Digital Image Processing

An Introduction to Digital Image Processing

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Overview

- **What is Digital Image?**
- **Why do we process images?**
- **Image processing Examples**
- **Applications of DIP**
- **Classification of DIP and Computer Vision processes**
- **Image processing Computer Vision and Pattern Recognition**
- **Image processing steps**
- **Scope of DIP course**

What is Digital Image?

Image

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

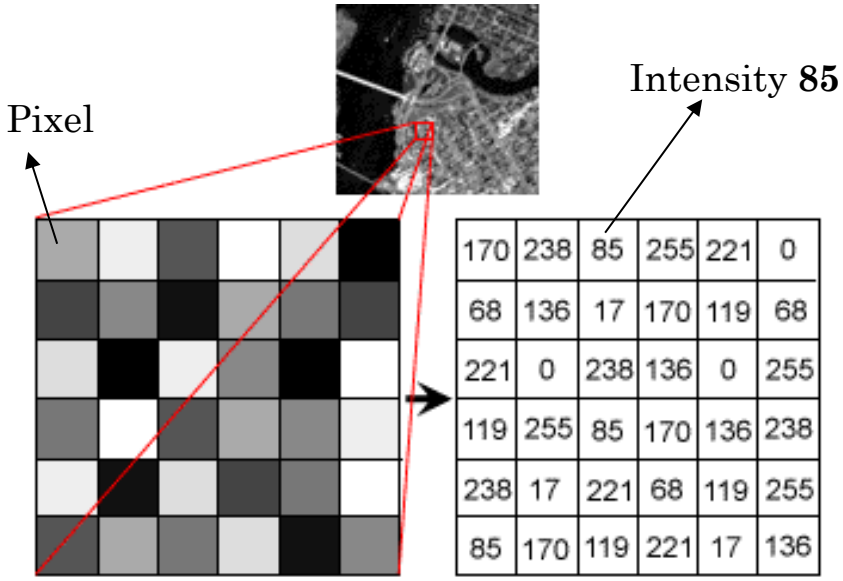
$$f(x,y) = \begin{bmatrix} f(0,0) & f(0,1) & f(0,2) & \dots & f(0,N-1) \\ f(1,0) & f(1,1) & f(1,2) & \dots & f(1,N-1) \\ \vdots & \vdots & \vdots & & \vdots \\ f(M-1,0) & f(M-1,1) & f(M-1,2) & \dots & f(M-1,N-1) \end{bmatrix}$$

Digital Image

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

OR

Digital images are 2D arrays (matrices) of numbers.



Digital Image Processing

Digital image processing refers to processing digital images by means of a digital computer.

Why do we process images?

Facilitate picture storage and transmission

- Efficiently store an image in a digital camera
- Send an image through mobile phone

Enhance and restore images

- Remove scratches from an old photo
- Improve visibility of tumor in a radiograph

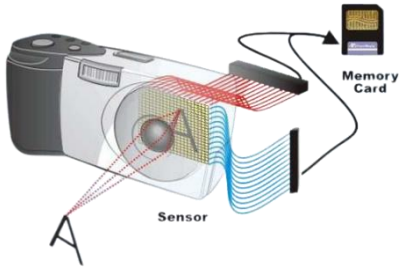
Extract information from images

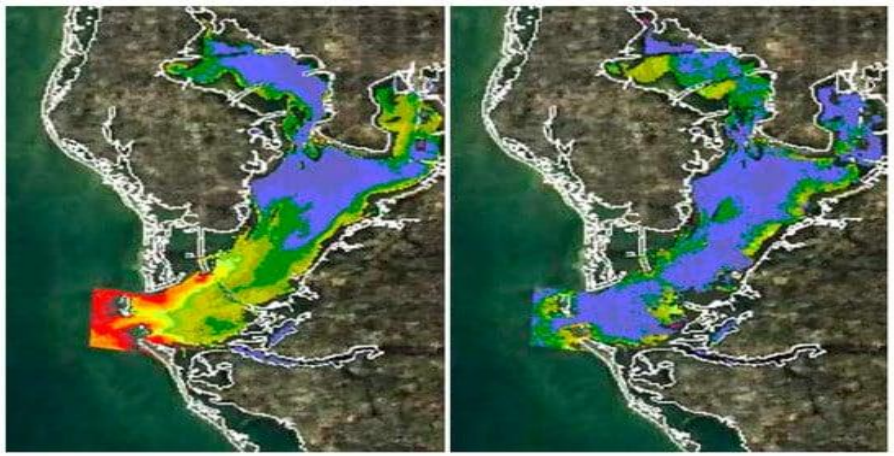
- Measure water pollution from aerial images
- Measure the 3D distances and heights of objects from stereo images

Prepare for display or printing

- Adjust image size
- Halftoning

Biometrics based identification





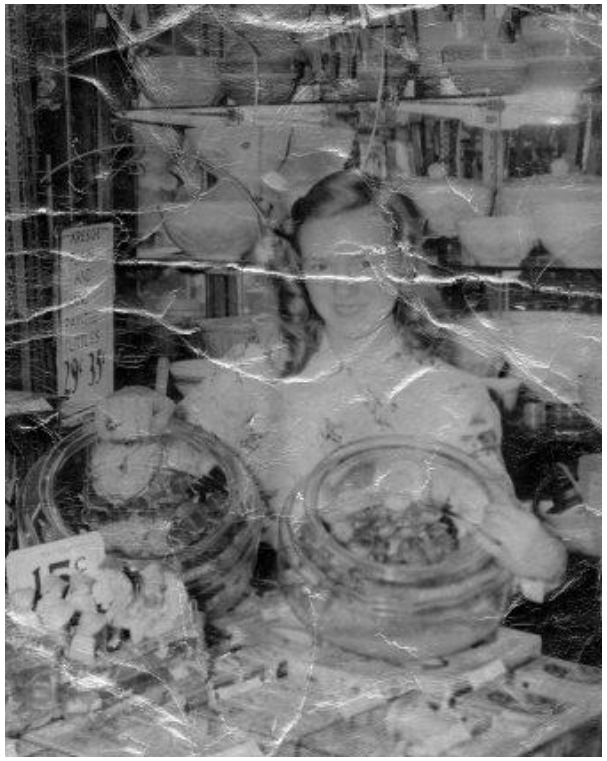
(a) Winter (b) Summer

Water quality of Florida's Tampa Bay decreases (Picture source NASA/USF).

Image Processing Examples

Photo Restoration

Repairing old, damaged, or degraded photographs to restore them to their original condition or even improve their visual quality.

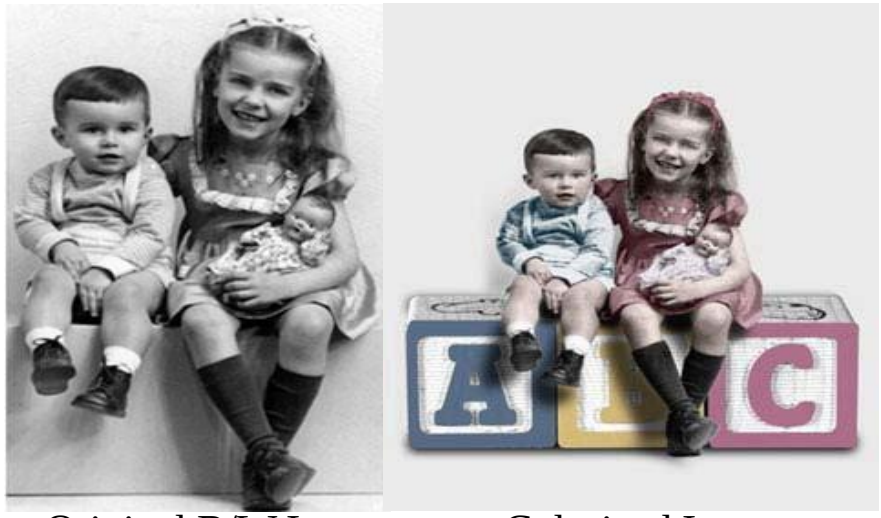


Damaged Image

Restored Image

Image Processing Examples

Photo Colorization



Original B/W Image Colorized Image

Original Image Colorized Image

Image Processing Examples

Color Photo Enhancement




Original Images

Enhanced Images

Image Processing Examples

Image Enhancement

Initial image

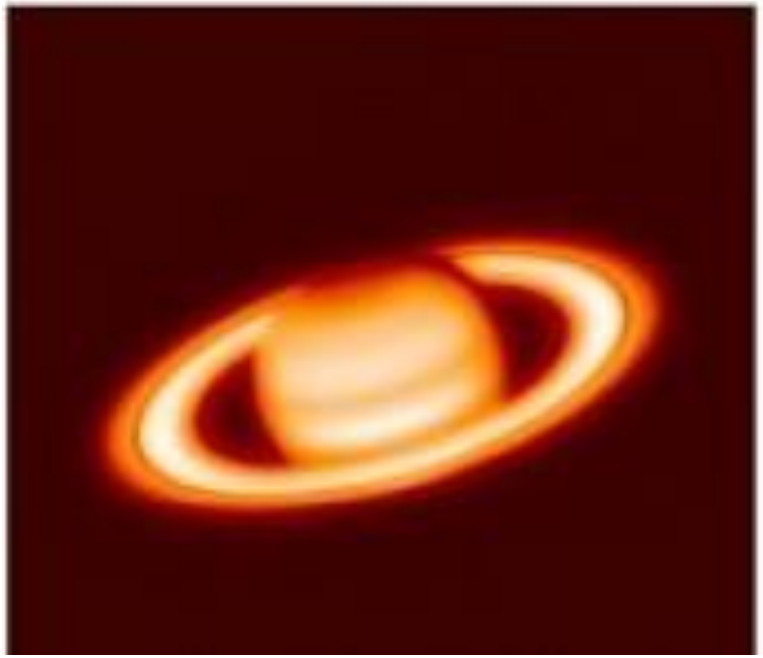
Final image

Performed steps: Gaussian blur, contrast enhancement, median filter and sharpening. Processing made by Photoshop.

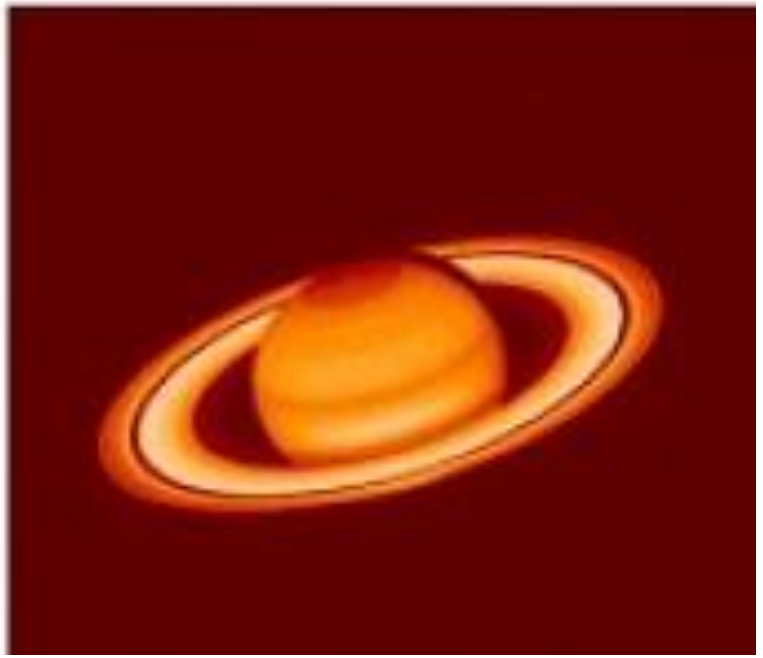
Example taken from microscopy.berkeley.edu/courses/dib

Image Processing Examples

Restoration of Image from Hubble Space Telescope



Faulty image of Saturn



Recovered image

Image Processing Examples

Extraction of settlement area from an Aerial Image

Image Processing Examples

Earthquake analysis from space

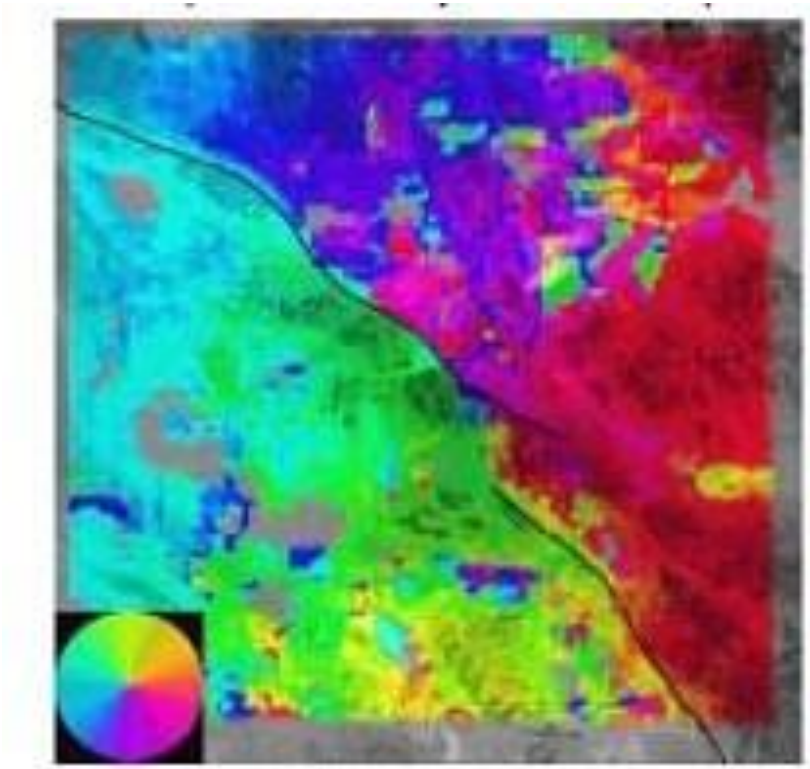


Image shows the ground displacement of a typical area due to earthquake

Image Processing Examples

Medical Imaging: Computer Tomography (CT)

- Generating 3-D images from 2-D slices.
- CAD, CAM applications
- Industrial inspections

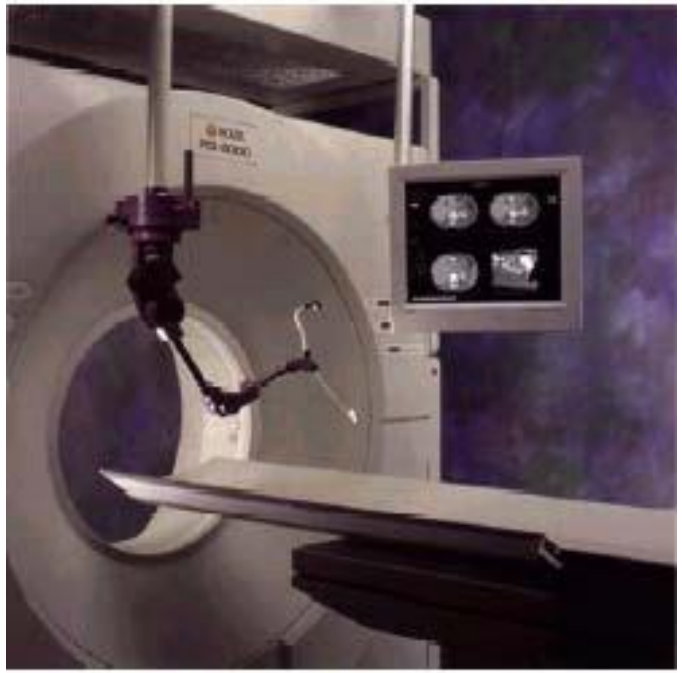
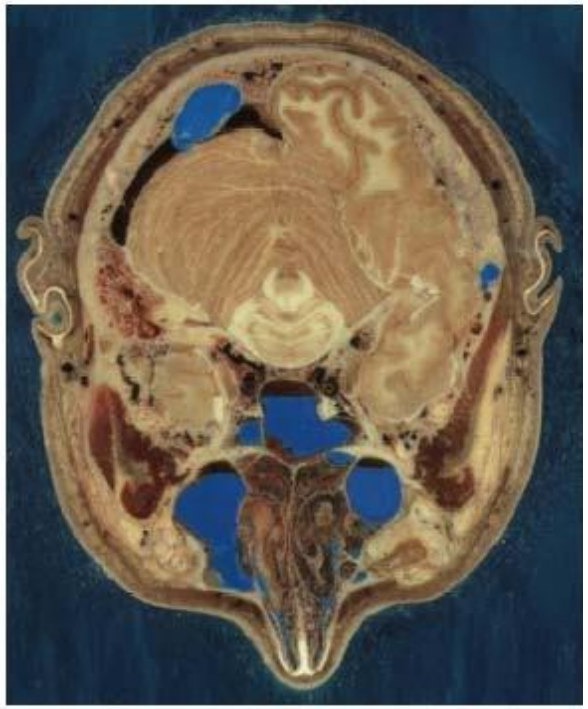


Image Processing Examples

Medical Imaging: Computer Aided Tomography (CAT)



[545x700 24-bit color JPEG, 69069 bytes]
Section through Visible Human Male – head, including cerebellum, cerebral cortex, brainstem, nasal passages.

Image Processing Examples

Medical Imaging: Ultrasound Imaging

- Profile of a fetus at four months. This face is approximately 1 inches (4cm) long.

Image Processing Examples

Medical Imaging: Averaging MRI slices for knee image

Image Processing Examples

Image Compression

Original

JPEG 27:1 Compression ratio

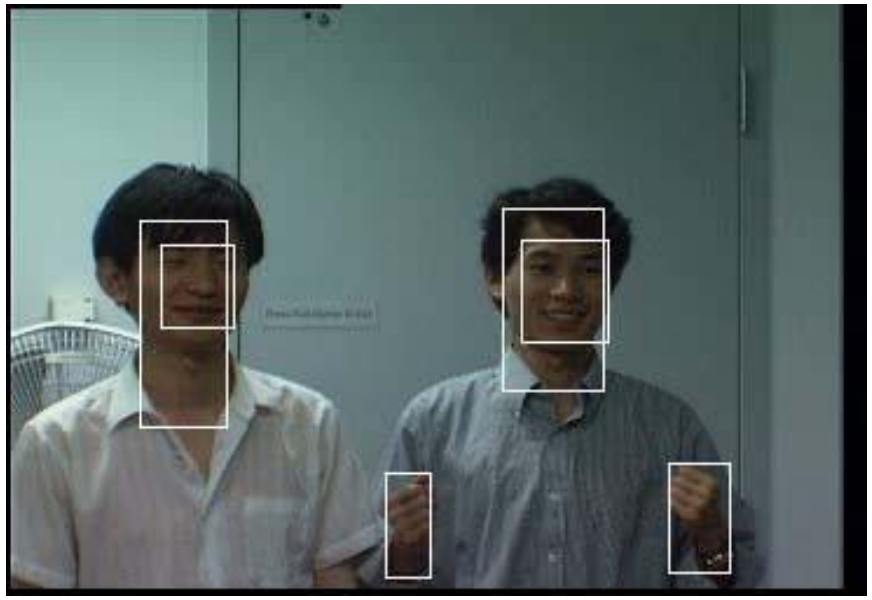
Image Processing Examples

Face Detection

Image Processing Examples

Face Tracking

Gesture Recognition



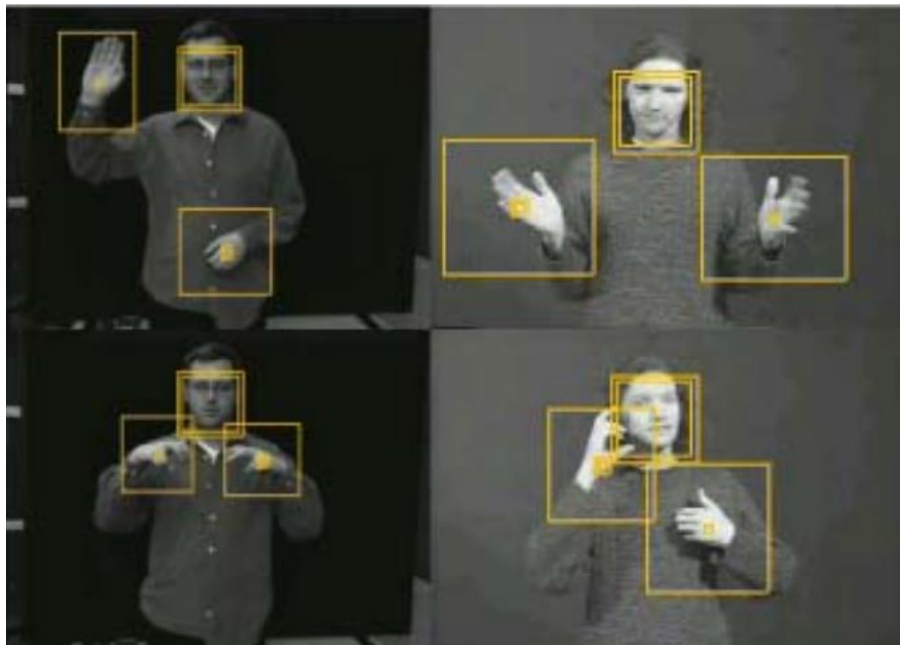


Image Processing Examples

Face Morphing

Image Processing Examples

Fingerprint Recognition

X

X

√

Image Processing Examples

Personal Identification using Iris Recognition

National Geographics: “Afghan Girl”

Image Processing Examples

Removing geometric distortions of camera

Applications of DIP

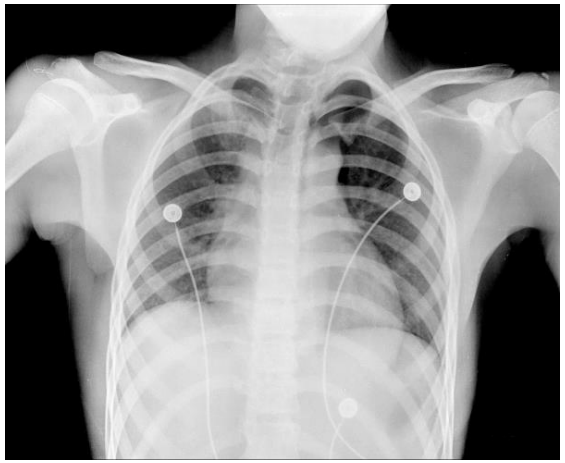
Categorization according to image sources

- **Electromagnetic (EM) band Imaging**
  - Gamma ray images
  - x-ray band images
  - ultra-violet band images
  - visual light and infra-red images
  - Imaging based on micro-waves and radio waves
- **Non-EM band Imaging**
  - Acoustic and ultrasonic images
  - Electron Microscopy
  - Computer-generated synthetic images

Applications of DIP

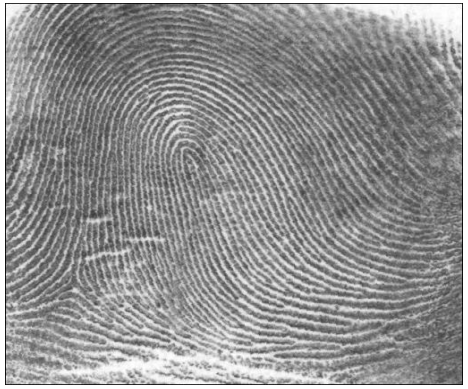
EM band imaging

- **Gamma-ray imaging**
  - Nuclear medicine, astronomical observations.
- **X-ray Imaging**
  - Medical diagnostics (CAT scans, x-ray scans), industry, astronomy.
- **Ultra-violet imaging**
  - Fluorescence microscopy, astronomy,
- **Visible & Infrared-band imaging (most widely used)**
  - Light microscopy, astronomy, remote sensing, industry, law enforcement, military recognizance, etc.
- **Micro-wave and radio band imagery**
  - Radar, Medicine (MRI), astronomy



X-ray imaging

gamma-ray imaging



Visible spectrum
Security, Biometrics

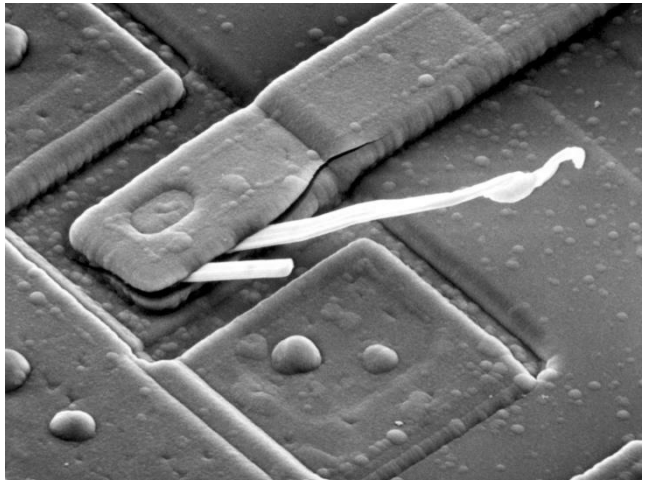
Applications of DIP

Non-EM band imaging

- **Acoustic imaging (hundreds of Hz)**
  - Geological exploration (oil exploration)
- **Ultrasound imaging (millions of Hz)**
  - Industry and medicine especially in obstetrics, determine the health of the fetal development
- **Electron microscopic imaging**
  - Used to achieve magnification of 10,000x or more

    (Light microscopy is limited to around 1000x)
- **Synthetic imaging**
  - 3D modeling or visualization systems for flight simulators, machine design, special effects and animations, etc.

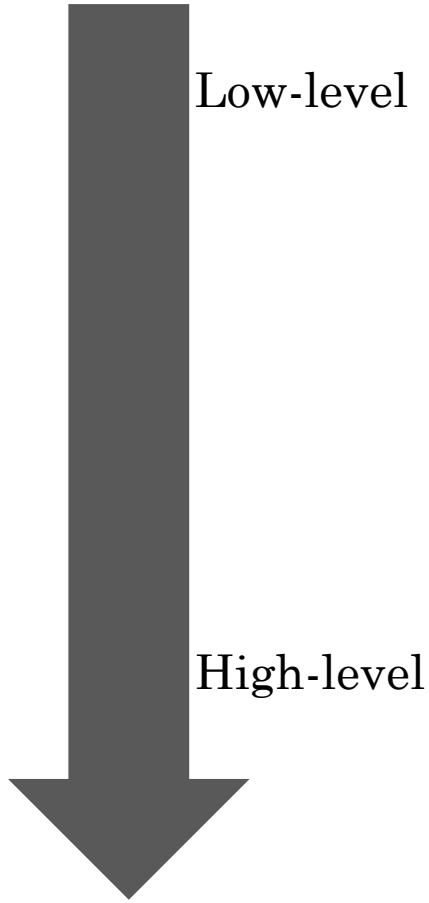
Ultrasound image of a fetus.



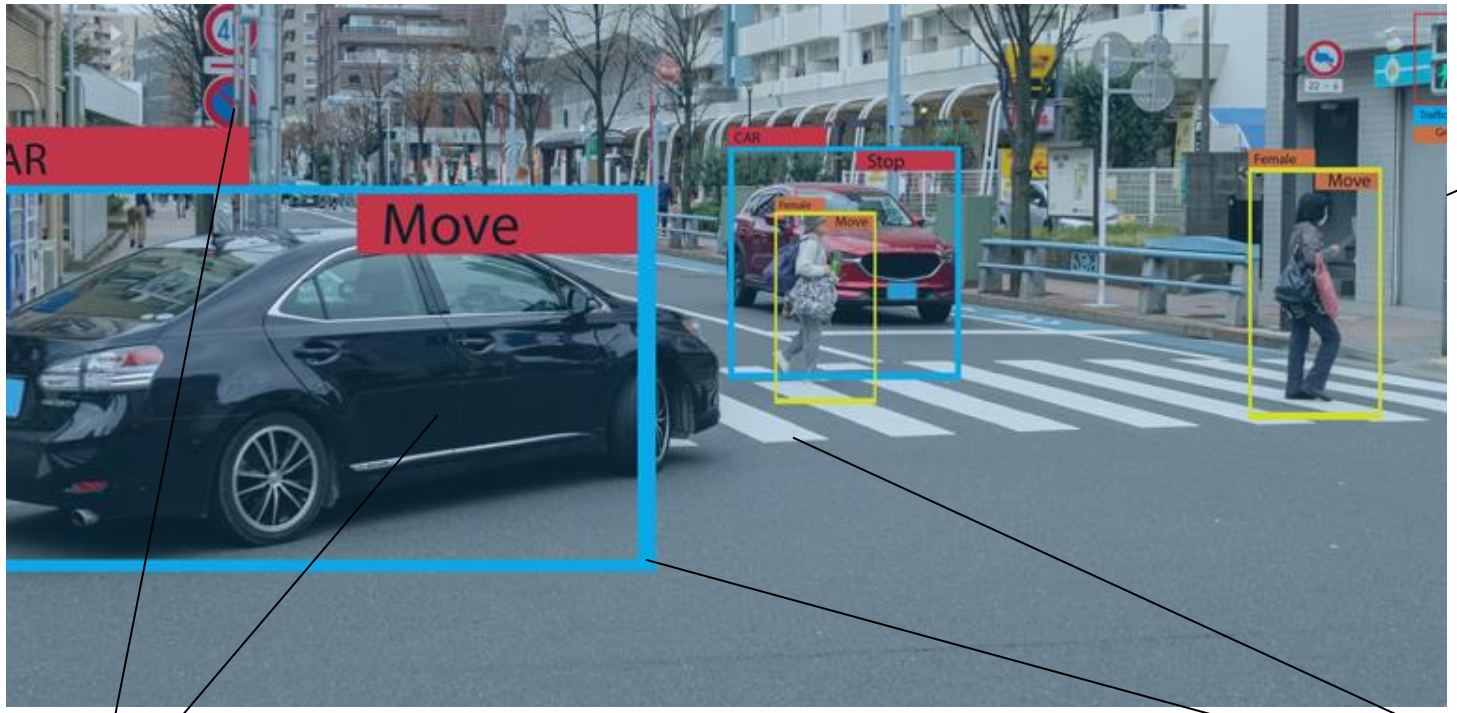
2500 × SEM image of a damaged integrated circuit.

Classification of DIP and Computer Vision Processes

- **Low-level process: (DIP)**
  - Primitive operations where inputs and outputs are images Major functions: image pre-processing like noise reduction, contrast enhancement, image sharpening, etc.
- **Mid-level process (DIP and Computer Vision and Pattern Recognition)**
  - Inputs are images, outputs are attributes (e.g., edges) major functions: segmentation, description, classification / recognition of objects
- **High-level process (Computer Vision)**
  - make sense of an ensemble of recognized objects; perform the cognitive functions normally associated with vision



Classification of DIP and Computer Vision Processes



Low-level process DIP

- Noise reduction
- Contrast enhancement

High-level process CV

- Cognitive decision-making, pedestrian crossing detected, vehicle slows down.
- Lane recognition: Vehicle stays in correct lane
- Traffic sign recognition: Stop Command.

Mid-level process DIP and CV

- Edge Detection
- Segmentation and recognition of objects (e.g., Car, Pedestrian, Stop Sign).

Image Processing Computer Vision and Pattern Recognition

Digital Image Processing

- Image acquisition by sensor
- Image sampling and quantization

Image enhancement and restoration

- Filtering in spatial domain or frequency domain

Feature Extraction

- Edge detection
- Interest points

Colored image Processing

- Pseudo coloring
- Color segmentation

Multi-resolution analysis

- Pyramids
- Wavelets
- Other transformations

Image and video compression

- Image compression standards
- Video compression standards

Computer Vision

Image Geometrical Rectification

- Camera geometry

Feature Extraction

- Edge and Interest points detection
- Texture and shading
- Shape from texture and shading

Calculation on Multiple Views

- Multi-view geometry and Stereo imaging
- Structure from motion

Segmentation

- Impose some order on group of pixels to separate them from each other

Template matching

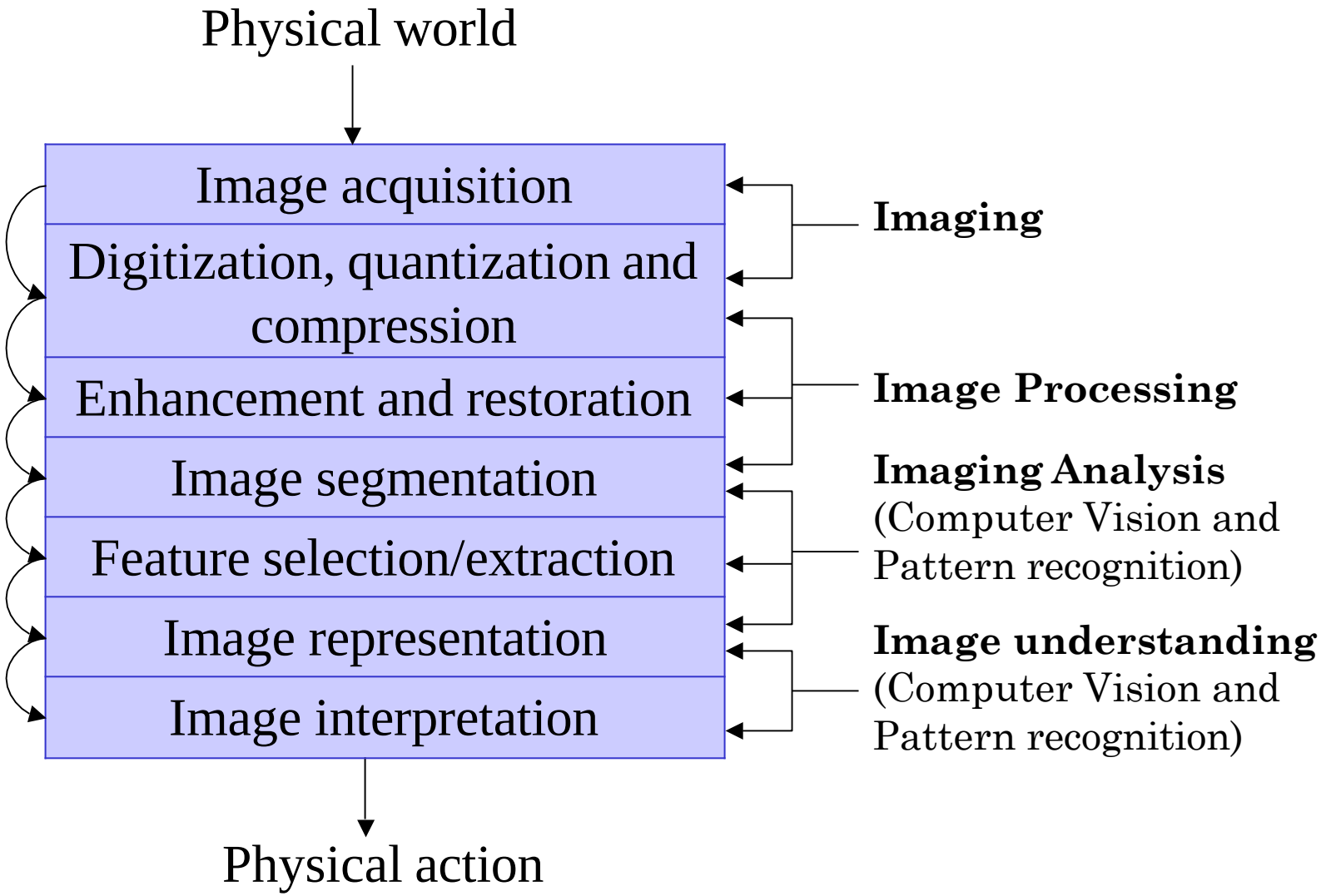
Pattern Recognition

Segmentation

Classification and Recognition

- Classification and interpretation of objects based on selected features
- Recognize objects using probabilistic techniques

Image Processing Steps



Scope of DIP Course

- **Digital image fundamentals and image acquisition (briefly)**
- **Image enhancement in spatial domain**
  - pixel operations
  - Histogram processing
  - Filtering
- **Image enhancement in frequency domain**
  - Transformation and reverse transformation
  - Frequency domain filters
  - Homomorphic filtering
- **Image sampling**
- **Image restoration**
  - Noise reduction techniques
  - Geometric transformations

Scope of DIP Course

- **Color image processing**
  - Color models
  - Pseudocolor image processing
  - Color transformations and color segmentation
- **Wavelets and multi-resolution processing**
  - Multi-resolution expansion
  - Wavelet transforms, etc.
- **Image compression**
  - Image compression models
  - Error free compression
  - Lossy compression, etc.

Scope of DIP Course

- **Image segmentation**
  - Edge, point and boundary detection
  - Thresholding
  - Region based segmentation, etc.
- **Morphological image processing**
  - Dilation and erosion
  - Opening closing
  - Hit or miss transformation
  - Basic morphological algorithms

Thank You