Digital Image Processing

By
Bhavik Soneji
Indus University

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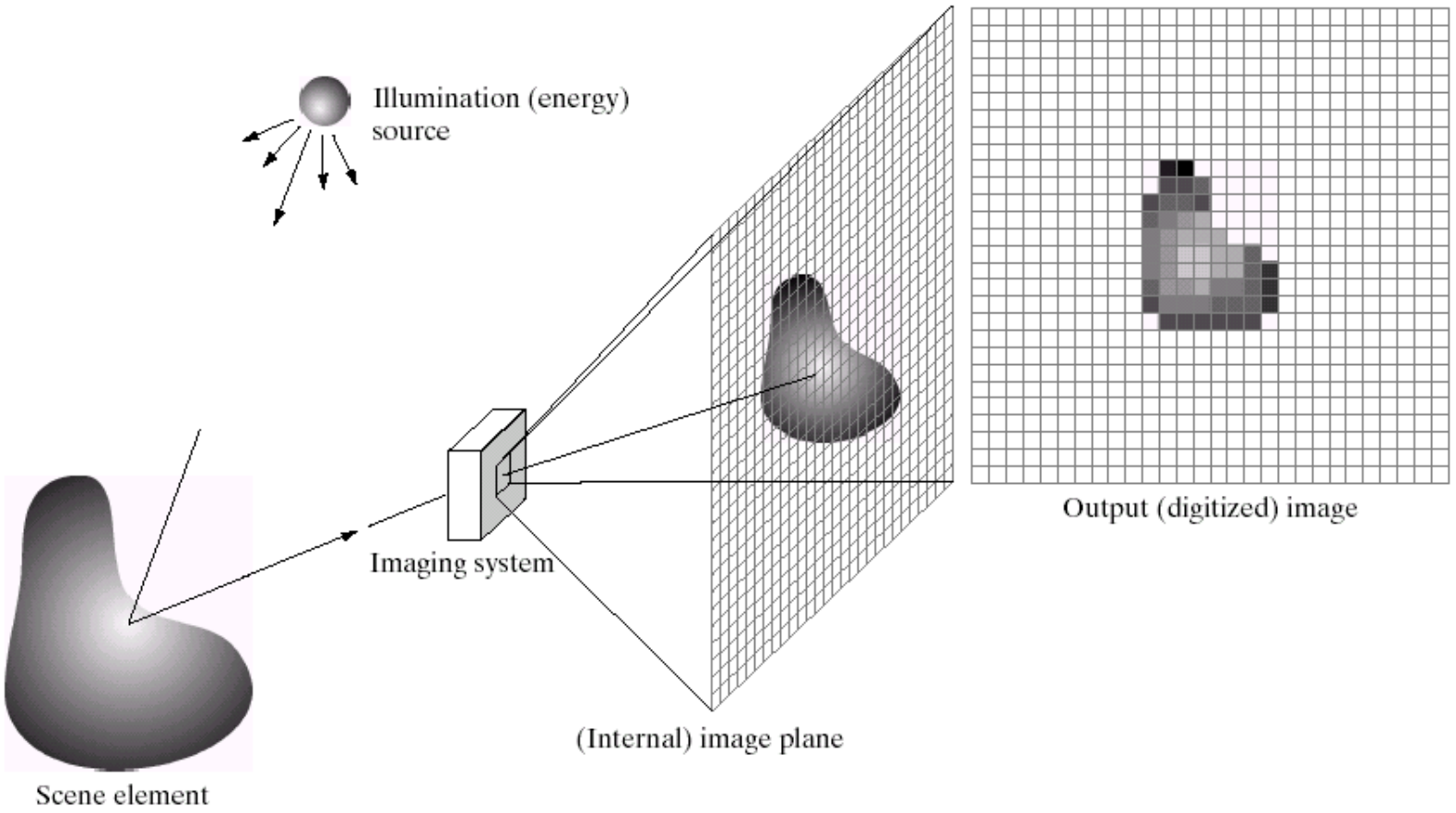
1.	**Image fundamentals:** A simple image formation model, sampling and quantization, connectivity and adjacency relationships between pixels
2.	**Spatial domain filtering:** Basic intensity transformations: negative, log, power-law and piecewise linear transformations, bit-plane slicing, histogram equalization and matching, smoothing and sharpening filtering in spatial domain, unsharp masking and high-boost filtering
3.	**Frequency domain filtering:** Fourier Series and Fourier transform, discrete and fast Fourier transform, sampling theorem, aliasing, filtering in frequency domain, lowpass and highpass filters, bandreject and bandpass filters, notch filters
4.	**Image restoration:** Introduction to various noise models, restoration in presence of noise only, periodic noise reduction, linear and position invariant degradation, estimation of degradation function
5.	**Image reconstruction:** Principles of computed tomography, projections and Radon transform, the Fourier slice theorem, reconstruction using parallel-beam and fan-beam by filtered backprojection methods

Image Acquisition Process



a
b c d e

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.

Introduction

- What is Digital Image Processing?

Digital Image $f(x, y)$

— a two-dimensional function

***x* and *y* are spatial coordinates**

The amplitude of *f* is called intensity or gray level at the point (x, y)

Digital Image Processing

— process digital images by means of computer, it covers low-, mid-, and high-level processes

low-level: inputs and outputs are images

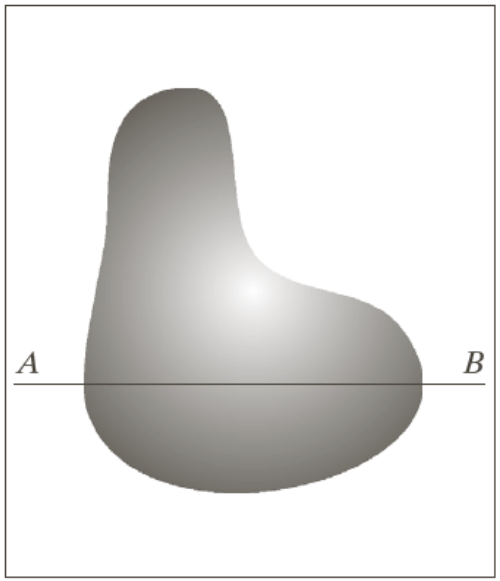
mid-level: outputs are attributes extracted from input images

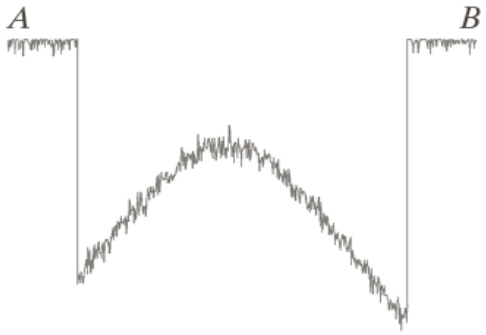
high-level: an ensemble of recognition of individual objects

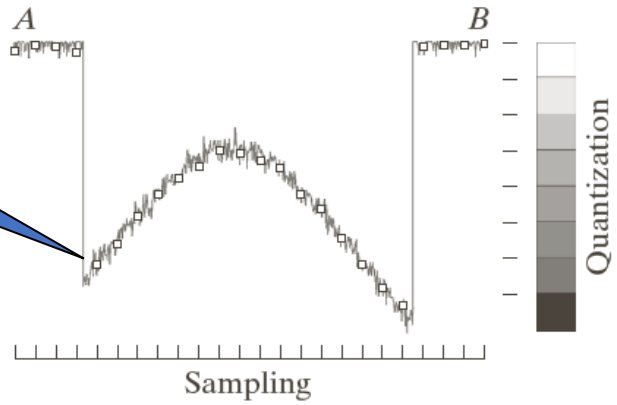
Pixel

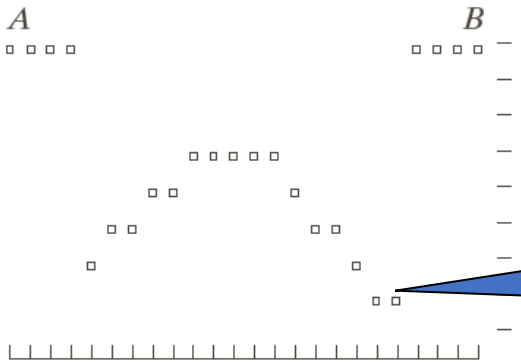
— the elements of a digital image

Image Sampling and Quantization









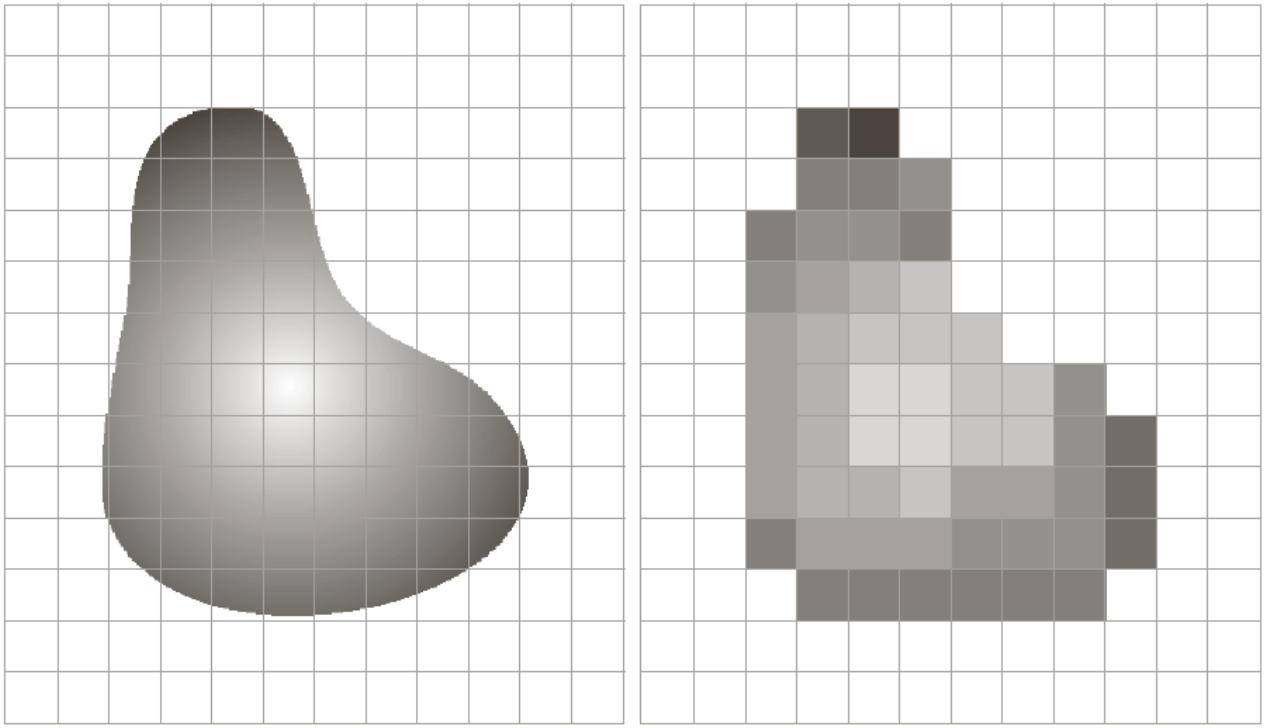
a b
c d

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.

Digitizing the coordinate values

Digitizing the amplitude values

Image Sampling and Quantization



a b

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

Representing Digital Images

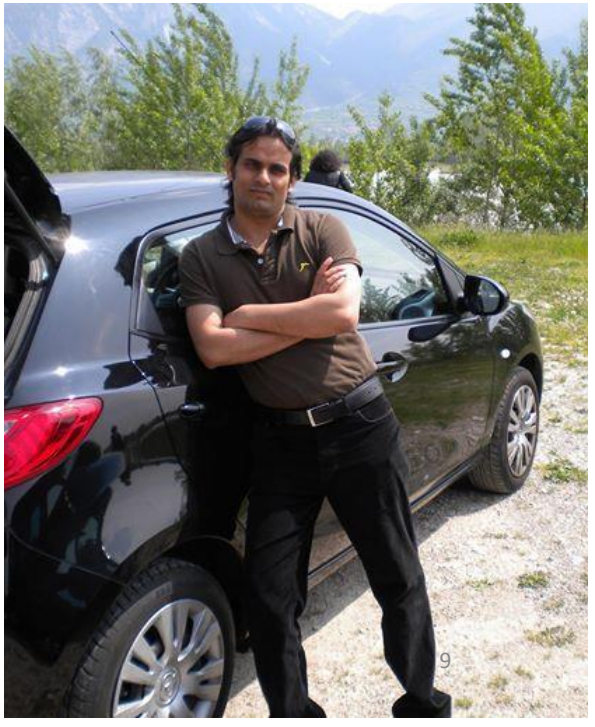
- The representation of an M×N numerical array as

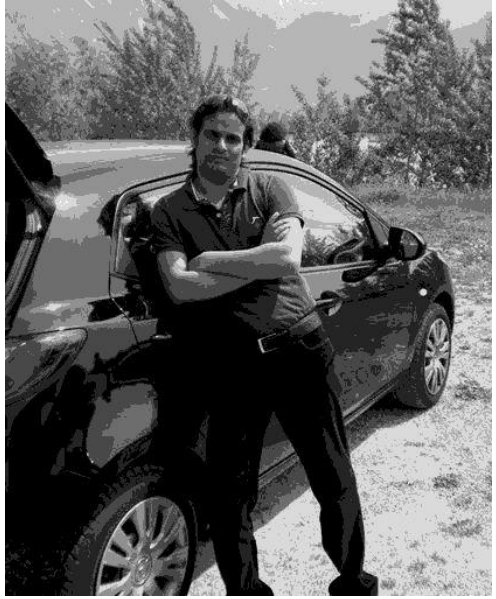
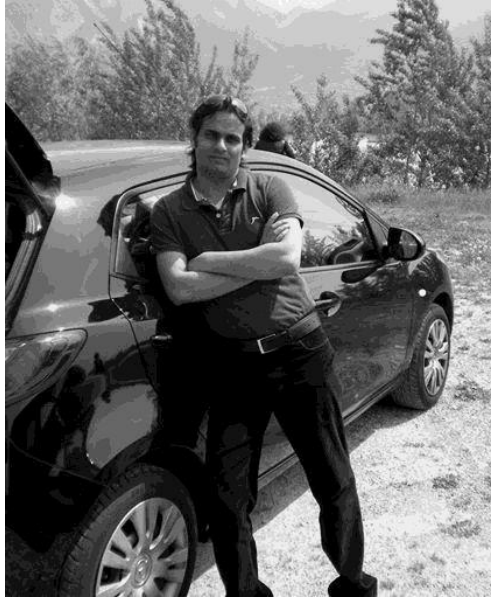
$$A = \begin{bmatrix} a_{0,0} & a_{0,1} & \cdots & a_{0,N-1} \\ a_{1,0} & a_{1,1} & \cdots & a_{1,N-1} \\ \cdots & \cdots & \cdots & \cdots \\ a_{M-1,0} & a_{M-1,1} & \cdots & a_{M-1,N-1} \end{bmatrix}$$

Representing Digital Images

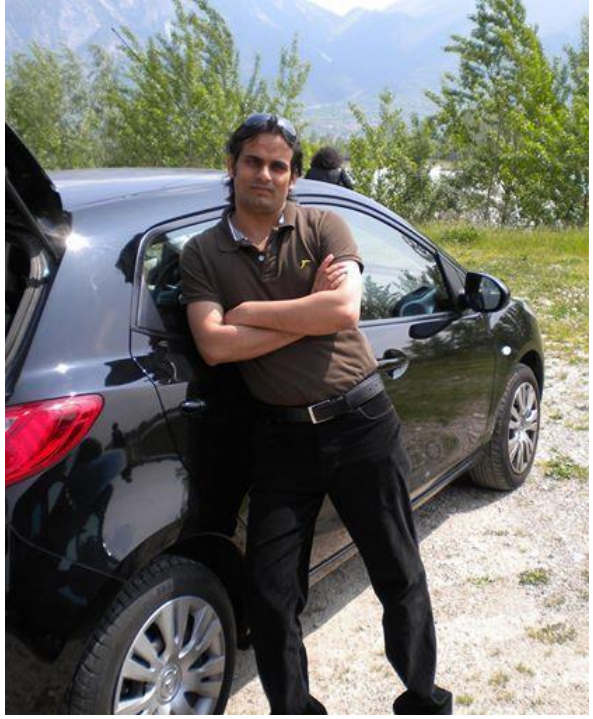
- Discrete intensity interval [0, L-1], $L=2^k$
- The number b of bits required to store a $M \times N$ digitized image

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





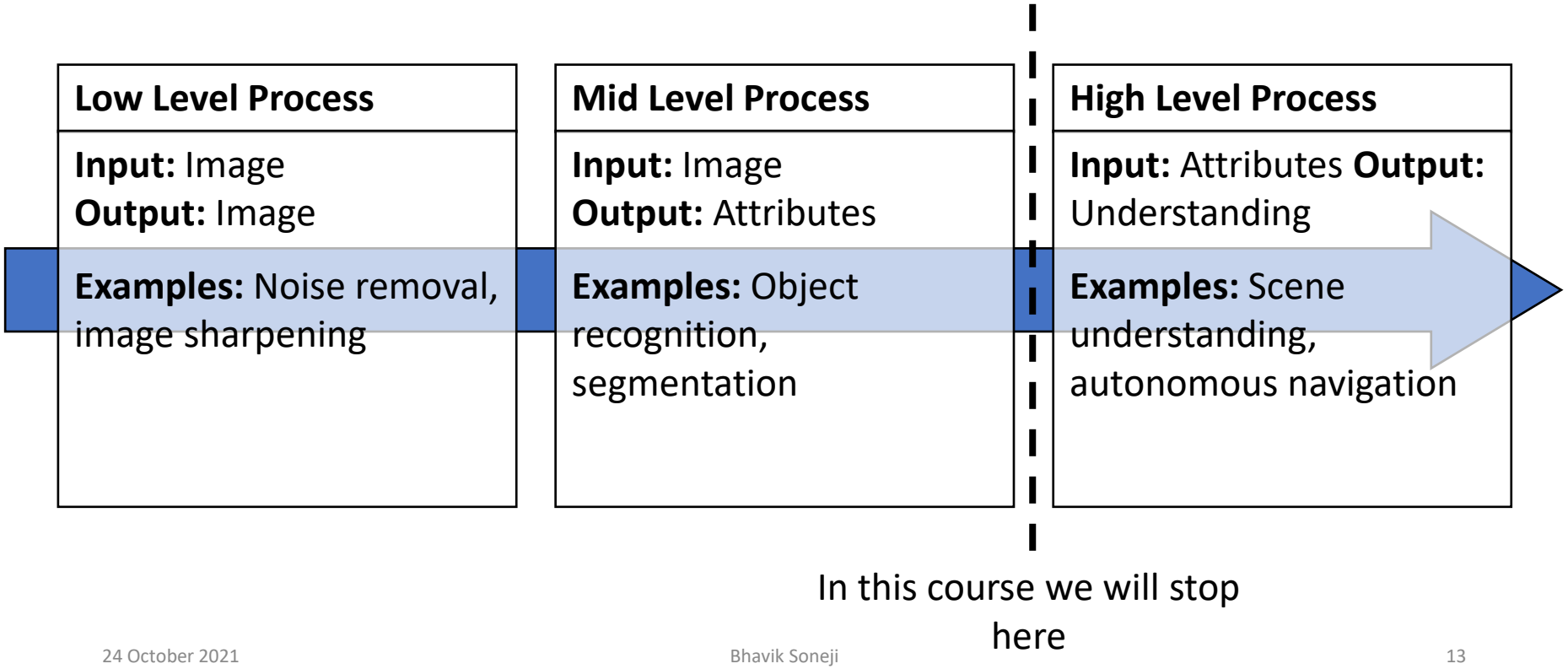
What is a Digital Image? (cont…)

- 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)

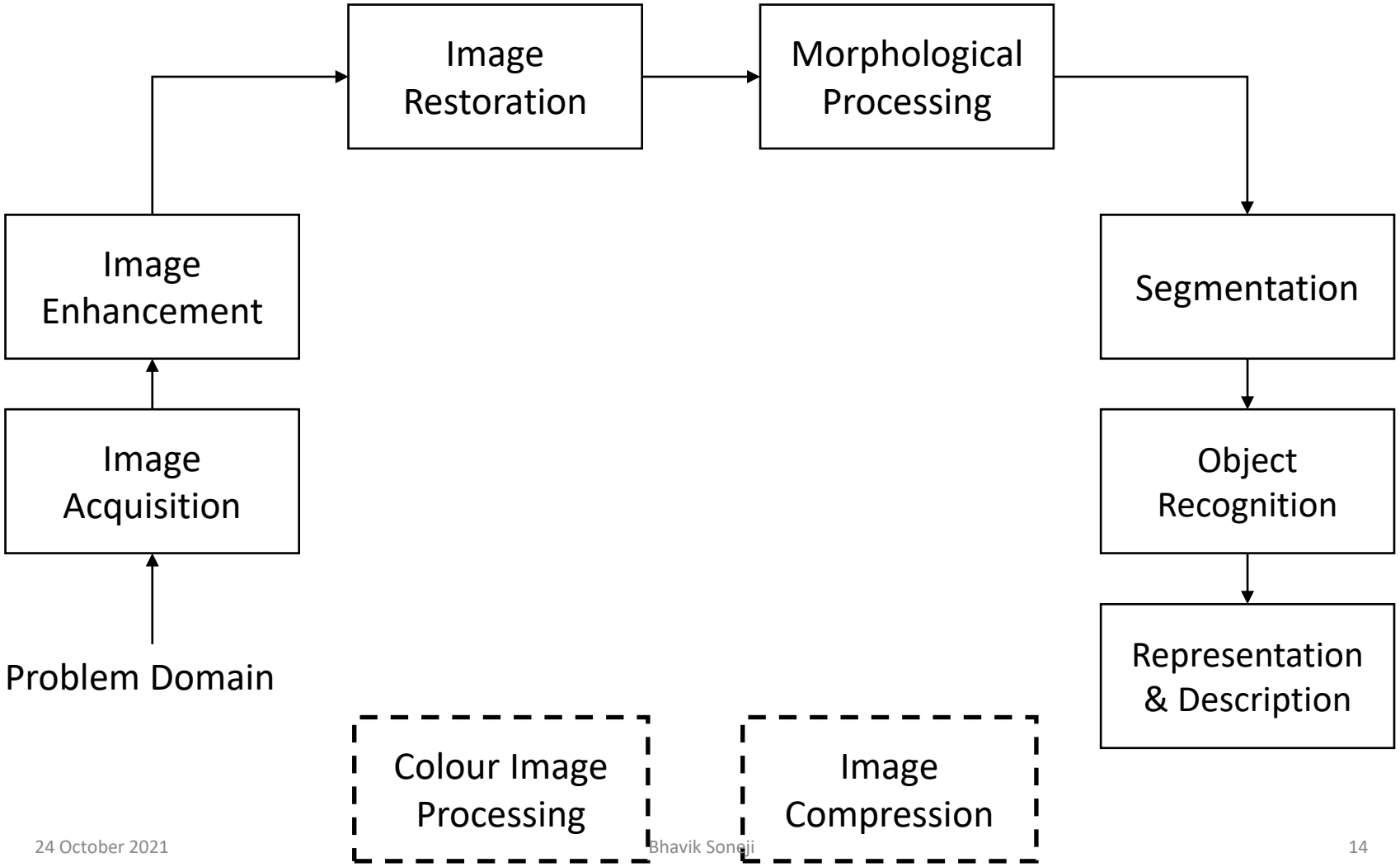
- For most of this course we will focus on g images

What is DIP? (cont…)

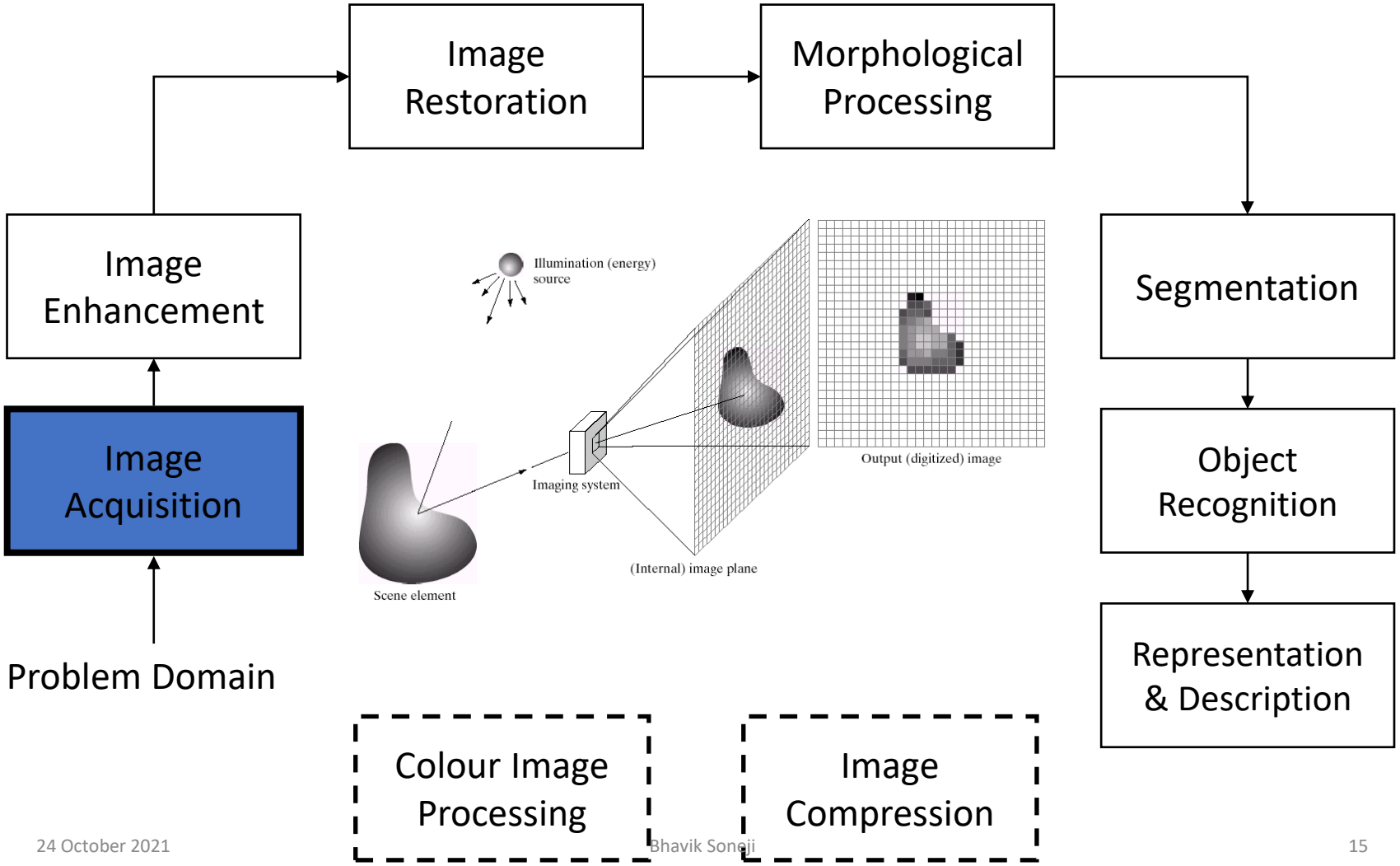
•The continuum from image processing to computer vision can be broken up into low-, mid- and high-level processes



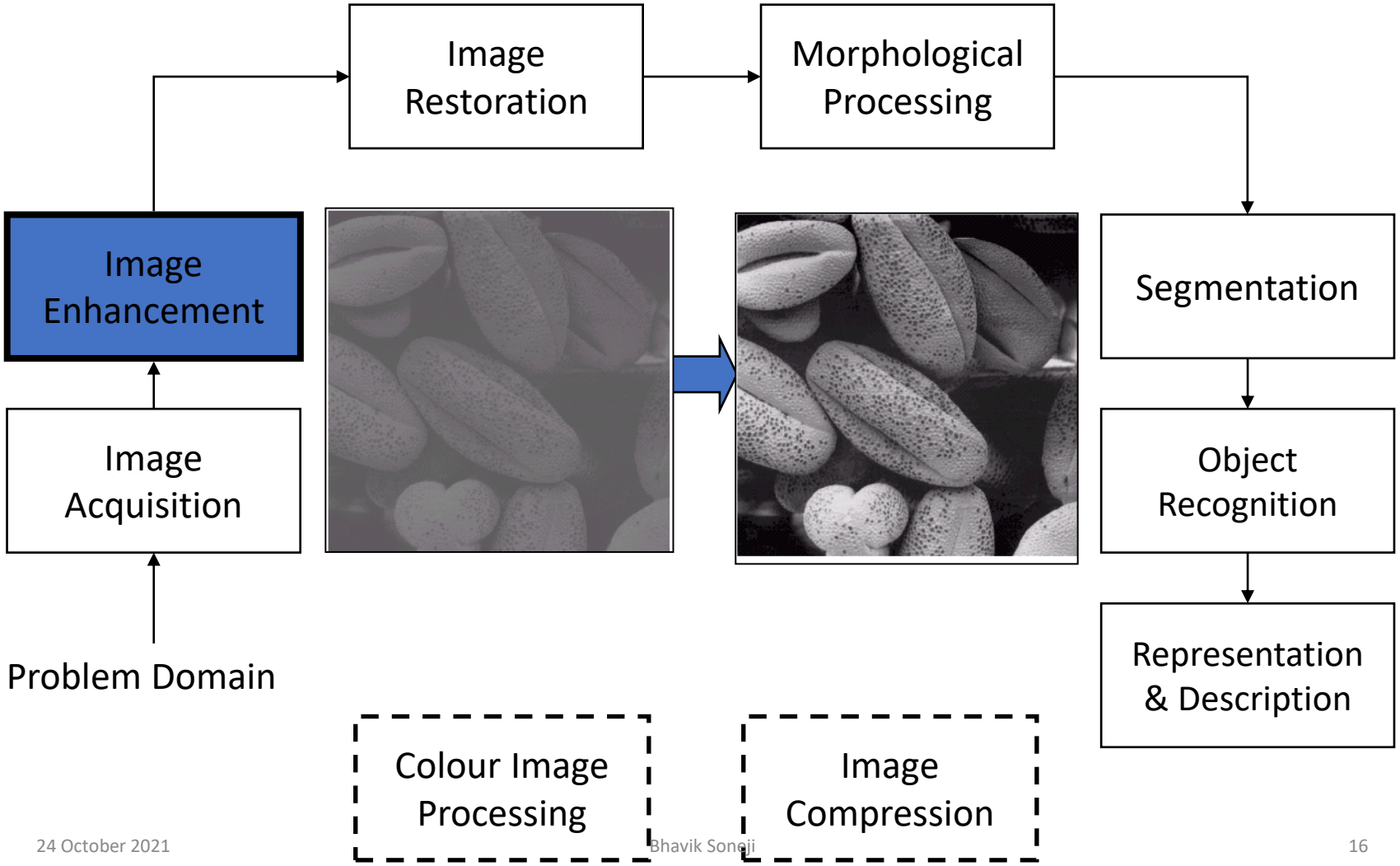
Key Stages in Digital Image Processing



Key Stages in Digital Image Processing: Image Aquisition

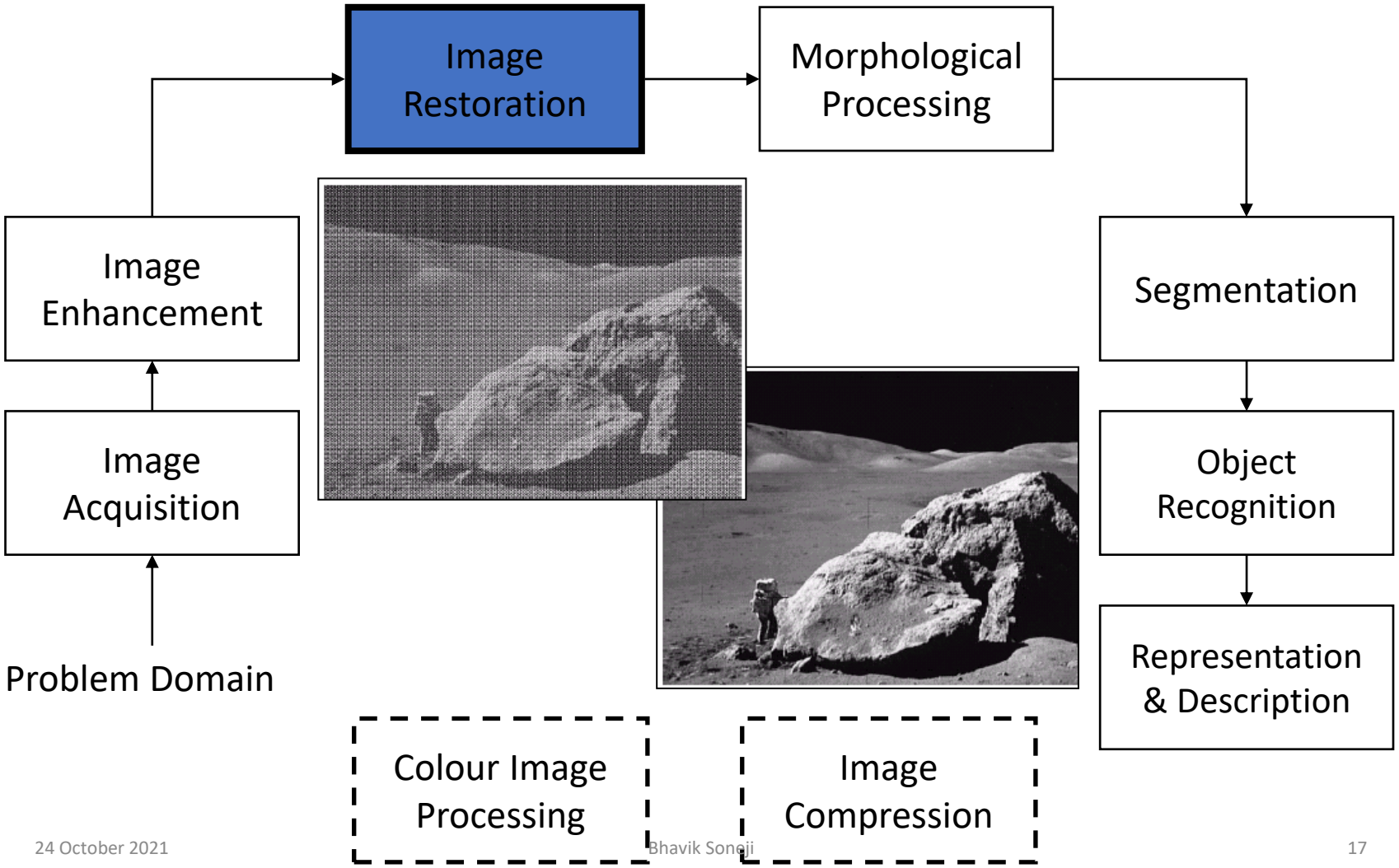


Key Stages in Digital Image Processing: Image Enhancement



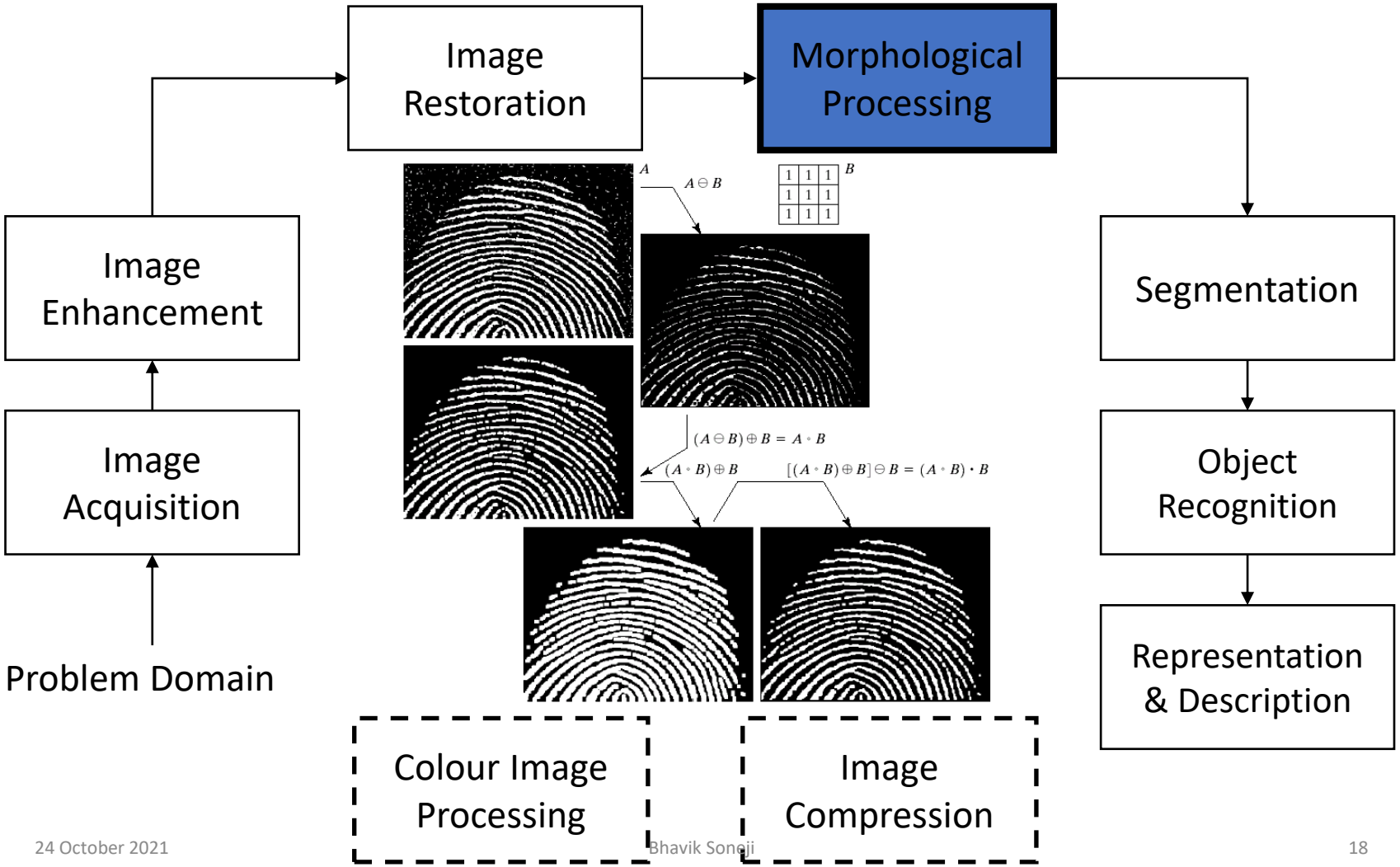
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Image Restoration



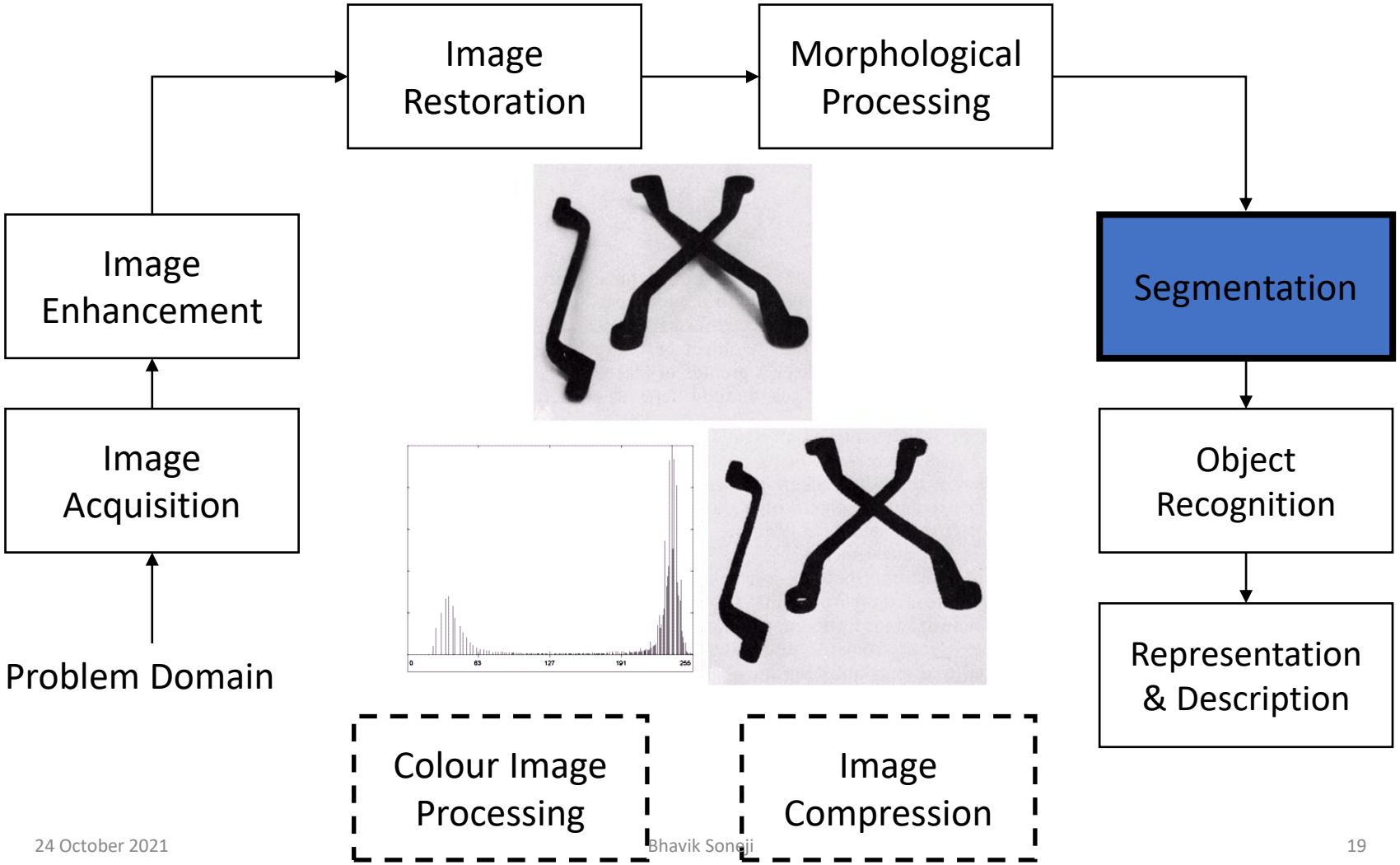
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Morphological Processing



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

Key Stages in Digital Image Processing: Segmentation



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

Key Stages in Digital Image Processing: Object Recognition

Image Restoration

Morphological Processing

Segmentation

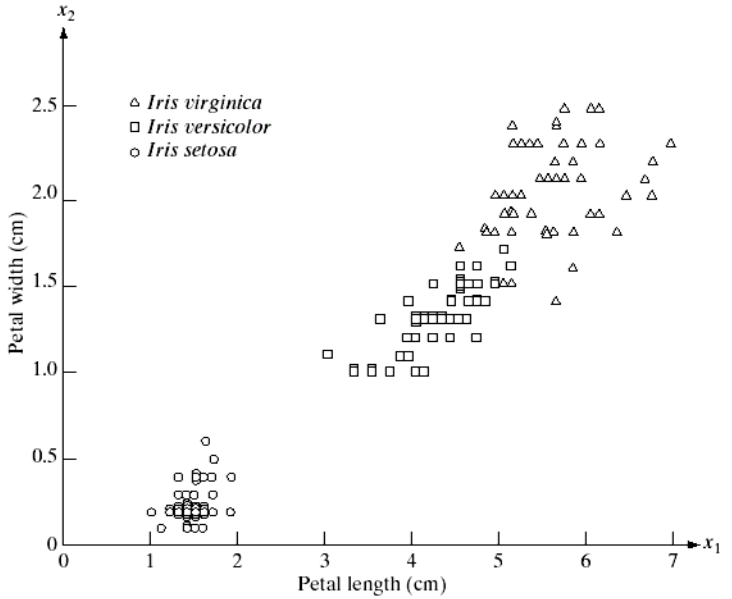
Object Recognition

Representation & Description

Image Enhancement

Image Acquisition

Problem Domain

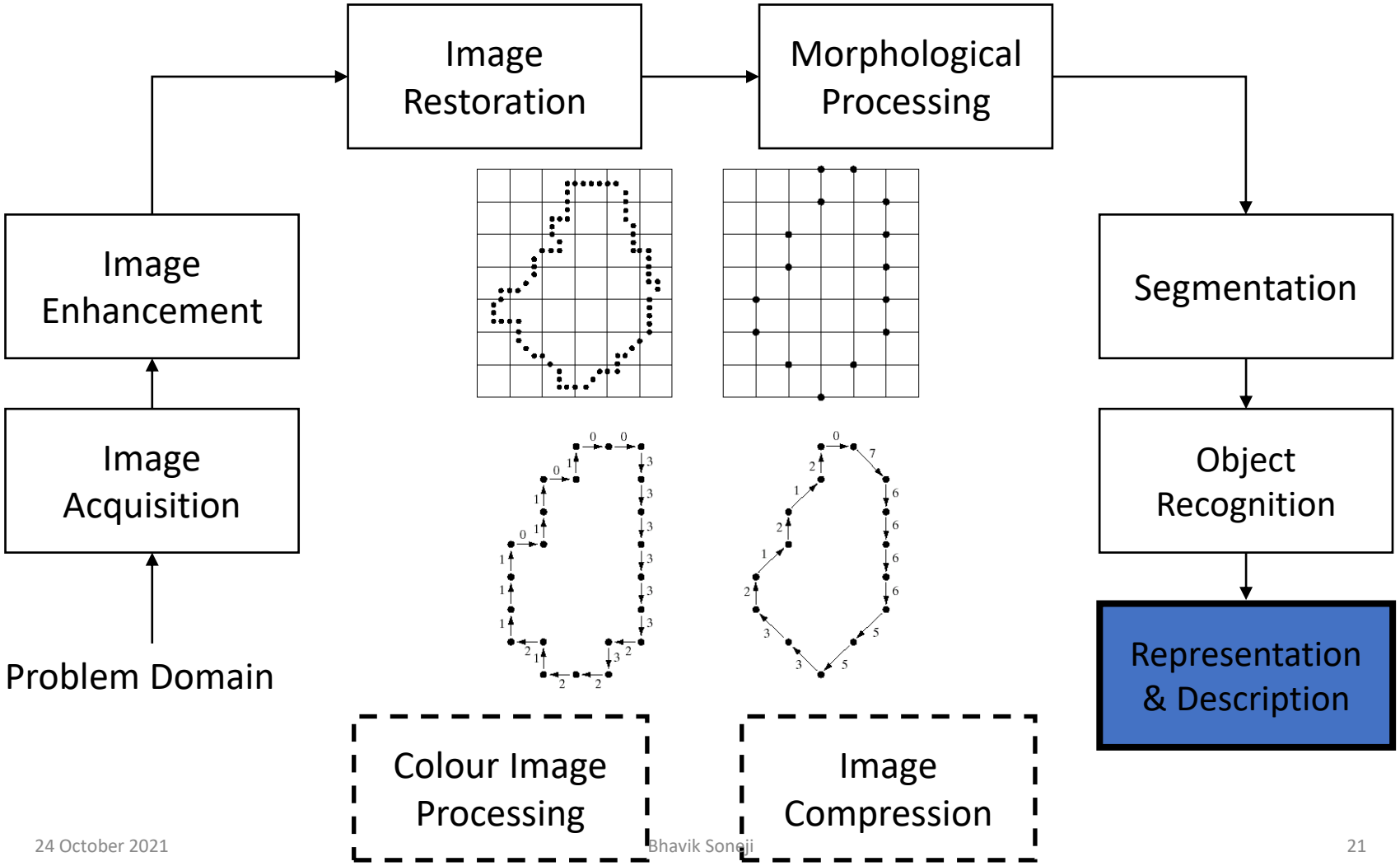


Colour Image Processing

Image Compression

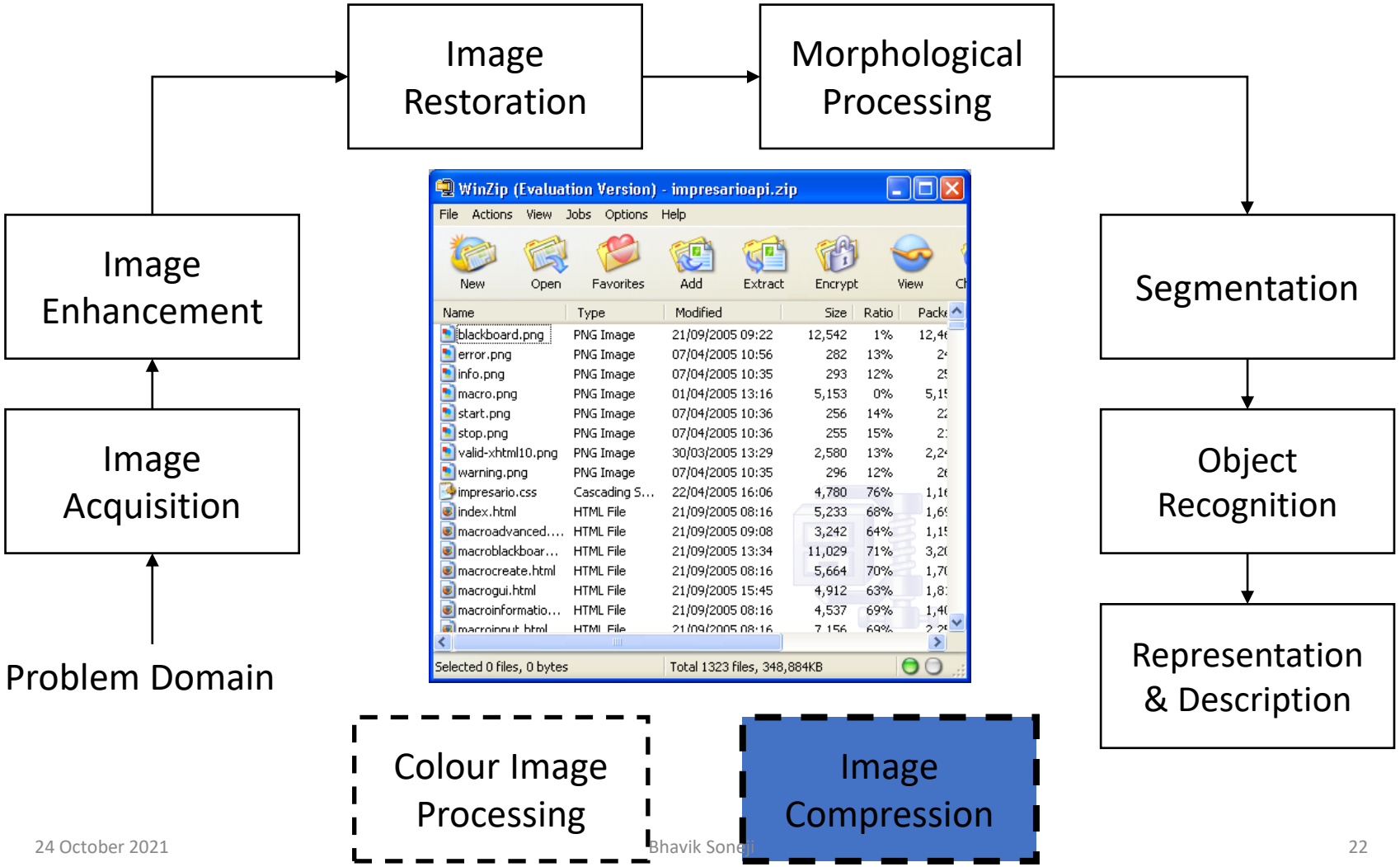
Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Representation & Description

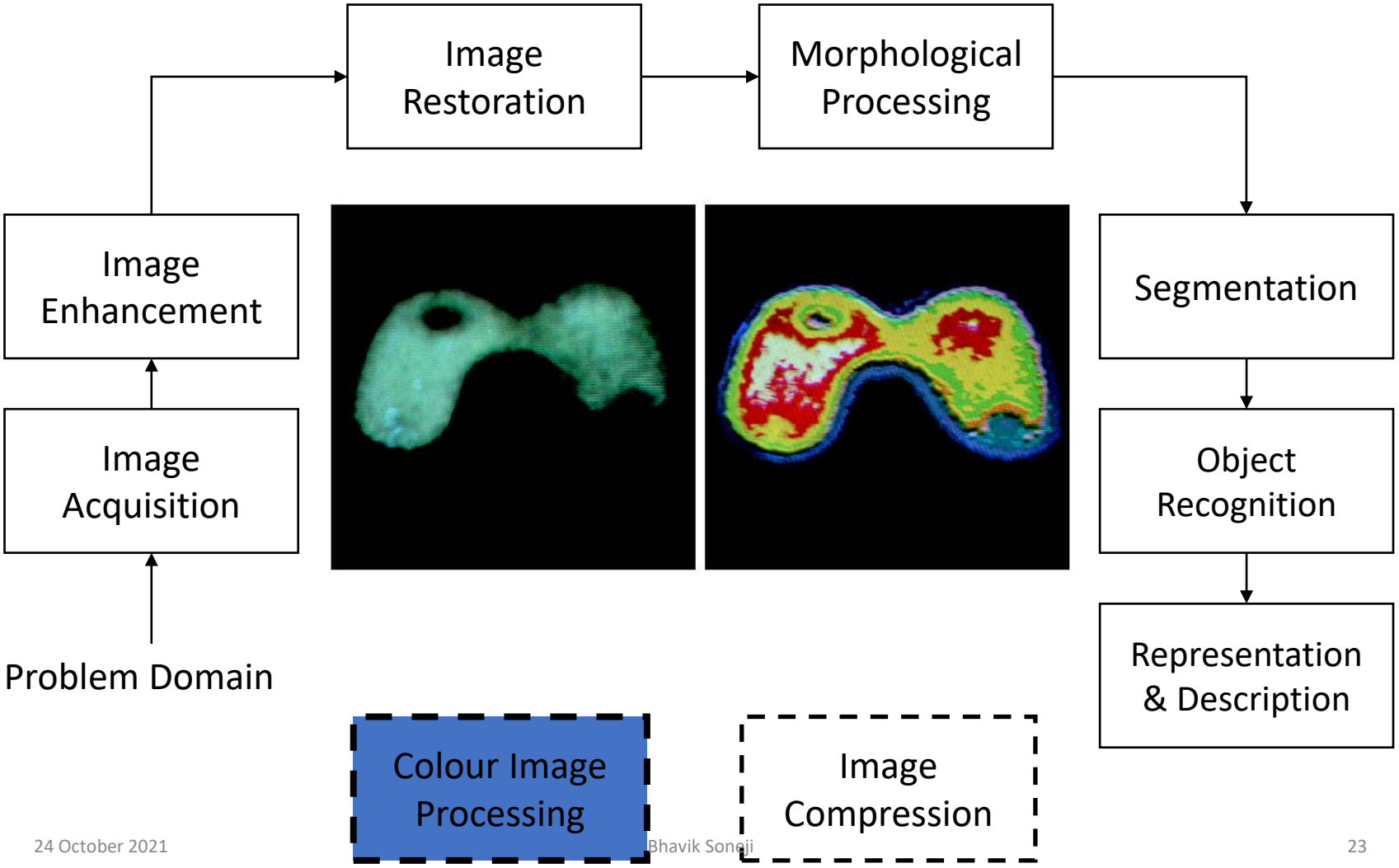


Images taken from Gonzalez & Woods, Digital Image Processing (2002)

Key Stages in Digital Image Processing: Image Compression

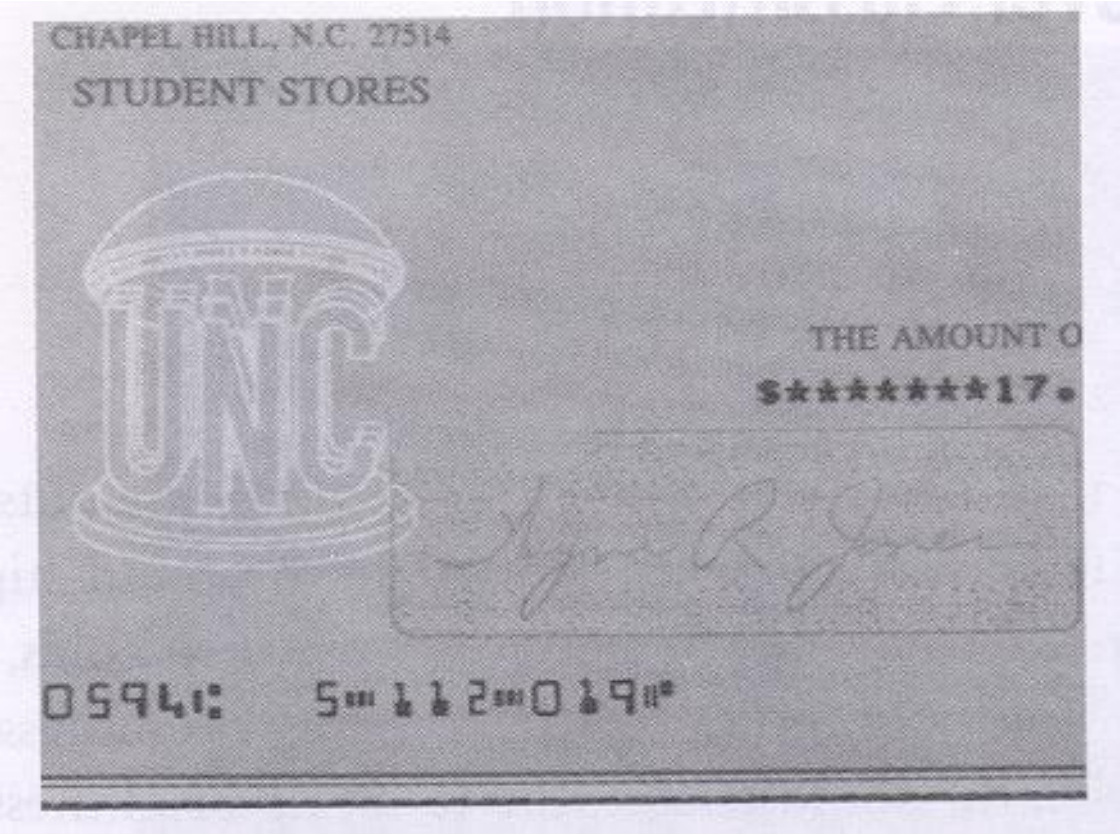


Key Stages in Digital Image Processing: Colour Image Processing

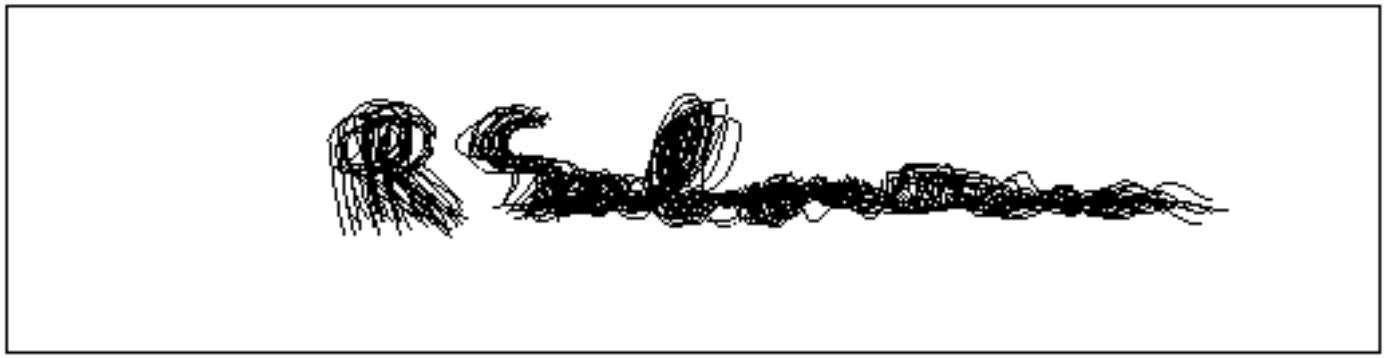


Applications
&
Research Topics

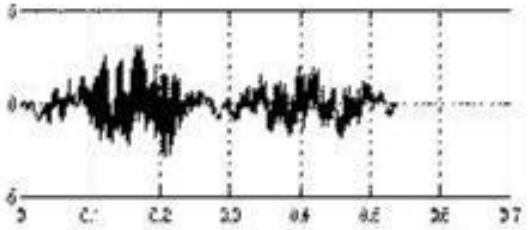
Document Handling



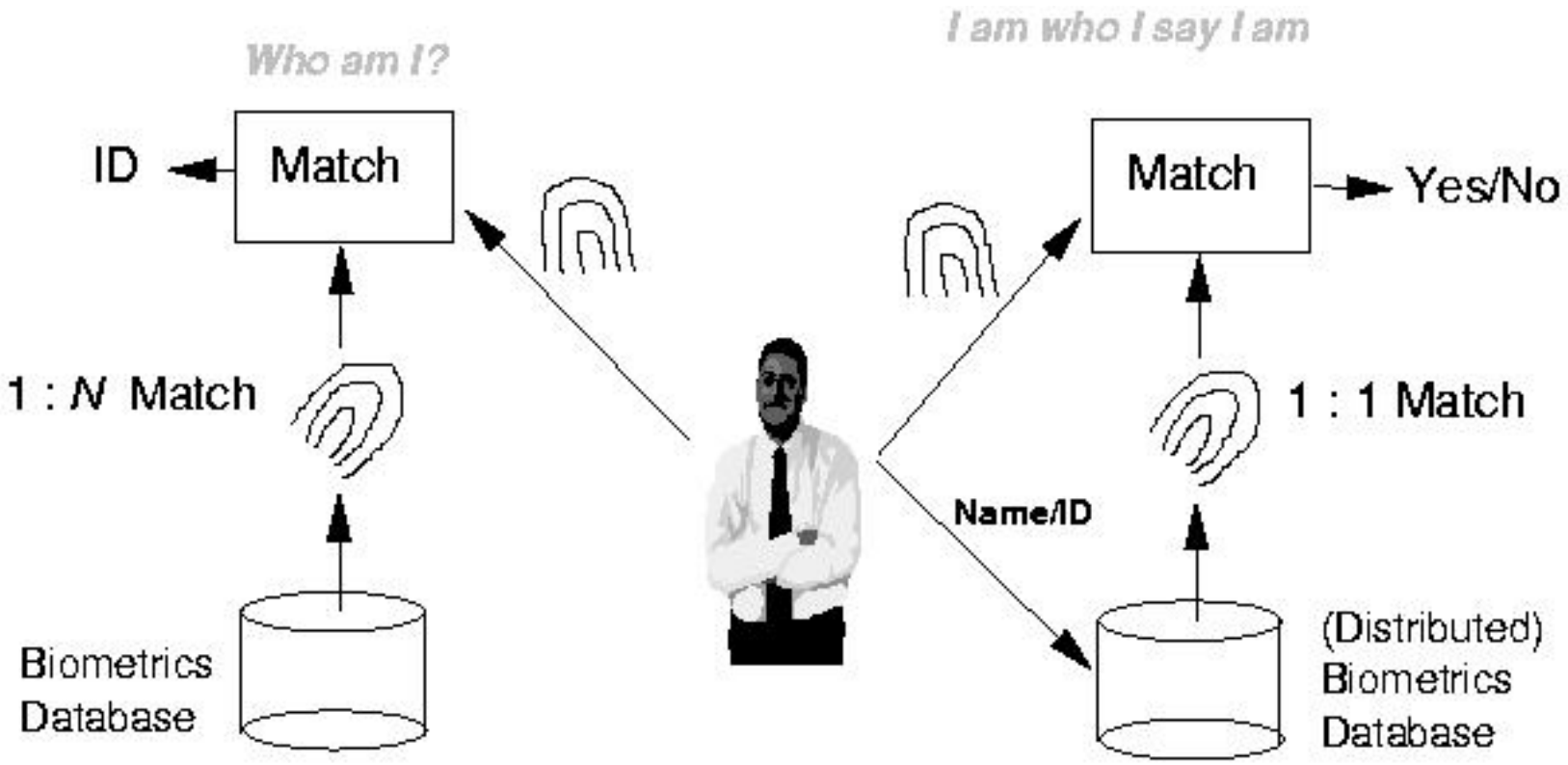
Signature Verification



Biometrics

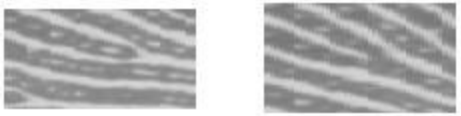


Fingerprint Verification / Identification



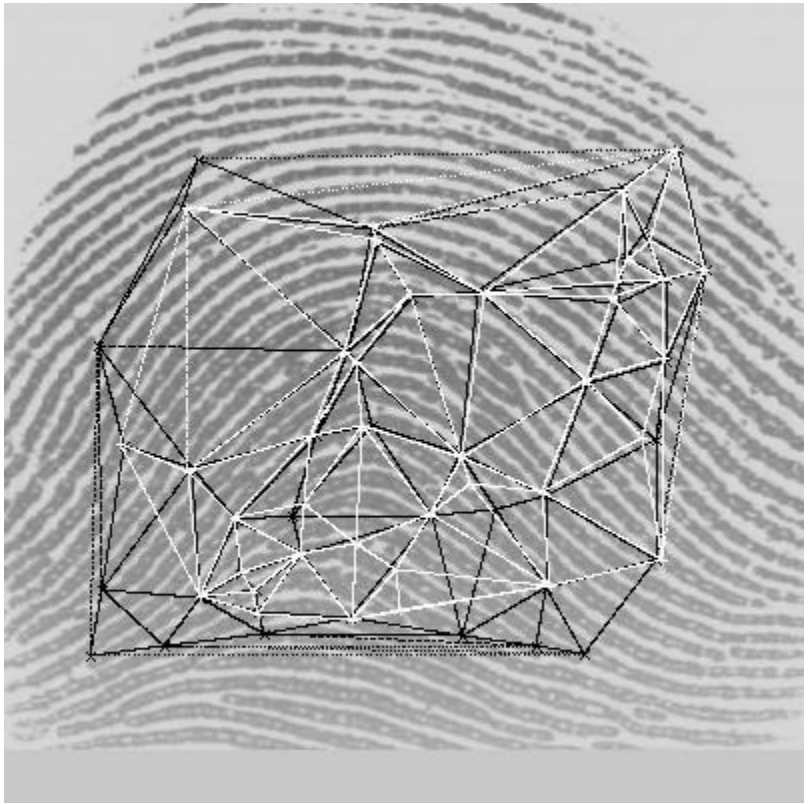
Fingerprint Identification Research at UNR

Minutiae

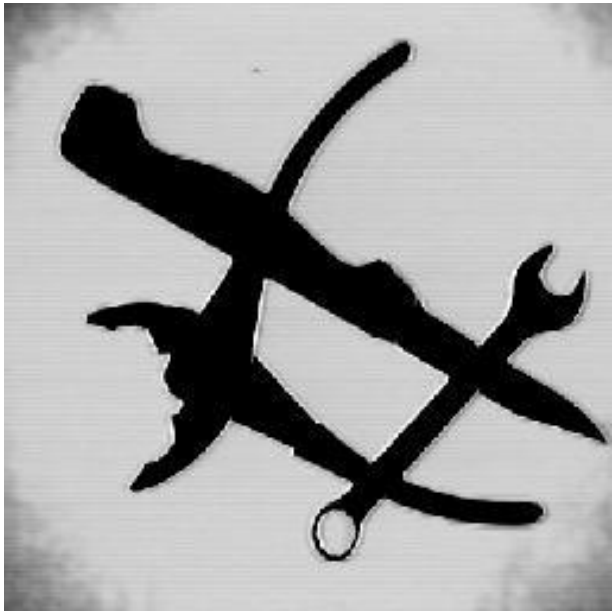


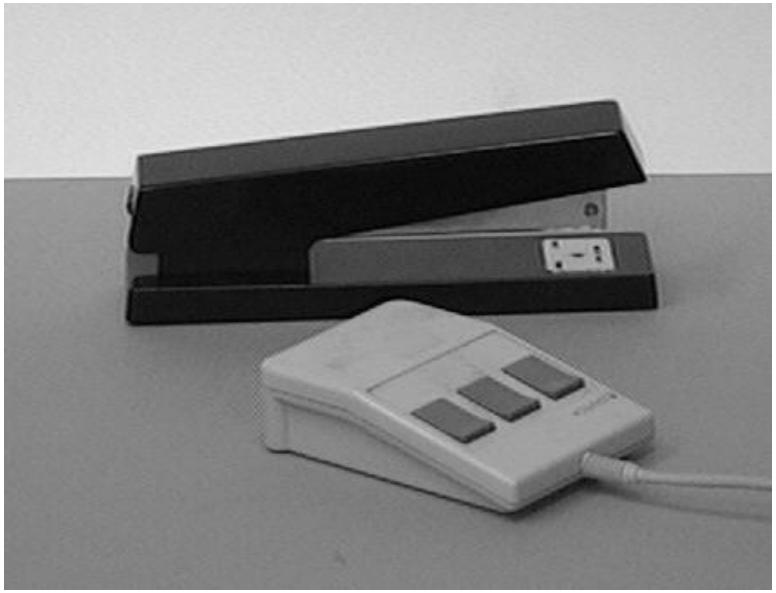
Delaunay Triangulation

Matching



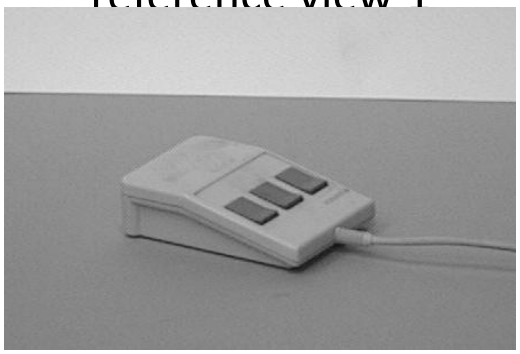
Object Recognition



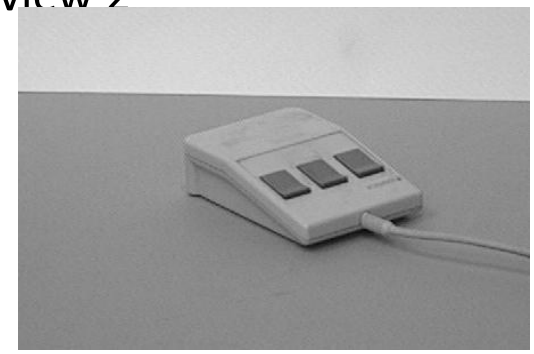


Object Recognition Research

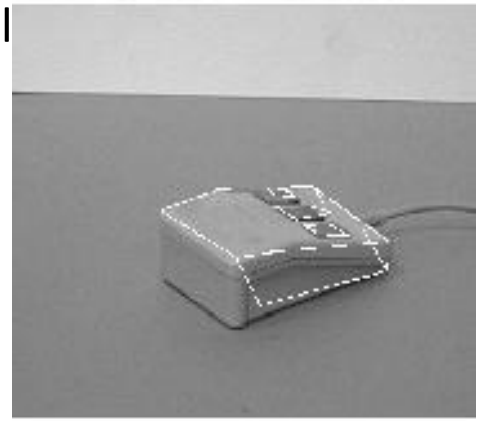
reference view 1



reference view 2

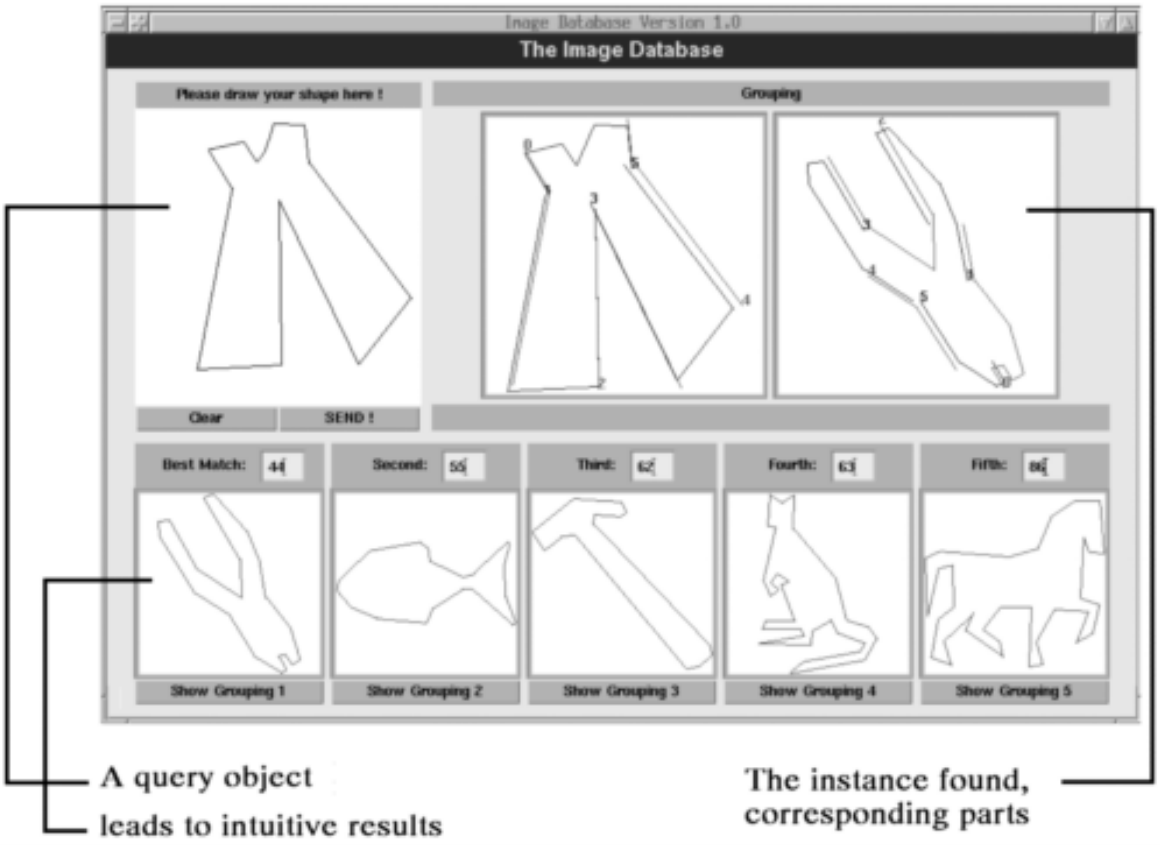


novel



Indexing into Databases

- Shape content



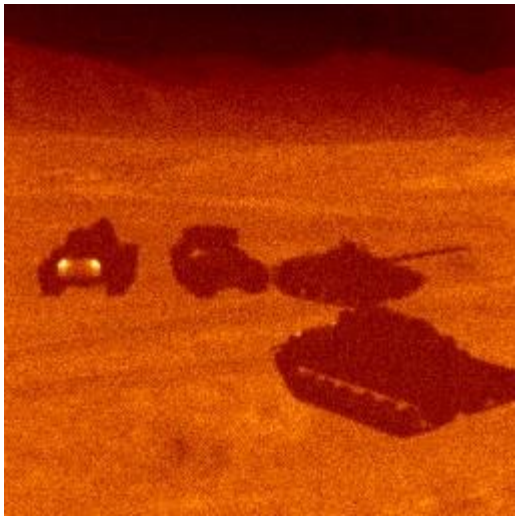
Indexing into Databases (cont'd)

- Color, texture

$T = 33.6\text{s}$, found 2 of 2

Target Recognition

- Department of Defense (Army, Airforce, Navy)

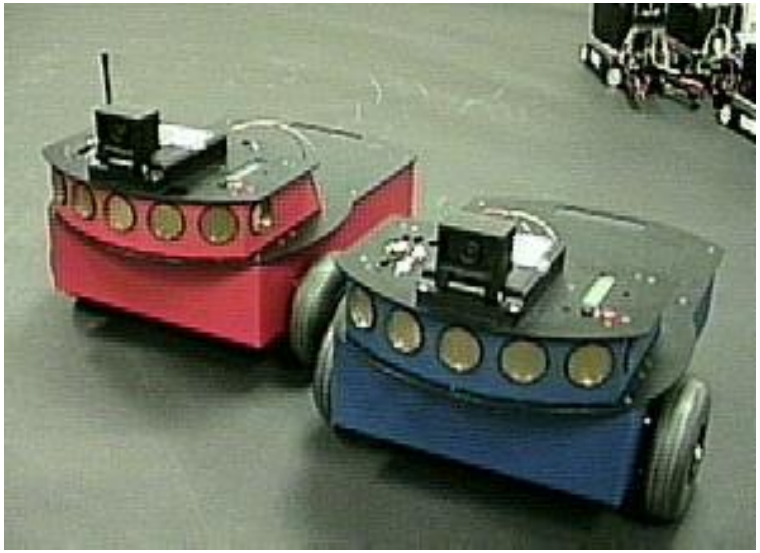


Interpretation of Aerial Photography

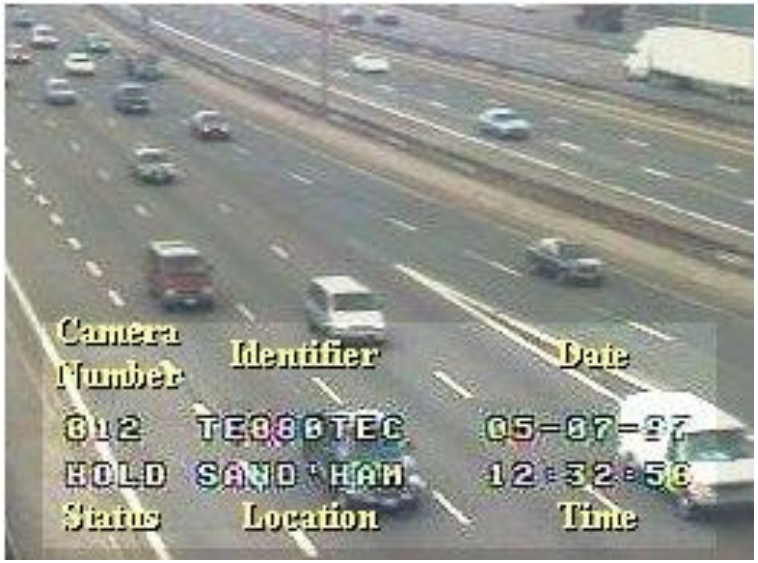
Interpretation of aerial photography is a problem domain in both computer vision and registration.

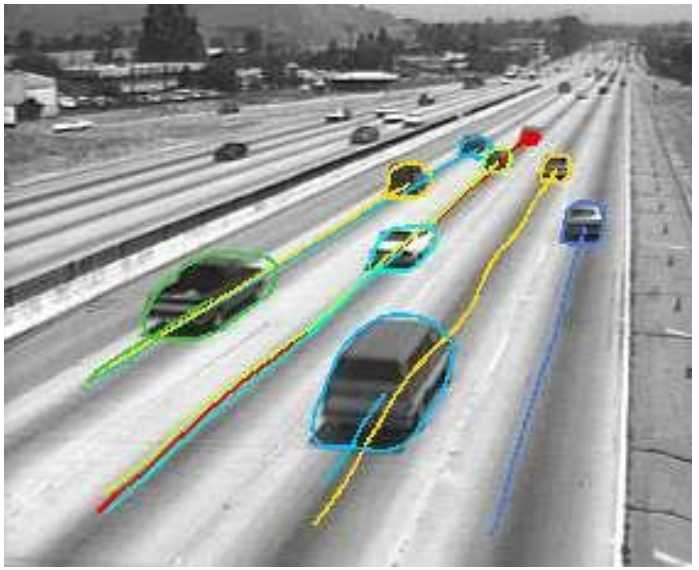
Autonomous Vehicles

- Land, Underwater, Space

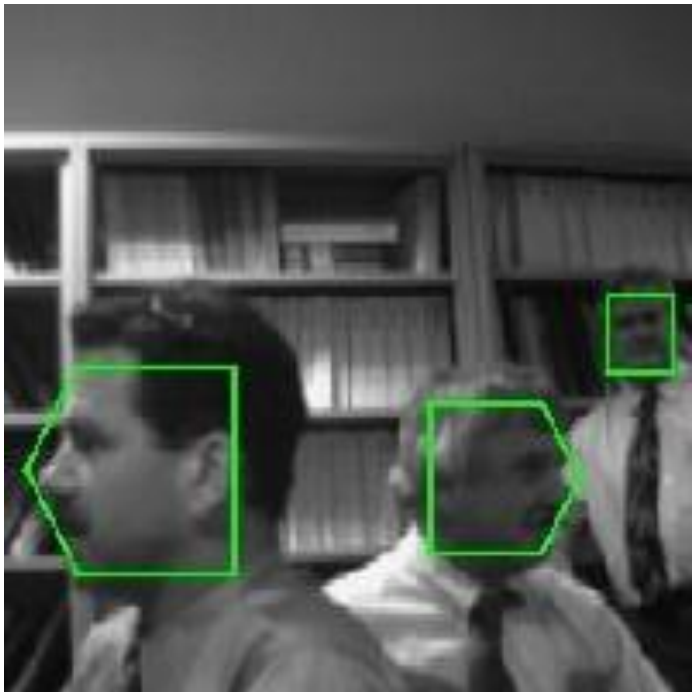


Traffic Monitoring





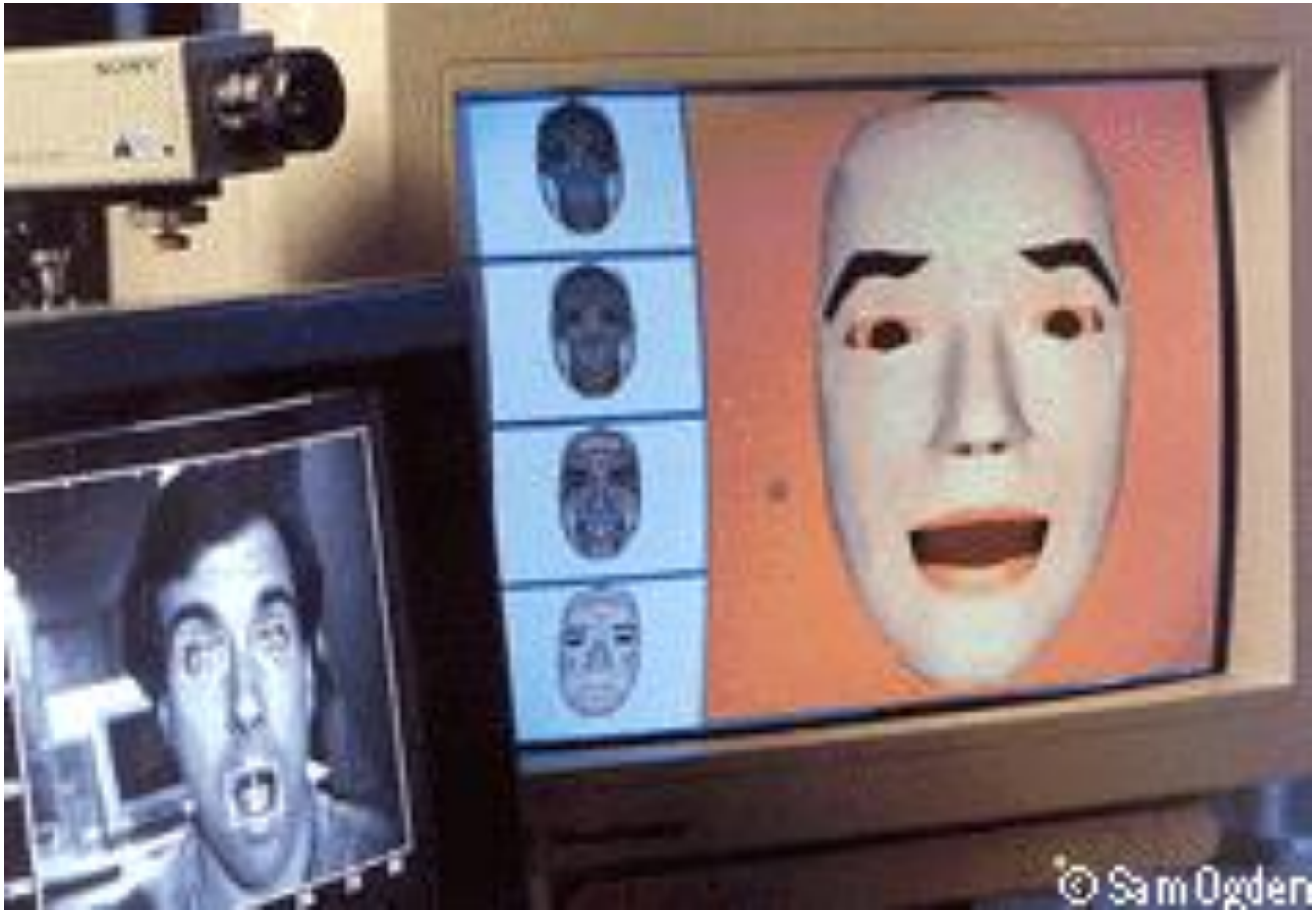
Face Detection



Face Recognition

Face Detection/Recognition Research at UNR

Facial Expression Recognition



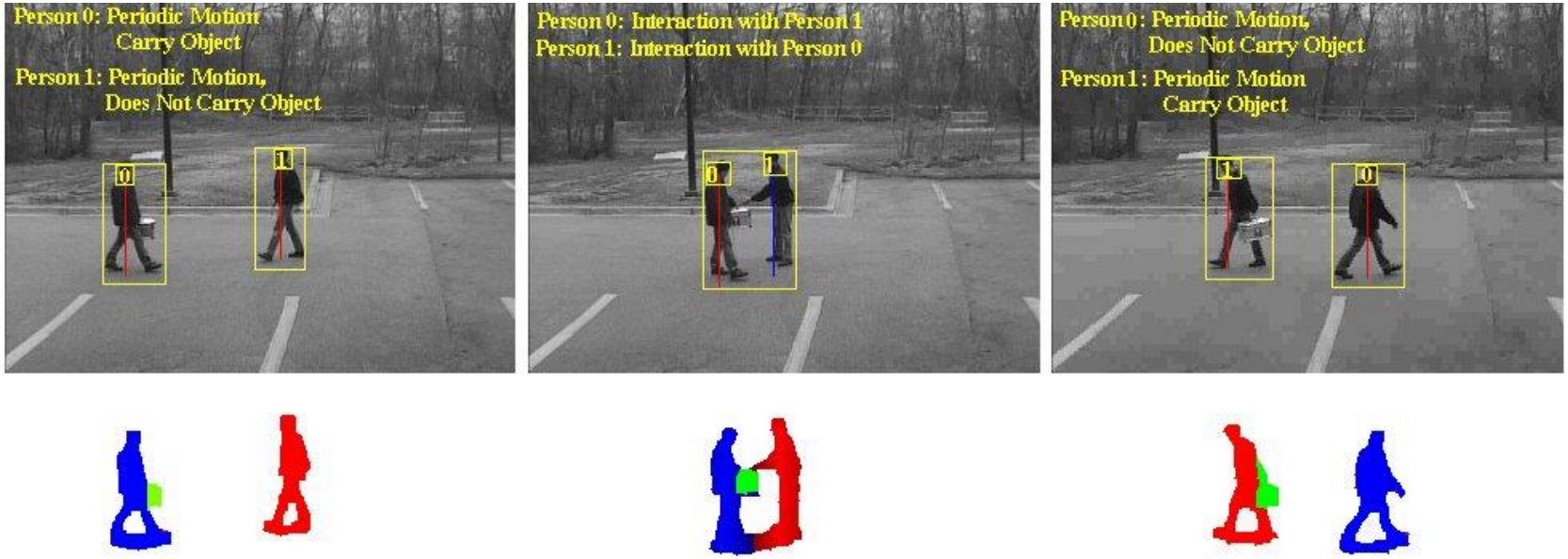
Face Tracking

Face Tracking (cont’d)

Hand Gesture Recognition

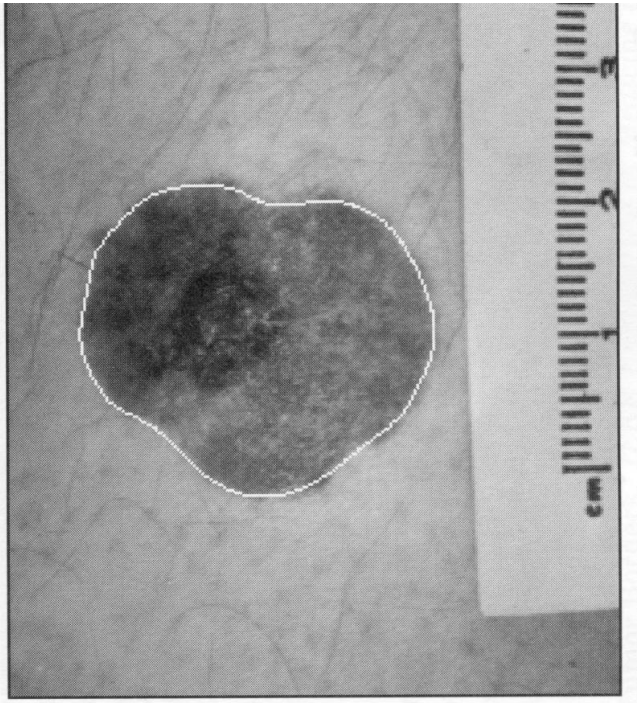
- Smart Human-Computer User Interfaces
- Sign Language Recognition

Human Activity Recognition



Medical Applications

- skin cancer



breast cancer