קורס גרפיקה ממוחשבת

2009 סמסטר ב'

Image Processing II

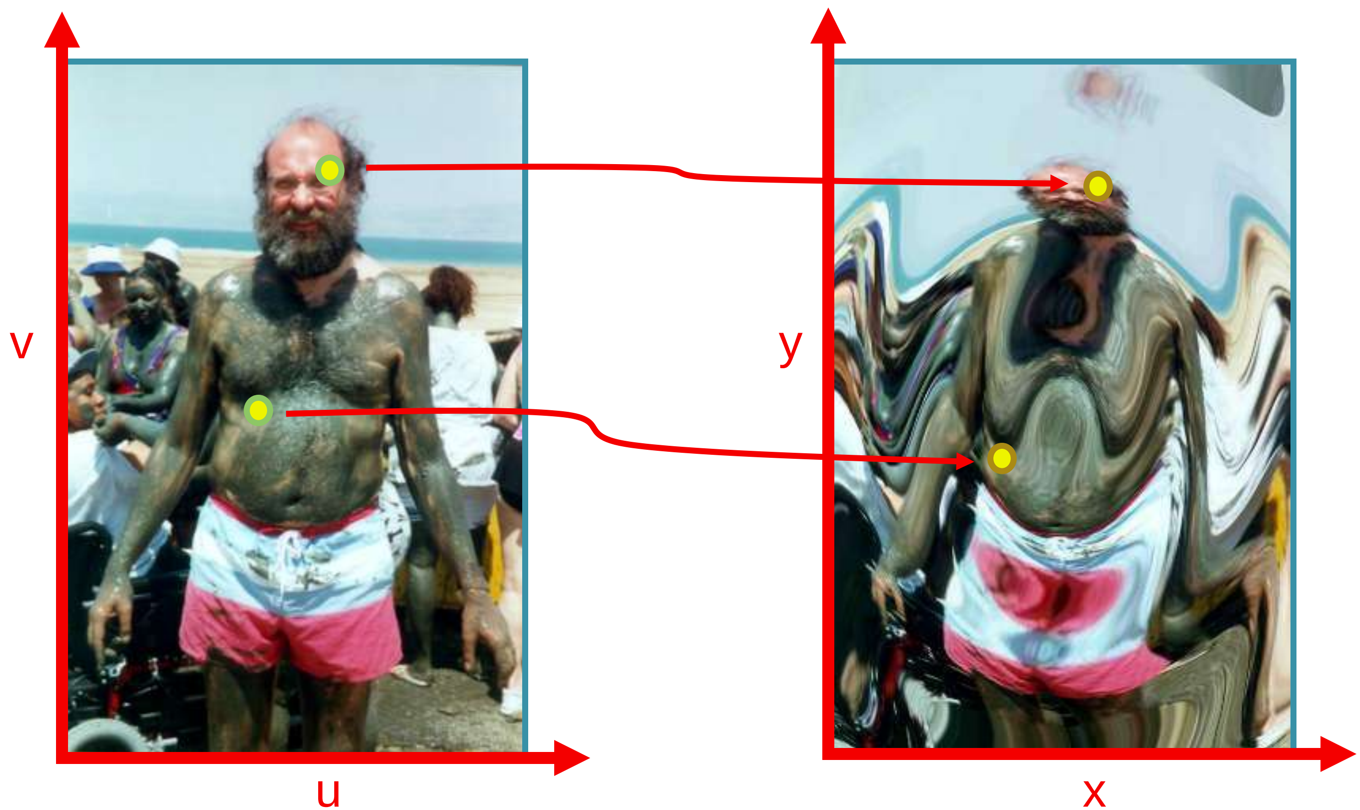
חלק מהשקפים מעובדים משקפים של פרדו דוראנד, טומס פנקהאוסר ודניאל כהן-אור

Agenda

- Warping to Mapping
- Quantization

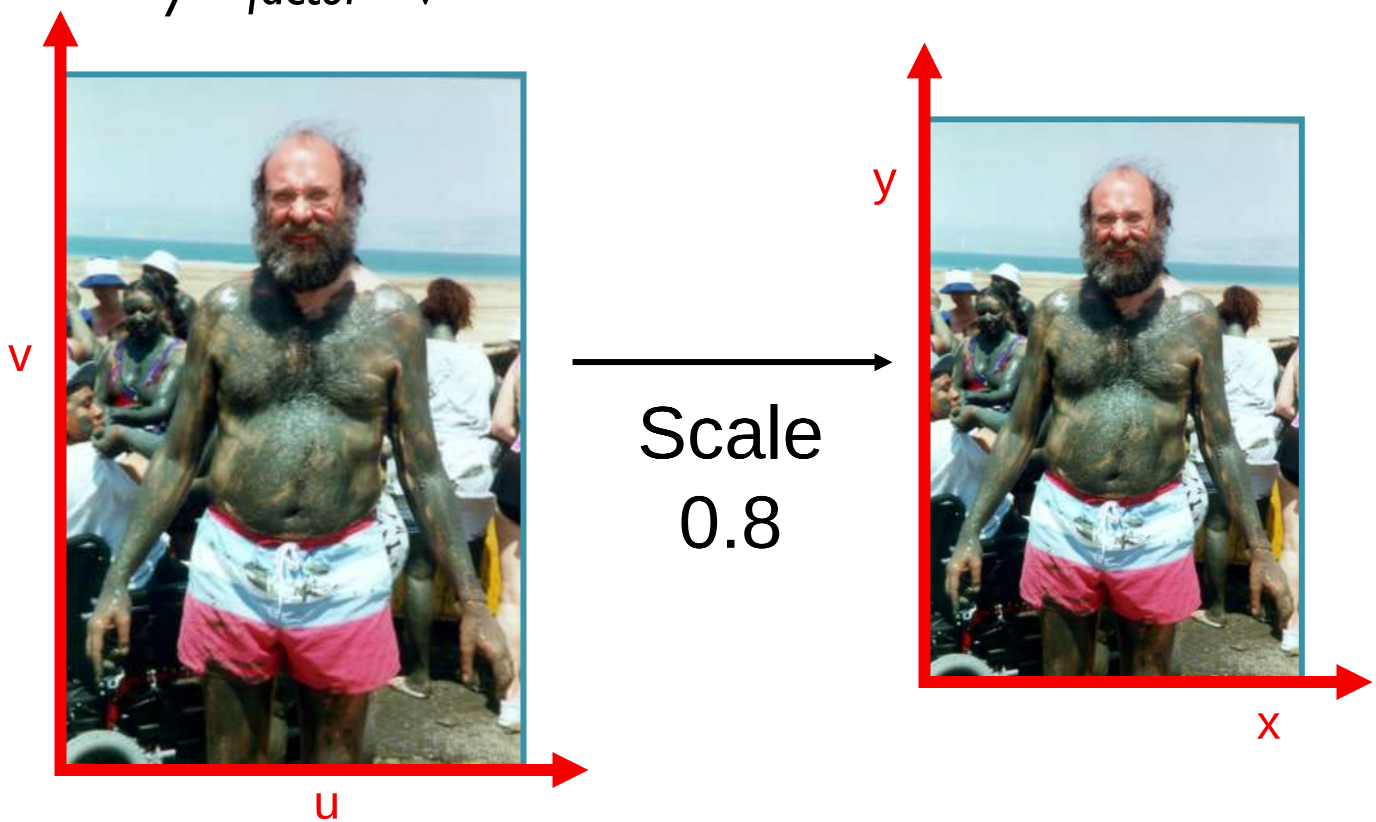
Mapping

- Last time we started to discuss warping and mapping
- In general, we define a transformation
  - Destination (x,y) for every source (u,v)



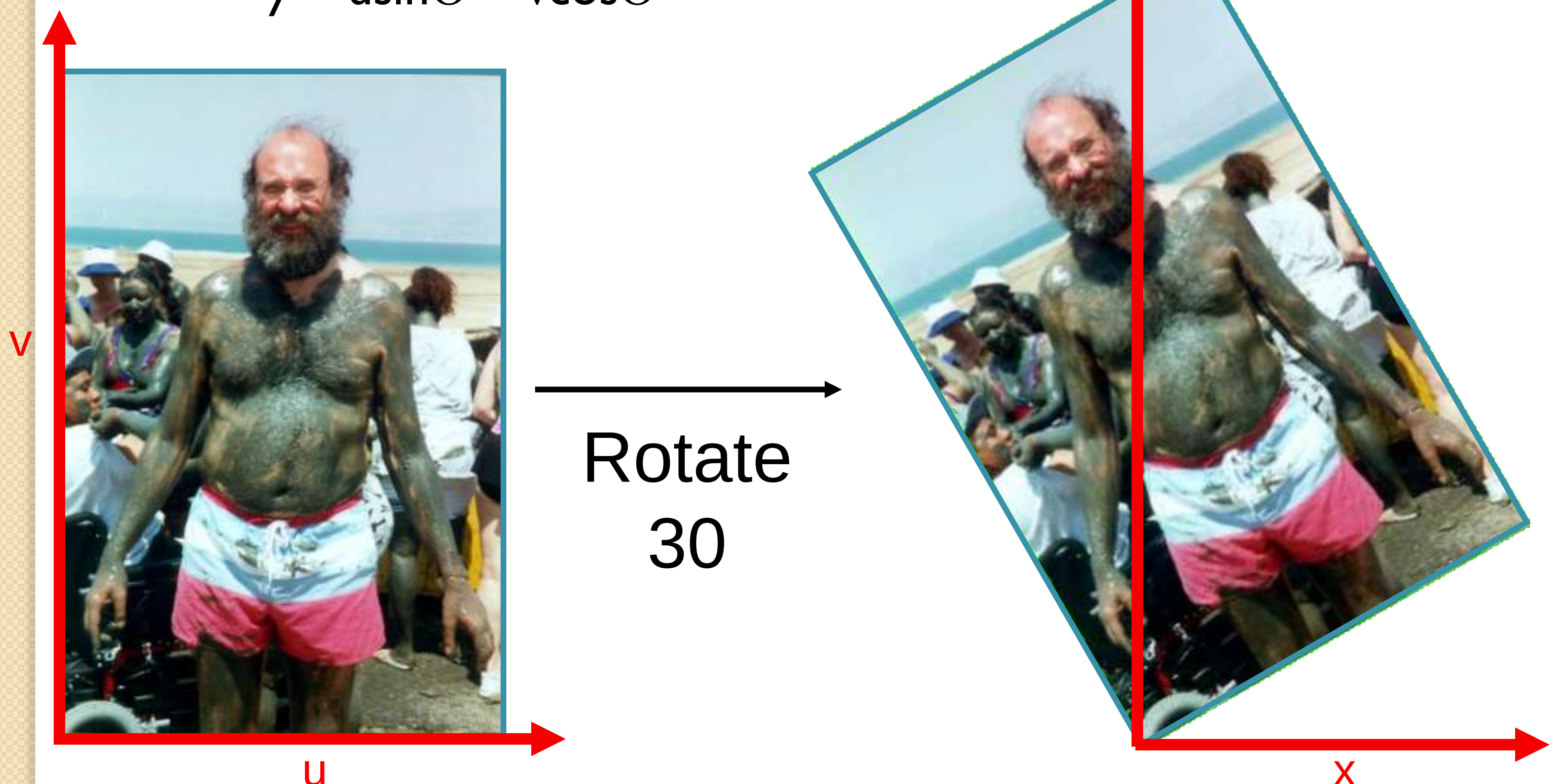
Example Mappings

- Scale by *factor*:
  - x = *factor* * u
  - y = *factor* * v



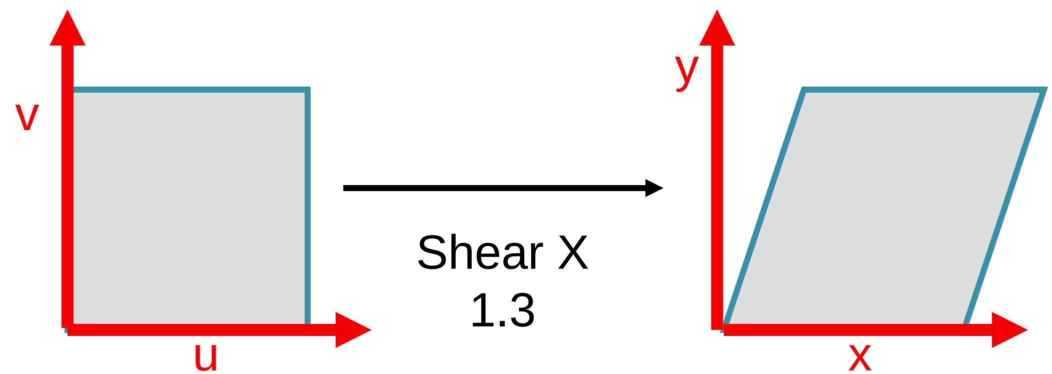
Example Mappings

- Rotate by Θ degrees:
  - x = ucosΘ - vsinΘ
  - y = usinΘ + vcosΘ

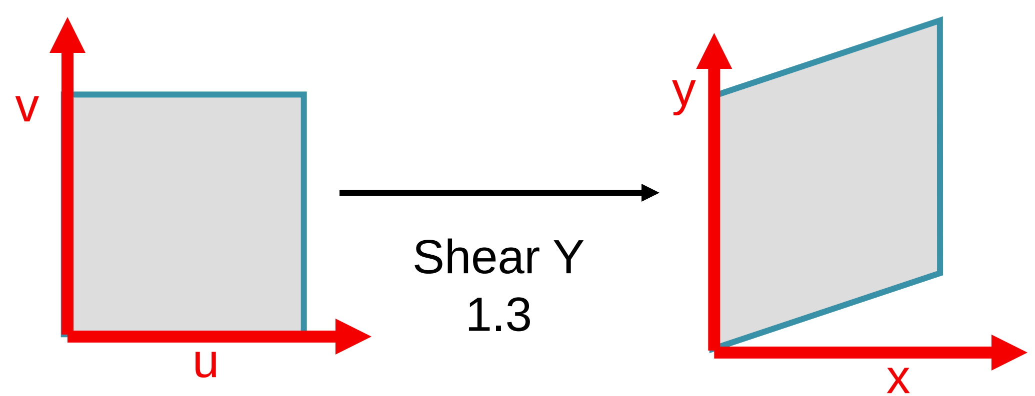


Example Mappings

- Shear in X by *factor:*
  - x = u + *factor* * v
  - y = v



- Shear in Y by *factor:*
  - x = u
  - y = v + *factor* * u

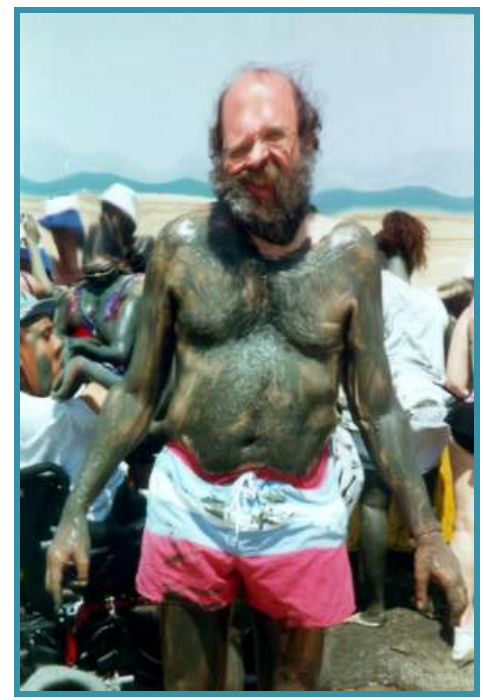


Other Mappings

- Any function of u and v:
  - $x = f_x(u,v)$
  - $y = f_y(u,v)$

Fish-eye

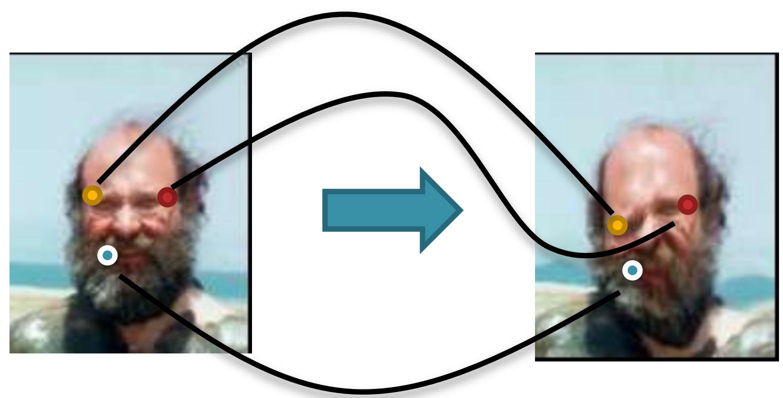
"Swirl"



"Rain"

Point Correspondence

- Another way to define mapping is by correspondences
  - A ←→ A'
  - B ←→ B'
  - C ←→ C'



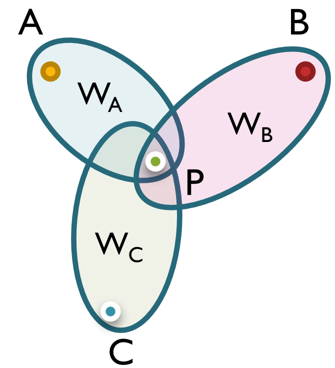
Point Correspondence

- Another way to define mapping is by correspondences
  - A ←→ A’
  - B ←→ B’
  - C ←→ C’

Point Correspondence

- How to compute P'

$$P' = w_A A + w_B B + w_C C$$

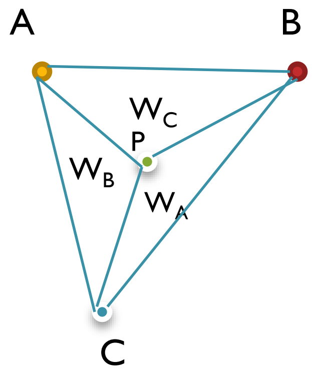


Point Correspondence

- Barycentric Coordinates

$$p = \lambda_1 A + \lambda_2 B + \lambda_3 C$$

$$\begin{cases} p_x = \lambda_1 x_1 + \lambda_2 x_2 + \lambda_3 x_3 \\ p_y = \lambda_1 y_1 + \lambda_2 y_2 + \lambda_3 y_3 \\ \lambda_1 + \lambda_2 + \lambda_3 = 1 \end{cases}$$



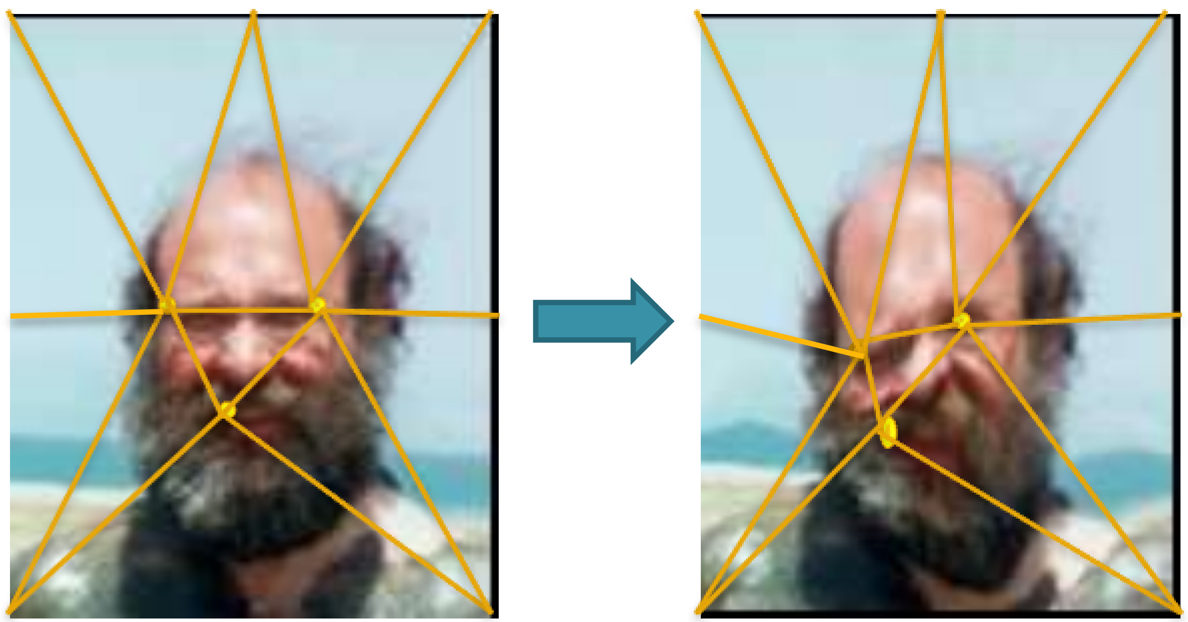
$$\Downarrow$$

$$\lambda_1 (x_1 - x_3) + \lambda_2 (x_2 - x_3) + x_3 - p_x = 0$$

$$\lambda_1 (y_1 - y_3) + \lambda_2 (y_2 - y_3) + y_3 - p_y = 0$$

Point Correspondence

1. Triangulate image
2. Transform mesh
3. Map each pixel using Barycentric coordinates



Possible application: Morphing

- User specifies corresponding points
- Blend while warping

Image Processing

- Pixel operations
  - Add random noise
  - Add luminance
  - Add contrast
  - Add saturation
- Filtering
  - Blur
  - Detect edges
  - Sharpen
  - Emboss
  - Median
- Quantization
  - Uniform Quantization
  - Floyd-Steinberg dither
- Warping
  - Scale
  - Rotate
  - Warps
- Combining
  - Composite
  - Morph

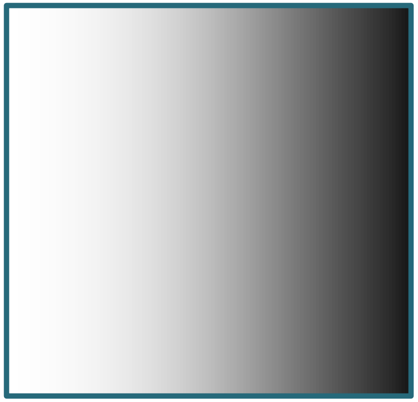
Quantization

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

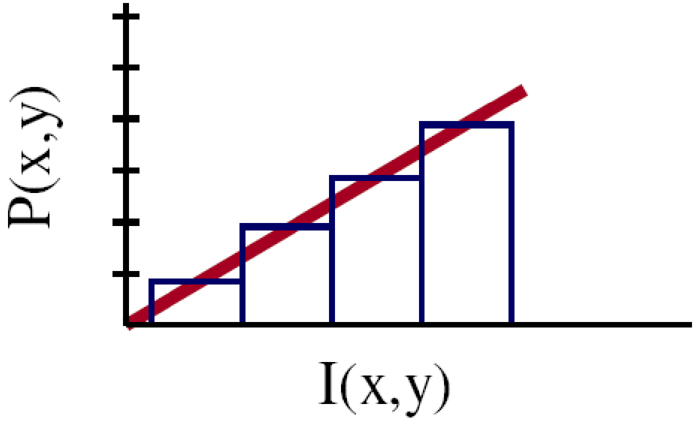
n=0.5

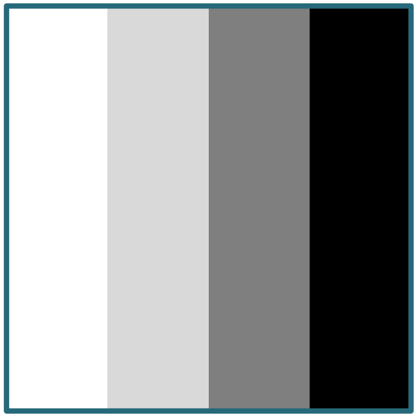
Uniform Quantization

- P(x,y) = round(I(x,y))



I(x,y)





P(x,y) – 2 bits per pixel

Uniform Quantization

- Images with decreasing bits per pixel:

8 bits

4 bits

2 bits

1 bit

Reducing effects of Quantization

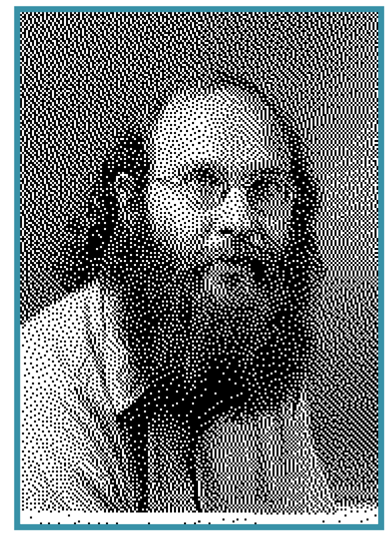
- Dithering
  - Random dither
  - Ordered dither
  - Error diffusion dither
- Halftoning
  - Classical halftoning

Dithering

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

Original
(8 bits)

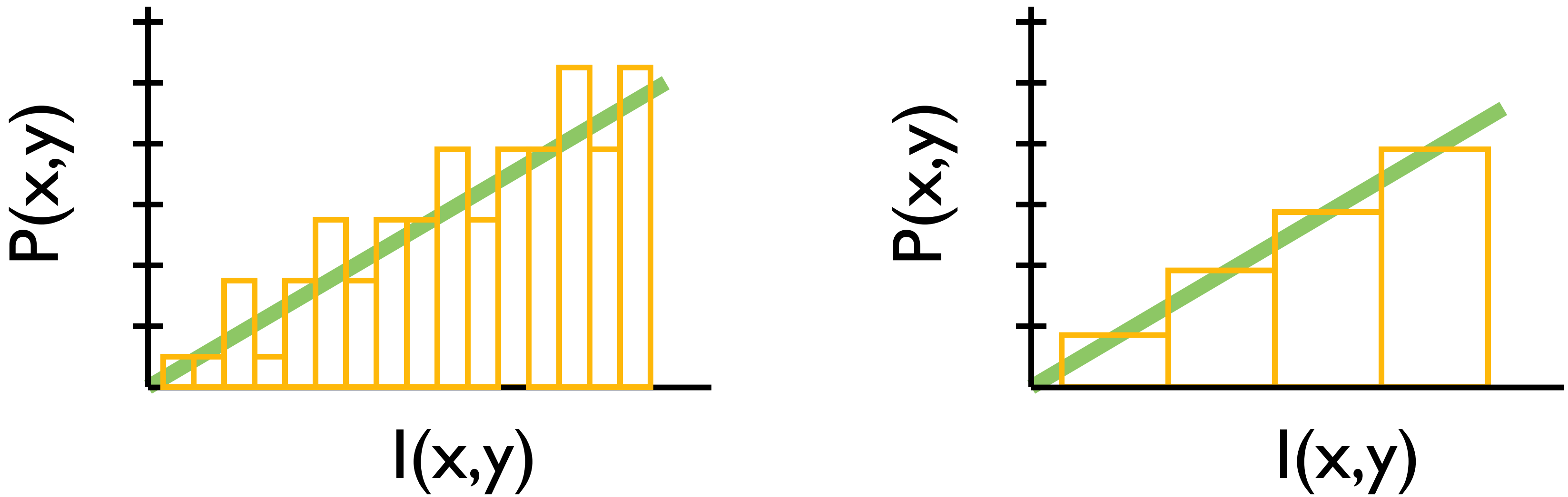
Uniform
Quantization
(1 bit)



Floyd-Steinberg
Dither
(1 bit)

Random Dither

- Randomize quantization errors
  - Errors appear as noise



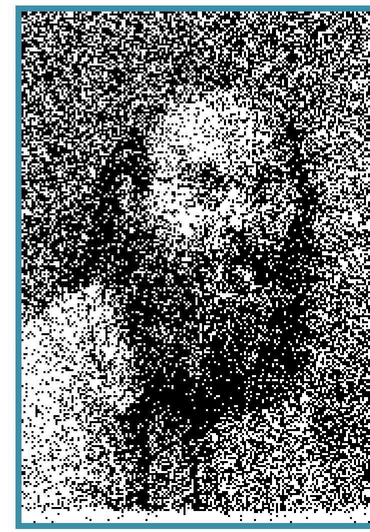
$$P(x, y) = \mathrm{trunc}(I(x, y) + \mathrm{noise}(x,y) + 0.5)$$

1 bit

Random Dither

Original
(8 bits)

Uniform
Quantization
(1 bit)



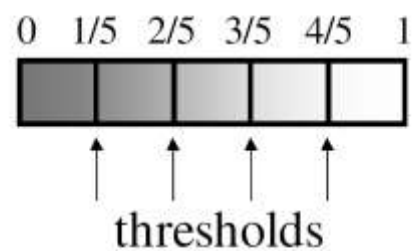
Random
Dither
(1 bit)

Ordered Dither

- Pseudo-random quantization errors
  - Matrix stores pattern of threshholds

$$D_2 = \begin{bmatrix} 3 & 1 \\ 0 & 2 \end{bmatrix}$$

For each pixel (x,y)
oldpixel = I(x,y) +D(x mod n,y mod n)
P(x,y)= find_closest_color(oldpixel)



Ordered Dither

- Bayer's ordered dither matrices

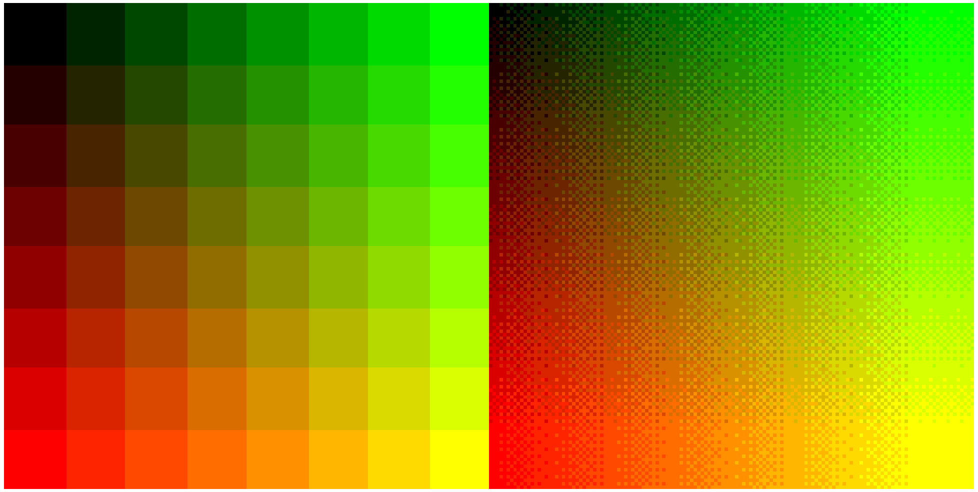
$$D_n = \begin{bmatrix} 4D_{n/2} + D_2(1,1)U_{n/2} & 4D_{n/2} + D_2(1,2)U_{n/2} \\ 4D_{n/2} + D_2(2,1)U_{n/2} & 4D_{n/2} + D_2(2,2)U_{n/2} \end{bmatrix}$$

$$D_2 = \begin{bmatrix} 3 & 1 \\ 0 & 2 \end{bmatrix} \qquad D_4 = \begin{bmatrix} 15 & 7 & 13 & 5 \\ 3 & 11 & 1 & 9 \\ 12 & 4 & 14 & 6 \\ 0 & 8 & 2 & 10 \end{bmatrix}$$

Basic idea: organize successive integers such that the average distance between two successive numbers in the map is as large as possible

Ordered Dither

- An example
  - Palette consists of 8 red tones, 8 green tones and their combinations (64 colors)
  - Original image had 19600 colors

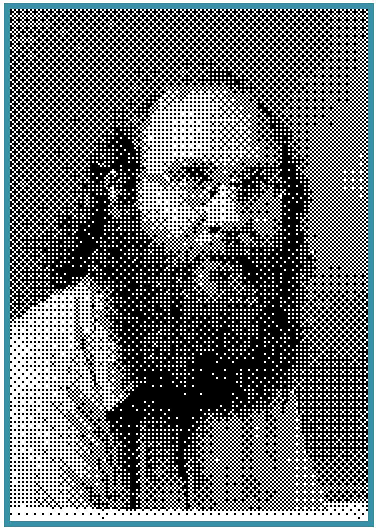


Undithered Dithered

Ordered Dither

Original
(8 bits)

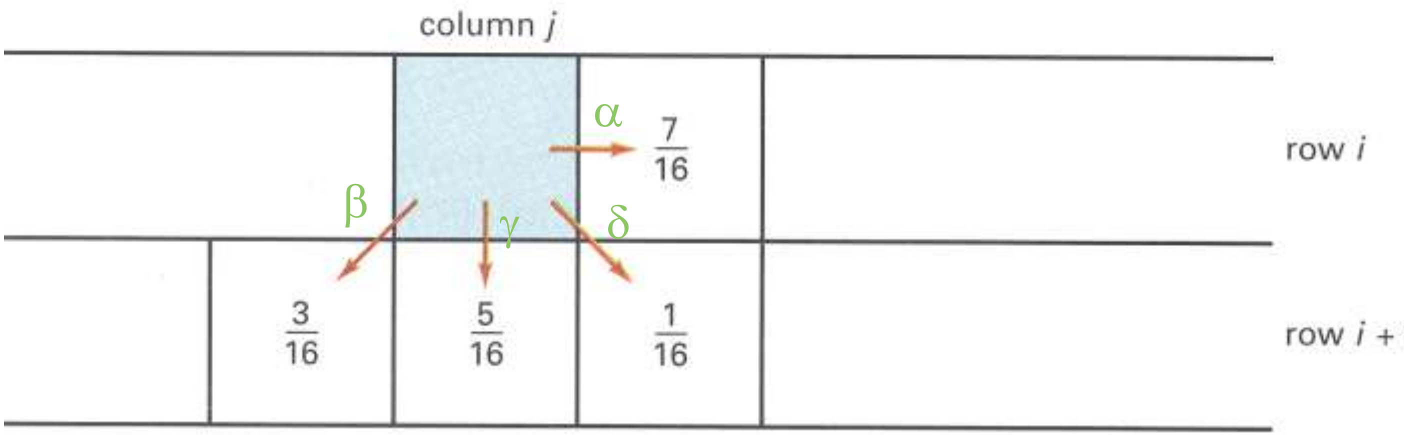
Random
Dither
(1 bit)



Ordered
Dither
(1 bit)

Error Diffusion Dither

- Spread quantization error over neighbor pixels



$$\alpha + \beta + \gamma + \delta = 1.0$$

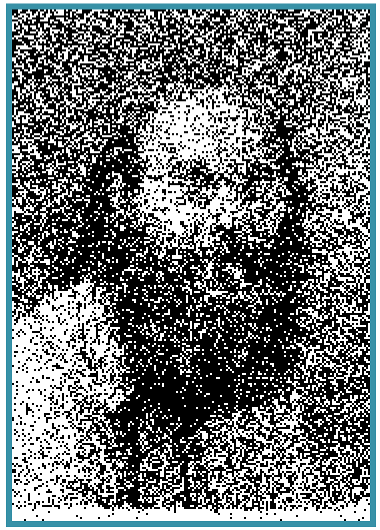
Figure 14.42 from H&B

Floyd-Steinberg Algorithm

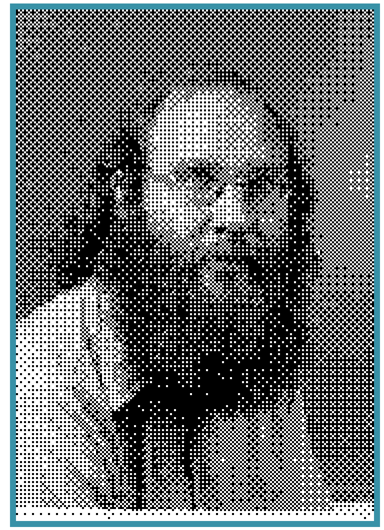
```
for (x = 0; x < width; x++) {
        for (y = 0; y < height; y++) {
                P(x,y) = trunc(I(x,y) + 0.5)
                e = I(x,y) - P(x,y)
                I(x,y+1) += α*e;
                I(x+1,y-1) += β*e;
                I(x+1,y) += γ*e;
                I(x+1,y+1) += δ *e;
        }
}
```

Error Diffusion Dither

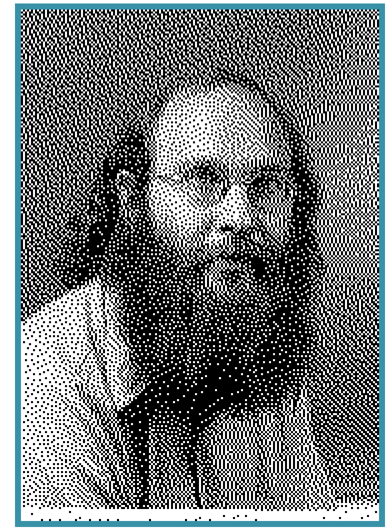
Original
(8 bits)



Random
Dither
(1 bit)



Ordered
Dither
(1 bit)



Floyd-Steinberg
Dither
(1 bit)

More examples

Original

Threshold

Random

Bayer

Floyd-Steinberg

Jarvice, Judice & Ninke

Stucki

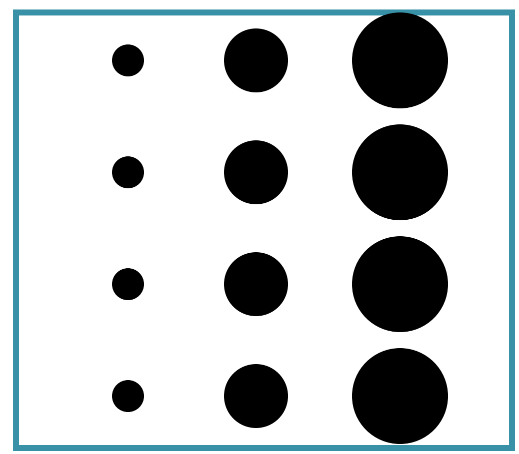
Burkes

Reducing effects of Quantization

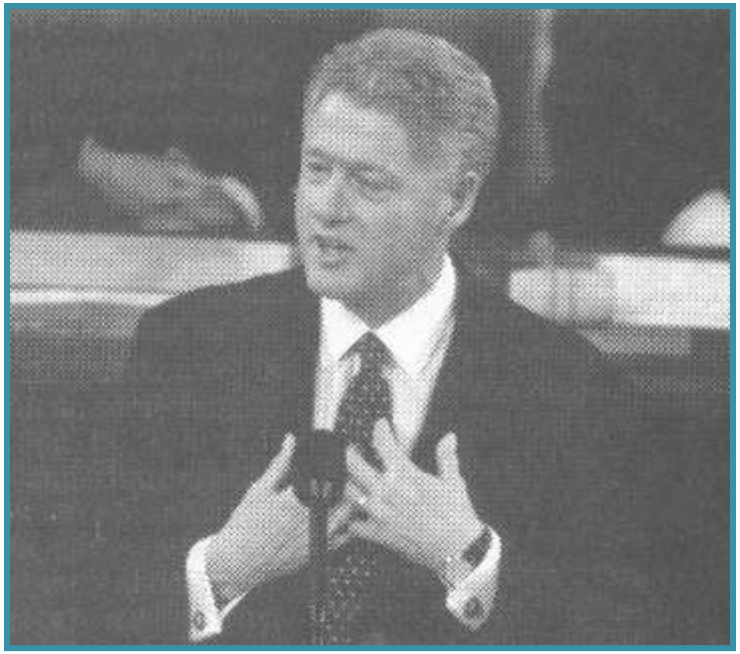
- Dithering
  - Random dither
  - Ordered dither
  - Error diffusion dither
- Halftoning
  - Classical halftoning

Classical Halftoning

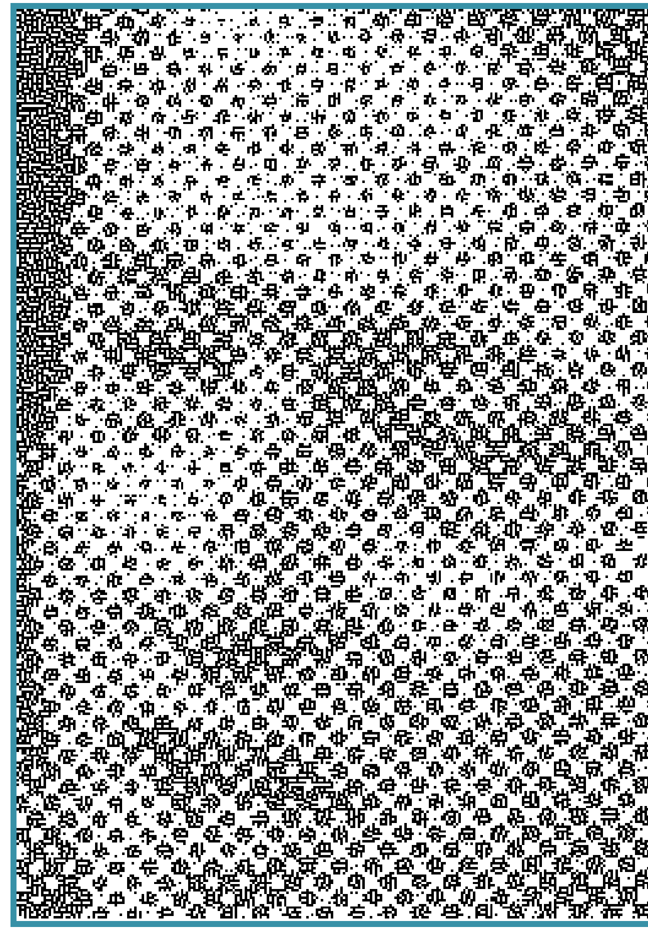
- Use dots of varying size to represent intensities
  - Area of dots proportional to intensity in image



Classical Halftoning



Newspaper Image



From New York Times, 9/21/99

Halftone patterns

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

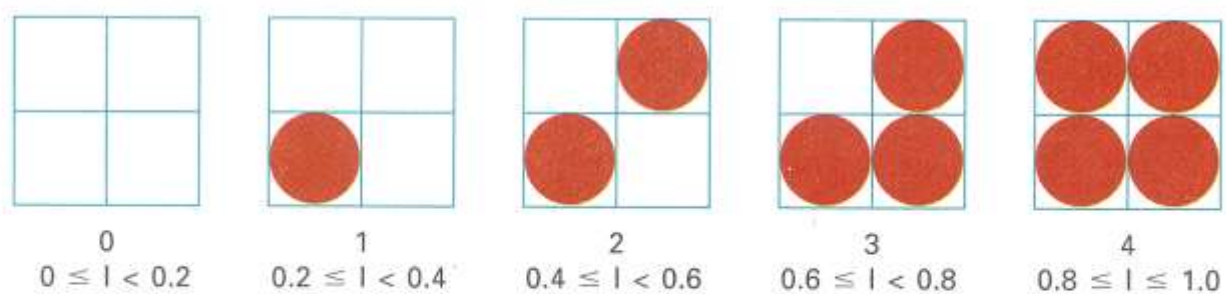


Figure 14.37 from H&B

Halftone patterns

- How many intensities in a n x n cluster?

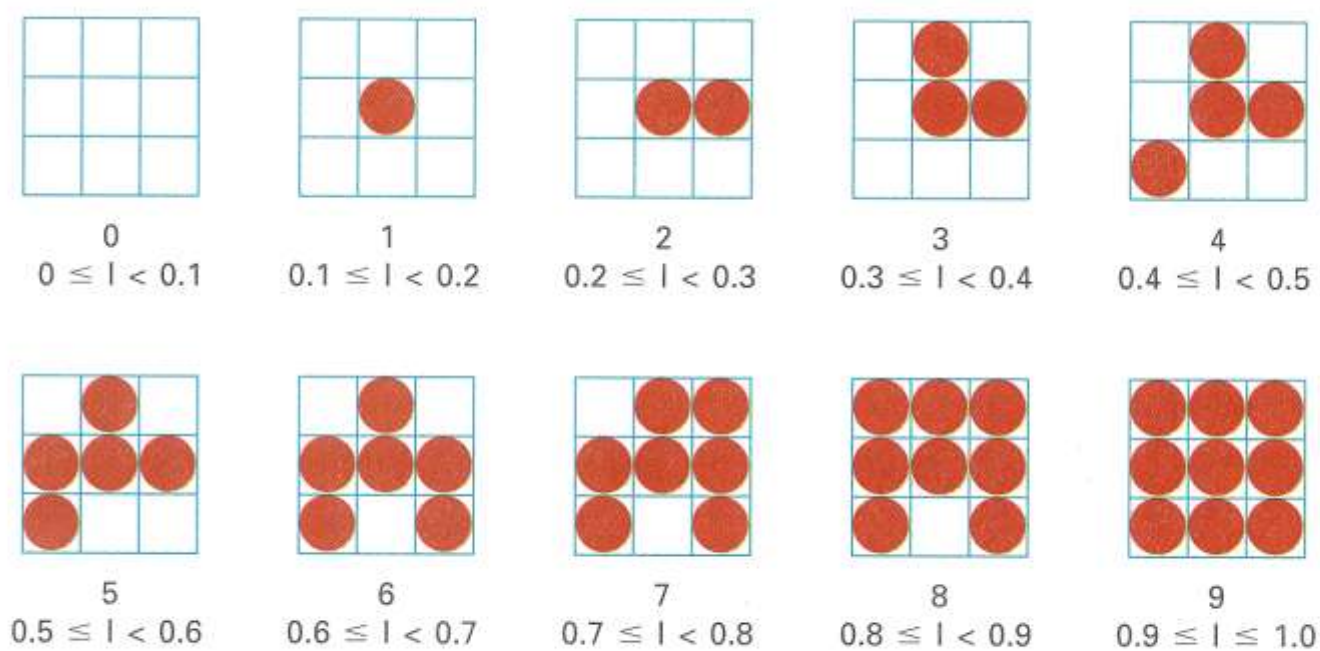


Figure 14.37 from H&B