Lecture Notes #14 - Halftoning

Reading:

Angel 7.12.3 -or- H&B 14-4 -or- Foley, et al, 13.1.2

Final word: Robert Ulichney, *Digital Halftoning,* MIT Press, 1987.

Overview:

Threshold, random dither

Dispersed-dot dither

Clustered-dot dither

Error diffusion

Halftoning

Many displays and printing devices are bilevel (black and white).

How can we reproduce images with a range of intensities?

Exploit spatial integration in our eyes.

Classical halftoning

Use dots of varying size

Area proportional to darkness

Take out-of-focus photograph through a screen

Dots per inch

Newspapers: 60-80

Magazines: 110-200

Figure 5.1

Precursors: mezzotint, Jacquard loom

Figures 4.5, 6.15

Fixed threshold

How do we choose where to put ink?

First stab: compare darkness with a fixed threshold.

Figure 1.1

Random dither

We can get smoother variation in darkness by comparing with a random threshold.

Looks noisy.

Figures 4.2, 4.3

Ordered dither

A 2x2 group of pixels can show 5 intensities.

0.0-0.2	0.2-0.4	0.4-0.6	0.6-0.8	0.8-1.0	shorthand
					0 2 3 1

How many levels for an NxN matrix?

3x3 matrix D3:

```
7 2 6
4 0 1
3 8 5
```

4x4 matrix D4:

```
 0  8  2 10
12  4 14  6
 3 11  1  9
15  7 13  5
```


Ordered dither

Why can't we just use one matrix for each pixel in the image?

To display Point(x,y) we compute:

i = x mod N

j = y mod N

and print a dot if:

Image(x,y) > M_{ij}

Figures 6.9, 6.11, 6.12

Clustered-dot dither

Previous examples used *dispersed dots.*

Appropriate for display on a monitor.

Ink likes to blob together on paper.

Classical screens use *clustered dots.*

Figures 5.5, 5.6, 5.7

Screen angle

The eye is most sensitive to horizontal and vertical edges.

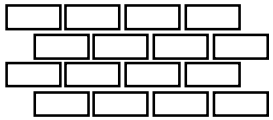
Figures 5.2, 5.3

Line up dots at a 45 degree angle

M3:

```
9  7  8 | 10 12 11
6  1  2 | 13 18 17
5  4  3 | 14 15 16
```

Use brick tiling:



Error diffusion

Due to Floyd-Steinberg (1975)

Difference between exact value and displayed value is distributed as follows:

E 7/16

3/16 5/16 1/16

Figure 8.10