Advanced Topics in Computer Science:
Electronic Publishing and Document Processing.

Dithering & Halftoning

® Adar Greenshpon & Boaz Bash

Introduction to Computer Image Display.

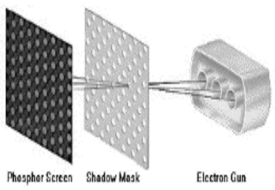
- CRT - Cathode Ray Tube.
- Raster VS. Vector Graphics.
- Hardcopy Devices.
- Color Theory.

2

CRT - Cathode Ray Tube.

•What is a Cathode Ray Tube?

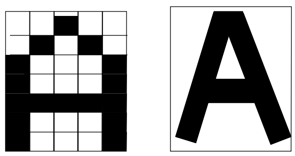
- The Cathode Ray Tube (CRT) is the most common device used in computer monitors .
- As such, Its limitations affects computer graphics.



3

Raster VS. Vector Graphics

- Trade Offs :
  - Cost of calculations.
  - Visibility.



4

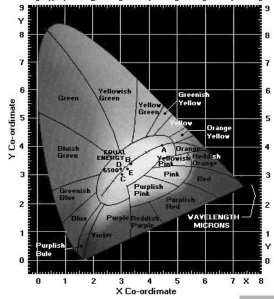
Hardcopy Devices

- Printers, Plotters.
- Paper Printing Machines.
  - Desktop Publishing.
- Printer Types:
  - Dot matrix B/W or Color.
  - Inkjet B/W or Color.
  - Laser B/W or Color.

5

Color Theory

- The human eye can see more than the screens can offer…
- Different Computer Screen Gamut.



Problems Using Computer Images

- The problem that raised the subject of *Dithering & Halftoning* is the transformation of images between different I/O devices.
- Resolution
  - Differ between I/O devices.
  - Screen Have Grown…
  - 256/65535/TrueColor Systems.
- Local Color-Space.

7

Dithering

- Definition.
- Dithering Techniques.
- Summary.

8

Dithering Definition

- *<u>What is dithering</u>?*

In the world of computer graphics *<u>Dithering</u>* refers to the process of applying patterns to areas of color in order to simulate a wider color range.

9

Dithering Introduction

- The dithering process is used for displaying an image on a device that doesn't have as many colors.
- For our discussion let's assumed that the range of colors (or intensity levels for gray-scale pictures) of the output device is fixed - No *quantization* problem (choosing between optimal output colors).
- We'll restrict ourselves to gray-scale images.
- How do we handle *color* images ?

Dithering Techniques

<u>Threshold</u>

- The simplest and probably the worst for common images.
- There is only one parameter: the threshold.
- process each point of the input image:
  - If (Intensity > Threshold) a white point is outputted.
  - Else a black point is outputted.

Dithering Techniques

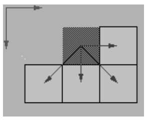
<u>Ordered dithering</u>

- Main Component is a dithering matrix.
- A matrix of n by n produce (n*n)+1 intensity levels.
- The matrix elements are similar to the threshold used in the previous technique.
- Once we have a *<u>dithering</u>* matrix we can process each point of the input image: (n is the size of the matrix):
  - Get an input pixel (x,y).
  - Compute the matrix element we'll use :
    ((x mod n)+1,(y mod n)+1)) element of the matrix.
  - Threshold (x,y) with the matrix element.

Dithering Techniques

Error diffusion dithering

- Preserve the global intensity of the input image.
- Use the error produced in the previous technique. (We approximate an intensity level by a black or white point.)
- Spread/diffuse this error on the pixels still needing to be processed by the algorithm.

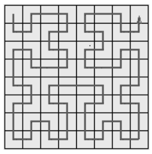


Dithering Techniques

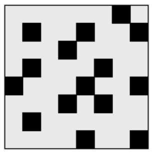
Space filling curves dithering

- High resolution output device and lower resolution input image. It's an excellent technique for device having problem rendering isolated points. (Laser Printer)

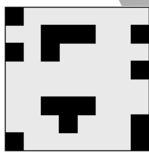
Space Filling Curve



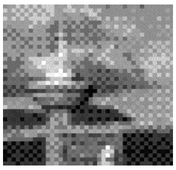
Before



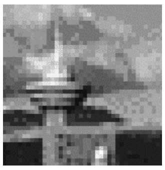
After



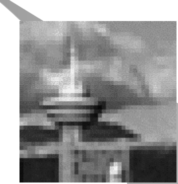
Dithering - Sample



Ordered Dithering



Error Diffusion



Original True-Color

Dithering Techniques Summary

	Threshold	***Ordered***	***Error Diffusion***	***Space Curve***
Pro's	Fast	Simple	Keep global intensity	Good laser printer output
Con's	Often awful	Ugly pattern	Some noise is added	Screen output awful

Halftoning - Introduction

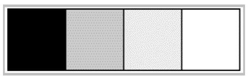
- *Halftoning* - a technique, originally developed for the printing industry, to reproduce continuous tone images using printing techniques capable of black and white only and not shades of gray (Gray Scale).
- The ability to represent many millions of colors on a computer screen.

Halftoning As a Solution

- A black and white photograph may have hundreds of shades of gray. A color photograph may have upwards of three million colors in it, but most printing presses use only these four process inks:
  - Cyan
  - Magenta
  - Yellow
  - Black
- The solution : *Screening*

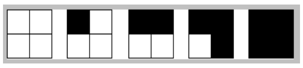
Halftoning

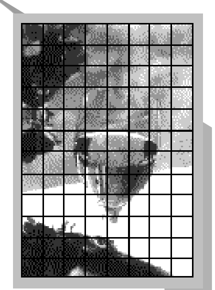
- In a black-and-white photograph, for example, a group of large dots placed closely together appears black.
- A group of smaller dots with larger spaces between them produces a , gray shade.
- A group of even smaller dots spaced widely apart appears almost white.



Halftoning Technique

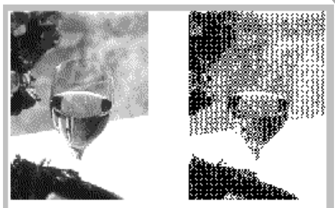
- A screen frequency can be represented by a grid like the one shown.
- Each square in this grid is a halftone cell, capable of holding one halftone dot.
- Example of Levels of gray:





Halftoning Technique

- And that's what we get after processing:
  - Left : in a frequency of 133 LPI (Lines Per Inch).
  - right: in a frequency of 65 LPI.



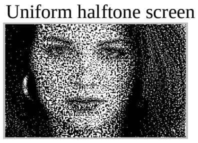
133 lpi   65 lpi

Adaptive Halftoning

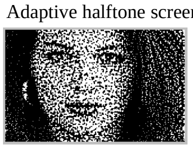
- As one can see the image is not processed perfectly.
- In *Adaptive Halftoning* the images traverse along a space-filling curve, based upon a Peano curve algorithm of the last decade. The space-filling curve halftoning is attractive because of the pleasant smooth grains in the resultant image and the relatively minimized blur.

Halftoning Samples

Uniform halftone screen



Adaptive halftone screen



Adaptive in action

Dithering & Halftoning Summary

- Dithering & halftoning help us get the maximum visually for a given output device.
- The techniques are usually simple and give a significant improvement.
- Each technique has Its unavoidable side effects.
- As always, tradeoffs: # of colors, quality...

24

Where to get more information

- Web sites :
  - www.cs.cmu.edu
  - www.sandybay.com/pcweb/dithering.htm
  - www.publish.com/0896/workshop/index.html
  - pertsserver.cs.uiuc.edu/~hul/halftone/dither.html
- Books :
  - Digital Typography - By Richard Rubinstein /Addison Wesley Publishing comp.

25