Selected topics in Computer Vision

CS3243 Foundations of Artificial Intelligence

(Textbook section 24.2, 24.3, 24.5, 24.6)

Slides due to Huang Weihua

Outline

- Image formation
- Low-level Vision
  - Smoothing
  - Edge detection
- High-level Vision
  - Object recognition
    - Brightness-based approach
    - Feature-based approach
- Application of Computer Vision
  - Manipulation
  - Navigation

Image Formation

- In computer vision, an **image** is a two-dimensional grid of **pixels**.

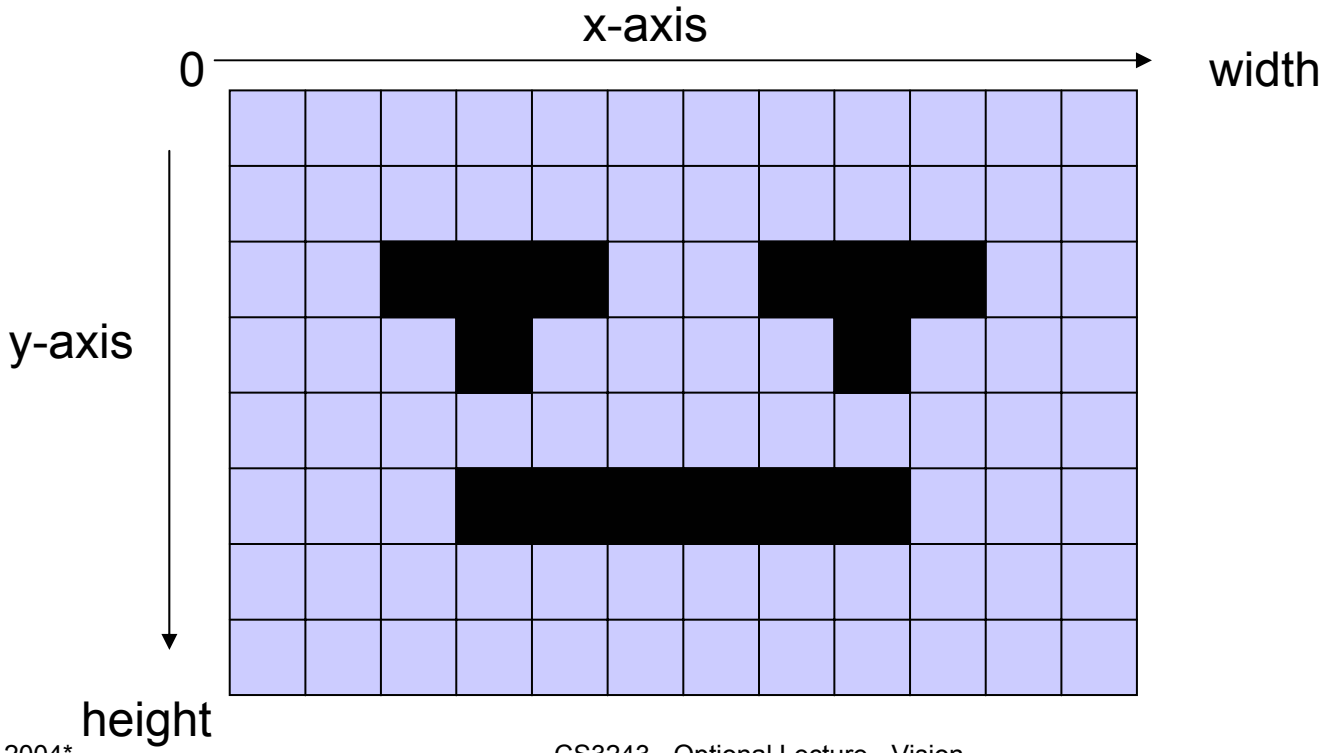


Image Formation

- Perspective projection: a process of projecting an object in a **scene** on an image plane.

$-x/f = X/Z, -y/f = Y/Z \Rightarrow x = -fX/Z, y = -fY/Z$

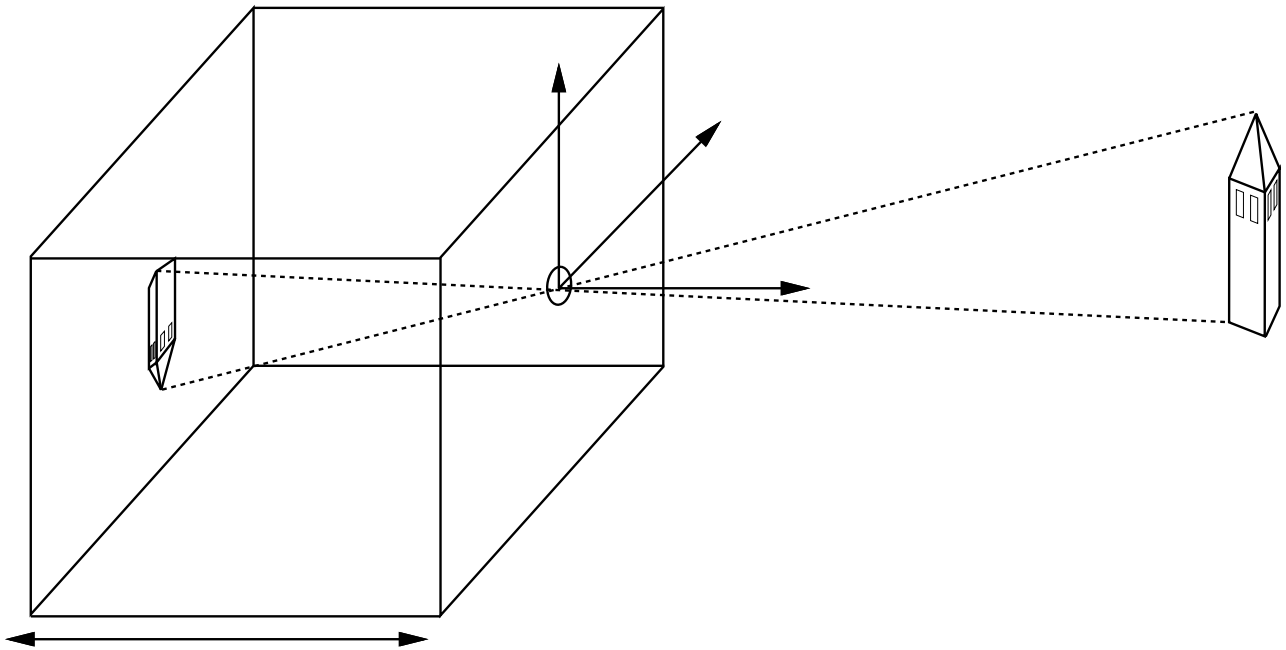
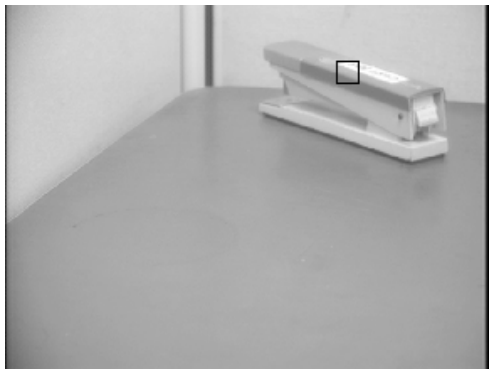


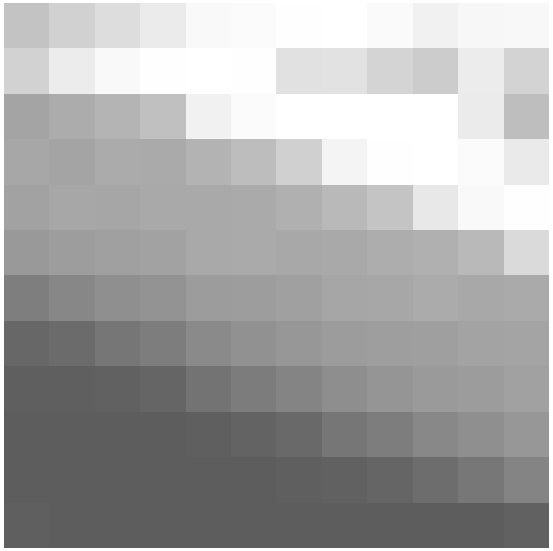
Image Formation

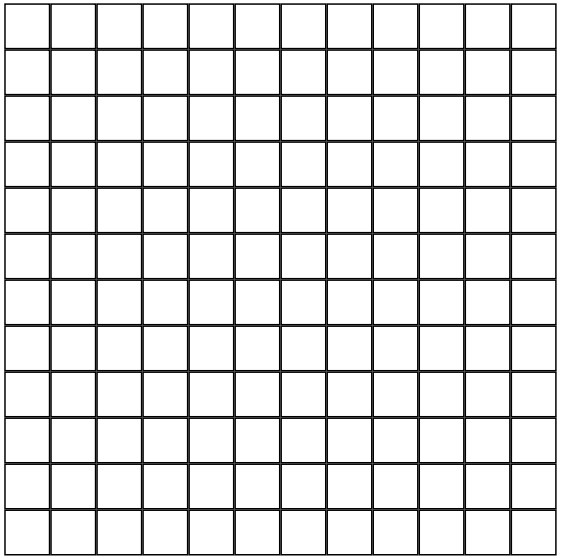
- Visible light comes in a range of wavelengths: 400 nm (the violet end) to 700 nm (the red end).

- Discrete representation:
  - Black and white (1 bit)
  - Grayscale: 0-255 brightness (1 byte)
  - RGB combination: each from 0-255 (3 bytes)

Image Formation







Low-level Vision

- **Smoothing**: removing extreme values from the image.
- **Gaussian filter**: replacing the original pixel $I(x_0, y_0)$ by summation of $I(x, y)G_\sigma(d)$ over all pixels, where:

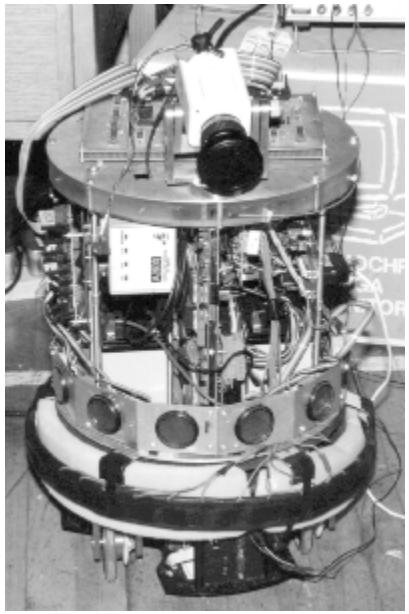
$$G(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{x^2}{2\sigma^2}}$$, in one dimension.

$$G(x,y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}}$$, in two dimensions.

And d is the distance between pixel (x, y) and (x_0, y_0)

- **Convolution:** h = f * g (Weighted sum)

Low-level Vision



Original Image

σ = 2.0

σ = 4.0

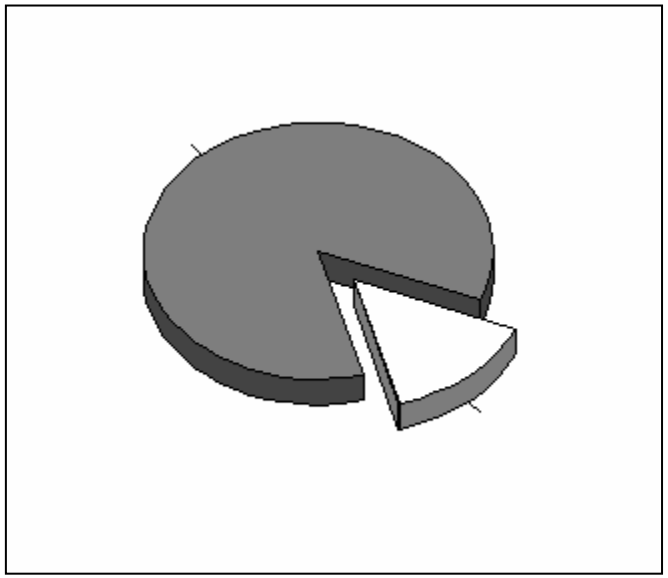
Low-level Vision

- **Edge detection**: finding lines and curves in the image plane that have significant change in brightness.

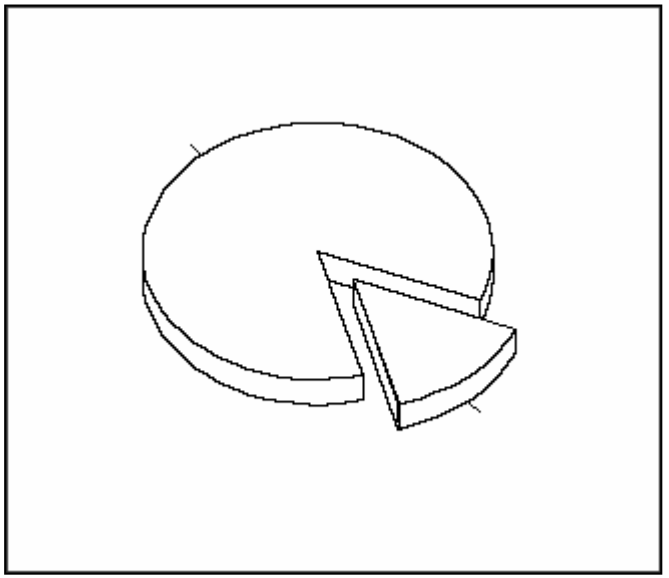
- Theorem: (f * g)’ = f * g’

- **Canny edge detection**: combining the Gaussian smoothing process and edge detection process.

Low-level Vision



Original Image



Edges extracted

Low-level Vision

- After edge detection, we can segment the edges into visual groups that are single objects or parts of an object.

- **Segmentation** is based on similarities of certain visual properties, such as:
  - Brightness
  - Color
  - Texture
  - Gradient

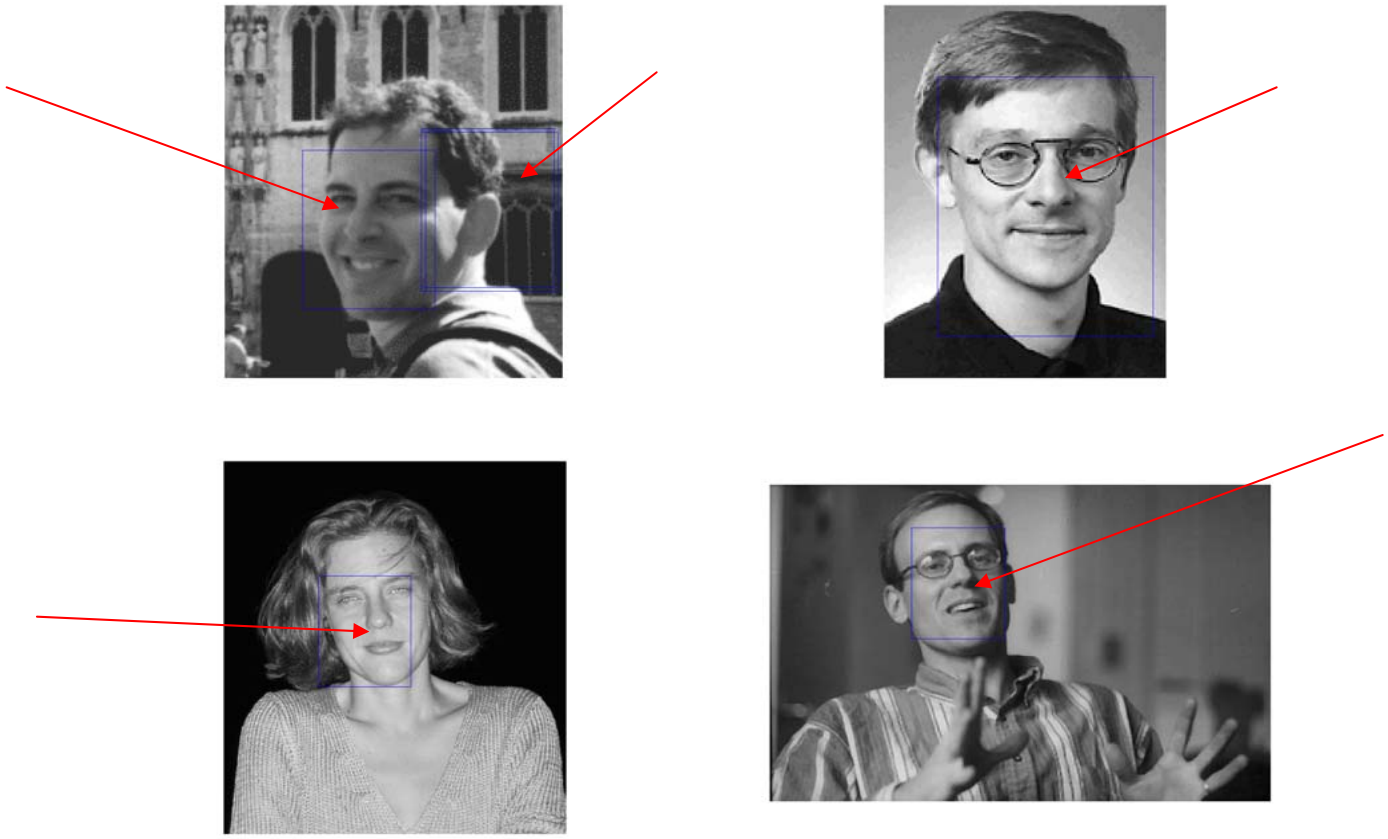
High-level Vision

- **Object recognition**
  - Applications: Biometric identification, content-based image retrieval, handwriting recognition, etc.
  - Approaches: brightness-based recognition and feature-based recognition.

High-level Vision

- **Brightness-based** recognition
  - Basic feature: the brightness of pixels.
  - Statistical approach to detect certain objects, such as faces and cars.
  - Disadvantage: great redundancy inherent in the representation.

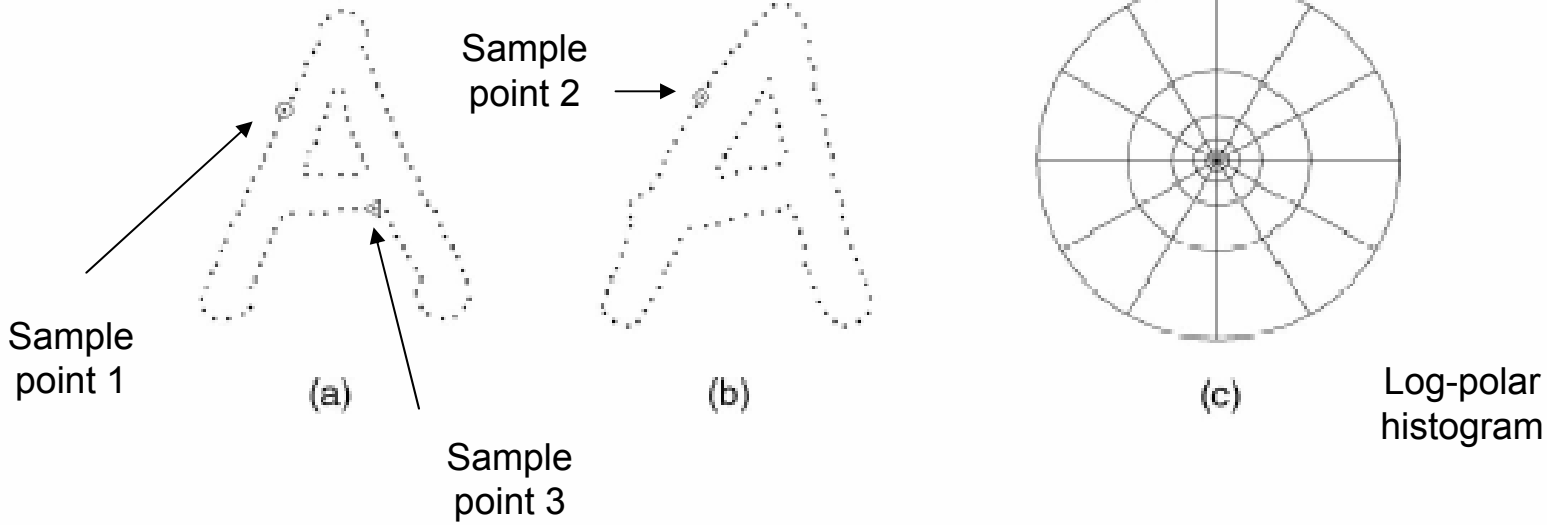
High-level Vision

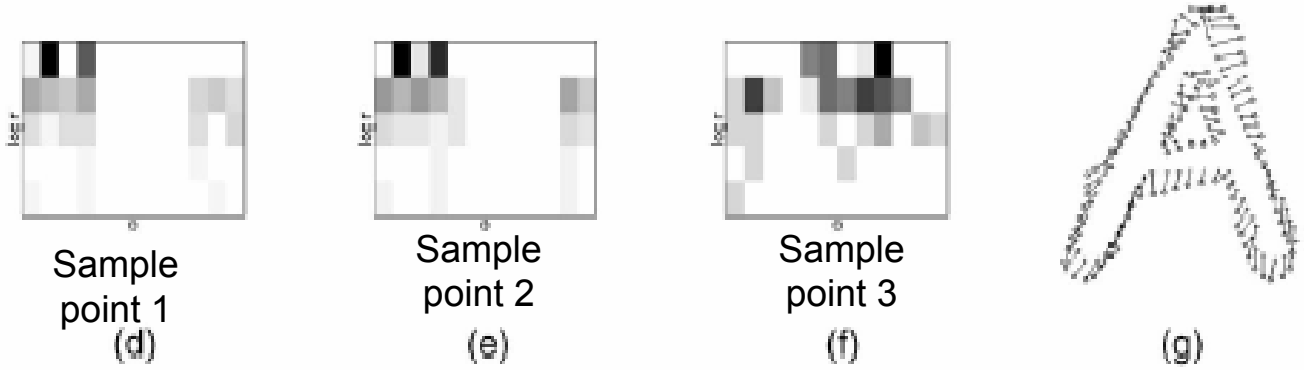


High-level Vision

- **Feature-based** recognition
  - Basic feature: regions and edges
  - Classification approach: finding configuration of edges corresponding to views of object.
  - Deformable matching: using simple coordinate transformations.
  - Shape context: arrangement of shapes.

High-level Vision



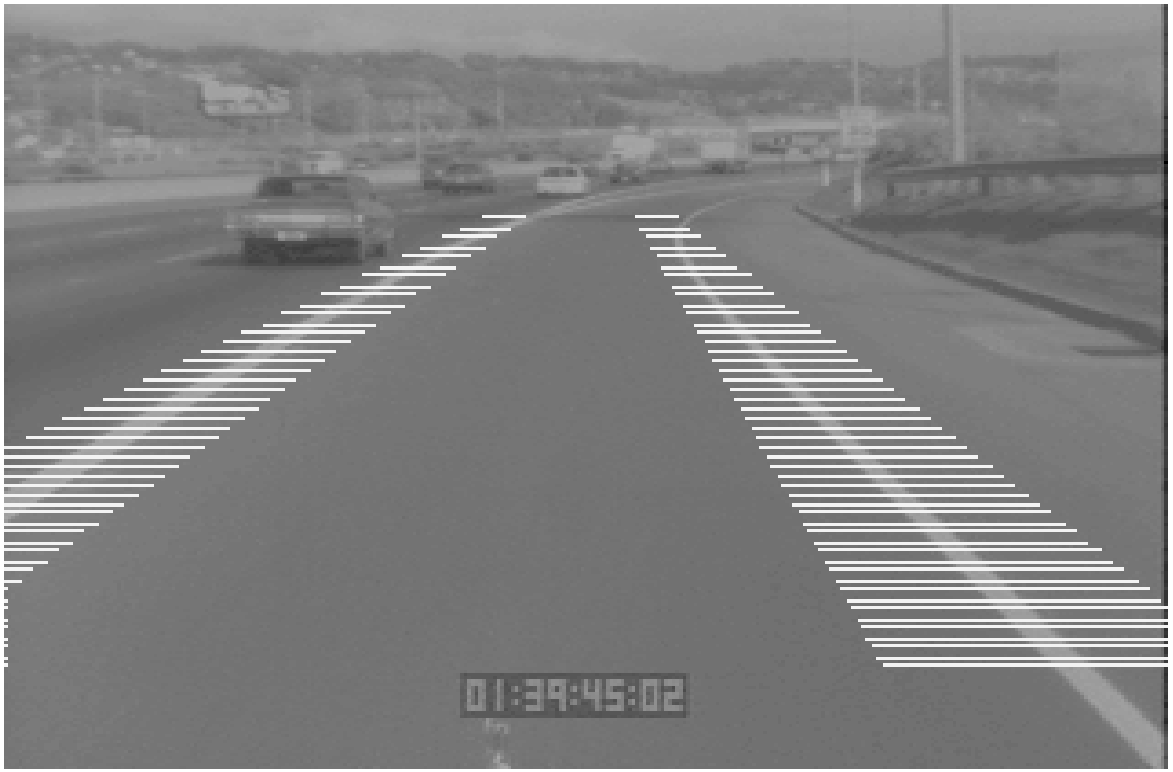


Application of Computer Vision

- Manipulation
  - Direct processing on the objects.
  - Example: manipulating engineering drawings.

- Navigation
  - Moving without colliding with obstacles.
  - Example: navigation system for an auto-driving vehicle.

Application of Computer Vision



For more information

- You can learn more from the following modules:
  - CS3241 Computer Graphics.
  - CS4243 Computer Vision and Pattern Recognition.

(END)