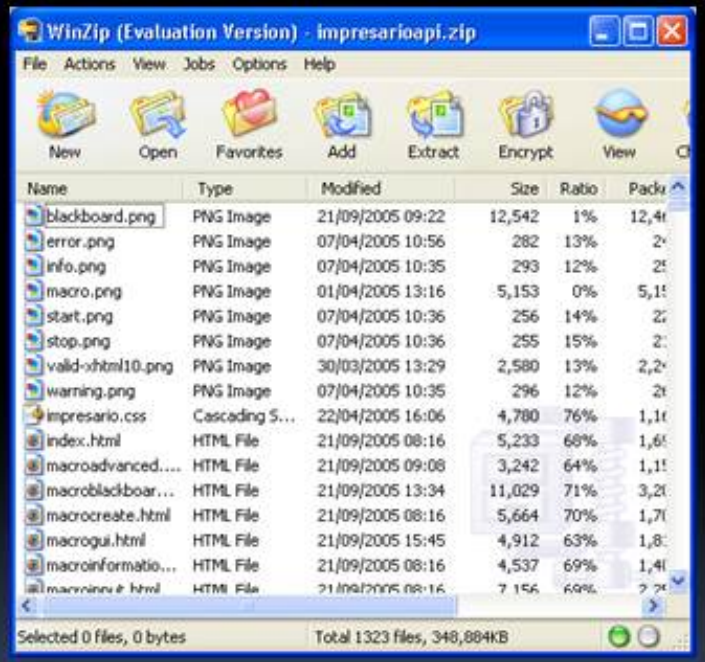


Image Acquisition

Object Recognition

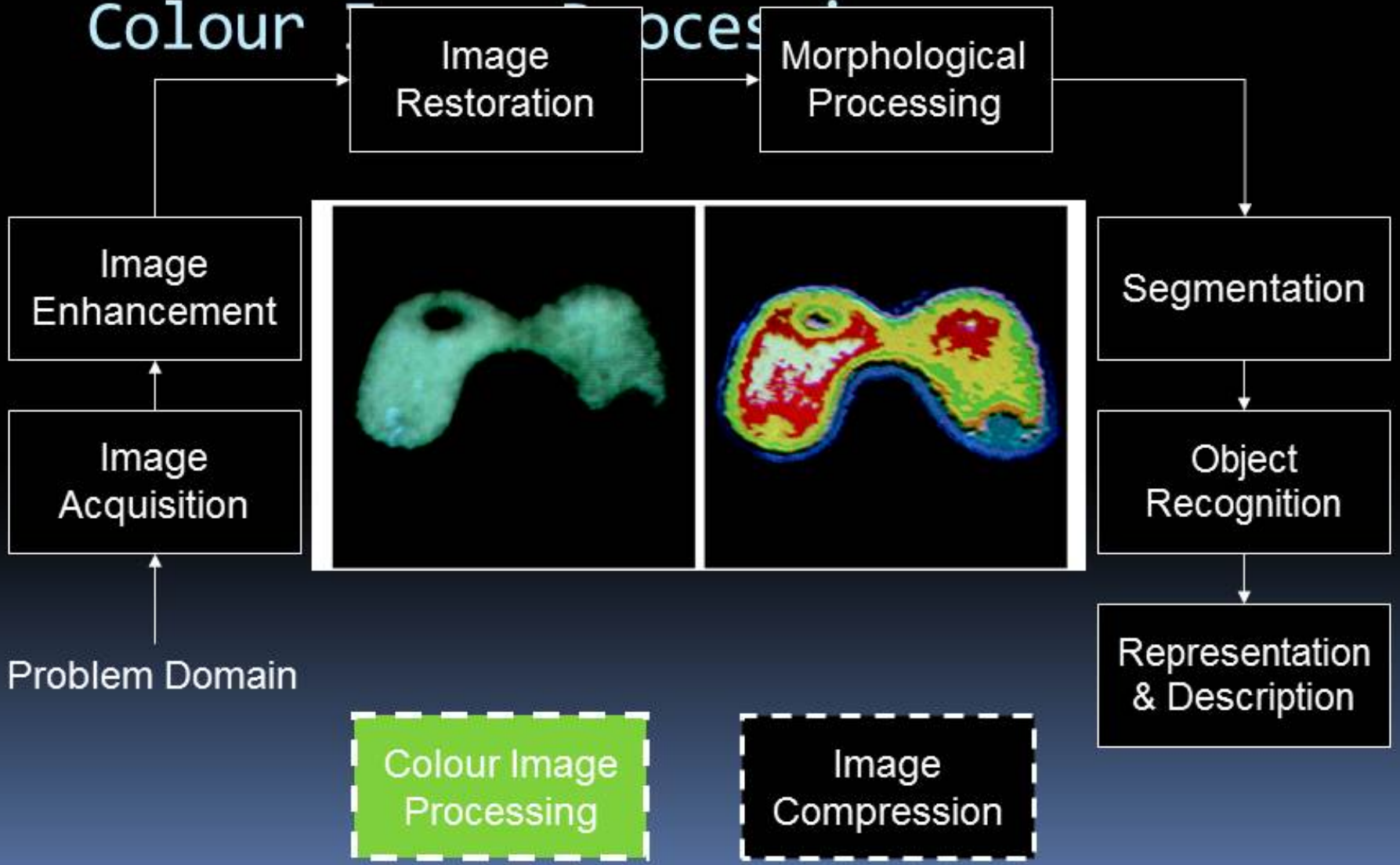
Problem Domain

Representation & Description

Colour Image Processing

Image Compression

Key Stages in Digital Image Processing:



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…

Contents

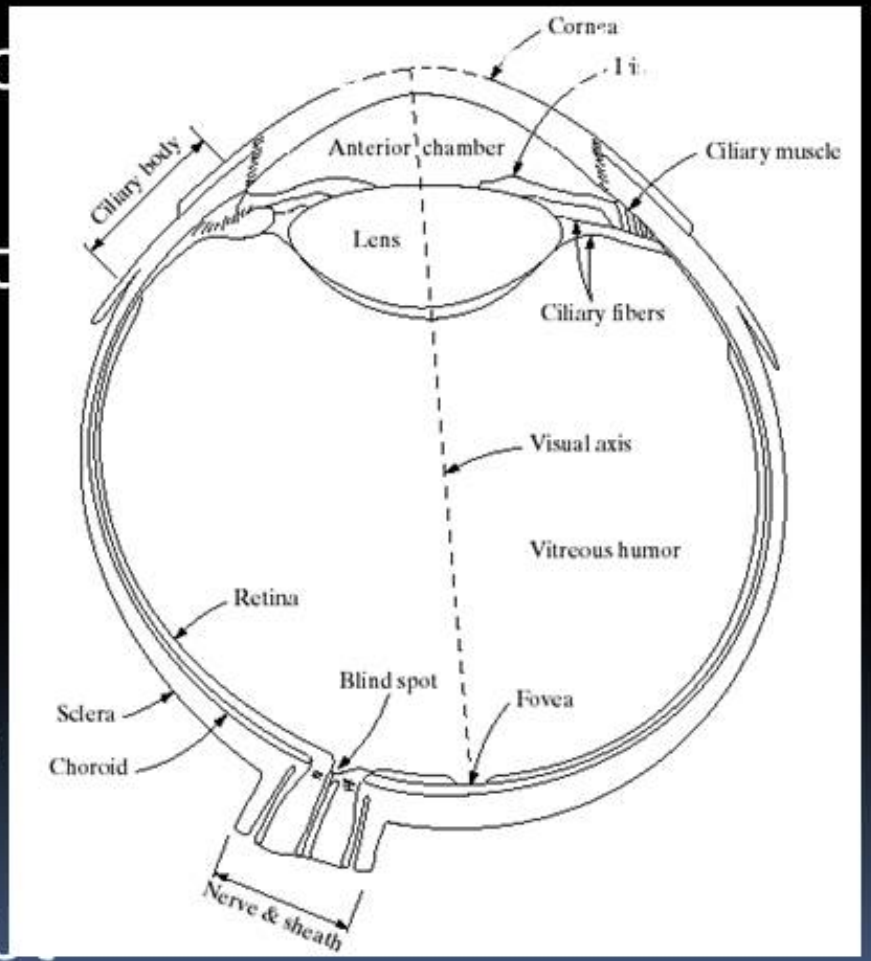
- This lecture will cover:
  - The human visual system
  - Light and the electromagnetic spectrum
  - Image representation
  - Image sensing and acquisition
  - Sampling, quantisation and resolution

Human Visual System

- The best vision model we have!
- Knowledge of how images form in the eye can help us with processing digital images
- We will take just a whirlwind tour of the human visual system

Structure Of The Human Eye

- The lens focuses light fro
retina
- The retina is covered wit
light receptors called
cones (6-7 million) and
rods (75-150 million)
- Cones are concentrated
around the fovea and are
very sensitive to colour
- Rods are more spread ou
and are sensitive to low levels of illumination



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

Blind-Spot Experiment

- Draw an image similar to that below on a piece of paper (the dot and cross are about 6 inches apart)

- Close your right eye and focus on the cross with your left eye
- Hold the image about 20 inches away from your face and move it slowly towards you
- The dot should disappear!

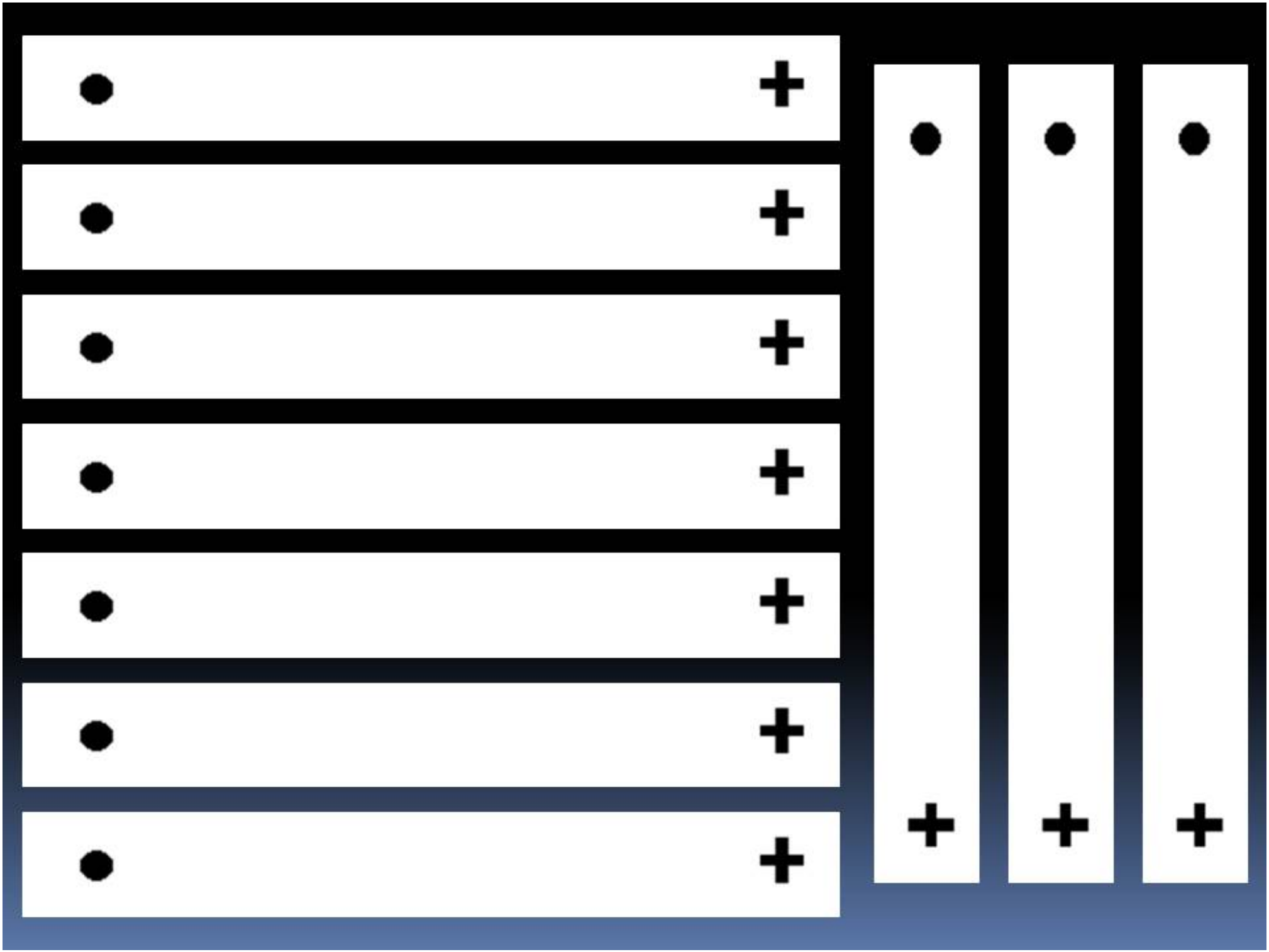
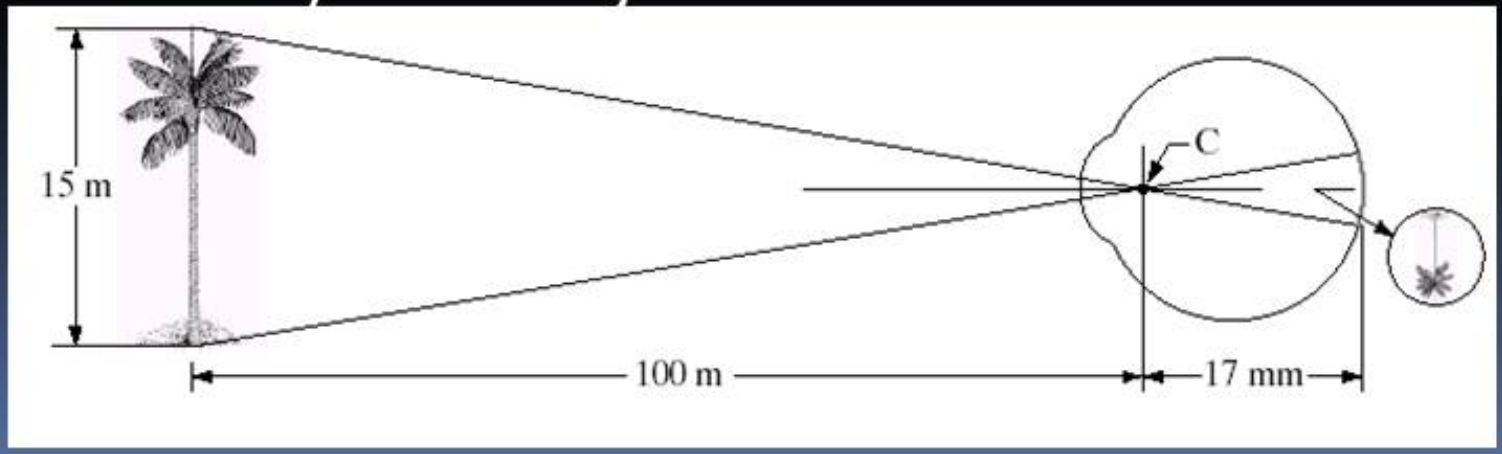


Image Formation In The Eye

- Muscles within the eye can be used to change the shape of the lens allowing us focus on objects that are near or far away
- An image is focused onto the retina causing rods and cones to become excited which ultimately send signals to the brain



Brightness Adaptation & Discrimination

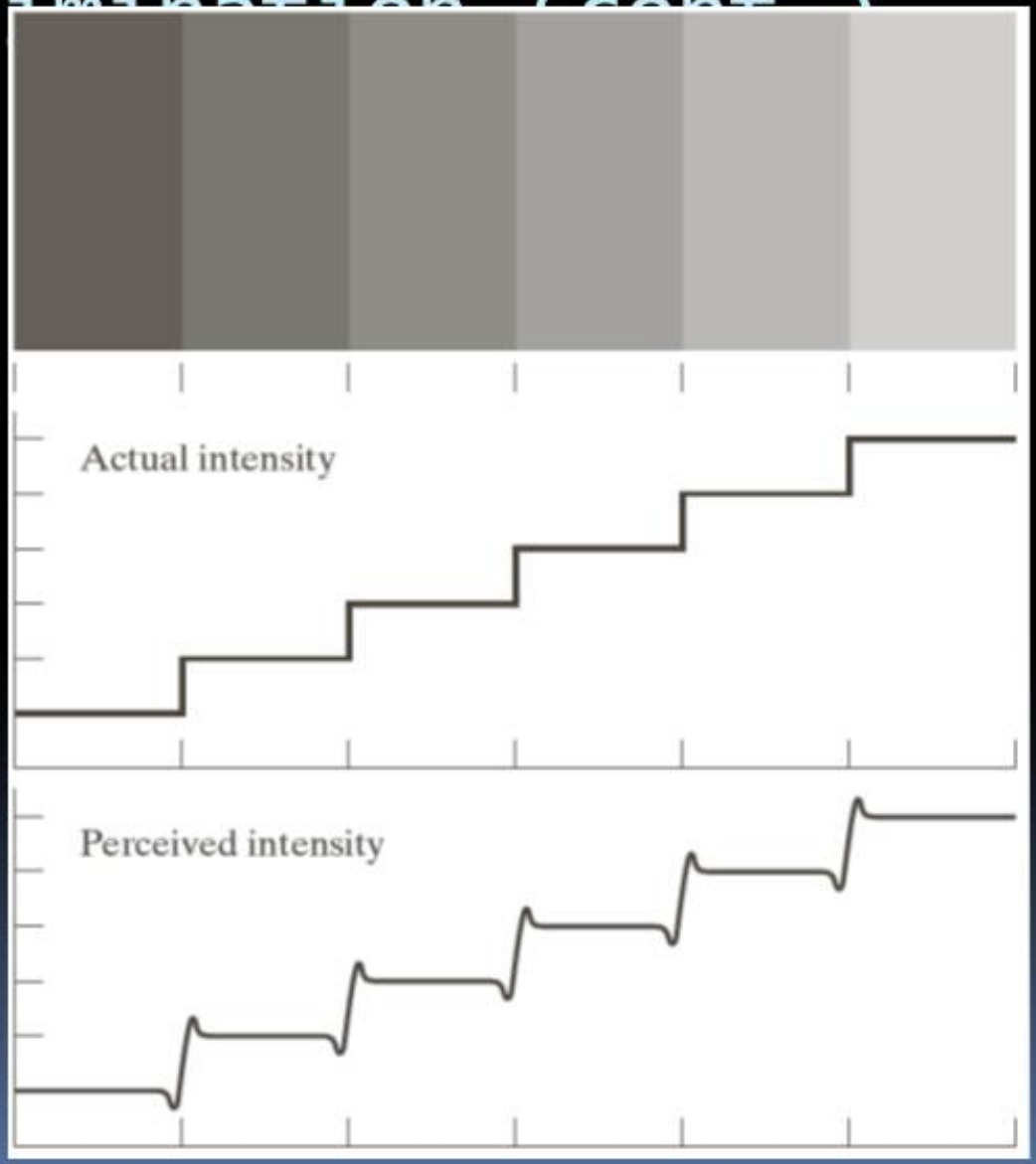
- The human visual system can perceive approximately 10^{10} different light intensity levels
- However, at any one time we can only discriminate between a much smaller number – *brightness adaptation*
- Similarly, the *perceived intensity* of a region is related to the light intensities of the regions surrounding it

Brightness Adaptation & Discrimination (cont.)

An example of Mach bands

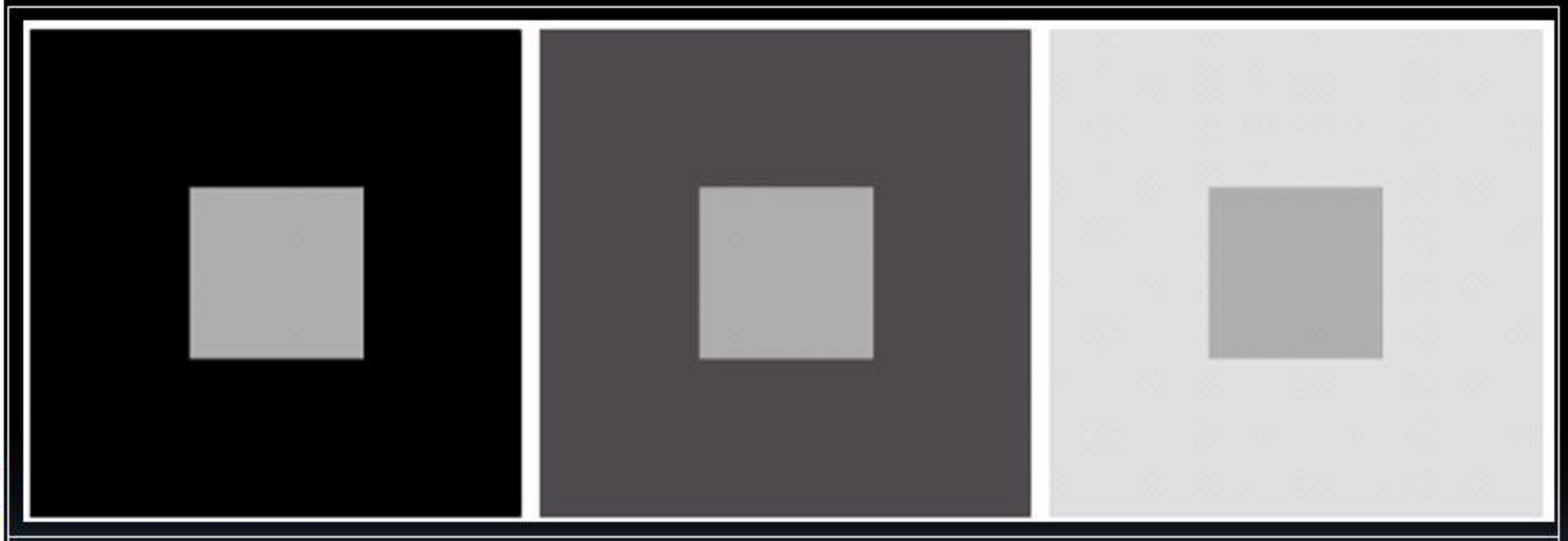
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Brightness Adaptation & Discrimination (cont.)



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

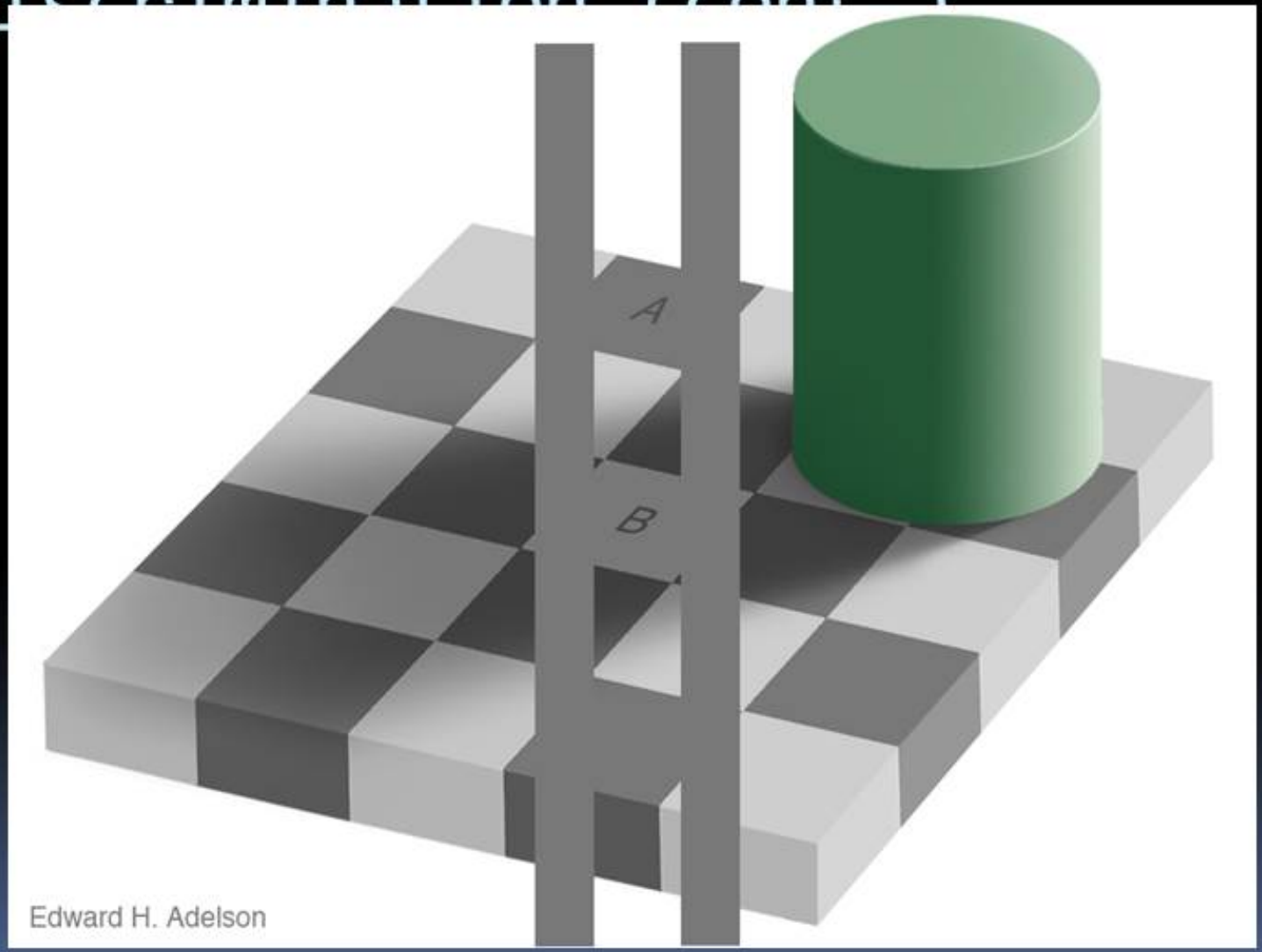
Brightness Adaptation & Discrimination (cont…)



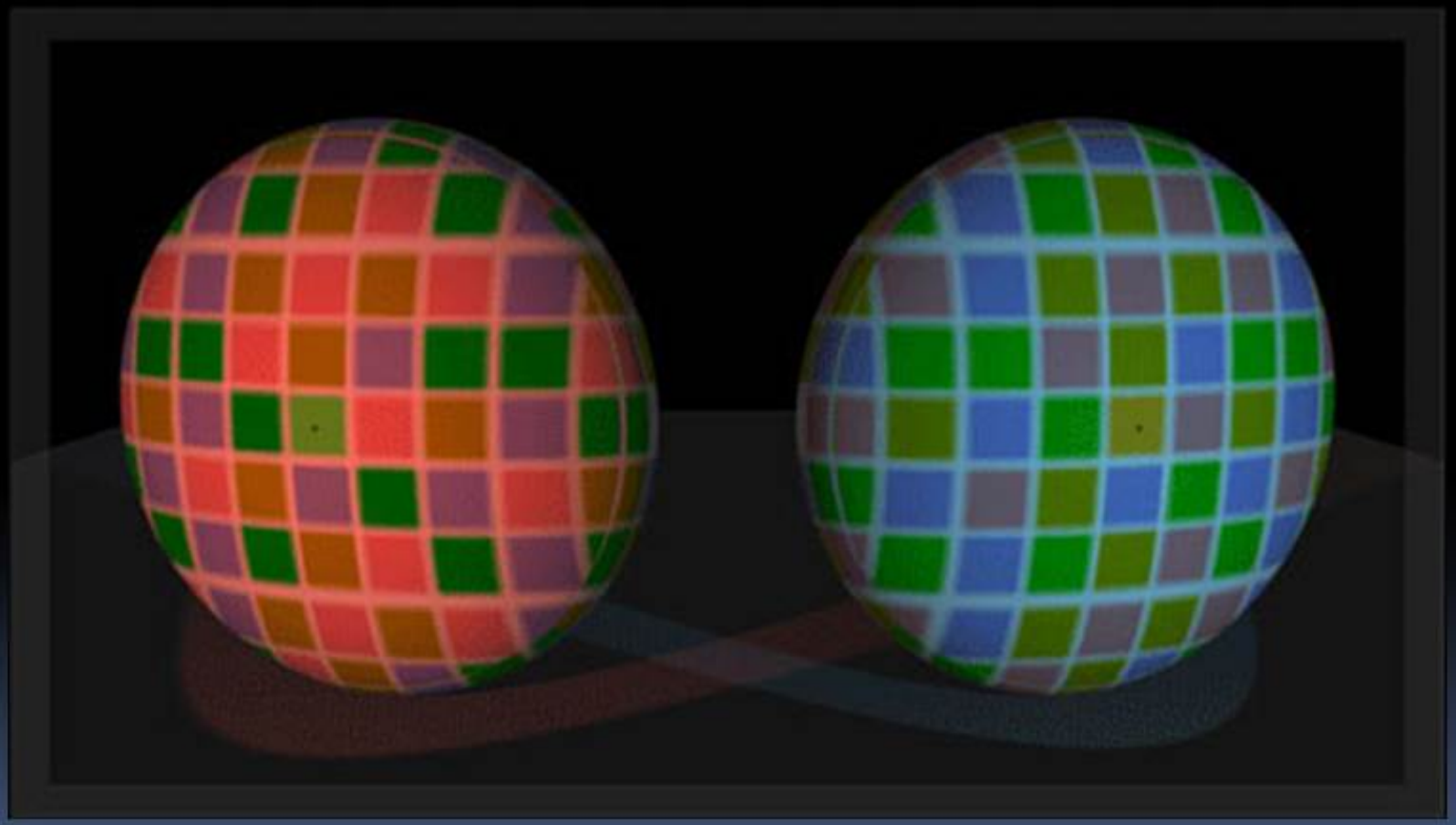
An example of *simultaneous contrast*

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

Brightness Adaptation & Discrimination (cont.)



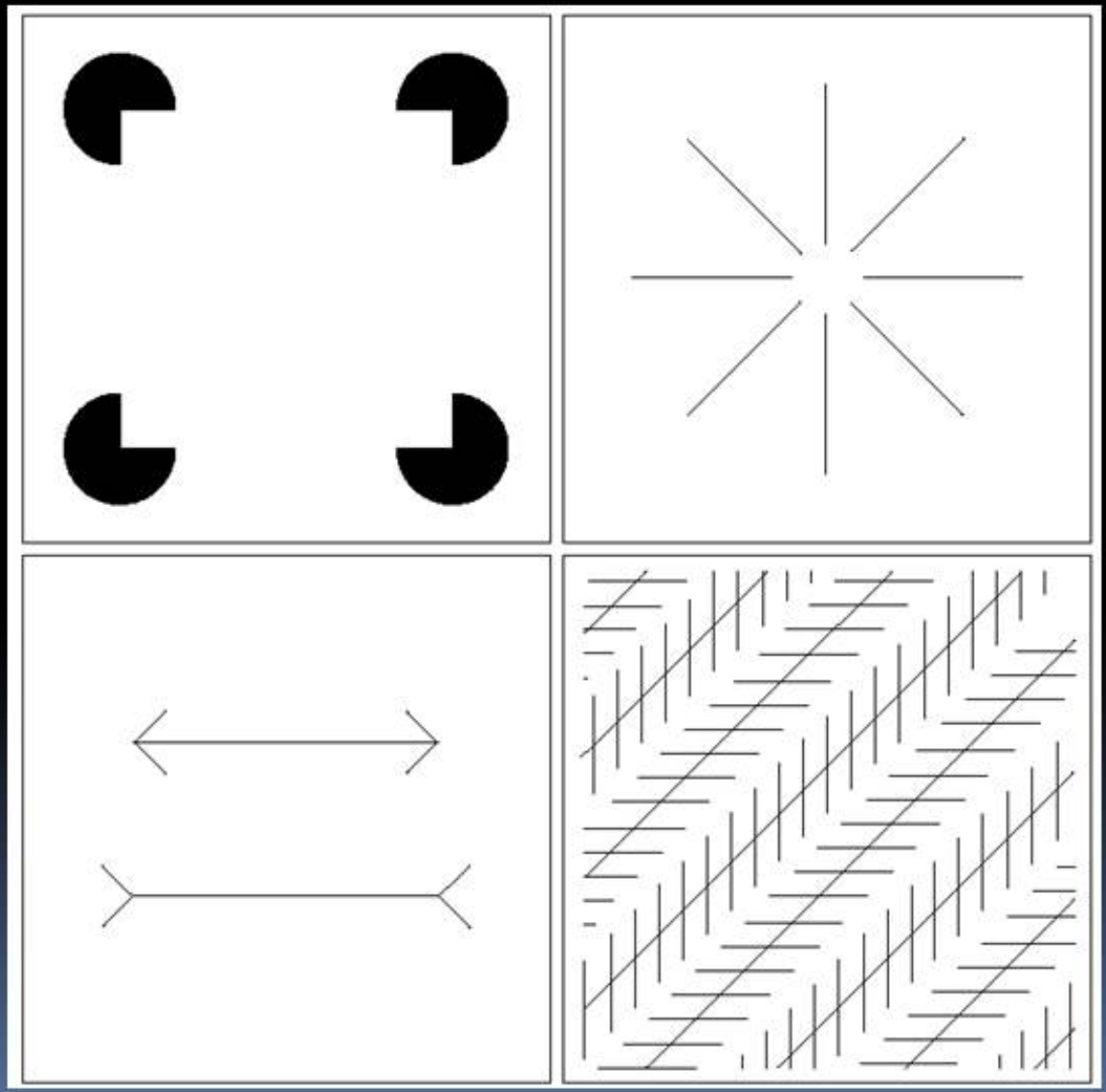
For more great illusion examples take a look at: http://web.mit.edu/persci/gaz/



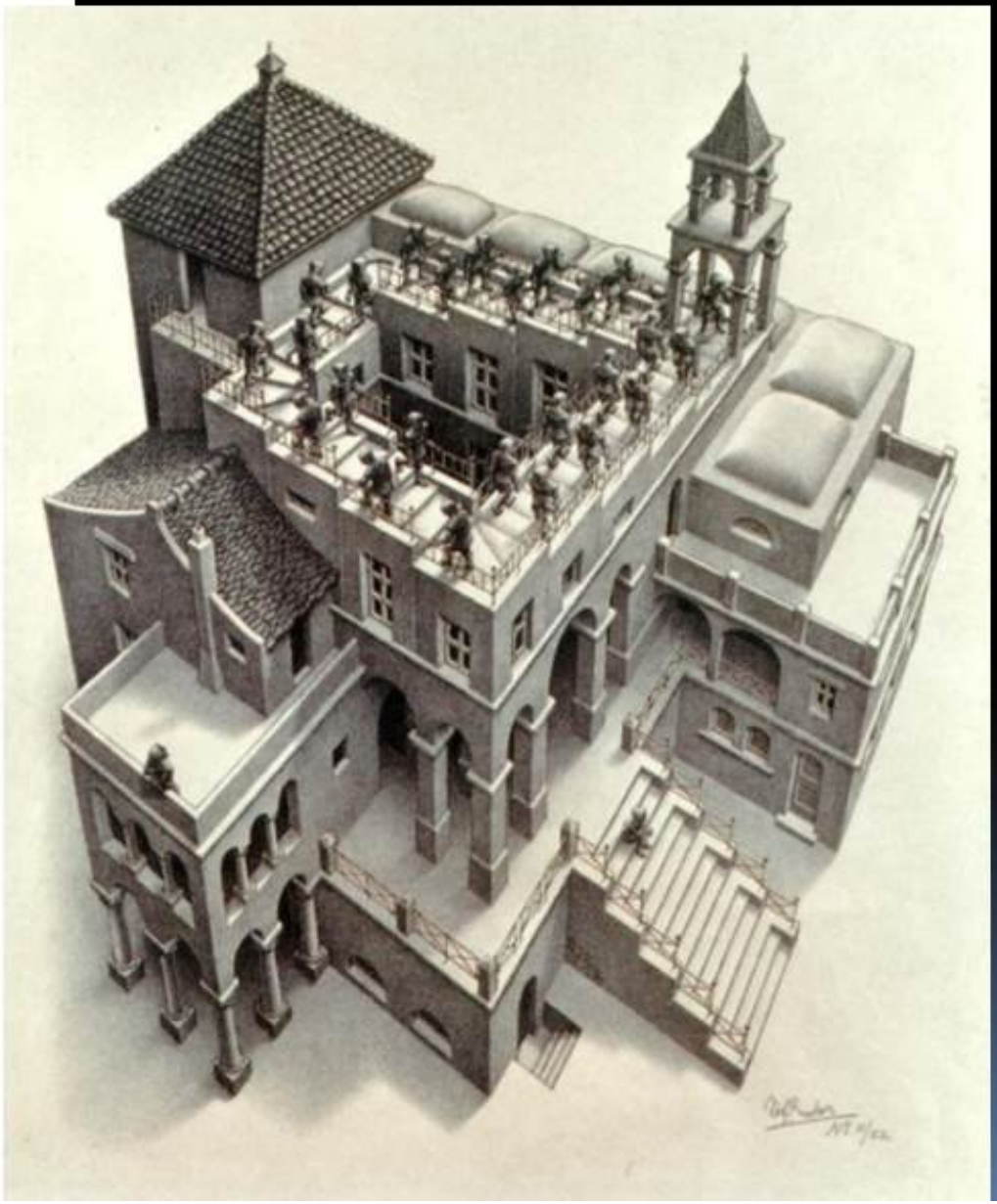
Available here: http://www.lottolab.org/Visual%20Demos/Demo%2015.html

Optical Illusions

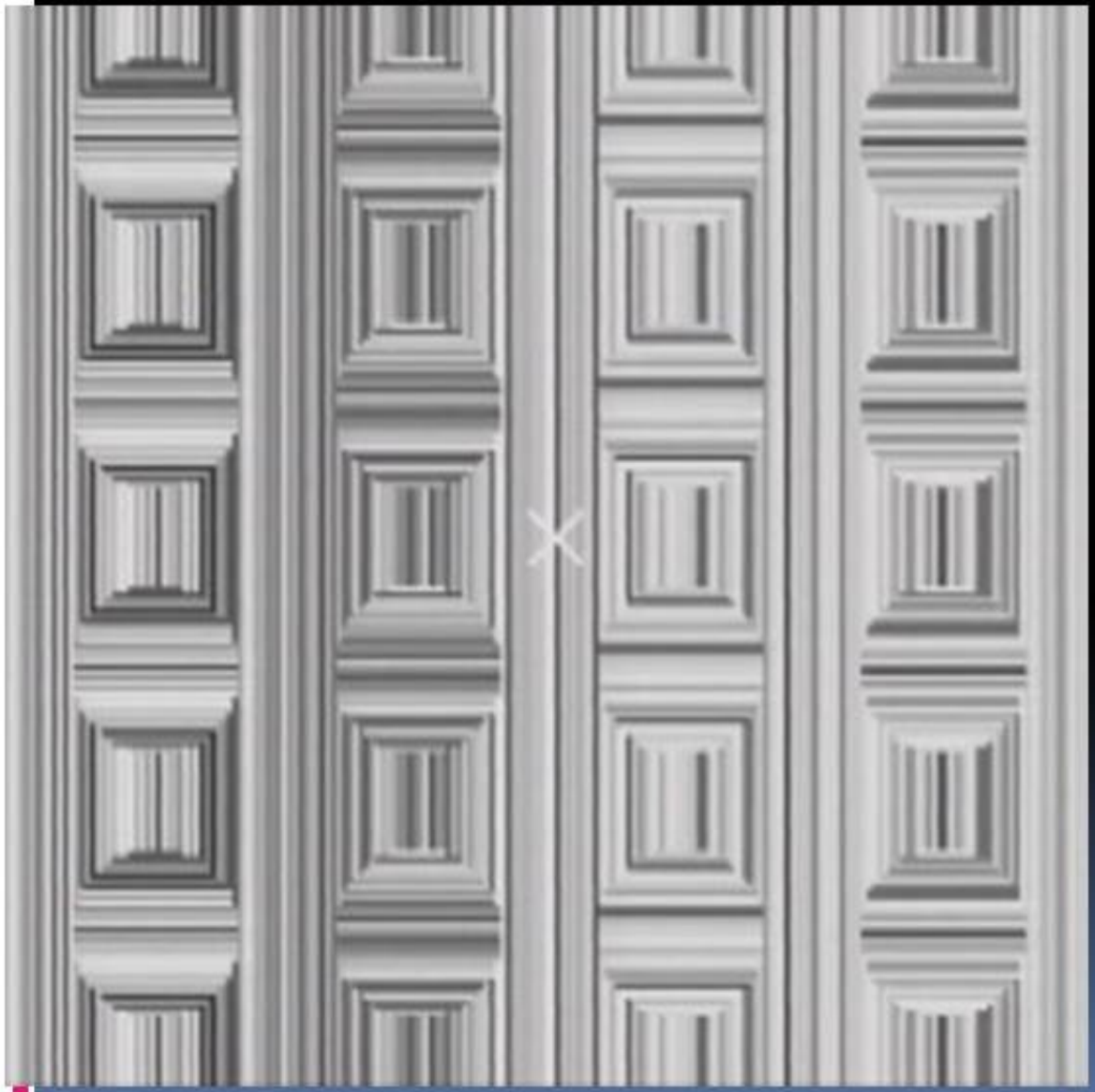
- Our visual systems play lots of interesting tricks on us



Optical Illusions (cont…)



Optical Illusions (cont…)



Stare at the cross in the middle of the image and think circles

Mind Map Exercise: Mind Mapping For Note Taking

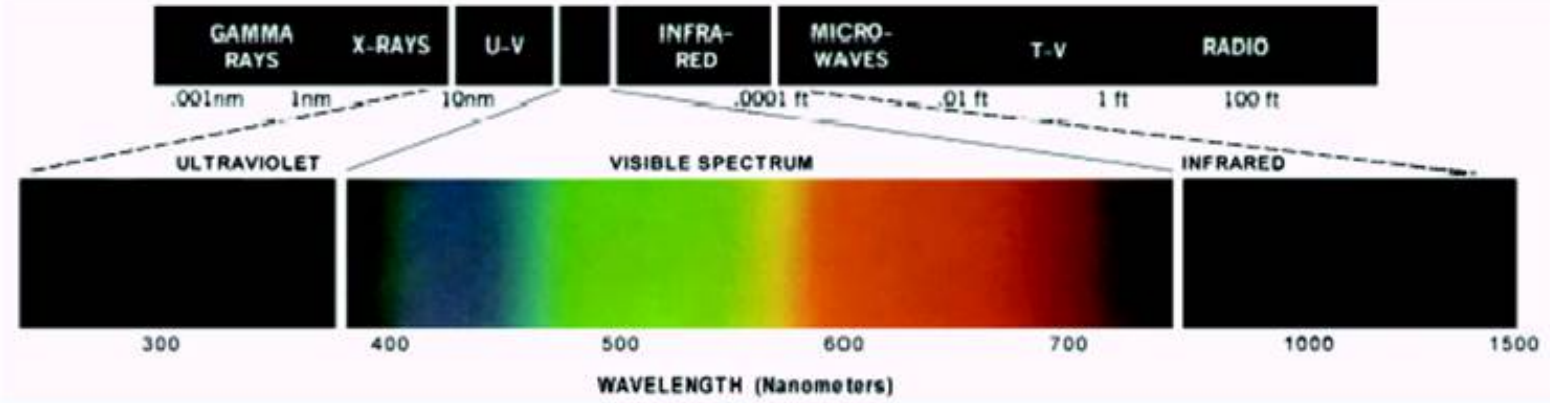
TED Ideas worth spreading

Beau Lotto: Optical Illusions Show How We See

http://www.ted.com/talks/lang/eng/beau_lotto_optical_illusions_show_how_we_see.html

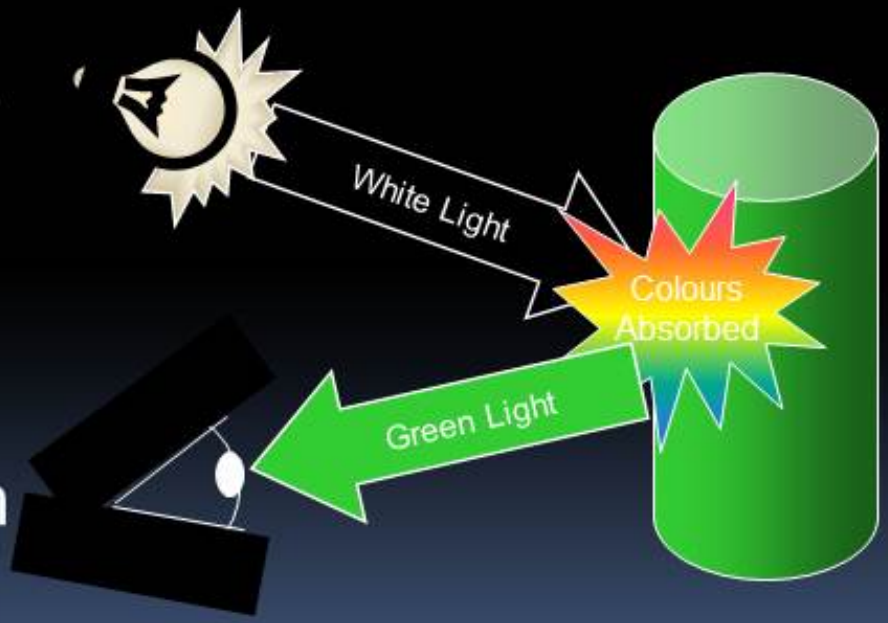
Light And The Electromagnetic Spectrum

- Light is just a particular part of the electromagnetic spectrum that can be sensed by the human eye
- The electromagnetic spectrum is split up according to the wavelengths of different forms of energy



Reflected Light

- The colours that we perceive are determined by the nature of the light reflected from an object
- For example, if white light is shone onto a green object most wavelengths are absorbed, while green light is reflected from the object

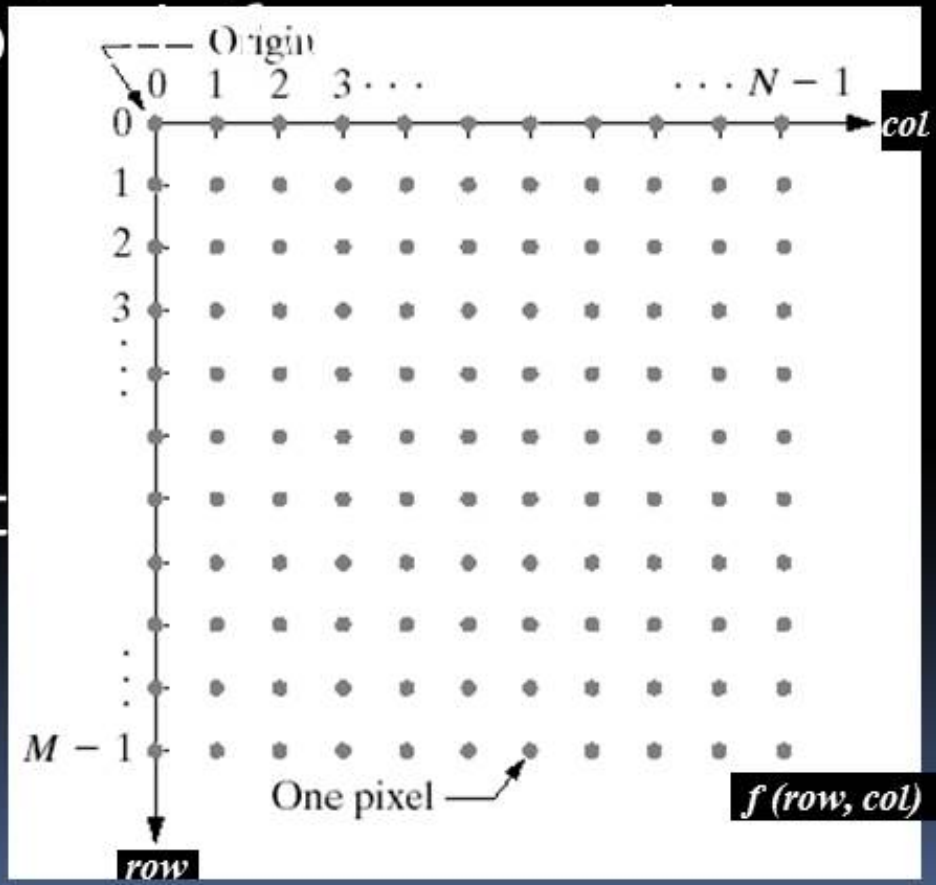


Sampling, Quantisation And Resolution

- In the following slides we will consider what is involved in capturing a digital image of a real-world scene
  - Image sensing and representation
  - Sampling and quantisation
  - Resolution

Image Representation

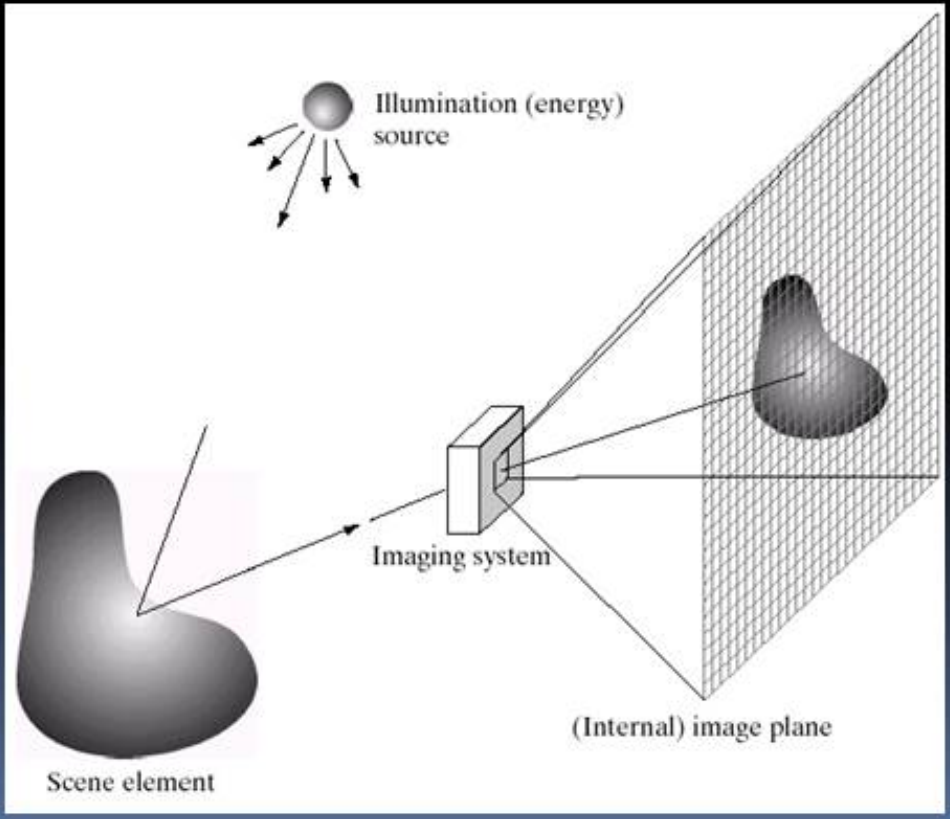
- Before we discuss image acquisition recall that a digital image is comp
columns of pixels
each storing a value
- Pixel values are most often grey levels in the range 0-255(black-whit
- We will see later on that images can easily be represented as matrices



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

Image Acquisition

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

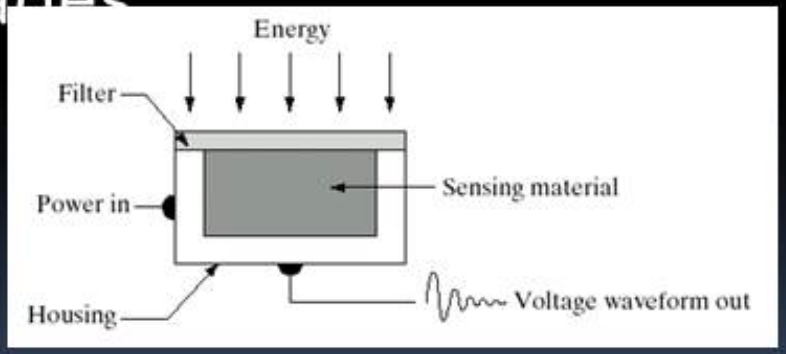


– Typical notions of illumination and scene can be way off:
  - X-rays of a skeleton
  - Ultrasound of an unborn baby
  - Electro-microscopic images of molecules

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

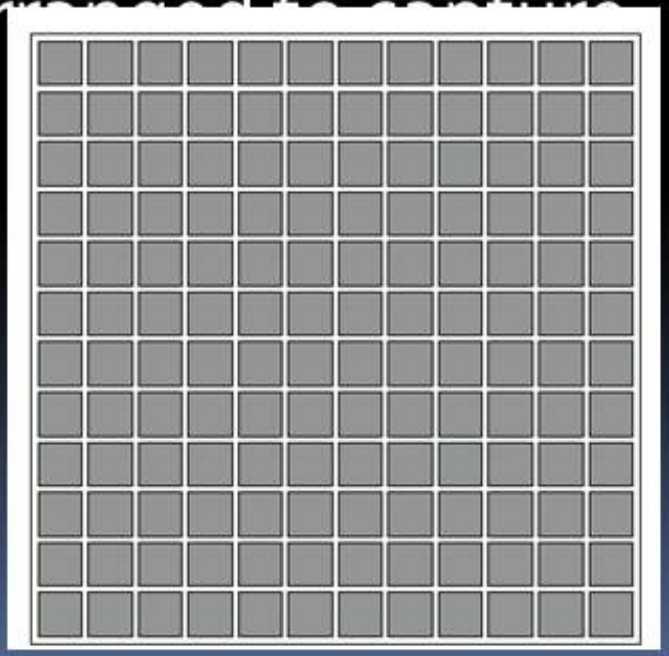
Image Sensing

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



Imaging Sensor

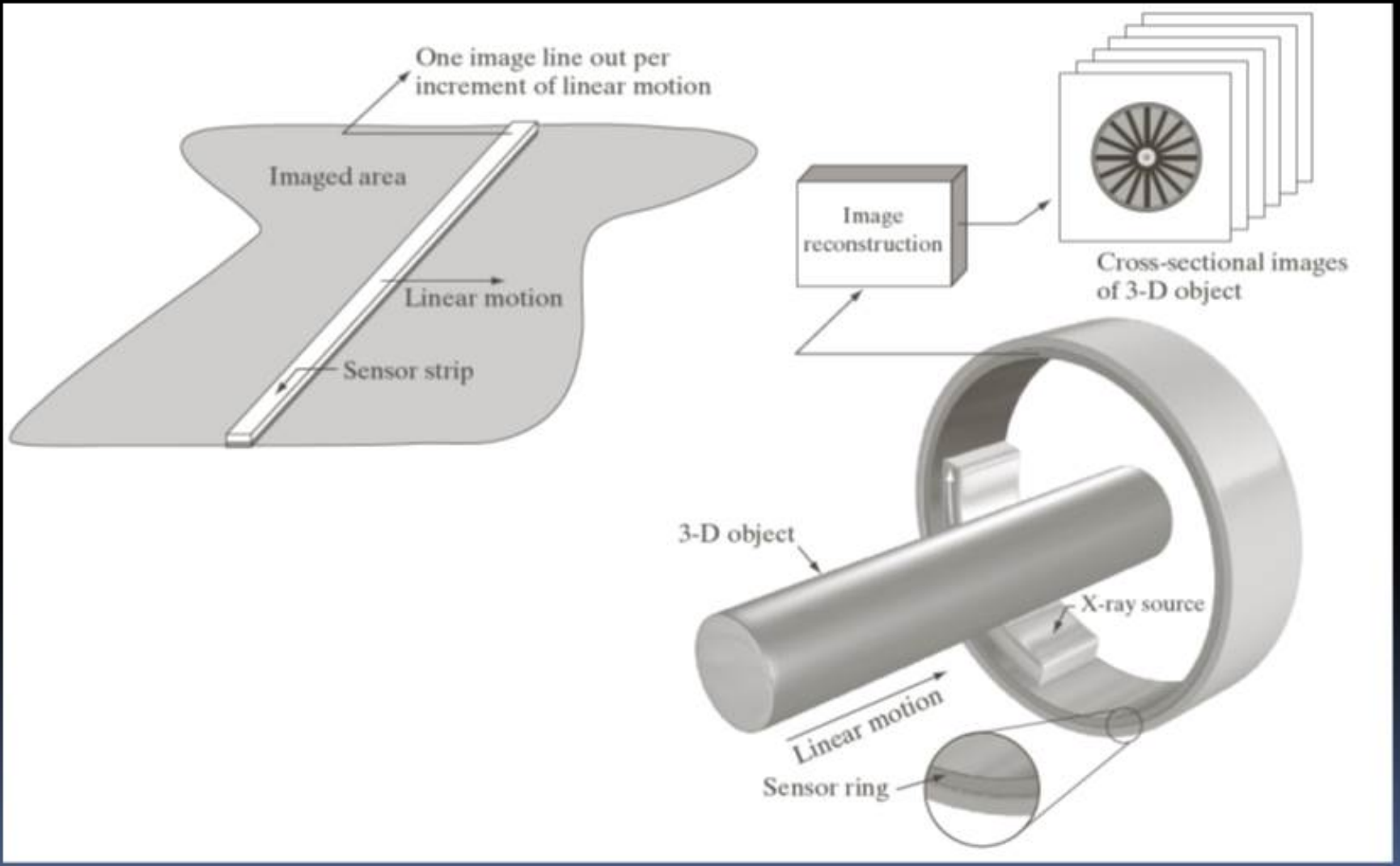
Line of Image Sensors



Array of Image Sensors

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

Image Sensing

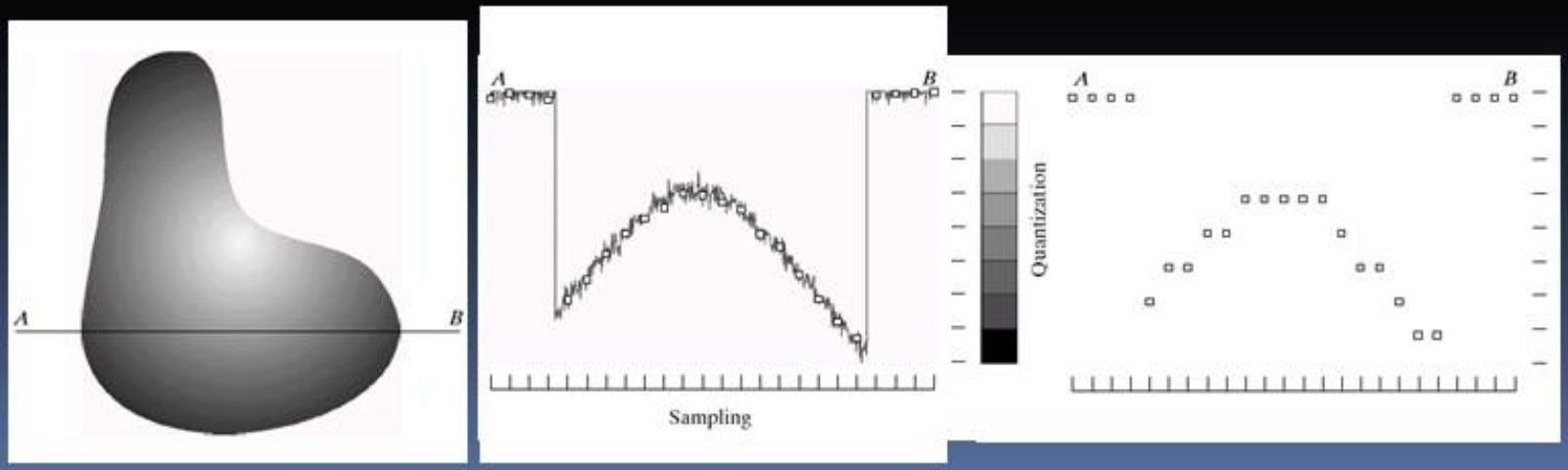


Using Sensor Strips and Rings

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

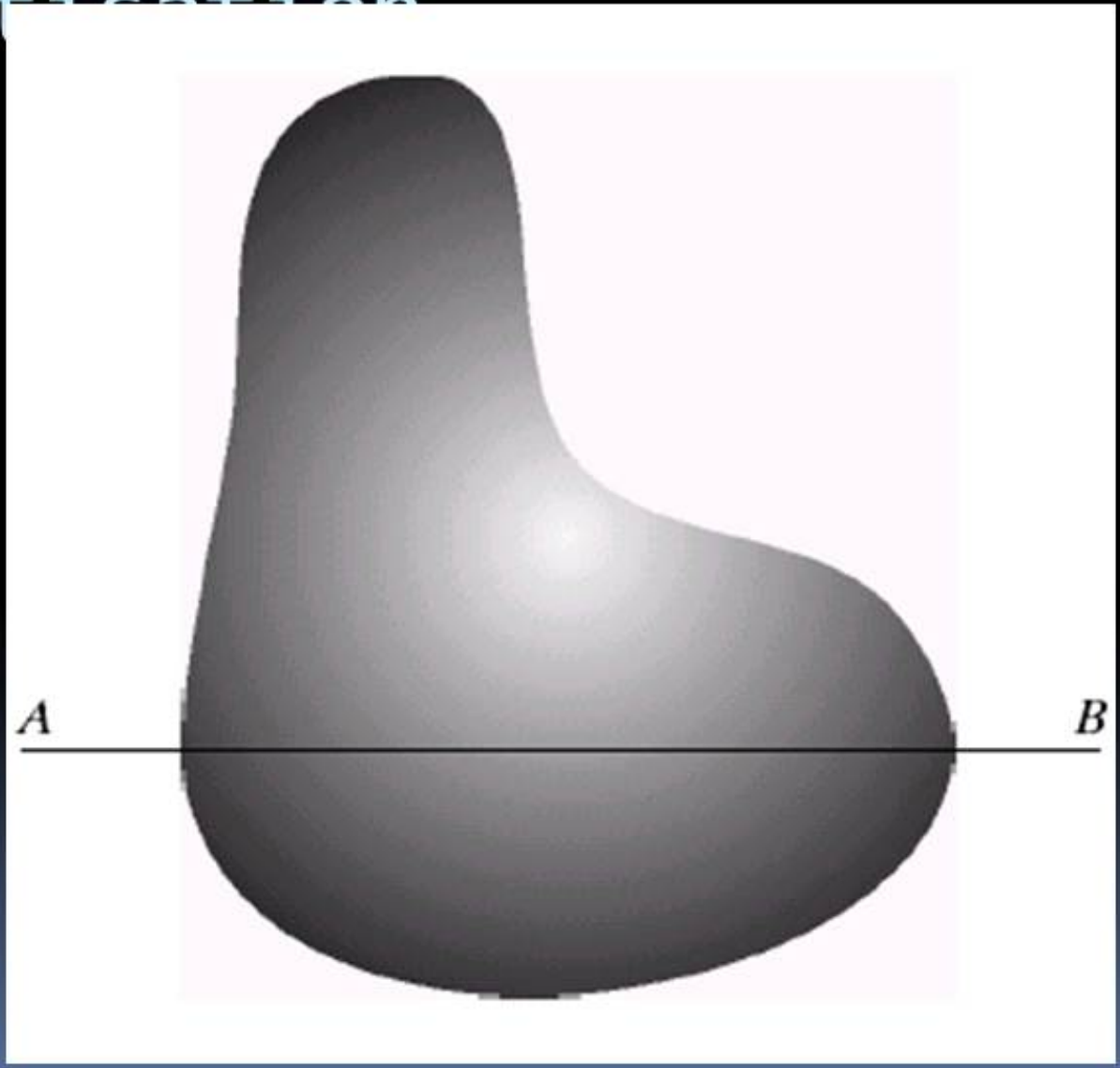
Image Sampling And Quantisation

- 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



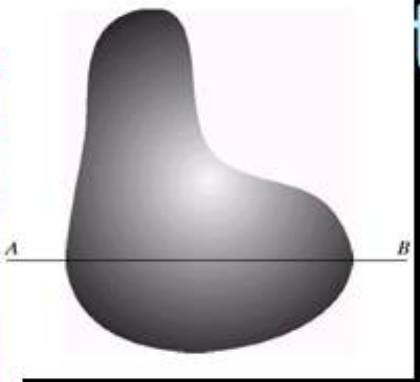
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

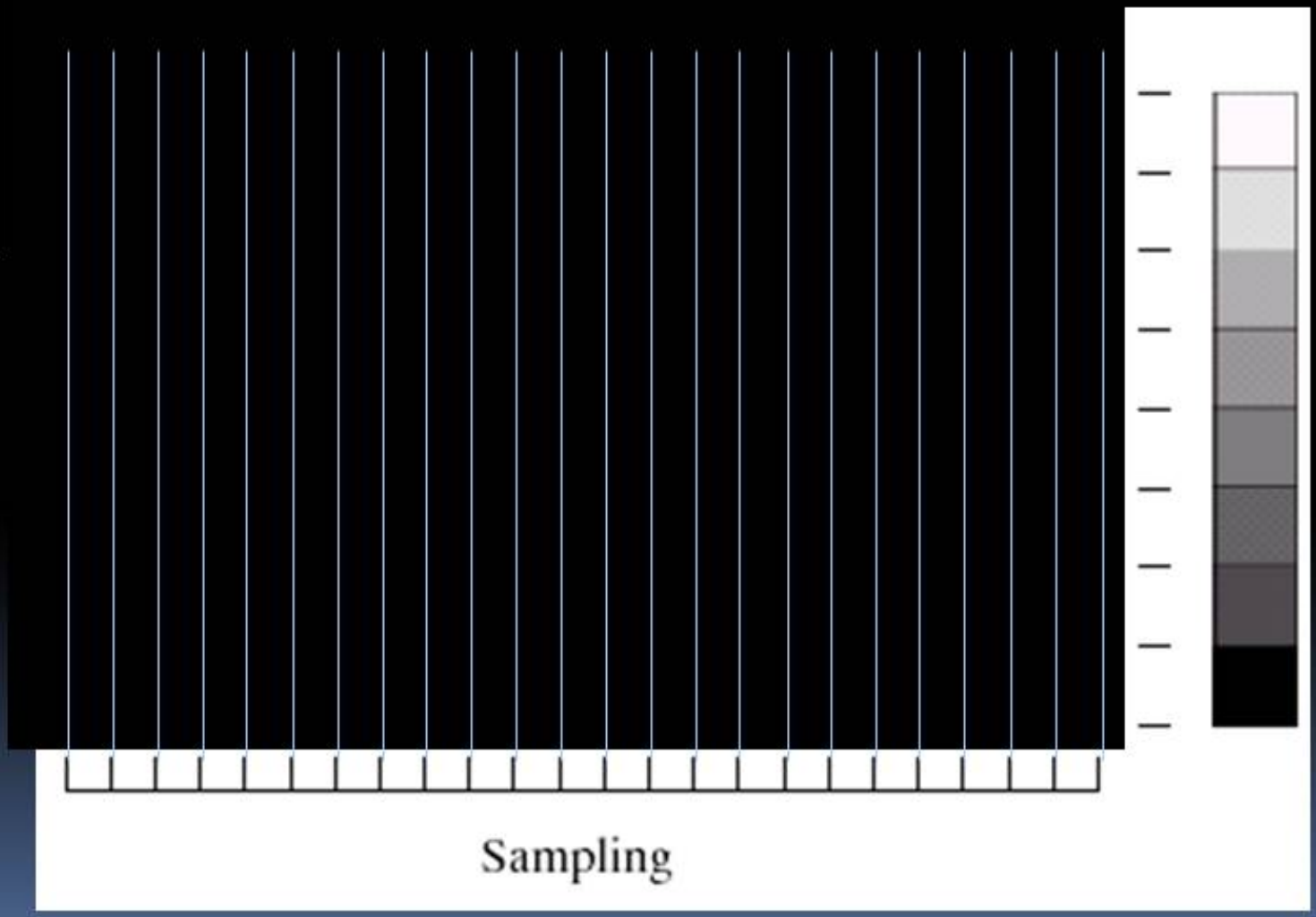
Image Sampling And Quantisation



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

Image Sampling And tisation

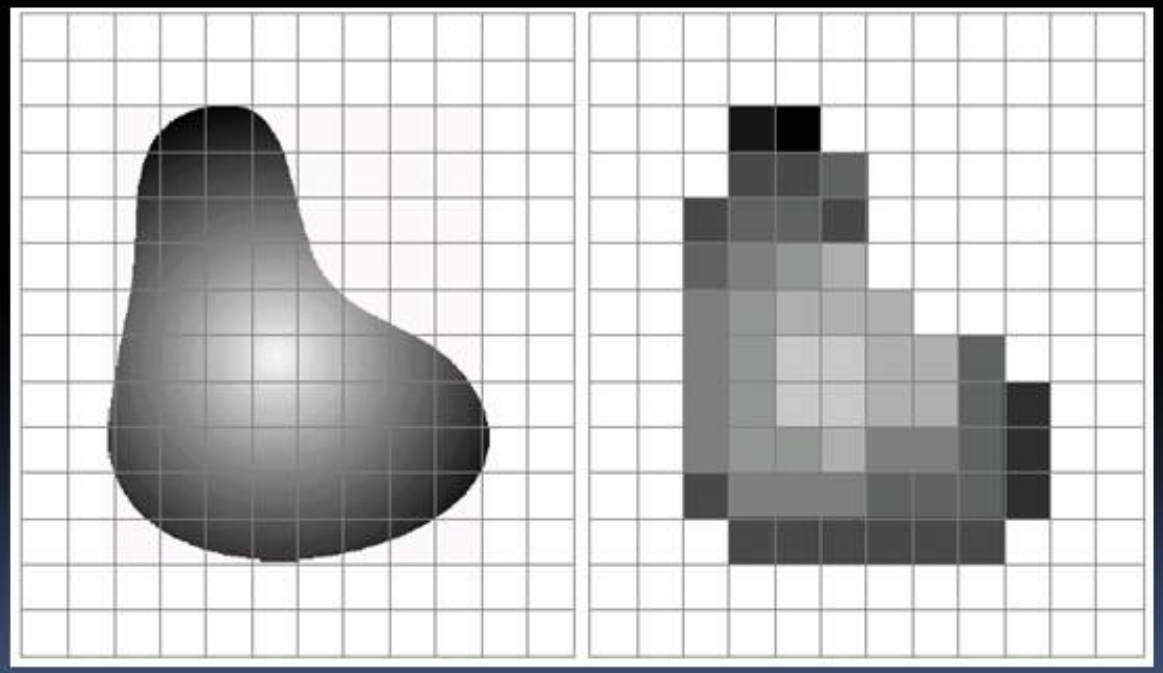




Images taken from Gonzalez & Woods, Digital Image Processing (2002)

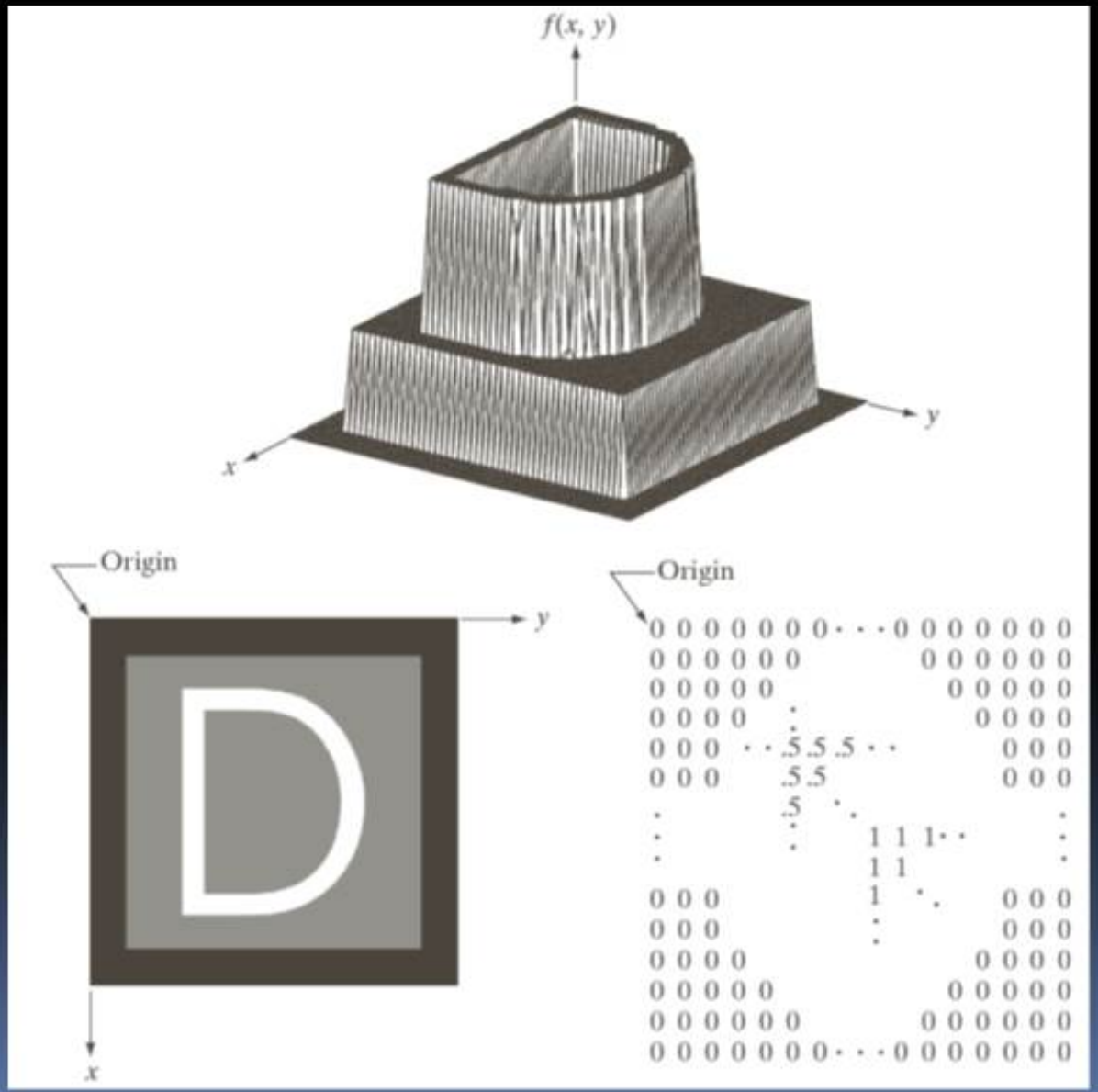
Image Sampling And Quantisation (cont…)

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



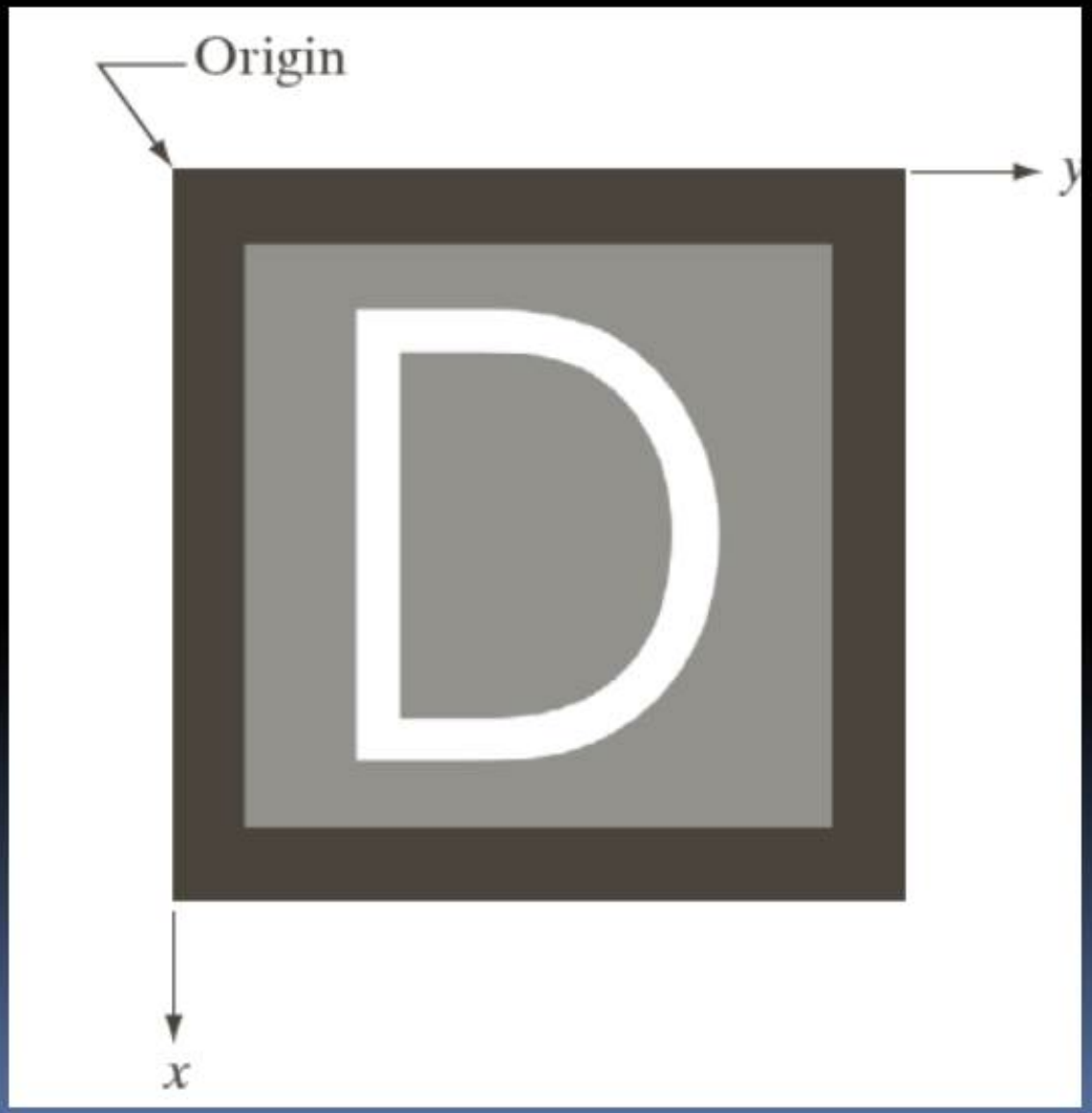
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Representation



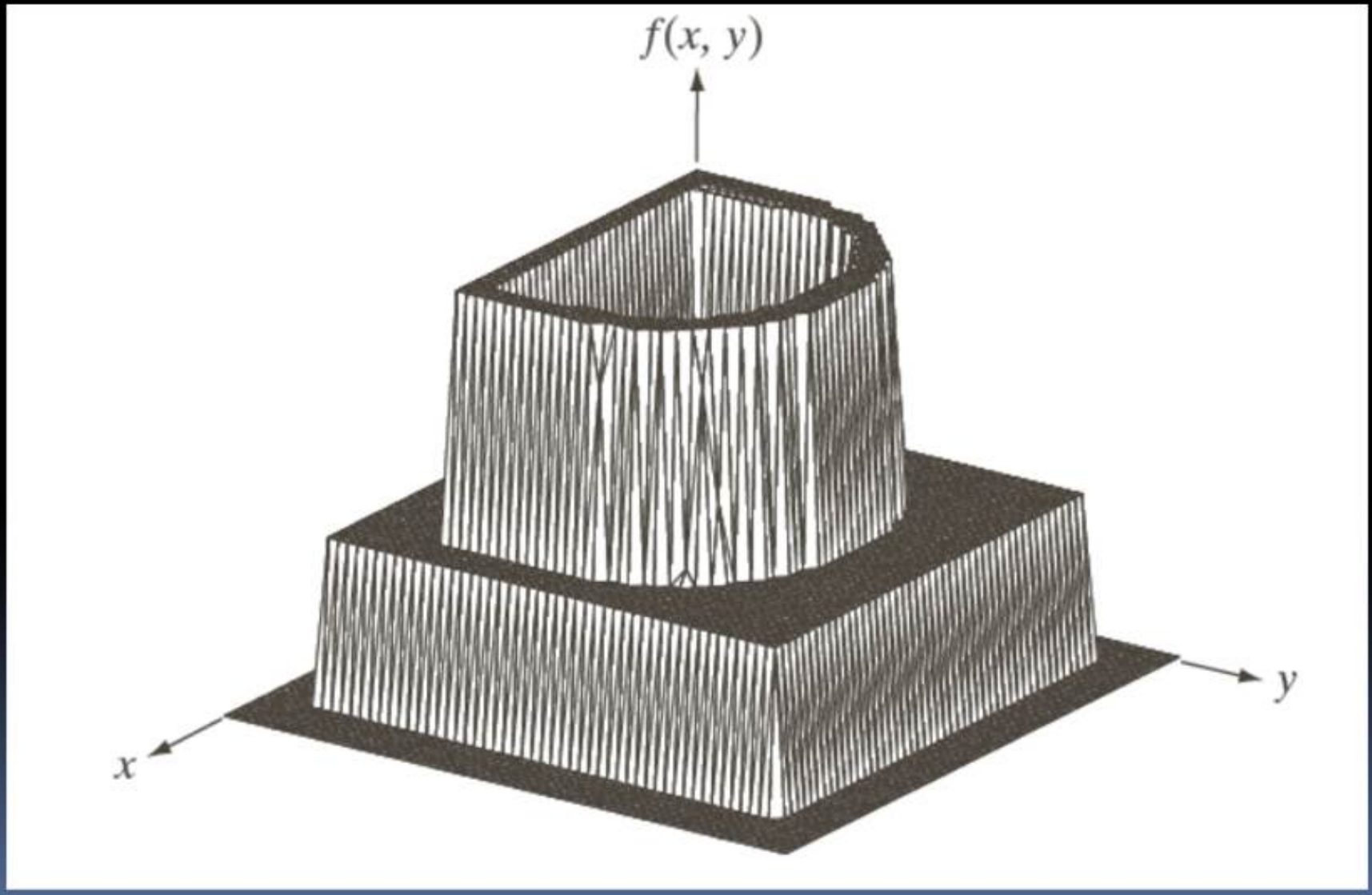
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Representation



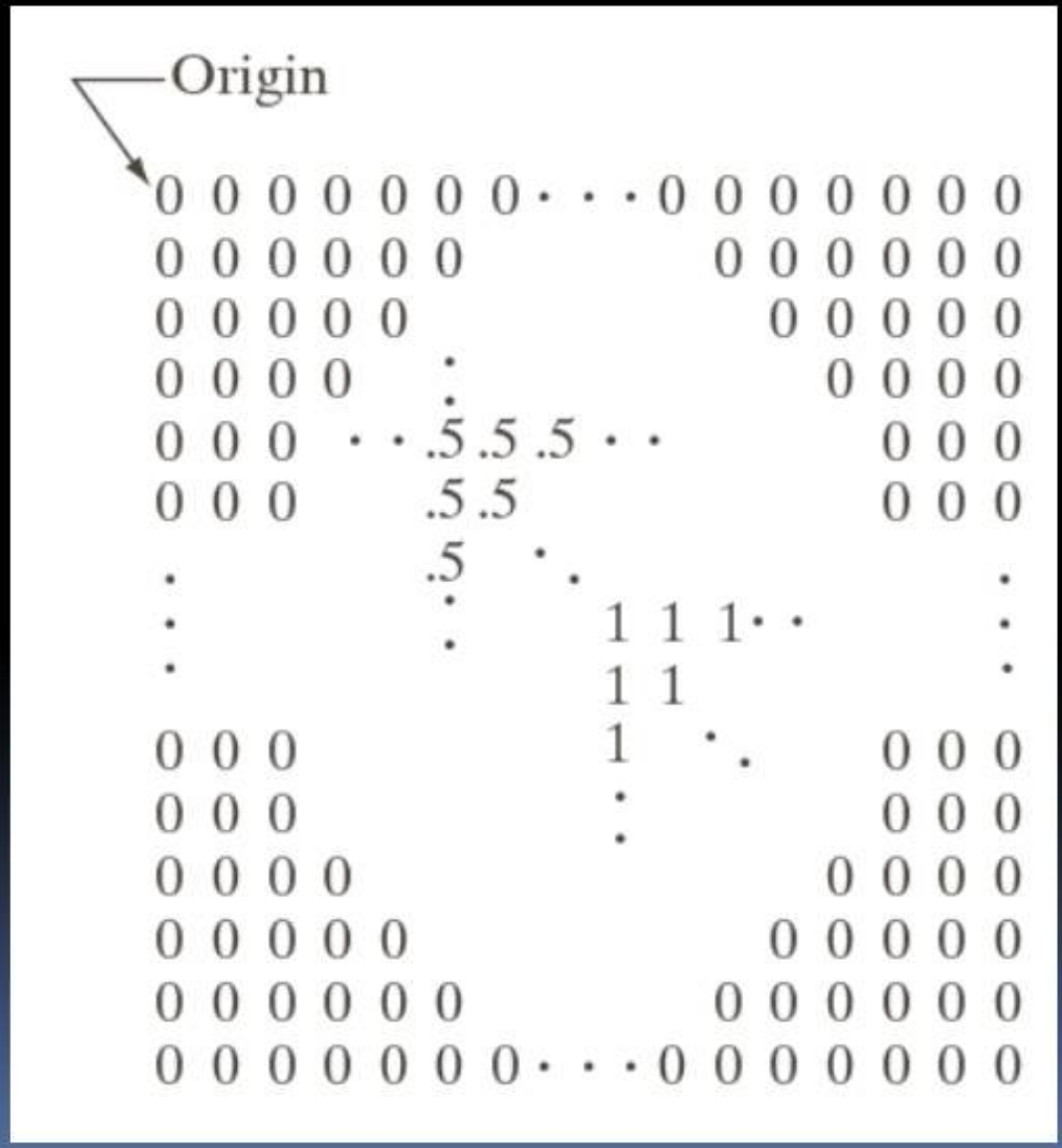
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Image Representation



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

Image Representation



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

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 ima
  - Vision specialists will often talk about pixel size
  - Graphic designers will talk about *dots per inch* (DPI)

Spatial Resolution (cont…)

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

Spatial Resolution (cont…)

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

Spatial Resolution (cont…)

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

Spatial Resolution (cont…)

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

Spatial Resolution (cont…)

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

Spatial Resolution (cont…)

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

Spatial Resolution (cont…)

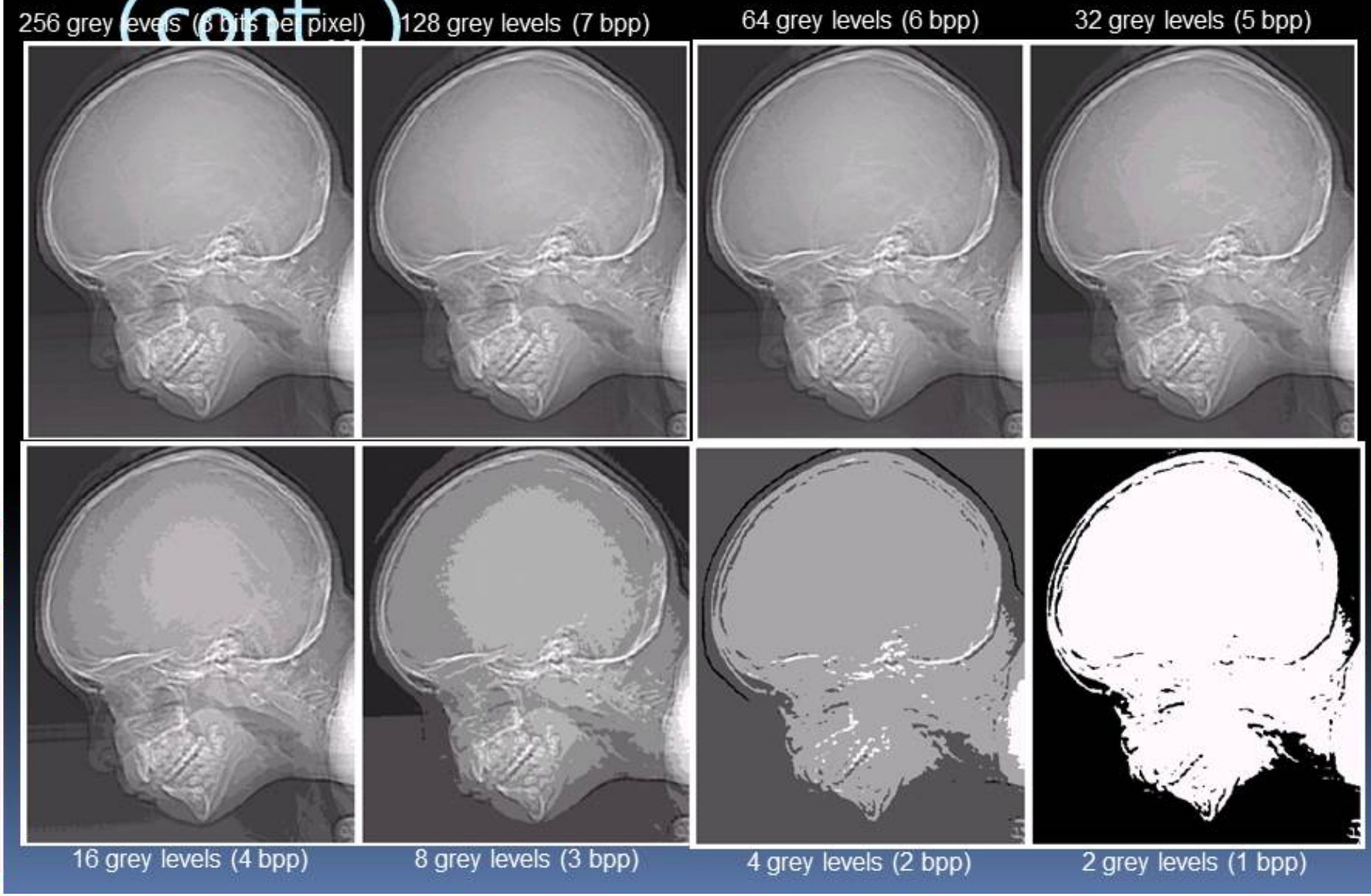
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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, 01010101
16	65,536	1010101010101010

Intensity Level Resolution (cont.)



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

Intensity Level Resolution (cont

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

Intensity Level Resolution (cont.)

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

Intensity Level Resolution (cont.)

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

Intensity Level Resolution (cont.)

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

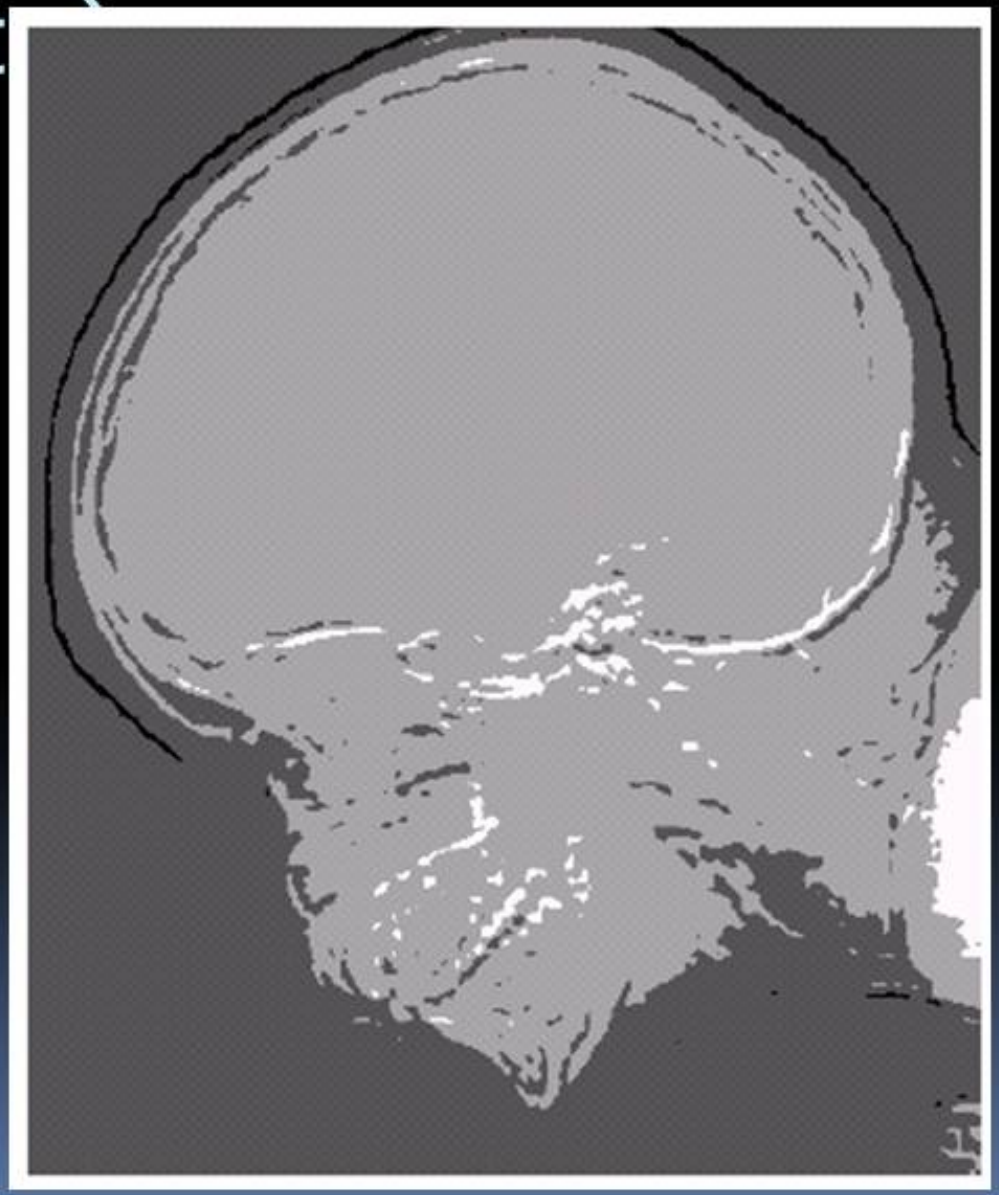
Intensity Level Resolution (cont.)

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

Intensity Level Resolution (cont.)

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

Intensity Level Resolution (cont.)

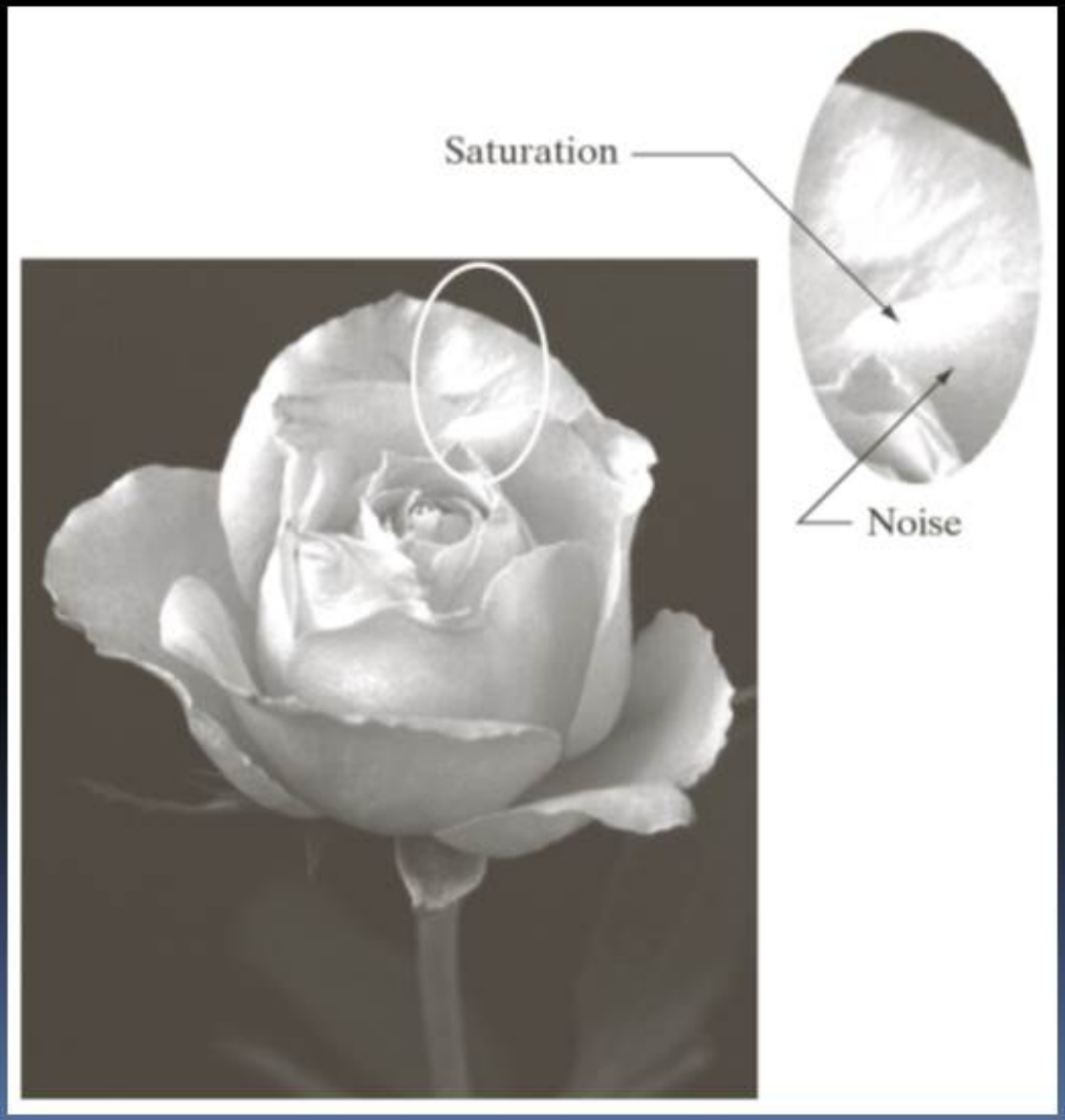


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Intensity Level Resolution (cont…)

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

Saturation & Noise



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

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?

Resolution: How Much Is Enough? (cont…)

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

Intensity Level Resolution (cont…)

Low Detail

Medium Detail

High Detail

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

Intensity Level Resolution (co

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

Intensity Level Resolution (co

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

Intensity Level Resolution (co

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

Summary

- We have looked at:
  - Human visual system
  - Light and the electromagnetic spectrum
  - Image representation
  - Image sensing and acquisition
  - Sampling, quantisation and resolution
- Next time we start to look at techniques for image enhancement