Lecture Notes #5 - Halftoning

Reading:

- H&B Section 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.

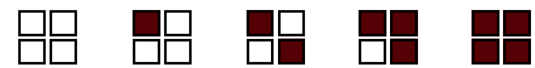
Looks noisy.

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.

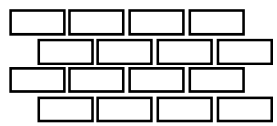
Figures 5.2, 5.3

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