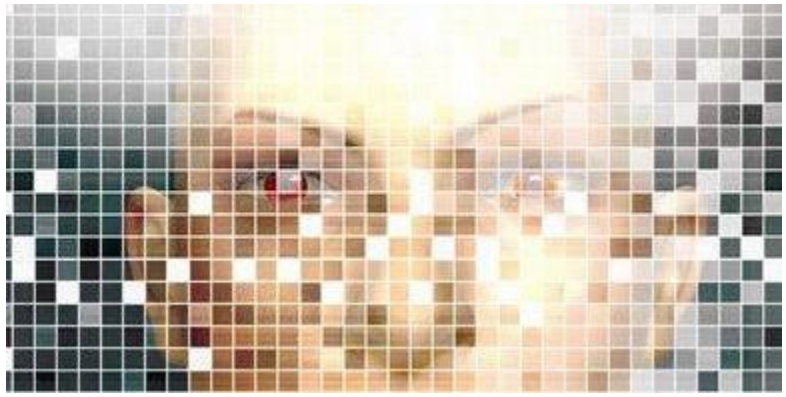
Introduction



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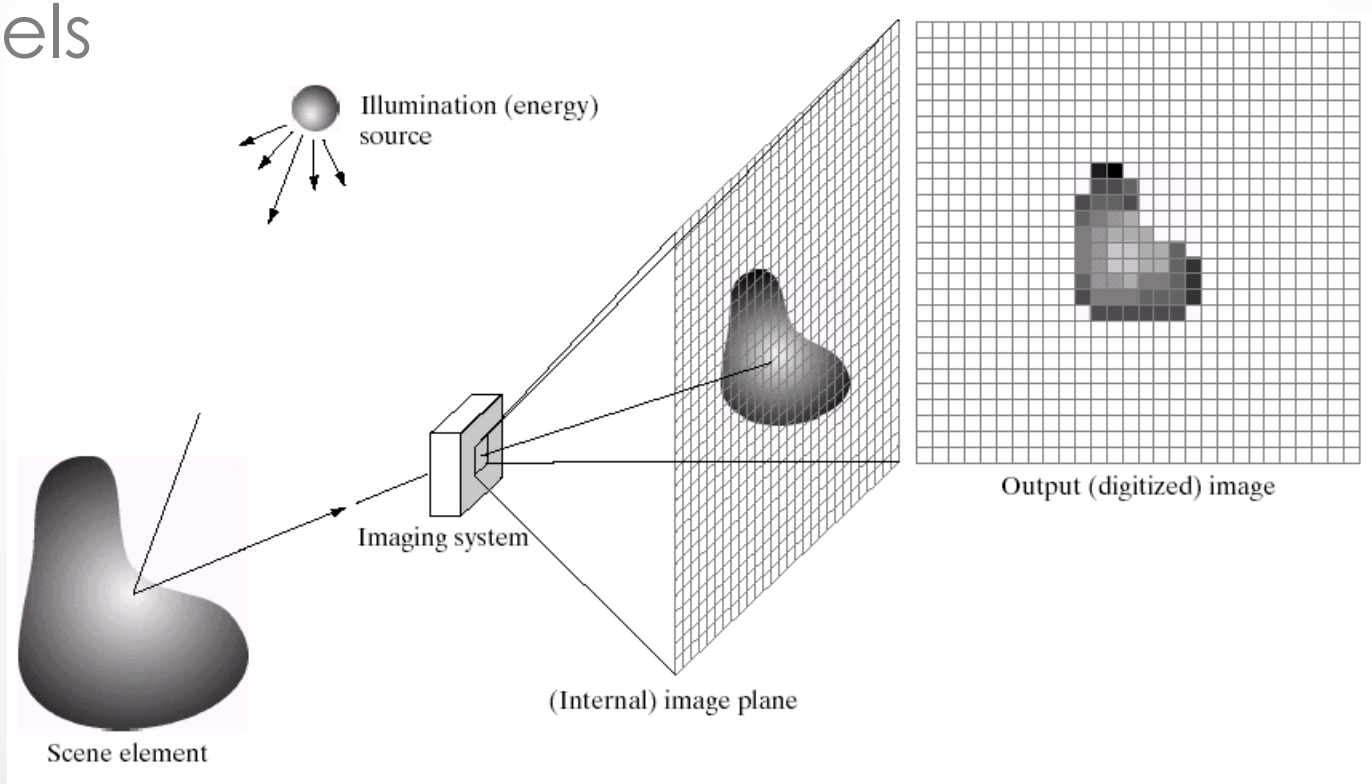
What is Digital Image

- A **digital image** is a representation of a two-dimensional function f(x,y) as a finite set of digital values, called picture elements or pixels



Energy Source of Images

- The principal energy source for images in use today is the electromagnetic (EM)energy spectrum.
- Synthetic images, used for modeling and visualization, are generated by computer.
- Electromagnetic waves can be conceptualized as propagating sinusoidal waves of varying wavelengths, or they can be thought of as a stream of massless particles, each traveling in a wavelike pattern and moving at the speed of light.
- Each mass-less particle contains a certain amount (or bundle) of energy. Each bundle of energy is called a photon.
- If spectral bands are grouped according to energy per photon, we obtain the spectrum

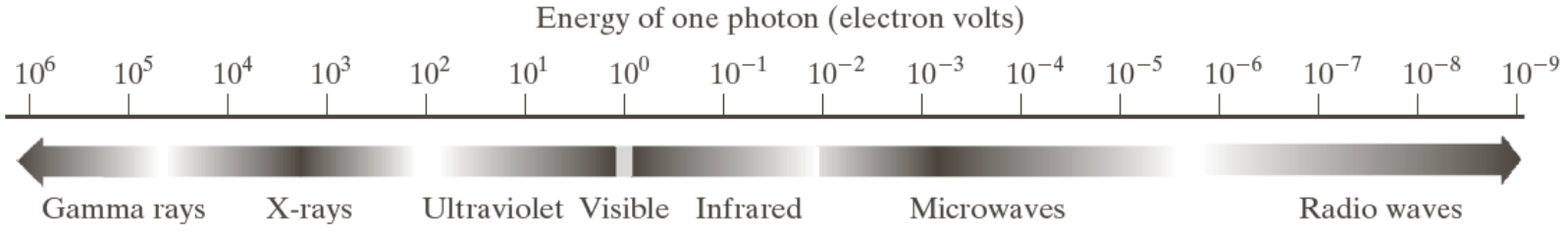
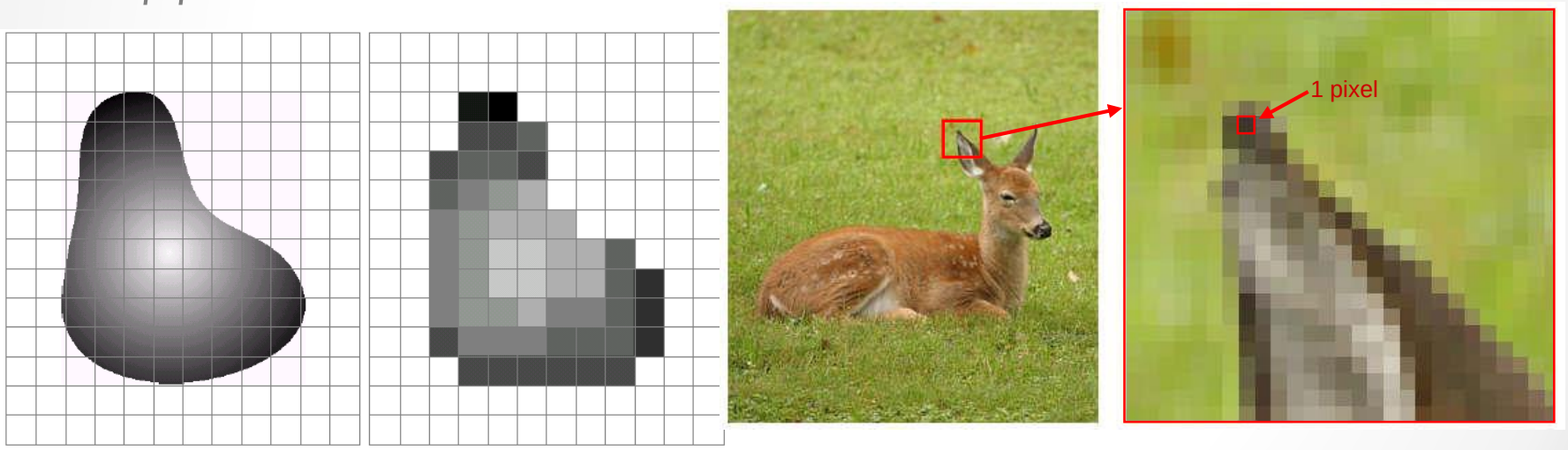


FIGURE 1.5 The electromagnetic spectrum arranged according to energy per photon.

What is Digital Image? (Cont.)

- Pixel values typically represent intensity, gray levels, colours, heights, depths, opacities etc
- **Remember** *digitization* implies that a digital image is an *approximation* of a real scene.



- **When** *x, y, and the intensity values of f are all finite, discrete quantities, we call the image a digital image.*

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

- No General agreement where Image Processing Starts and Stops
  - Computer Vision
  - Computer Graphics
  - Artificial Intelligence

Digital Image Processing

- The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes

Low Level Process	Mid Level Process	High Level Process
Input: Image **Output:** Image **Examples:** Noise removal, image sharpening	**Input:** Image **Output:** Attributes **Examples:** Object recognition, segmentation	**Input:** Attributes **Output:** Understanding **Examples:** Scene understanding, autonomous navigation

Few Applications: Satellite Imaging

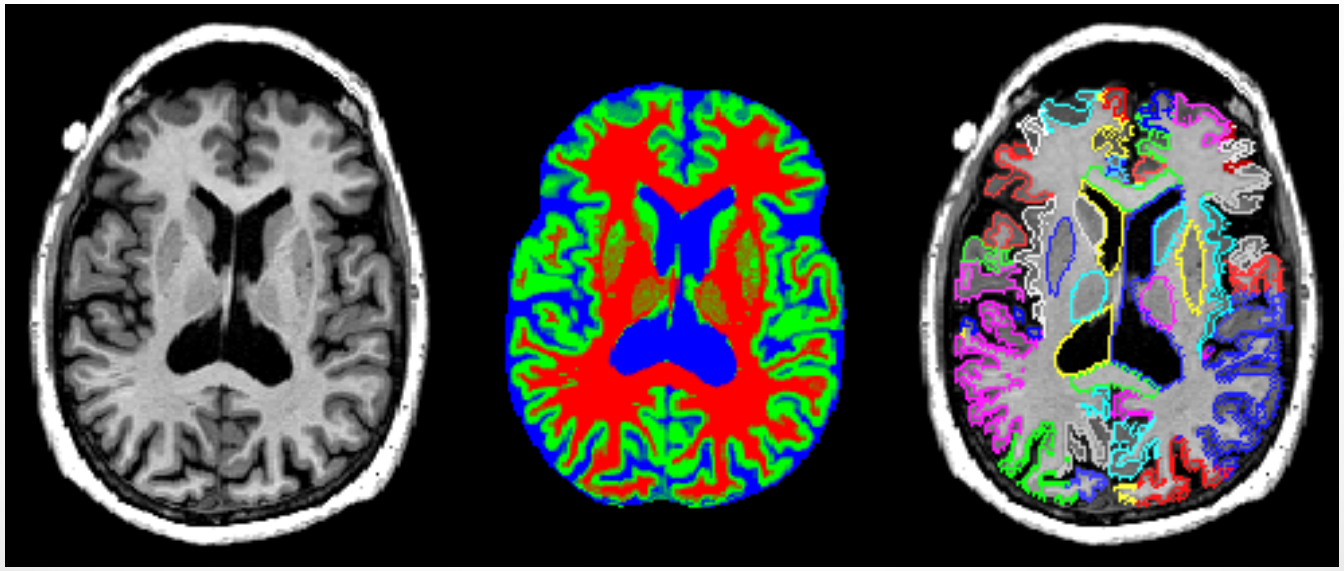
- Launched in 1990 the Hubble telescope can take images of very distant objects
- However, an incorrect mirror made many of Hubble's images useless
- Image processing techniques were used to fix this

Animation

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

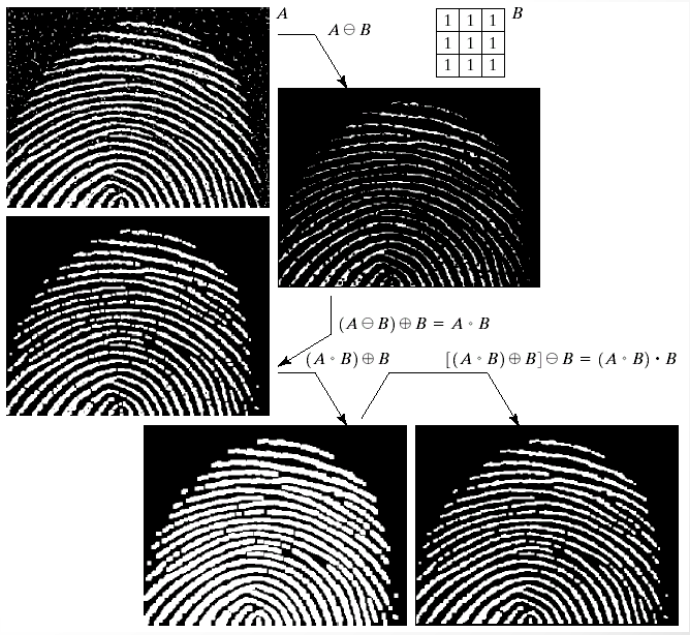
Medicine

- Take slice from MRI (Magnetic Resonance Imaging) scan of a heart, and find boundaries between types of tissue
  - Image with color levels representing tissue regions
  - Use a suitable filter to highlight edges

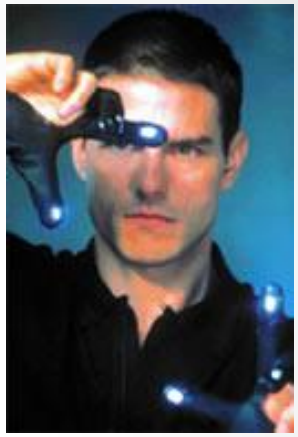


Law Enforcement

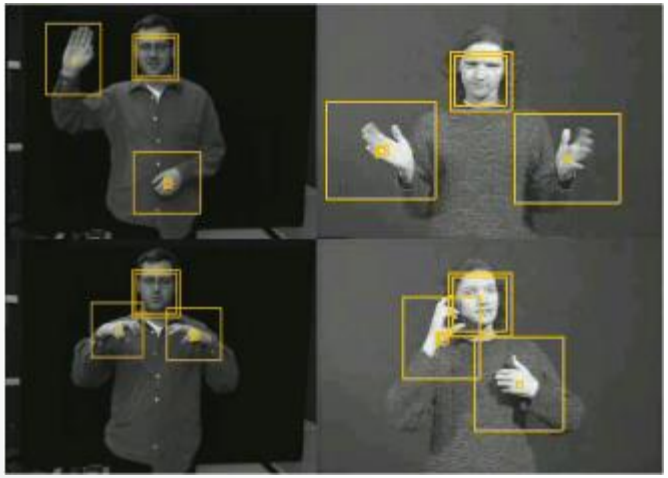
- Image processing techniques are used extensively by law enforcers
  - Number plate recognition for speed cameras/automated toll systems
  - Fingerprint recognition

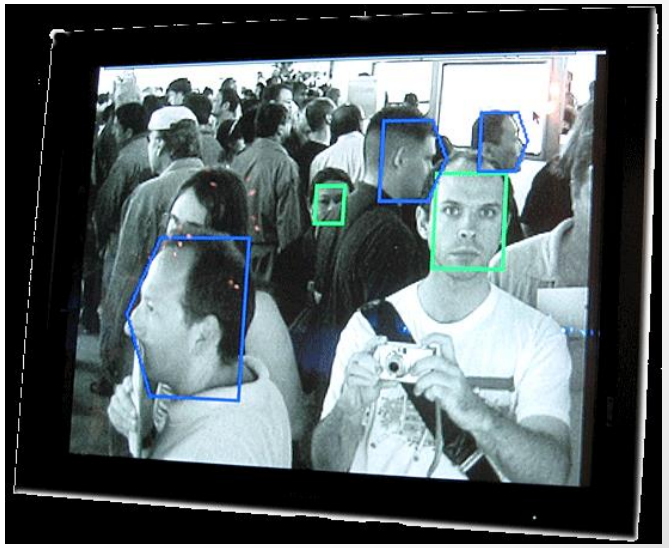


Human Computer Interaction



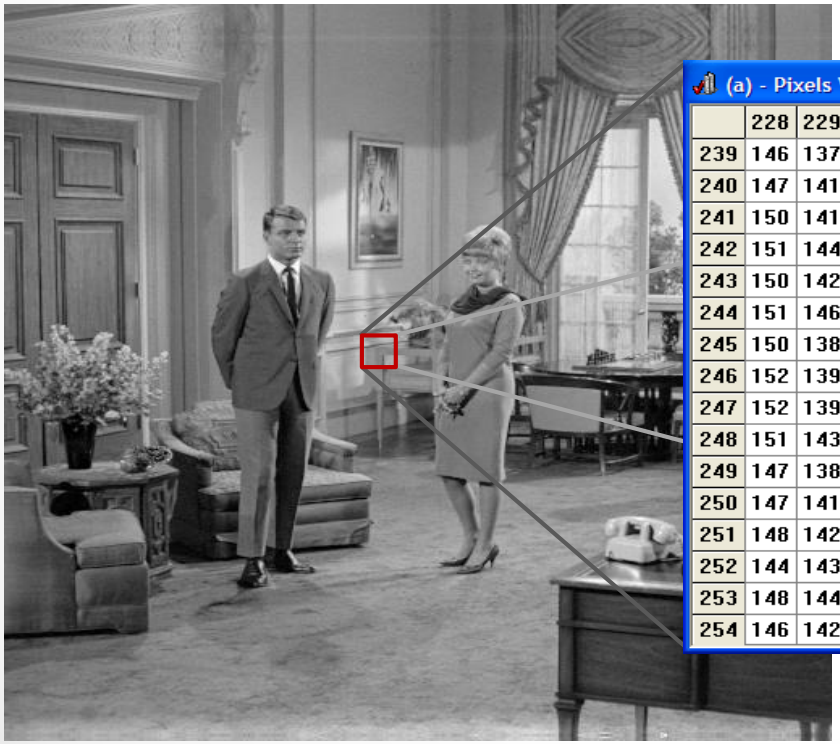
- Try to make human computer interfaces more natural
  - Face recognition
  - Gesture recognition
- Does anyone remember the user interface from "Minority Report"
- These tasks can be extremely difficult





Digital Image Representation

- A digital image is an image ***f(x,y)*** that has been digitized both in spatial coordinates and brightness.
- The value of ***f*** at any point ***(x,y)*** is proportional to the brightness (or gray level) of the image at that point.



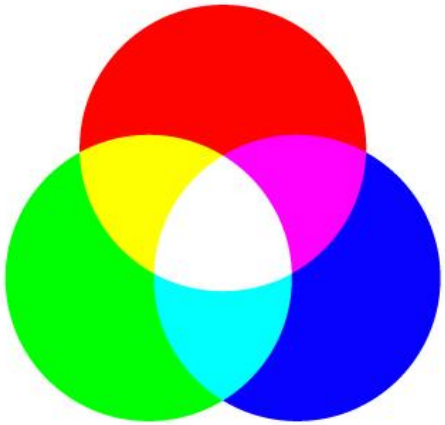
(a) - Pixels Value

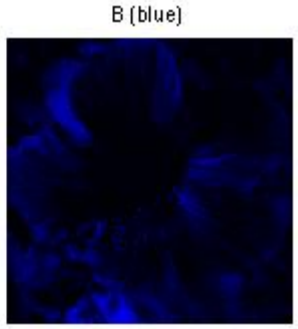
	228	229	230	231	232	233	234	235	236	237	238	239	240	241
239	146	137	126	126	134	130	135	133	133	135	137	144	141	141
240	147	141	131	129	135	137	139	141	135	134	135	138	134	137
241	150	141	135	138	138	138	141	141	138	135	134	131	133	135
242	151	144	134	128	141	139	135	138	134	133	133	135	135	129
243	150	142	133	131	143	139	124	146	146	141	138	139	138	135
244	151	146	133	130	134	131	96	155	159	160	169	172	174	174
245	150	138	131	134	134	130	100	157	161	164	174	174	180	174
246	152	139	129	133	137	135	95	154	164	169	174	178	173	173
247	152	139	134	129	135	129	91	148	167	176	174	178	178	172
248	151	143	134	133	135	130	95	157	168	177	176	176	176	180
249	147	138	137	135	131	128	95	160	176	174	177	174	173	173
250	147	141	137	134	129	128	96	159	177	178	172	180	176	177
251	148	142	135	135	134	129	94	142	182	177	168	168	163	156
252	144	143	138	133	134	131	90	112	143	138	133	129	128	129
253	148	144	142	137	141	135	98	85	104	122	133	134	137	133
254	146	142	142	141	138	135	96	86	96	128	135	139	146	142

$$0 \leq f(\mathrm{i}, \mathrm{j}) < 2^{bpp}$$

Color Image

- Separate Channel for different color
  - RGB
- Some model separates Color information from Brightness intensity
  - HSI





Coordinate Convention

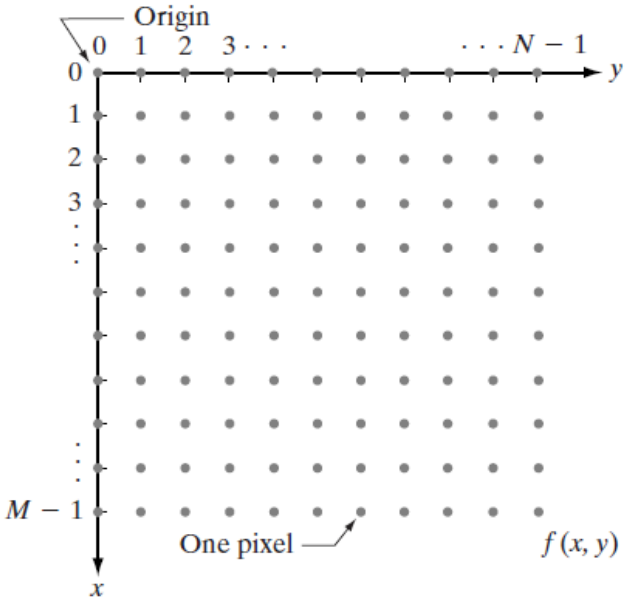


FIGURE: Coordinate convention to represent Digital Image

$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & \cdots & f(0,N-1) \\ f(1,0) & f(1,1) & \cdots & f(1,N-1) \\ \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & \cdots & f(M-1,N-1) \end{bmatrix}.$$

FIGURE: Matrix Representation

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

FIGURE: Element-wise Representation

Matrix Flattening

- For performance reasons we usually do not store images in the matrix fashion when coding image processing algorithms in Embedded Systems.
- There are two prevalent ordering schemes for storing flattened 2D matrices:
  - Row-major and
  - Column-major.

row-major	column-major
$f[0][0]$	$f[0][0]$
$f[0][1]$	$f[1][0]$
$f[0][2]$	$f[2][0]$
...	...
$f[0][N-1]$	$f[M-1][0]$
$f[1][0]$	$f[0][1]$
$f[1][1]$	$f[1][1]$
$f[1][2]$	$f[2][1]$
...	...
$f[1][N-1]$	$f[M-1][1]$
...	...
$f[M-1][N-1]$	$f[M-1][N-1]$

Fundamental Steps of Image Processing

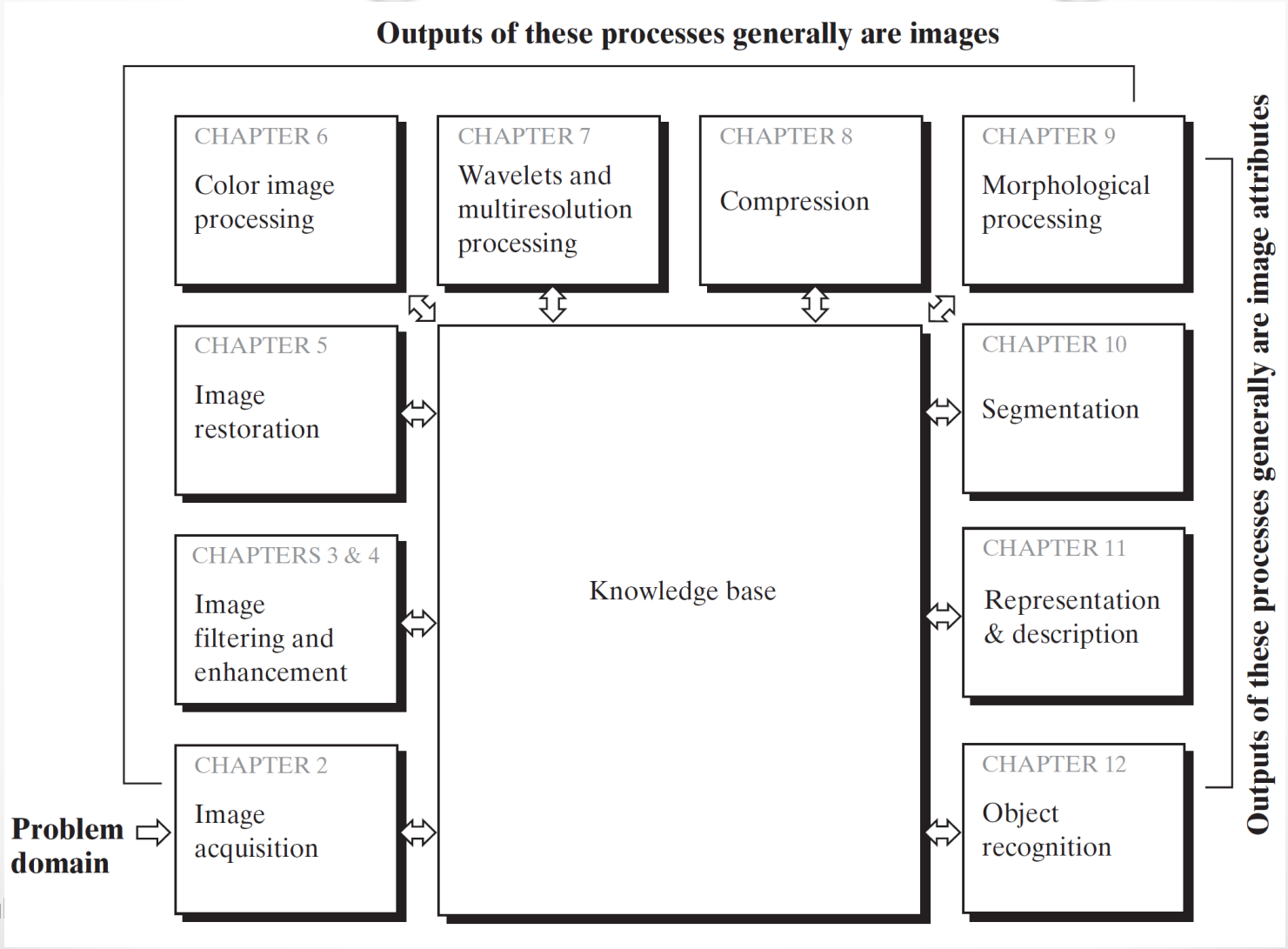


Image Processing System Components