

# Image Processing

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(covering for Finkelstein 9/18)  
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## Overview

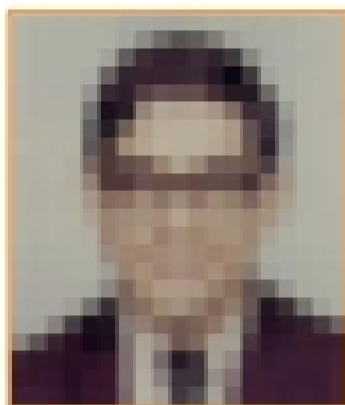
- Image representation
  - What is an image?
- Halftoning and dithering
  - Trade spatial resolution for intensity resolution
  - Reduce visual artifacts due to quantization
- Sampling and reconstruction
  - Key steps in image processing
  - Avoid visual artifacts due to aliasing

## What is an Image?

- An image is a 2D rectilinear array of pixels



Continuous image



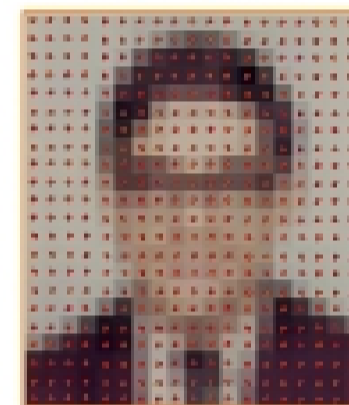
Digital image

## What is an Image?

- An image is a 2D rectilinear array of pixels



Continuous image



Digital image

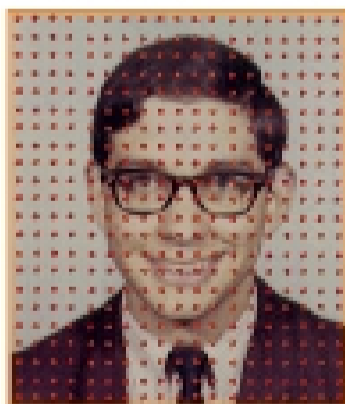
A pixel is a sample, not a little square!

## What is an Image?

- An image is a 2D rectilinear array of pixels



Continuous image

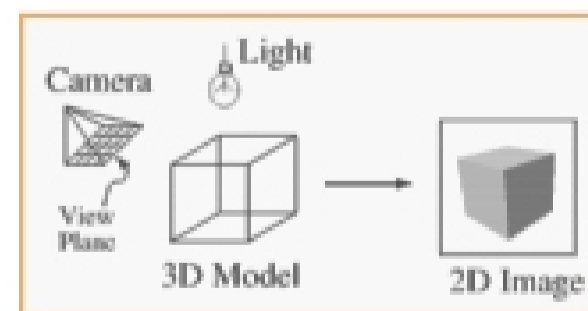


Digital image

A pixel is a sample, not a little square!

## Image Acquisition

- Pixels are samples from continuous function
  - Photoreceptors in eye
  - CCD cells in digital camera
  - Rays in virtual camera



## Image Display

7

- Re-create continuous function from samples
  - Example: cathode ray tube

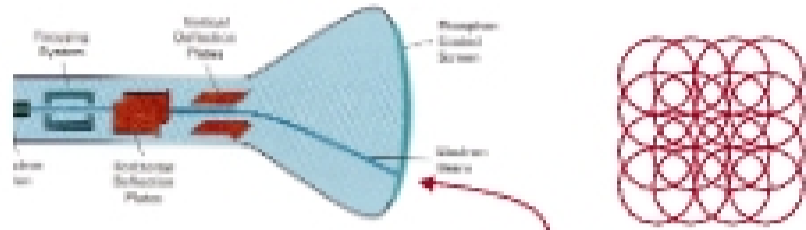


Image is reconstructed by displaying pixels with finite area (Gaussian)

## Image Resolution

8

- Intensity resolution
  - Each pixel has only "Depth" bits for colors/intensities
- Spatial resolution
  - Image has only "Width" x "Height" pixels
- Temporal resolution
  - Monitor refreshes images at only "Rate" Hz

Typical Resolutions	Width x Height	Depth	Rate
NTSC	640 x 480	8	30
Workstation	1280 x 1024	24	75
Film	3000 x 2000	12	24
Laser Printer	6600 x 5100	1	-

## Sources of Error

9

- Intensity quantization
  - Not enough intensity resolution
- Spatial aliasing
  - Not enough spatial resolution
- Temporal aliasing
  - Not enough temporal resolution

$$E^2 = \sum_{(x,y)} (I(x,y) - P(x,y))^2$$

## Overview

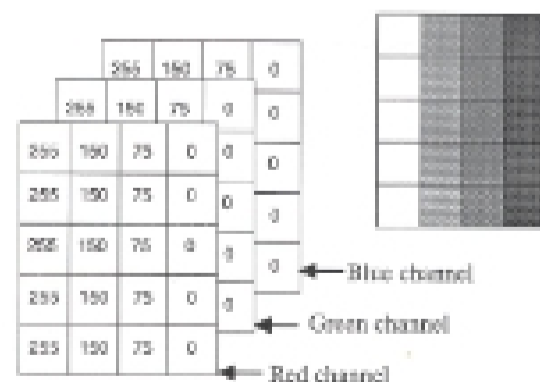
10

- Image representation
  - What is an image?
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  - Reduce visual artifacts due to quantization
- Sampling and reconstruction
  - Reduce visual artifacts due to aliasing

## Quantization

11

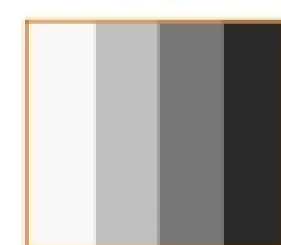
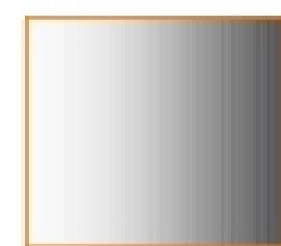
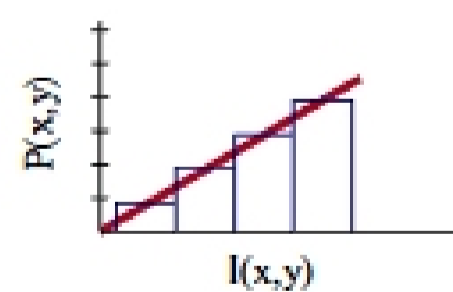
- Artifacts due to limited intensity resolution
  - Frame buffers have limited number of bits per pixel
  - Physical devices have limited dynamic range



## Uniform Quantization

12

$$P(x, y) = \text{trunc}(I(x, y) + 0.5)$$



(4 bits per pixel)

## Uniform Quantization

13

- Images with decreasing bits per pixel:



8 bits

4 bits

2 bits

1 bit

Notice contouring

## Reducing Effects of Quantization

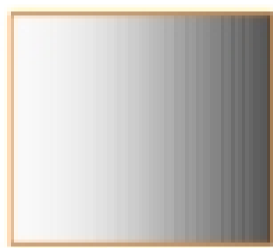
14

- Halftoning
  - Classical halftoning
- Dithering
  - Random dither
  - Ordered dither
  - Error diffusion dither

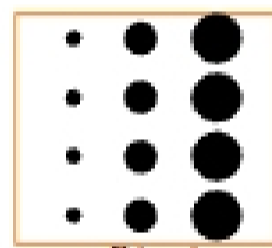
## Classical Halftoning

15

- Use dots of varying size to represent intensities
  - Area of dots proportional to intensity in image



$I(x,y)$



$P(x,y)$

## Classical Halftoning

16



Newspaper Image

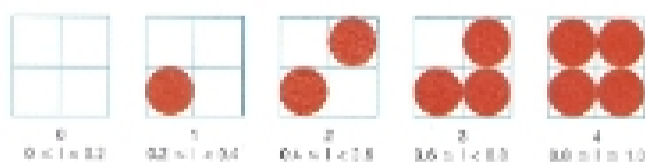


From New York Times, 9/21/99

## Halftone patterns

17

- Use cluster of pixels to represent intensity
  - Trade spatial resolution for intensity resolution



0

1

2

3

4

$0 \leq I < 0.25$

$0.25 \leq I < 0.5$

$0.5 \leq I < 0.75$

$0.75 \leq I < 1.0$

$1.0 \leq I < 1.25$

Figure 14.37 from H&B

## Dithering

18

- Distribute errors among pixels
  - Exploit spatial integration in our eye
  - Display greater range of perceptible intensities



Original  
(8 bits)



Uniform  
Quantization  
(1 bit)



Floyd-Steinberg  
Dither  
(1 bit)