CPE 428 Computer Vision: Basics

- Geometry of image formation
- Imaging devices
- Digital image representation
- Effects of sampling and quantization
- Digital image types

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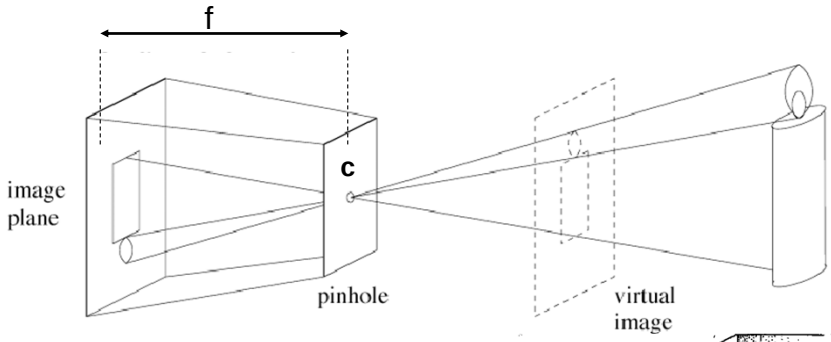
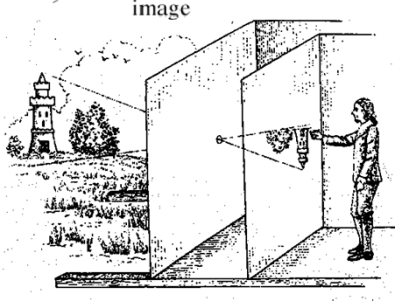
Pinhole Camera

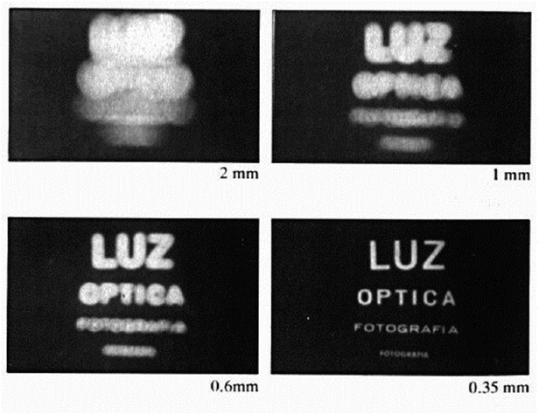


f = focal length
c = center of the camera
(pinhole, aperture)



The pinhole camera used by Renaissance painters to understand perspective projection

Shrinking the Aperture



Why not make the aperture as small as possible?

- Less light gets through
- Diffraction effects

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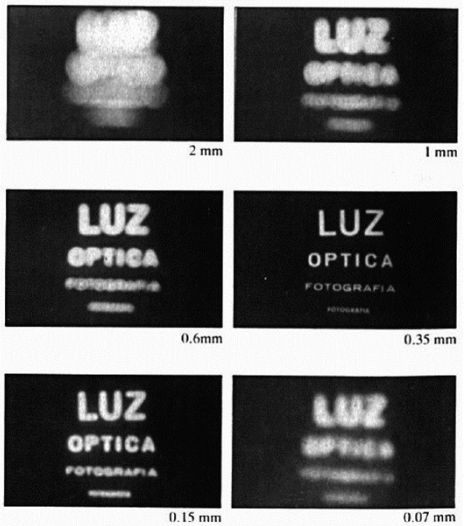
Shrinking the Aperture



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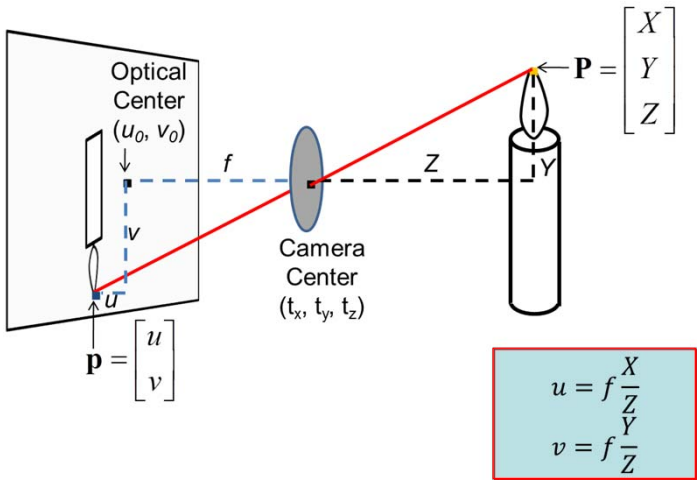
Projection: World Coordinates → Image Coordinates



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Examples

1. Assume the focal length of a pinhole camera is 5 mm. A scene point is located at (X,Y,Z)= (1m, 2m, 5m). What are the image plane coordinates (u,v) of its projection?

2. Assume the focal length of a pinhole camera is 40 mm. If the projection of a 160 cm tall car is 2 mm tall, how far is the car away from the camera?

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Perspective Projection
- Distant objects are smaller

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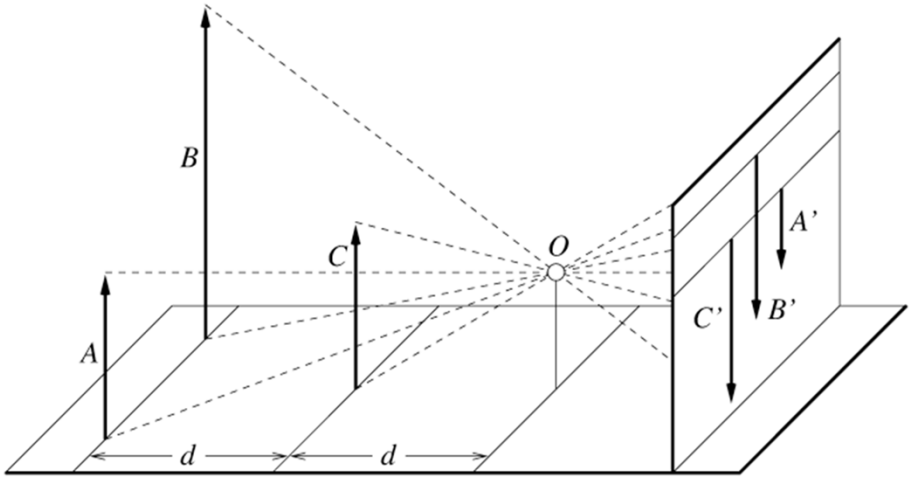
Perspective Projection
– Length is Not Preserved



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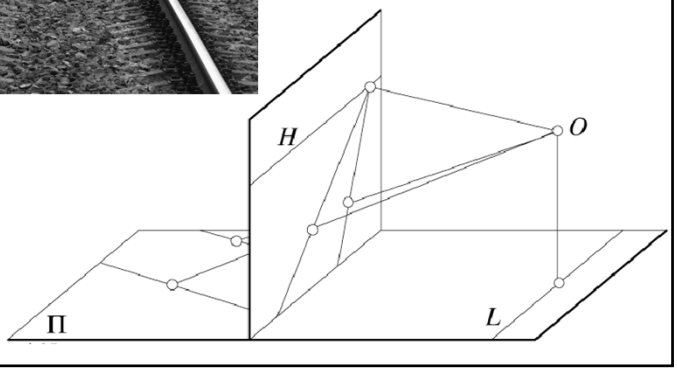
Perspective Projection - Parallel lines meet

Parallel lines converge at a vanishing point



Digital Camera

- A digital camera replaces film with a sensor array
  - Each cell in the array is light-sensitive diode that converts photons to electrons
  - Two common types
    - **Charge Coupled Device** (CCD)
    - **Complementary metal oxide semiconductor** (CMOS)

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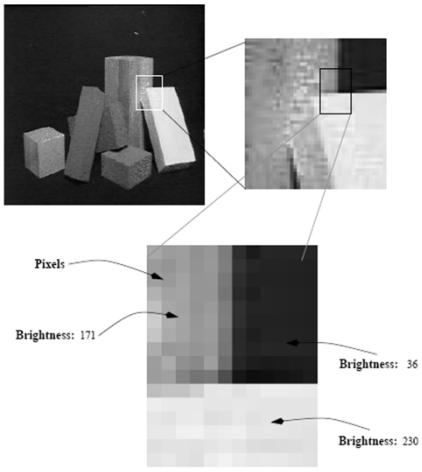
Digital Images



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Mathematical Representation of Digital Images

- Digital images are 2D arrays (matrices) of numbers
- Depending on the type, the numbers represent:
  - light intensities,
  - distances, or
  - other physical quantities.

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Mathematical Representation of Digital Images

- An **image** is a two-dimensional function, $f(x,y)$, where x and y are spatial coordinates, and the amplitude of f is the intensity of the image at that point.
- When x, y, and the amplitude value of f are all finite, discrete quantities, we call the image a **digital image**.
- Each element of the 2D array of samples is called a **pixel** or pel ("picture element").

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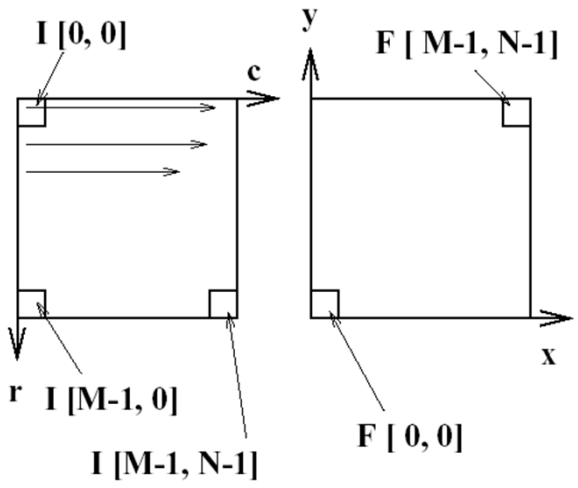
Coordinate systems



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Coordinate systems

- Raster coordinate system
  - Derives from printing an array on a line printer
  - Origin (0,0) is at upper left
  - Row (r) increases downward; Column (c) increase to right
- Cartesian coordinate system
  - Typical system used in mathematics
  - Origin (0,0) is at lower left
  - x increases to the right; y increases upward

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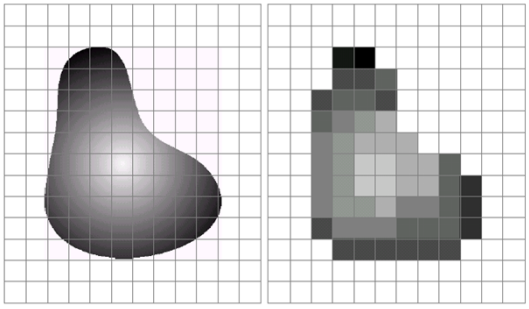
Sampling and Quantization



a b

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

Sampling: digitizing spatial coordinate values
Quantization: digitizing the amplitude values

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Effects of Sampling

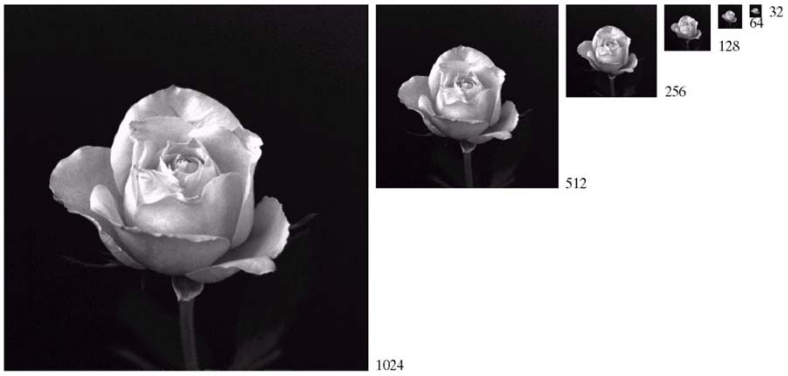

FIGURE 2.19 A 1024 × 1024, 8-bit image subsampled down to size 32 × 32 pixels. The number of allowable gray levels was kept at 256.

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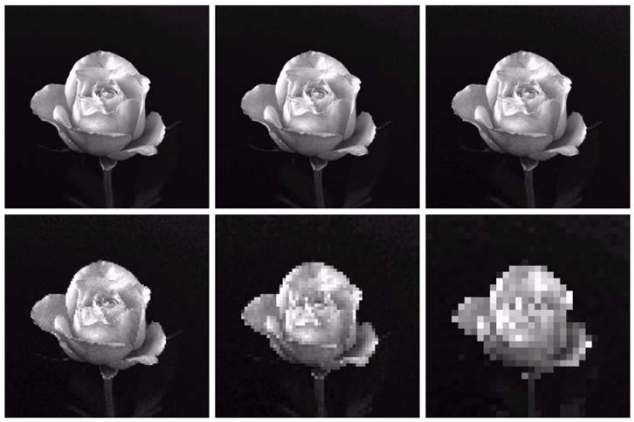
Effects of Sampling



a b c
d e f

FIGURE 2.20 (a) 1024 × 1024, 8-bit image. (b) 512 × 512 image resampled into 1024 × 1024 pixels by row and column duplication. (c) through (f) 256 × 256, 128 × 128, 64 × 64, and 32 × 32 images resampled into 1024 × 1024 pixels.

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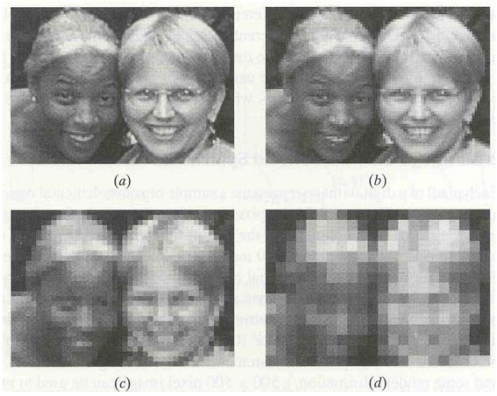
Resolution Examples



- Resolution decreases by one half in cases at left
- Human faces can be recognized at 64 x 64 pixels per face

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Effects of Quantization

From 8-bit (256 gray levels) to 1-bit (2 gray levels)

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Type of Digital Images

Digital image - a discrete array I[r,c], f(x,y) with limited precision (rows, columns, max I)

- A **gray-scale image** is a monochrome image with one intensity value per pixel.
- A **binary image** is a digital image with all pixels values 0 or 1.
- A **multispectral image** is a digital image that has a vector of values at each pixel. e.g. (R,G,B)
- A **labeled image** is a digital image whose pixel is a *symbol* denoting the outcome of a decision, e.g. grass vs. sky vs. house

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