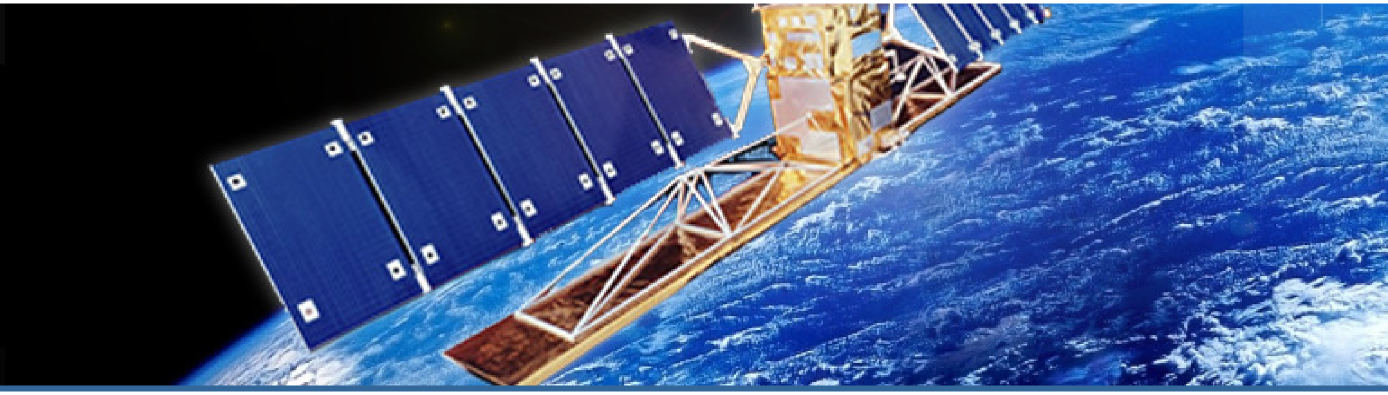

Digital Image Processing

Introduction

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2016

Structure of Course

Assessment

- Final exam (70%)
- Project (30%)

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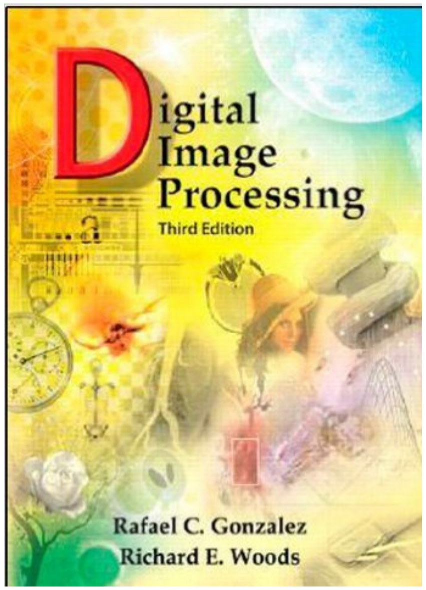
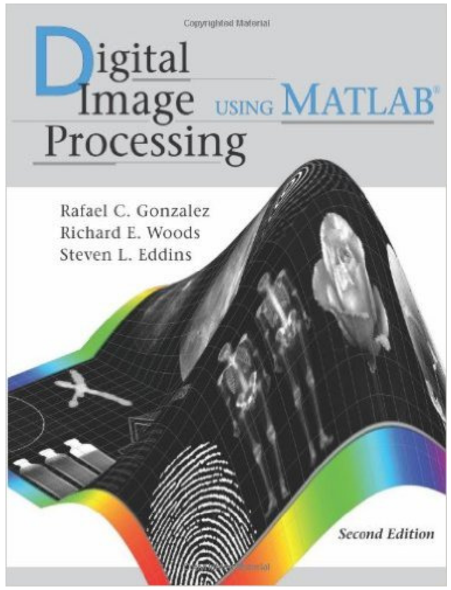
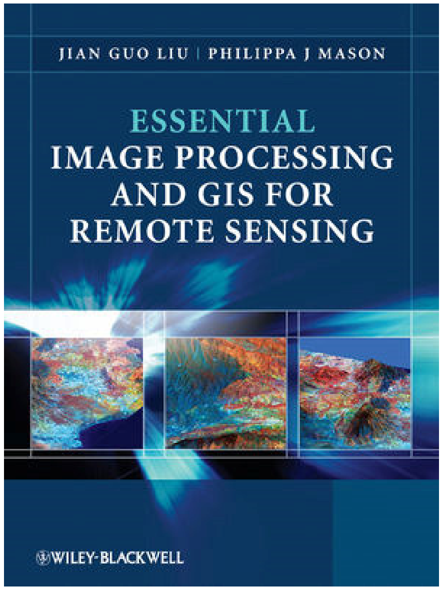
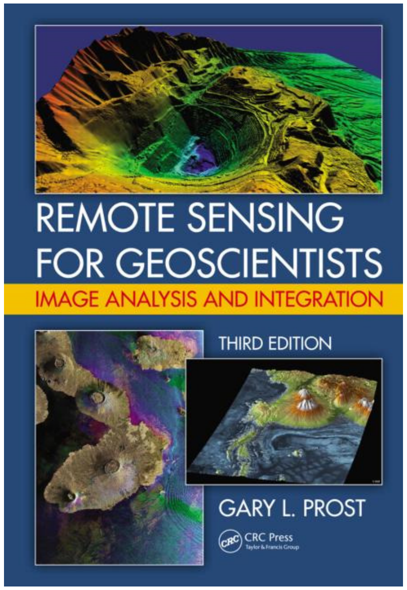
References



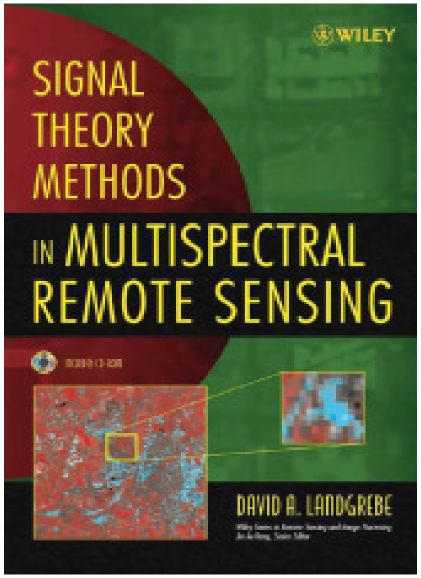


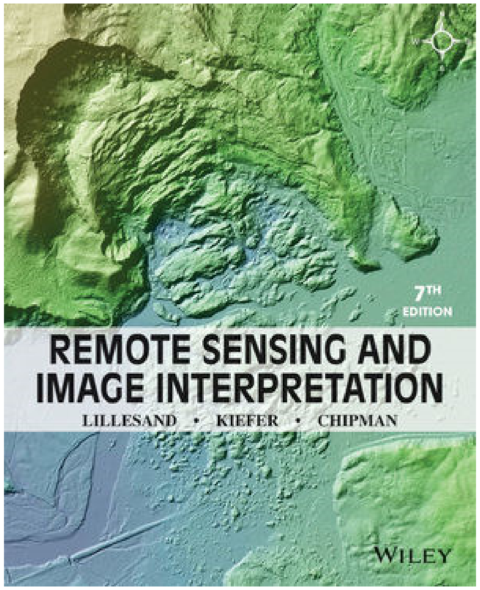


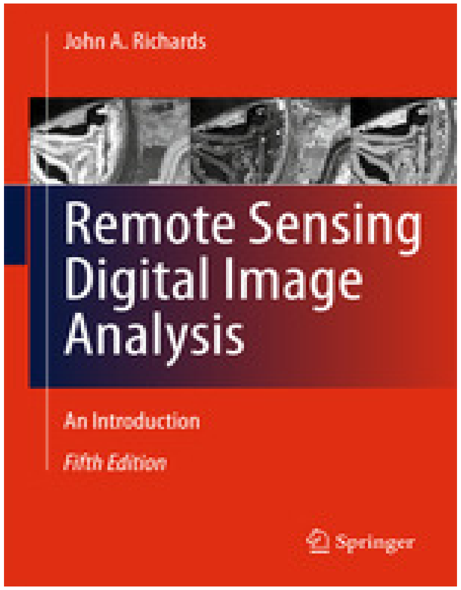


- ✓ *Digital Image Processing (3rd Edition)*
- ✓ *Digital Image Processing Using MATLAB, 2nd ed*
- ✓ *Essential Image Processing and GIS for Remote Sensing*
- ✓ *Remote Sensing for Geoscientists: Image Analysis and Integration*

References







- ✓ *Signal Theory Methods in Multispectral Remote Sensing*
- ✓ *Remote Sensing and Image Interpretation*
- ✓ *Remote Sensing Digital Image Analysis*

Course Overview

1. Introduction to Digital Image Processing
2. Introduction to Remotely sensed images
3. Image Pre-processing
4. Image Transformations
5. Image Filtering in spatial and frequency domain
6. Image classification

Introduction to Digital Image Processing

Content

- ✓ What is image processing?
- ✓ History
- ✓ Introduction
- ✓ Electro-Magnetic Spectrum
- ✓ Fundamental steps in DIP
- ✓ Components of an Image Processing System
- ✓ What is an Image?
- ✓ Images and Photographs
- ✓ Image Sampling and Quantization
- ✓ Representing Digital Images
- ✓ Definition of Sampling Frequency
  - Spatial Resolution
  - Intensity Level Resolution
  - Brightness
  - Tone
  - Image Texture
- ✓ Neighborhood
- ✓ Images Files and Formats

What is image processing

- ✓ *Is enhancing an image or extracting information or features from an image*
- ✓ *Computerized routines for information extraction (eg, pattern recognition, classification) from remotely sensed images to obtain categories of information about specific features.*

Image Processing Includes

- ✓ *Image quality and statistical evaluation*
- ✓ *Radiometric correction*
- ✓ *Geometric correction*
- ✓ *Image enhancement and sharpening*
- ✓ *Image classification*
  - *Pixel based*
  - *Object-oriented based*
- ✓ *Accuracy assessment of classification*
- ✓ *Post-classification and GIS*
- ✓ *Change detection*

History

- *In 1920s Submarine cables were used to transmit digitized newspaper pictures between London and New York using Bartlane systems.*

- *Specialized printing equipments were used to code the images and reproduced at receiver using telegraphic printers.*

Image produced using telegraphic printer

History

In 1921, photographic printing press improved the resolution and tonal quality of images.

Bartlane system was capable of coding 5 distinct brightness levels.

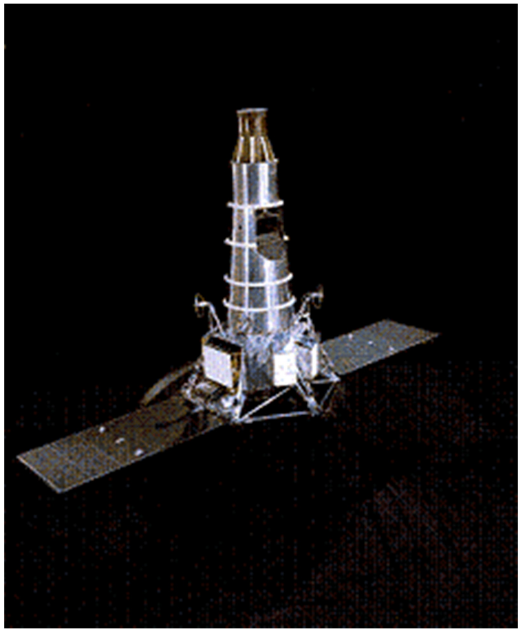
It increased to 15 by 1929.

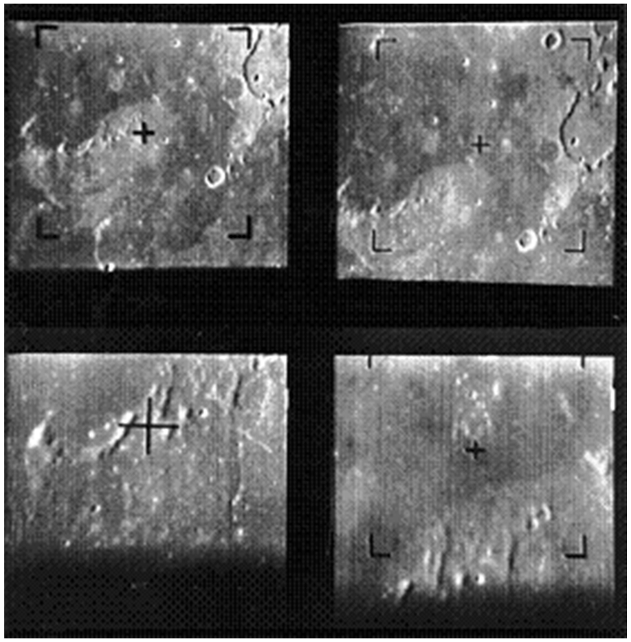
History

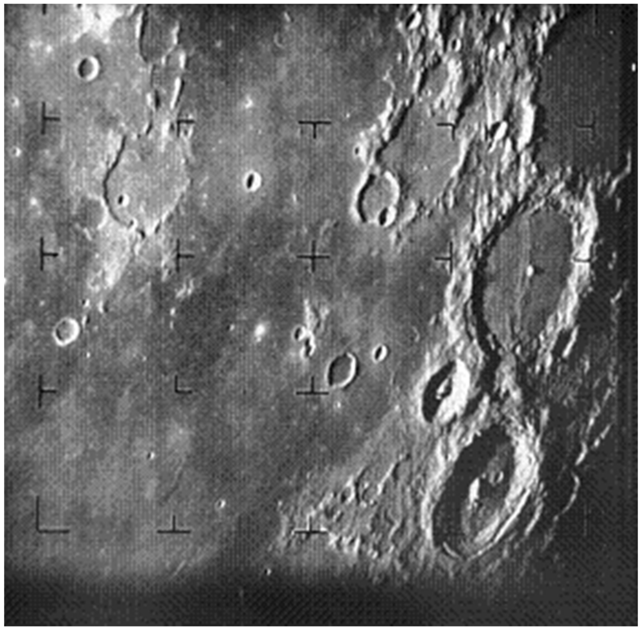
After 35 years of improvement in processing technique

In 1964, Computer processing techniques were used to improve picture of moon transmitted by Ranger 7 at JPL.

This was the basis of modern image processing technique.







Introduction

- ✓ *Why do we need Image Processing?*

- ✓ *It is motivated by 3 major applications:*
  - *Improvement of pictorial information for human perception.*
  - *Image processing for autonomous machine application.*
  - *Efficient storage & transmission.*

Introduction

Improvement of pictorial information for human interpretation and analysis.

Typical applications:

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

Filtering

Image Enhancement

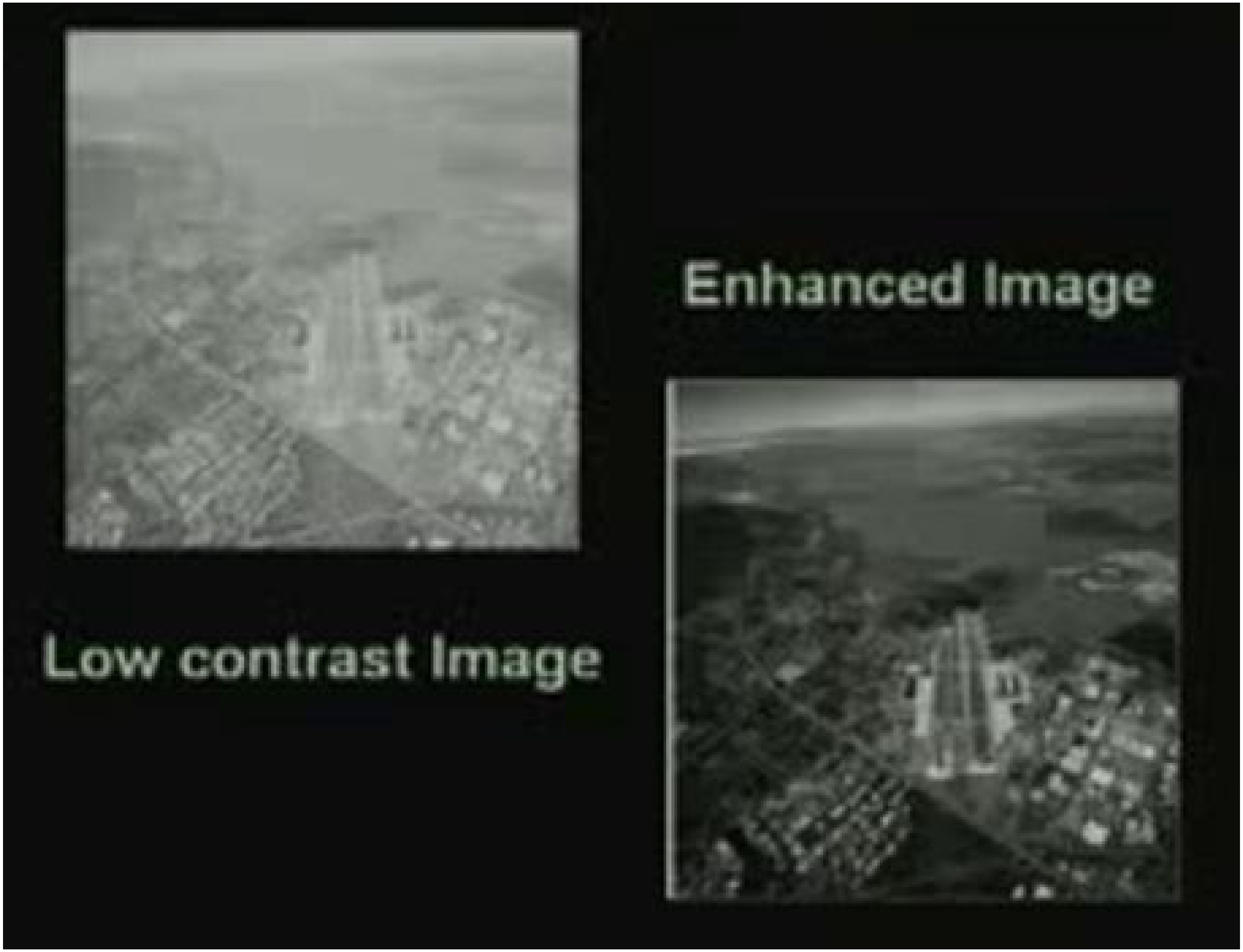
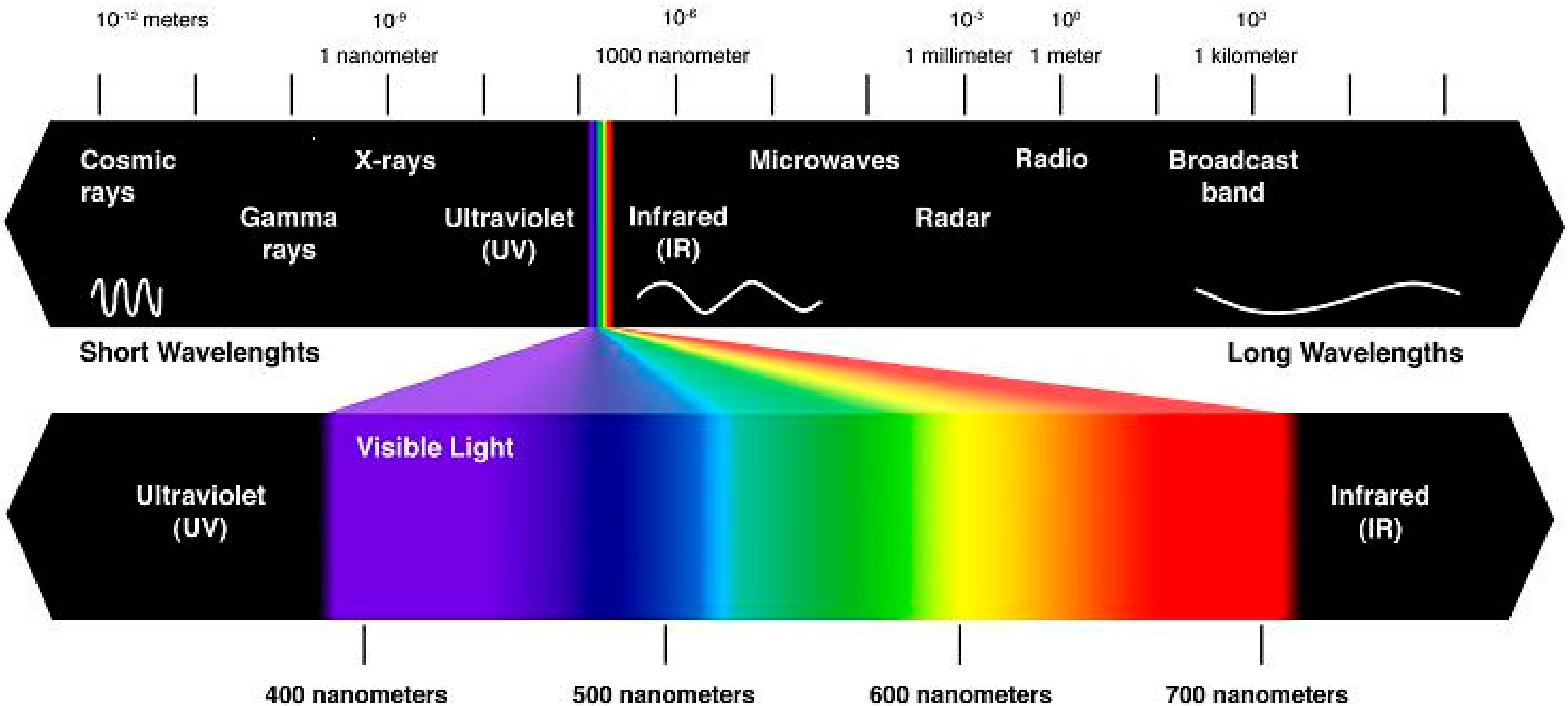
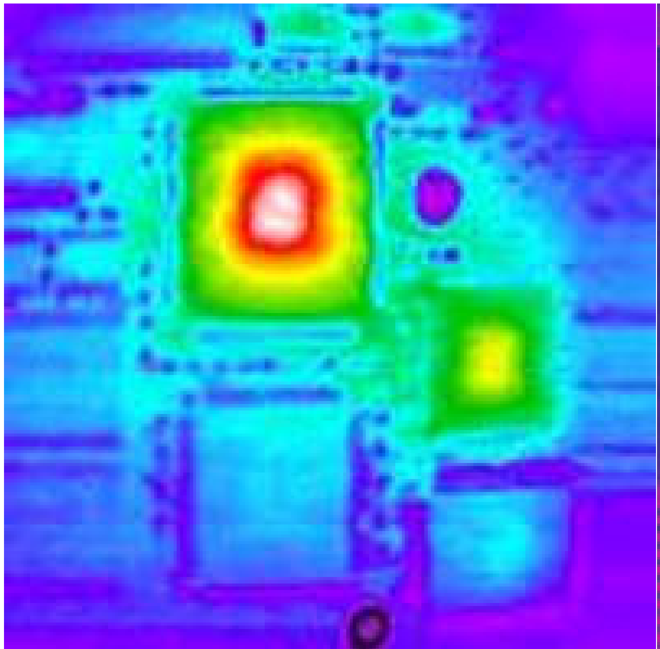


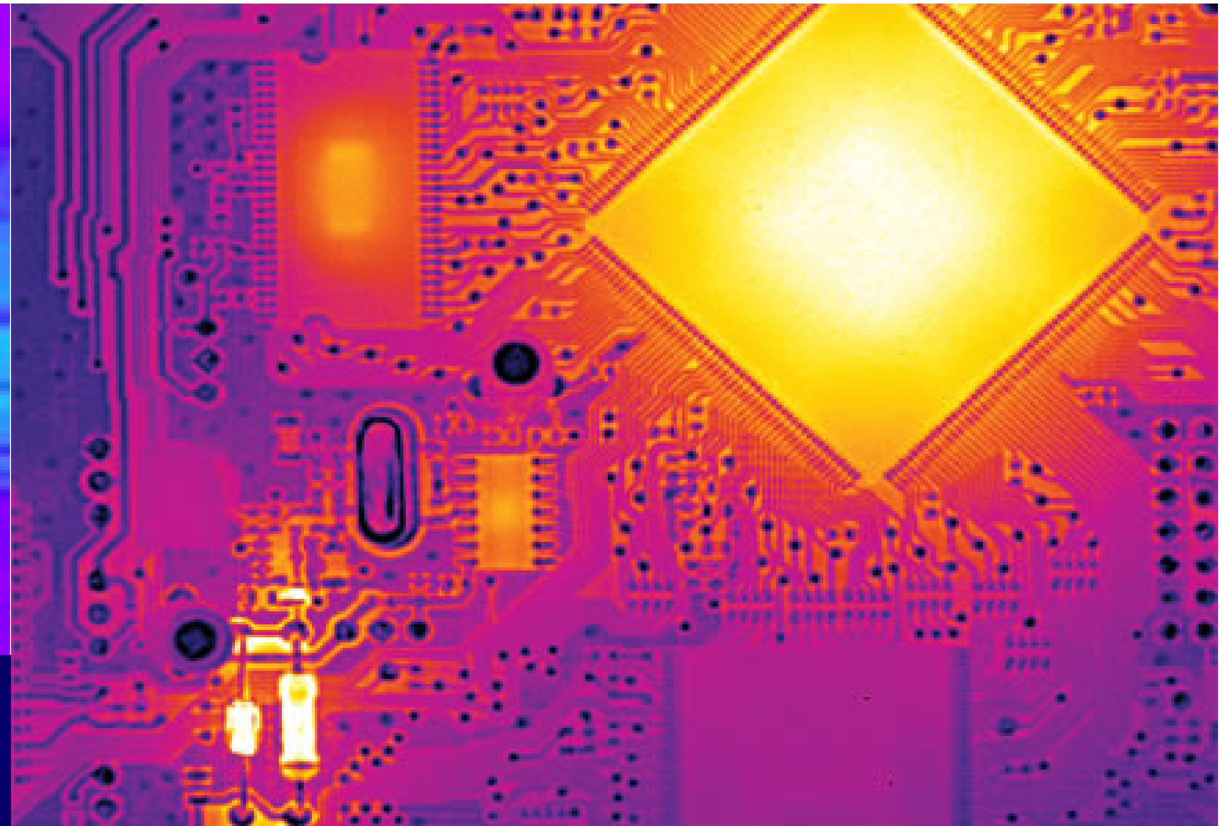
Image Deblurring

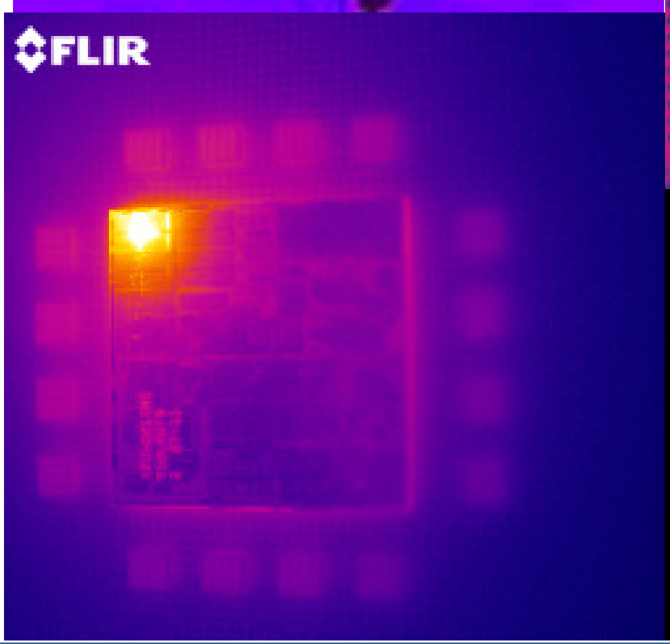
Electro-Magnetic Spectrum



IR Imaging (Performance)





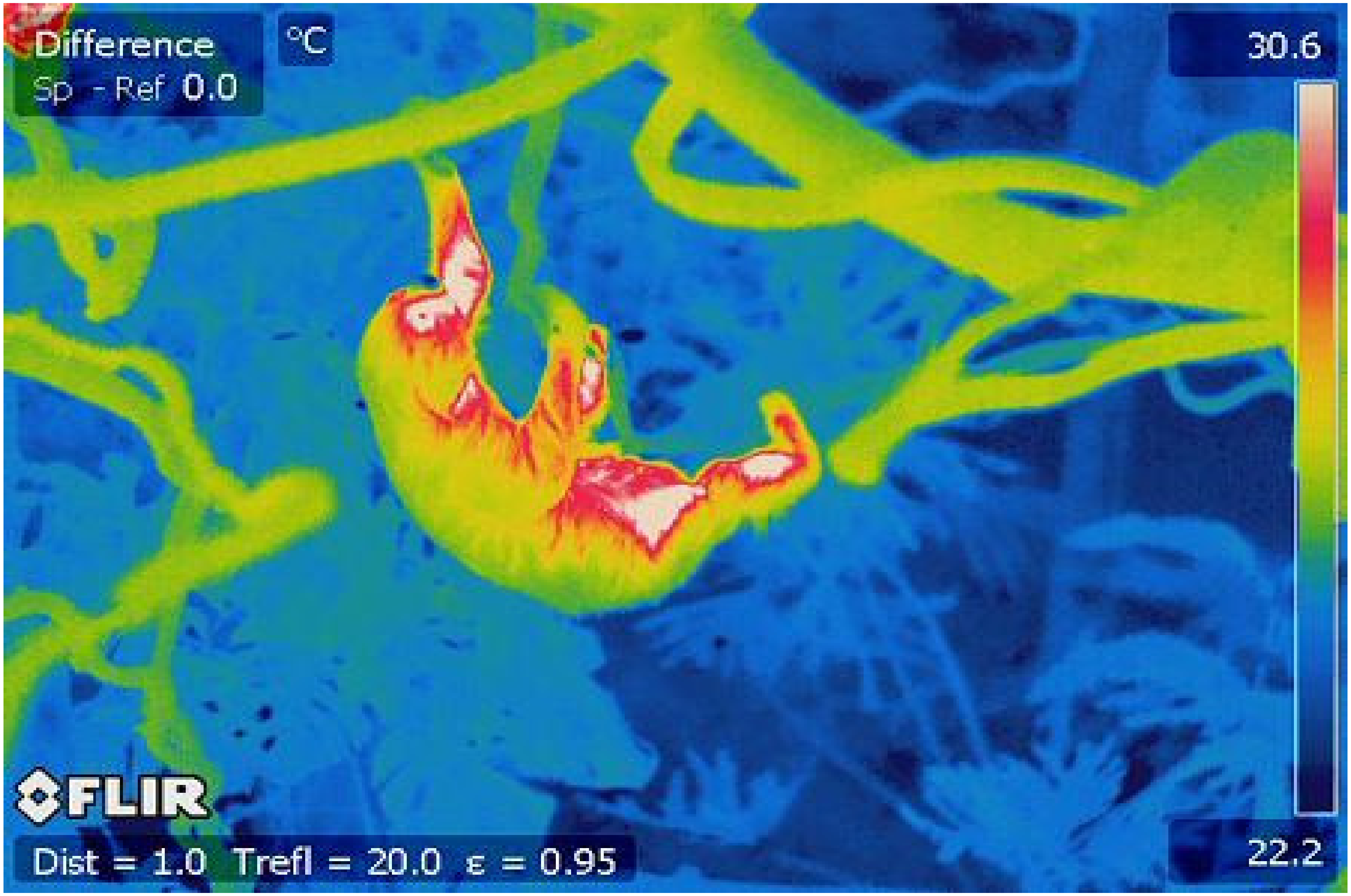


Thermal / IR view of a Chip

IR Imaging (Natural Calamity)

IR satellite view of Augustine volcano

IR Imaging (Night Vision)

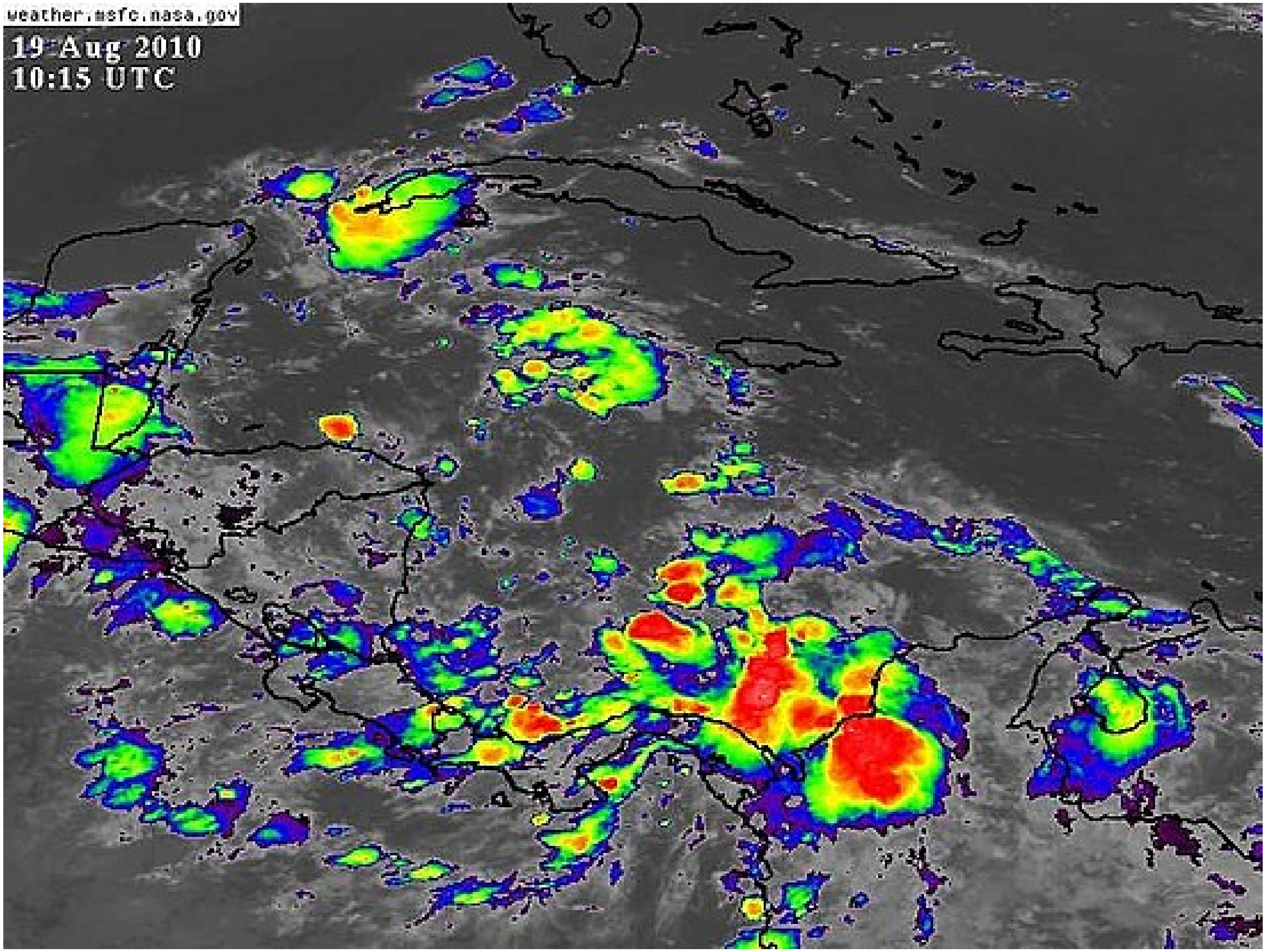


IR image of a sloth at night

IR Imaging (Night Vision)

Night vision system used by soldiers

IR Imaging (Weather)

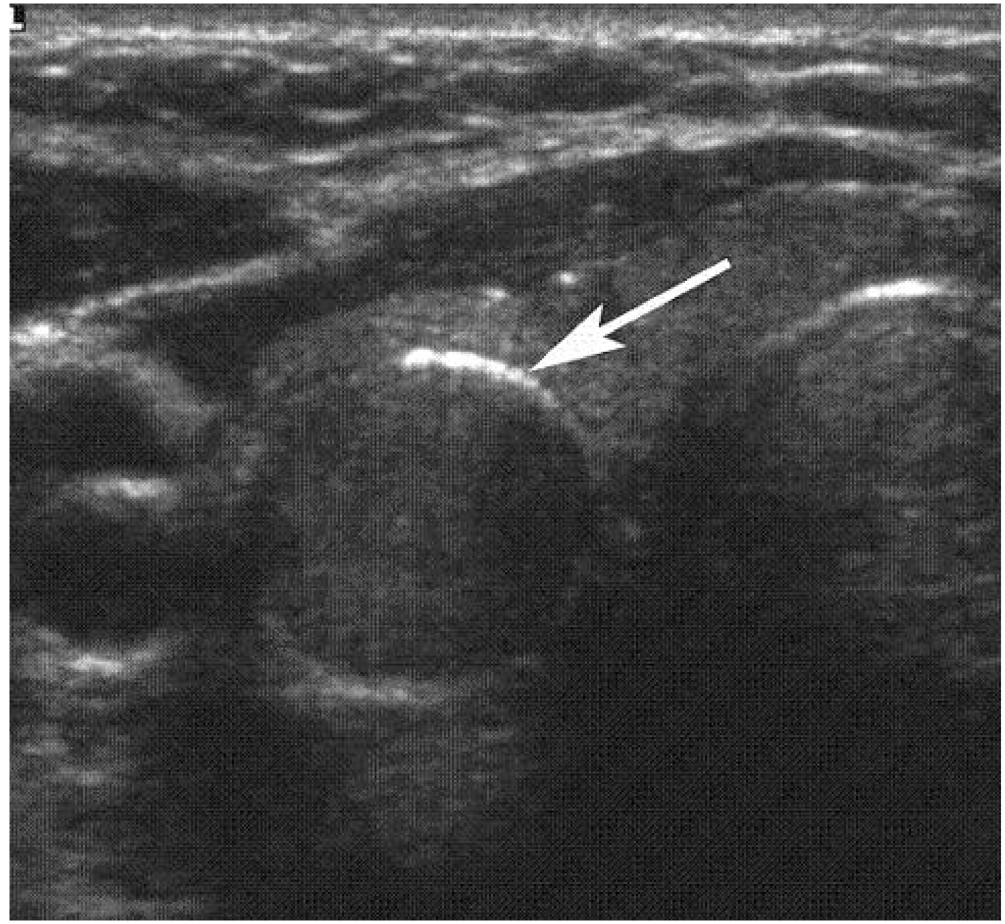


IR Satellite Imagery

IR Imaging (Astronomy)

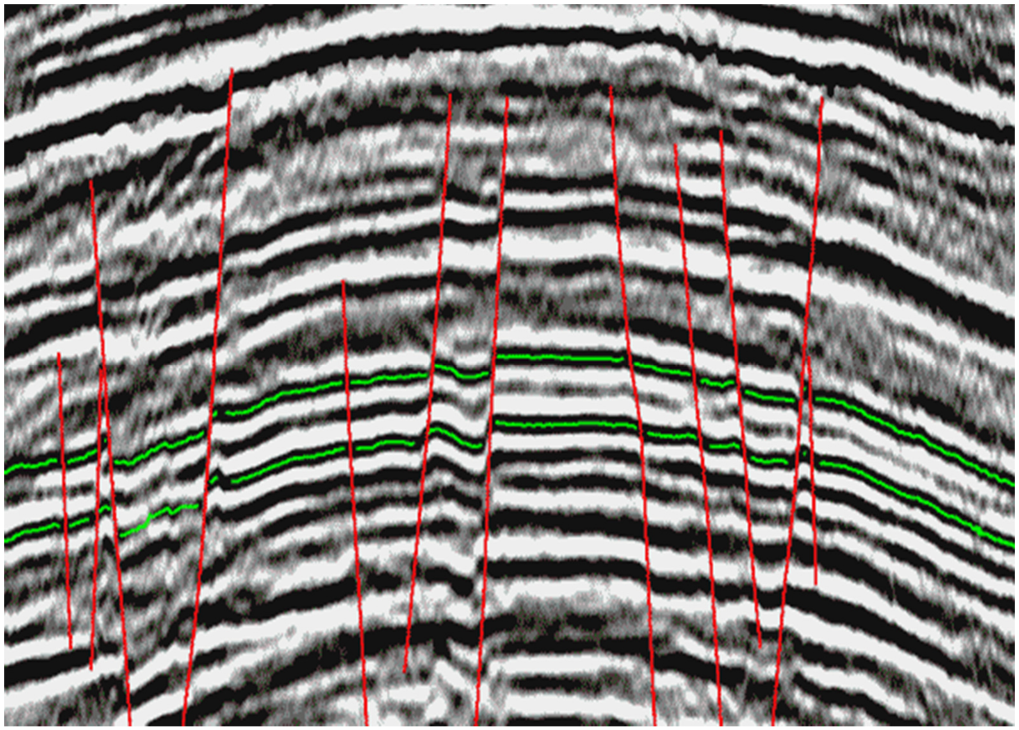
Nebula NGC 1514 01 in Visible (left) and Infrared (right)

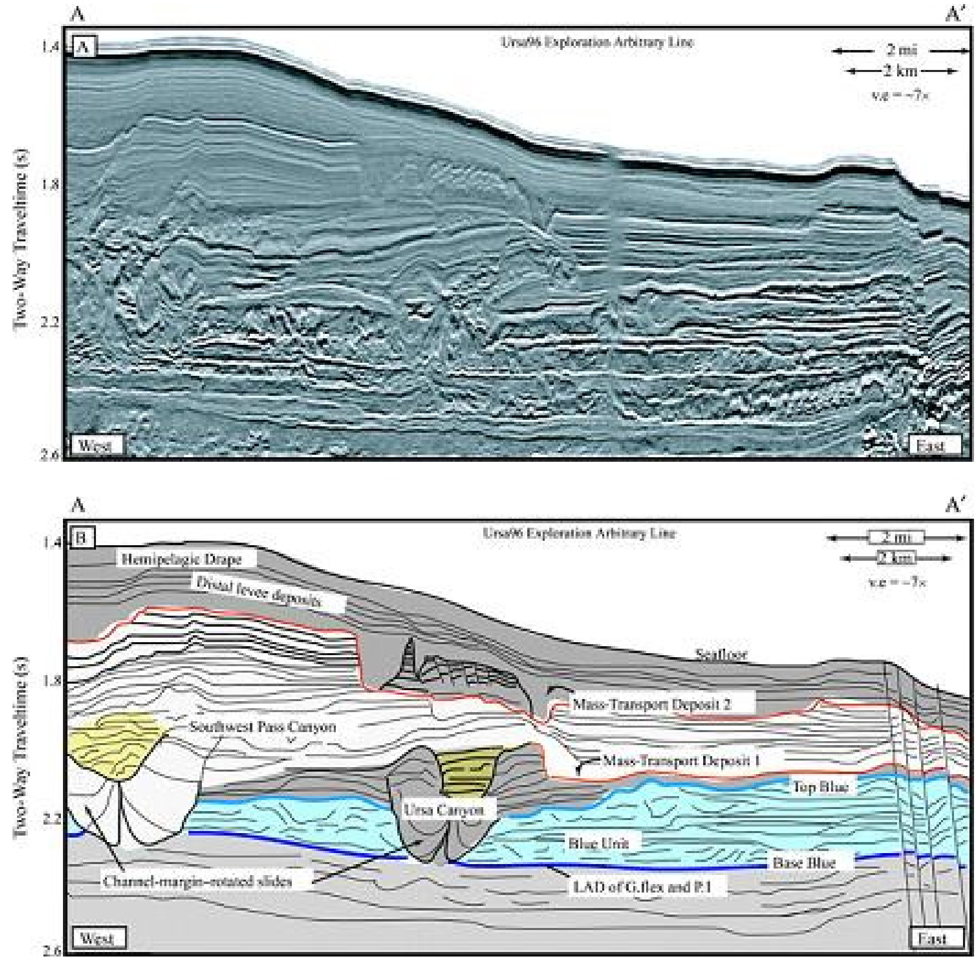
Ultrasound imaging (Medical)



Fetus and Thyroid using ultrasound

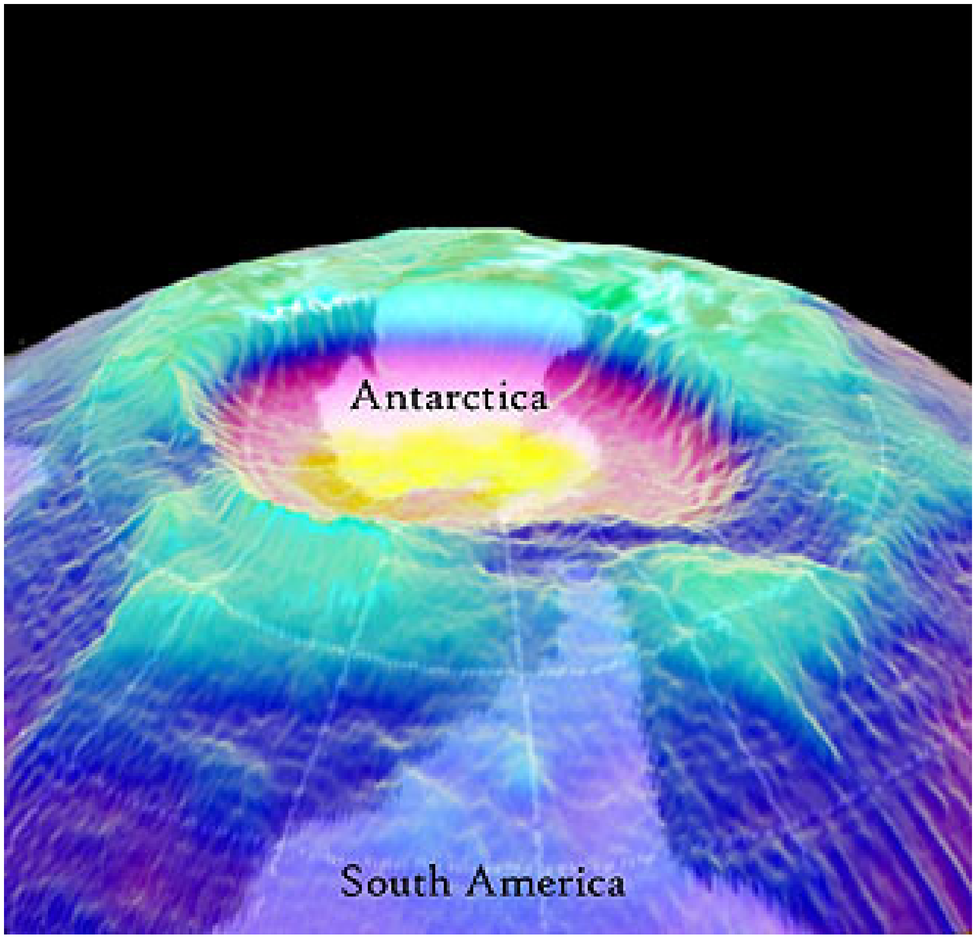
Seismic imaging (Earthquake)

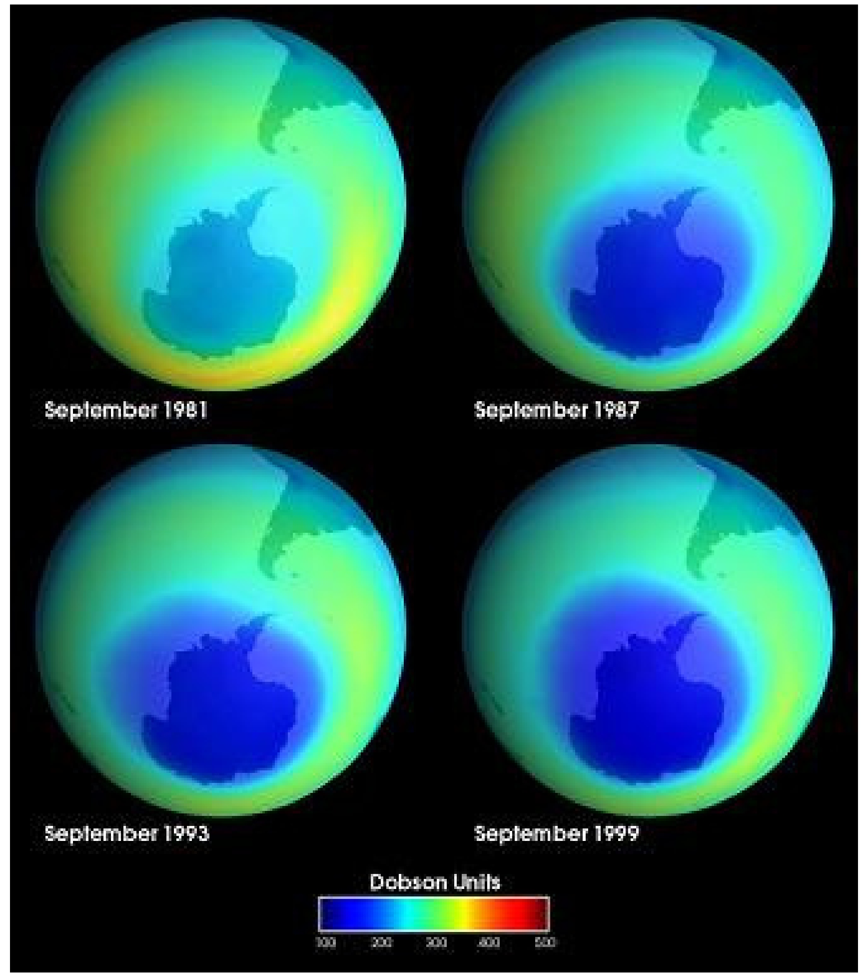




Detecting Earthquakes and its cause using cross sectional view

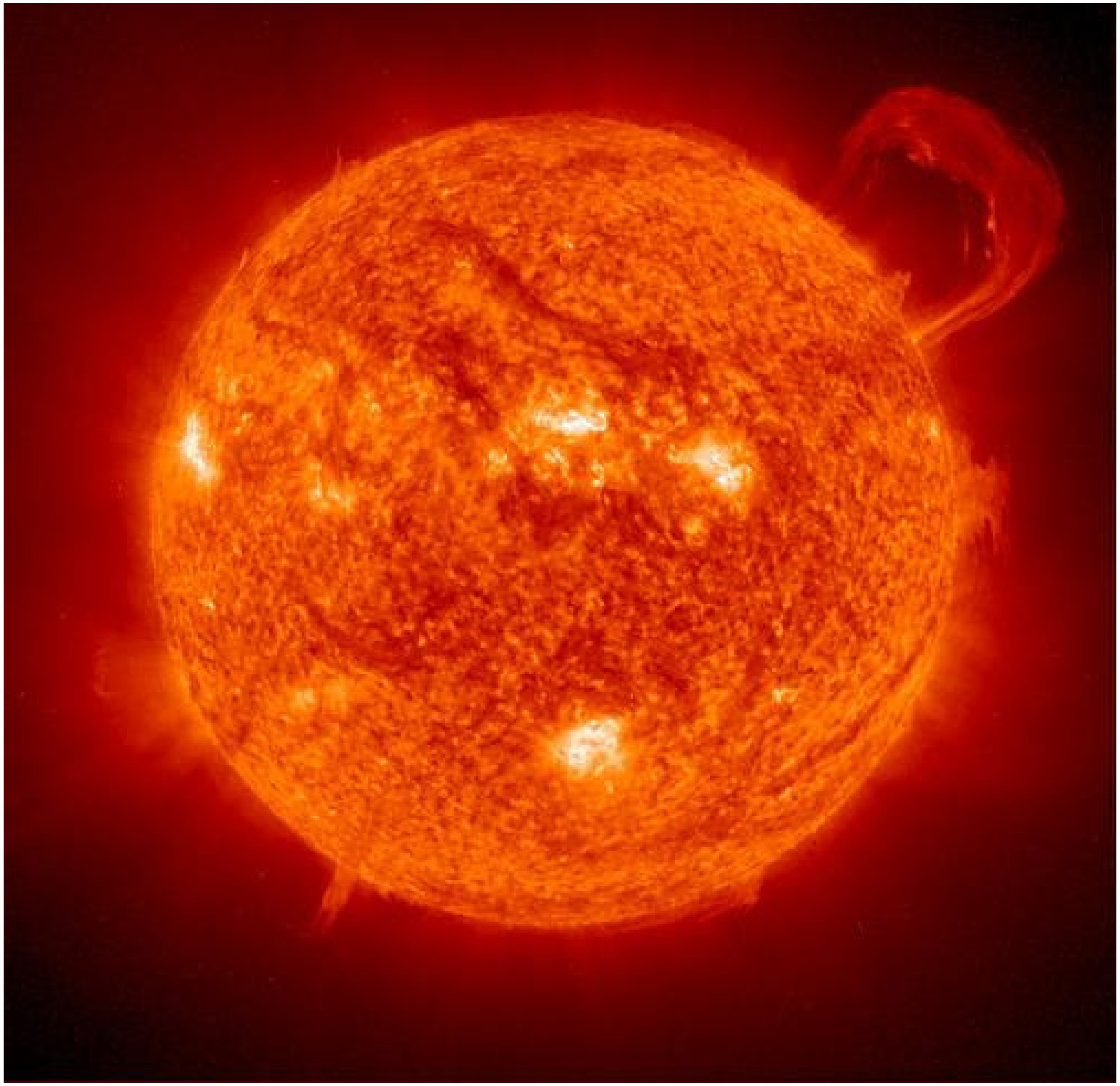
UV imaging (Ozone)





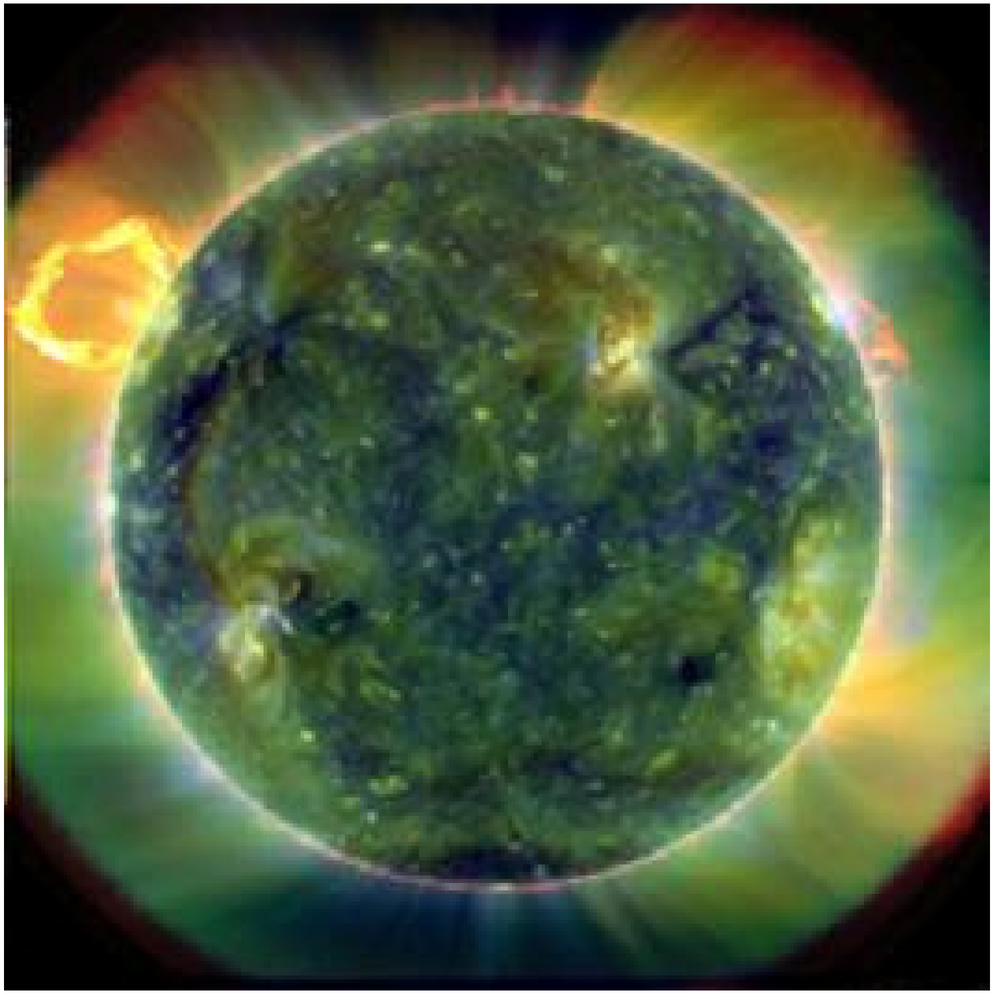
Detect ozone layer damage

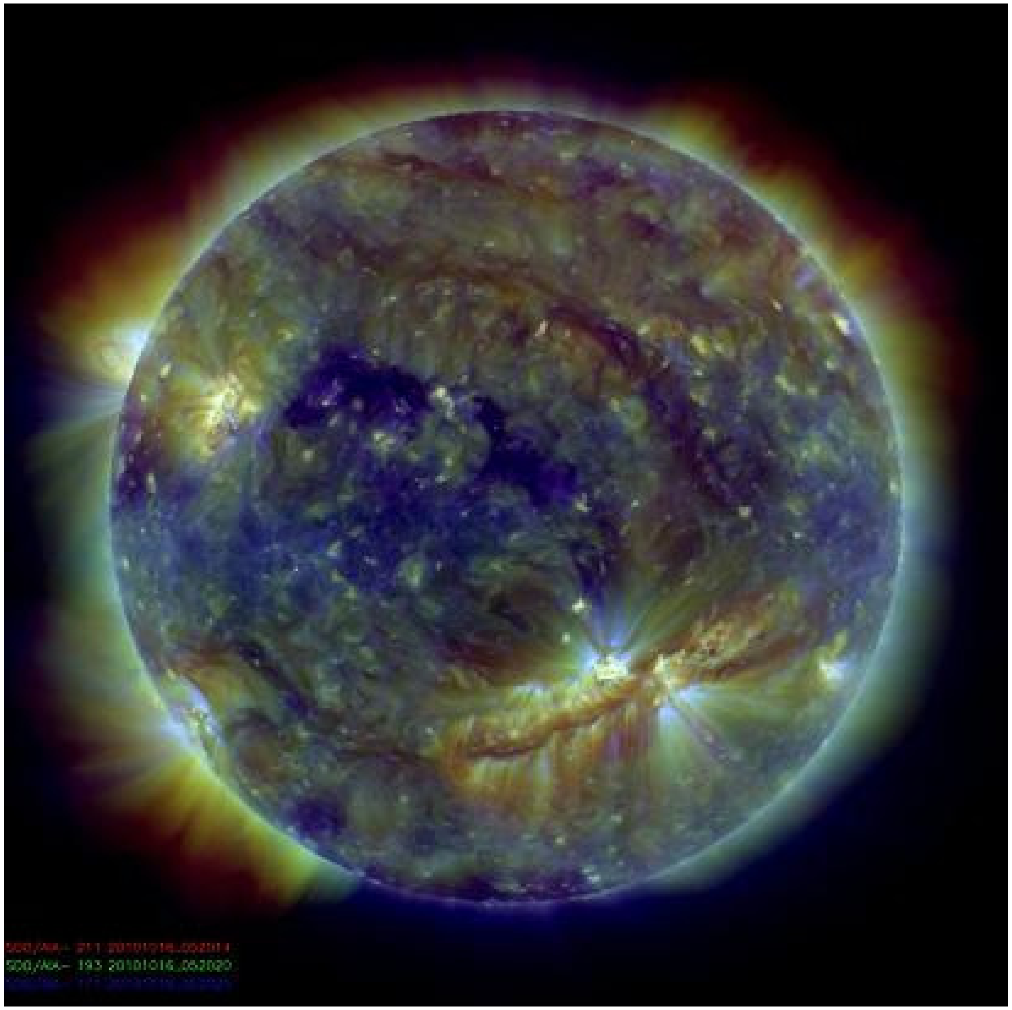
UV imaging (Sun spots)



Identify sun spots

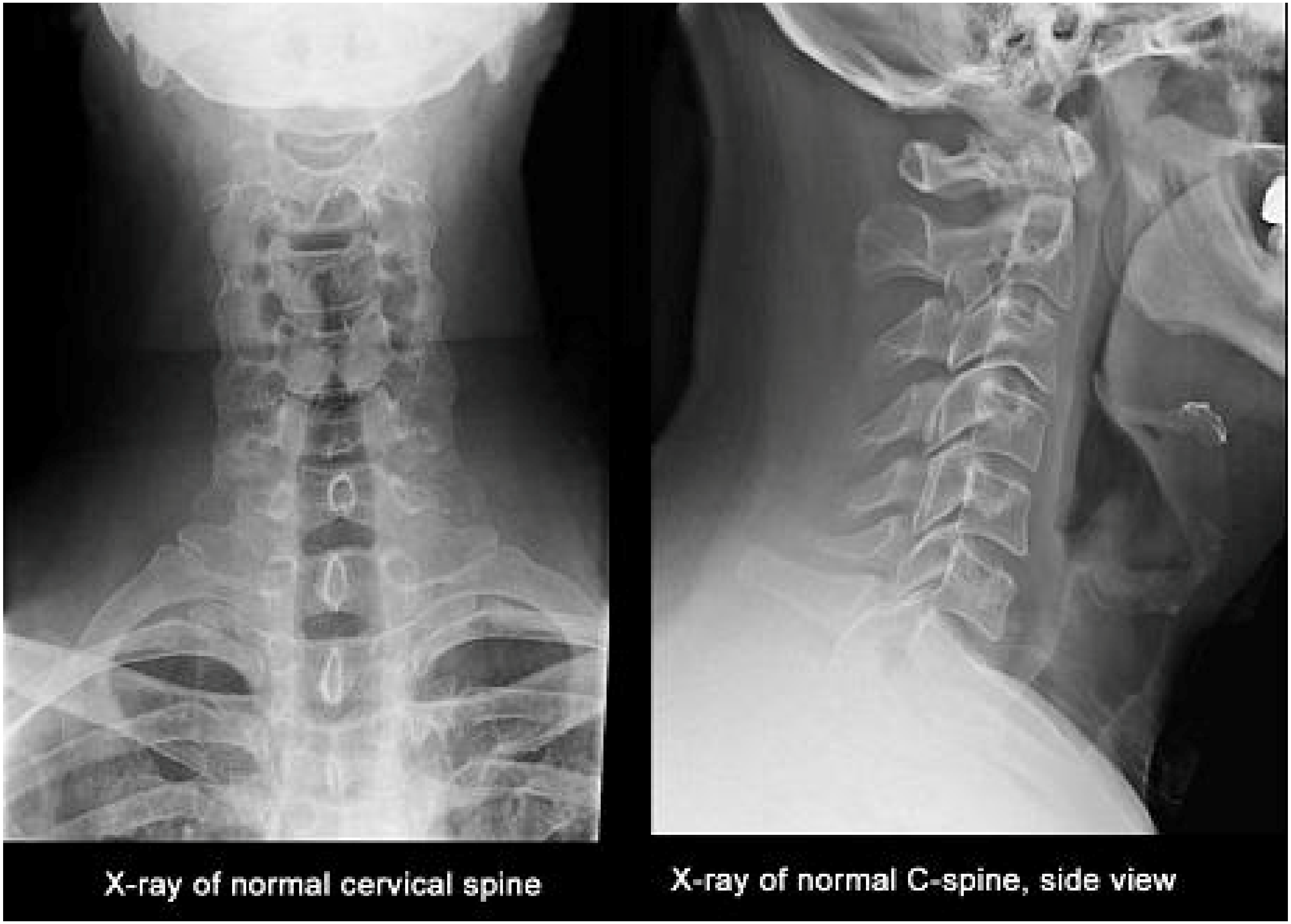
UV imaging (Solar flares)





Identify solar flares

X-Ray imaging (Medical)

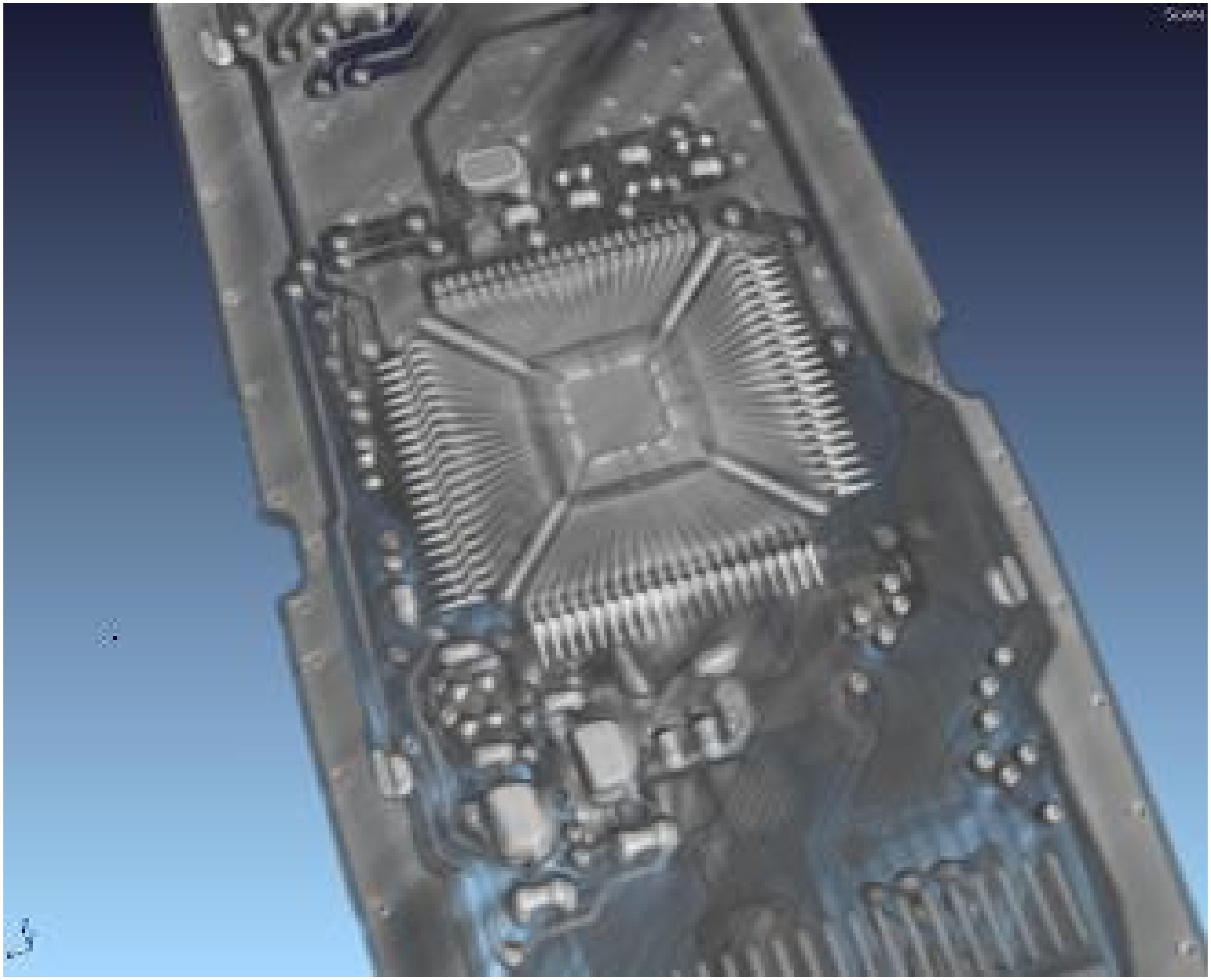


X ray of neck

X-Ray imaging (Medical)

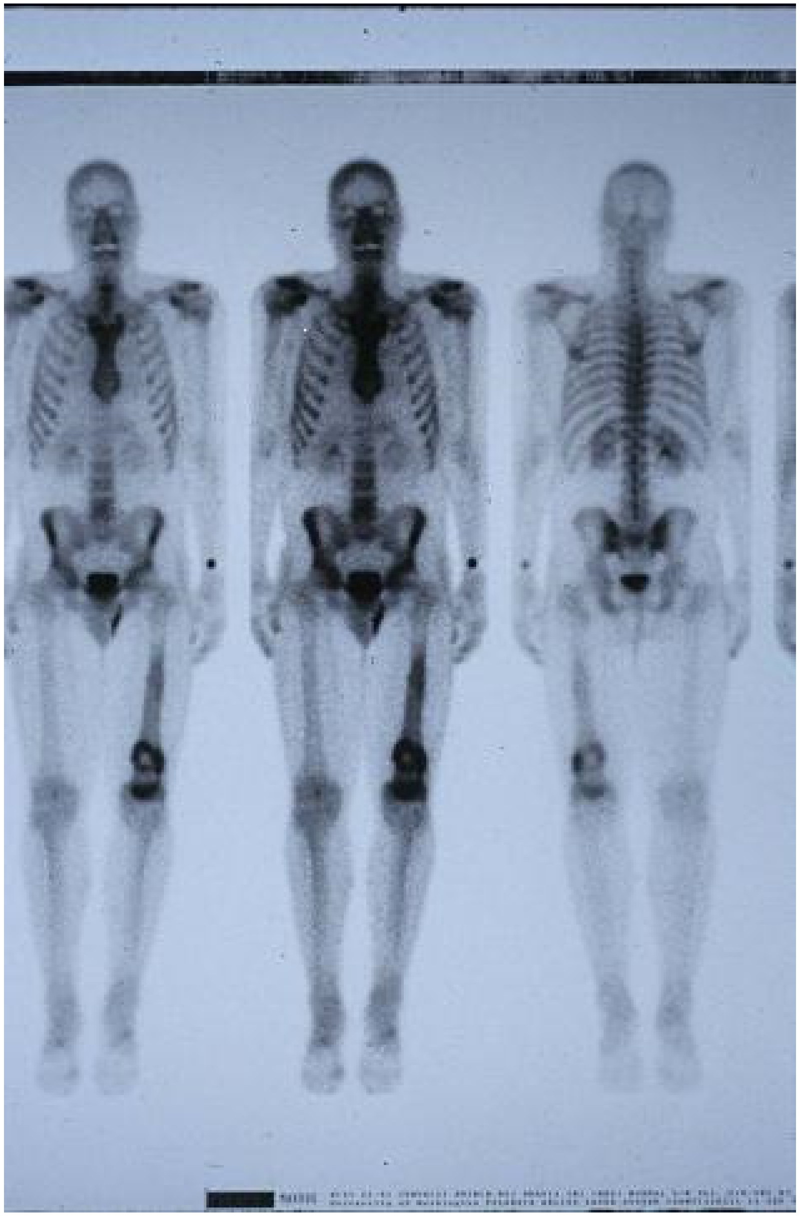
X ray of head

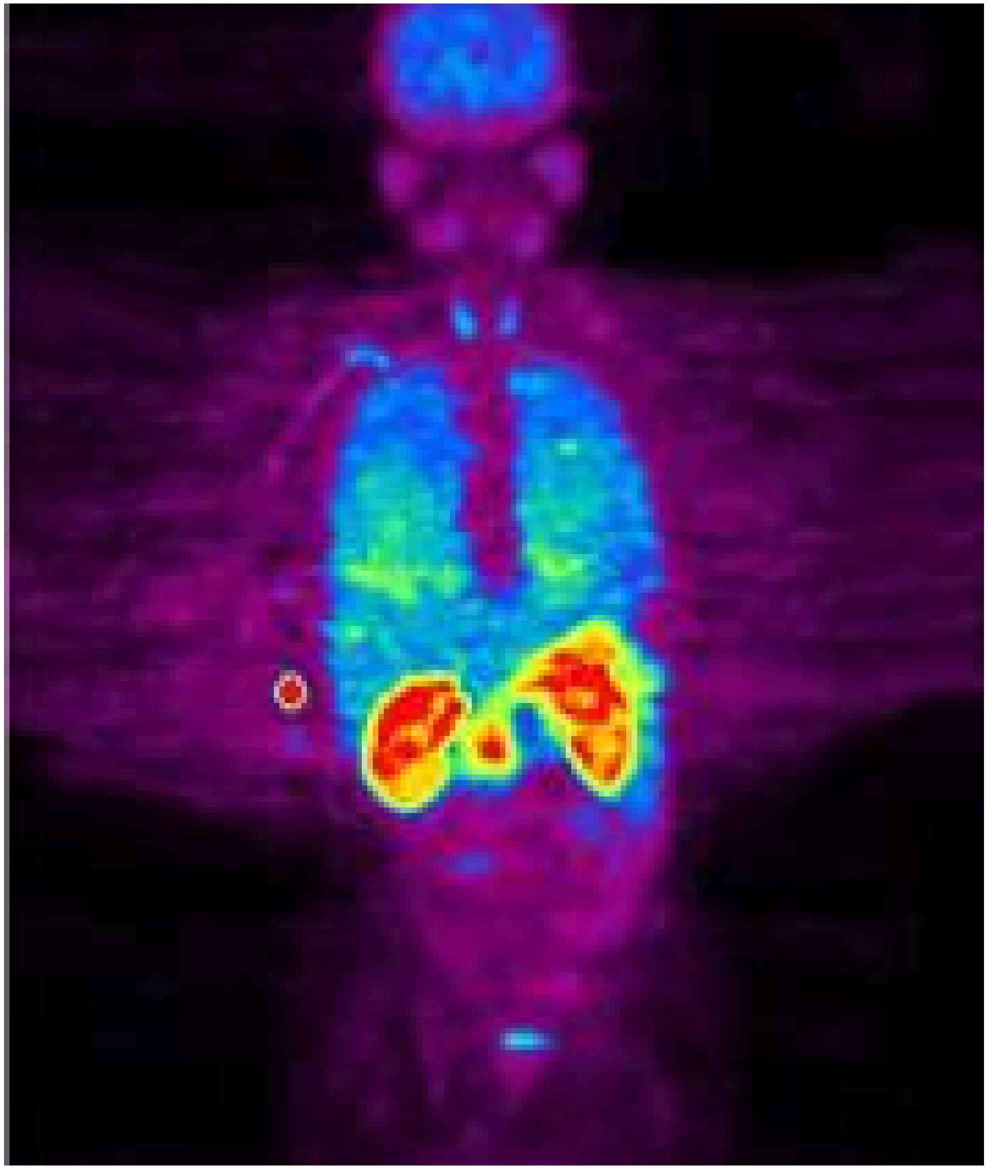
X-Ray imaging (Circuits)



X ray of a Glucose meter circuit

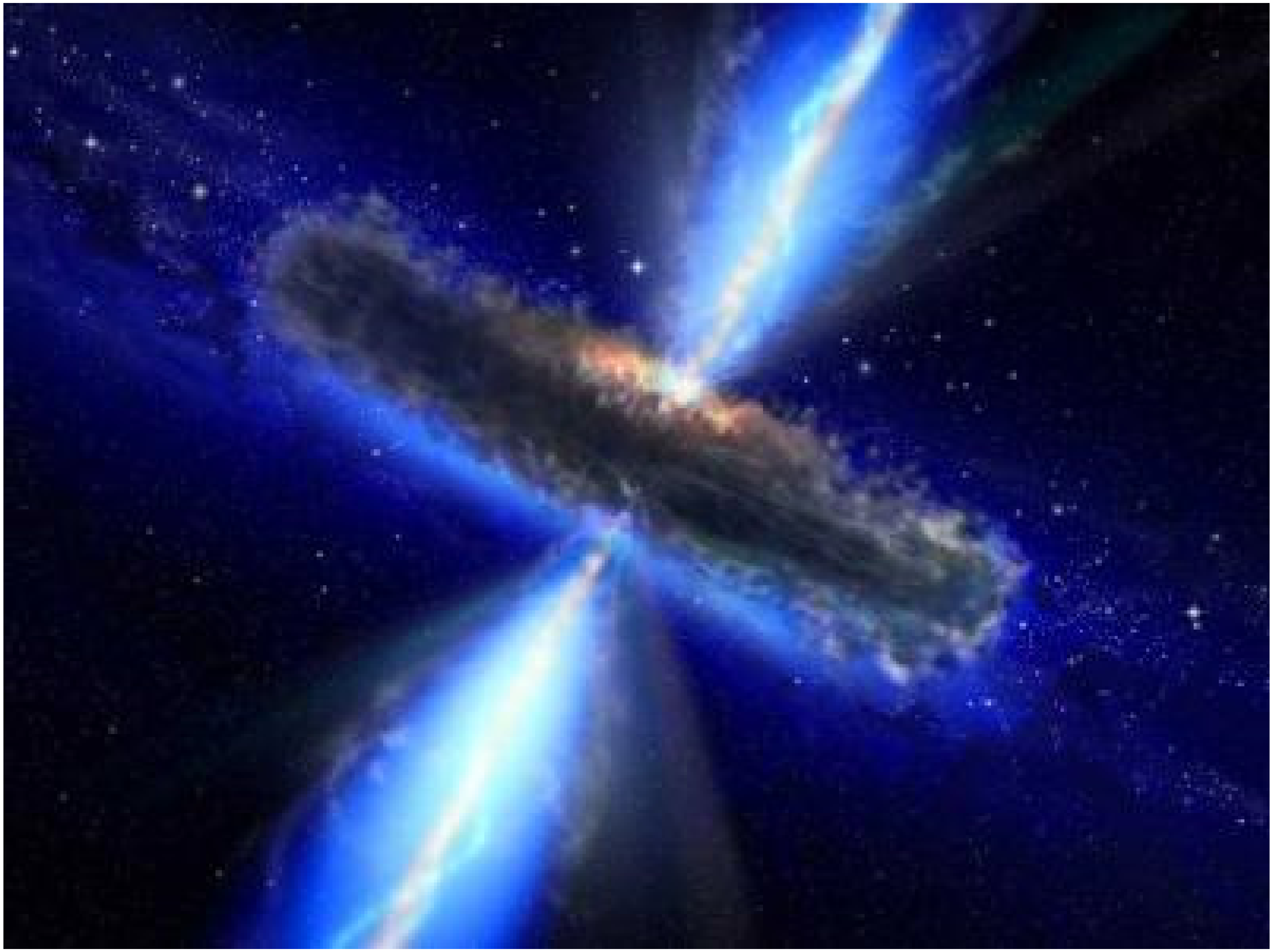
Gamma-Ray imaging (Medical)





Gamma ray exposed images

Gamma-Ray imaging (Astronomy)

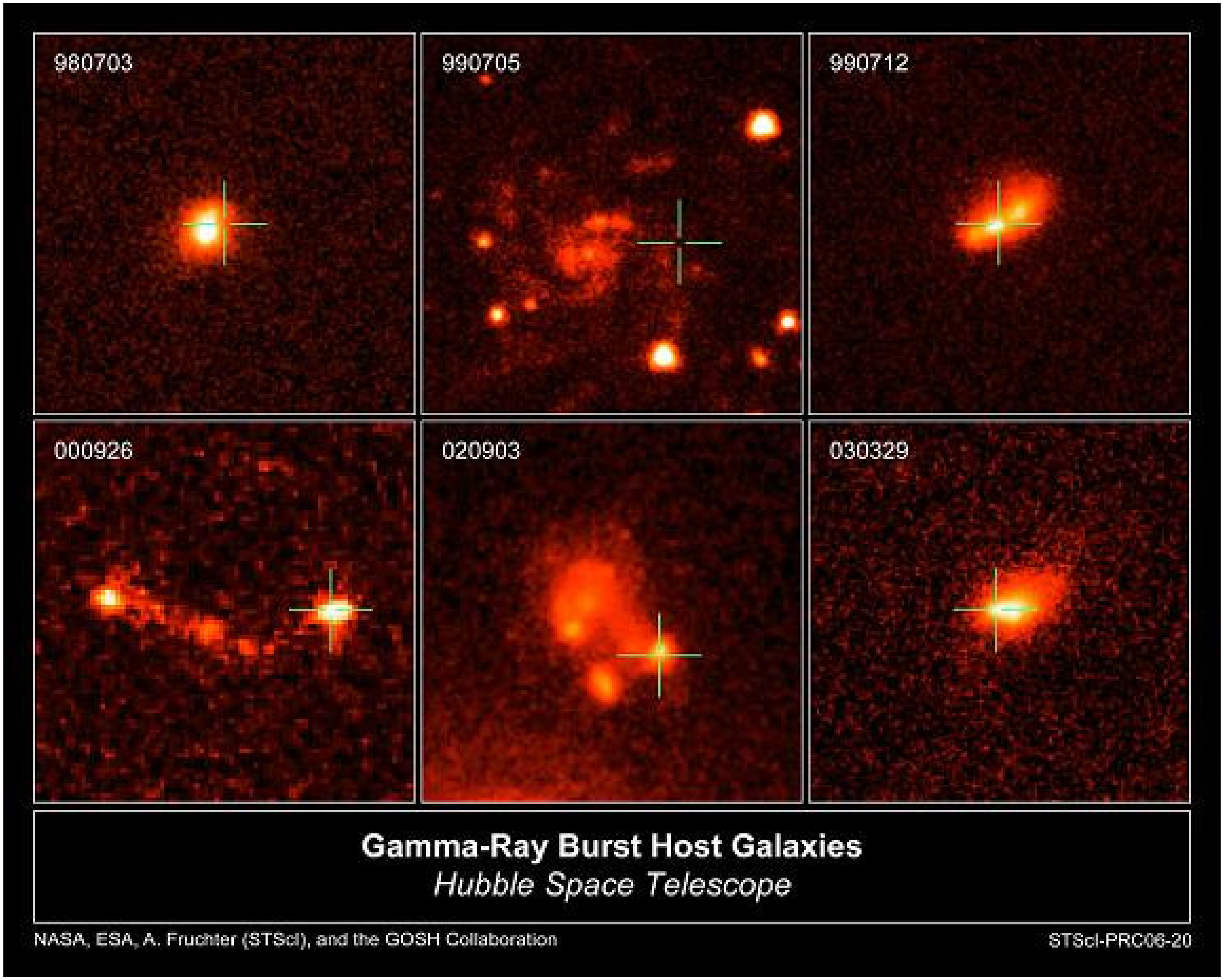


Gamma ray bursts in space

Gamma-Ray imaging (Astronomy)

Gamma ray bursts in space

Gamma-Ray imaging (Astronomy)



Gamma ray bursts in space

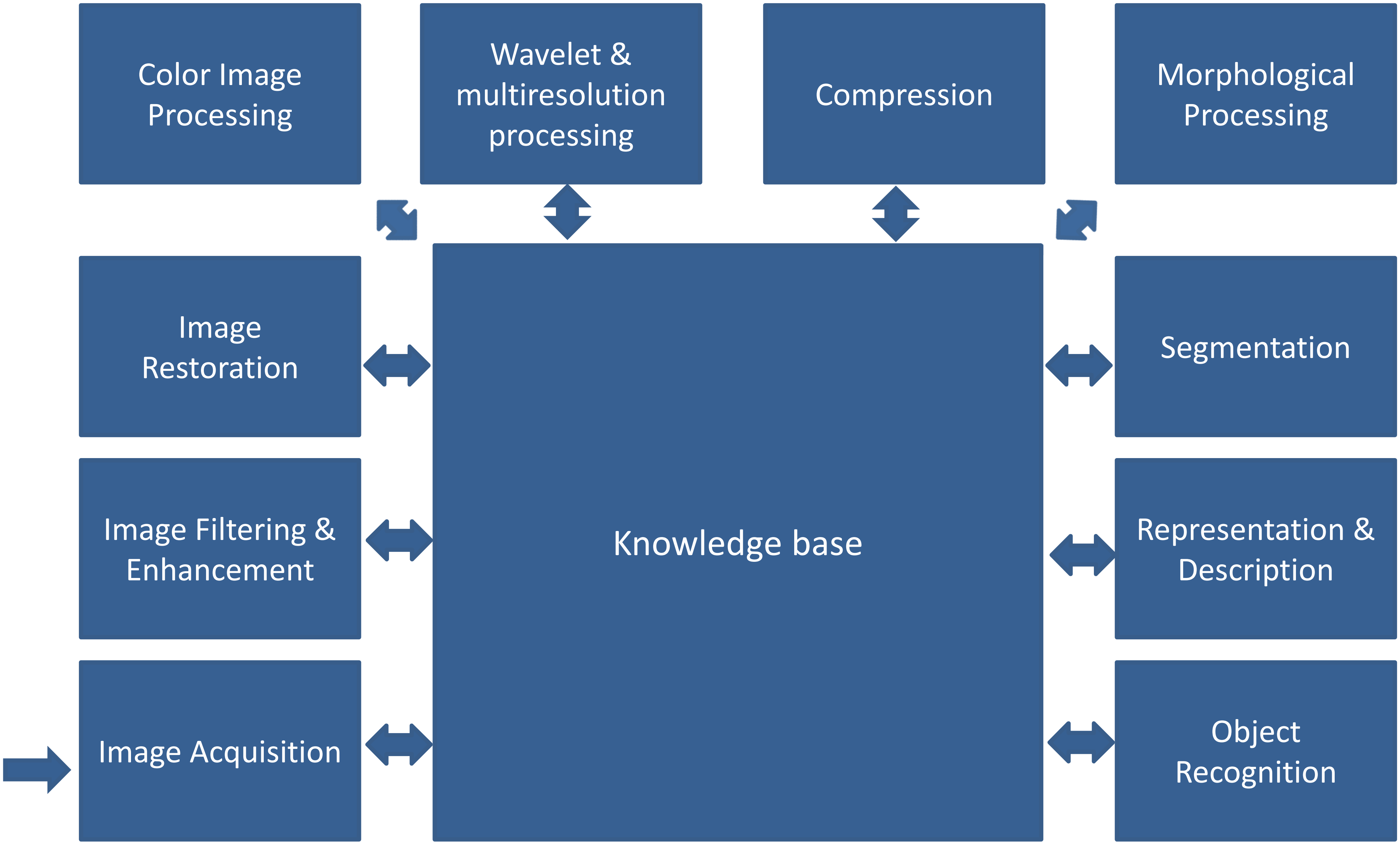
Remote Sensing

Satellite images of Mumbai suburban(Left) and Gateway of India (Right)

Remote Sensing

Satellite images of Taj Mahal

Fundamental steps in DIP



Fundamental steps in DIP

Image Acquisition:

- ✓ *First process*
- ✓ *Involves image preprocessing viz. scaling*

Image Enhancement:

- ✓ *Process of image manipulation to make it more suitable for specific use*
- ✓ *Different images require different enhancement methods*
- ✓ *Subjective technique*

Image Restoration:

- ✓ *Based on mathematical or probabilistic models of image degradation thus objective.*

Fundamental steps in DIP

Color Image Processing:

✓ *Gained importance due to increase use of internet*

Wavelets:

✓*Used mainly for image data compression & pyramidal representation where images are divided into smaller regions.*

Compression:

✓*Technique for reducing the storage required to save image, or bandwidth required to transmit it.*

✓*JPEG (Joint Photographic Experts Group)*
✓*TIF(Tagged Image File) or TIFF(Tagged Image File Format)*
✓*PNG(Portable Network Graphics)*
✓*GIF(Graphics Interchange Format)*
✓*BMP(Bitmap image file)*

Fundamental steps in DIP

Morphological Processing :

✓ *Deals with tools for extracting image components*

Segmentation:

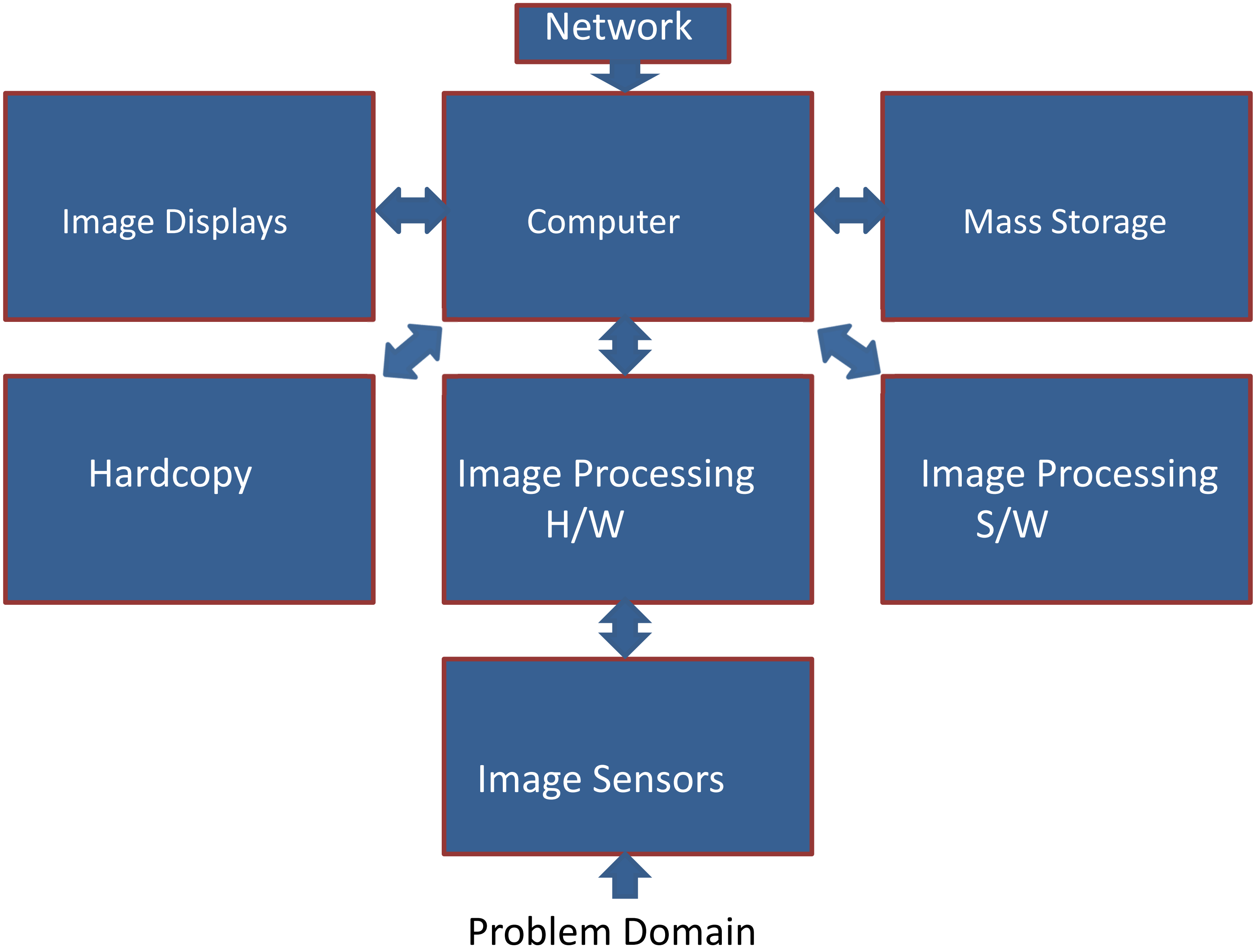
✓ *partition an image into constituent parts or objects.*

Representation & description:

✓ *follows output of segmentation with raw pixel data usually boundary information or regional description.*

Object recognition:

✓ *process of assigning a label to an object based on its description.*


Network
Image Displays
Computer
Mass Storage
Hardcopy
Image Processing H/W
Image Processing S/W
Image Sensors
Problem Domain

Components of an Image Processing System

Sensors:

❖ Two elements required to acquire digital images

❖ Physical device: sensitive to the energy radiated by the object we wish to image.

❖ Digitizer: converts output of physical sensing device into digital form.

Specialized image processing hardware:

❖ Digitizer + hardware

❖ Hardware: Performs Arithmetic Logic Unit (ALU) on entire image.

Computer:

❖ Image processing system ranging from PC to supercomputer

Image Processing Software:

❖ Specialized modules performing specific tasks

Components of an Image Processing System

Mass Storage:

❖ *Image of size 1024 $\times$ 1024 pixels with pixel intensity of 8-bit requires 1 Mb storage space.*

Image Displays:

❖ *Flat screen, TV, Monitors, LCD, LED, 3D displays*

Hardcopy:

❖ *Laser Printers, Camera Films, Heat Sensitive devices, inkjet units, digital units like optical and CD-ROM.*

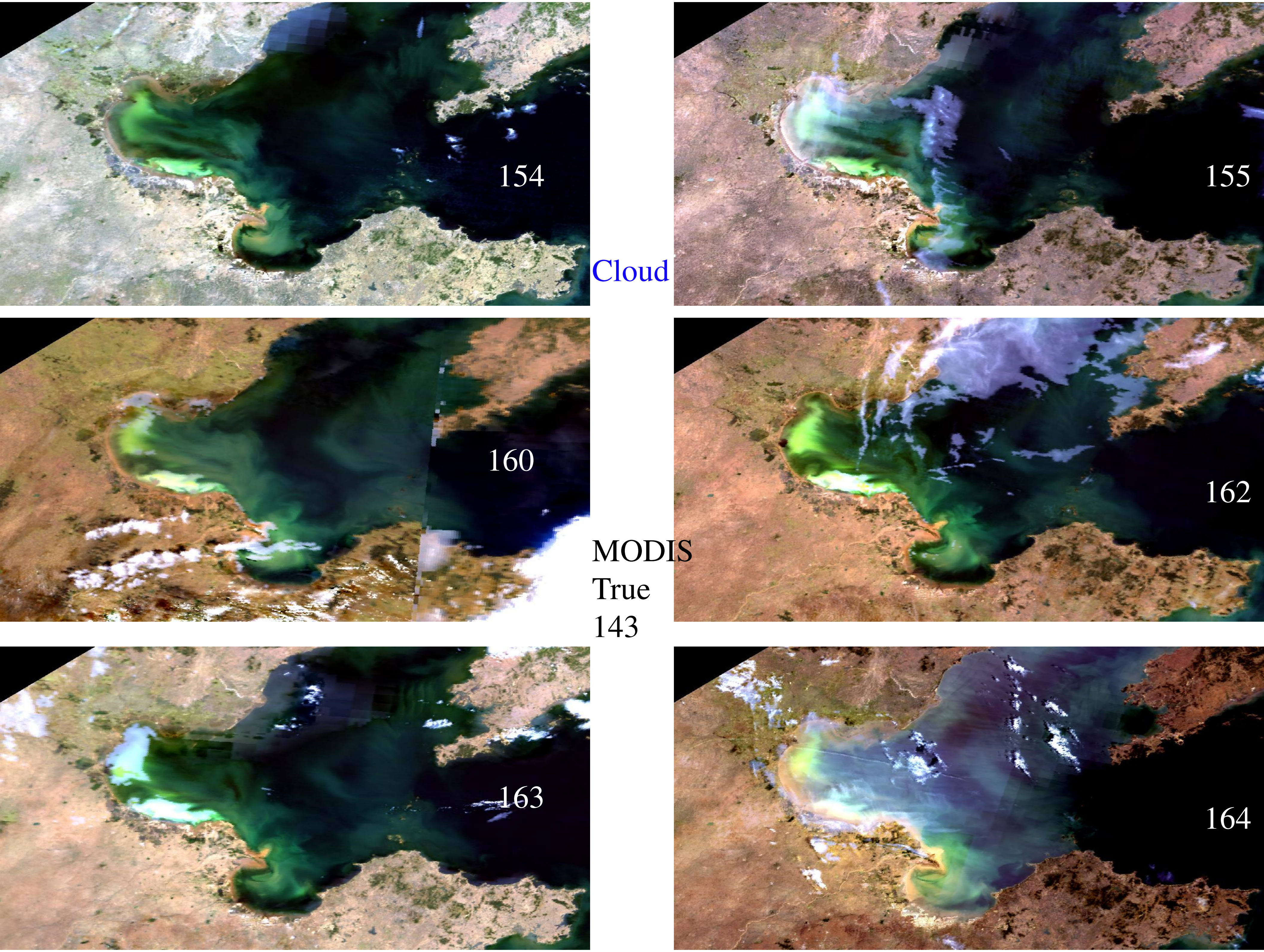
Networking:

❖ *Communicating with remote sites on internet.*

Image Quality

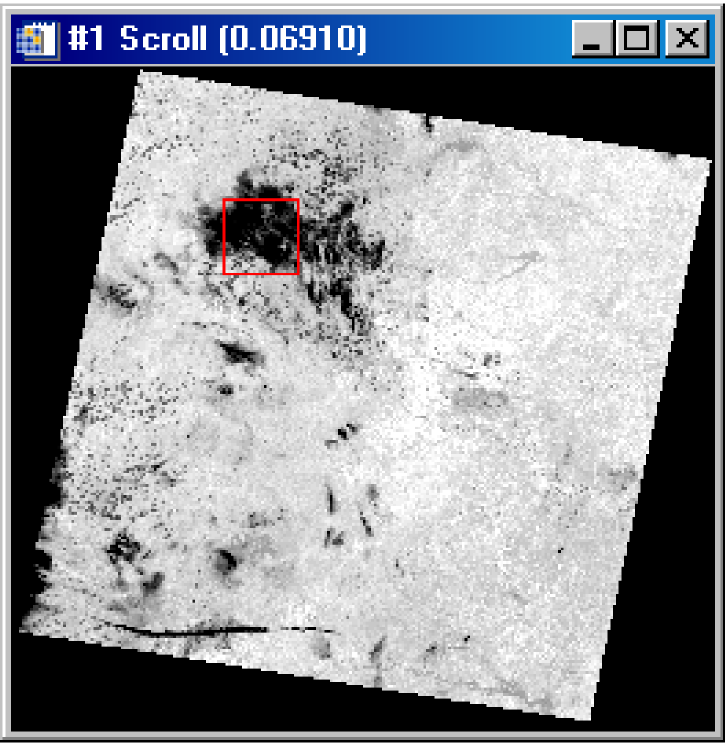
✓ *Many remote sensing datasets contain high-quality, accurate data. Unfortunately, sometimes error (or noise) is introduced into the remote sensor data by:*

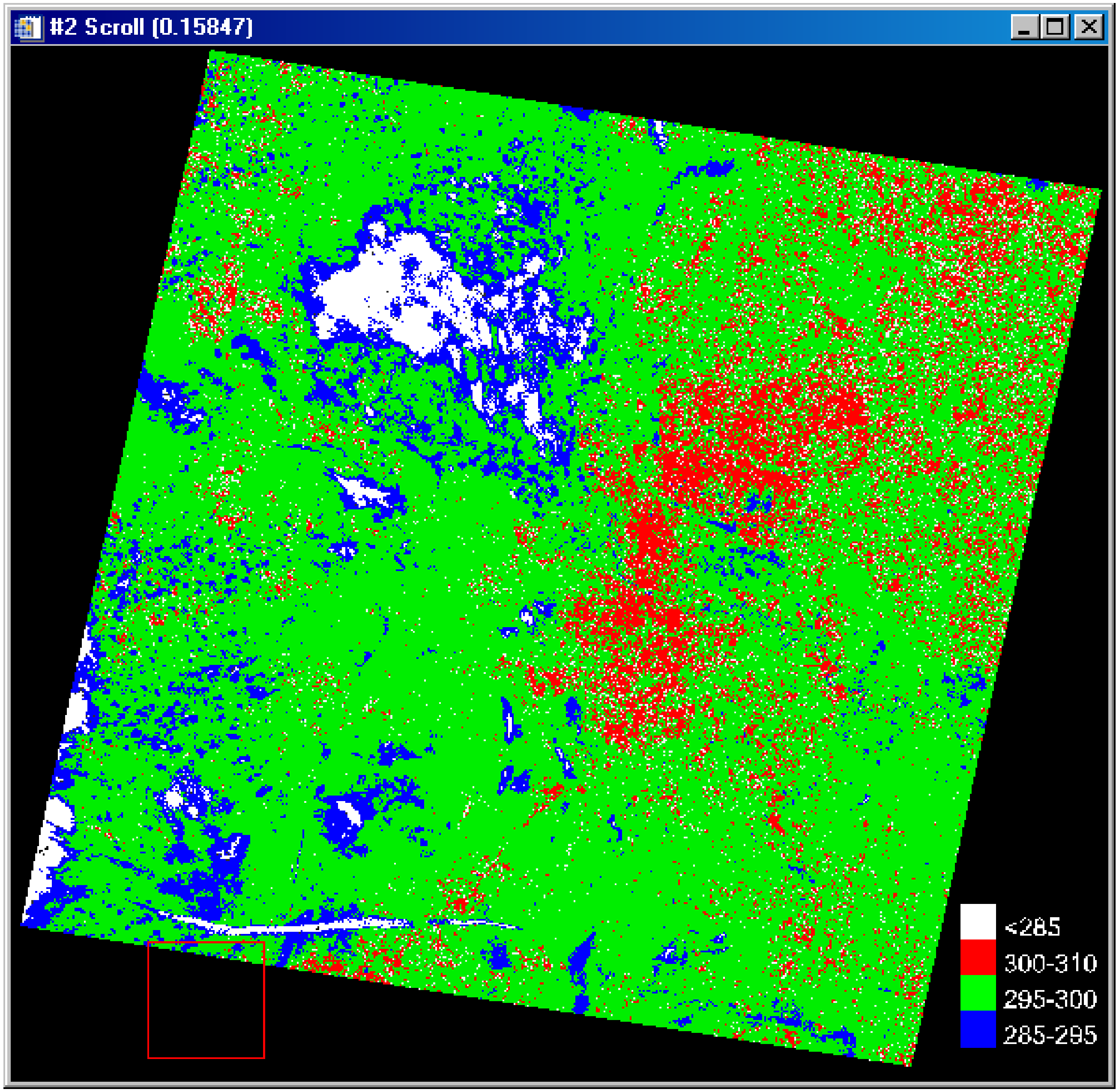
- *the environment (e.g., atmospheric scattering, cloud),*
- *random or systematic malfunction of the remote sensing system (e.g., an un calibrated detector creates striping), or*
- *improper pre-processing of the remote sensor data prior to actual data analysis (e.g., inaccurate analog-to-digital conversion).*



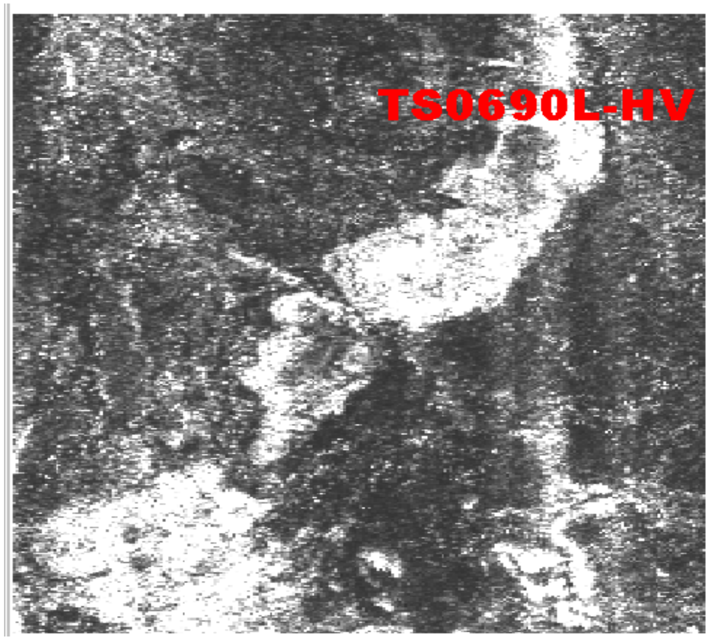
154
155
Cloud
160
162
MODIS
True
143
163
164

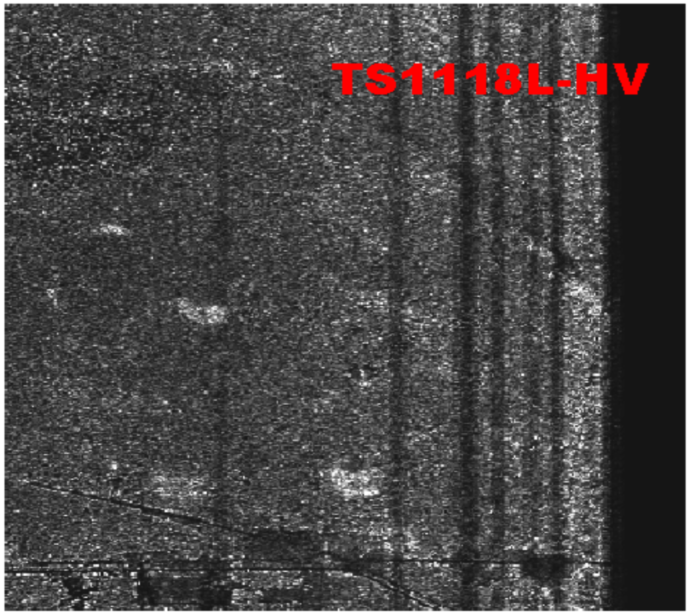
Clouds in ETM+

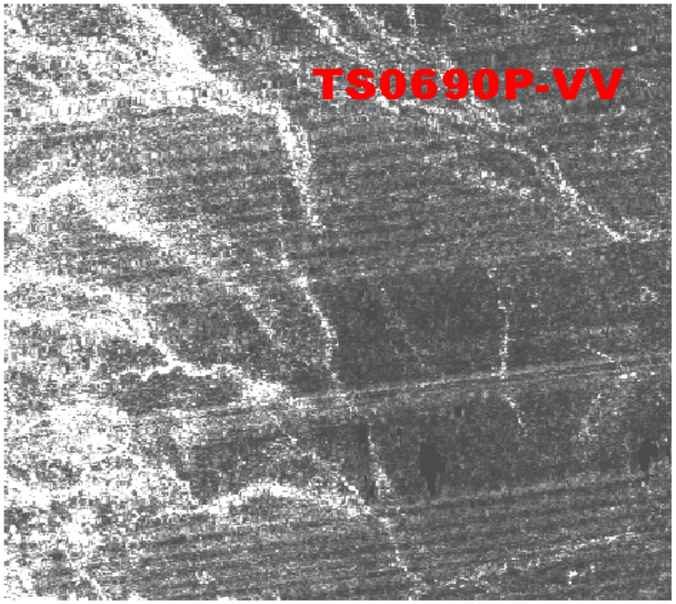


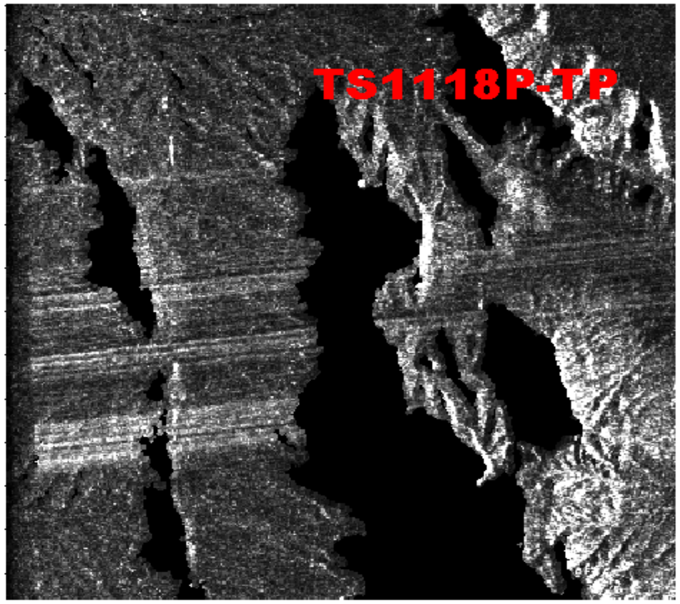


Striping Noise and Removal





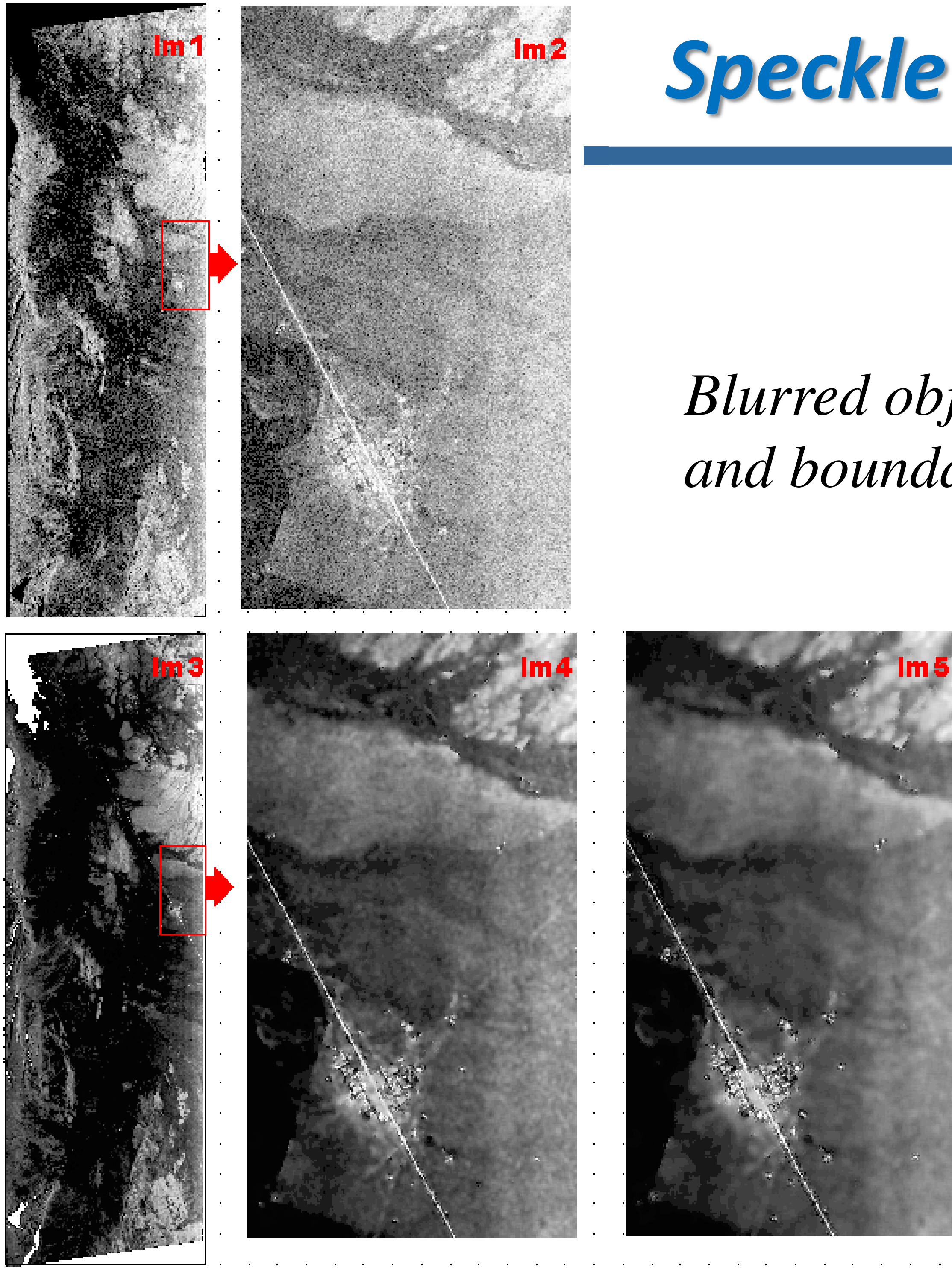




CPCA

Combined Principle Component Analysis

Speckle Noise and Removal

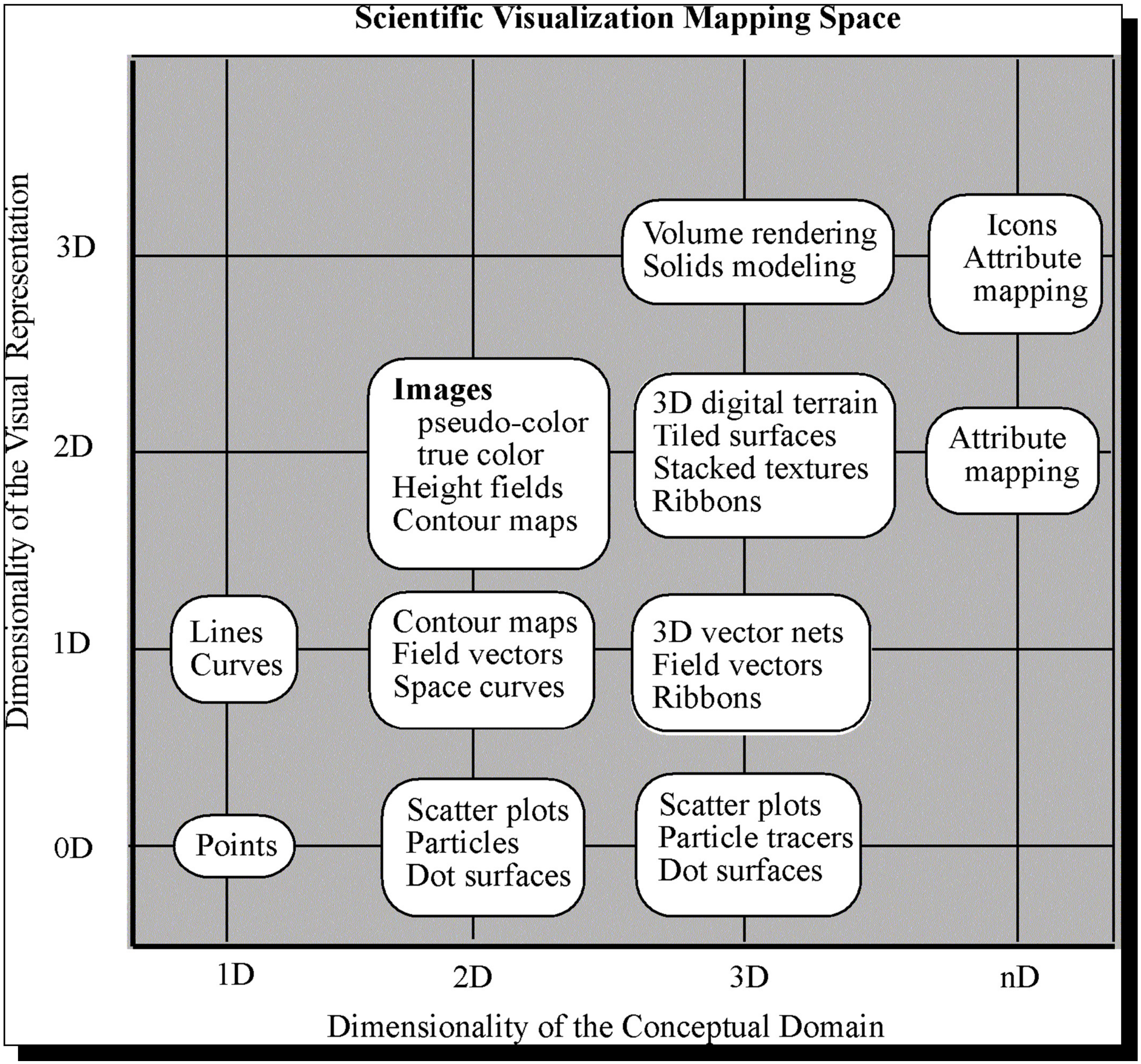


Blurred objects and boundary

G-MAP

Gamma Maximum A Posteriori Filter

Scientific Visualization



What is an Image?

✓ Image Definition

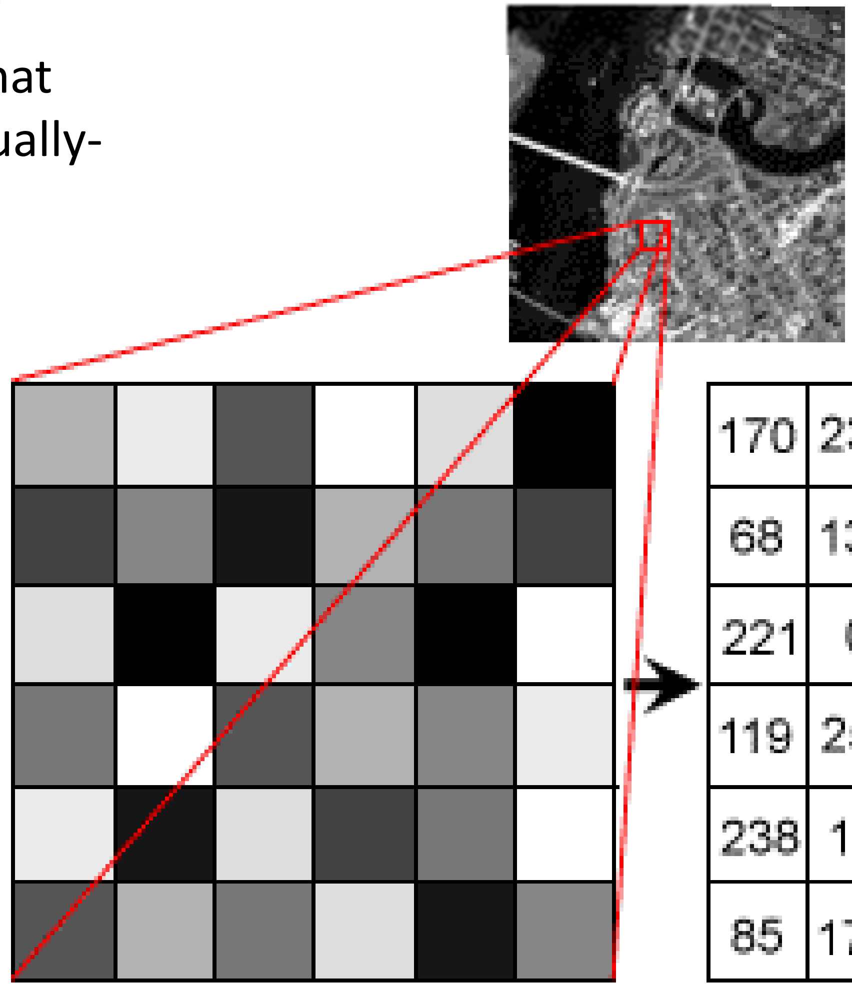
- *An image may be defined as a two dimensional function, f(x,y), where x and y are spatial (plane) coordinates, and the amplitude of f at any pair of coordinates (x,y) is called the intensity or gray level of the image at that point. When x, y, and the amplitude values of f are all finite, discrete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

Images and Photographs

Representation in digital format by subdividing image into equally-shaped areas called pixels

The ‘brightness’ of each area can be attributed a numeric value or digital number

Information from narrow wavelength ranges can be stored in **channels**, also called **bands**



170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

Often, data from multiple channels can be represented as one of three primary colours which combine according to brightness.
We are, thus, no longer blind to these λ’s.

Image Sampling and Quantization

✓ Basic Concepts in Sampling and Quantization

- *Digitizing the coordinate values is called sampling.*
- *Digitizing the amplitude values is called quantization.*

Image Sampling and Quantization

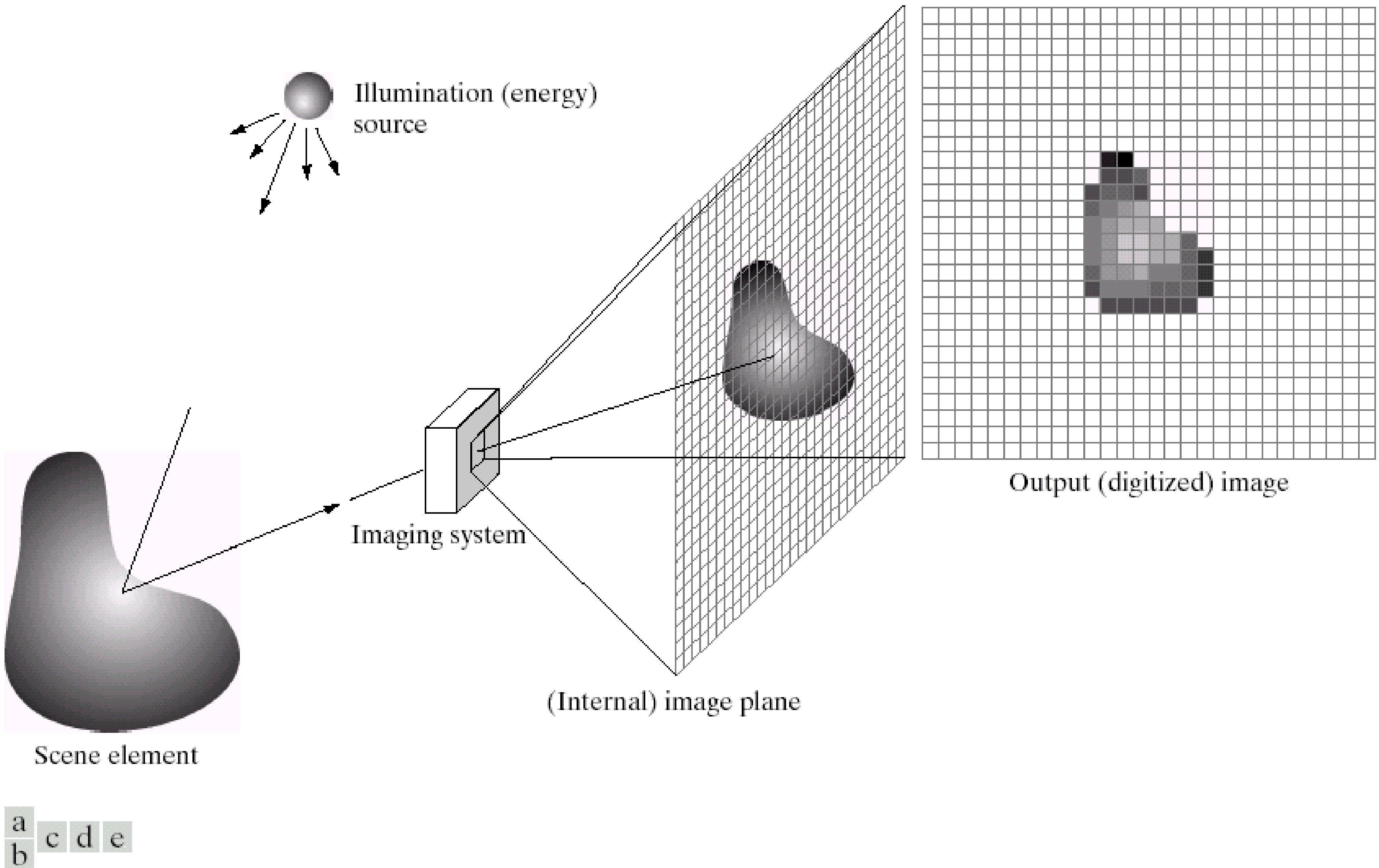


FIGURE 2.15 An example of the digital image acquisition process. (a) Energy ("illumination") source. (b) An element of a scene. (c) Imaging system. (d) Projection of the scene onto the image plane. (e) Digitized image.

Image Sampling and Quantization

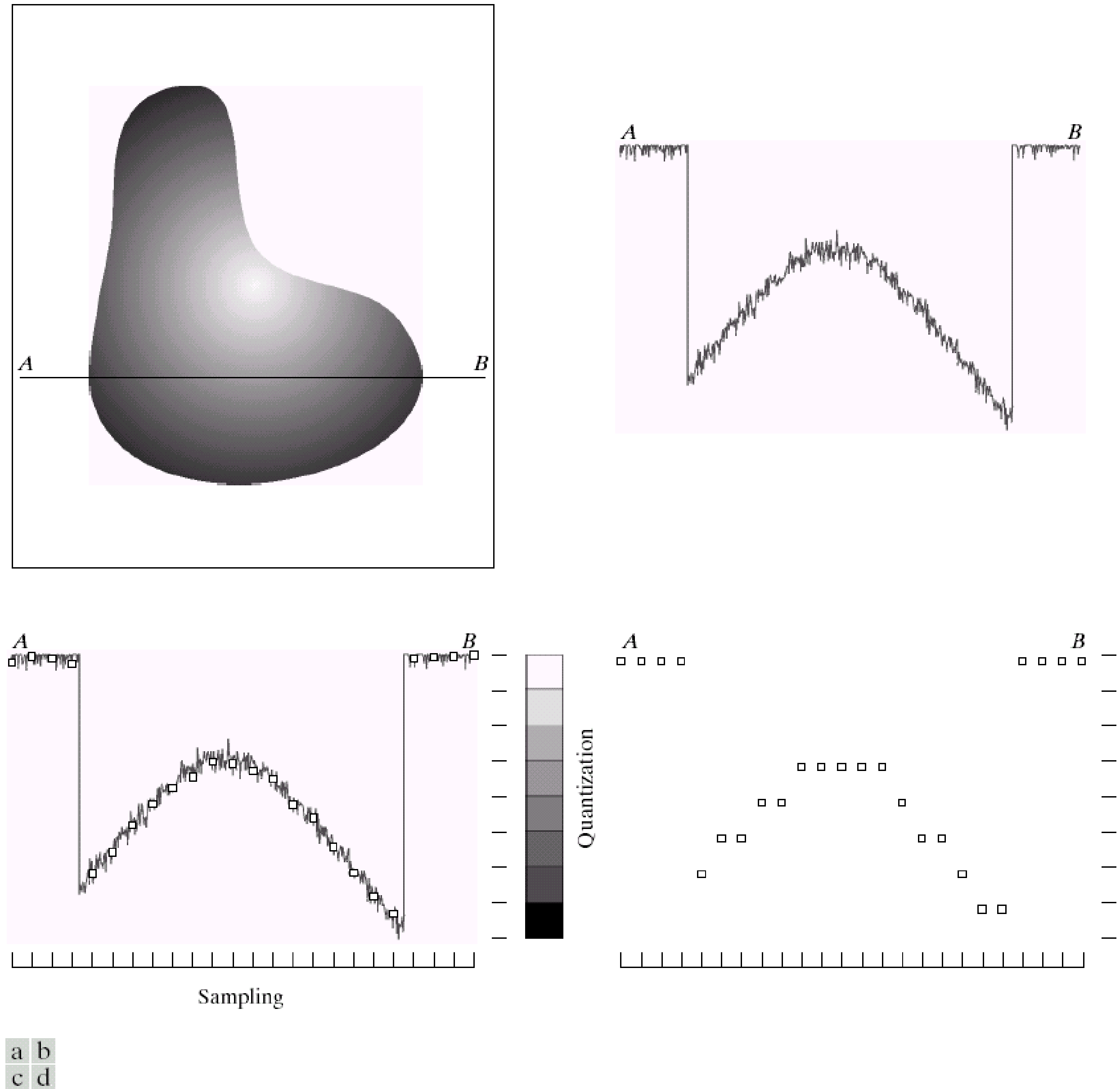


FIGURE 2.16 Generating a digital image. (a) Continuous image. (b) A scan line from A to B in the continuous image, used to illustrate the concepts of sampling and quantization. (c) Sampling and quantization. (d) Digital scan line.

Image Sampling and Quantization

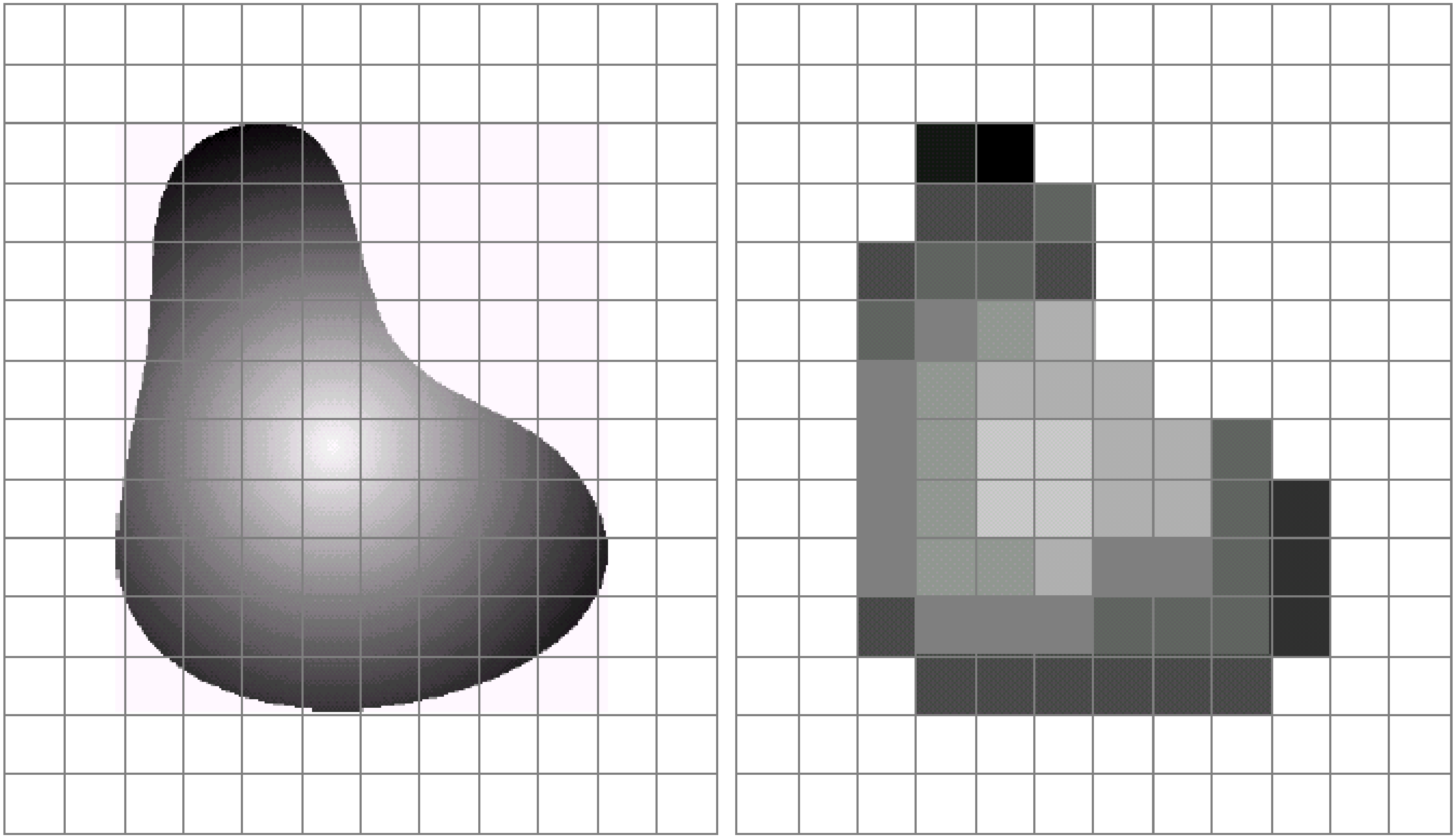
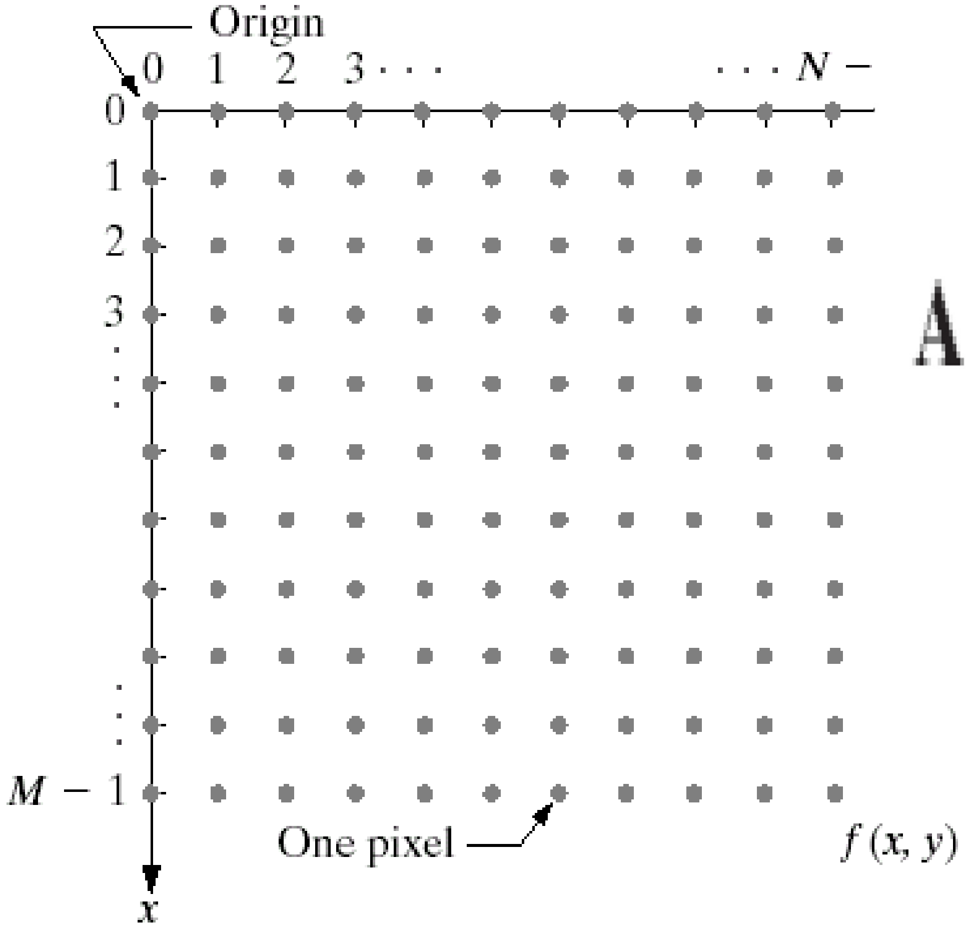


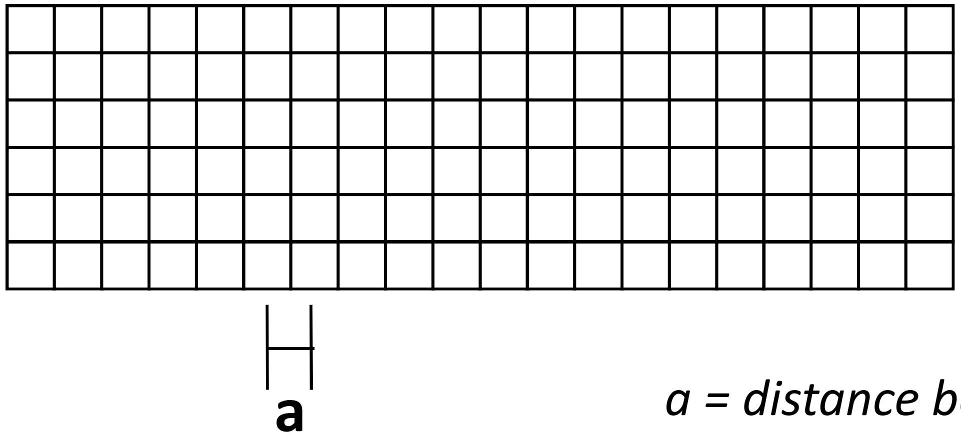
FIGURE 2.17 (a) Continuos image projected onto a sensor array. (b) Result of image sampling and quantization.

Representing Digital Images



$$\mathbf{A} = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\ a_{1,0} & a_{1,1} & \cdots & a_{1,N-1} \\ \vdots & \vdots & & \vdots \\ a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1} \end{bmatrix}$$

Definition of Sampling Frequency



Section of a digital image consisting of discrete pixels

a = distance between two pixel centers
(called: pixel pitch or pixel size)

Sampling Frequency $f_s = 1 / a$

= number of pixels per unit of length

example:	*pixel size*	*200 µm*
	f_s	*5 pixel/mm*

Sampling Theorem

also called

Nyquist-Shannon Sampling Theorem

WKS Whittaker-Kotelnikow S T

Definition of the "Nyquist frequency" for a digital imaging system:

$$f_{Nyquist} = \frac{f_s}{2}$$

called:
limiting spatial frequency

There is no loss of information by sampling an image, if

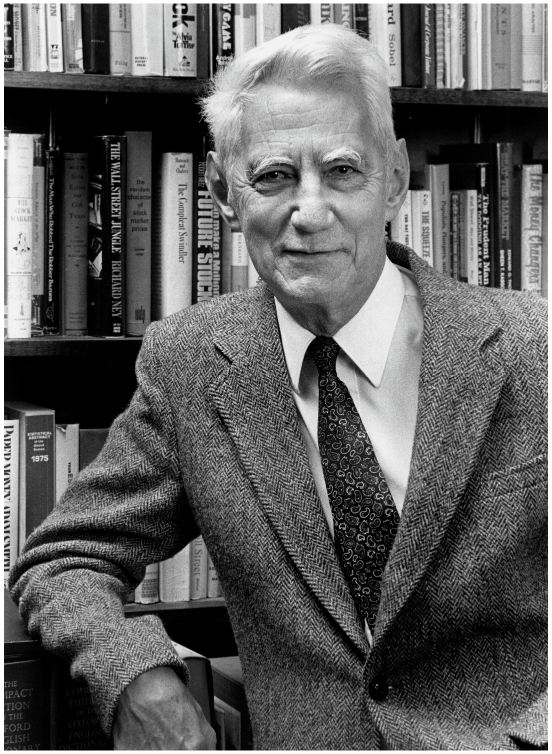
Nyquist frequency >
highest spatial frequency component of the signal

Historical background

Claude Elwood Shannon

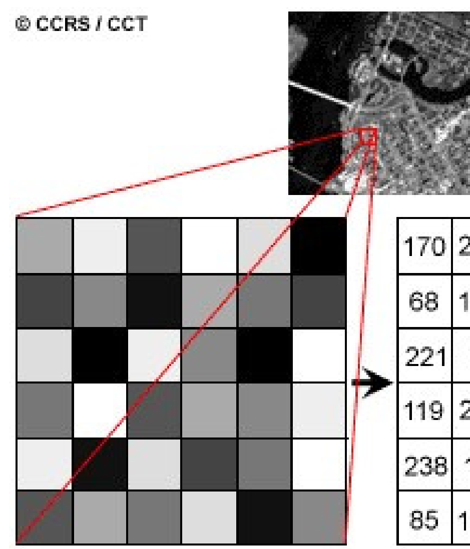
American engineer + mathematician

founder of information theory (1948)



Pixel

✓ *A digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are referred to as picture elements, image elements, pels, and pixels.* ***Pixel*** *is the term most widely used to denote the elements of a digital image.*



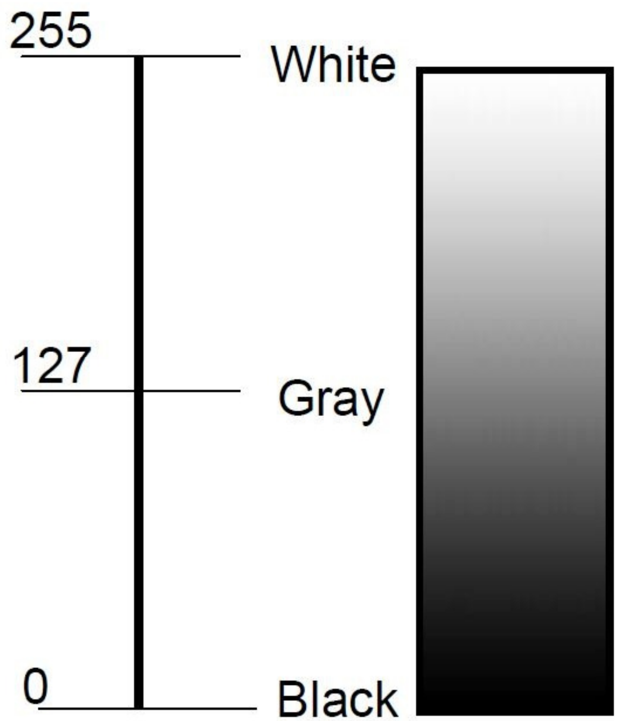
170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136

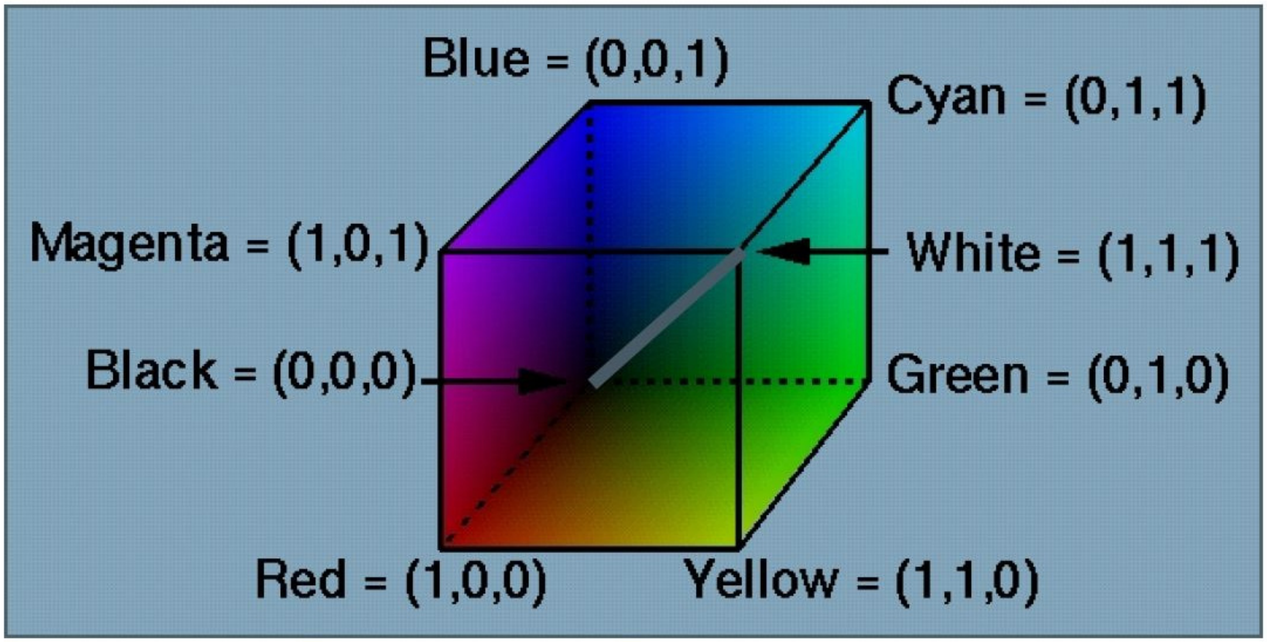
Gray Level (Gray Scale)

- ✓ *The number of gray levels typically is an integer power of 2:*

  k = bit image. **$L = 2^K$**

- ✓ *We assume that the discrete levels are equally spaced and that they are integers in the interval [0, L-1].*





Gray Level (Gray Scale)

✓ The number, b, of bits required to store a digitized image is

$$b = M \times N \times k.$$

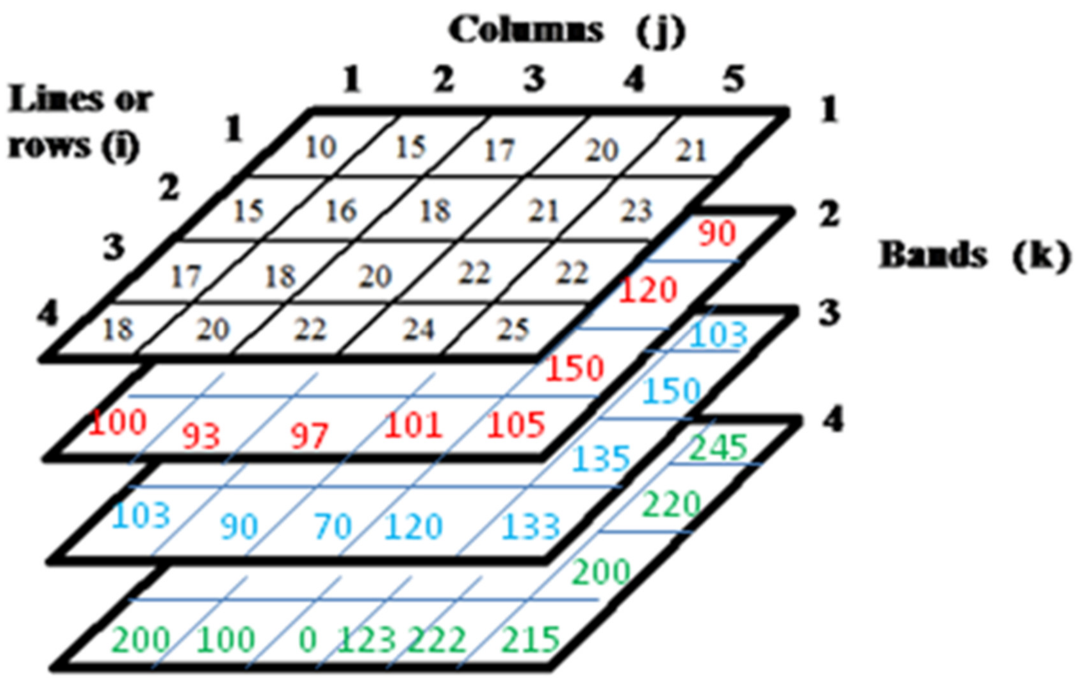
When M=N, this equation becomes

$$b = N^2 \times k.$$

TABLE 2.1
Number of storage bits for various values of N and k.

N/k	1 (L = 2)	2 (L = 4)	3 (L = 8)	4 (L = 16)	5 (L = 32)	6 (L = 64)	7 (L = 128)	8 (L = 256)
32	1,024	2,048	3,072	4,096	5,120	6,144	7,168	8,192
64	4,096	8,192	12,288	16,384	20,480	24,576	28,672	32,768
128	16,384	32,768	49,152	65,536	81,920	98,304	114,688	131,072
256	65,536	131,072	196,608	262,144	327,680	393,216	458,752	524,288
512	262,144	524,288	786,432	1,048,576	1,310,720	1,572,864	1,835,008	2,097,152
1024	1,048,576	2,097,152	3,145,728	4,194,304	5,242,880	6,291,456	7,340,032	8,388,608
2048	4,194,304	8,388,608	12,582,912	16,777,216	20,971,520	25,165,824	29,369,128	33,554,432
4096	16,777,216	33,554,432	50,331,648	67,108,864	83,886,080	100,663,296	117,440,512	134,217,728
8192	67,108,864	134,217,728	201,326,592	268,435,456	335,544,320	402,653,184	469,762,048	536,870,912

Remote Sensing Raster (Matrix) Data Format



Digital number of column 5, row 4 at band 2 is expressed as $BV_{5,4,2}$ = 105.

Bit & Byte

- **Bit (BInary digiT):** *The smallest element of computer storage. It is a single digit in a binary number (0 or 1). The bit is physically a transistor or capacitor in a memory cell, a magnetic domain on disk or tape, a reflective spot on optical media or a high or low voltage pulsing through a circuit.*

- **Bytes for Storage:** *Groups of bits make up storage units in the computer, called "characters," "bytes," or "words," which are manipulated as a group. The most common is the byte, made up of eight bits and equivalent to one alphanumeric character.*

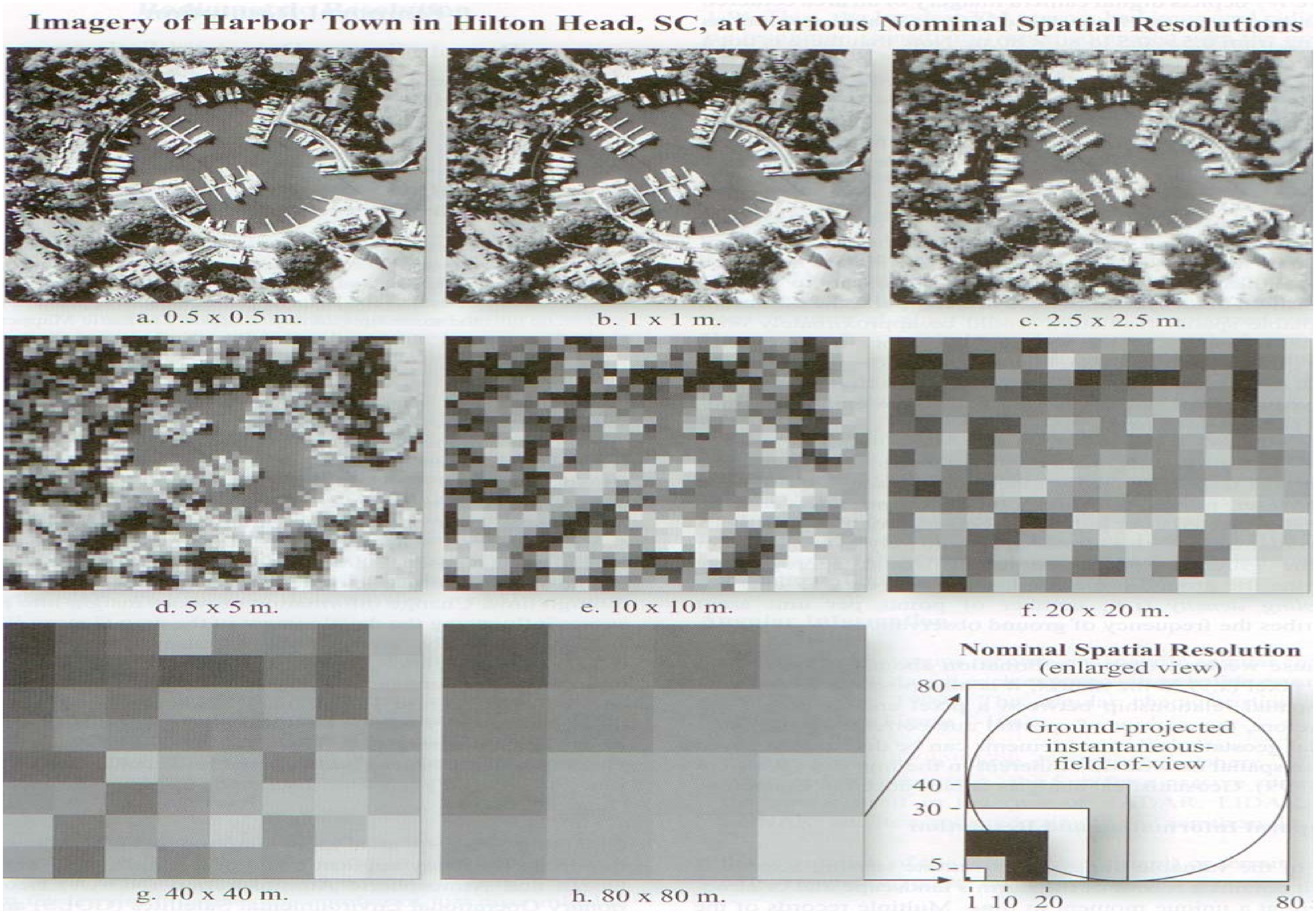
Gray-Level Resolution

2-bit image **8-bit image**

Spatial Resolution

- ✓ *There is a general relationship between the size of an object or area to be identified and the spatial resolution of the remote sensing system.*
- ✓ ***Spatial resolution** is a measure of the smallest angular or linear separation between two objects that can be resolved by the remote sensing system.*
- ✓ *Typically, we describe a sensor system's nominal spatial resolution as being 10×10 m or 30 ×30 m*

Spatial Resolution



Spatial Resolution

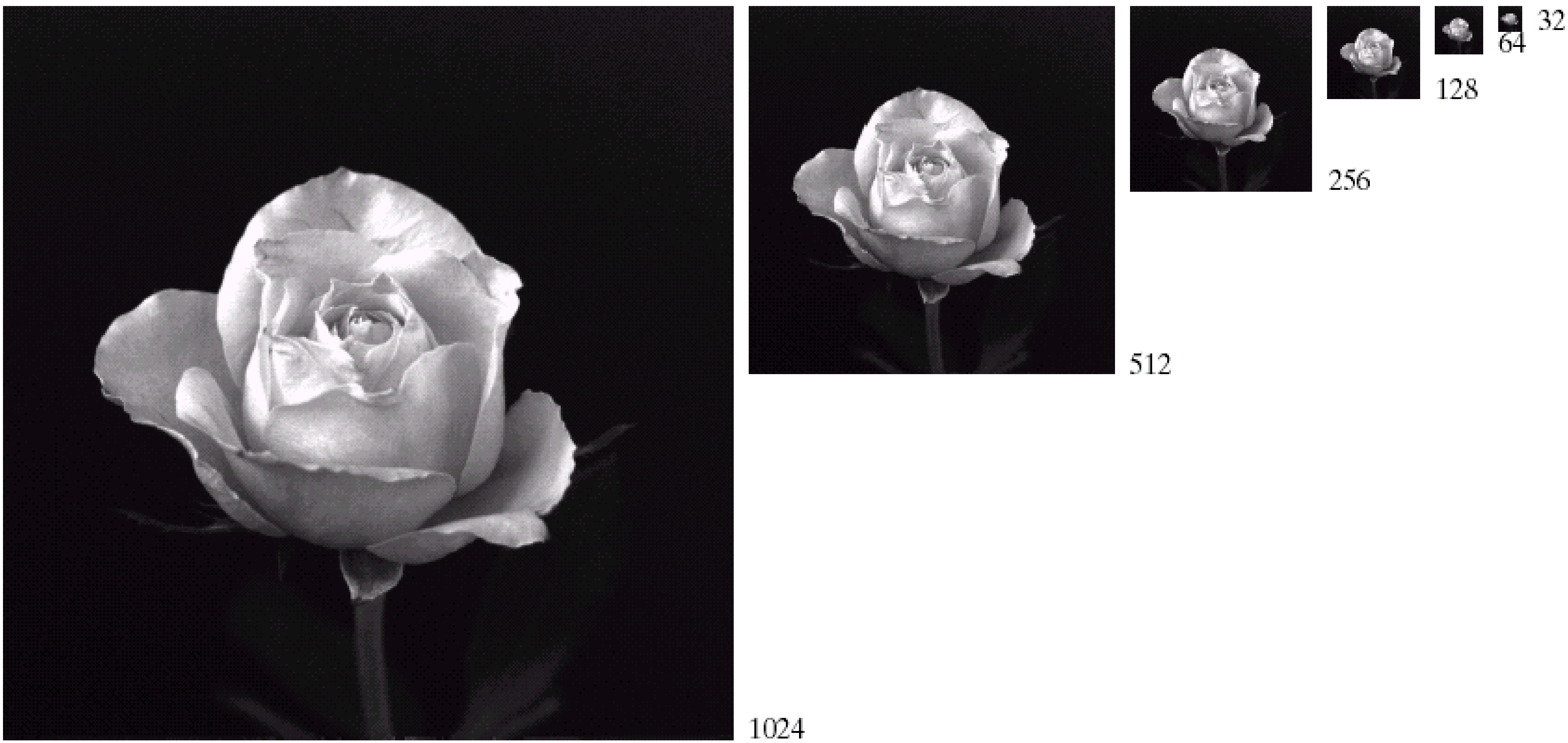


FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

Spatial Resolution (cont…)

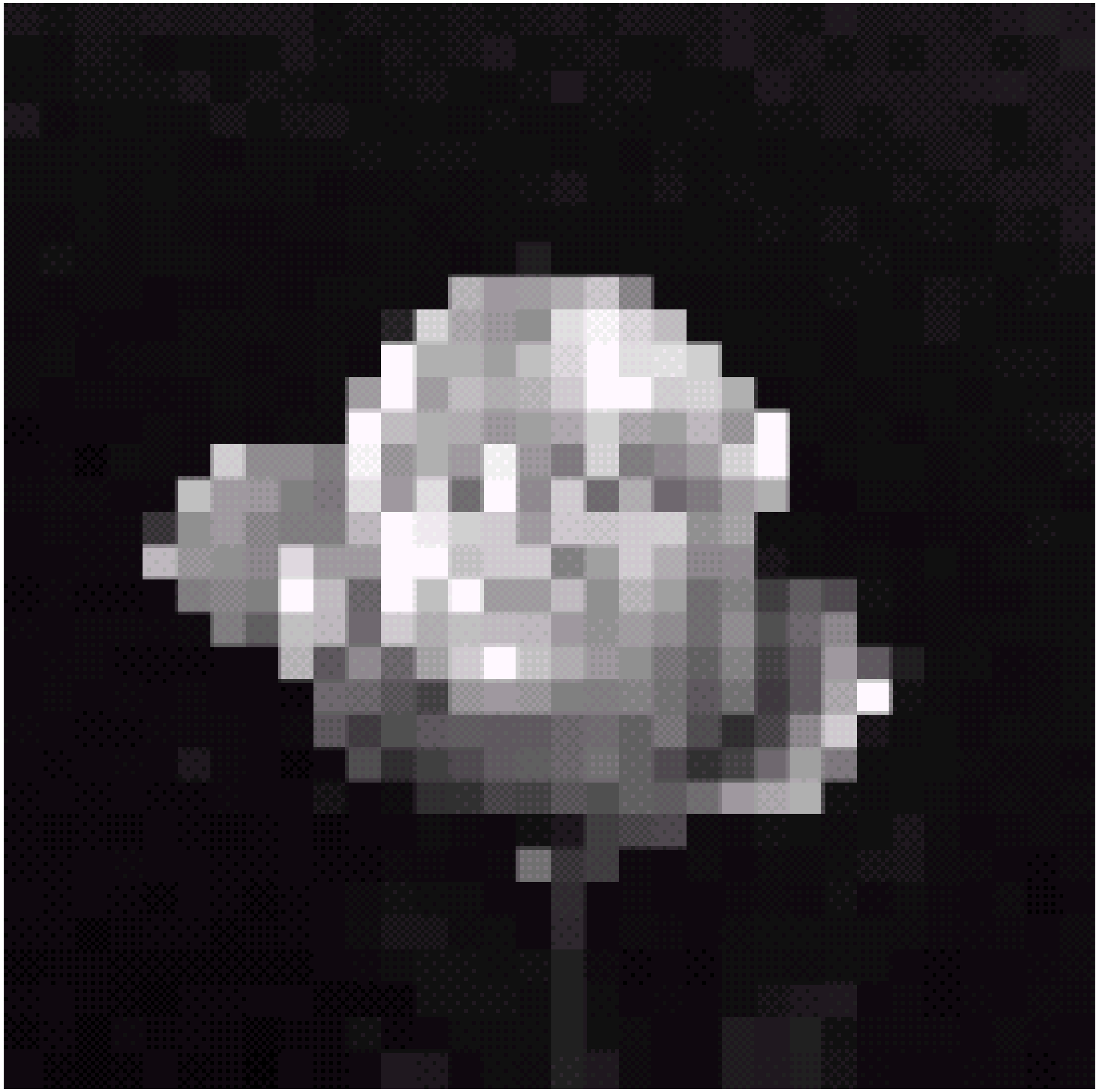
Spatial Resolution (cont...)

Spatial Resolution (cont…)

Spatial Resolution (cont…)

Spatial Resolution (cont…)

Spatial Resolution (cont…)



Intensity Level Resolution

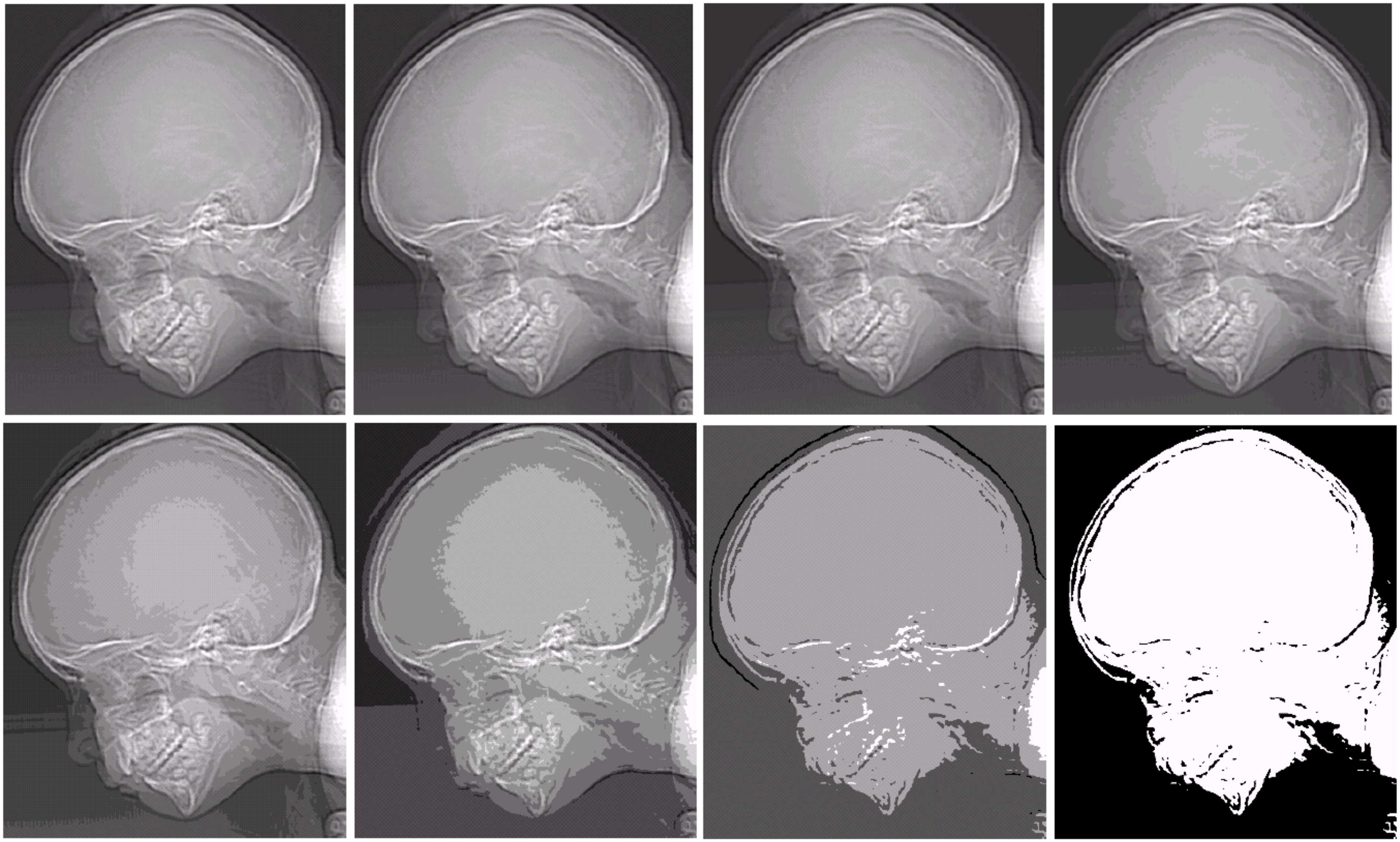
✓ *Intensity level resolution refers to the number of intensity levels used to represent the image*

- *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…)

256 grey levels (8 bits per pixel) | 128 grey levels (7 bpp) | 64 grey levels (6 bpp) | 32 grey levels (5 bpp)



16 grey levels (4 bpp) | 8 grey levels (3 bpp) | 4 grey levels (2 bpp) | 2 grey levels (1 bpp)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

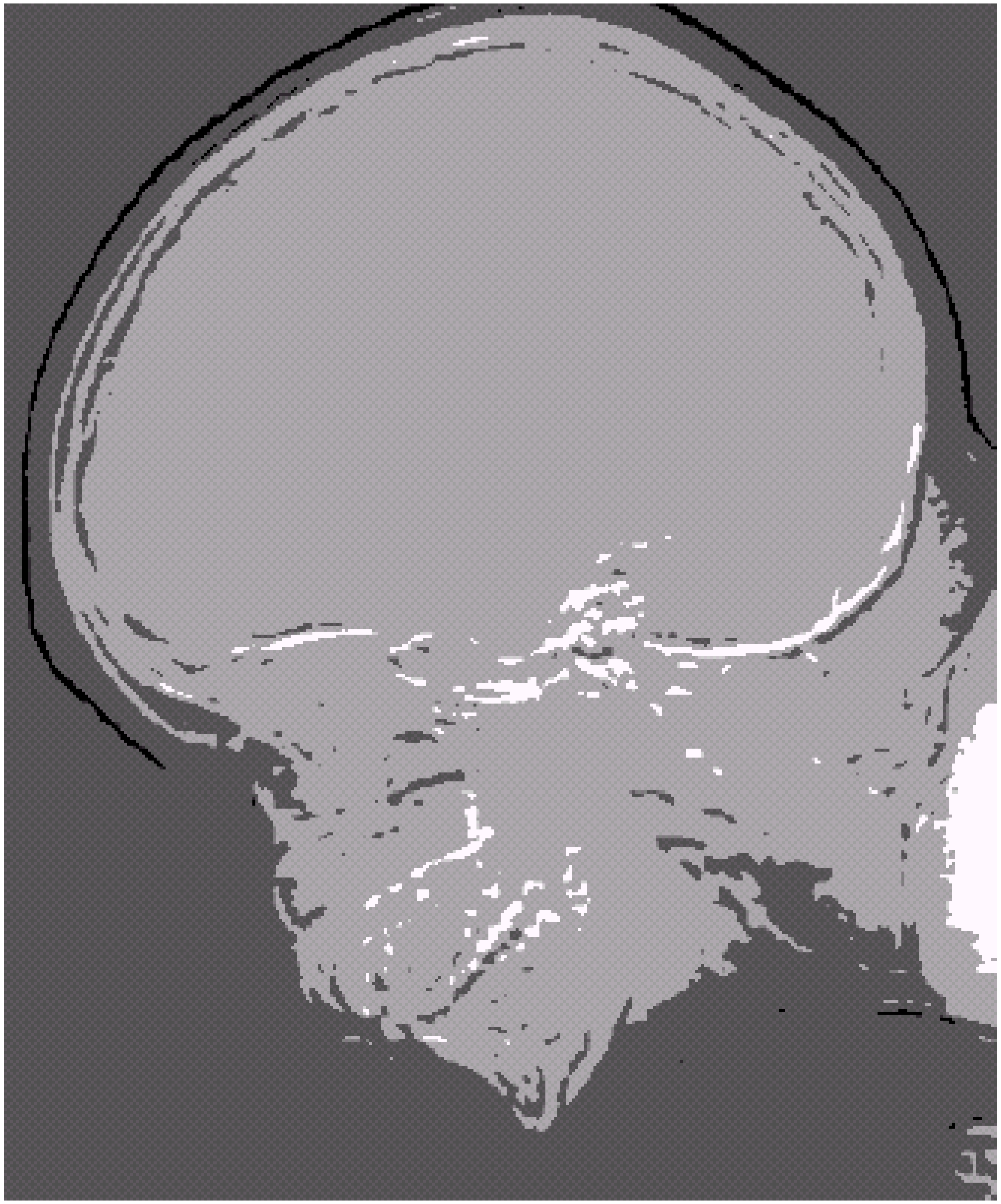
Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)

Intensity Level Resolution (cont…)



Intensity Level Resolution (cont...)

Spatial Resolution

72 Pixel / inch

22 Pixel / inch

Spatial Resolution

Medium resolution

High resolution

Brightness

- **Definition:**
- The attribute of visual perception in accordance with which an area appears to emit more or less light or, according to which the area in which the visual stimulus is presented appears to emit more or less light.
- **Explanation:**
- Magnitude of the response produced in the eye by light

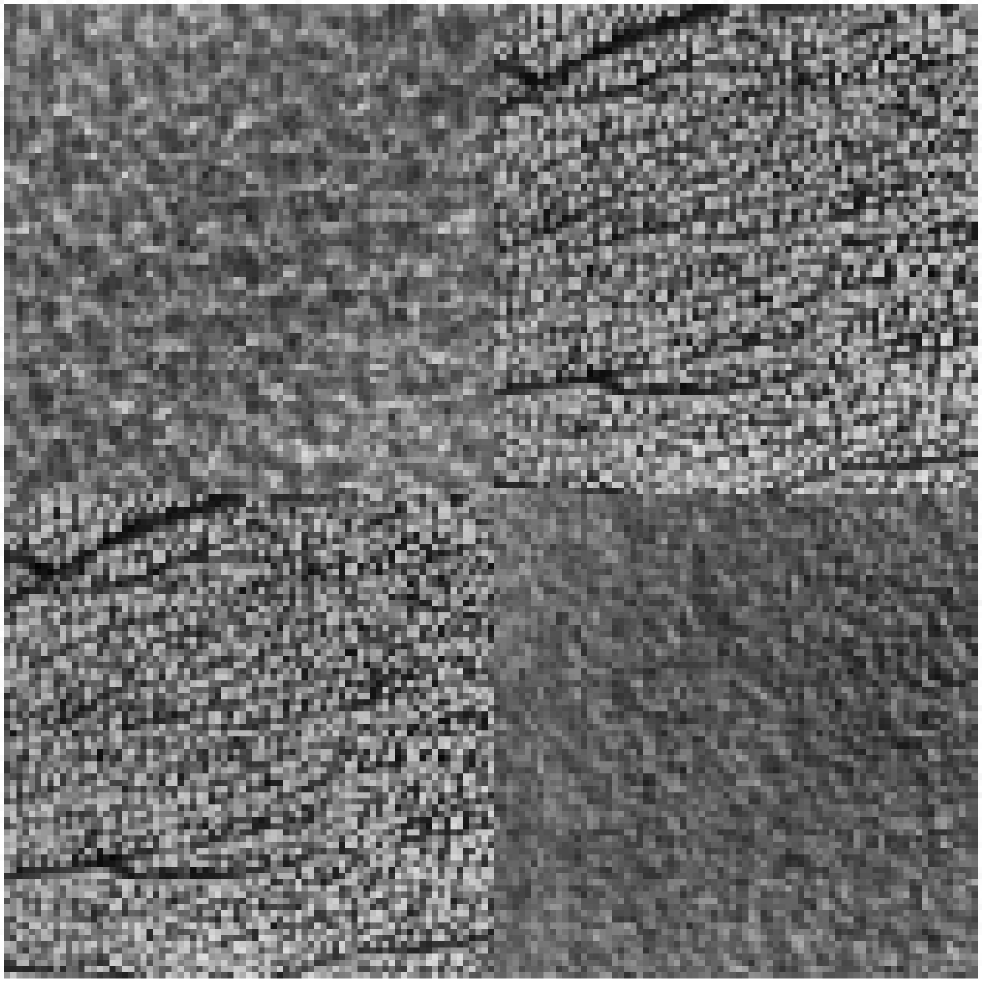
Tone

- ✓ ***Definition:***
- ✓ *Tone refers to each distinguishable grey level from black to white on an image .*
- ✓ ***Explanation:***
- ✓ *Tone refers to the relative brightness or color of objects in an image.*
- ✓ *For color imagery, image tone refers simply to color.*

Image Texture

- ***Definition:***
- *The frequency of change and arrangement of image tones, or the pattern of spatial tone variations.*
- ***Explanation:***
- *Texture is a function of spatial uniformity of scene targets. It may be described as fine, medium, or coarse and stippled or mottled.*

Image Texture



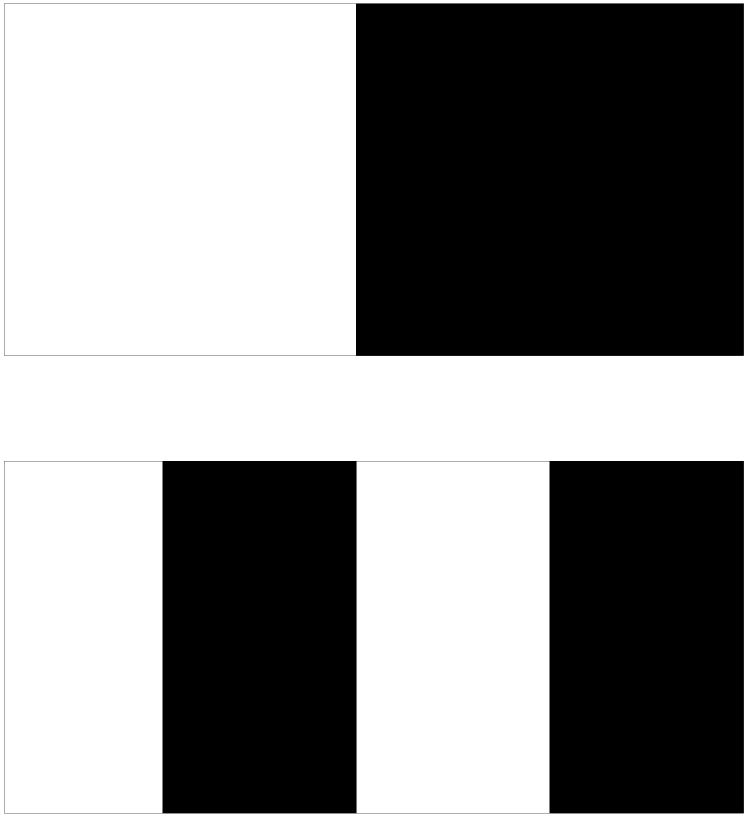
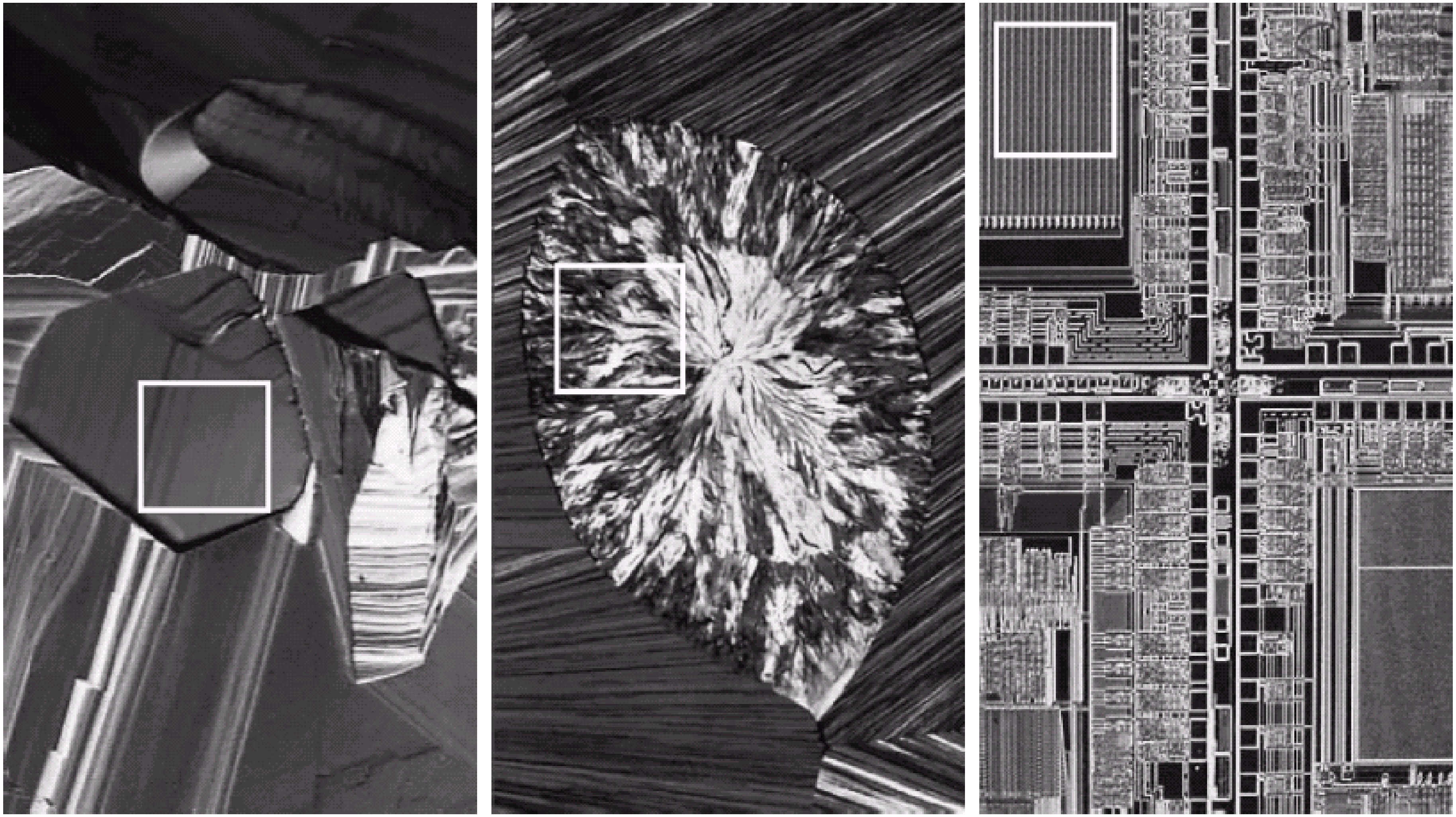


Image Texture



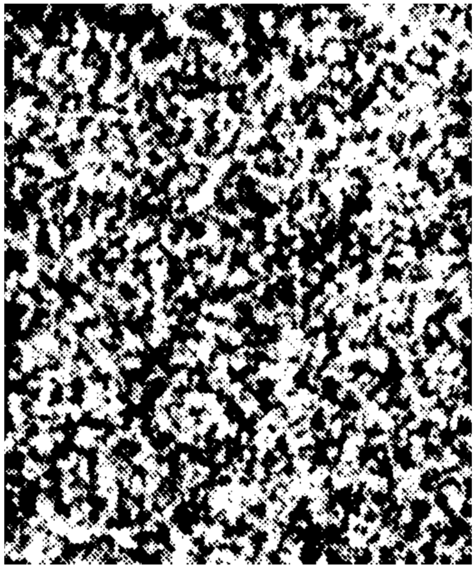
a b c

FIGURE 11.22 The white squares mark, from left to right, smooth, coarse, and regular textures. These are optical microscope images of a superconductor, human cholesterol, and a microprocessor. (Courtesy of Dr. Michael W. Davidson, Florida State University.)

Image Texture

Corn Field

Spatially Uniform Target Fine Texture

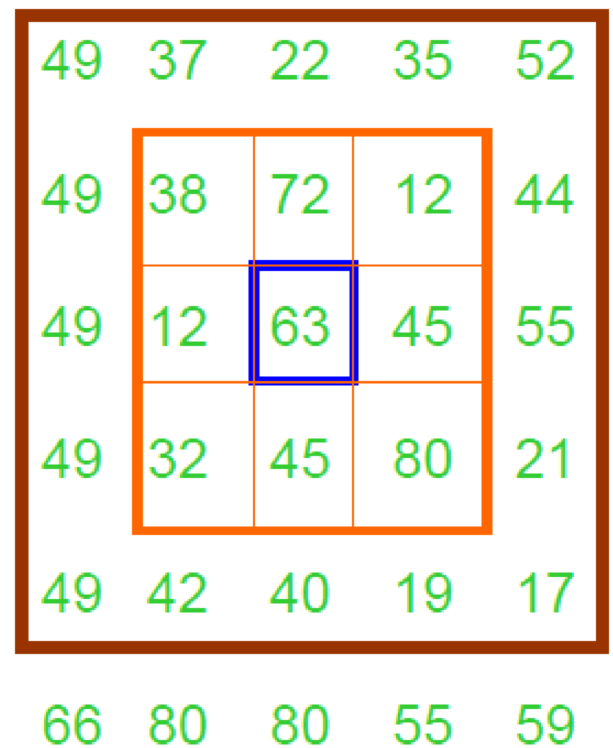


Forest

Spatially Non-Uniform Target Coarse Texture

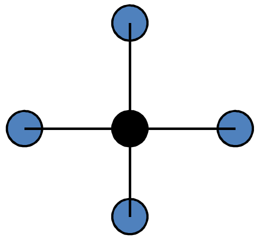
Neighborhood

- ✓ **Definition:**
- ✓ The pixels surrounding a given pixel constitute its *neighborhood*.
- ✓ **Explanation:**
- ✓ It can be characterized by its shape in the same way as a matrix (3×3, 5 ×7, etc.)
- ✓ Generally it has odd number of rows and columns

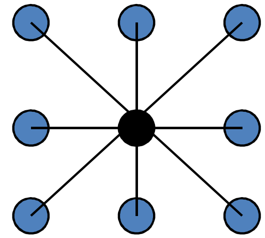


Neighborhood

<u>Neighbors of a pixel</u> *p=(i,j)*



$N_4(p)=\{(i-1,j),(i+1,j),(i,j-1),(i,j+1)\}$



$N_8(p)=\{(i-1,j),(i+1,j),(i,j-1),(i,j+1),$
$(i-1,j-1),(i-1,j+1),(i+1,j-1),(i+1,j+1)\}$

<u>Adjacency</u>

4-adjacency: p,q are 4-adjacent if p is in the set $N_4(q)$

8-adjacency: p,q are 8-adjacent if p is in the set $N_8(q)$

Note that if p is in $N_{4/8}(q)$*, then q must be also in* $N_{4/8}(p)$

Common Distance Definitions

- ✓ *Distance measures*
  - *Distance function: a function of two points, p and q, in space that satisfies three criteria*

$$(a)\ D(p,q) \geq 0$$

$$(b)\ D(p,q) = D(q,p), \text{ and}$$

$$(c)\ D(p,z) \leq D(p,q) + D(q,z)$$

  - *The Euclidean distance $D_e(p, q)$*

$$D_e(p,q) = \sqrt{(x-s)^2 + (y-t)^2}$$

  - *The city-block (Manhattan) distance $D_4(p, q)$*

$$D_4(p,q) = |x-s| + |y-t|$$

  - *The chessboard distance $D_8(p, q)$*

$$D_8(p,q) = \max(|x-s|, |y-t|)$$

Common Distance Definitions

Euclidean distance *(2-norm)*

$2\sqrt{2}$	$\sqrt{5}$	2	$\sqrt{5}$	$2\sqrt{2}$
$\sqrt{5}$	$\sqrt{2}$	1	$\sqrt{2}$	$\sqrt{5}$
2	1	0	1	2
$\sqrt{5}$	$\sqrt{2}$	1	$\sqrt{2}$	$\sqrt{5}$
$2\sqrt{2}$	$\sqrt{5}$	2	$\sqrt{5}$	$2\sqrt{2}$

D_4 distance (city-block distance)

4	3	2	3	4
3	2	1	2	3
2	1	0	1	2
3	2	1	2	3
4	3	2	3	4

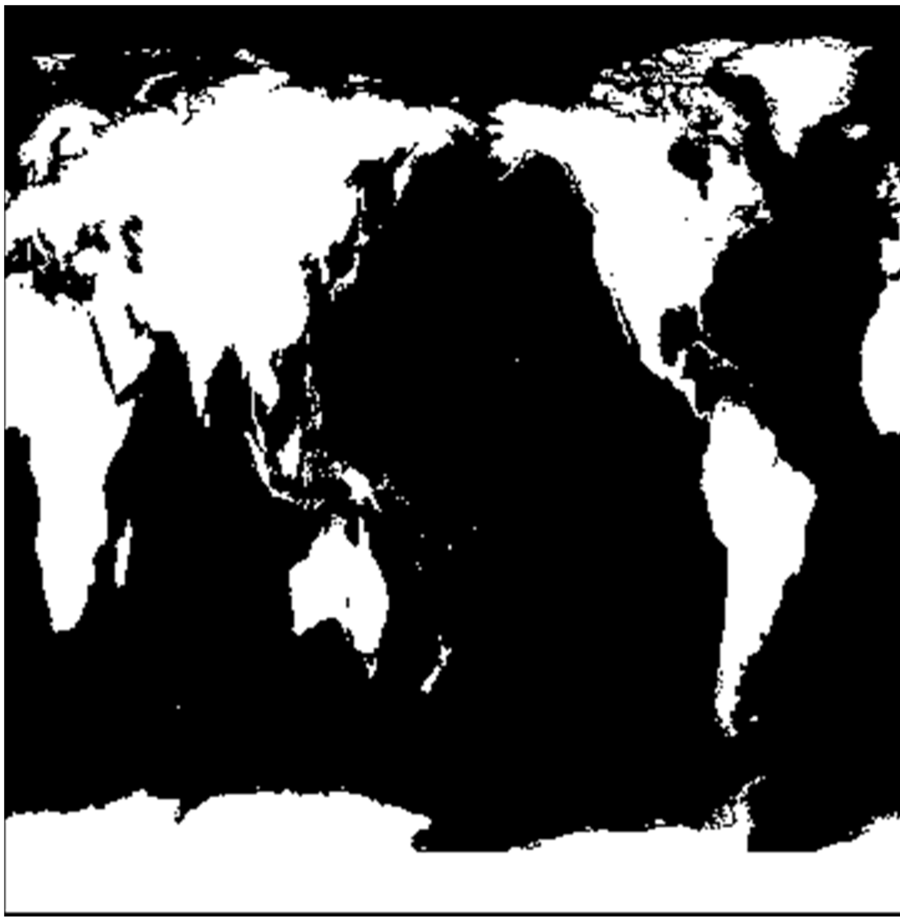
D_8 distance (checkboard distance)

2	2	2	2	2
2	1	1	1	2
2	1	0	1	2
2	1	1	1	2
2	2	2	2	2

Type of Digital images

✓ *We shall consider four basic types of images*

1) Binary*: Each pixel is just black or white.*



1	1	0	0	0	0
1	1	0	0	1	0
1	1	1	0	0	0
1	0	1	0	0	0
1	1	1	0	0	0
1	1	0	0	0	0
1	1	1	1	0	0

Type of Digital images

2) **Grayscale**: Each pixel is a shade of gray, normally from 0 (black) to 255 (white) or 8 bits.

49	37	22	35	52
50	38	72	12	44
51	12	63	45	55
52	32	45	80	21
53	42	40	19	17
66	80	80	55	59
67	41	41	12	44

Type of Digital images

***3)* True color or red-green-blue (RGB)**: Each pixel has a particular color, that color being described by the amount of red, green, and blue in it.

36	52	55	52	49
50	48	12	12	44
51	12	23	75	56
52	32	45	89	71
53	44	66	11	87

49	37	22	35	52
50	38	72	12	44
51	12	63	45	55
52	32	45	80	21
53	42	40	19	17

66	80	80	55	59
67	41	41	12	44
68	10	19	35	55
69	55	15	99	11
70	70	70	12	22

Type of Digital images

4) **Indexed**: For convenience of storage and file handling, the image has an associated *color map*, or *color palette*, which is simply a list of all the color used in that image. Each pixel has a value that does not give its color (as RGB images), but an ***index*** to the color in the map.

49	37	22	35	52
50	38	72	12	44
51	12	63	45	55
52	32	45	80	21
53	42	40	19	17
66	80	80	55	59
67	41	41	12	44

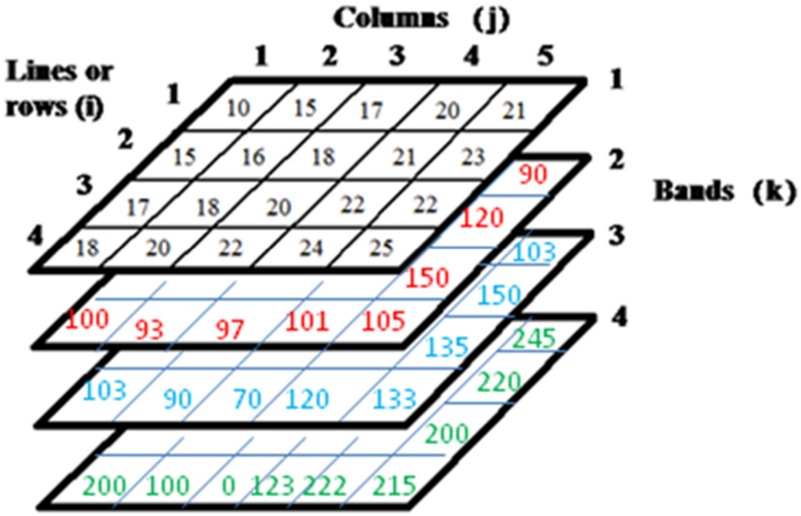
0.1211	0.1211	0.1411
0.1852	0.1255	0.1477
0.1522	0.1233	01911
0.1145	0.1322	0.1222
0.1455	0.1255	0.1799
0.1455	0.1633	0.1632
.	.	.
.	.	.
.	.	.

Image file formats

- ✓ *BSQ (Band Sequential Format):*
  - *each line of the data followed immediately by the next line in the same spectral band. This format is optimal for spatial (X, Y) access of any part of a single spectral band. Good for multispectral images*

- ✓ *BIP (Band Interleaved by Pixel Format):*
  - *the first pixel for all bands in sequential order, followed by the second pixel for all bands, followed by the third pixel for all bands, etc., interleaved up to the number of pixels. This format provides optimum performance for spectral (Z) access of the image data. Good for hyperspectral images*

- ✓ *BIL (Band Interleaved by Line Format):*
  - *the first line of the first band followed by the first line of the second band, followed by the first line of the third band, interleaved up to the number of bands. Subsequent lines for each band are interleaved in similar fashion. This format provides a compromise in performance between spatial and spectral processing and is the recommended file format for most ENVI processing tasks. Good for images with 20-60 bands*



Band 2

20	50	50	90	90
76	66	55	45	120
80	80	60	70	150
100	93	97	101	105

Band 3

120	150	100	120	103
176	166	155	85	150
85	80	70	77	135
103	90	70	120	133

Band 4

210	250	250	190	245
156	166	155	415	220
180	180	160	170	200
200	0	123	222	215

Matrix notation for band 2

1,1,2	2,1,2	3,1,2	4,1,2	5,1,2
1,2,2	2,2,2	3,2,2	4,2,2	5,2,2
1,3,2	2,3,2	3,3,2	4,3,2	5,3,2
1,4,2	2,4,2	3,4,2	4,4,2	5,4,2

BIL

10	15	17	20	21	20	50	50	90	90	120	150	100	120	103	210	250	250	190	245
15	16	18	21	23	76	66	55	45	120	176	166	155	85	150	156	166	155	415	220
17	18	20	22	22	80	80	60	70	150	85	80	70	77	135	180	180	160	170	200
18	20	22	24	25	100	93	97	101	105	103	90	70	120	133	200	0	123	222	215

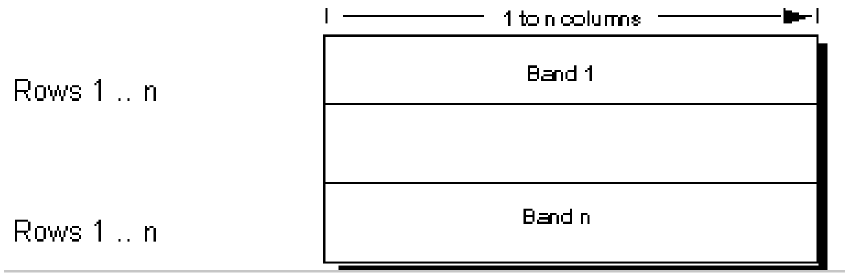
BSQ

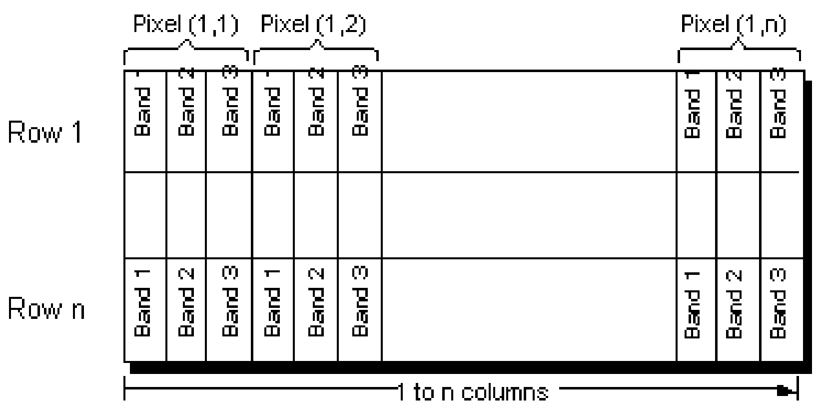
10	15	17	20	21	15	16	18	21	23	17	18	20	22	22	18	20	22	24	25
20	50	50	90	90	76	66	55	45	120	80	80	60	70	150	100	93	97	101	105
120	150	100	120	103	176	166	155	85	150	85	80	70	77	135	103	90	70	120	133
210	250	250	190	245	156	166	155	415	220	180	180	160	170	200	200	0	123	222	215

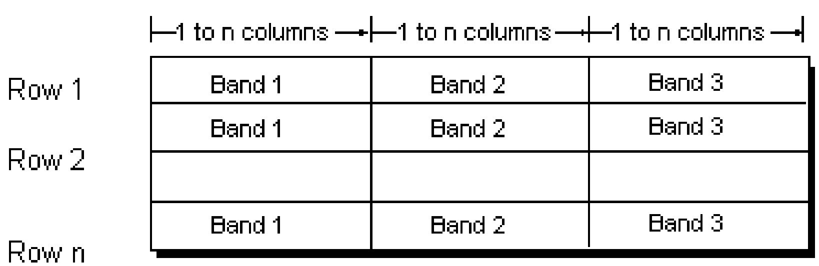
BIP

10	20	120	210	15	50	150	250	17	50	100	250	20	90	120	190	21	90	103	245
15	76	176	156	16	66	166	166	18	55	155	155	21	45	85	415	23	120	150	220
17	80	85	180	18	80	80	180	20	60	70	160	22	70	77	170	22	150	135	200
18	100	103	200	20	93	90	0	22	97	70	123	24	101	120	222	25	105	133	215

Image file formats







- ✓ *Band sequential (BSQ) format stores information for the image one band at a time. In other words, data for all pixels for band 1 is stored first, then data for all pixels for band 2, and so on.*
  - *Value=image(c, r, b)*
- ✓ *Band interleaved by pixel (BIP) data is similar to BIL data, except that the data for each pixel is written band by band. For example, with the same three-band image, the data for bands 1, 2 and 3 are written for the first pixel in column 1; the data for bands 1, 2 and 3 are written for the first pixel in column 2; and so on.*
  - *Value=image(b, c, r)*
- ✓ *Band interleaved by line (BIL) data stores pixel information band by band for each line, or row, of the image. For example, given a three-band image, all three bands of data are written for row 1, all three bands of data are written for row 2, and so on, until the total number of rows in the image is reached.*
  - *Value=image(c, b, r)*

Images Formats

- ✓ *There are a great many different formats for storing image data. However, we can use software for image processing very happily without ever really knowing the difference between different formats.*
- ✓ *Header information*
- ✓ *Vector versus Raster Images*
  - *Vector example: Adobe PostScript*

Images Files and Formats

✓ ASCII PGM

```
P2
305  734
255
41  54  67  12  34  56  89  32  23  15  76  76   34
65  23  56   33  22  15  89  43  21  32  56  77  32
```

Images Files and Formats

✓ Microsoft BMP

- *Binary Image format*
- *Header is divided into two parts: the first 14 bytes (bytes 0-13) are the File Header, and the following 40 bytes are the Information Header.*
- *After the header comes the Color Table (no of bytes = 4×color)*

Images Files and Formats

✓ Microsoft BMP

- *Binary Image format*
- *Header is divided into two parts: the first 14 bytes (bytes 0-13) are the File Header, and the following 40 bytes are the Information Header.*
- *After the header comes the Color Table (no of bytes = 4×color)*

```
42 4D 6E 18 00 00 00 00 00 00 36 00 00 00 28 00   BMn.......6...(.
00 00 42 00 00 00 1F 00 00 00 01 00 18 00 00 00   ..B.............
00 00 38 18 00 00 C4 0E 00 00 C4 0E 00 00 00 00   ..8.............
00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00   ................
```

Images Files and Formats

✓ GIF

- CompuServe GIF is an image format that was first proposed in the late 1980s as a means for distributing images over networks. Like PGM, it is a raster format, but it has the following properties:

1. Colors are stored using a color map. The GIF specification allows a maximum of 256 colors per image.

2. GIF doesn't allow binary or grayscale images, except as can be produced with RGB values.

3. The pixel data is compressed using LZW (Lempel- Ziv-Welch) compression. This works by constructing a "codebook" of the data.

Images Files and Formats

✓ GIF

4. The GIF format allows multiple images per file. This aspect can be used to create animated GIFs.

5. A GIF file will contain a header including the image size (in pixels), the color map, the color resolution (number of bits per pixel), a flag indicating whether or not the color map is ordered, and the color map size.

Images Files and Formats

✓ JPEG

- The compression method used by GIF is lossless: the original information can be recovered completely. The JPEG algorithm uses lossy compression, in which not all the original data can be recovered. Such methods result in much higher compression rates, and JPEG images are in general much smaller than GIF images.
- Compression of JPEG images works by breaking the image into 8x8 blocks, applying the discrete cosine transform (DCT) to each block, and removing small values.
- JPEG images are best used for the representation of natural scenes, in which case they are preferred.

Images Files and Formats

✓ JPEG

- For data with any legal significance or scientific data, JPEG is less suitable for the very reason that not all information is preserved.
- However, the mechanics of the JPEG transform ensures that a JPEG image, when restored from its compression routine, will generally look the same as the original image. The differences are, in general, too small to be visible to the human eye. JPEG images are thus excellent for display.
- A JPEG image then contains the compression data with a small header providing the image size and file identification

Images Files and Formats

✓ TIFF

- The *Tagged Image File Format*, or TIFF, is one of the most comprehensive image formats.
- It can store multiple images per file.
- It allows different compression routines (none at all, LZW, JPEG, Huffman, run-length encoding) and different byte orderings.
- It allows binary, grayscale, true color indexed images, and allows opacity or transparency.

Images Files and Formats

✓ TIFF

- The TIFF header is, in fact, very simple; it consists of just 8 bytes:

Bytes	Information
0-1	Byte order
2-3	TIFF version
4-8	Image offset (Pointer to the position in the file of the data for the first image)

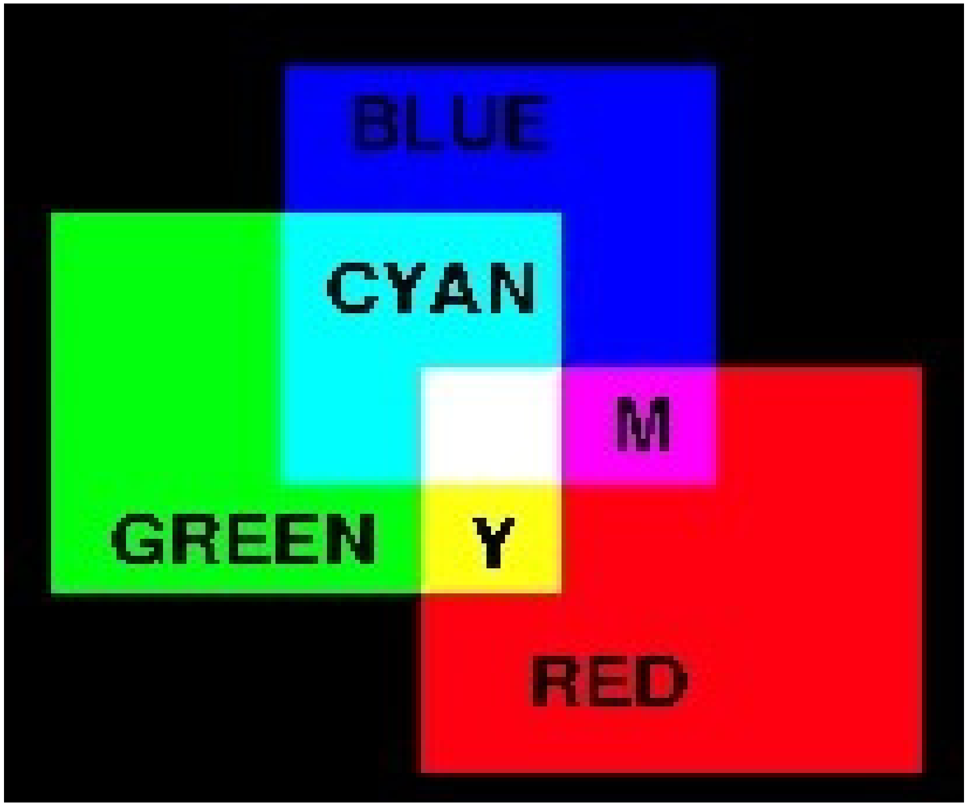
Color Images

- ✓ Primary colors: Red, Blue, Green
- ✓ Secondary colors:

    Magenta (purple) = Red+ Blue

    Cyan = Blue + Green

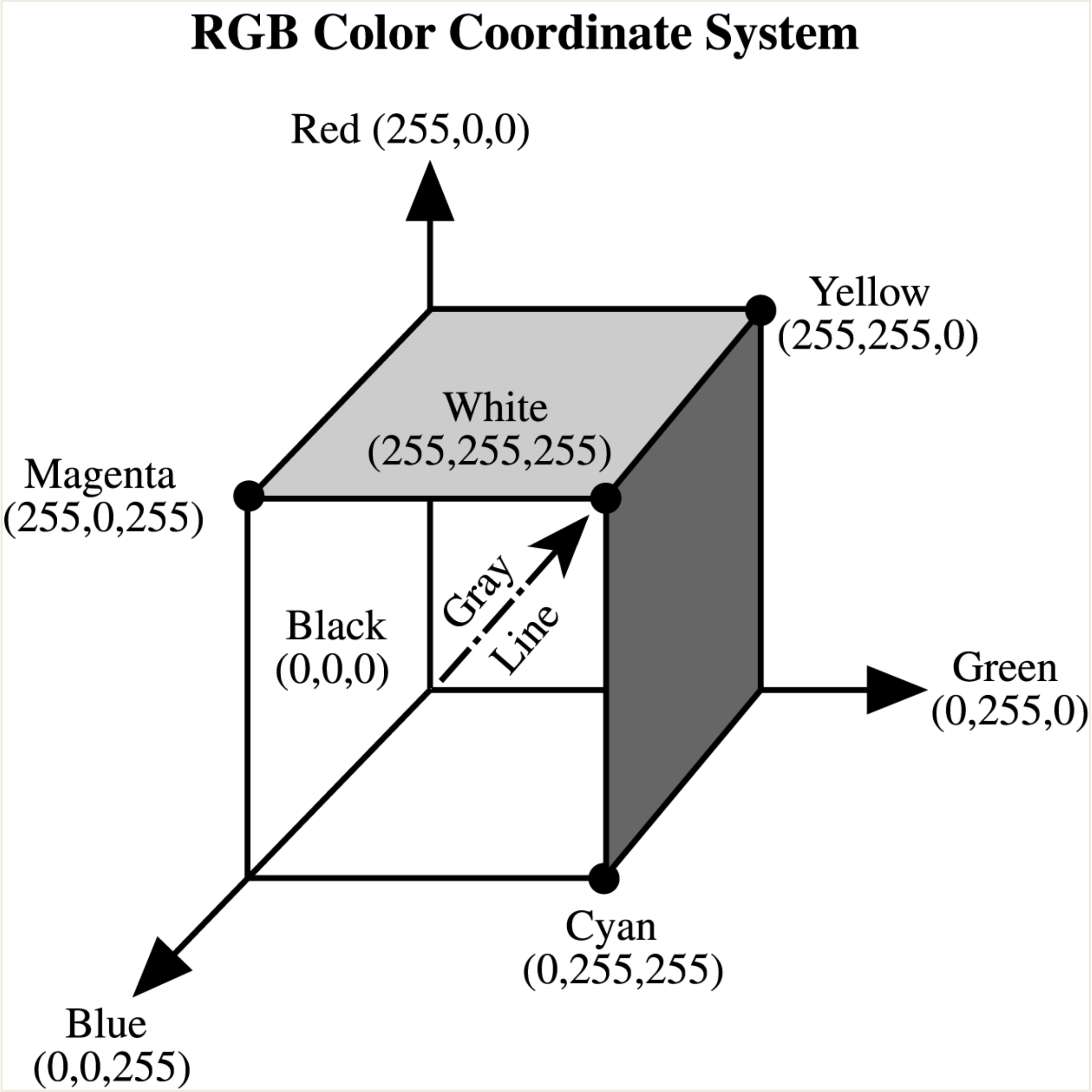
    Yellow = Red + Green



RGB Color Coordinate System

✓ Color Models

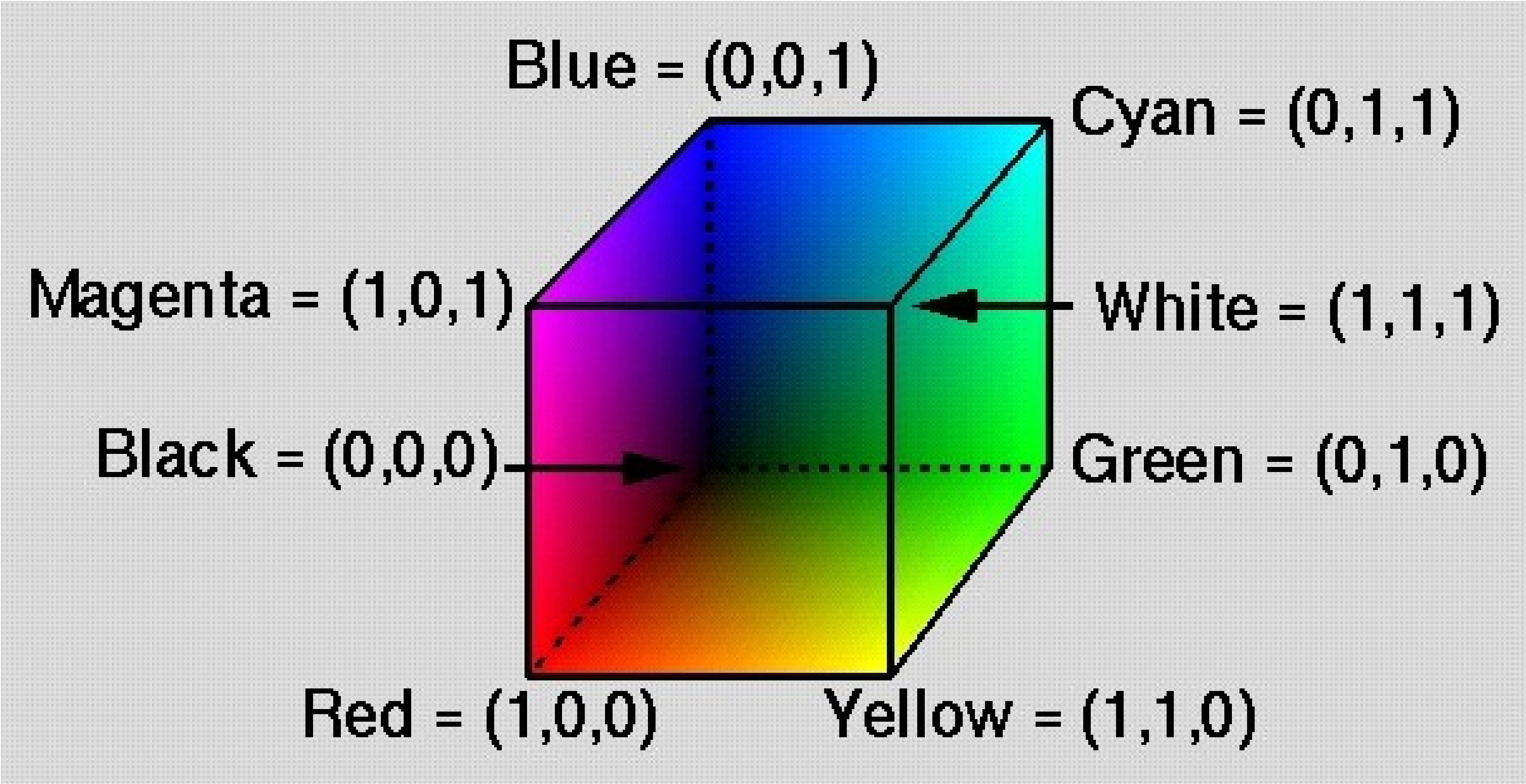
- *RGB*



RGB Color Coordinate System

✓ Color Models

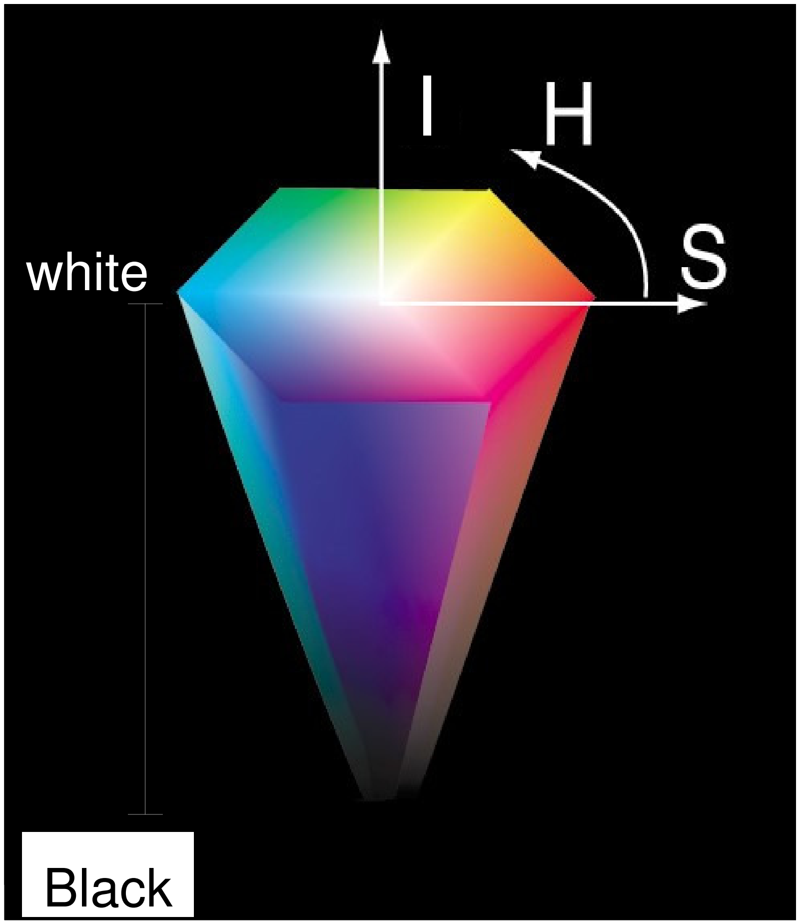
- *RGB*

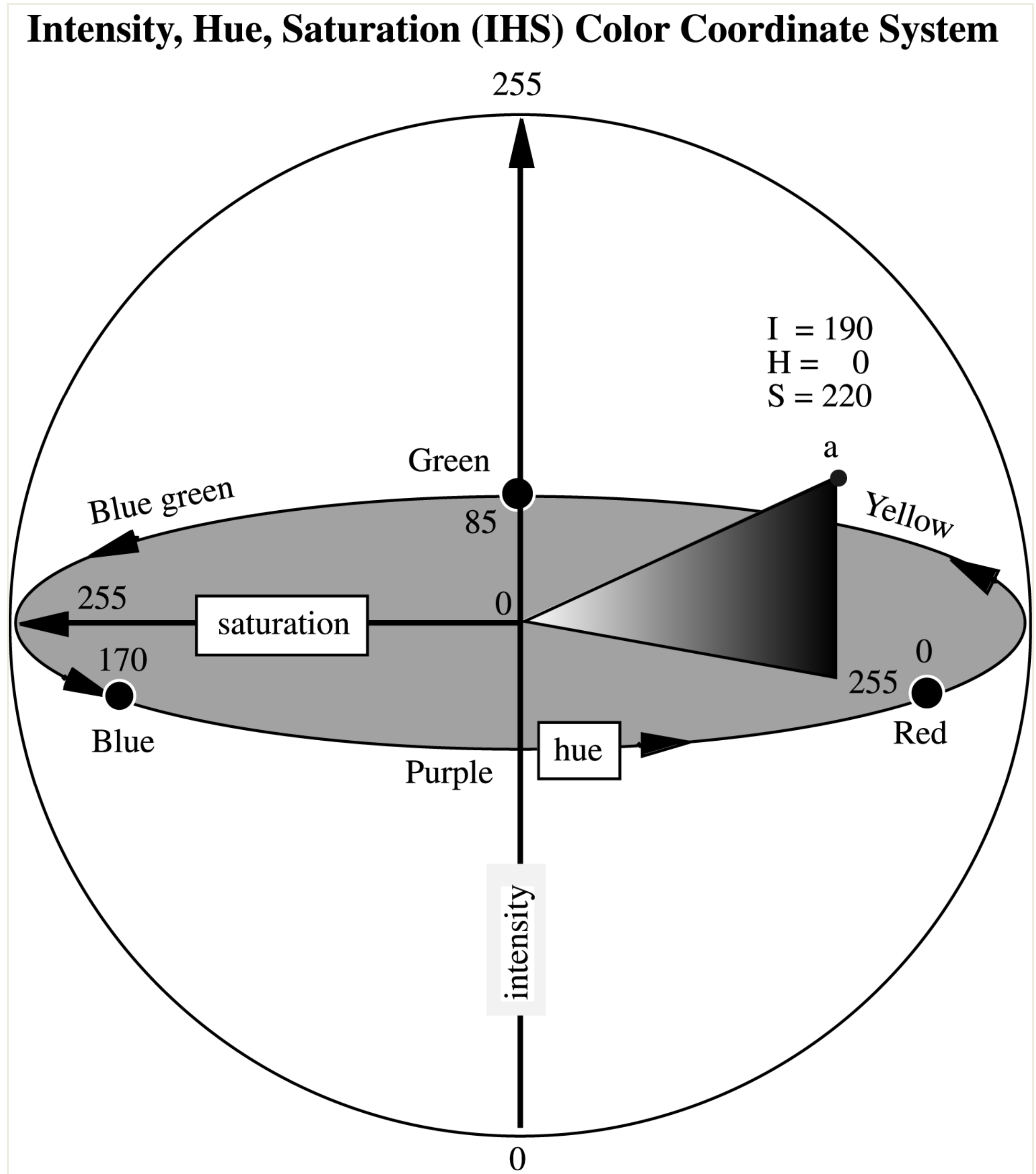


Merging Different Types of Remotely Sensed Data for Effective Visual Display

- *Intensity-Hue-Saturation (HIS) Substitution:*
  - *The vertical axis represents intensity (I) which varies from black (0) to white (255) and is not associated with any color. The circumference of the sphere represents hue (H), which is the dominant wavelength of color. Hue values begin with 0 at the midpoint of red tones and increase counterclockwise around the circumference of the sphere to conclude with 255 adjacent to 0. Saturation (S) represents the purity of the color and ranges from 0 at the center of the color sphere to 255 at the circumference. A saturation of 0 represents a completely impure color in which all wavelengths are equally represented and which the eye will perceive as a shade of gray that ranges from white to black depending on intensity.*

Intensity, Hue, Saturation (HIS) Color Coordinate System





Merging Different Types of Remotely Sensed Data for Effective Visual Display

- *Intensity-Hue-Saturation (HIS) Substitution:*
  - *IHS values can be derived from the RGB values through the transformation equations:*

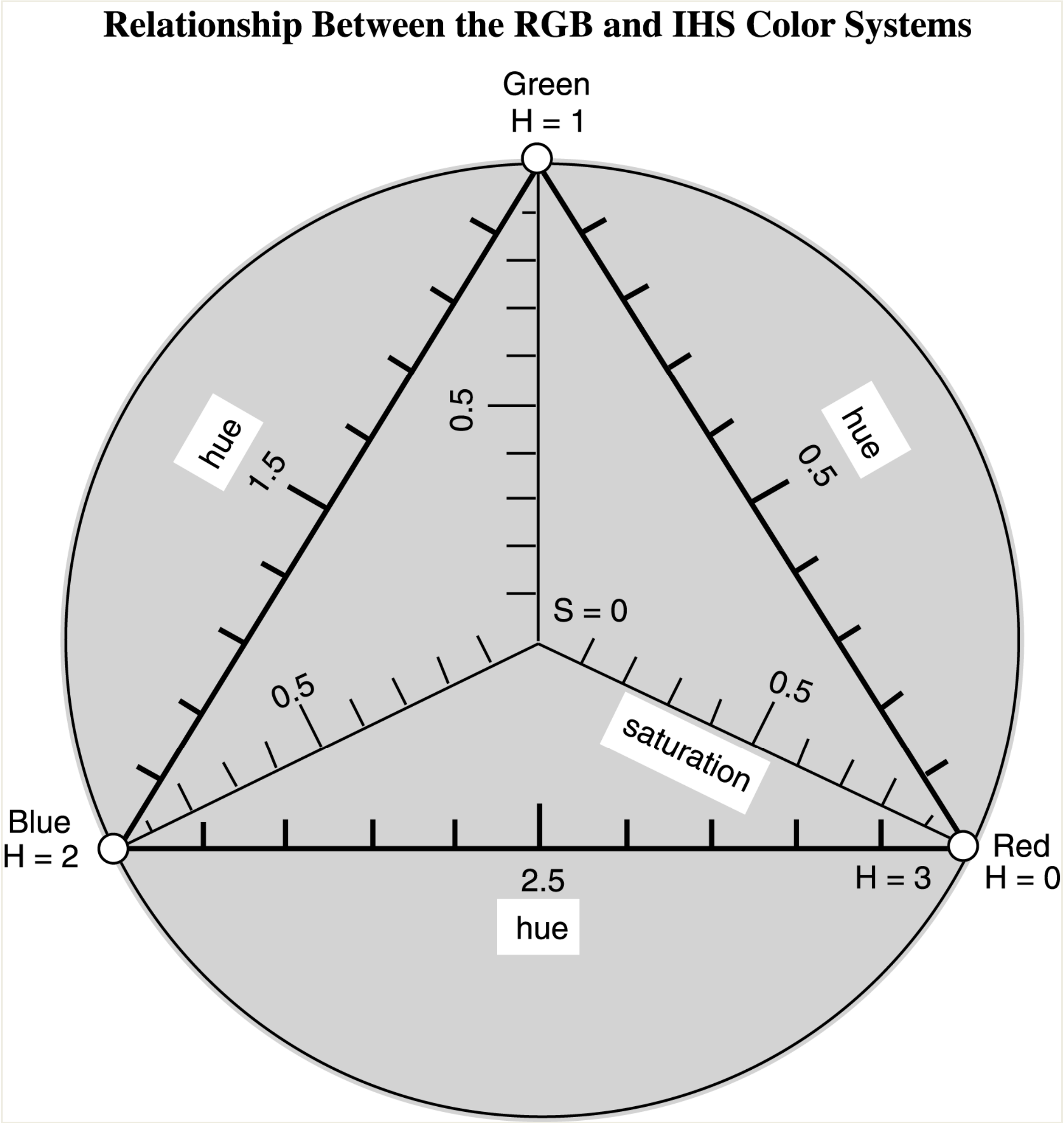
$$I = R + G + B$$

$$H = \frac{G - B}{I - 3B}$$

$$S = \frac{I - 3B}{I}$$

Substitute ***Intensity*** data from the ***IHS transformation*** for one of the bands, e.g., RGB = ***4, I, 2***

Relationship Between RGB and IHS Color Systems



RGB to HSI

$$\begin{pmatrix} I \\ v_1 \\ v_2 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} & -\frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix}$$

$$H = \tan^{-1}\left(\frac{v_2}{v_1}\right)$$

$$S = \sqrt{v_1^2 + v_2^2} \quad (c)$$

Color Images

- ✓ CMY (Cyan, Magenta, Yellow)

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Some Definitions

✓ True Color:

- A color imaging process whereby the color of the image is the same as the color of the object imaged.

✓ False Color (pseudo-color):

- Using one color to represent another. A color imaging process which produces an image of a color that does not correspond to the true color of the scene.

Some Definitions

✓ Color Composite:

- A color image produced through optical combination of multiband images by projection through filters.

✓ False Color Composite :

- An image produced by displaying multiple spectral bands as colors different from the spectral range they were taken in.

Some Definitions

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- A color image produced through optical combination of multiband images by projection through filters.

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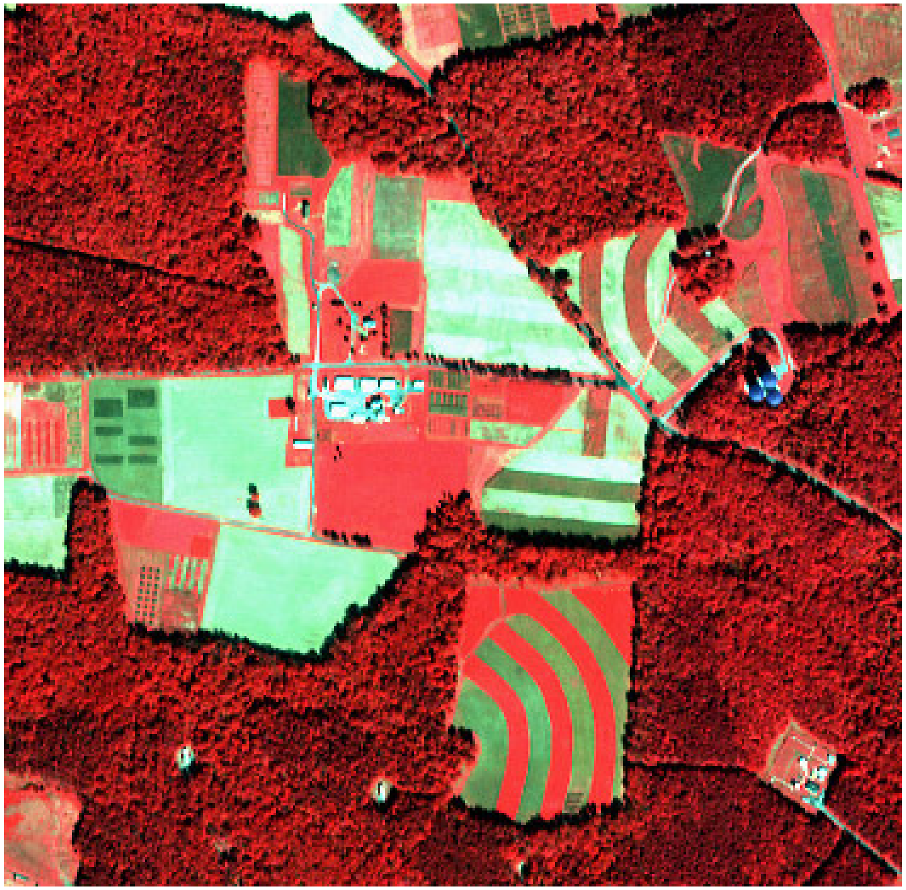
Some Definitions

True Color Composite

False Color Composite

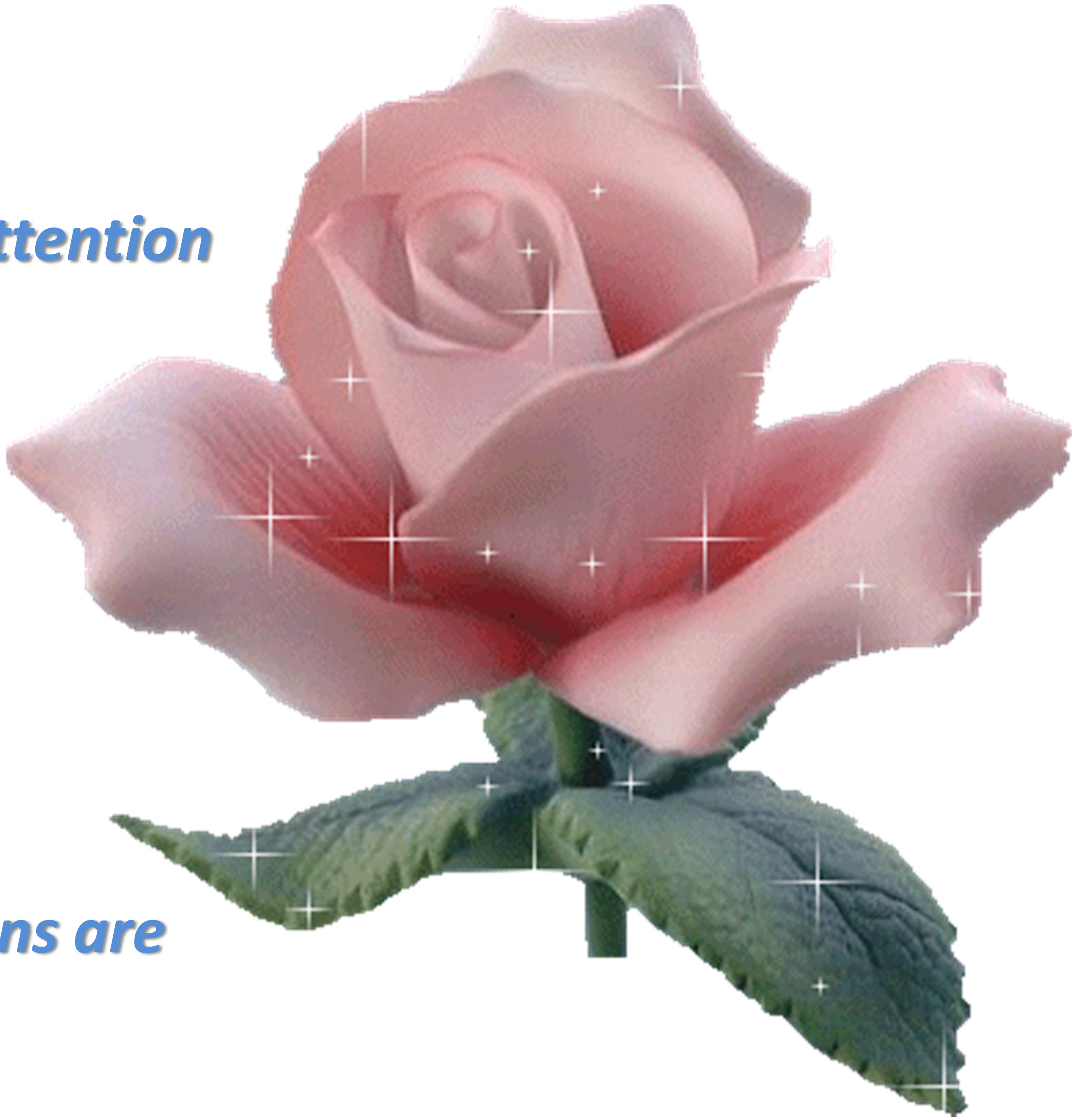
Some Definitions

True Color Composite



False Color Composite

Thanks for your attention



Advices & questions are always welcome!