Image Processing and Pattern Recognition (IPPR)

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https://www.researchgate.net/profile/Basanta_Joshi2

About me

- Bachelor of Electronics and Communication Engineering, IOE 2005
- MSc in Information and Communication Engineering, IOE, 2008
- Doctor of Engineering, Osaka Sangyo University, Japan 2013

Industry Experience

- Senior Software Engineer, D2hawkeye
- Research Consultant, LogPoint
- IT Consultant In Various Project

My Interests and Research Area

- 3D Reconstruction/ Motion Tracking
- Nepali Language Processing
- Video Analytics
- Network Analytics
- Medical Data Analytics
- Edge Analytics
- Use of Enterprise Computing in above mentioned Areas

Course Objectives

- To be familiar with processing of images, recognition of the pattern and their applications.

Syllabus

1. Introduction to Digital Image Processing (4 hrs)
Digital image representation, Digital image processing: Problems and application, Elements of visual perception, Sampling and quantization, Relationships between pixels.
2. Two-dimensional Systems (5 hrs)
Fourier transform and Fast fourier Transform, Other image transforms and their properties: Cosine transform, Hadamard transform, Haar transform.
3. Image Enhancement and Restoration (8 hrs)
Point operations, Contrast stretching, Clipping and thresholding, Digital negative, Intensity level slicing, Bit extraction, Histogram modeling, Equalization modification, Specification, Spatial operations, Averaging, Directional smoothing, Median, Filtering spatial low pass, High pass and band pass filtering, Magnification by replication and interpolation.
4. Image Coding and Compression (4 hrs)
Pixed coding: run length, bit plan, Predictive and inter-frame coding.
5. Introduction to Pattern Recognition and Image (3 hrs)

Syllabus

6. Recognition and Classification (5 hrs)
Recognition classification, Feature extraction, Models, Division of sample space.
7. Grey Level Features Edges and Lines (6 hrs)
Similarity and correlation, Template matching, Edge detection using templates, Edge detection using gradient models, Model fitting, Line detection, Problems with feature detectors.
8. Segmentation (3 hrs)
Segmentation by thresholding, Regions for edges, line and curve detection.
9. Frequency Approach and Transform Domain (3 hrs)
10. Advanced Topics (4 hrs)
Neural network and their application to pattern recognition, Hopfield nets, Hamming nets, Perceptron.

Teaching Methodology

- Lecture includes slides, video and discussions
- Students should submit assignments including programming assignments/Quizzes in google classrom
- Students should do presentation upload in google classrom
- Google classroom
  - **Class code: uir4rki**
  - https://classroom.google.com/c/NDI5MDMyNzc4Mzg4?cjc=uir4rki

Marking Scheme

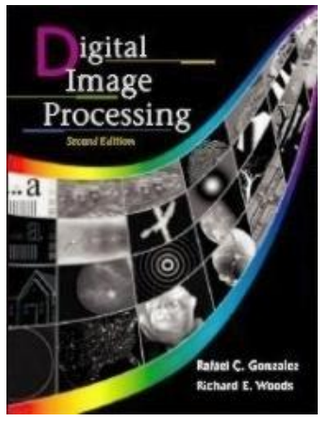
S.N.	Course Code	Course Title	Credit	Internal	Final	Total
		Image Processing and Pattern Recognition				

- Marks distribution: Theory
  - Attendance + Student Performance (Assignments + Quiz+ Presentation) => 40%
  - Assessment => 60%
- Marks distribution: Practical
  - Attendance + Student Performance (Assignments +Quiz) => 40%
  - Quiz + Projects+ Presentation => 60%

References

- **1. R. C. Gonzalez and P. Wintz, "Digital Image Processing", Second Edition, Addison-Wesley Publishing, 1987.**
  2. K. Castlemann. "Digital Image Processing", Prentice Hall of India Ltd., 1996.
  3. A. K. Jain, "Fundamentals of Digital Image Processing", Prentice Hall of India Pvt. Ltd., 1995.
  4. Sing Tze Bow, M. Dekker, "Pattern Recognition and Image Processing", 1992
  5. M. James, "Pattern Recognition", BSP professional books, 1987.
  6. P. Monique and M. Dekker, "Fundamentals of Pattern Recognition", 1989.
- **7. Himanshu Singh, Practical Machine Learning and Image Processing For Facial Recognition, Object Detection, and Pattern Recognition Using Python, 2019**

References



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

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

–Image Processing and Pattern Recognition Slides of Dr. Sanjeeb Prasad Panday

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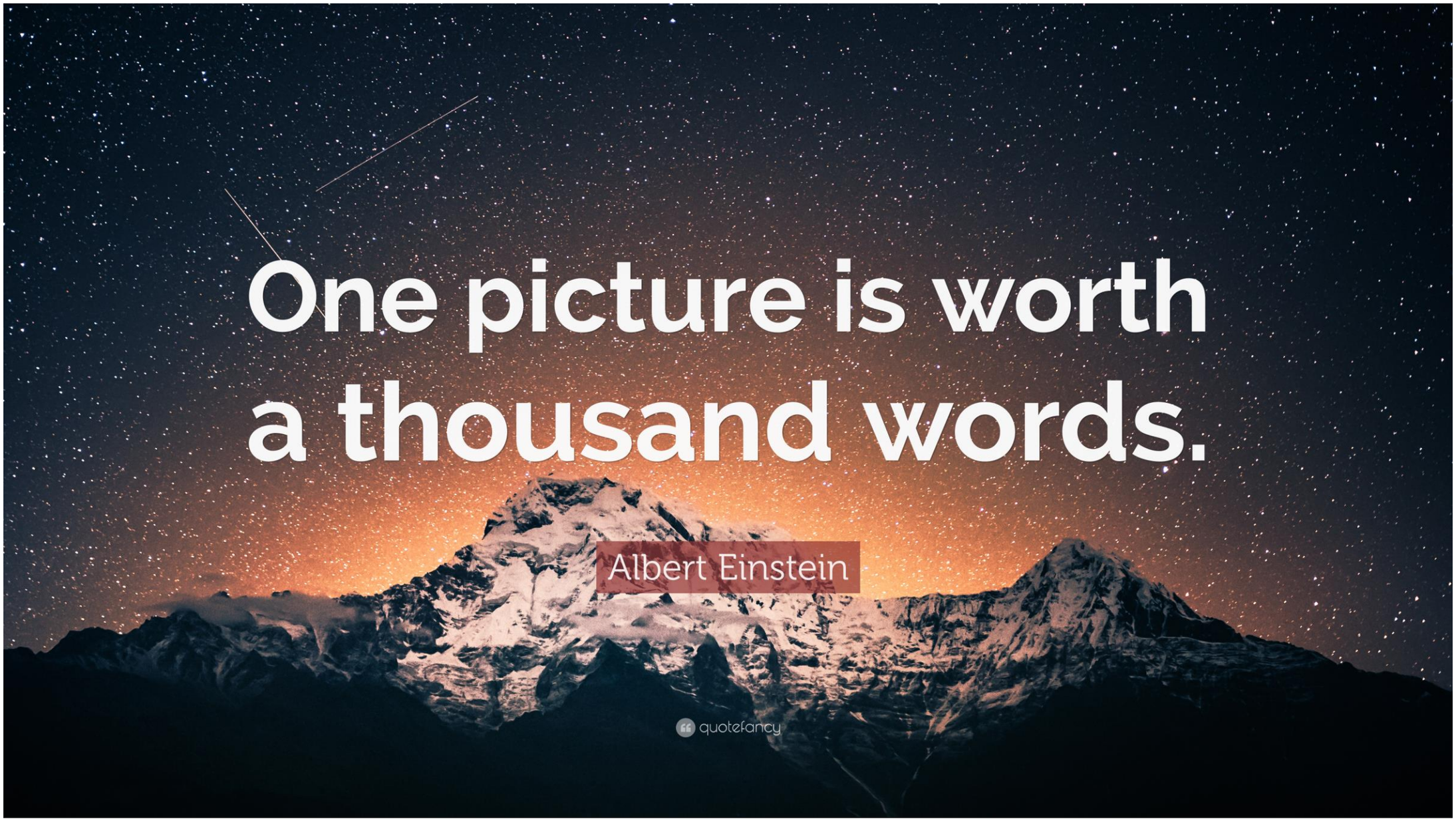
Introduction



Contents

This lecture will cover:

--Computer Graphics Vs Image Processing

–What is a digital image?

–What is digital image processing?

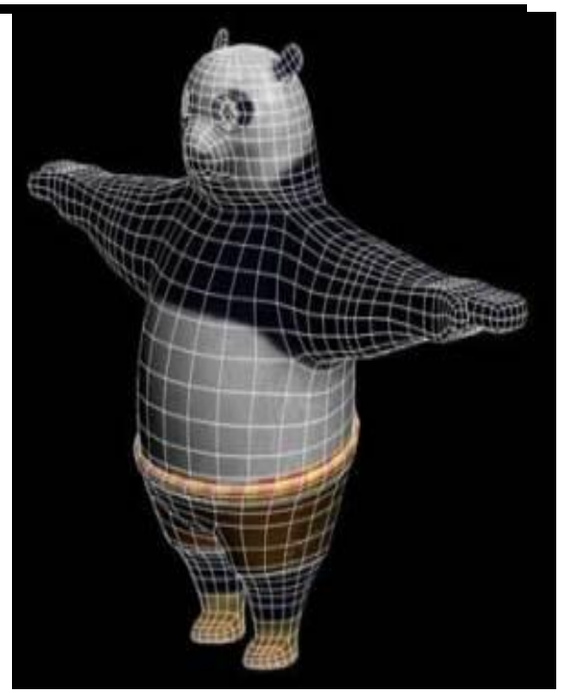
–History of digital image processing

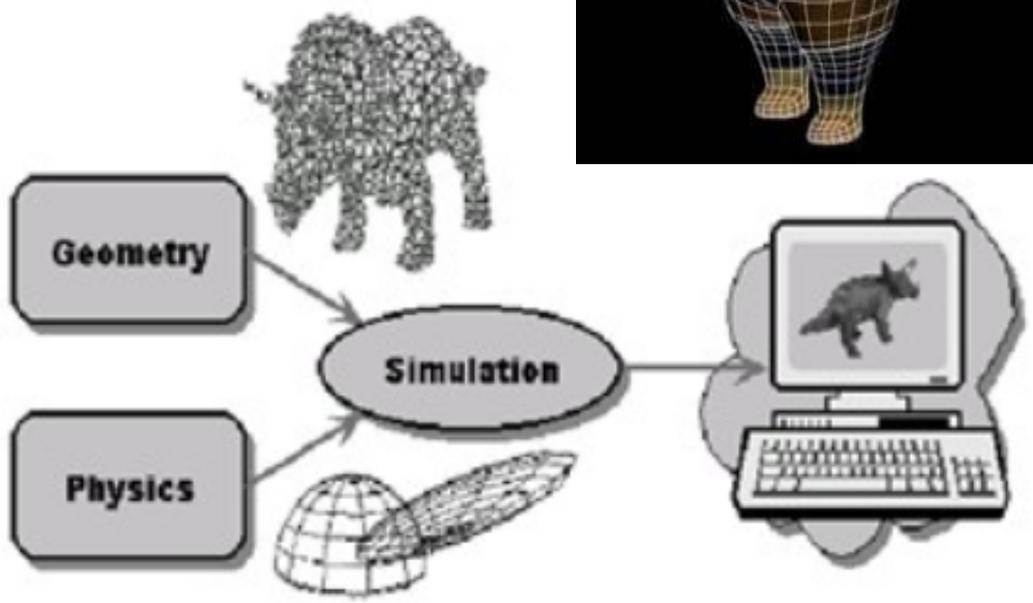
–State of the art examples of digital image processing

–Key stages in digital image processing

Computer Graphics Vs Image Processing

- **Computer Graphics(C.G)**
  - a computer is used to create a picture.
  - model based approach
  - concerns pictorial synthesis of real or imagery objects from computer based model
  - deals with vector data
    - ex) Jurrassic park, Game



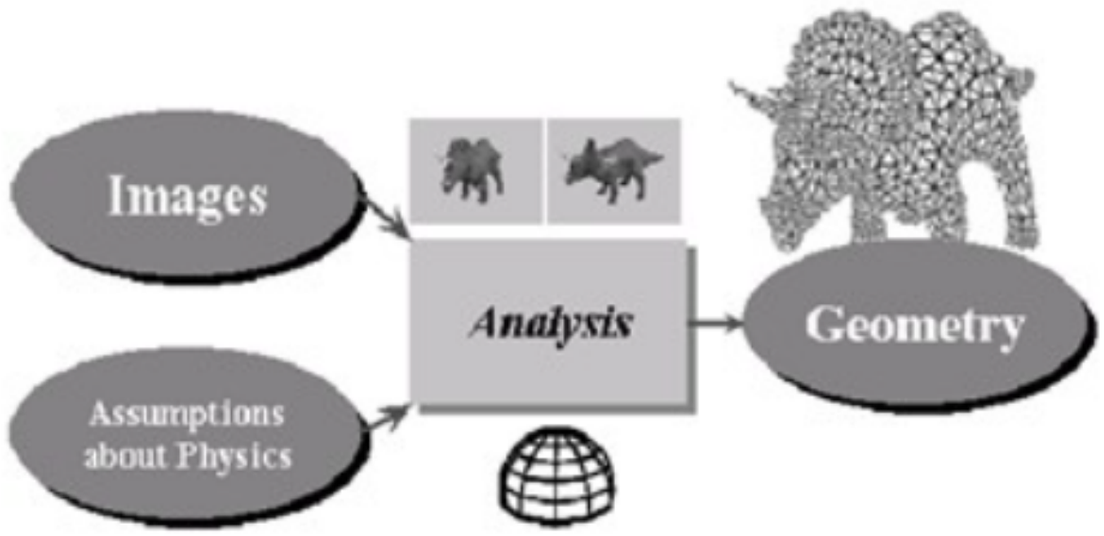


Computer Graphics Vs Image Processing

- **Image Processing (I.P)**
  - a computer is used to modify or interpret existing pictures.
  - processing of sensor based data
  - concerns scene analysis.
    - improving picture quality
    - machine perception of visual info
  - deals with pixel data

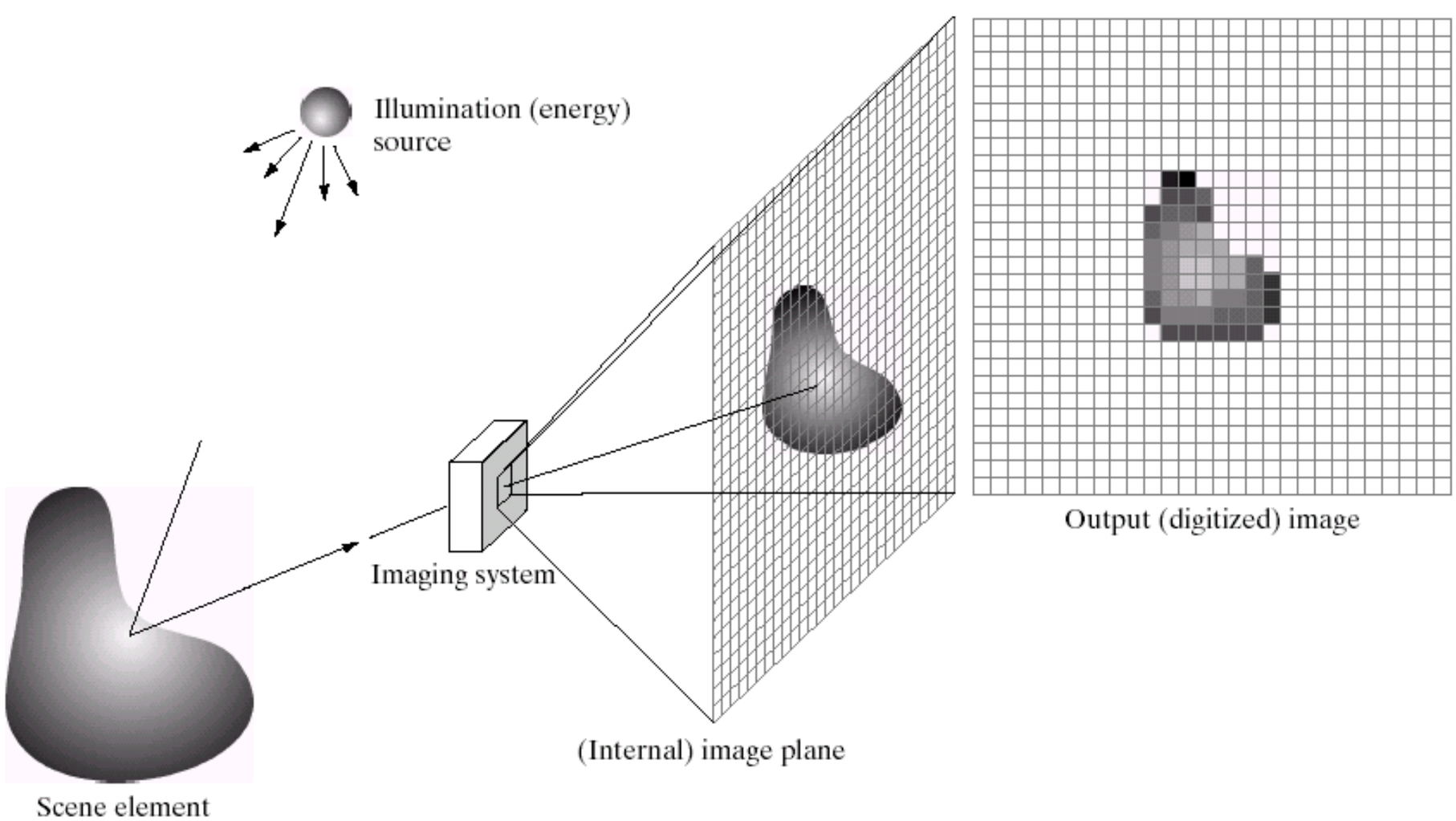
ex) Recognition of car license plate
Interpretation of satellite image

The Making of Kung Fu Panda



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

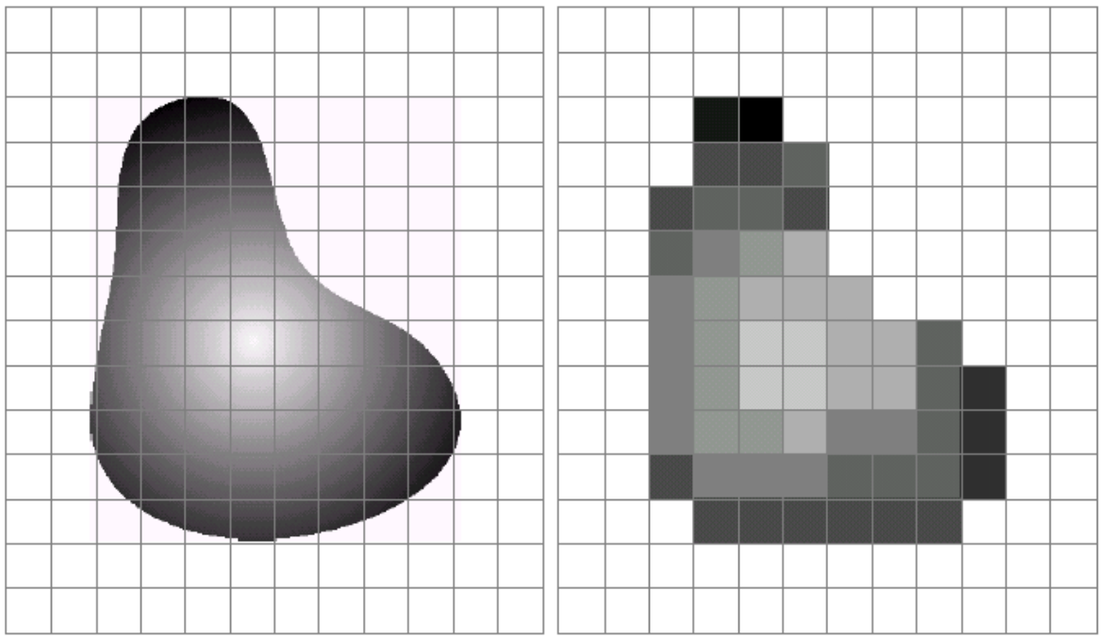


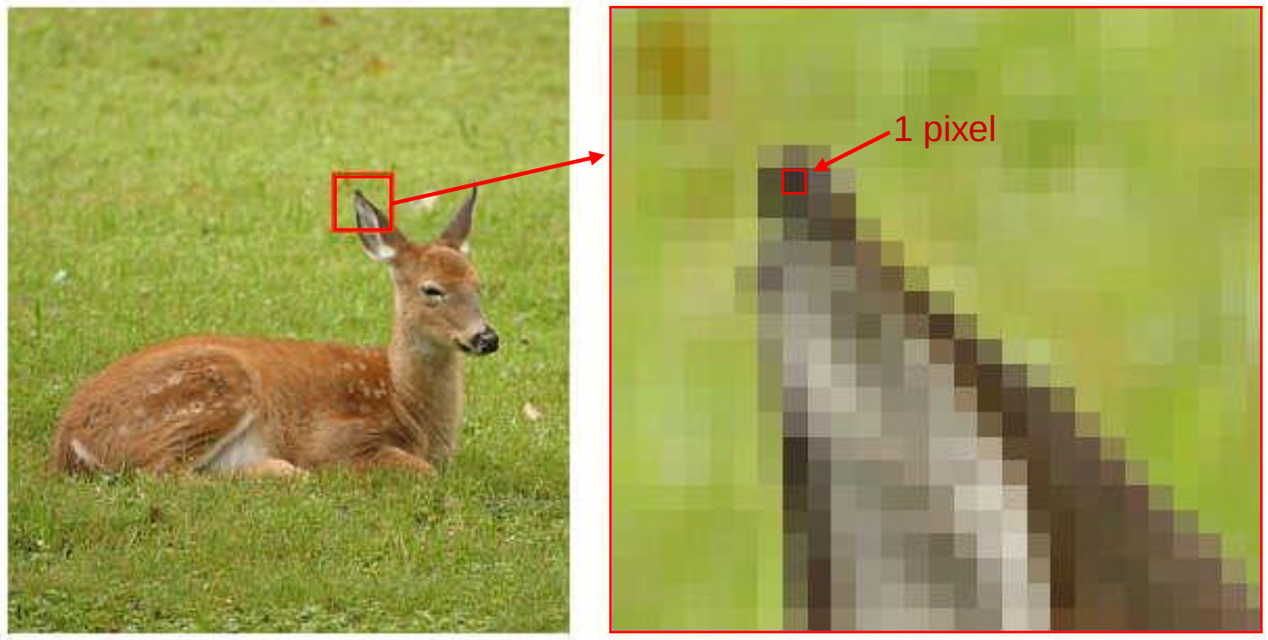
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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?

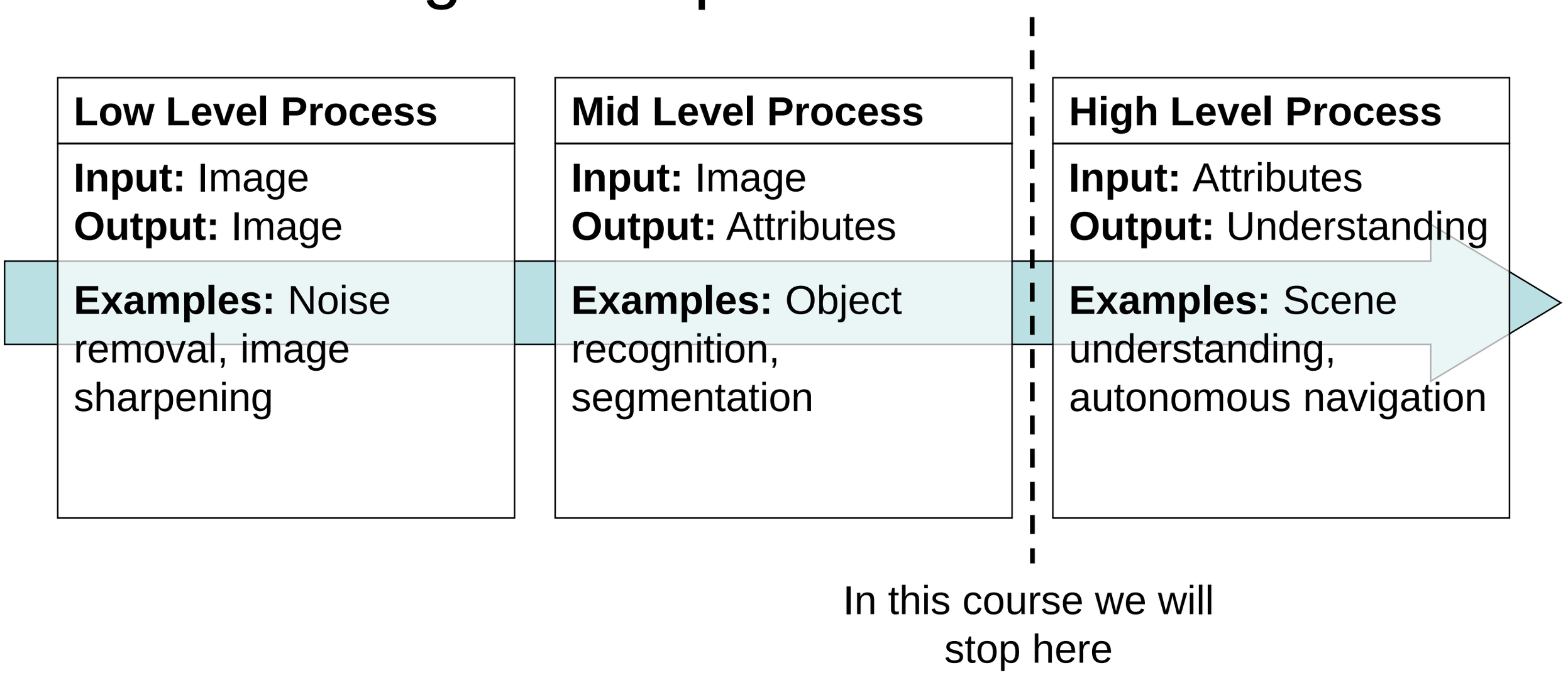
Digital image processing focuses on two major tasks

- 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

Early digital image

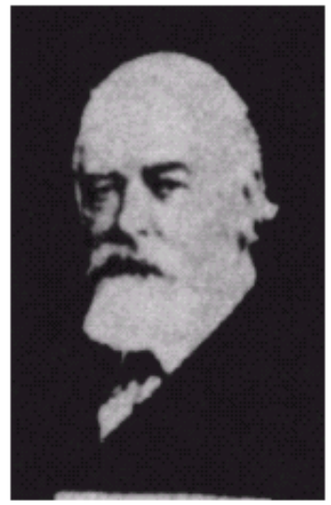
- The Bartlane cable picture transmission service
- Images were transferred by submarine cable between London and New York
- Pictures were coded for cable transfer and reconstructed at the receiving end on a telegraph printer

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

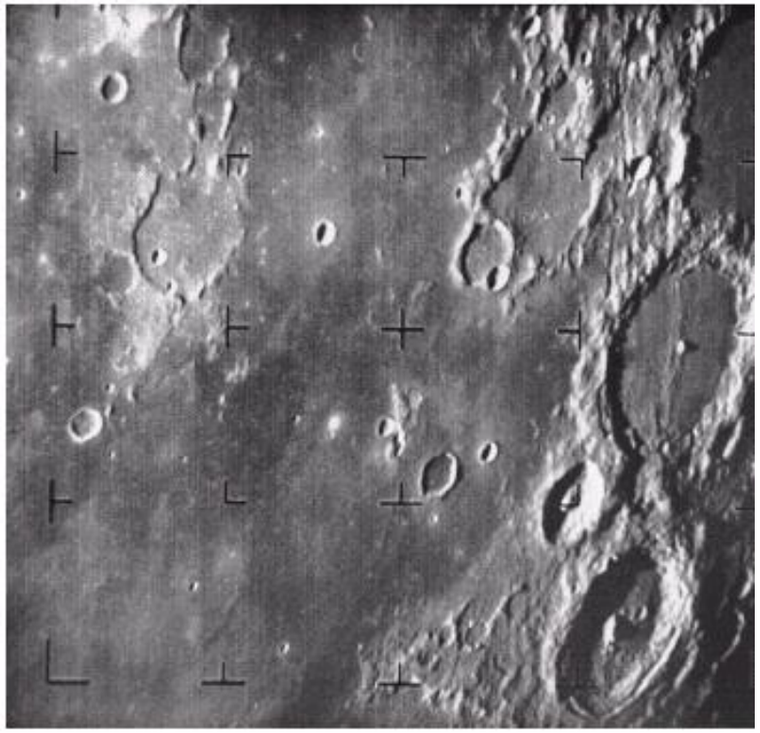
Early 15 tone digital image

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 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



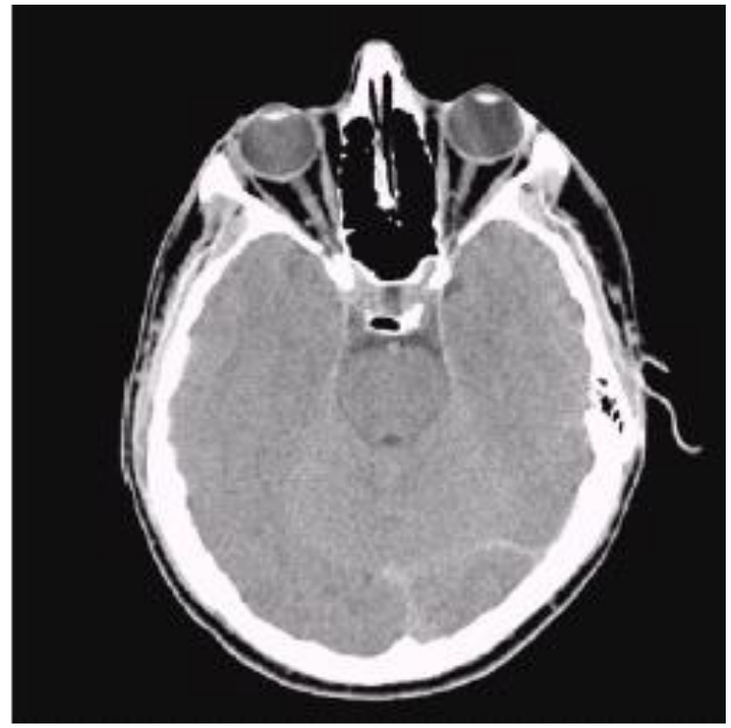
A picture of the moon taken by the Ranger 7 probe minutes before landing

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)

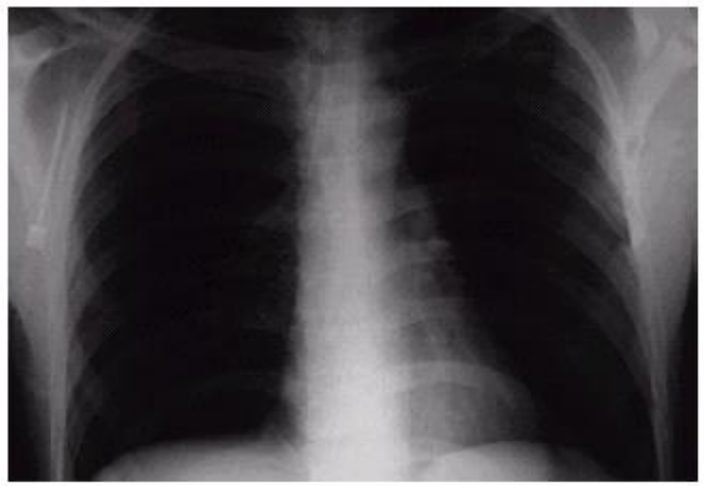
History of DIP (cont…)

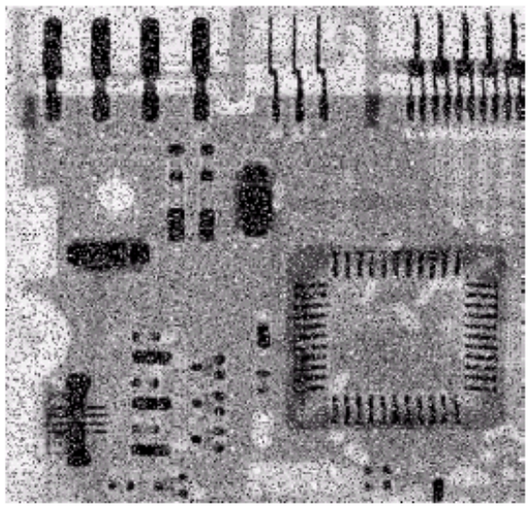
1980s - Today: The use of digital image processing techniques has exploded and they are now used for all kinds of tasks in all kinds of areas

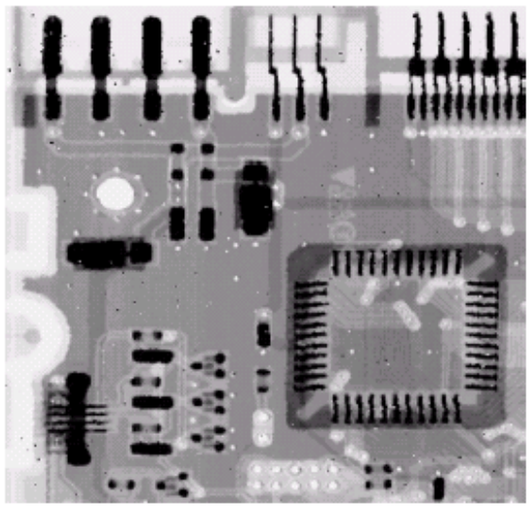
- Image enhancement/restoration
- Artistic effects
- Medical visualisation
- Industrial inspection
- Law enforcement
- Human computer interfaces

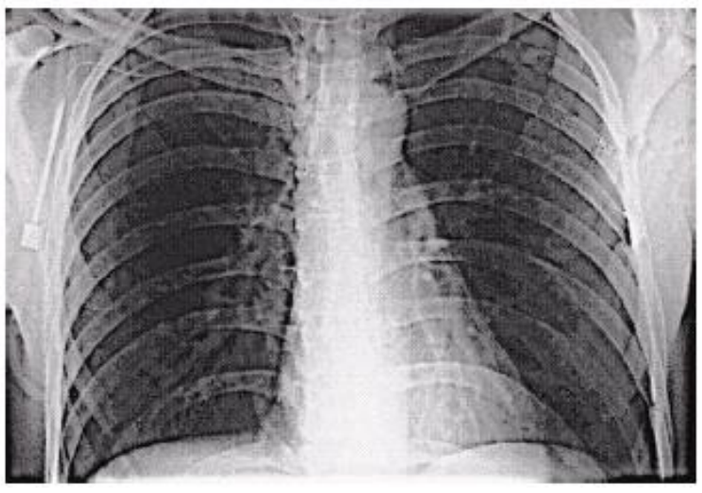
Examples: Image Enhancement

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







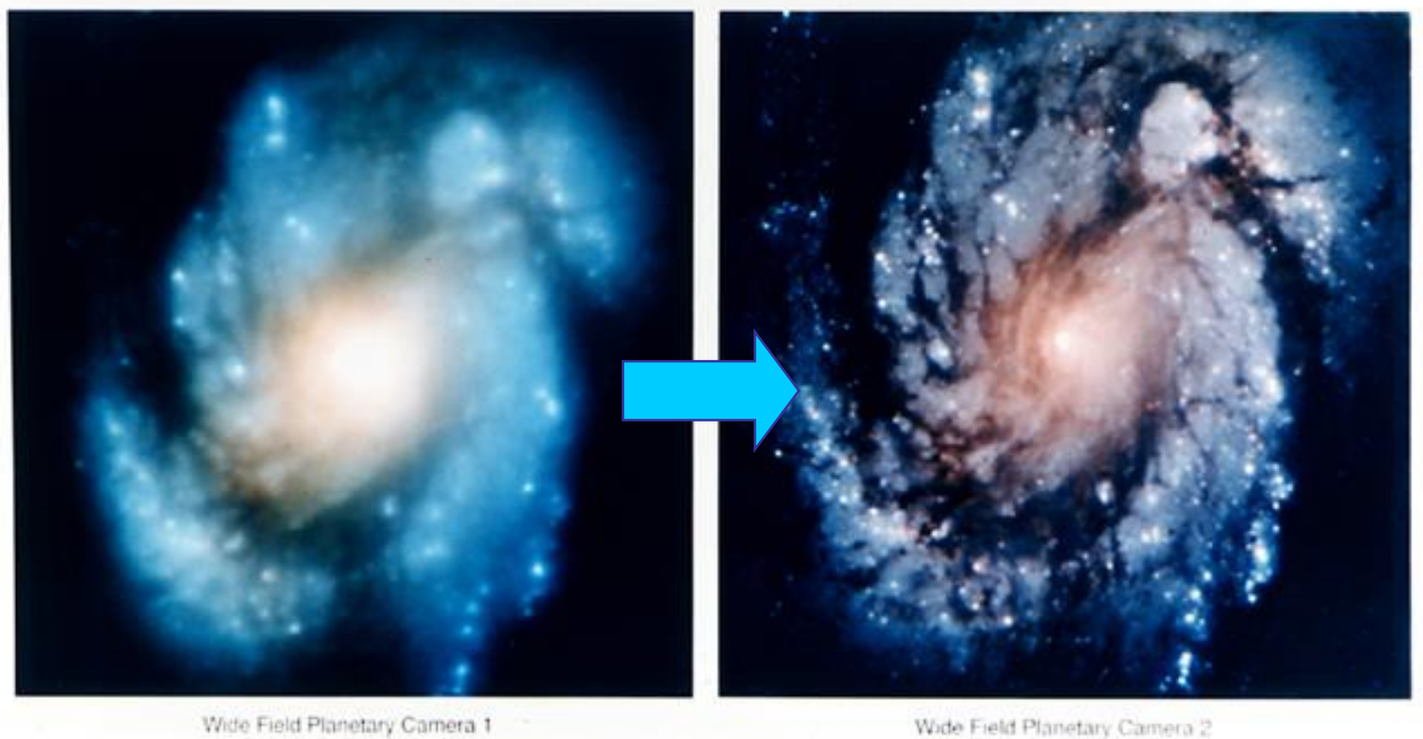


Examples: The Hubble Telescope

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



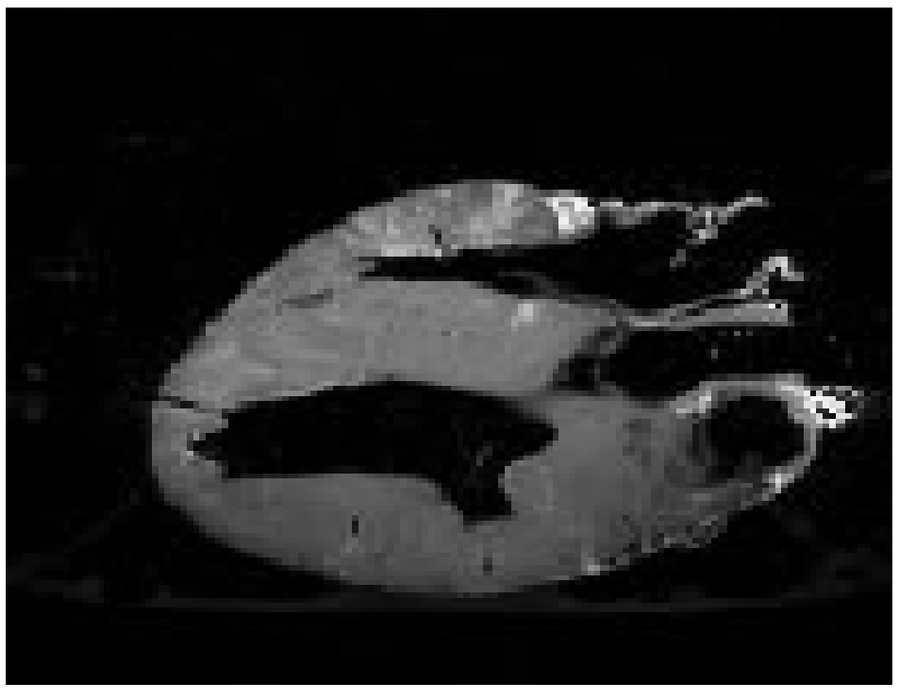
Examples: Artistic Effects

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

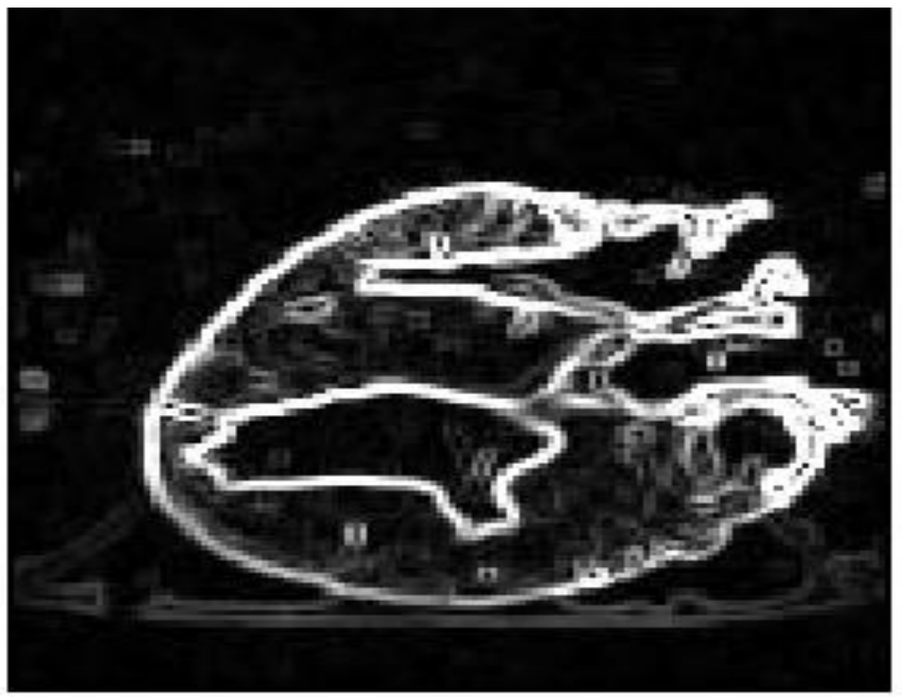
Examples: Medicine

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



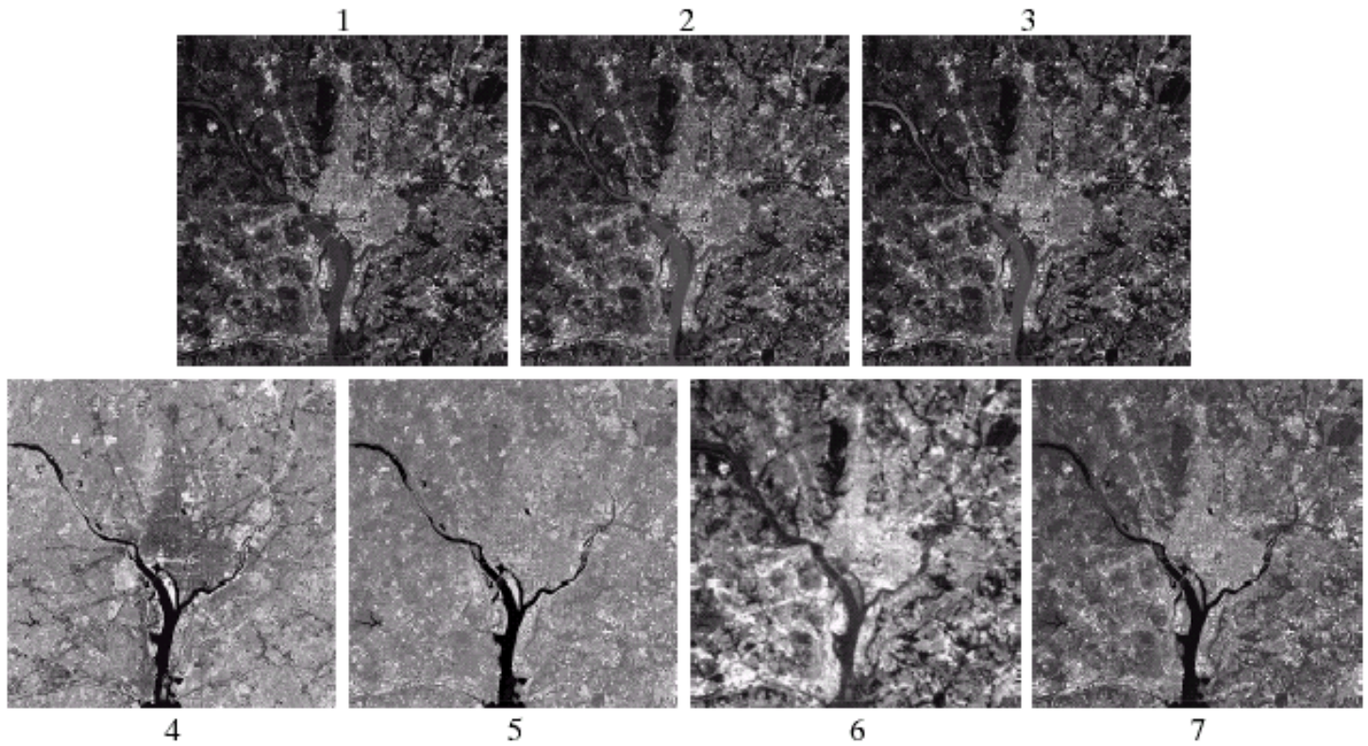
Edge Detection Image

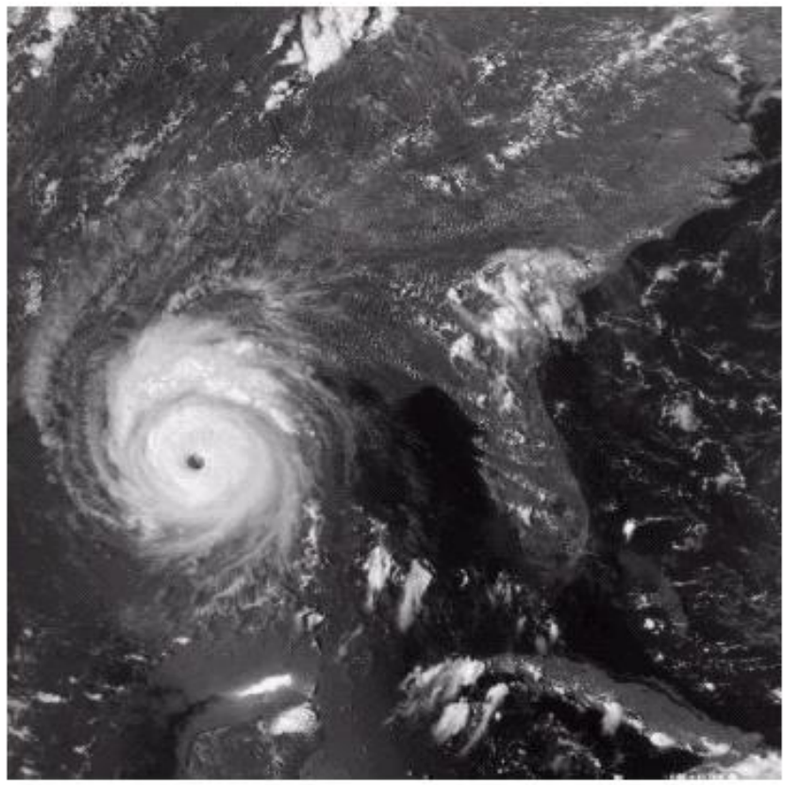
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Examples: GIS

Geographic Information Systems

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





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

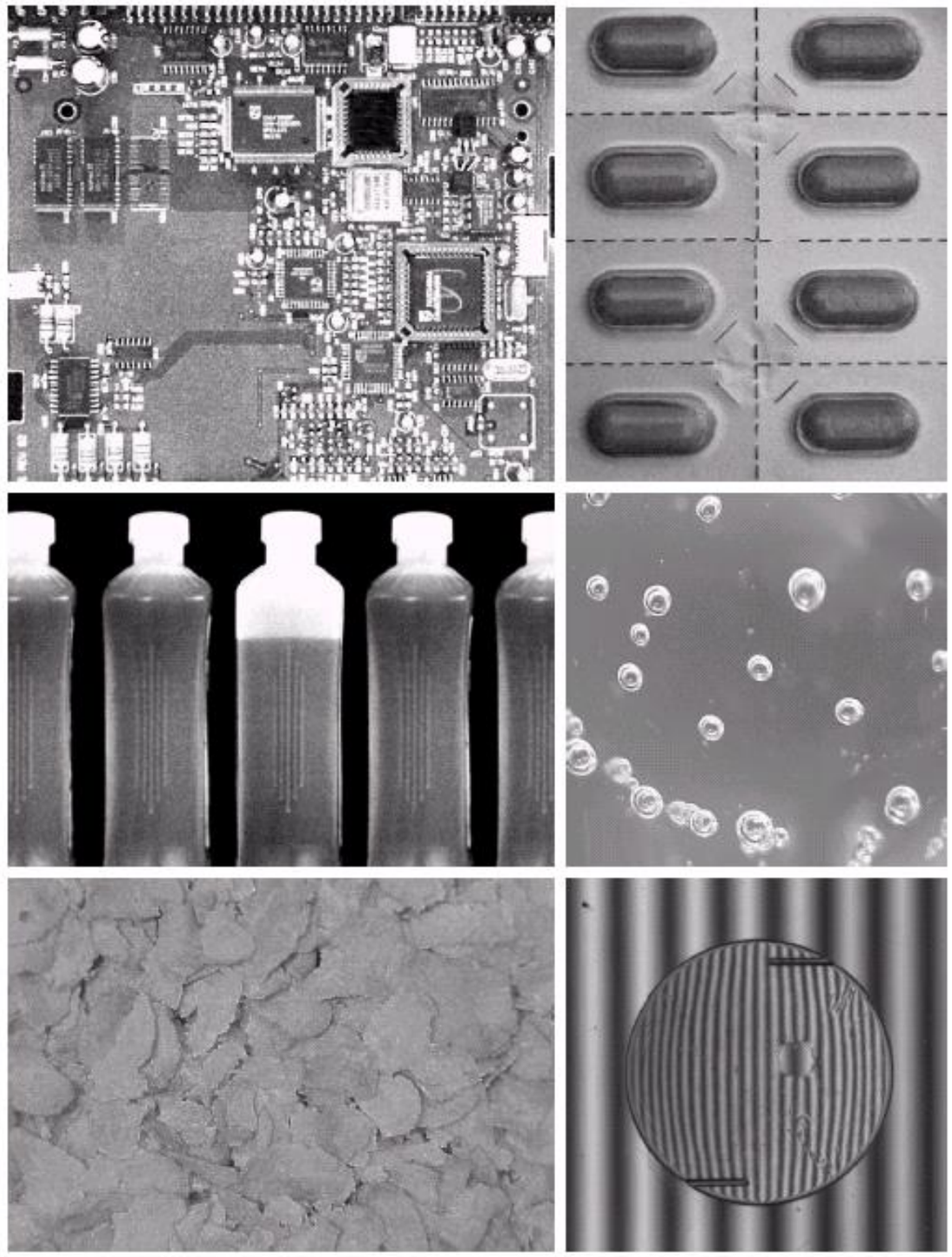
Examples: Industrial Inspection

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?

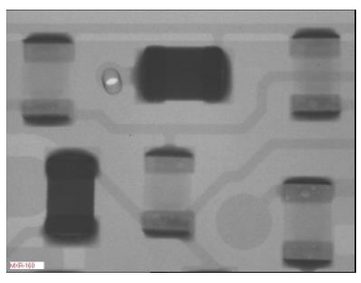


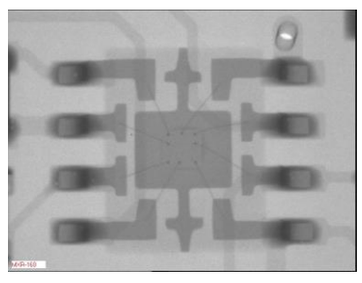
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

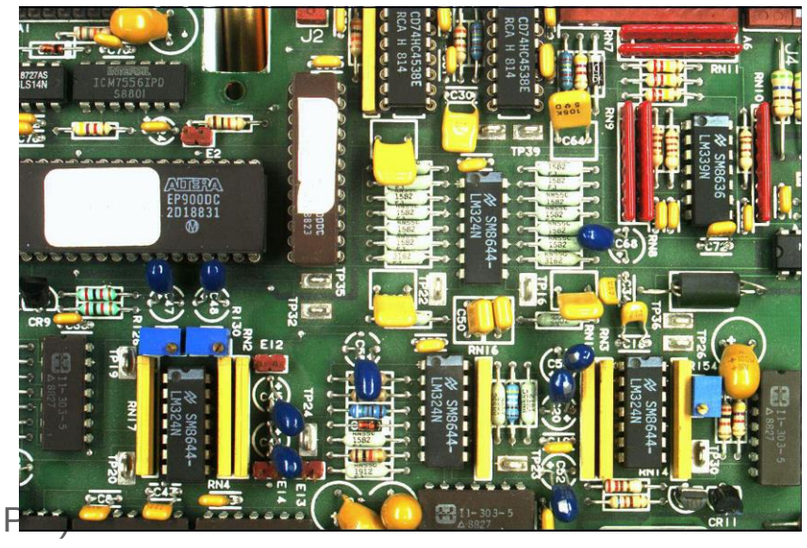
Examples: PCB Inspection

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



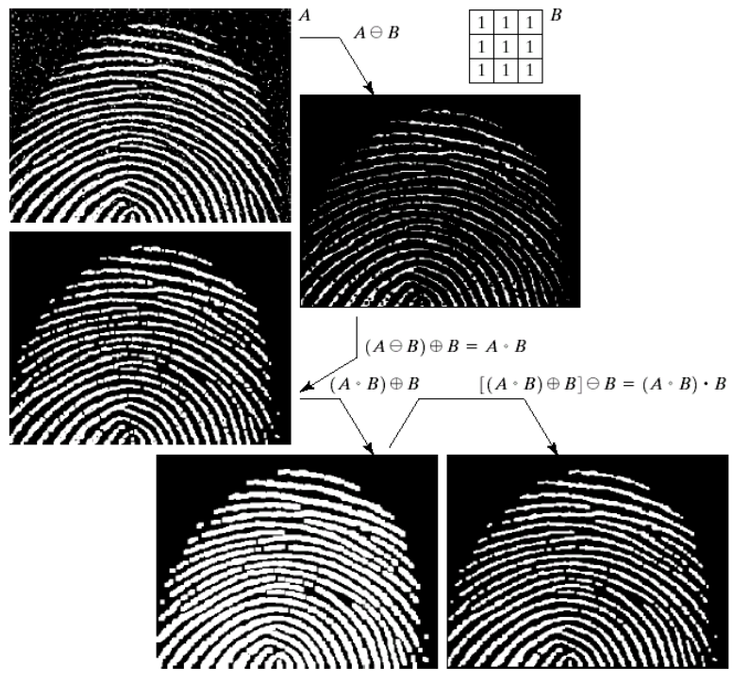




Examples: Law Enforcement

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)

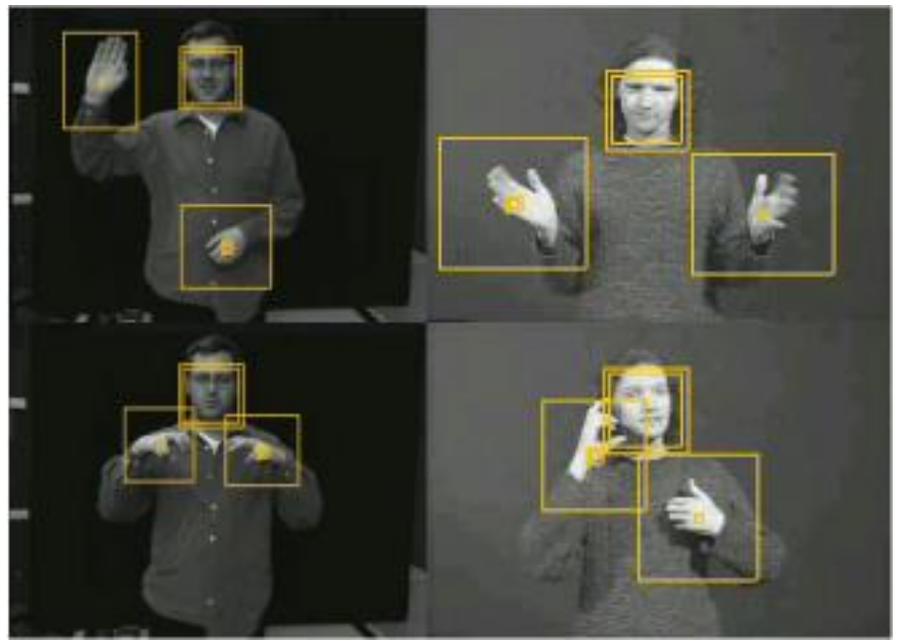
Examples: HCI

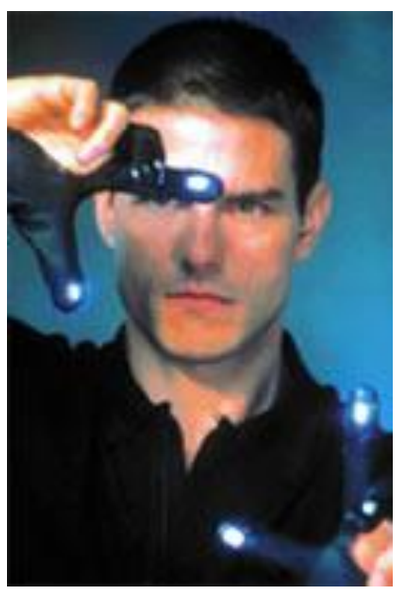
Try to make human computer interfaces more natural

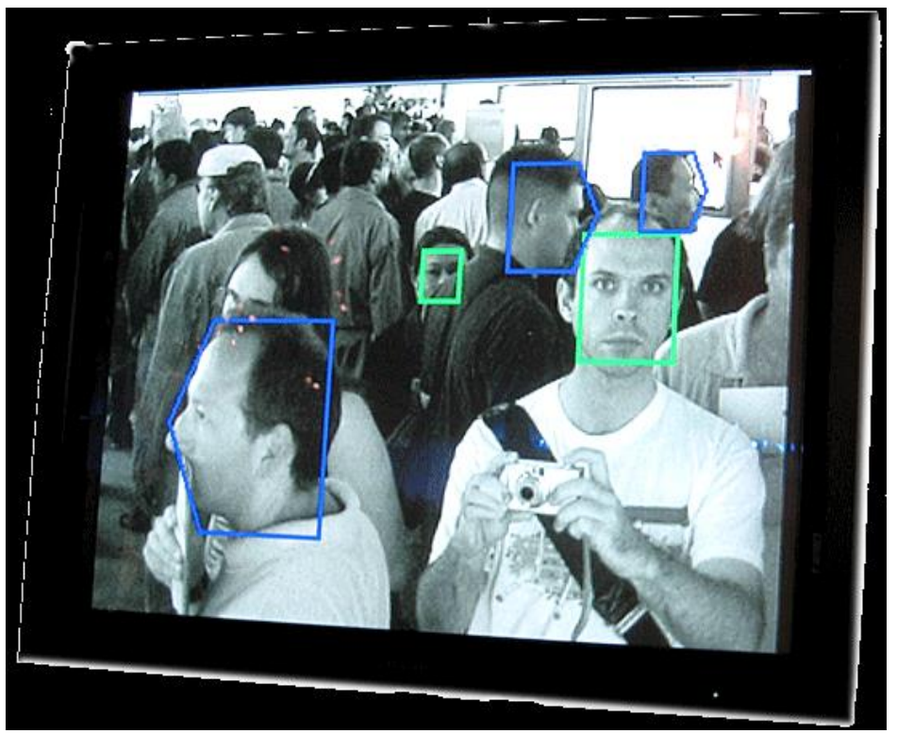
- –Face recognition
- –Gesture recognition

Does anyone remember the user interface from “Minority Report”?

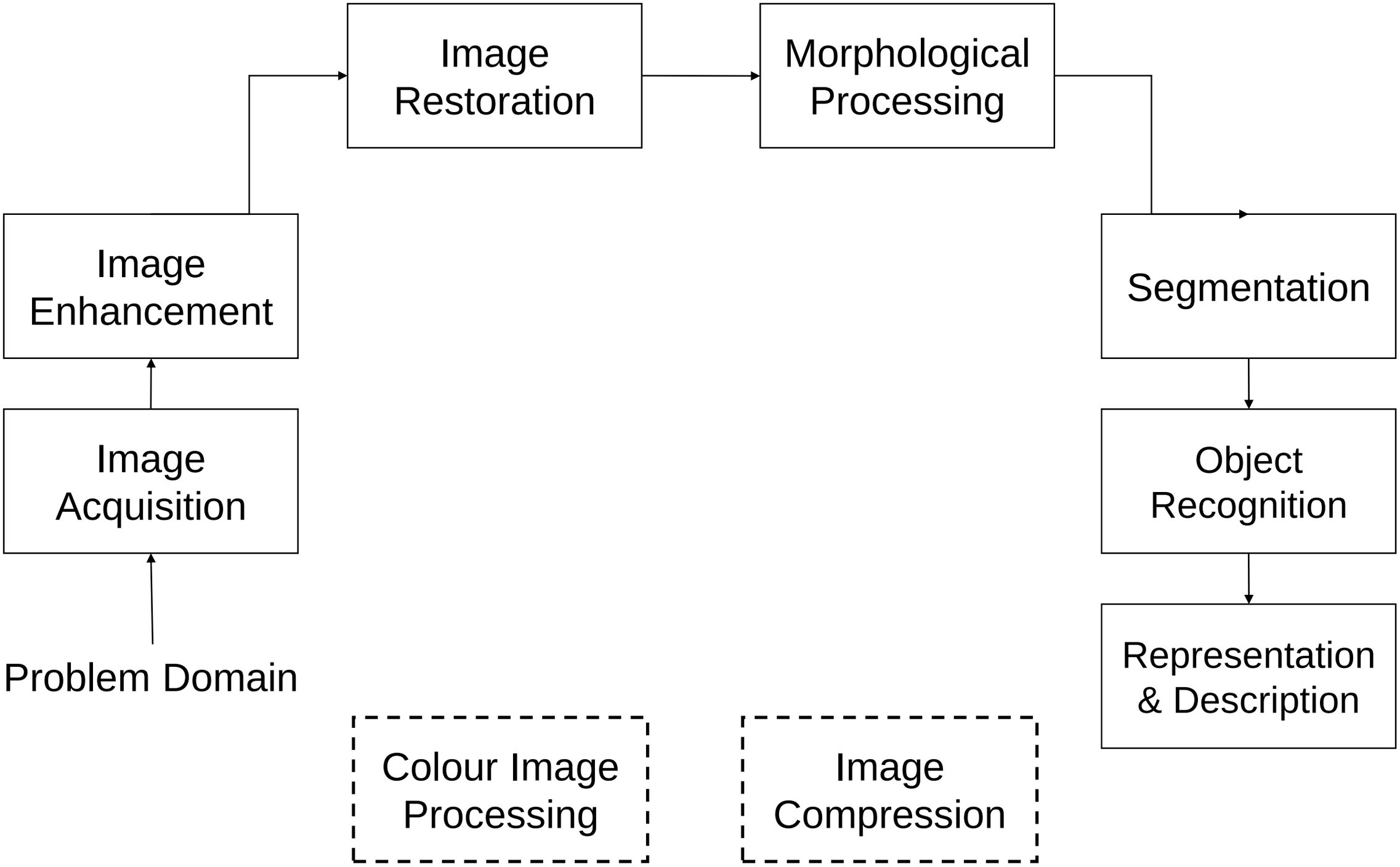
These tasks can be extremely difficult







Key Stages in Digital Image Processing



Key Stages in Digital Image Processing: Image Aquisition

Image Enhancement

Image Restoration

Morphological Processing

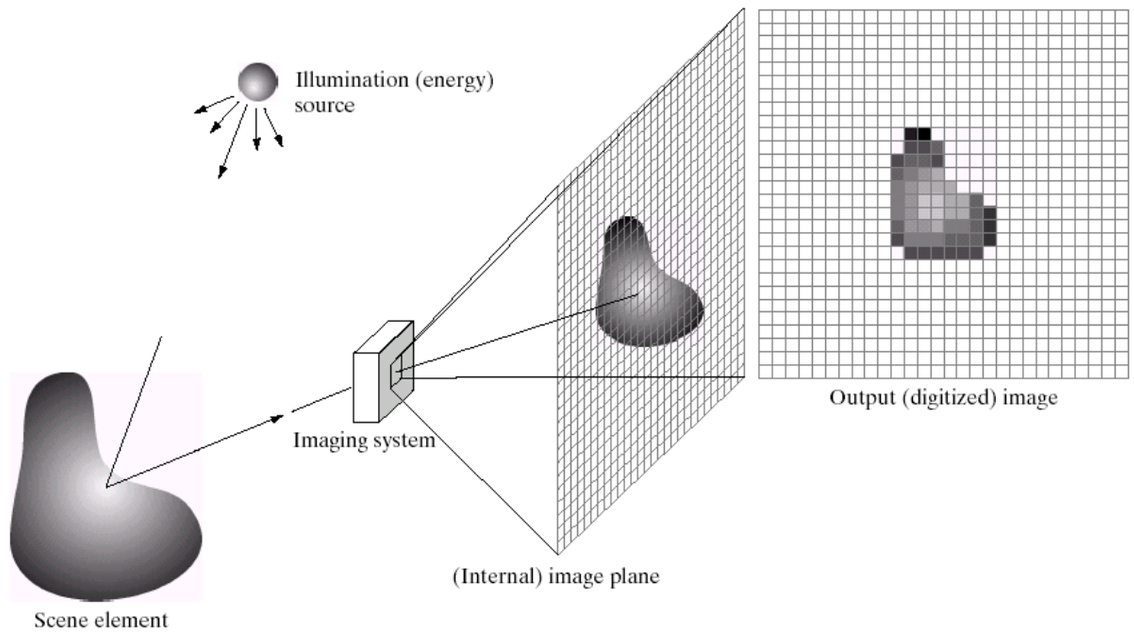
Segmentation

Object Recognition

Representation & Description

Image Acquisition

Problem Domain



Colour Image Processing

Image Compression

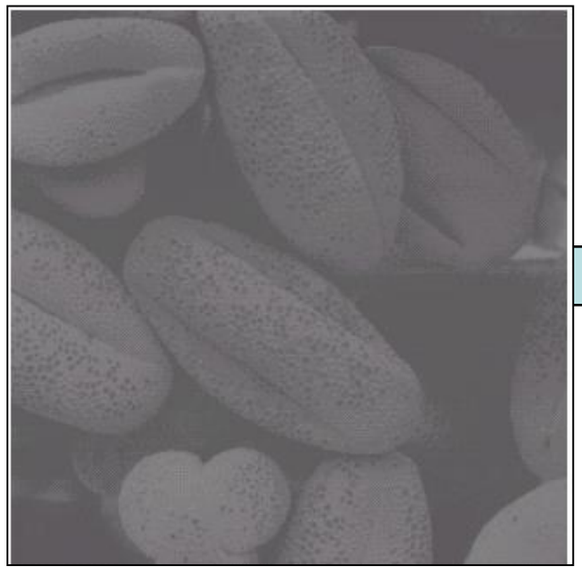
Key Stages in Digital Image Processing: Image Enhancement

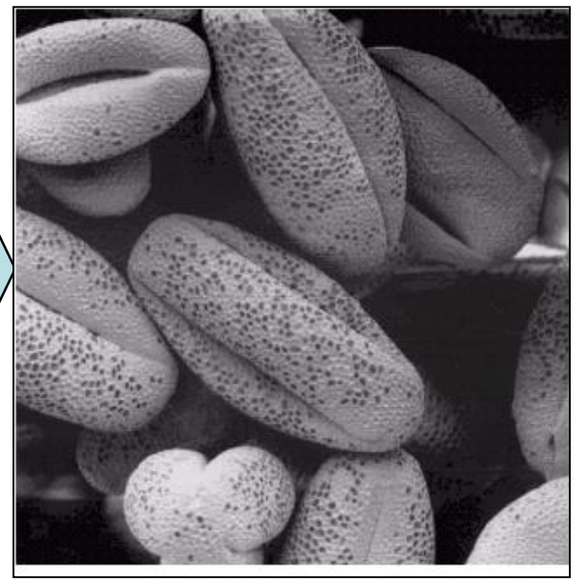
Image Processing (2002)

Image Restoration

Morphological Processing

Image Enhancement





Segmentation

Image Acquisition

Object Recognition

Representation & Description

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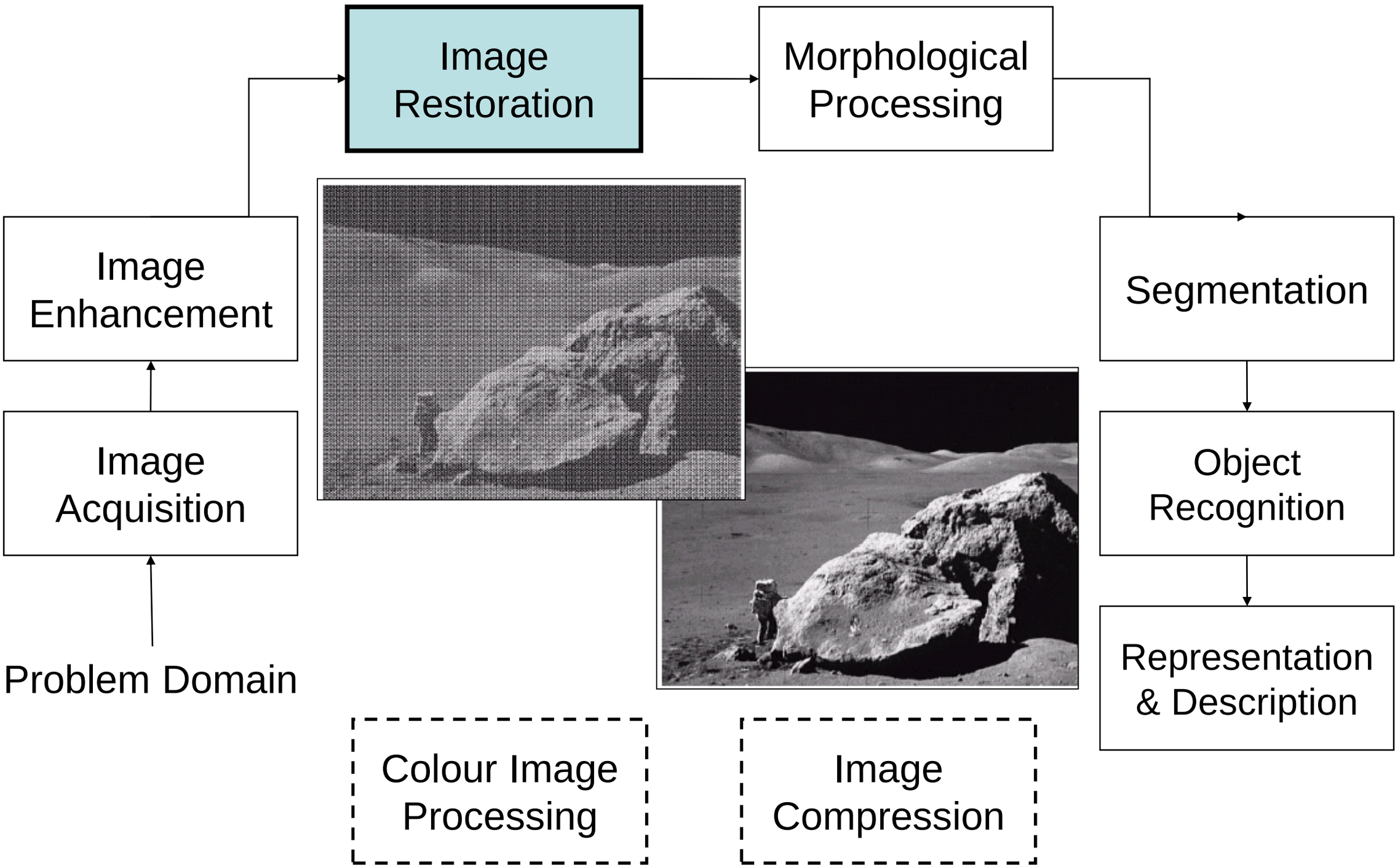
Colour Image Processing

Image Compression

Images taken from Gonzalez & Woods, Digital Image

Key Stages in Digital Image Processing: Image Restoration

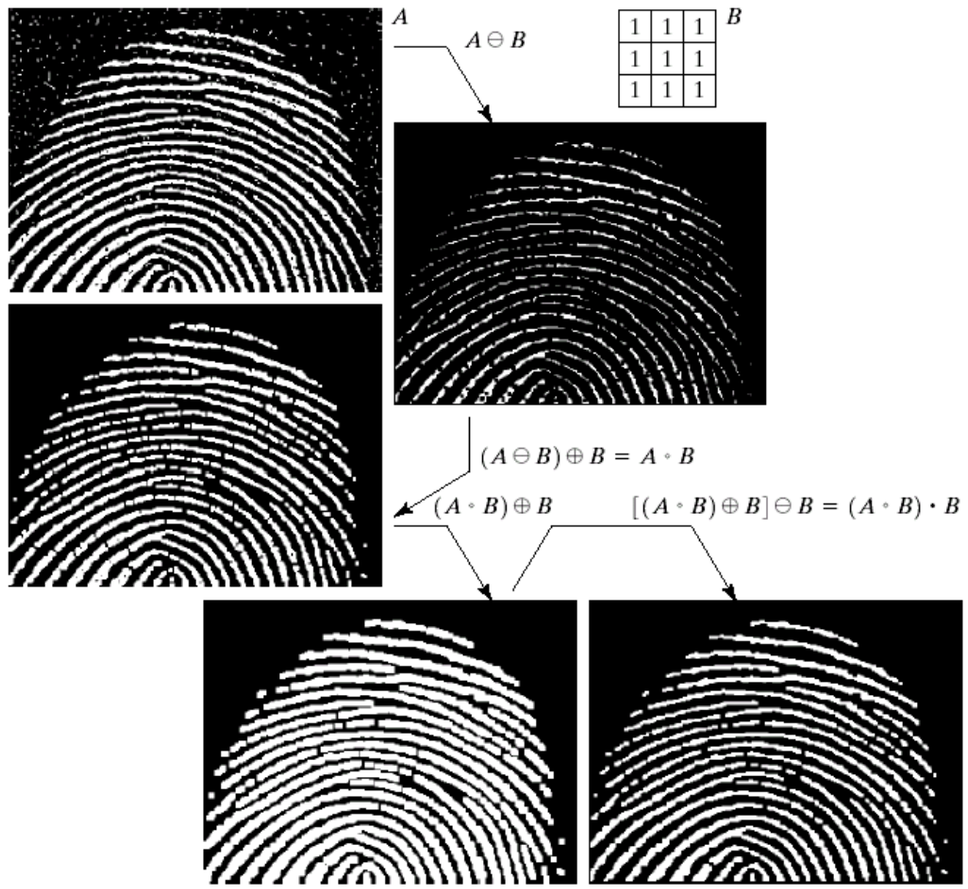


Key Stages in Digital Image Processing: Morphological Processing

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: Segmentation

Problem Domain

Image Acquisition

Image Enhancement

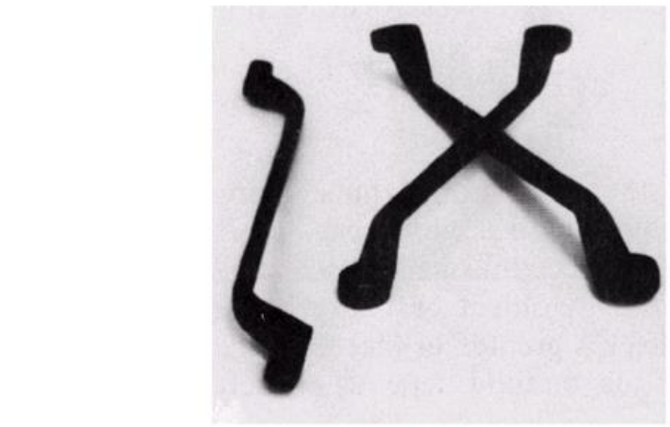
Image Restoration

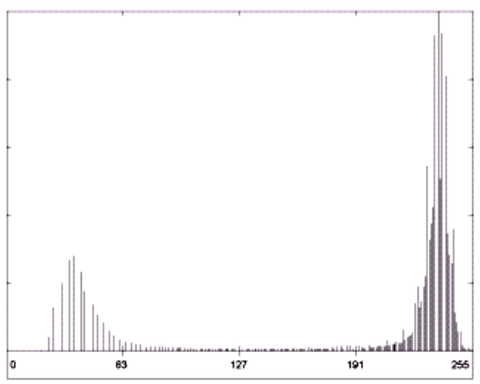
Morphological Processing

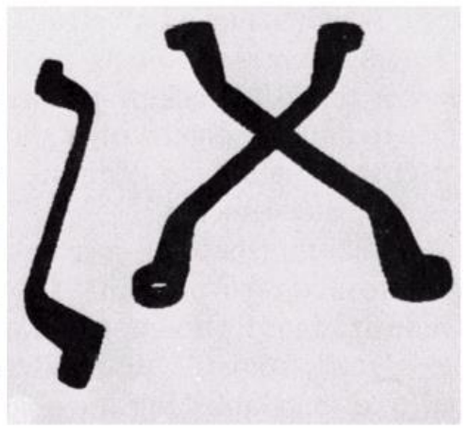
Segmentation

Object Recognition

Representation & Description







Colour Image Processing

Image Compression

Key Stages in Digital Image Processing: Object Recognition

Image Acquisition

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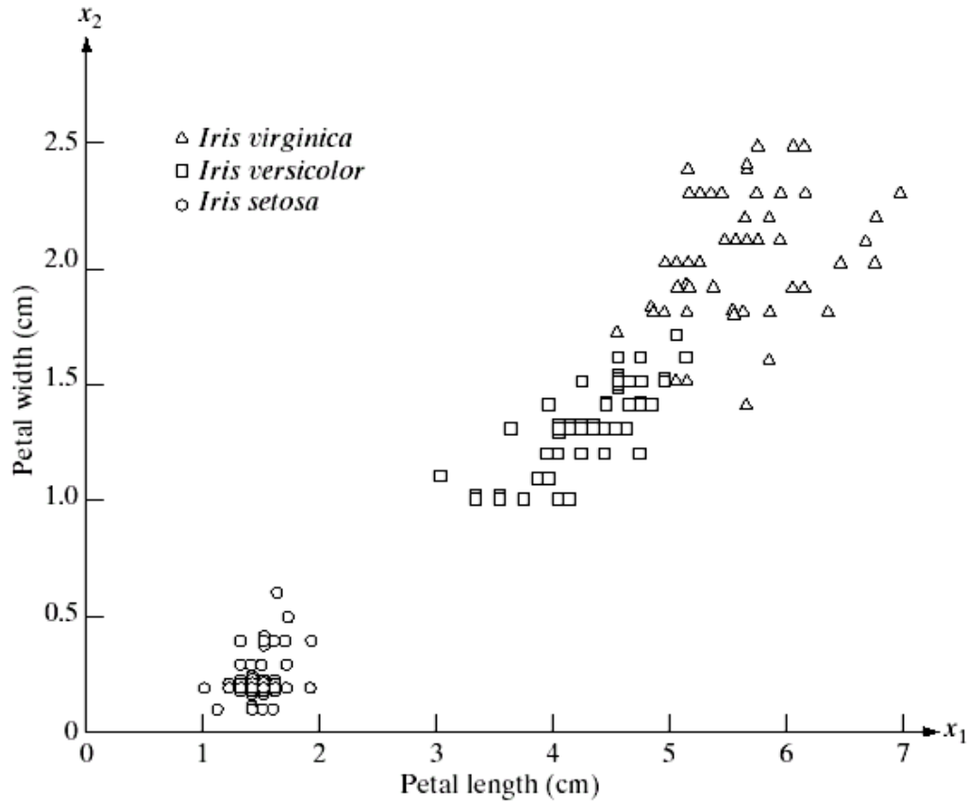
Representation & Description

Problem Domain

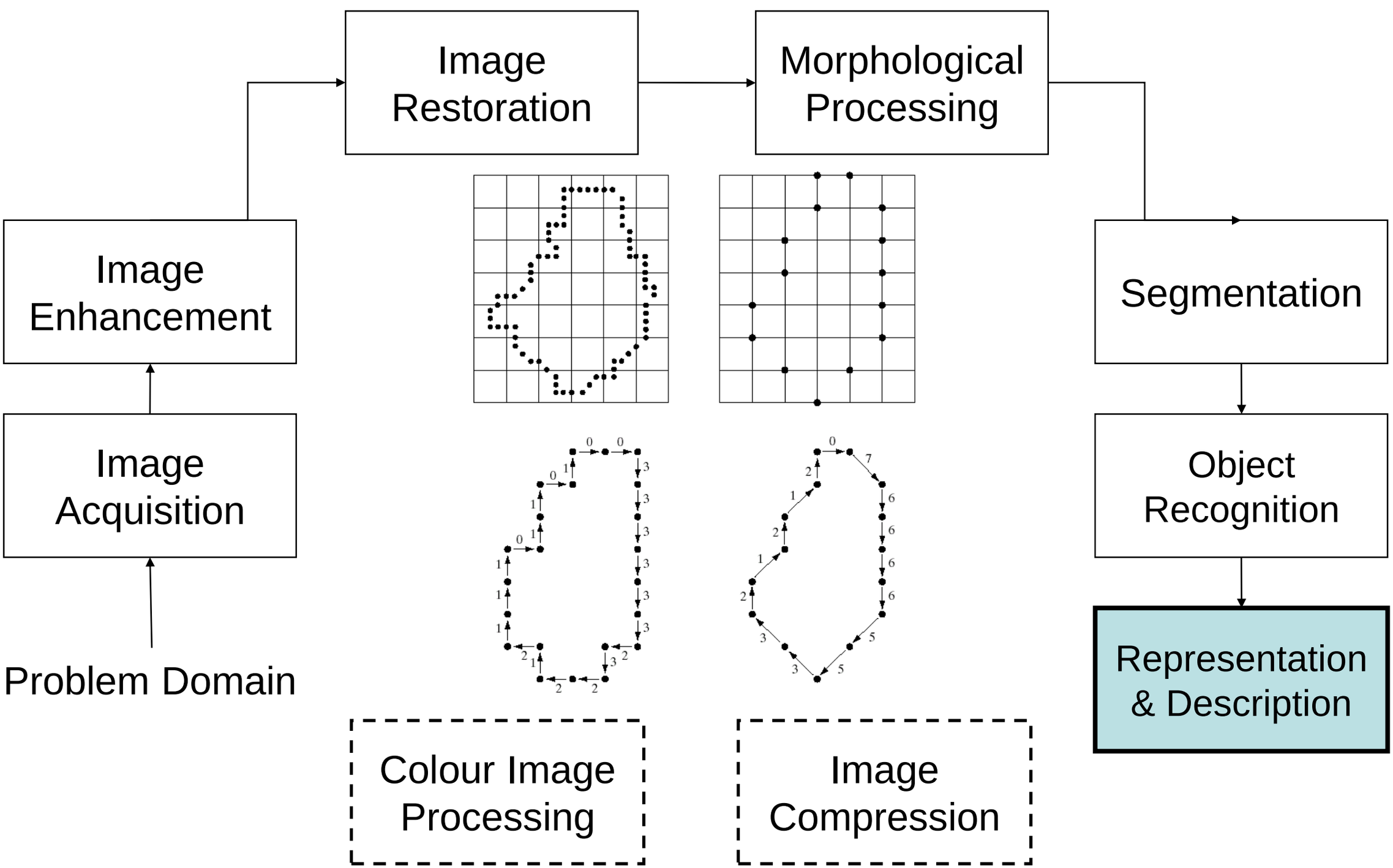


Colour Image Processing

Image Compression

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

Key Stages in Digital Image Processing: Representation & Description



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

Key Stages in Digital Image Processing: Image Compression

Problem Domain

Image Acquisition

Image Enhancement

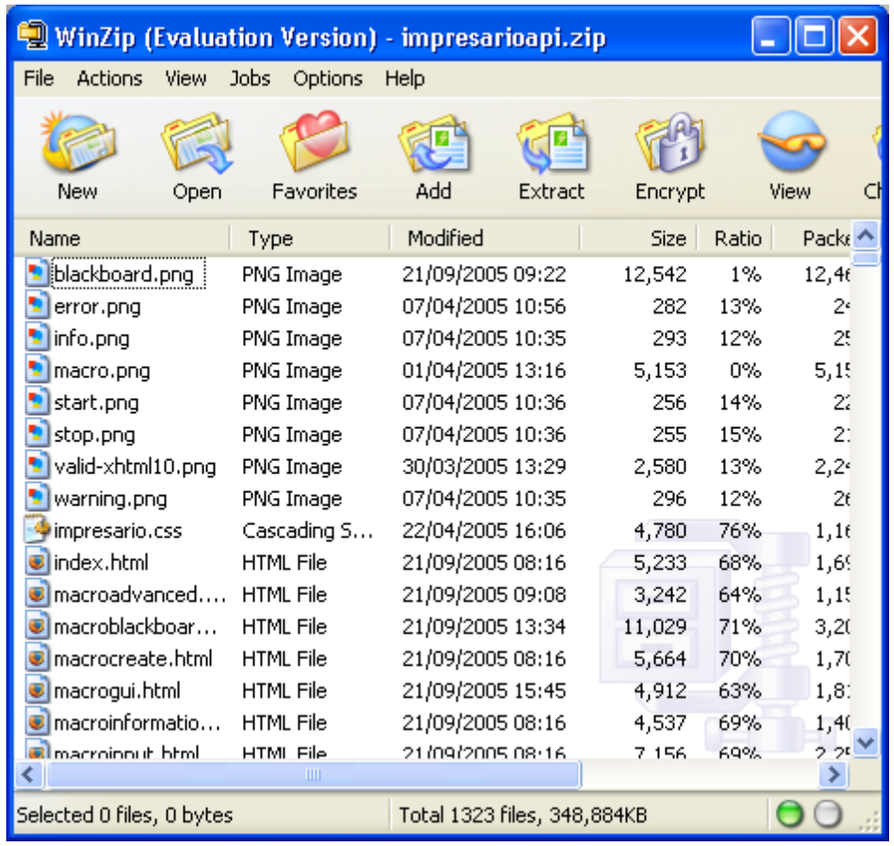
Image Restoration

Morphological Processing

Segmentation

Object Recognition

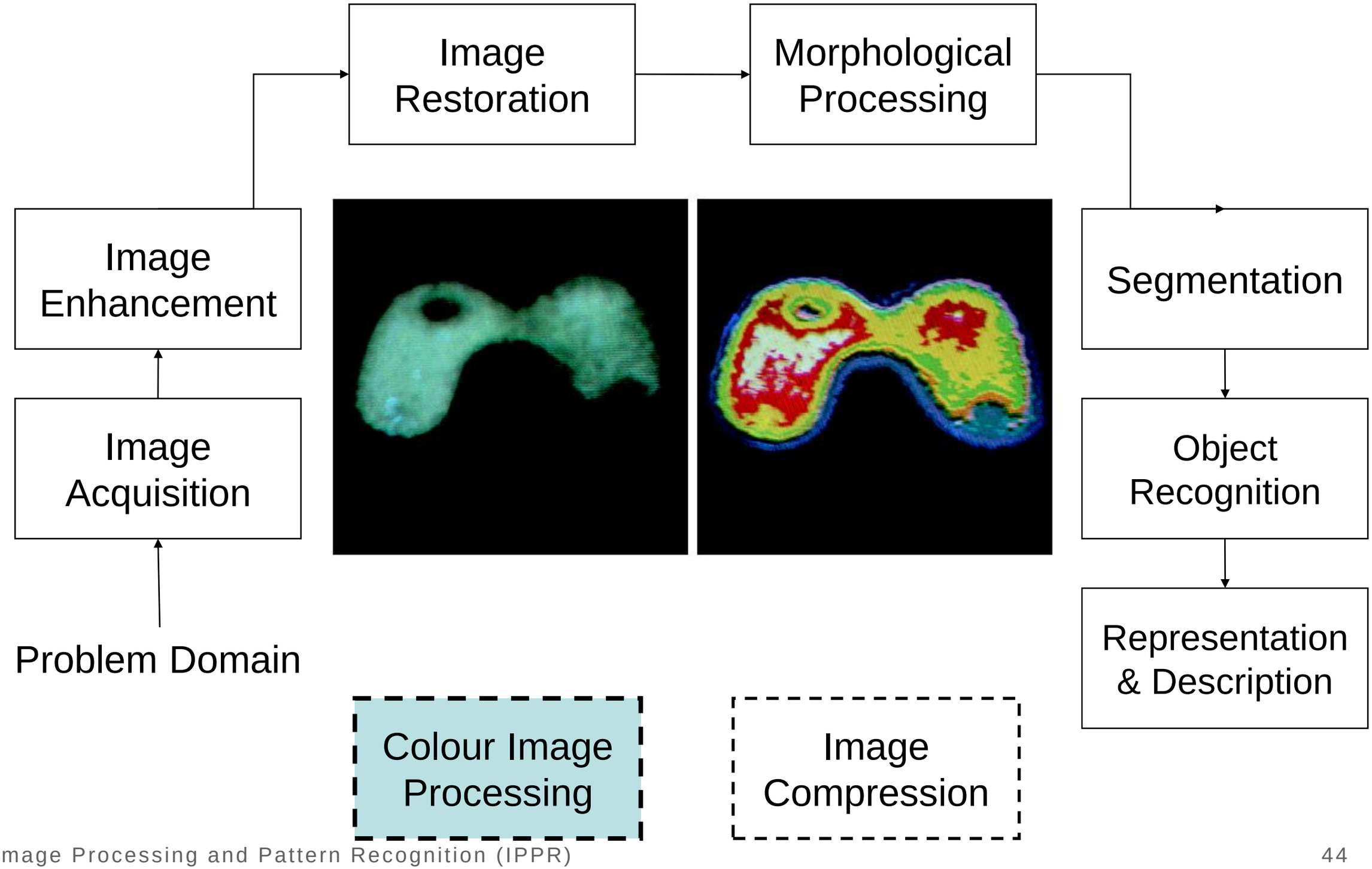
Representation & Description



Colour Image Processing

Image Compression

Key Stages in Digital Image Processing: Colour 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

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

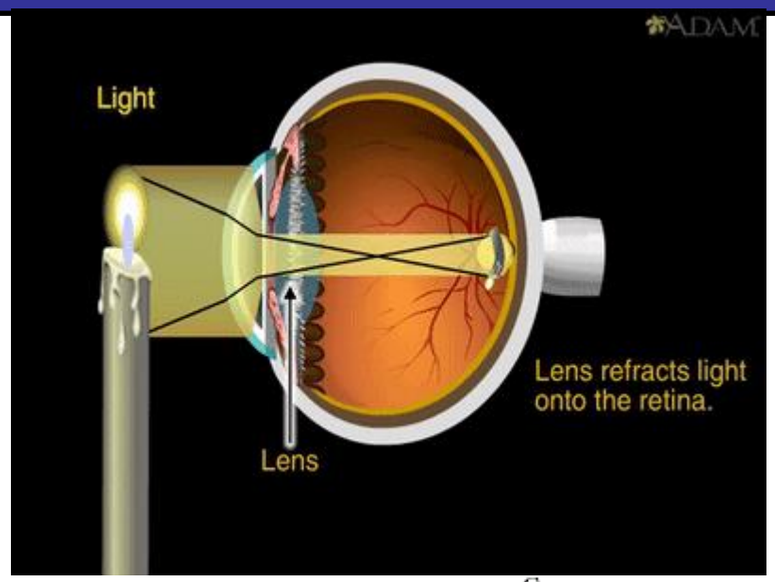
The best vision model we have!

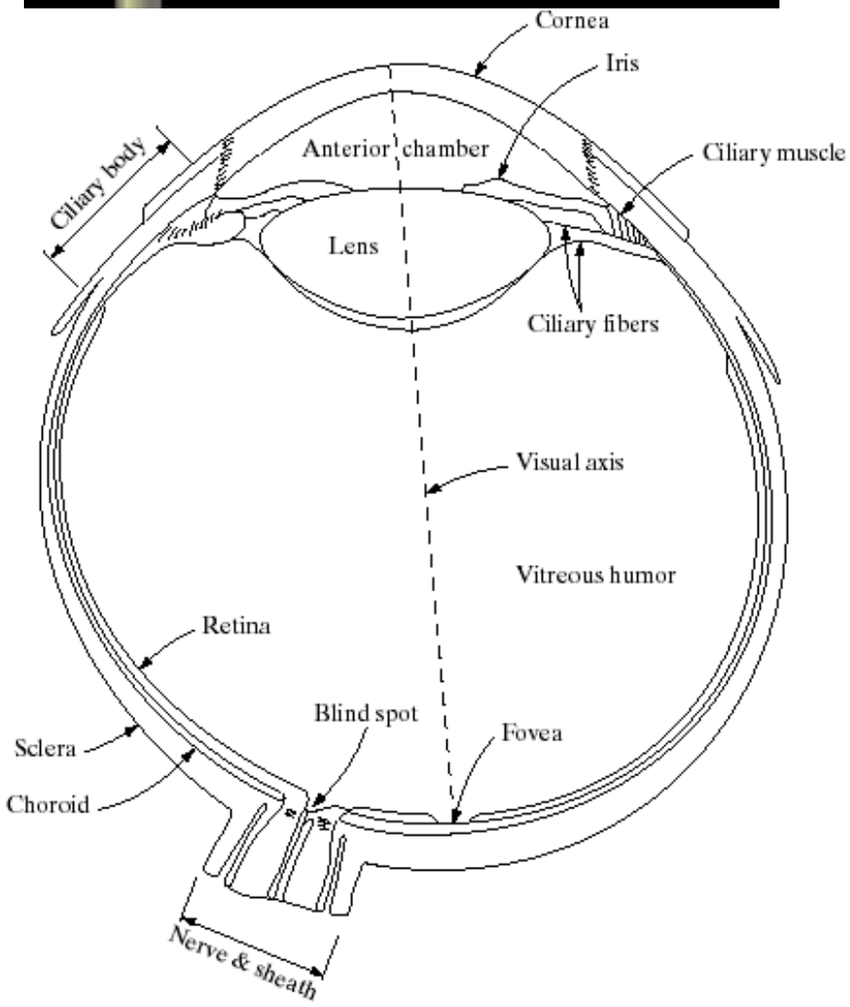
Knowledge of how images form in the eye can help us with processing digital images

We will take just a whirlwind tour of the human visual system

Structure Of The Human Eye

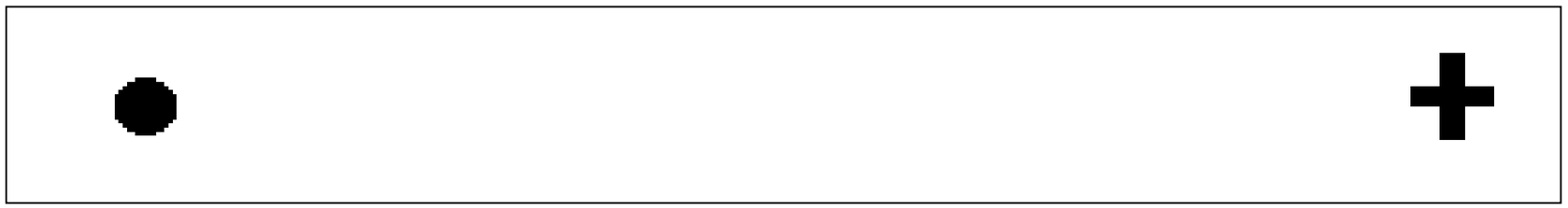
- The lens focuses light from objects onto the retina
- The retina is covered with light receptors called *cones* (6-7 million) and *rods* (75-150 million)
- Cones are concentrated around the fovea and are very sensitive to colour
- Rods are more spread out and are sensitive to low levels of illumination





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

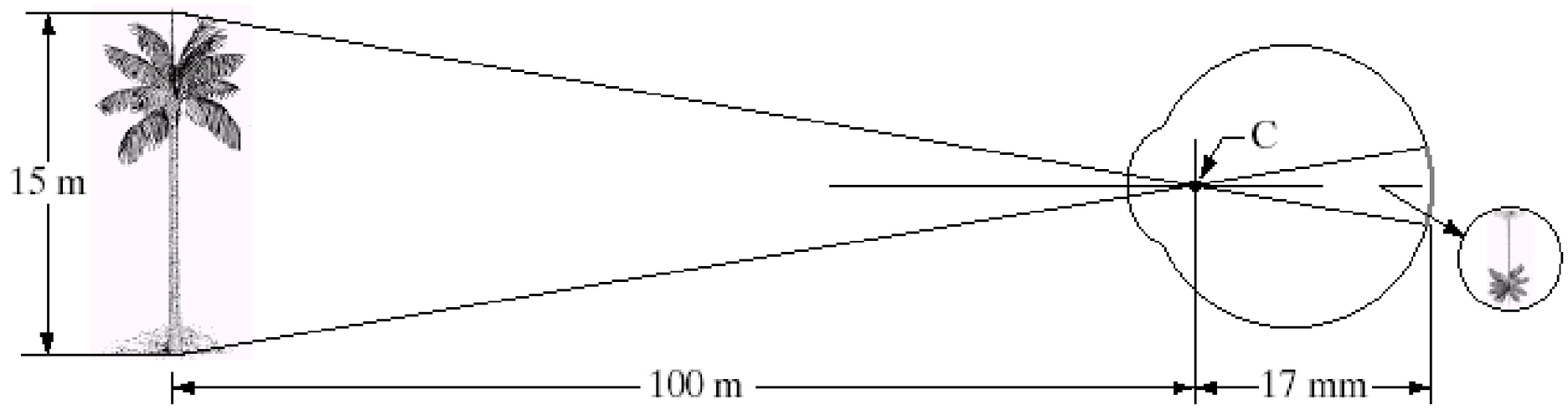
Hold the image about 20 inches away from your face and move it slowly towards you

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



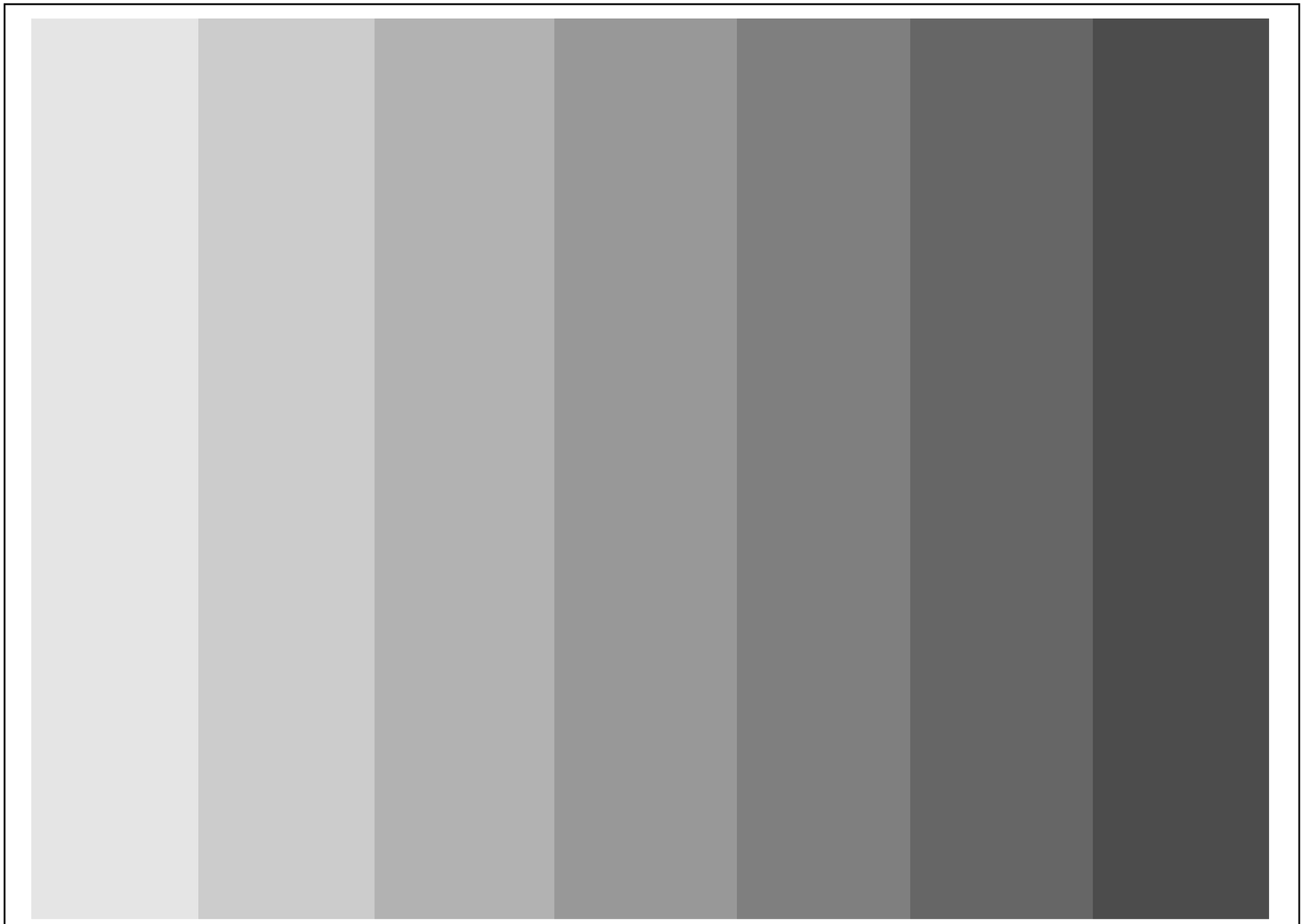
Brightness Adaptation & Discrimination

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

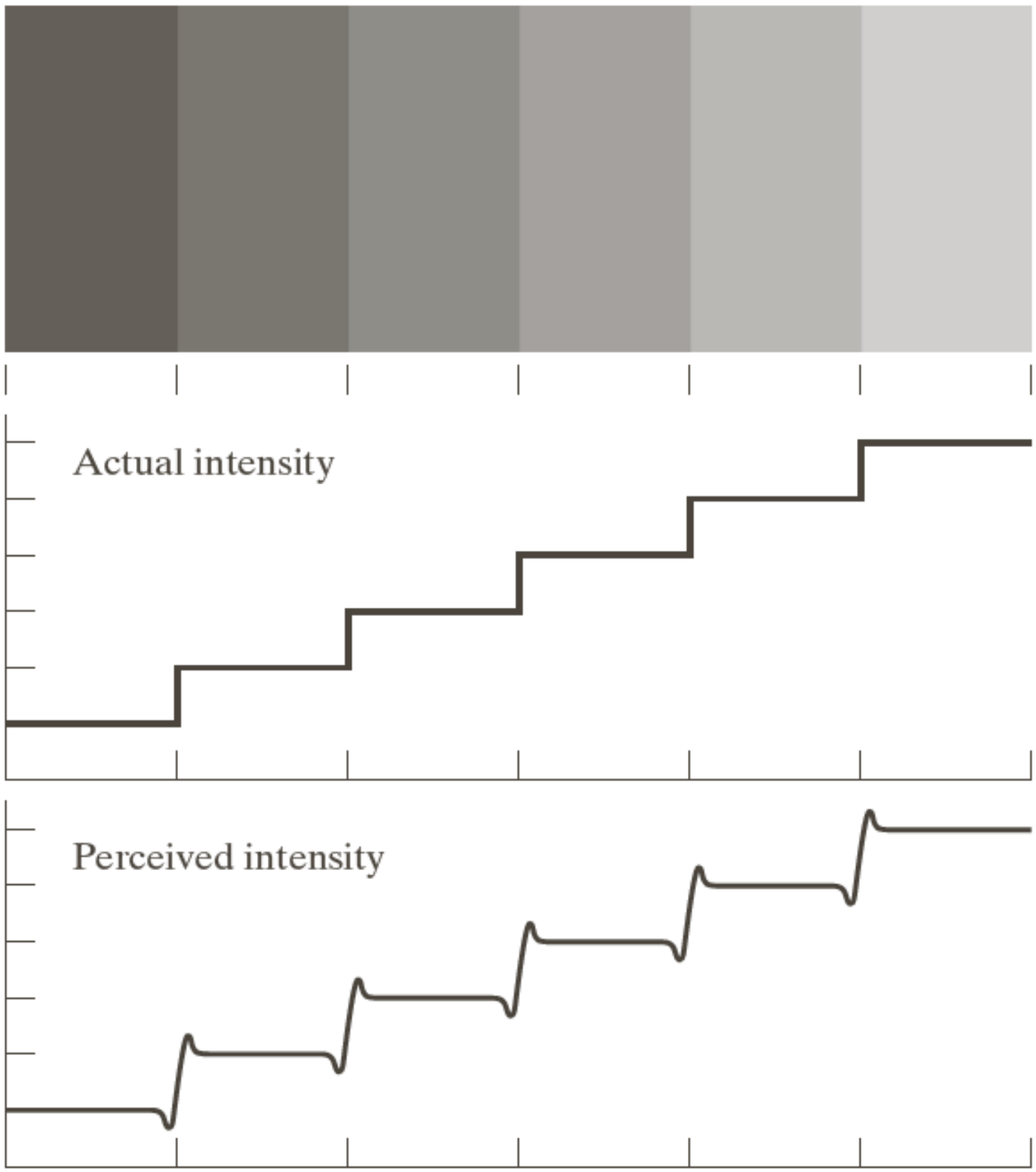
Brightness Adaptation & Discrimination (cont…)



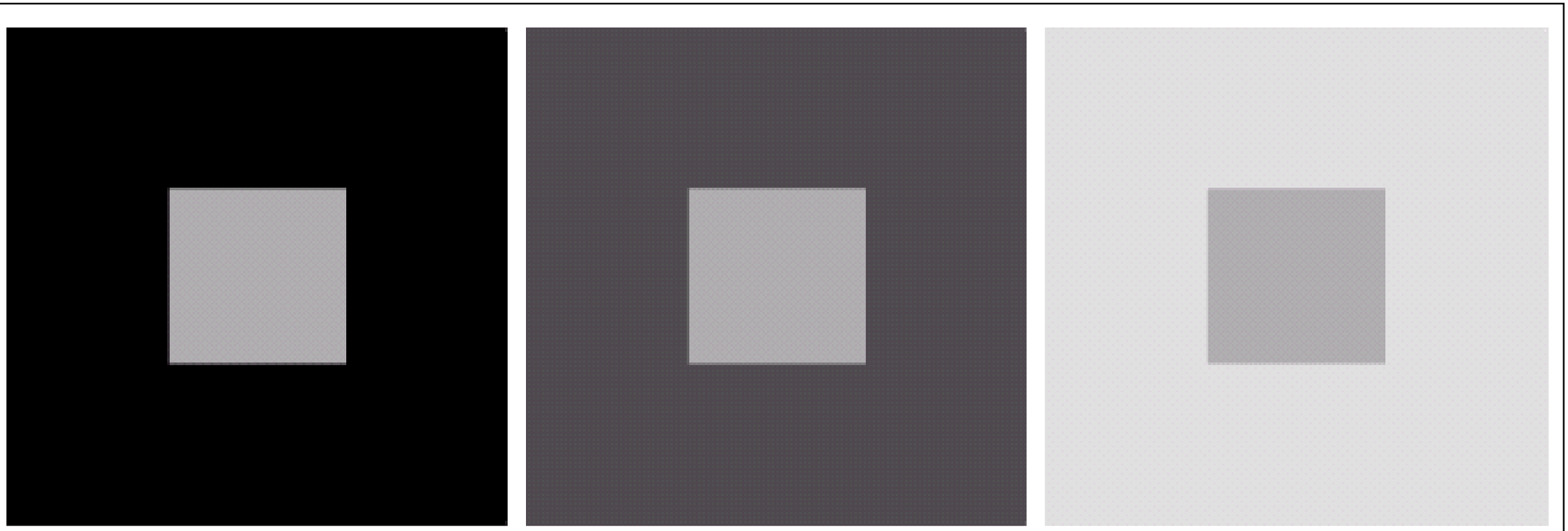
An example of Mach bands

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

Brightness Adaptation & Discrimination (cont…)



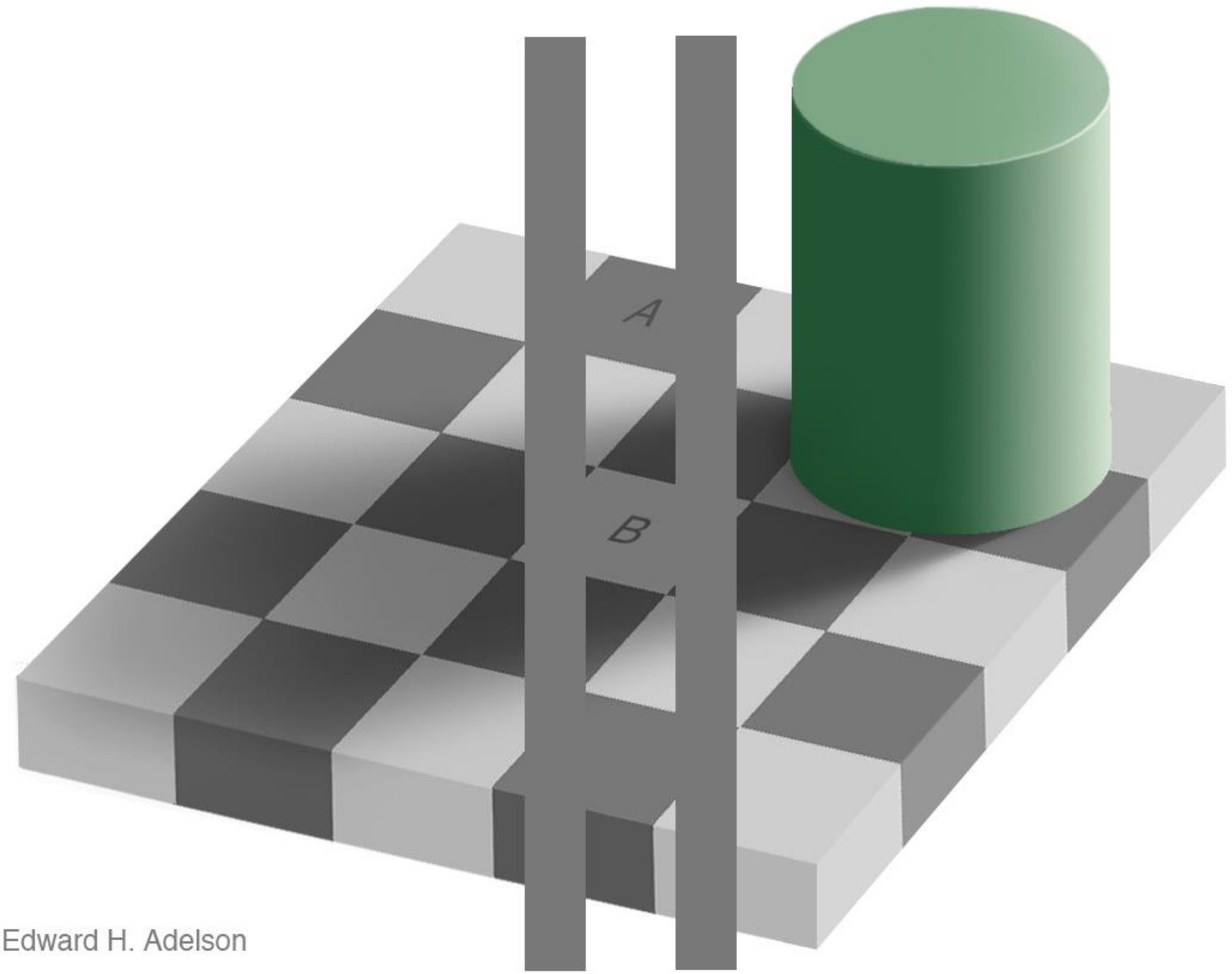
Brightness Adaptation & Discrimination (cont…)



An example of *simultaneous contrast*

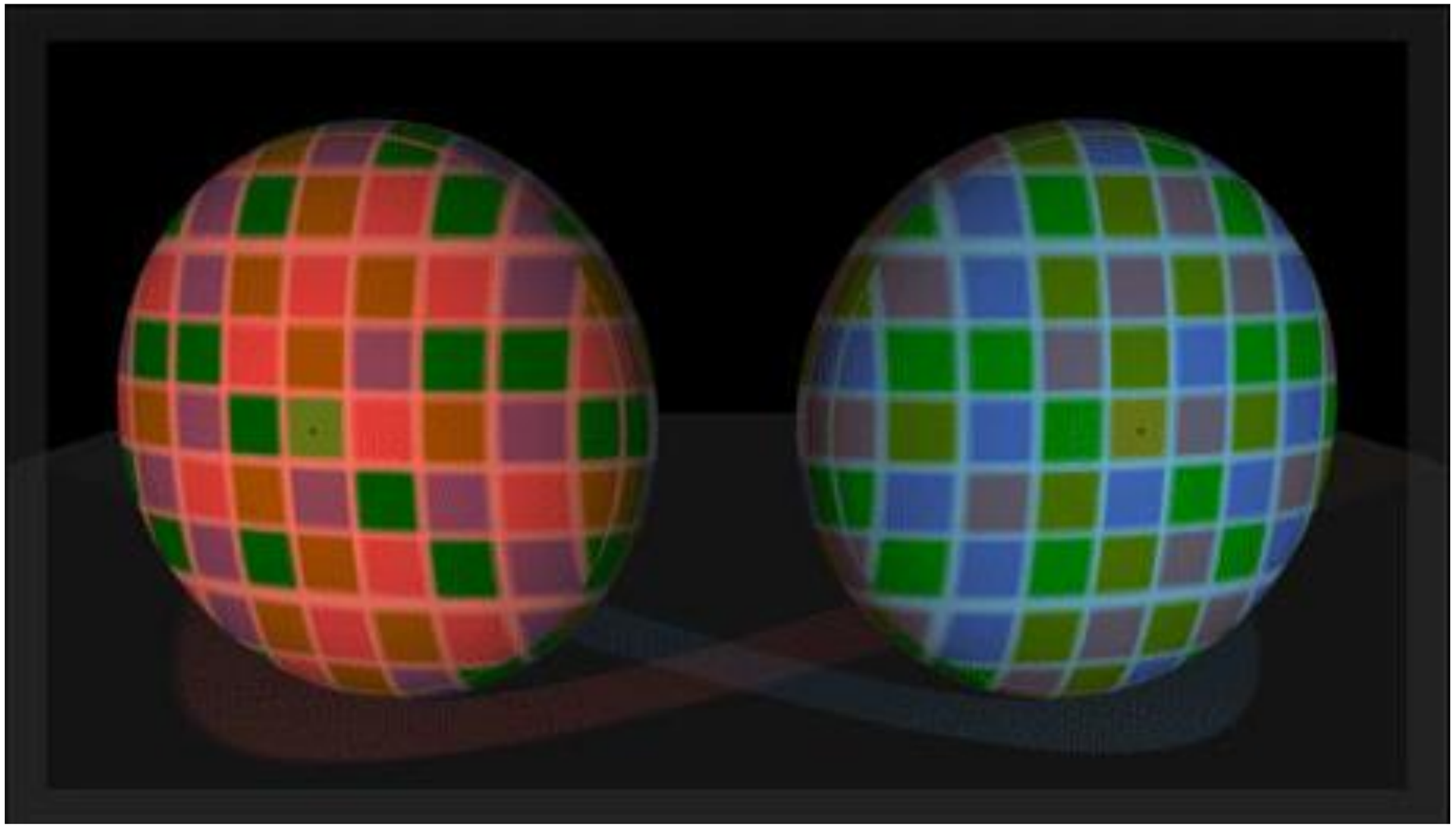
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Brightness Adaptation & Discrimination (cont…)



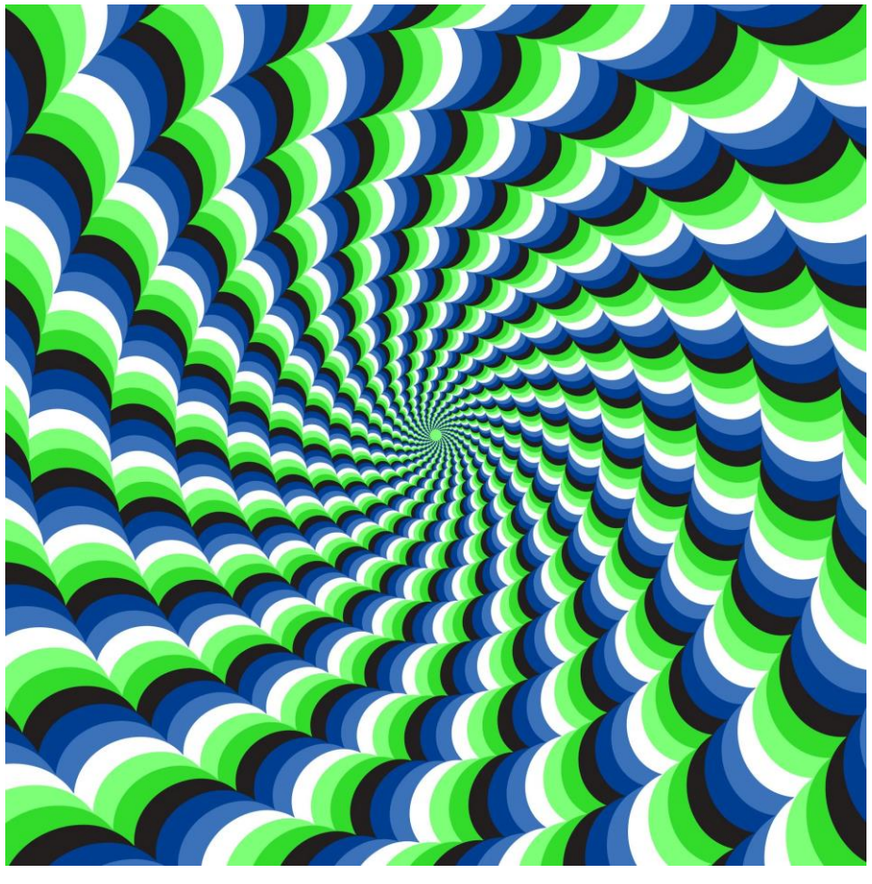
Edward H. Adelson

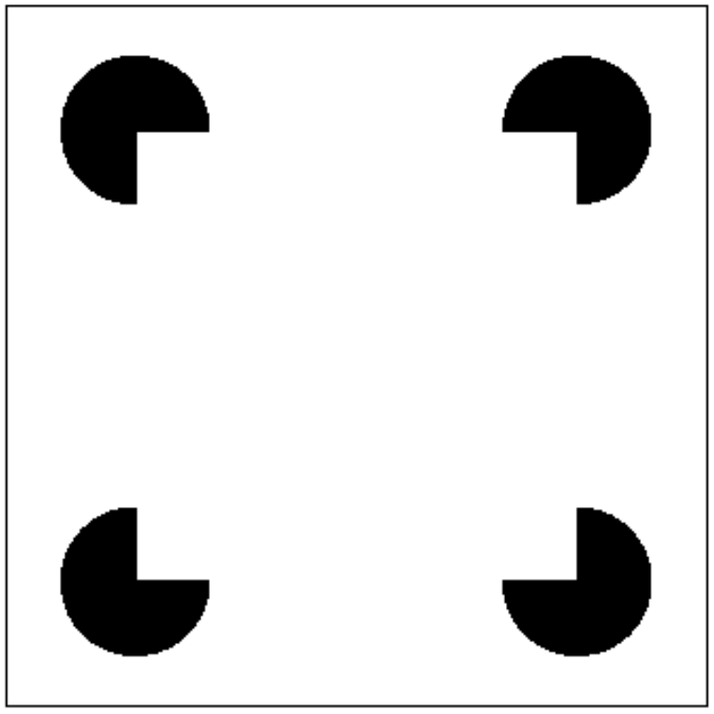
For more great illusion examples take a look at: http://web.mit.edu/persci/gaz/

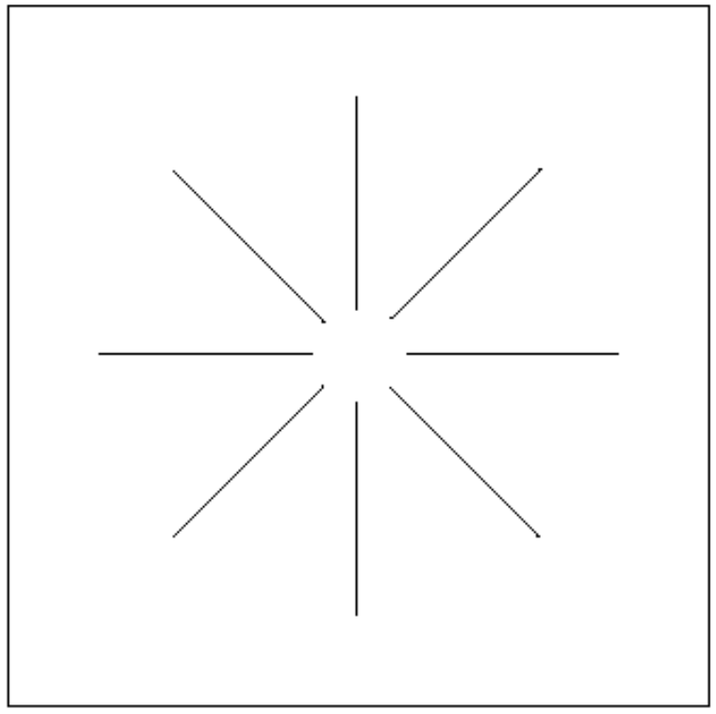


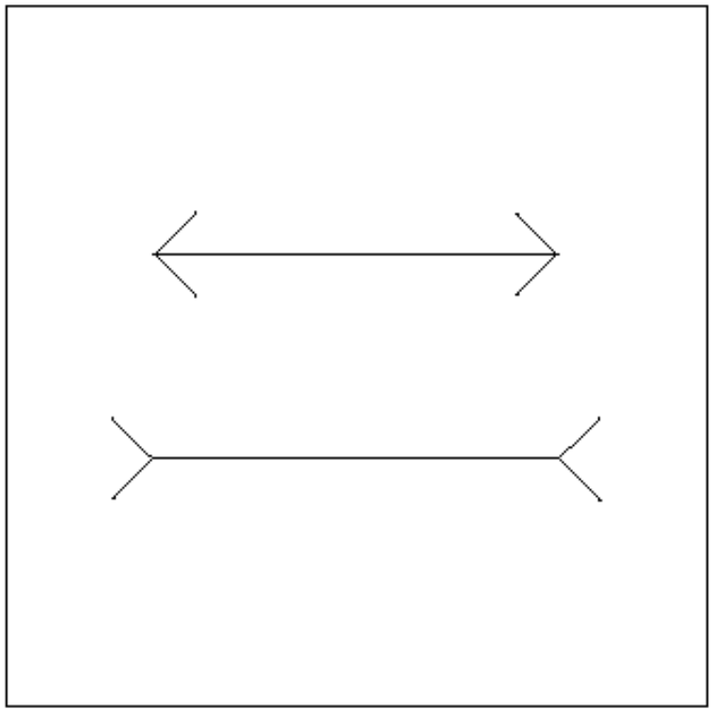
Available here: http://www.lottolab.org/Visual%20Demos/Demo%2015.html

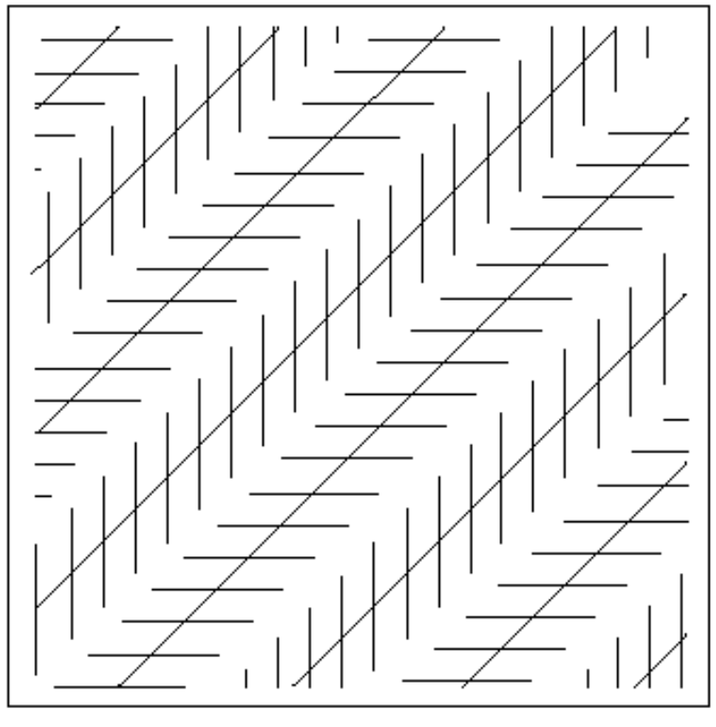
Our visual systems play lots of interesting tricks on us







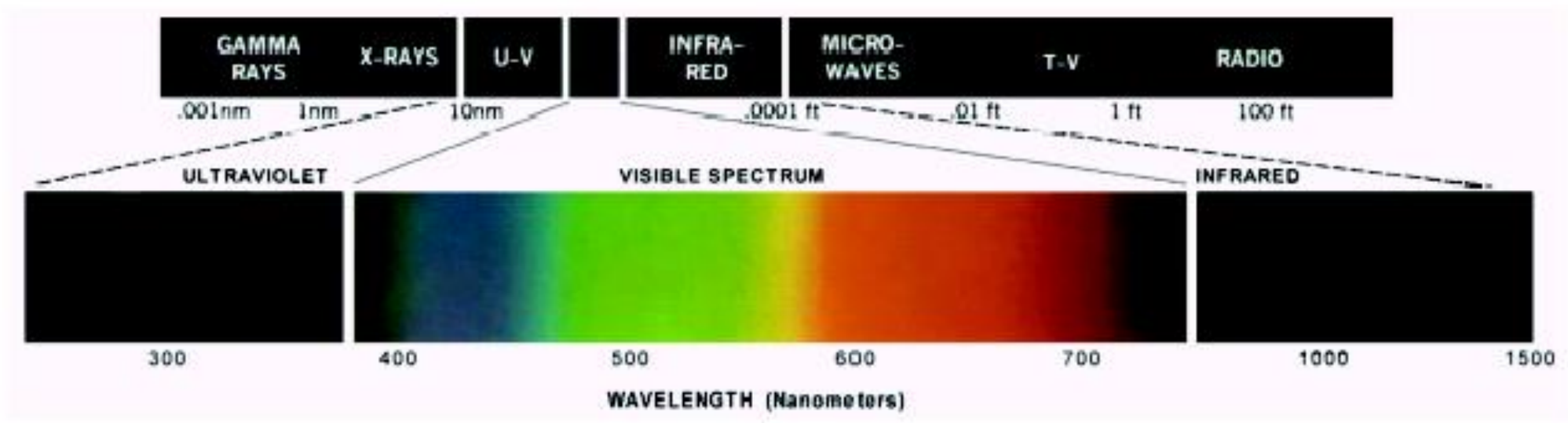




Light And The Electromagnetic Spectrum

Light is just a particular part of the electromagnetic spectrum that can be sensed by the human eye

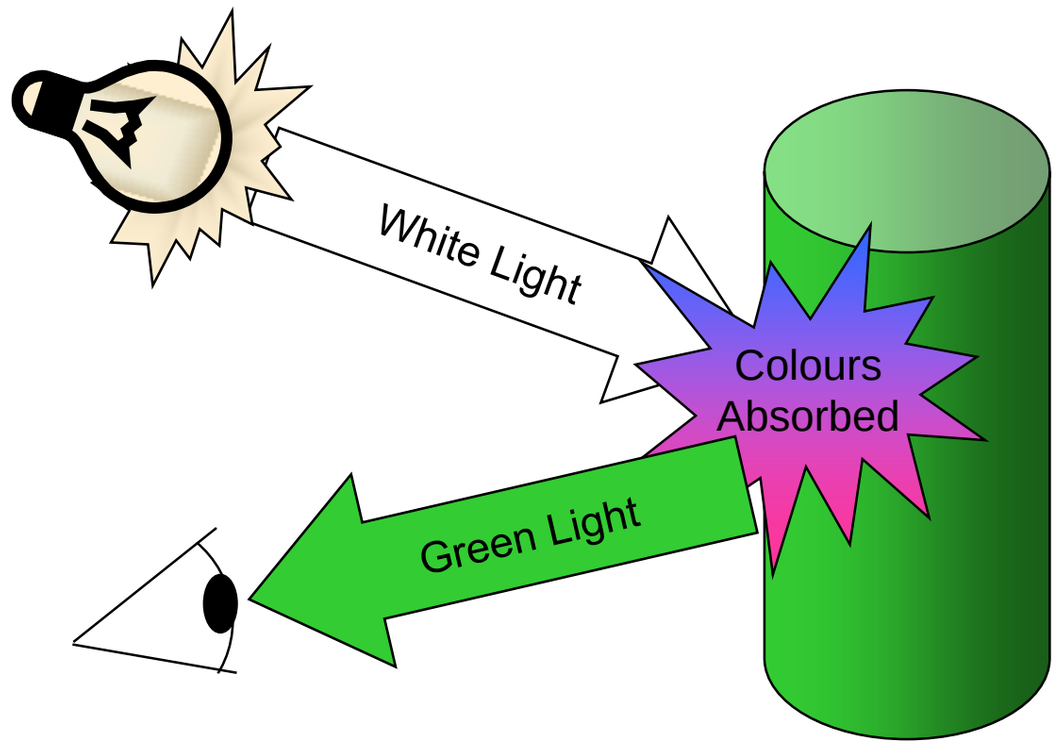
The electromagnetic spectrum is split up according to the wavelengths of different forms of energy



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 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

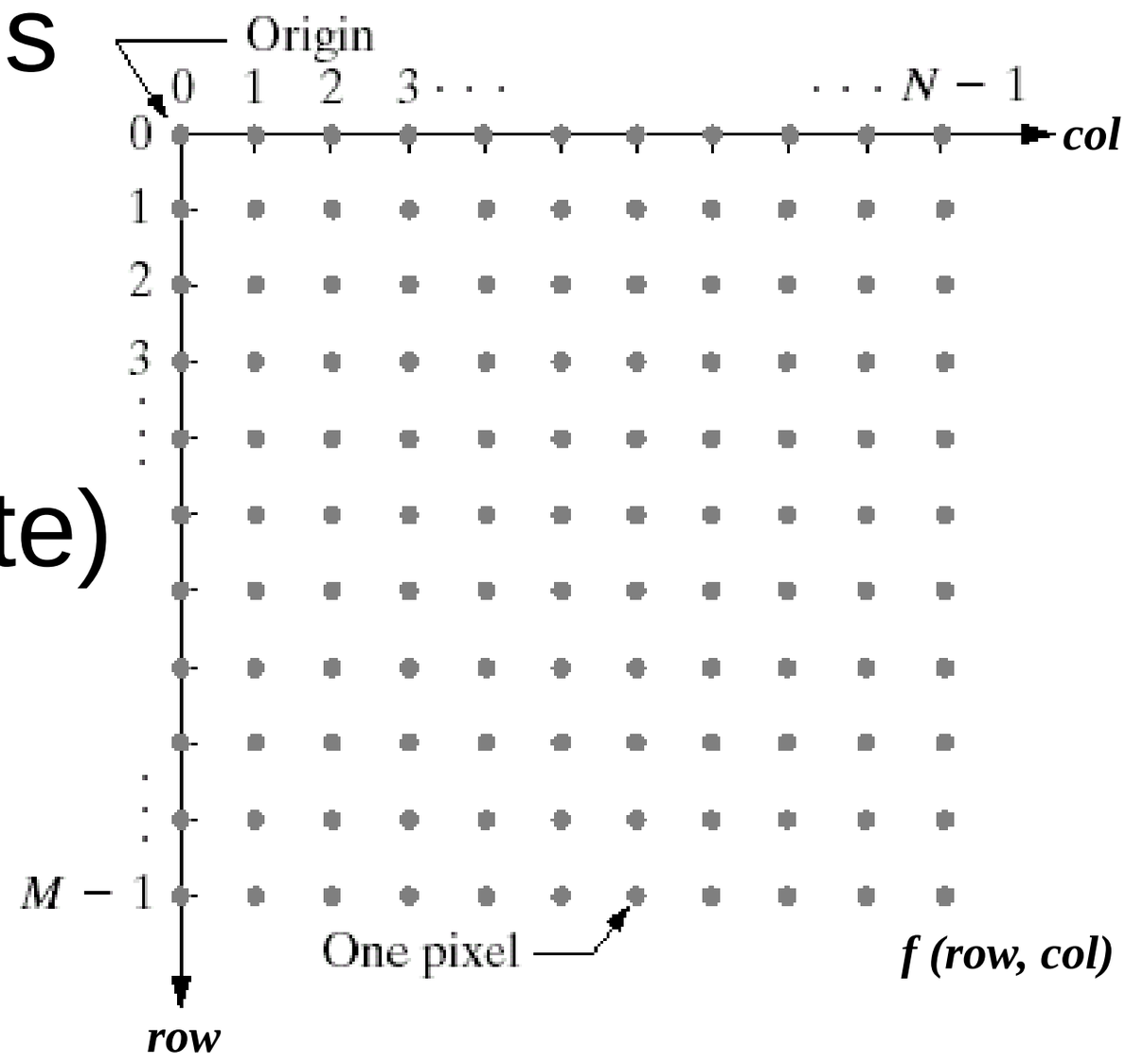
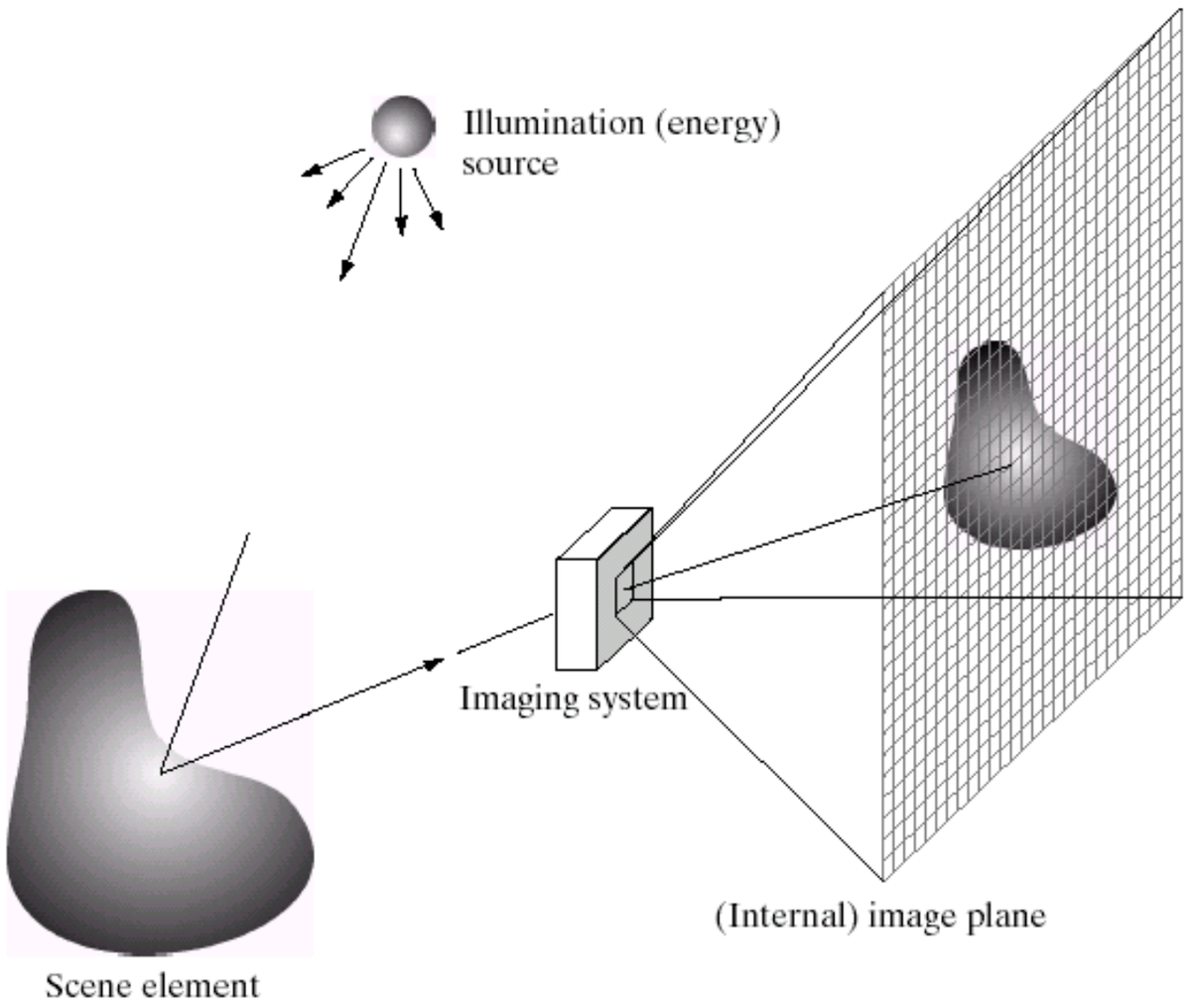


Image Acquisition

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



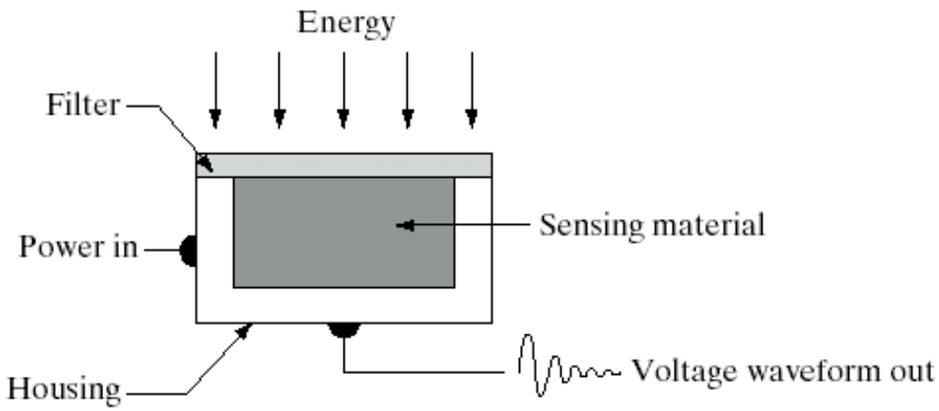
– Typical notions of illumination and scene can be way off:

- X-rays of a skeleton
- Ultrasound of an unborn baby
- Electro-microscopic images of molecules

Image Sensing

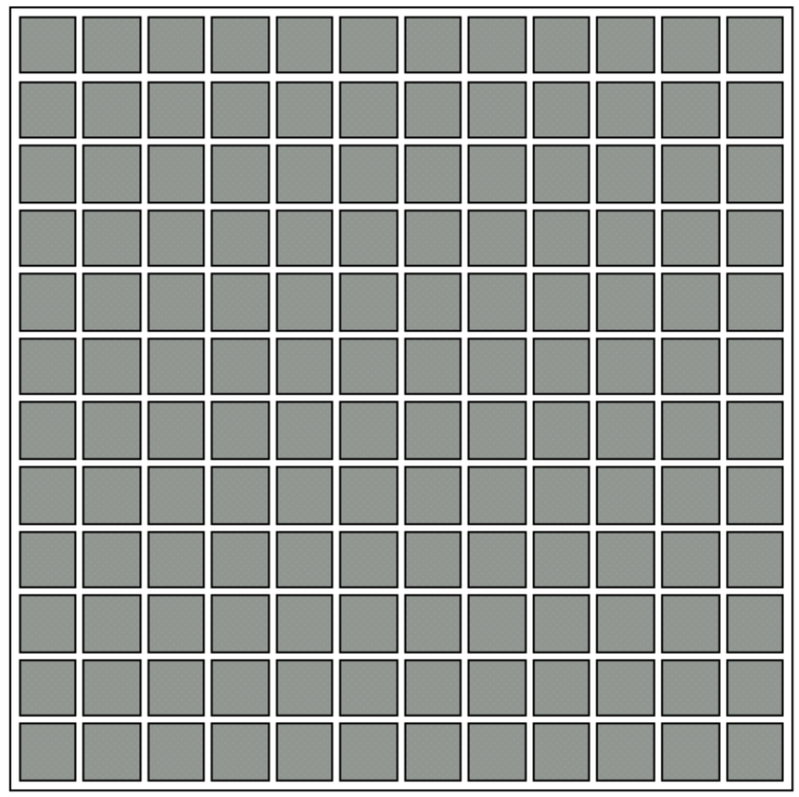
Incoming energy lands on a sensor material responsive to that type of energy and this generates a voltage

Collections of sensors are arranged to capture images



Imaging Sensor

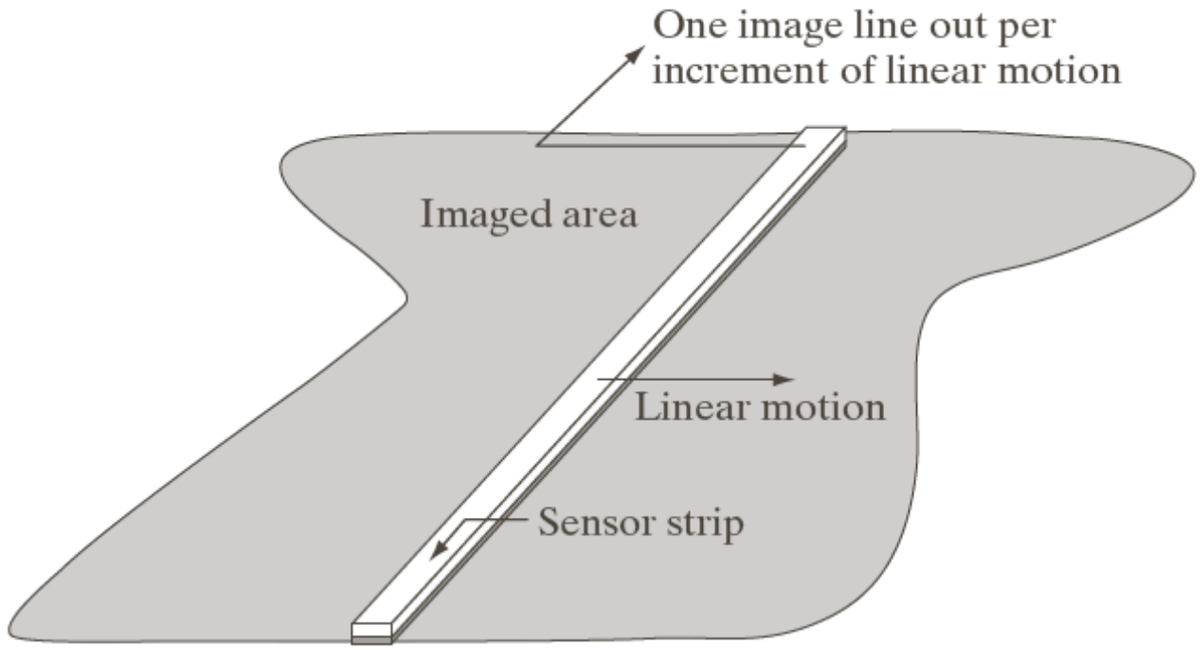
Line of Image Sensors

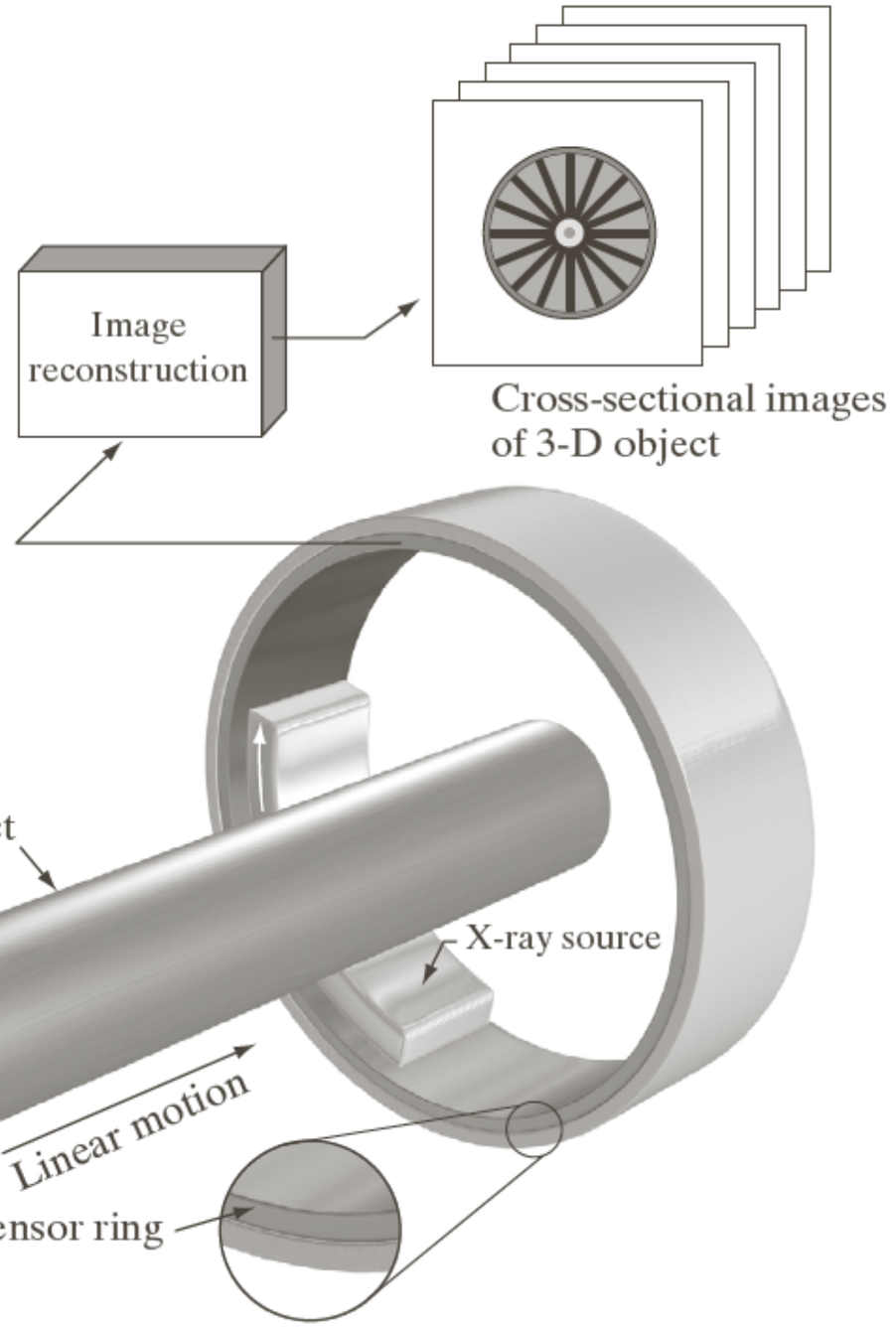


Array of Image Sensors

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

Image Sensing





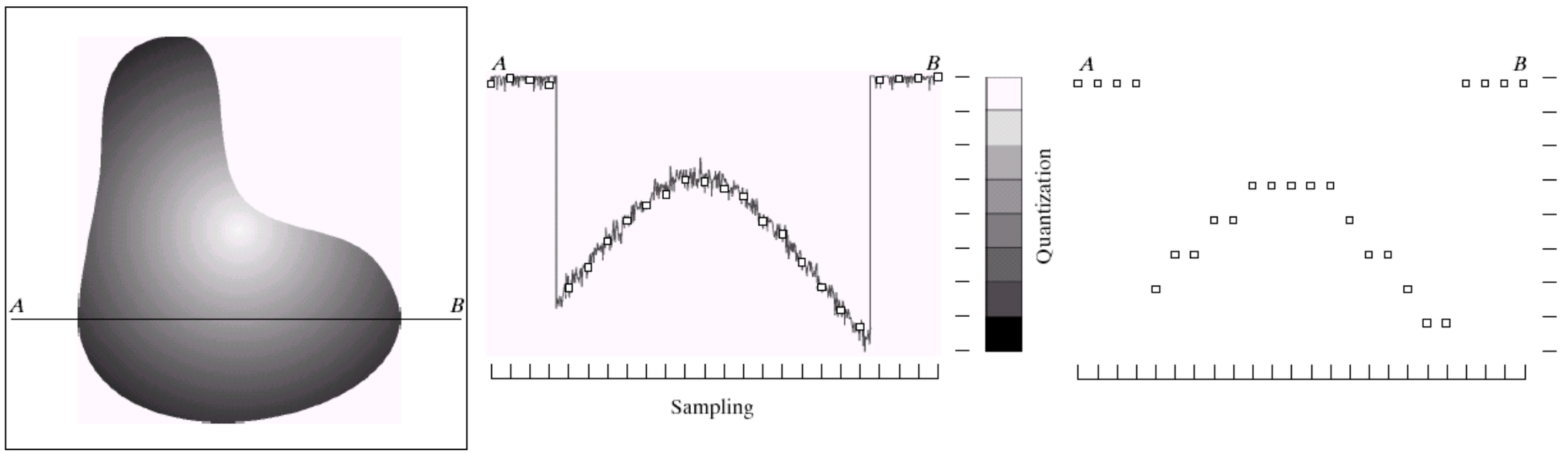
Using Sensor Strips and Rings

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

Image Sampling And Quantisation

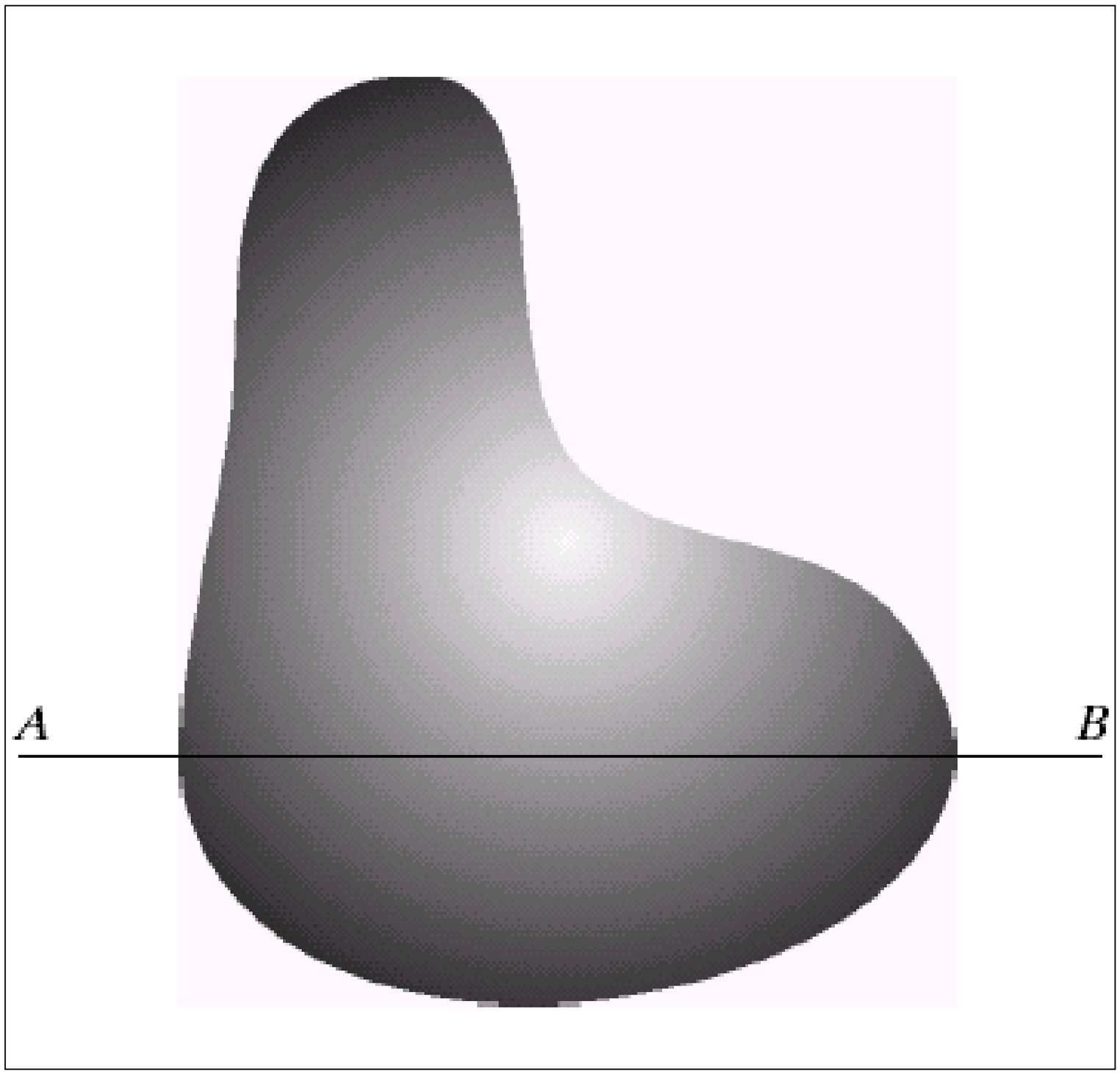
A digital sensor can only measure a limited number of **samples** at a **discrete** set of energy levels

Quantisation is the process of converting a continuous **analogue** signal into a digital representation of this signal



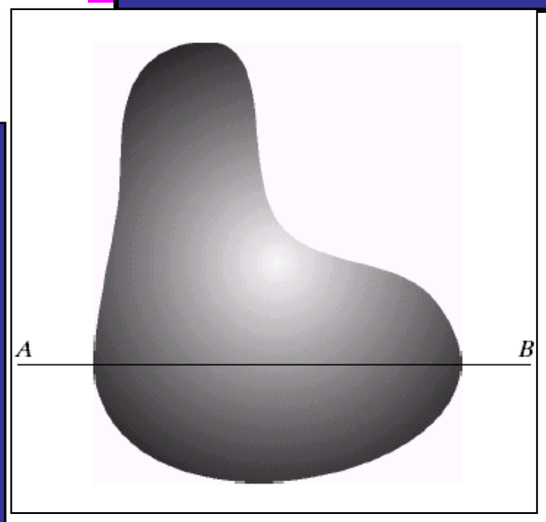
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

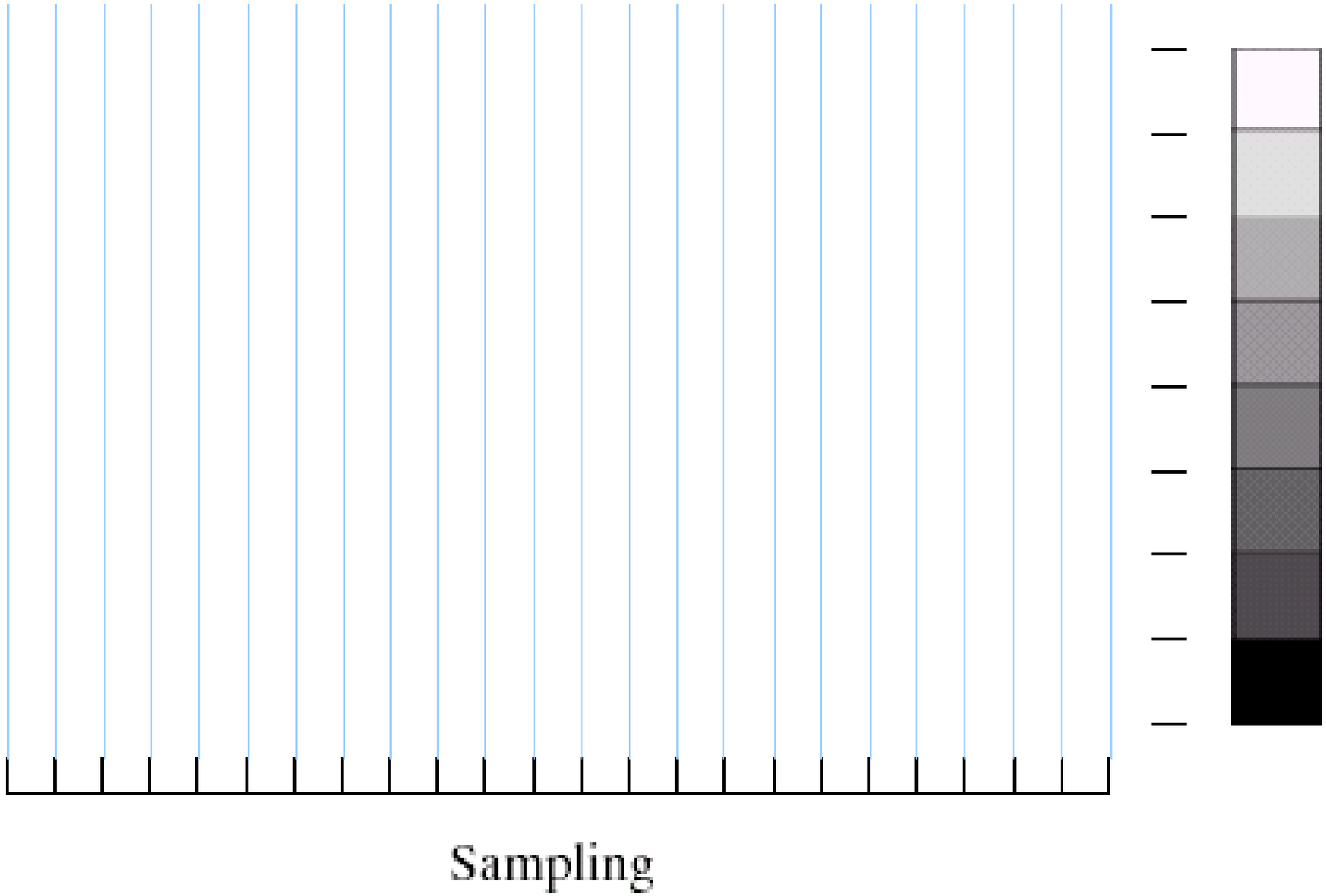
Image Sampling And Quantisation



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

Image Sampling And Quantisation





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

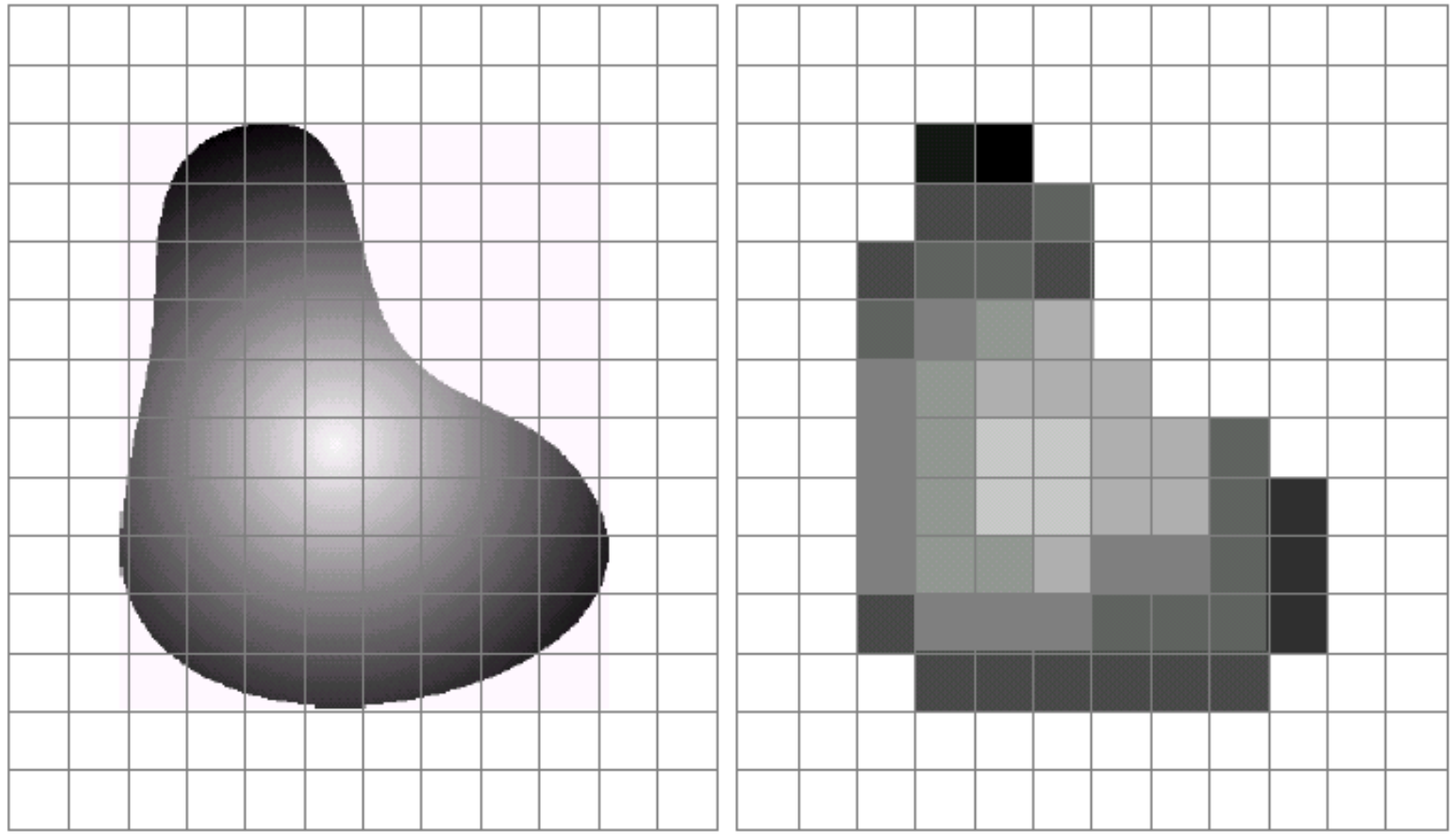
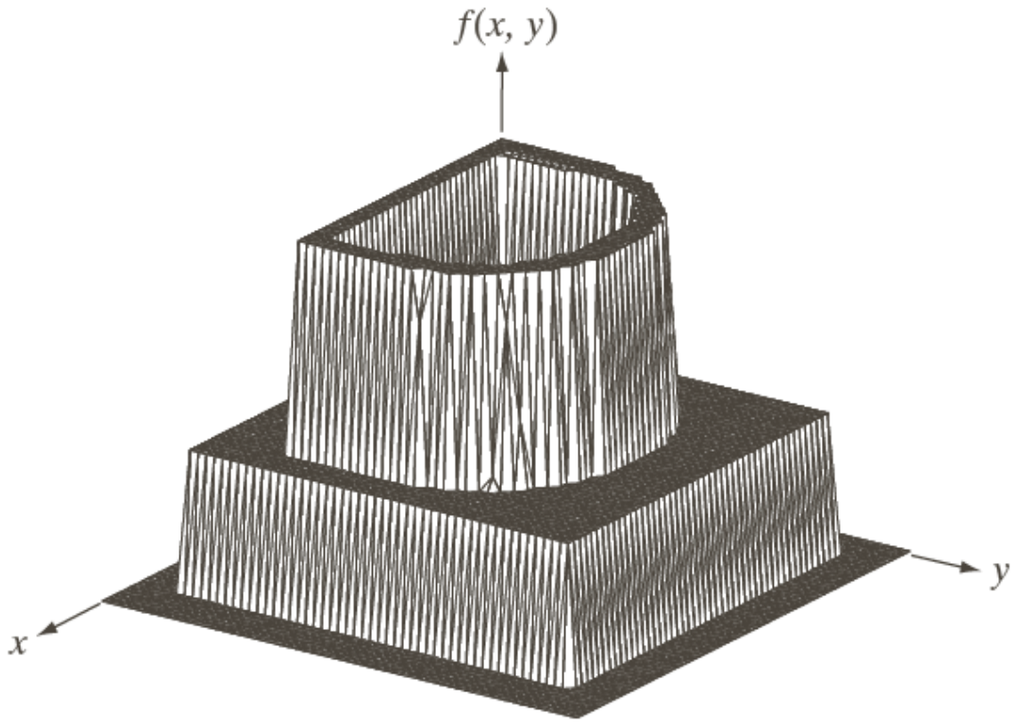
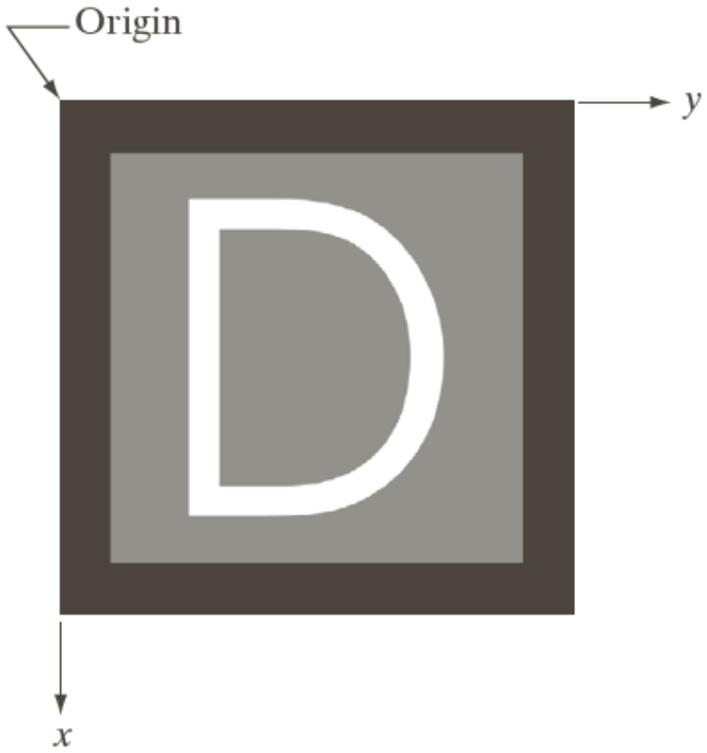


Image Representation





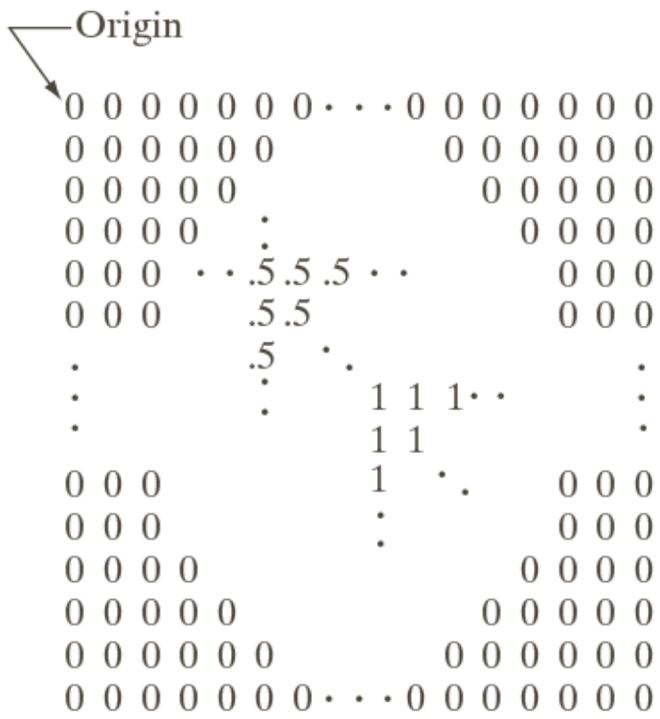
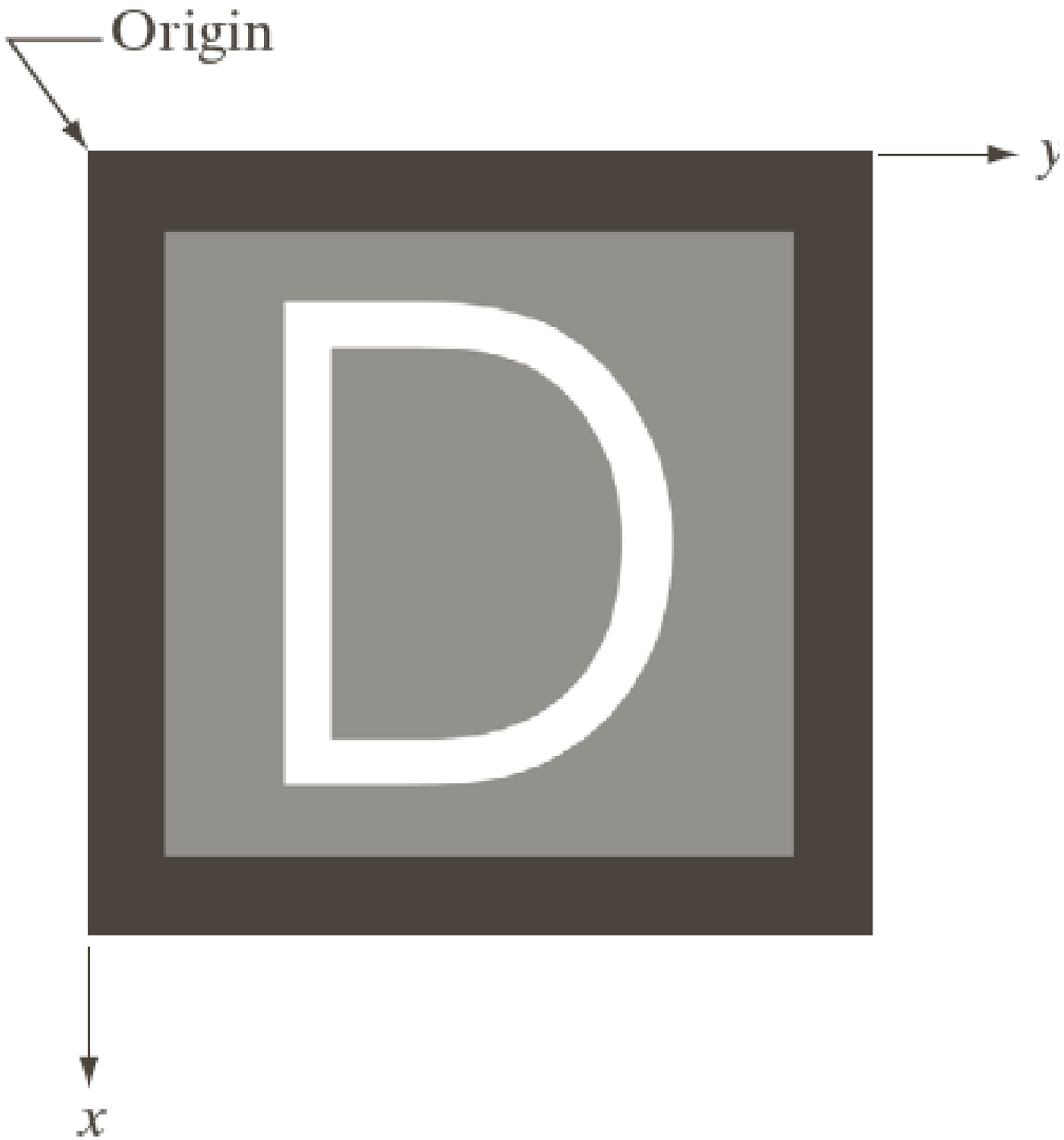
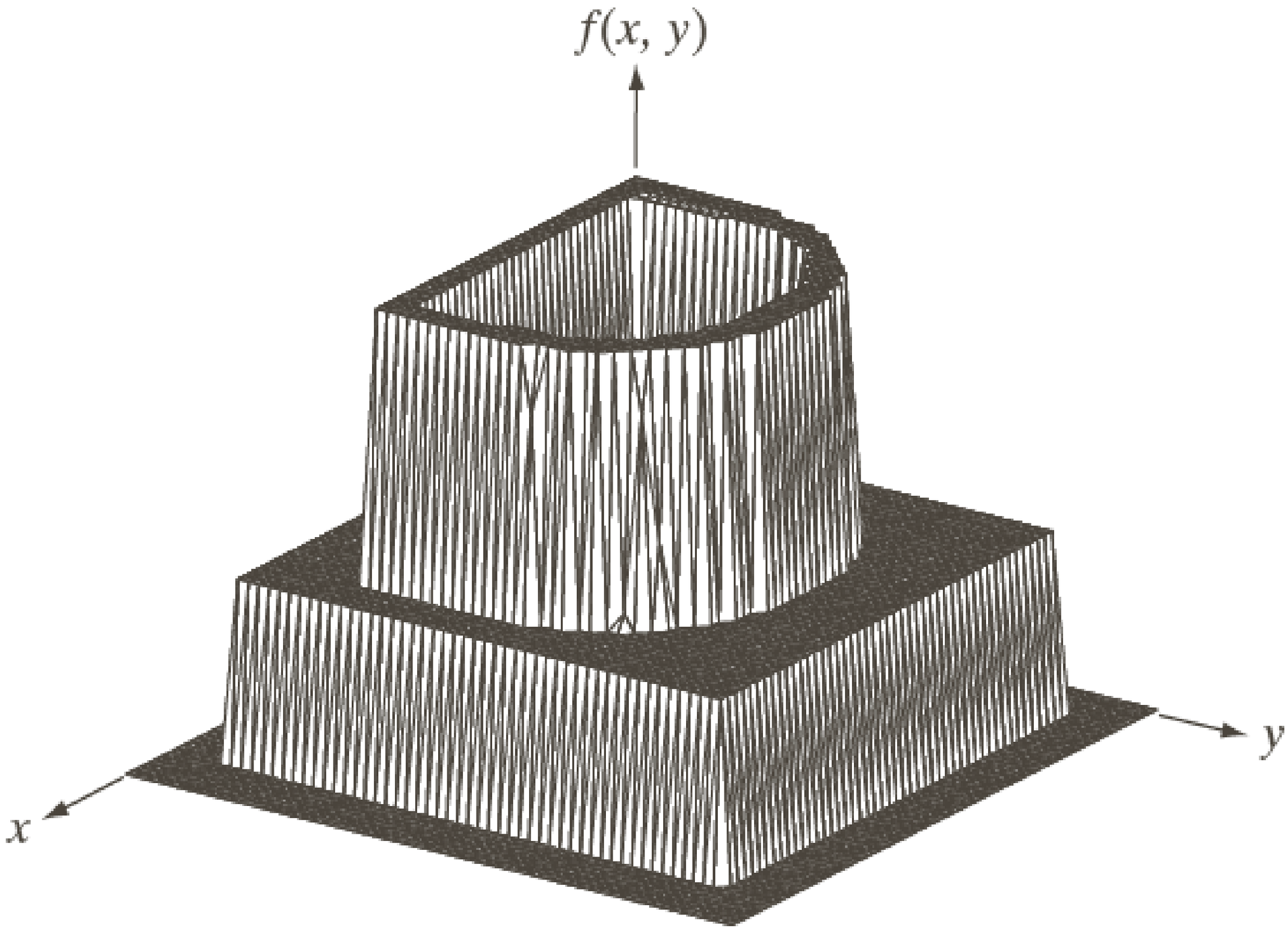


Image Representation



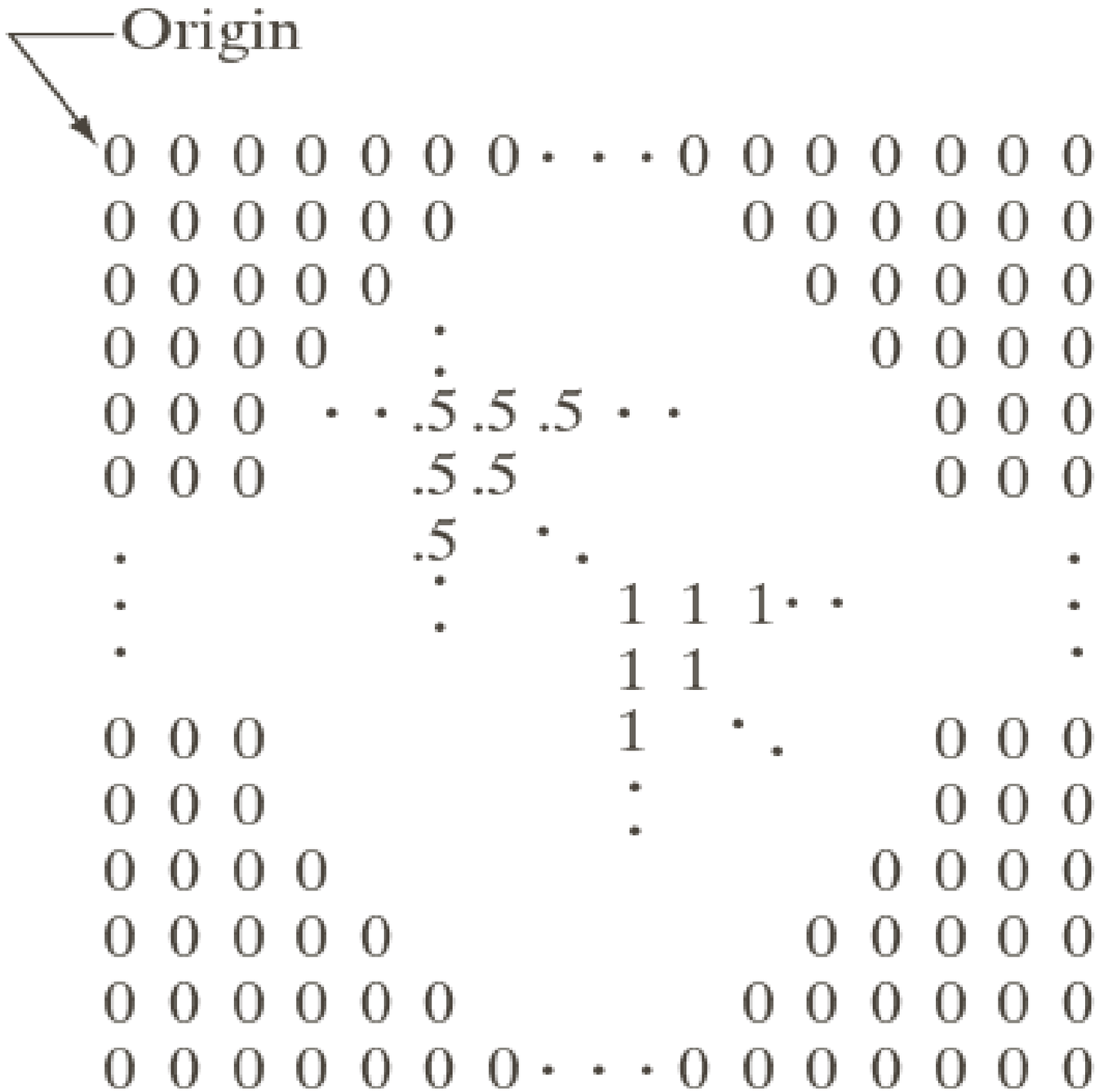
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

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 image

Vision specialists will often talk about pixel size

Graphic designers will talk about *dots per inch* (DPI)

Spatial Resolution (cont…)

1024

512

256

128

64

32

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

Spatial Resolution (cont…)

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

Spatial Resolution (cont…)

Spatial Resolution (cont…)

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

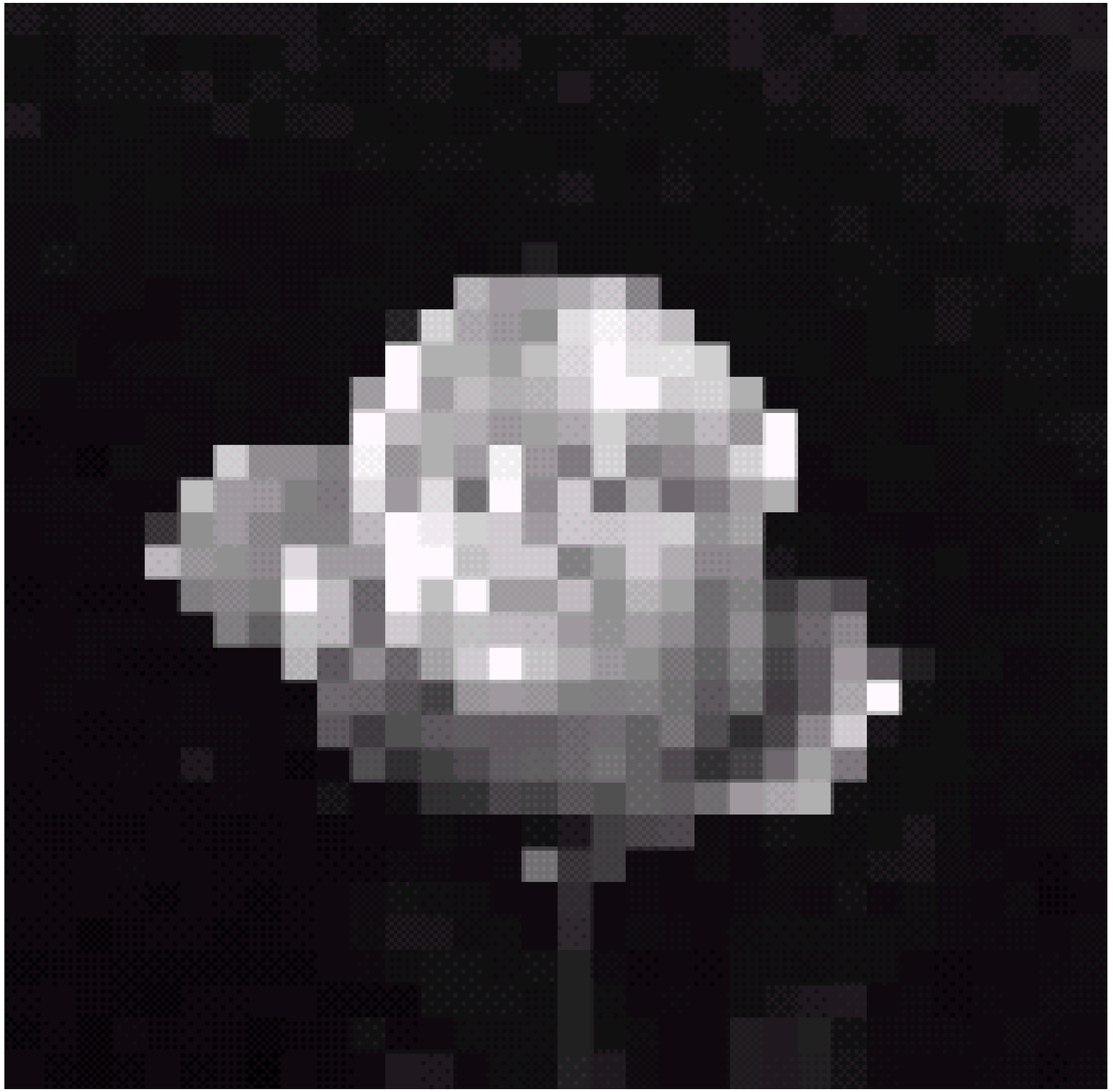
Spatial Resolution (cont…)

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

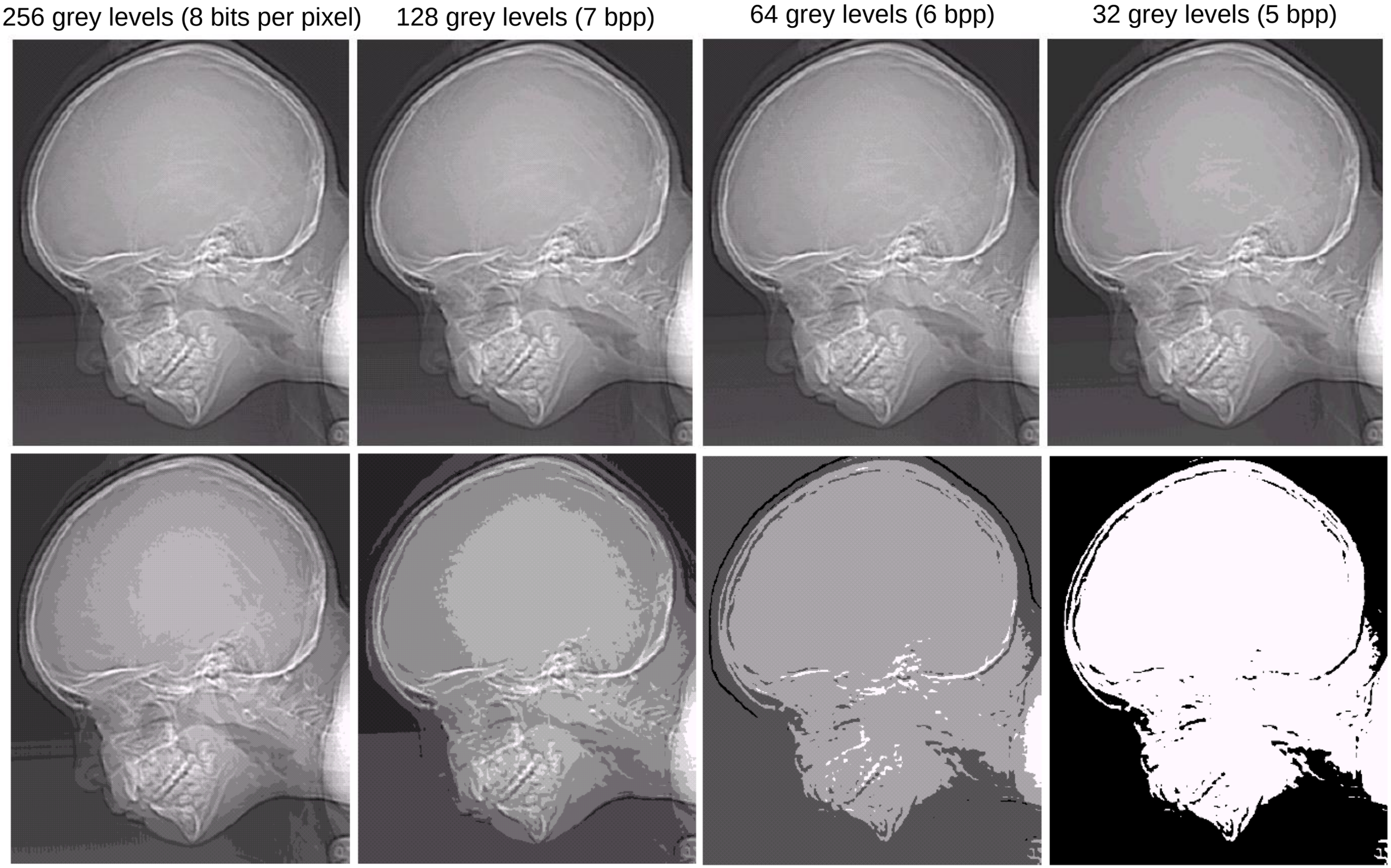
Intensity level resolution refers to the number of intensity levels used to represent the image

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…)

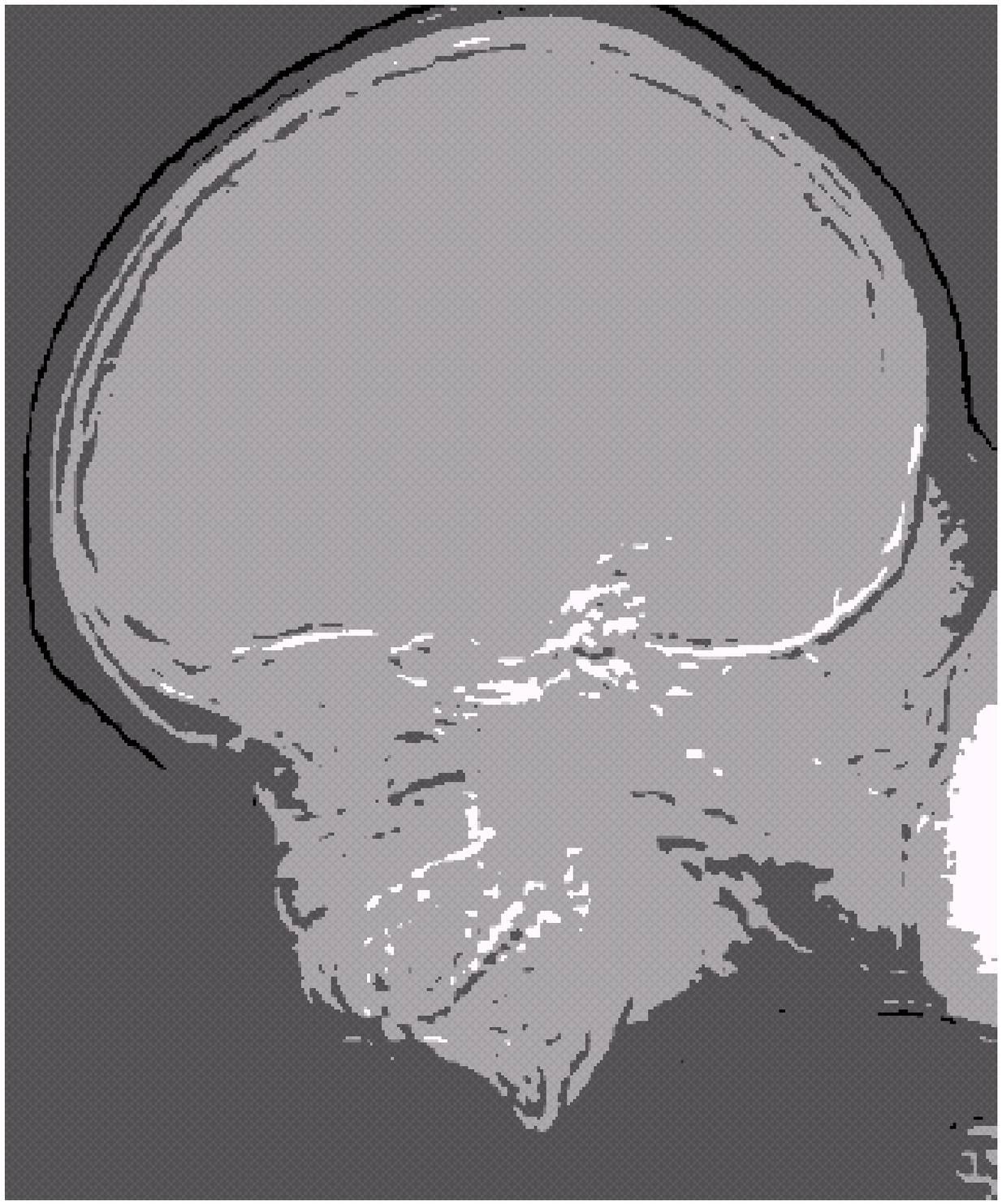
Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)



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

Intensity Level Resolution (cont…)

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

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

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

Thank you !!!