Image Analysis

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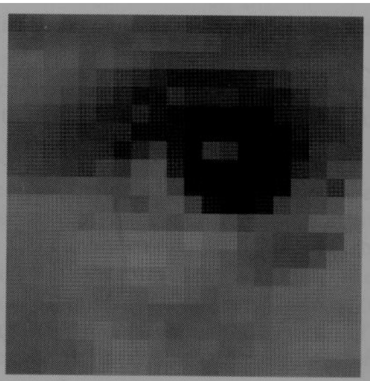
What is a digital Image?

- A digital image is a representation of a 2D image as a finite set of digital values called **pixels**.

What is a digital Image?

- Each pixel has a particular location and an associated number known as **digital number(DN)** or **sample.**

- This digital number determines the **color** and **brightness** for that particular pixel.



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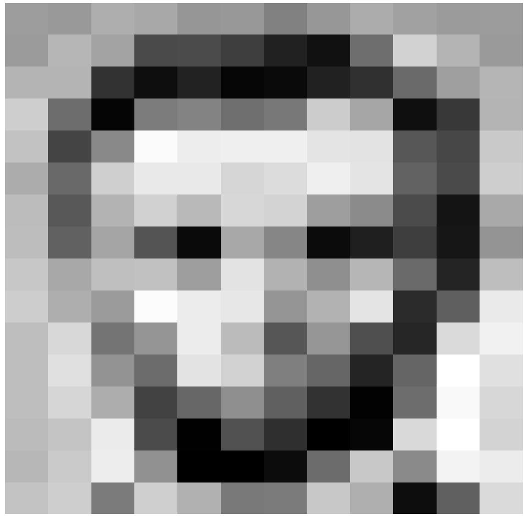
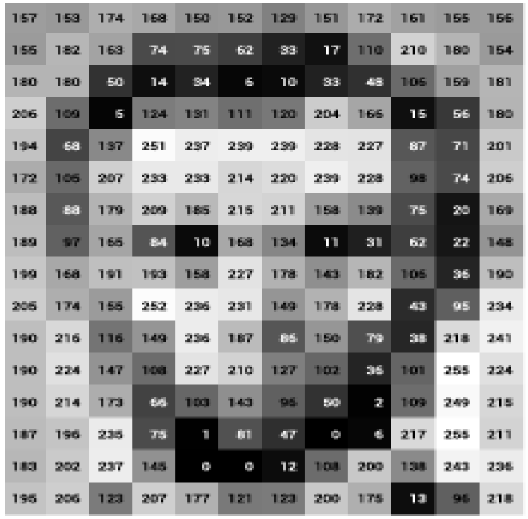
136	133	136	135	144	159	168	159	151	142	141	145	139	146	153	156	164	167	172	168
133	129	140	142	146	159	167	165	154	151	146	141	147	154	156	160	161	157	153	154

What is a digital Image?

- An image may be defined as a 2-dimensional function $f(x, y)$, where x and y are spatial coordinates.
- The amplitude of f at any coordinate (x, y) is called the intensity or gray level of the image at that point.





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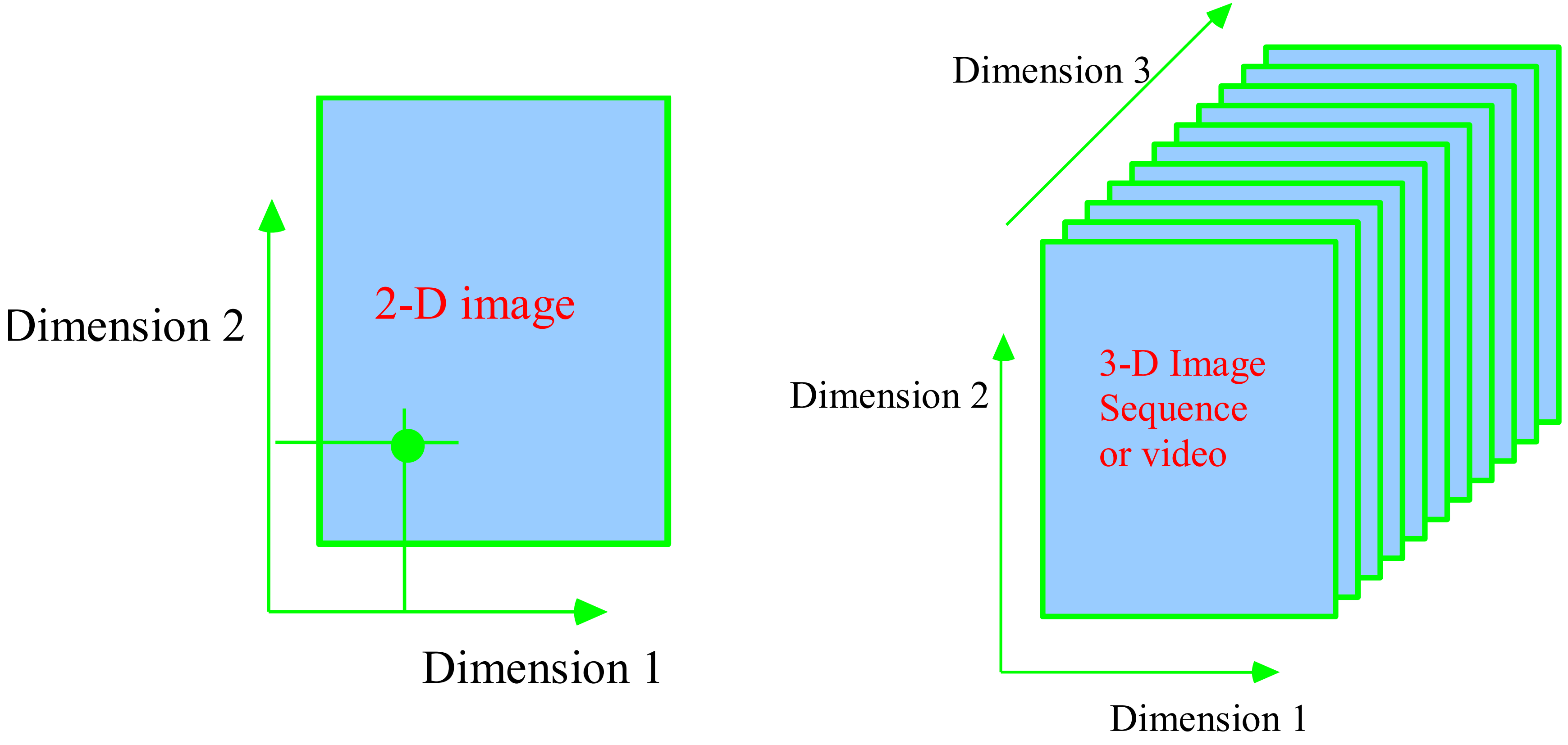
206	109	5	124	131	111	120	204	166	15	56	180
194	68	137	251	237	239	239	228	227	87	71	201
172	105	207	233	233	214	220	239	228	98	74	206
188	88	179	209	185	215	211	158	139	75	20	169
189	97	165	84	10	168	134	11	31	62	22	148
199	168	191	193	158	227	178	143	182	106	36	190
205	174	155	252	236	231	149	178	228	43	95	234
190	216	116	149	236	187	86	150	79	38	218	241
190	224	147	108	227	210	127	102	36	101	255	224
190	214	173	66	103	143	96	50	2	109	249	215
187	196	235	75	1	81	47	0	6	217	255	211
183	202	237	145	0	0	12	108	200	138	243	236
195	206	123	207	177	121	123	200	175	13	96	218

Dimensionality of Digital Image



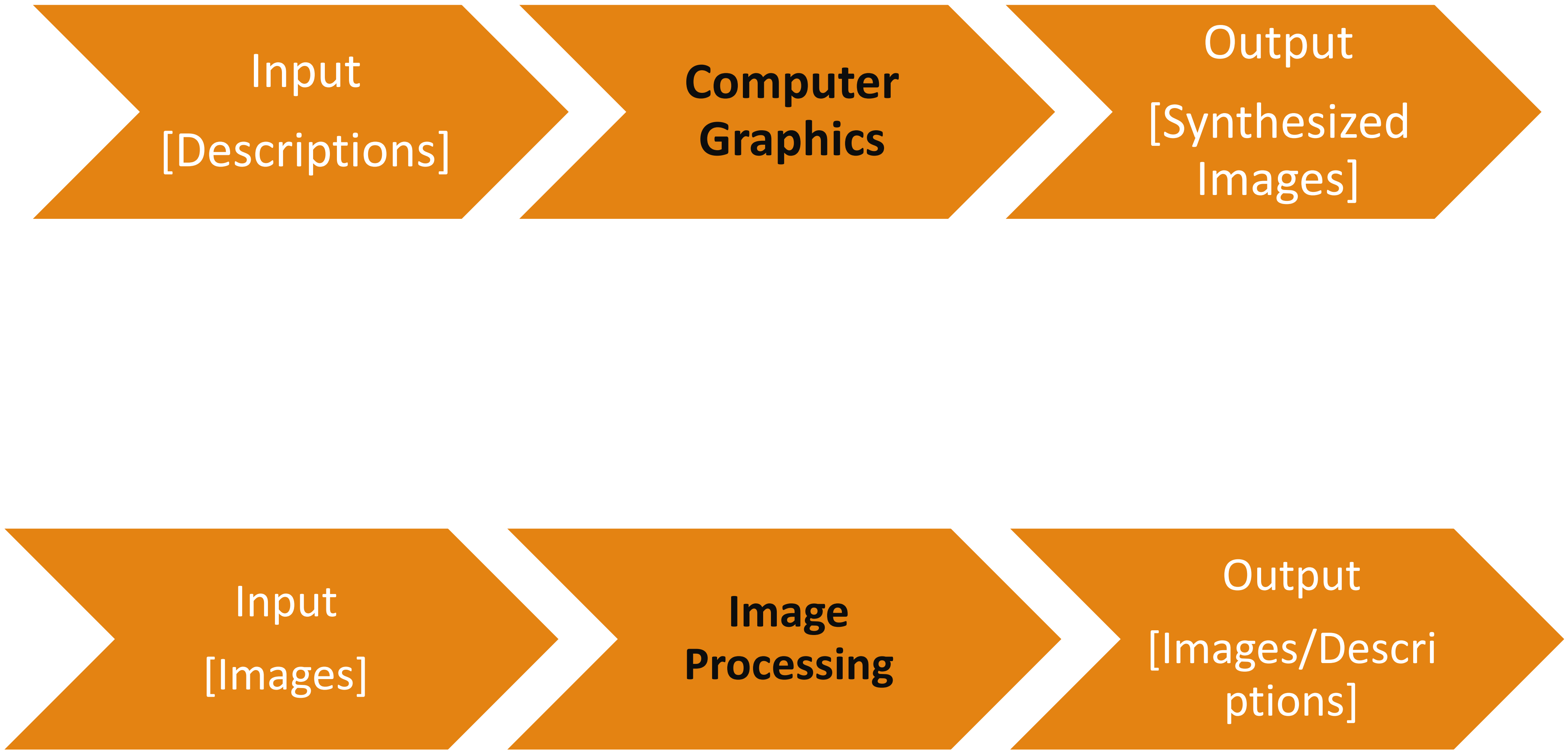
What is Digital Image Processing (DIP)?

- Manipulation and analysis of picture by a computer to:
  - Improve pictorial information for better clarity or human interpretation.
  - Automatic machine processing of scene data.

Difference between Image Processing and Computer Graphics?

- In general **Computer graphics** is all about **Synthesizing** a new image from **Geometry**, **Lighting parameter**, **materials** and **textures.**
- The emphasis is on **digital image synthesis**.

- **Image processing** is the process of **manipulating** an **image** acquired through some device.
- The emphasis is on **analysis and enhancement** of *images.*


Input
[Descriptions]
Computer Graphics
Output
[Synthesized Images]
Input
[Images]
Image Processing
Output
[Images/Descriptions]

Levels of Digital Image Processing

- **Low-Level Processes**
  - **Input** and **output** are images.
  - **Tasks:**
    - Primitive operations, such as, image processing to reduce noise, contrast enhancement and image sharpening

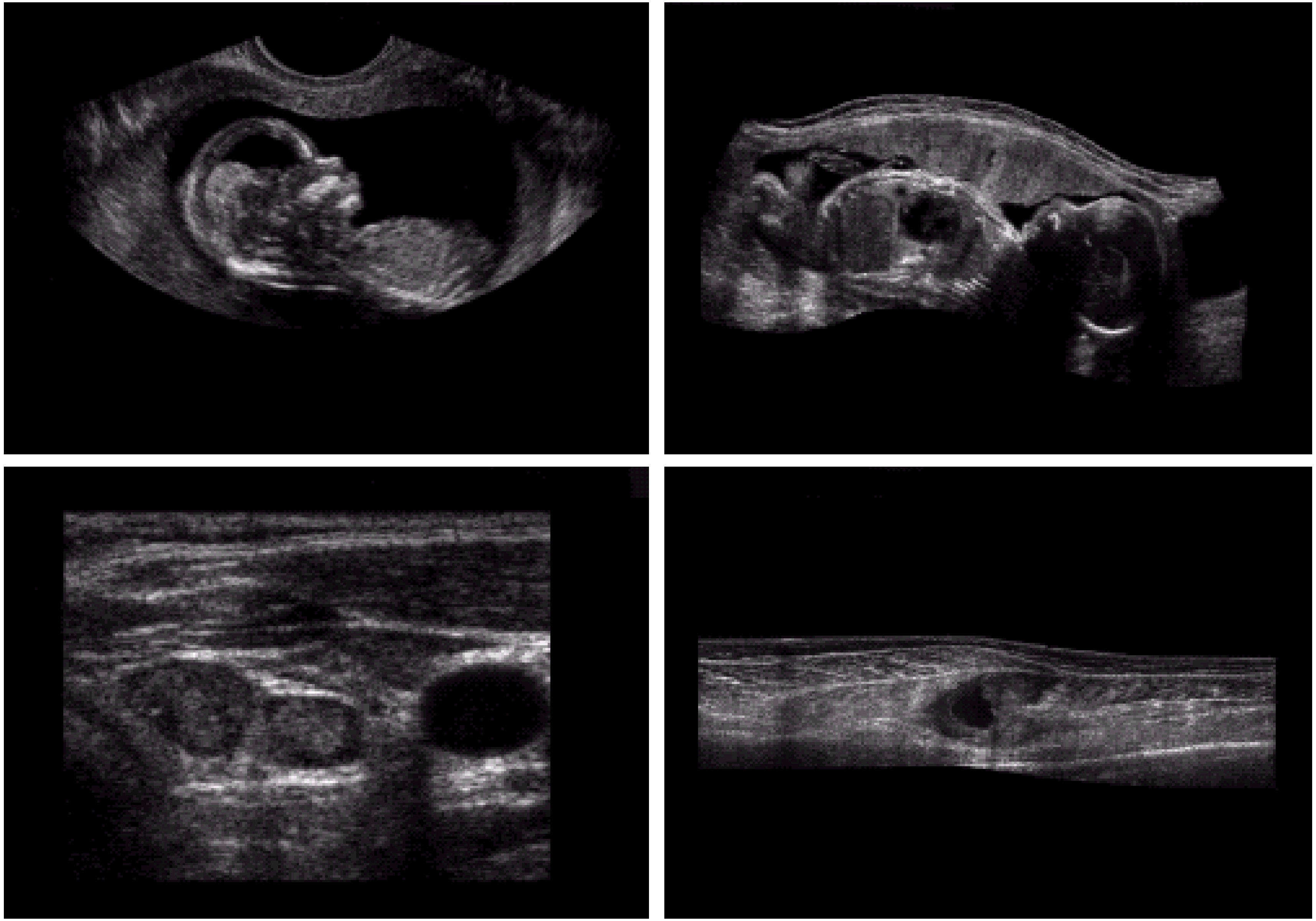
- **Mid-Level Processes**
  - **Inputs**, generally, are images.
  - **Outputs** are attributes extracted from those images (edges, contours, identity of individual objects).

- **Tasks:**
  - Segmentation (partitioning an image into regions or objects)
  - Description of those objects to reduce them to a form suitable for computer processing
  - Classifications (recognition) of objects

- **High-Level Processes:**
  - Image analysis and computer vision

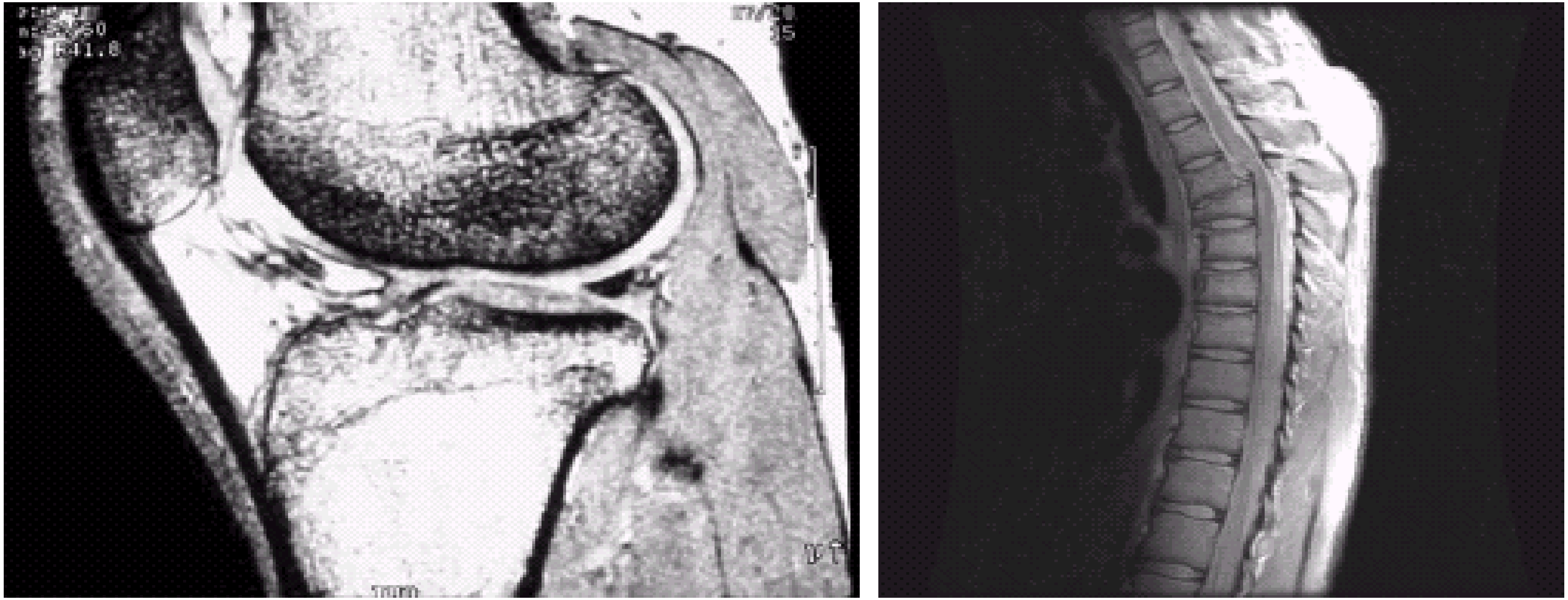
Applications of DIP

- Medical Imaging:
  - Generate images of human body for analysis for better diagnosis.
  - Ultrasonic, X-Ray, Computerized Tomography (CT), MRI are some of the commonly known applications.
  - Image retrieval



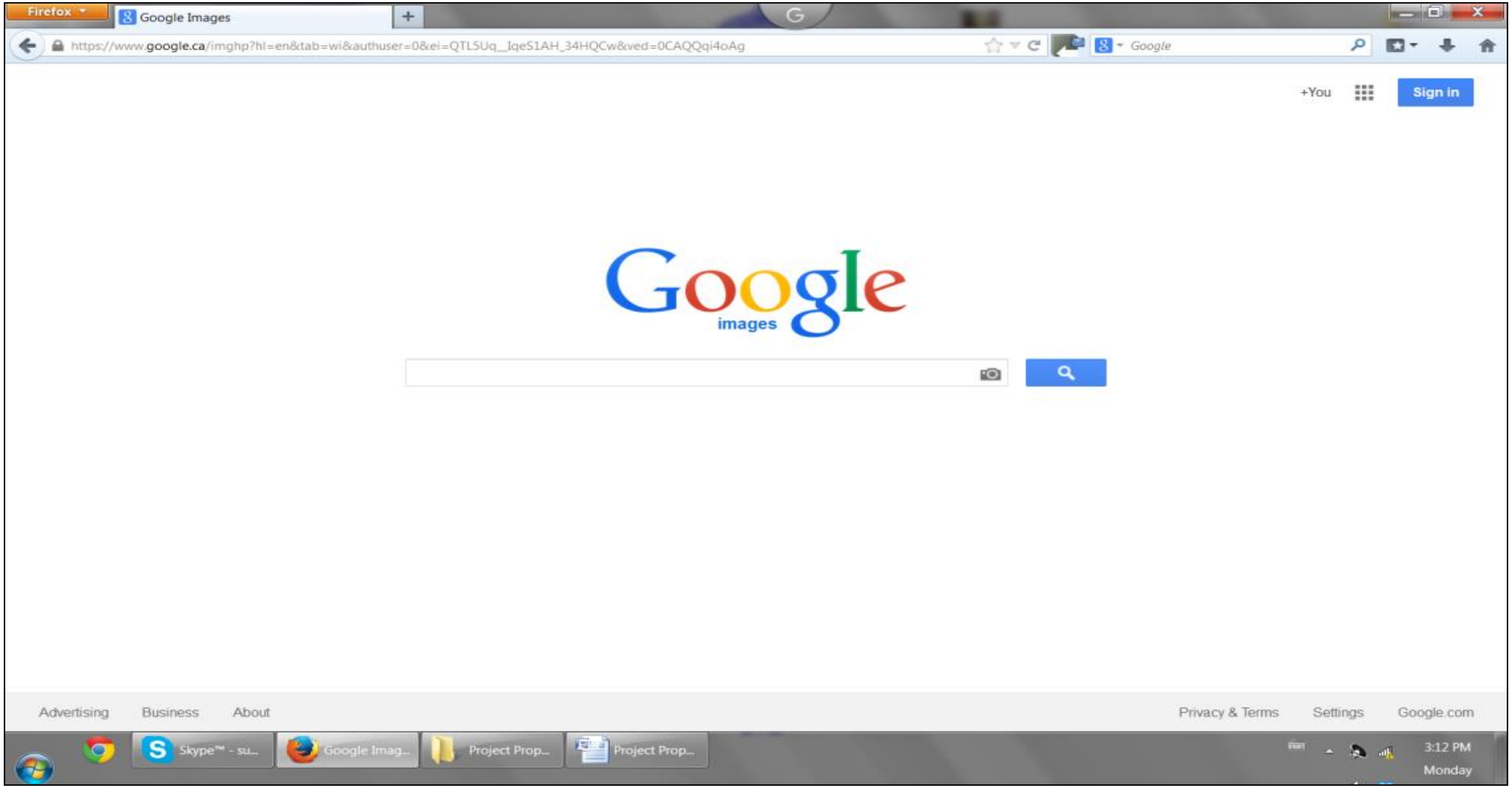
a b
c d

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



a b

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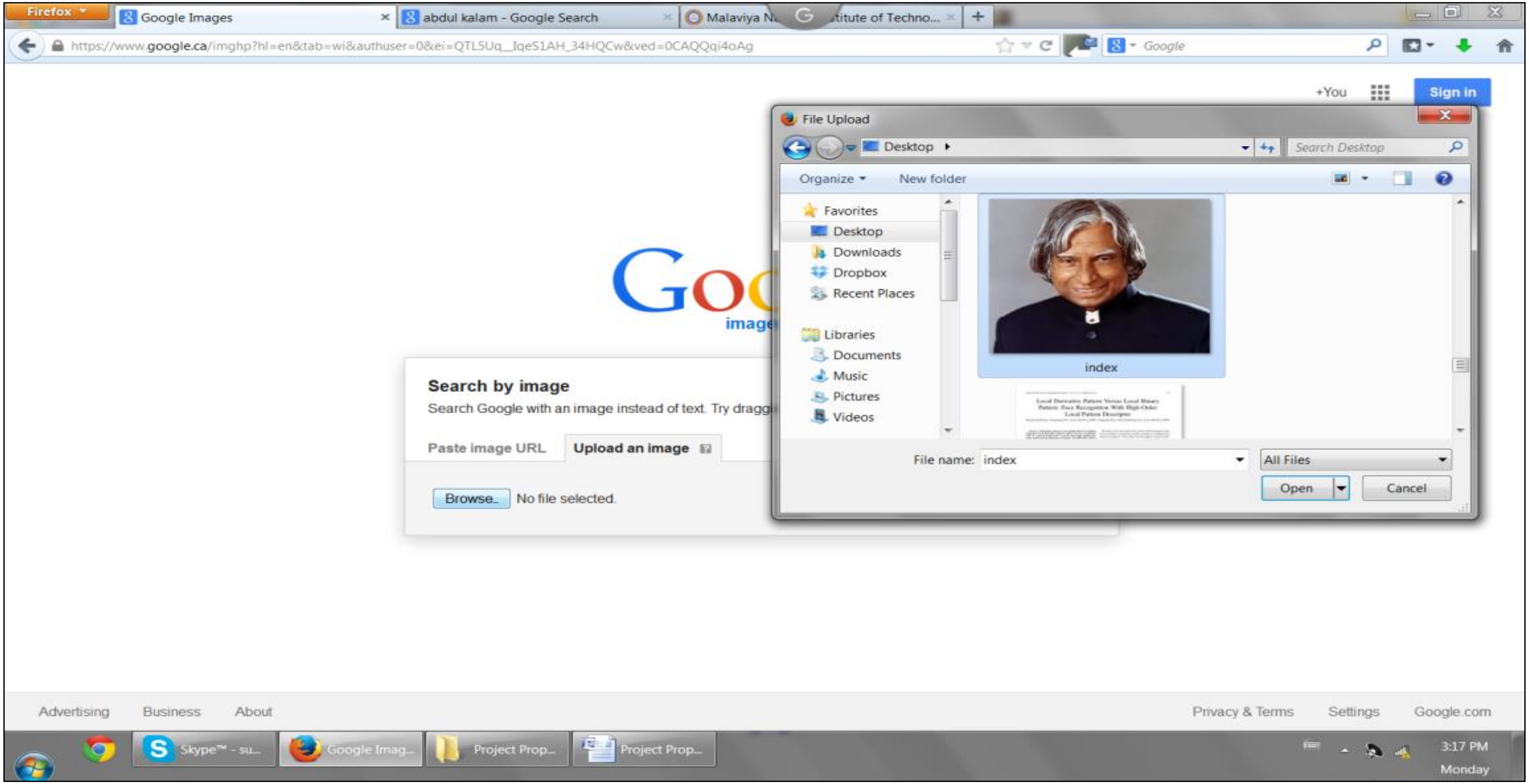
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New folder
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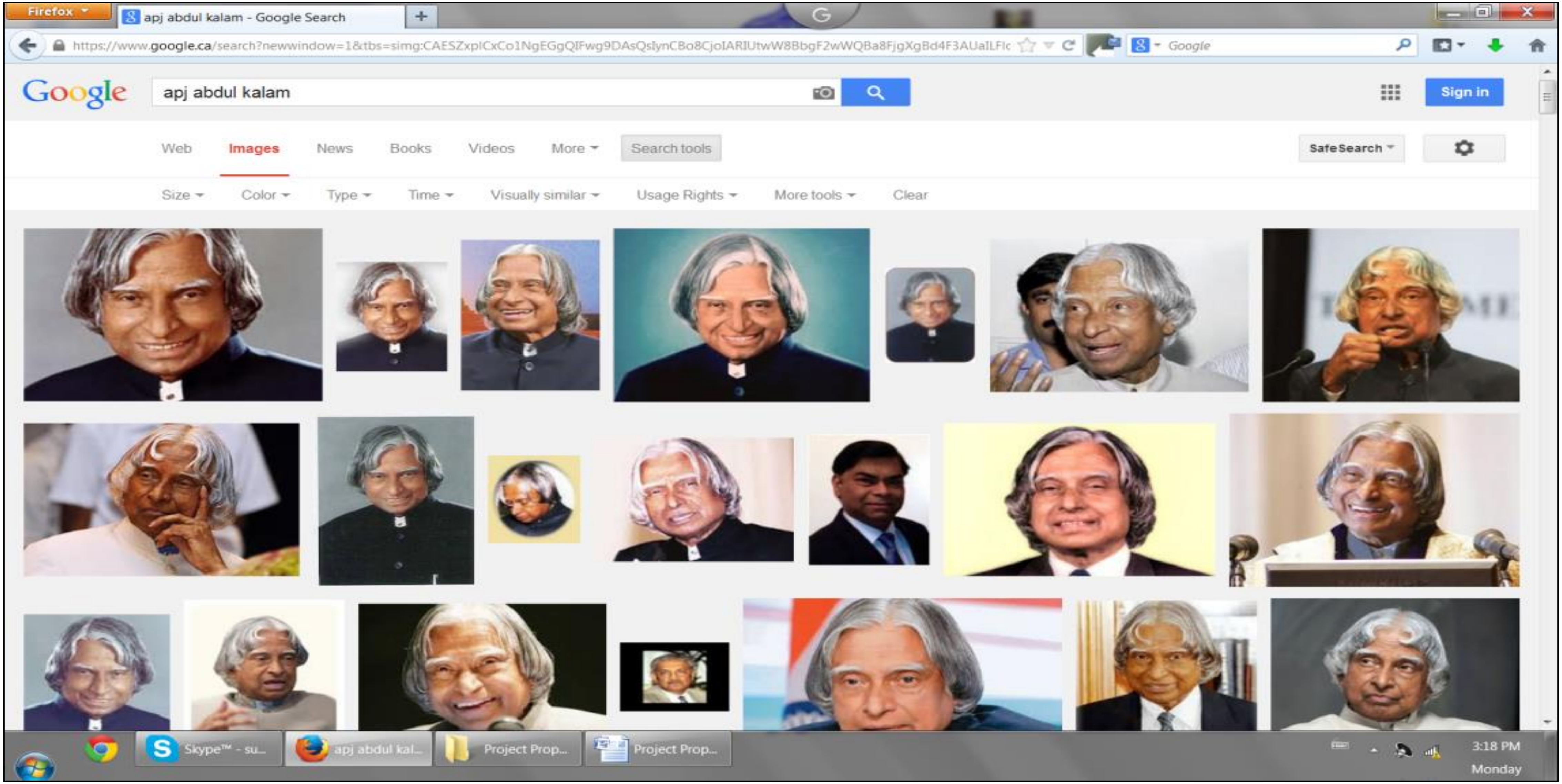
Monday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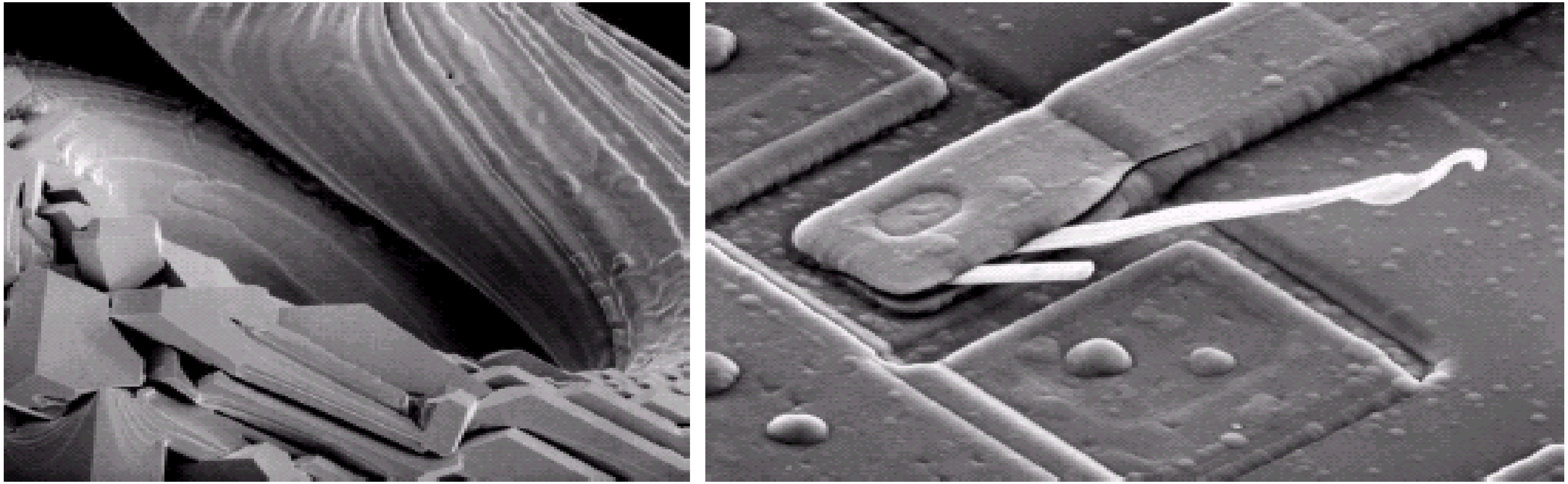
Monday

Applications of DIP

- Industrial Inspection/ Quality Control:

  - Automated visual inspection of electronic goods.

  - For example – Inspect for missing parts, detecting anomalies/damage in the electronic device.

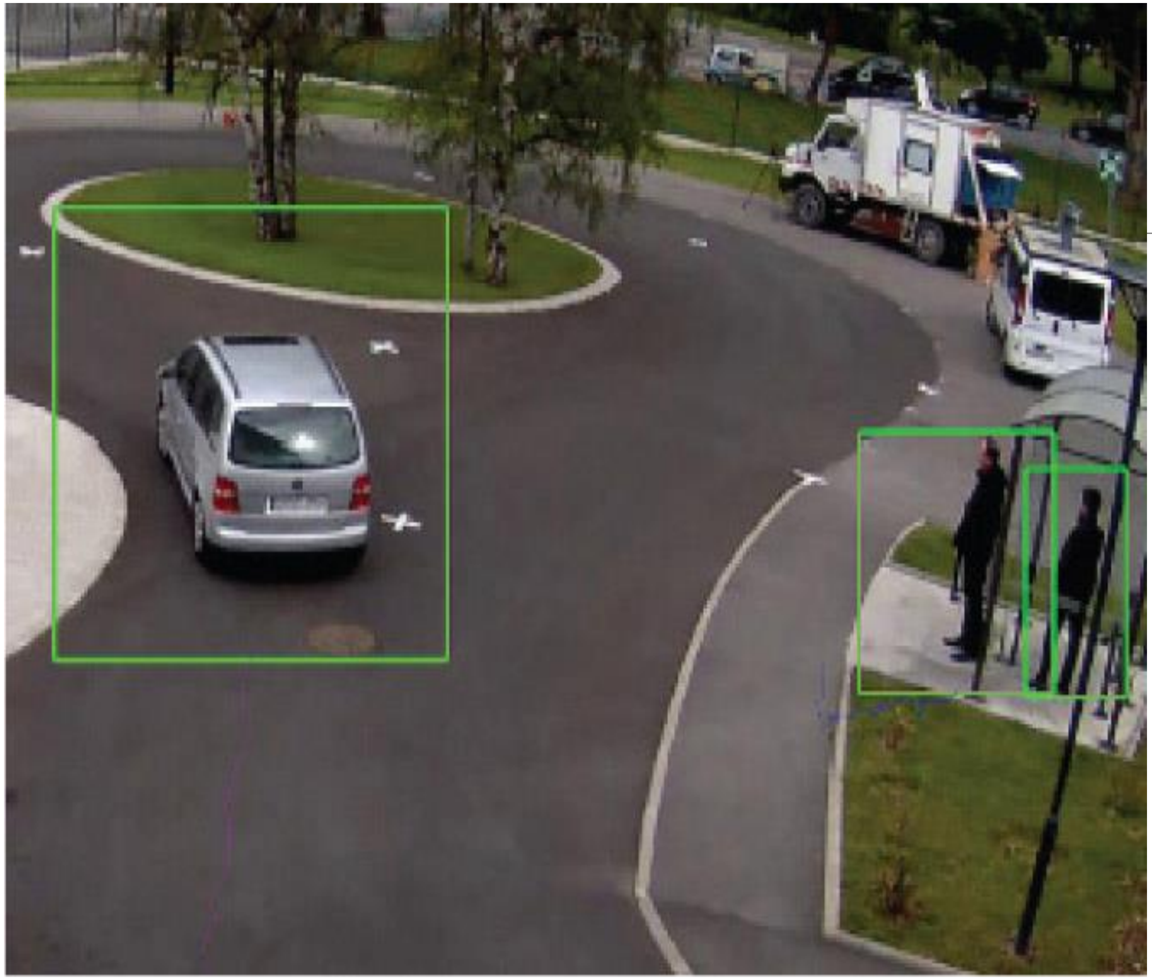


a b

FIGURE 1.21 (a) 250× SEM image of a tungsten filament following thermal failure. (b) 2500× SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)

Applications of DIP

- Military:
  - Object detection and tracking.
  - 3-D reconstruction of territory.
  - Target Classification.
  - Surveillance.

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Applications of DIP

Criminology/Forensics:

- Digital processing and enhancement of evidence photographs or video recordings which are damaged, blurry, grainy or having poor contrast.

Transportation:

- Automatically driven vehicles e.g. **google self-driving car project**.
- Unmanned aerial Vehicles.
- Imaging systems play a vital role in **path planning, obstacle avoidance and control**.
- Also it has application in traffic control and transportation planning. E.g. **Google maps**.

This is how a Google's self-driving car sees the world

Applications of DIP

❑ Augmented Reality(AR):

➢ AR is a term for direct/indirect view of real-world environment whose elements are augmented by computer-generated sensory input such as sound or graphics. E.g. **Pokemon Go!**

Applications of DIP

Computer Vision:

- Computer vision is the science and technology of machines which needs to perform some tasks or solve problems based on imagery inputs.

- The image data can take form of video sequences, view from multiple camera, multidimensional data from medical images.


building
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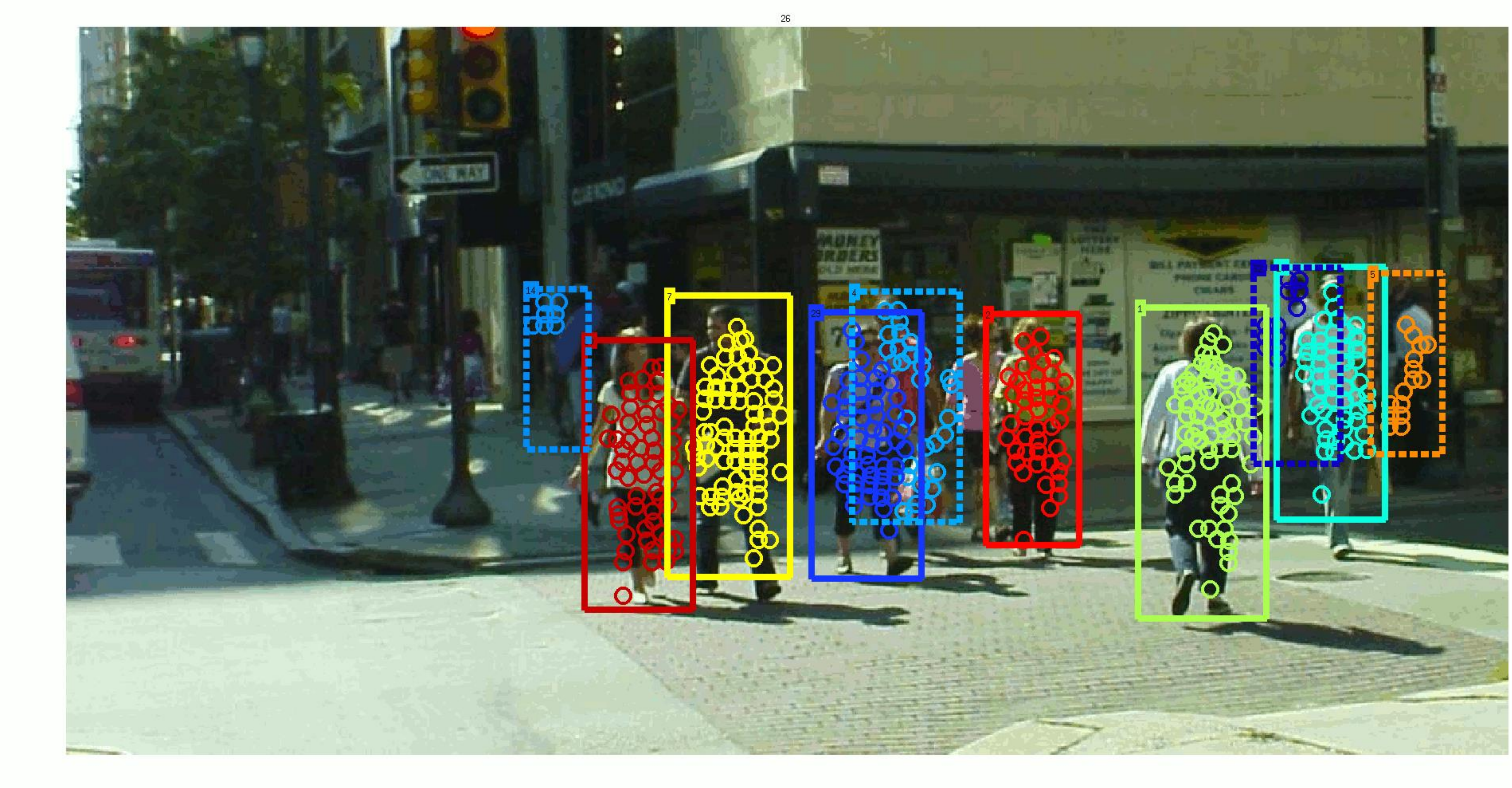
26
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7
29
4
2
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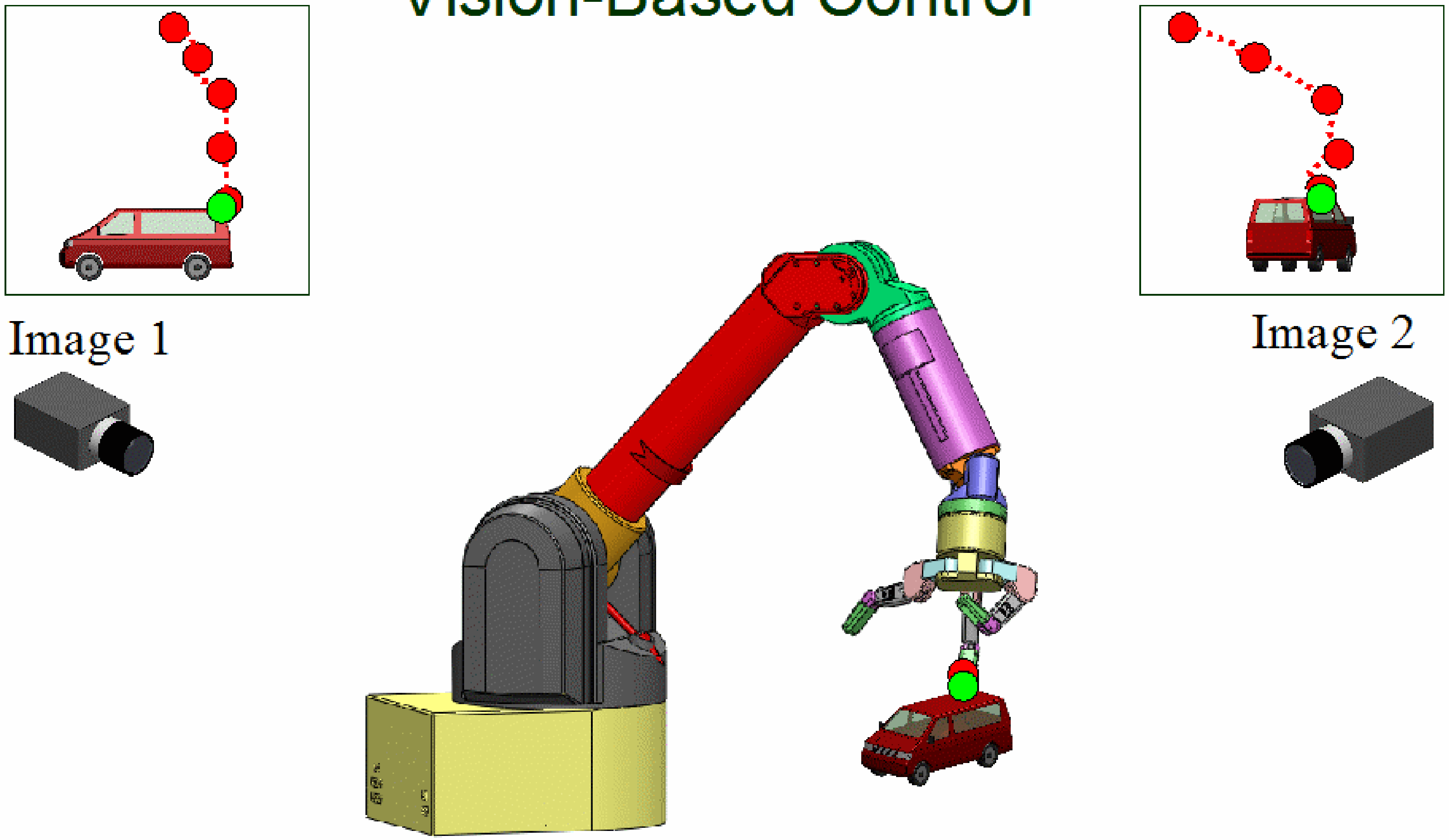
5
ONE WAY

Applications of DIP

➢ Computer vision application includes:

- Human Computer Interaction.
- Modeling of objects and environments.
- Visual surveillance.
- Controlling processes e.g. industrial robots.
- Organizing Information e.g. indexing databases of images and image sequences.

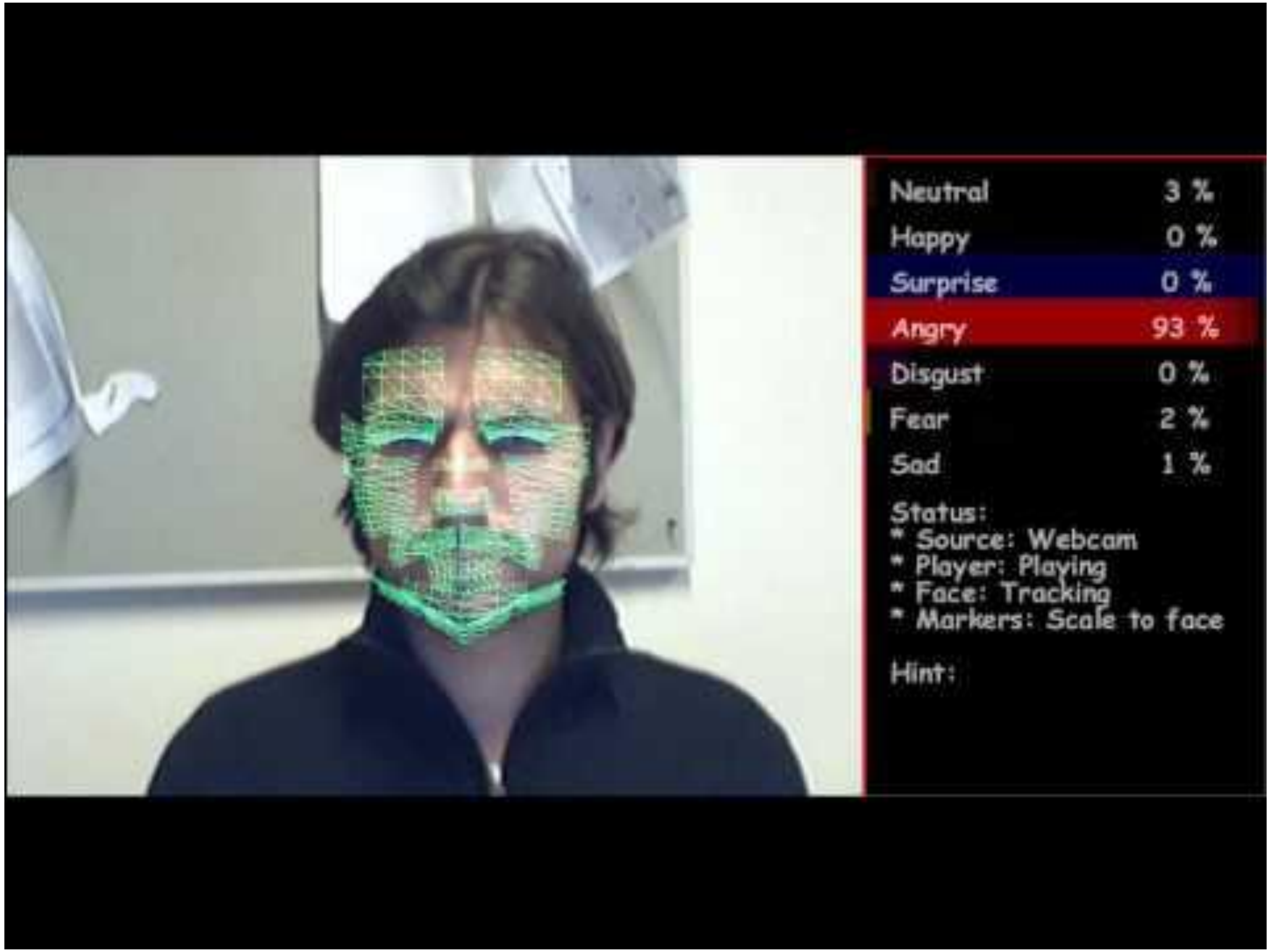
Vision-Based Control



Applications of DIP

Other Application:

- Face recognition, facial expression classification, iris detection, fingerprint classification etc.
- digital watermarking for data security.
- Remotely sensed data is captured through multispectral camera e.g. images of crops are analyzed using such remotely sensed images.


Neutral 3 %
Happy 0 %
Surprise 0 %
Angry 93 %
Disgust 0 %
Fear 2 %
Sad 1 %
Status:
* Source: Webcam
* Player: Playing
* Face: Tracking
* Markers: Scale to face
Hint:

(a) (b) (c)

Visible Watermarking

Properties of Image

- Spatial resolution
  - Width pixels/width cm and height pixels/ height cm
- Intensity resolution
  - Intensity bits/intensity range (per channel)
- Number of channels
  - RGB (Red, Green, Blue) is 3 channels, grayscale is one channel.

Fundamental steps in DIP

- Image Acquisition
- Preprocessing
- Segmentation
- Representation and Description
- Recognition and Interpretation

Fundamental steps in DIP

➢ Image Acquisition

- The image is captured by an imaging sensor (e.g. Camera), and digitized the signal produced by the sensor.
- Two elements are required to acquire digital images:

o A ***physical device (sensor)*** which is sensitive to a band in the electromagnetic energy spectrum and that produces an electrical signal output proportional to the level of energy sensed.

oA ***digitizer*** for converting the electrical output from the sensor into digital form.

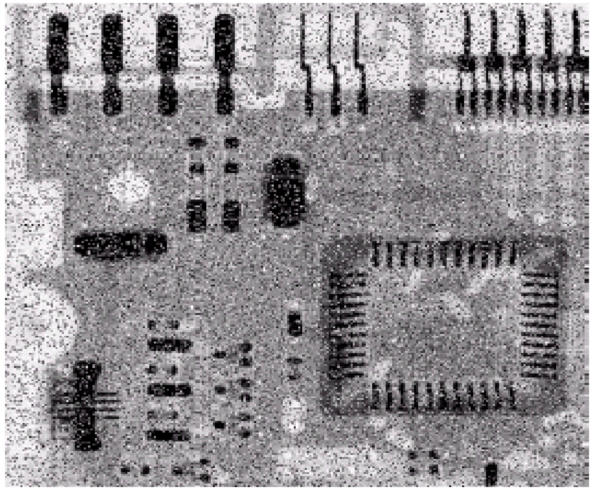
Fundamental steps in DIP

- Image Preprocessing:

- The purpose of *preprocessing* is to improve the image for increasing the success of other processes.

- Three main categories of image processing are:

  - *Image enhancement* e.g. modify the brightness and contrast, remove blurriness, remove noise etc.
  - *Image compression* e.g. reduce the amount of memory needed to store a digital image.
  - *Image measurement* e.g. extract information about the distribution of the sizes of the objects. Usually involves separating the region of interest from the background.



Original Image With Noise

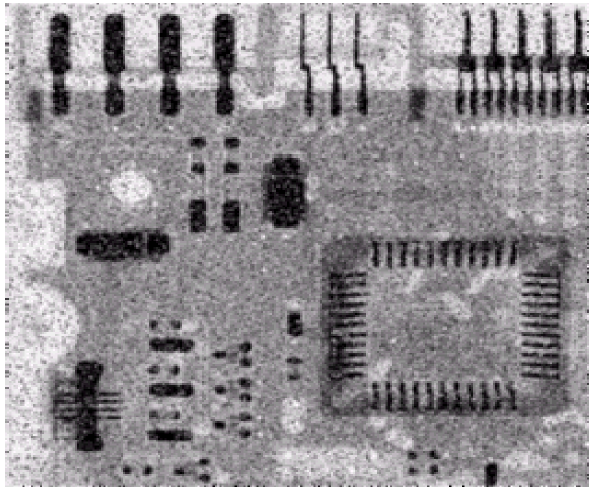


Image After Averaging Filter

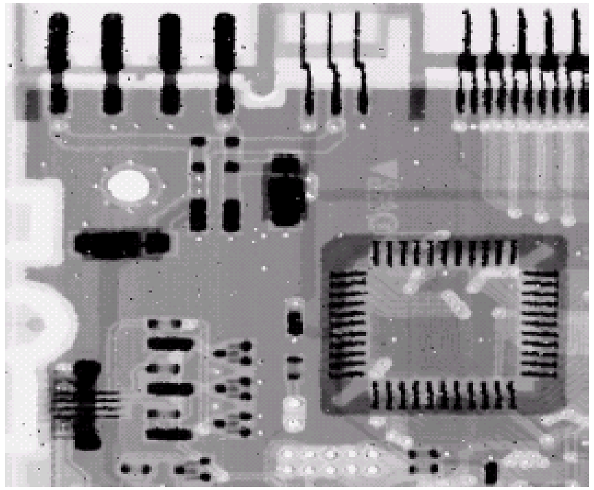
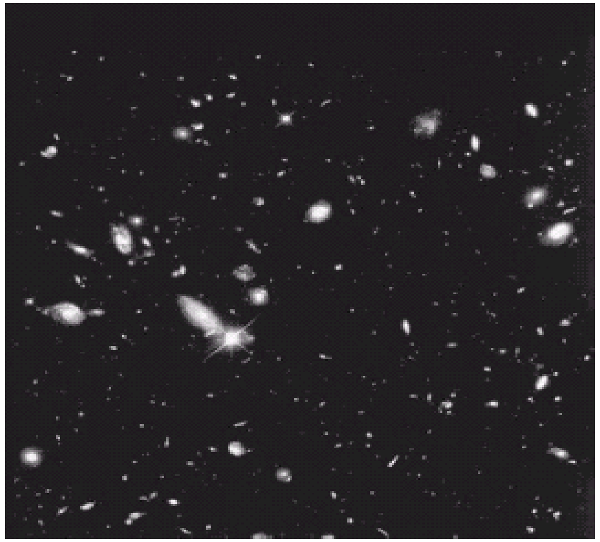
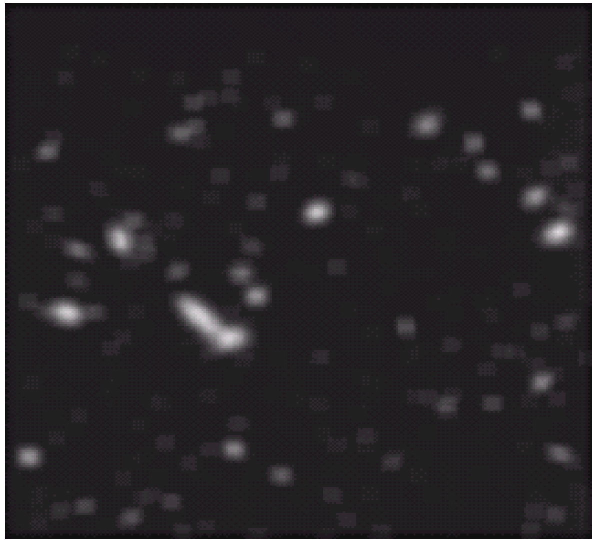


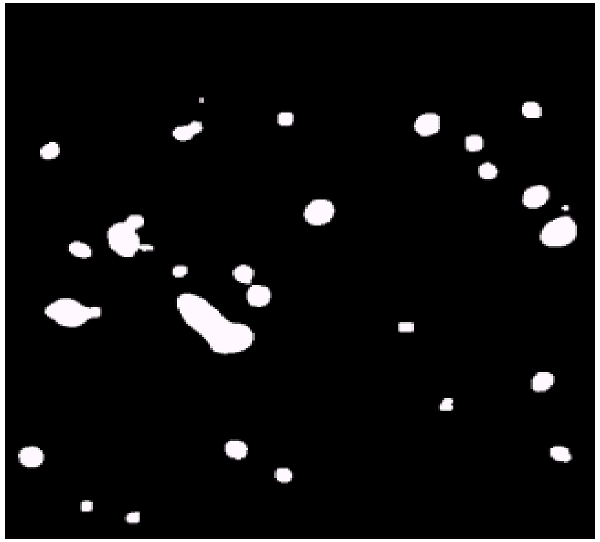
Image After Median Filter



Original Image



Smoothed Image



Thresholded Image

Fundamental steps in DIP

➢ Segmentation

- The first step in image processing is generally to segment the image.
- Segmentation divides the image into its constituent parts.
- Segmentation should stop when the object of interest in an application has been isolated.

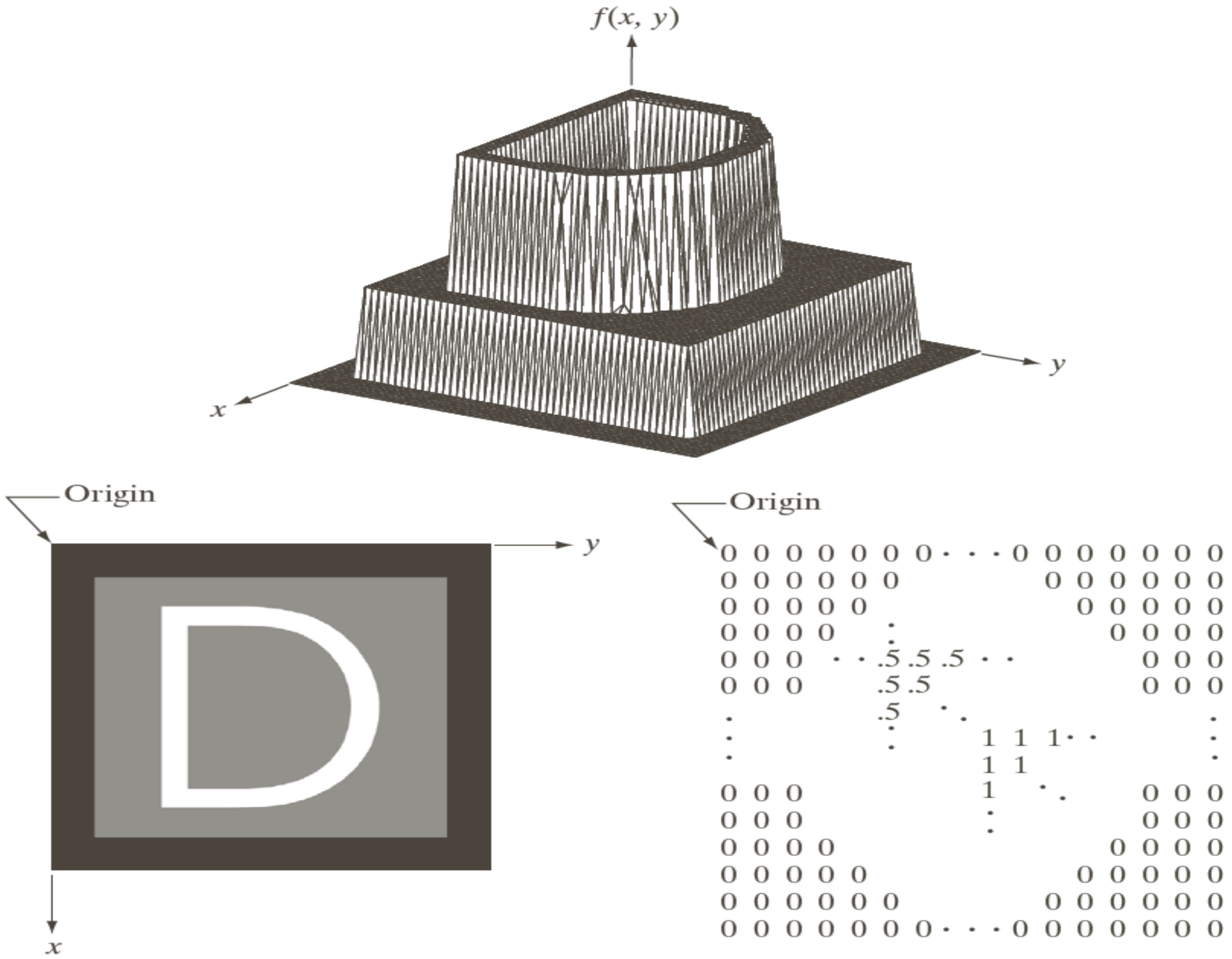
Fundamental steps in DIP

➢ Representation and Description:

- Representation and description usually follows the output of the segmentation stage.
- After the segmentation stage, the result usually consists of raw pixel data constituting either boundary or the region itself.

  - **Boundary Representation:** Focus on external shape characteristics, such as corners and edges.
  - **Region Representation:** Focus on internal properties, such as texture or shape.

Representing Digital Images



a
b c

FIGURE 2.18
(a) Image plotted as a surface.
(b) Image displayed as a visual intensity array.
(c) Image shown as a 2-D numerical array (0, .5, and 1 represent black, gray, and white, respectively).

Fundamental steps in DIP

- Recognition and Interpretation:

- ***Recognition*: The process that assigns label to an object based on the information provided by its description.**

- ***Interpretation*** :Assigning meaning to an ensemble of recognized objects.

Image Acquisition

- Energy
  - Illumination
- The Optical System
  - The Lens
- The Image Sensor
- The Digital Image

Energy

✓**To capture an image a camera requires some sort of measurable energy.**

✓**Light or *electromagnetic* waves (*Photon*). It is massless entity.**

✓**Electromagnetic wave:** electric and magnetic fields vary sinusoidally

1. **A photon can be described by its energy E, which is measured in [eV]**
2. **A photon can be described by its frequency f , which is measured in Hertz [Hz]. A frequency is the number of cycles or wave-tops in one second.**
3. **A photon can be described by its wavelength λ, which is measured in meters [m]. A wavelength is the distance between two wave-tops.**

$$\lambda = \frac{c}{f}, \qquad E = h \cdot f \quad \Rightarrow \quad E = \frac{h \cdot c}{\lambda}$$

c= 2.998 x 10^8 m/s

h=6.626176 x 10^{-34} joule-seconds (Planck'^s^ Constant)

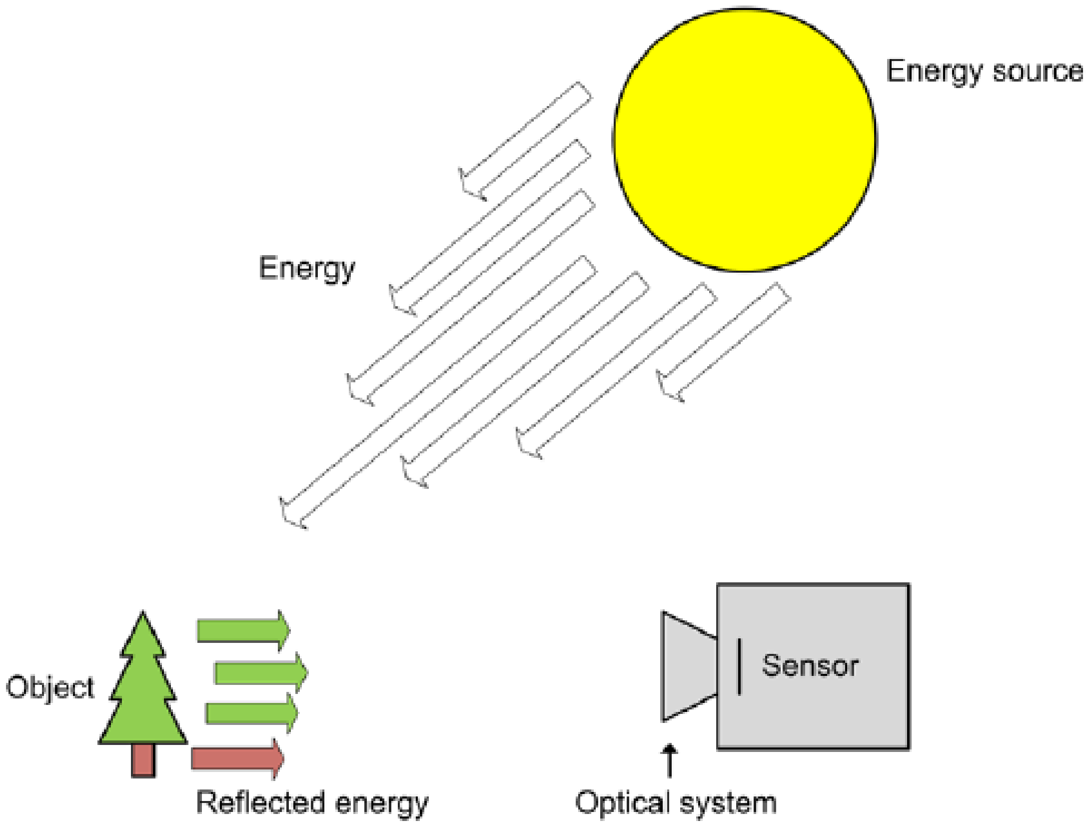


Fig. Overview of the typical image acquisition process.

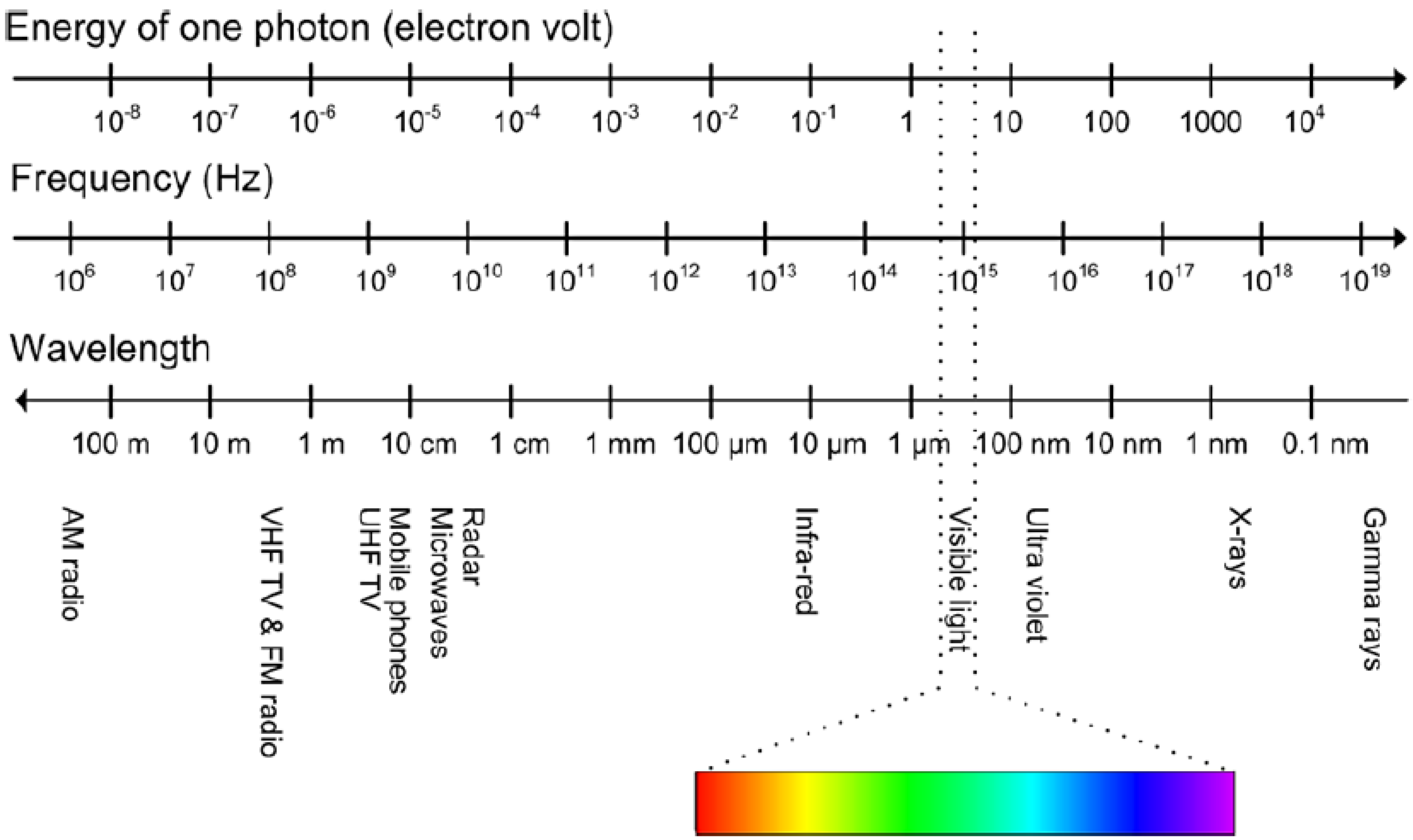


Fig. The electromagnetic spectrum

Light and Electromagnetic Spectrum

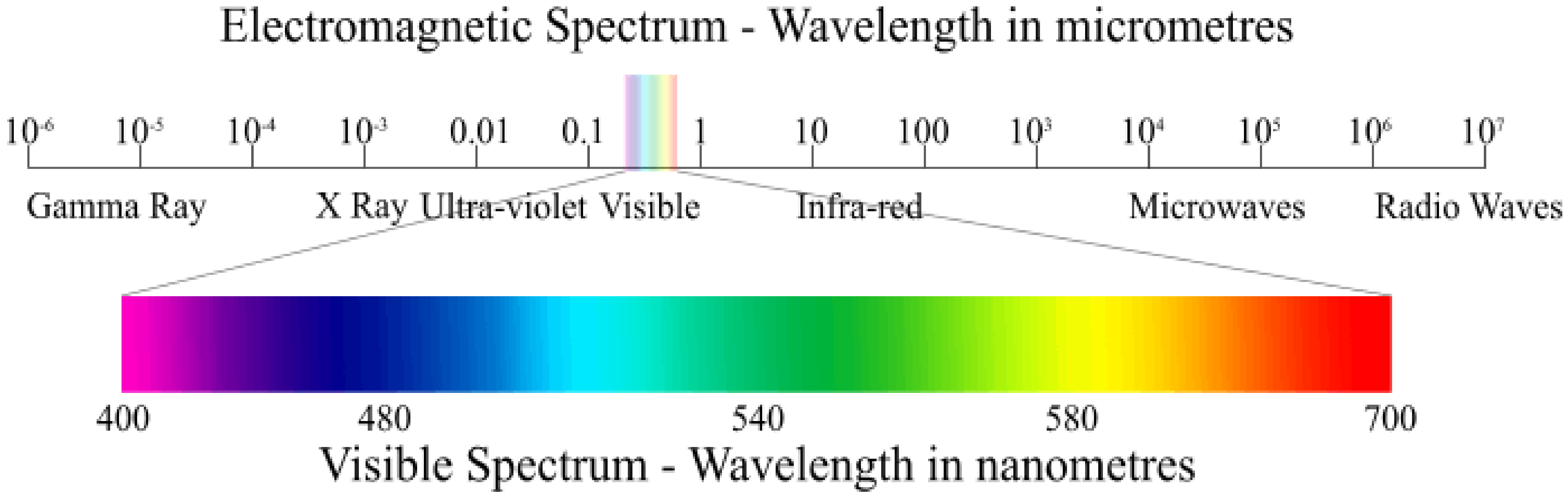


FIGURE 2.10 The electromagnetic spectrum. The visible spectrum is shown zoomed to facilitate explanation, but note that the visible spectrum is a rather narrow portion of the EM spectrum.

- ✓ **Energy is proportional to Frequency.**
- ✓ **Gamma Rays are more dangerous because of their energy.**
- ✓ **Radio waves energy is very less.**
- ✓ **Visible light range: 400 nm to 700 nm**

Illumination

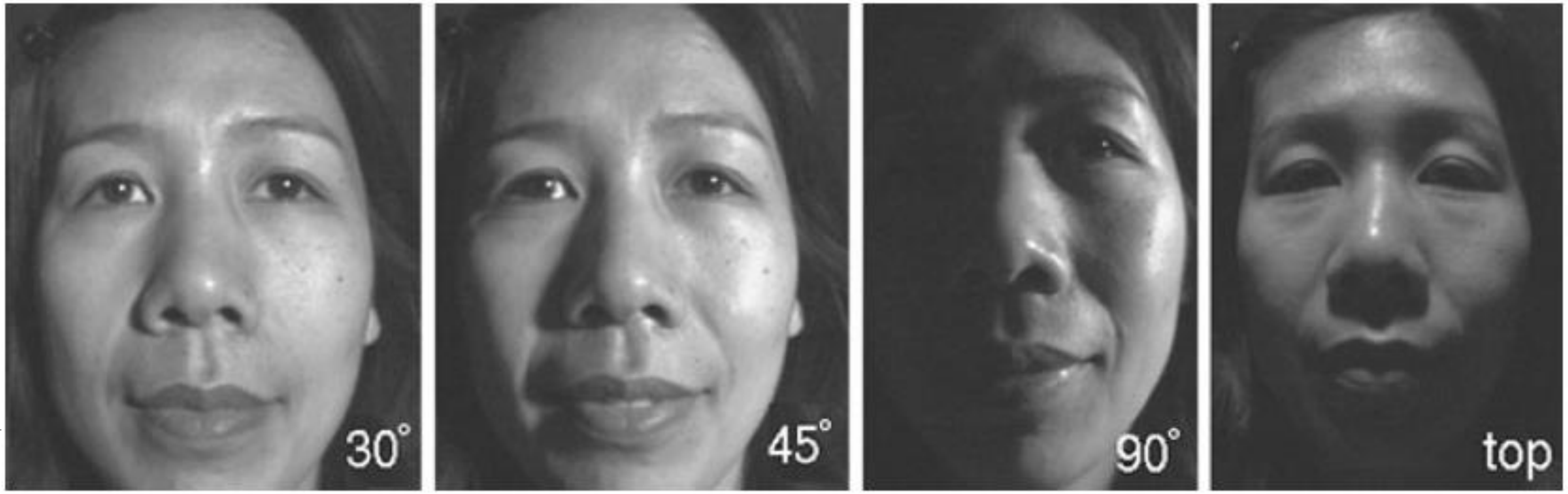


Fig. The effect of illuminating a face from four different directions

Fig. A focused image (*left) and an unfocused image* (*right). The difference* between the two images is different values of *b.*

Fig.: Three different camera settings resulting in three different depth-of-fields

Image Capture

- Distance to Object
- Motion of Object
- Zoom
- Focus
- Depth-of-field
- Focal Length
- Shutter
- Aperture
- Sensor

Image Processing Fundamentals

- We can think of an **image** as a function, *f*, from R^2 to R:
  - *f*(*x*, *y*) gives the **intensity** at position (*x*, *y*)
- Suppose the image is sampled into a 2-D array, *f*(*x*, *y*), containing M rows and N columns.
- The number of bits b, required to store a digitized image is

$$b = \mathrm{MxNxk}$$

Where an image is having 2^k intensity levels. It is common to refer practice to refer to the image as a “k-bit image”.

- A color image is just three functions pasted together. We can write this as:

$$f(x,y) = \begin{bmatrix} r(x,y) \\ g(x,y) \\ b(x,y) \end{bmatrix}$$

$f(x, y) = f(1,1) = 62$

y

x

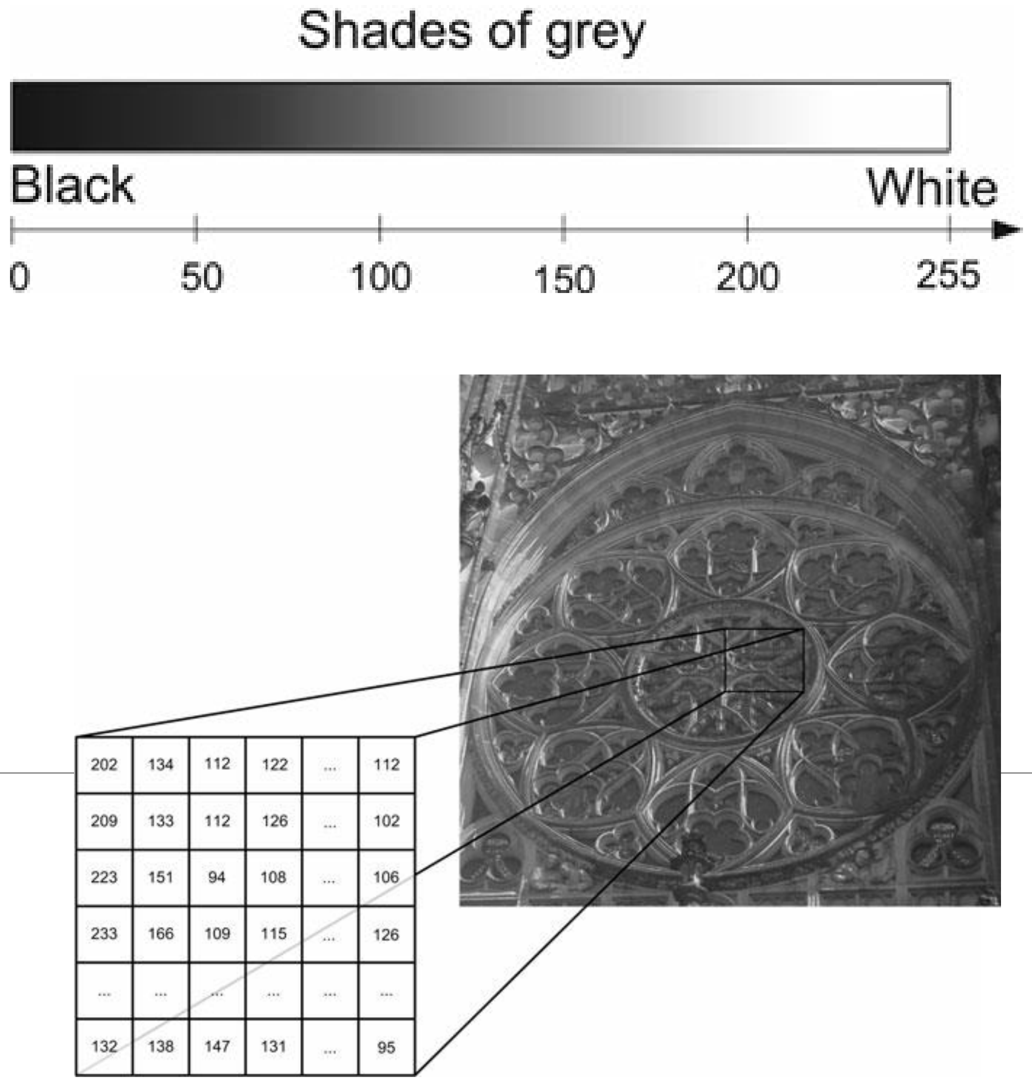
62	79	23	119	120	105	4	0
10	10	9	62	12	78	34	0
10	58	197	46	46	0	0	48
176	135	5	188	191	68	0	49
2	1	1	29	26	37	0	77
0	89	144	147	187	102	62	208
255	252	0	166	123	62	0	31
166	63	127	17	1	0	99	30

Image Types

RGB	Grayscale	Black & White



The Digital Image



Color Images

Photoreceptor cell	Wavelength in nanometers (nm)	Peak response in nanometer (nm)	Interpretation by the human brain
Cones (type L)	[400–680]	564	Red
Cones (type M)	[400–650]	534	Green
Cones (type S)	[370–530]	420	Blue
Rods	[400–600]	498	Shade of gray

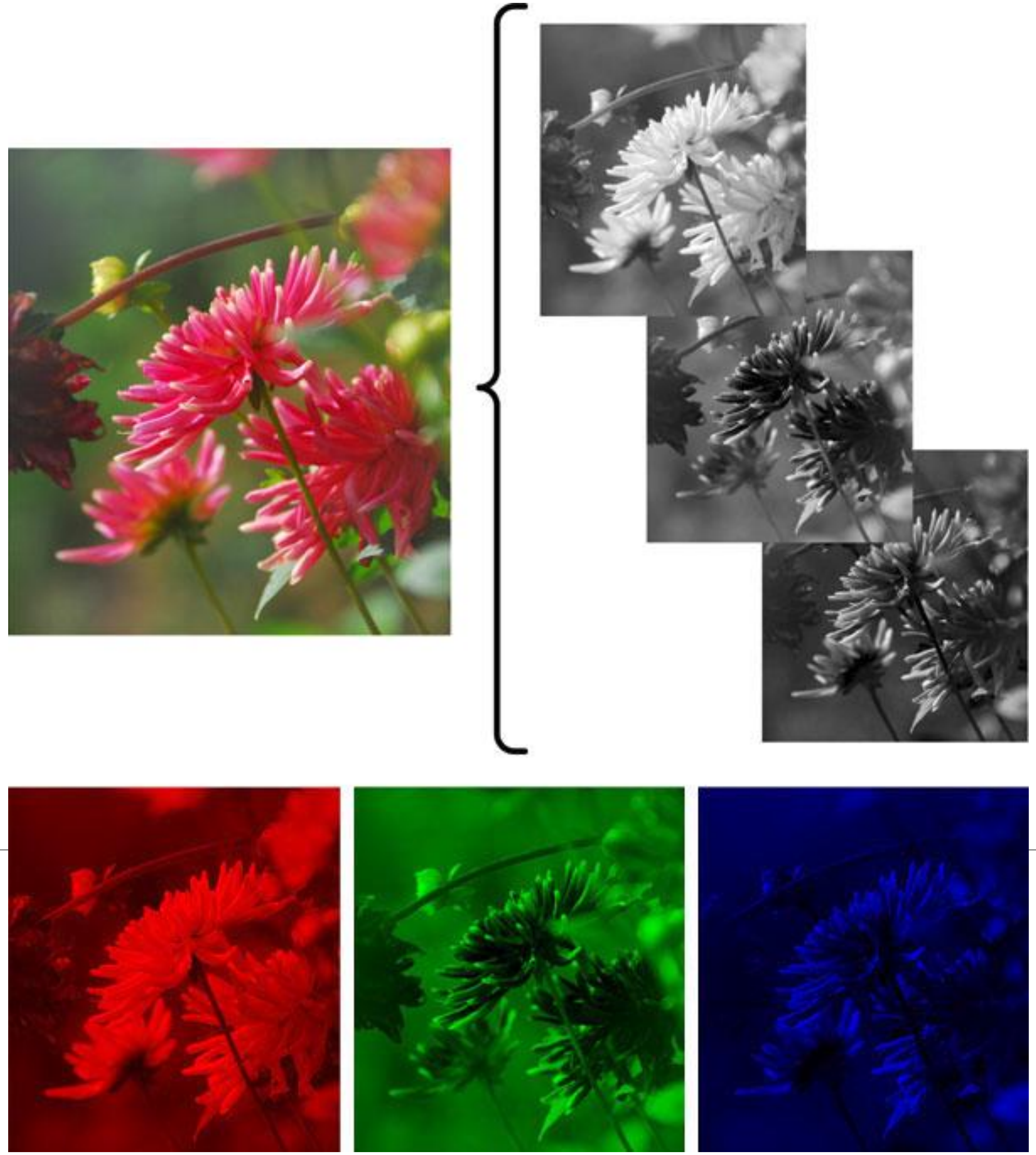
Color

- When the resulting color is created by illuminating an object by white light and then absorbing some of the wavelengths (colors) we use the notion of subtractive colors.
- Exactly as when you mix paint to create a color. Say you start with a white piece of paper, where no light is absorbed. The resulting color will be white.
- If you then want the paper to become green you add green paint, which absorbs everything but the green wavelengths.
- If you add yet another color of paint, then more wavelengths will be absorbed, and hence the resulting light will have a new color.
- Keep doing this and you will in theory end up with a mixture where all wavelengths are absorbed, that is, black.
- In practice, however, it will probably not be black, but rather dark gray/brown.

Color Image

- This notion applies when you create the wavelengths as opposed to manipulating white light.
- A good example is a color monitor like a computer screen or a TV screen. Here each pixel is a combination of emitted red, green and blue light.
- Meaning that a black pixel is generated by not emitting anything at all.
- White (or rather a shade of gray) is generated by emitting the same amount of red, green, and blue.
- Red will be created by only emitting red light etc.
- All other colors are created by a combination of red, green and blue.
- For example yellow is created by emitting the same amount of red and green, and no blue.

Fig.: A color image



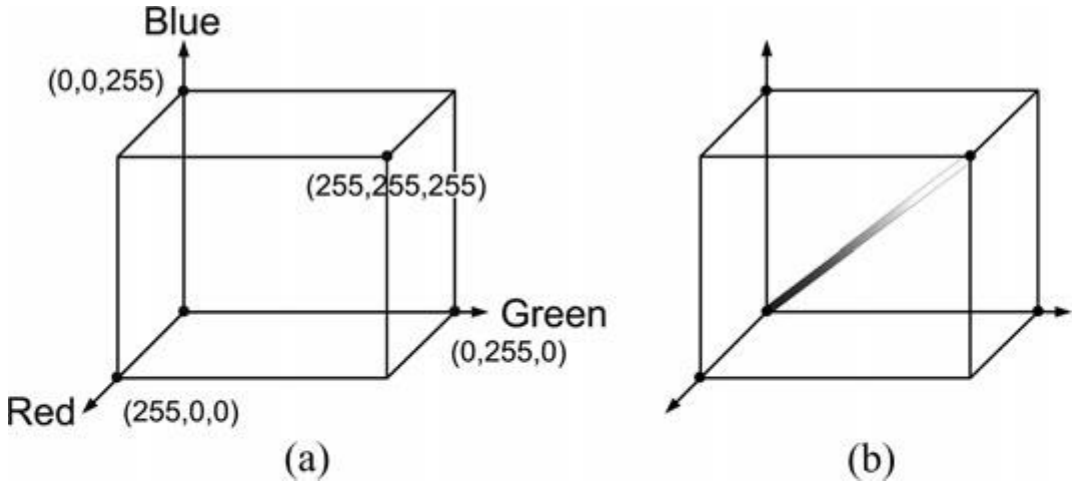


Fig. : (a) The RGB color cube. (b) The gray-vector in the RGB color cube

Corner	Color
(0, 0, 0)	Black
(255, 0, 0)	Red
(0, 255, 0)	Green
(0, 0, 255)	Blue
(255, 255, 0)	Yellow
(255, 0, 255)	Magenta
(0, 255, 255)	Cyan
(255, 255, 255)	White

RGB to GRAY

$$I = W_R \cdot \mathrm{R} + W_G \cdot \mathrm{G} + W_B \cdot \mathrm{B}$$

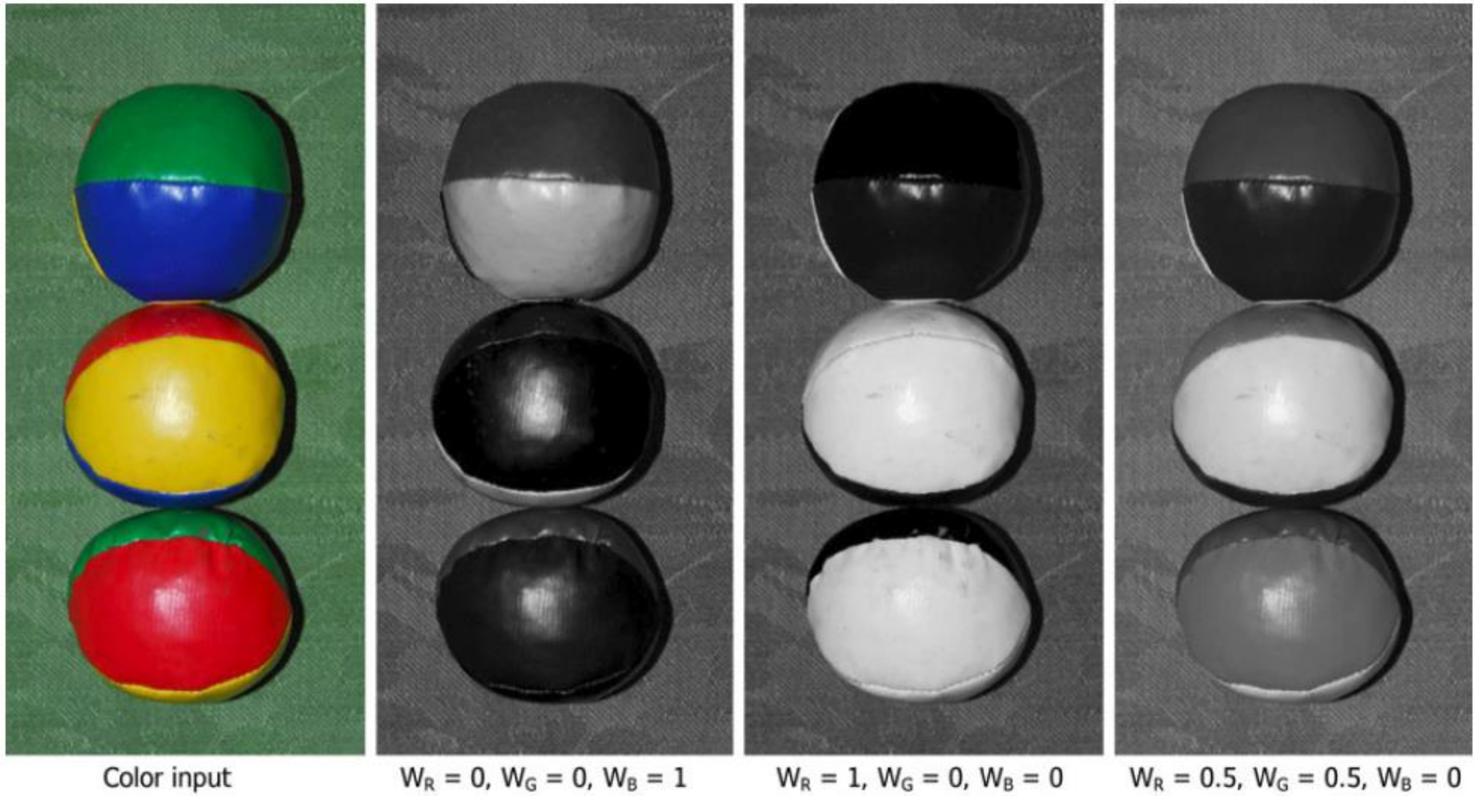


Fig.: A color image and how it can be mapped to different gray-scale images depending on the weights

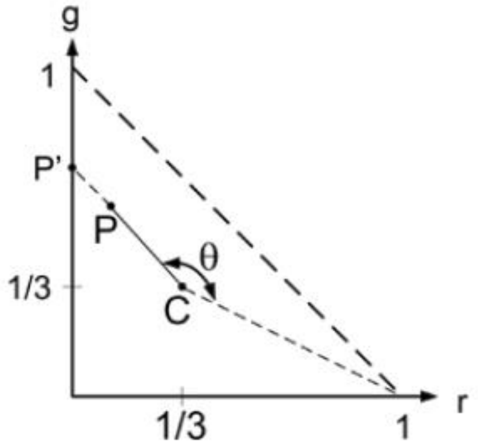
Normalized RGB

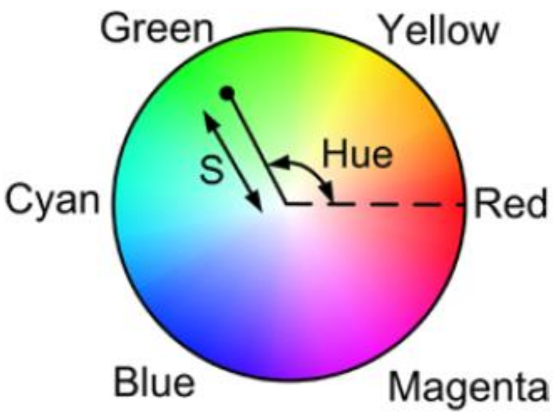
$$(r, g, b) = \left(\frac{R}{R+G+B}, \frac{G}{R+G+B}, \frac{B}{R+G+B} \right)$$

$$(R, G, B) \quad \Leftrightarrow \quad (r, g, I)$$

Hue and Saturation

- The **hue** is the dominant wavelength in the perceived light and represents the pure color, i.e., the colors located on the edges of the triangle in Fig.
- The **saturation** is the purity of the color and represents the amount of white light mixed with the pure color.





$$\text{Saturation} = \frac{\|\overrightarrow{CP}\|}{\|\overrightarrow{CP'}\|}, \qquad \text{Hue} = \theta$$

The HSI Color Representation

$$H = \begin{cases} \cos^{-1}\left(1/2 \cdot \frac{(R-G)+(R-B)}{\sqrt{(R-G)(R-G)+(R-B)(G-B)}}\right), & \text{if } G \geq B; \\ 360^\circ - \cos^{-1}\left(1/2 \cdot \frac{(R-G)+(R-B)}{\sqrt{(R-G)(R-G)+(R-B)(G-B)}}\right), & \text{Otherwise} \end{cases}$$

$$H \in [0, 360[$$

$$S = 1 - 3 \cdot \frac{\min\{R, G, B\}}{R+G+B} \quad S \in [0, 1]$$

$$I = \frac{R+G+B}{3} \quad I \in [0, 255]$$

The HSV Color Representation

$$H = \begin{cases} \frac{G-B}{V-\min\{R,G,B\}} \cdot 60^\circ, & \text{if } V = R \text{ and } G \geq B; \\ \left(\frac{B-R}{V-\min\{R,G,B\}} + 2\right) \cdot 60^\circ, & \text{if } G = V; \\ \left(\frac{R-G}{V-\min\{R,G,B\}} + 4\right) \cdot 60^\circ, & \text{if } B = V; \\ \left(\frac{R-B}{V-\min\{R,G,B\}} + 5\right) \cdot 60^\circ, & \text{if } V = R \text{ and } G < B \end{cases} \qquad H \in [0^\circ, 360^\circ$$

$$S = \frac{V - \min\{R, G, B\}}{V} \qquad S \in [0, 1]$$

$$V = \max\{R, G, B\} \qquad V \in [0, 255]$$