Advanced Computer Graphics

CSE 163 [Spring 2018], Lecture 2

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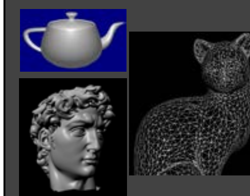
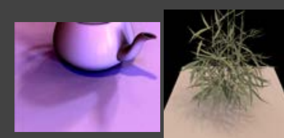
Course Outline

- 3D Graphics Pipeline

Modeling (Creating 3D Geometry) → **Rendering** (Creating, shading images from geometry, lighting, materials)





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Unit 1: Foundations of Signal and Image Processing

Understanding the way 2D images are formed and displayed, the important concepts and algorithms, and to build an image processing utility like Photoshop

Weeks 1 – 3. **Assignment 1**

To Do

- Assignment 1, Due Apr 27.
  - Anyone need help finding partners?
  - Should already have downloaded code, skimmed assn
  - After today, enough to finish 3.2, 3.3 (first half)
  - Should START EARLY (this week) on assn
  - Second half next week.
- Class participation, discussion important
  - If you have to miss a class, see podcast if available
- Please sign up for Piazza

Outline

- *Intensity and Color (briefly)*
  - Basic operations (3.2 in assignment [10 points])
- Quantization, Halftoning and Dithering
  - (3.3 in assignment [10 points])
- Next week: Sampling and Reconstruction
  - Including signal processing and fourier analysis
  - Implementation of simple digital filters, resizing
  - Second half of assignment
- Lectures main source; will also try handout

Intensities: Human Perception

- Human eye can perceive wide range of intensities
  - Dimly lit darkened room to bright sunlight
  - Radiance ratio in these cases is a million to one or more
- How does it work? [image only 256 gray levels]
  - Nonlinear human response $S = I^p \qquad p \approx .33$
  - Care about ***ratio*** of intensities (log scale). So jump from 0.1 to 0.11 as important as 0.50 to 0.55 (*not* .5 to .51)
  - E.g.: cycle through 50W,100W,150W (step from 50 to 100 much greater than from 100 to 150)
- Technically, equispaced intensities multiplicative
  - 0.02, 0.0203, 0.0206, … 0.9848, 1.000 [for 100 values]
- Area of CG known as tonemapping (we ignore)

Gamma Correction

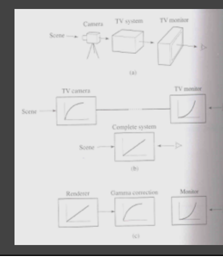
- Website: http://graphics.stanford.edu/gamma.html
- Practical problem: Images look too dark/bright…


Gamma Correction

- Monitors were CRT displays with nonlinear resp.

$$I = aV^{\gamma} \qquad V = \left(\frac{I}{a}\right)^{1/\gamma} \qquad \gamma = 2.5+$$

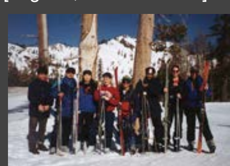
- NTSC, use 2.2 (camera pre-corrected)
- Rendering linear (physical space) ***Gamma Correct***



Watt Page 440

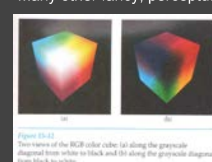
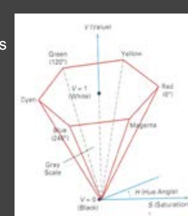
Example

- Say RGB is something like (1, 0.5, 0)
- Values of 1 and 0 don't change (black, white, primary colors unaffected by gamma correction)
- Value of .5 becomes .707 (power of ½, gamma = 2)
- Final color is (1, 0.707, 0) [brighter, less saturated]

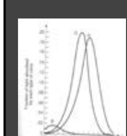
Color

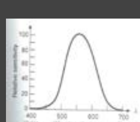
- Already seen: RGB model (color cube)
- Today: A very brief overview of real story
- Intuitive specify: Hue, Saturation, Lightness
  - Hexacone
  - Can convert HSV to RGB
  - Many other fancy, perceptual spaces

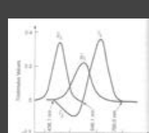



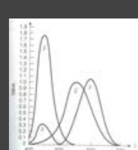
Color: Tristimulus Theory

- Perception: Tri-stimulus theory
  - 3 types of cones: basis for RGB
  - Cone response functions
  - Luminous efficiency (G>R>B)
  - Color matching: Note "negative colors"
  - CIE overview


Cone response


Luminous efficiency


Color Matching


Match w CIE primaries

Basic Image Processing (HW 1: 3.2)

- Brightness: Simply scale pixel RGB values (1 leaves image intact, 0 makes it black)


0.1


0.4


0.7


1.0

- Gamma Correction
- Crop (integer coords) to focus on important aspects

Basic Image Processing (HW 1: 3.2)

- Contrast [0 is constant grey image, 1 is original]
  - Find constant grey image by averaging
  - Interpolate between this and original

Basic Image Processing (HW 1: 3.2)

- Saturation [0 is greyscale, 1 is original colors]
  - Interpolate between grayscale (but not const) and orig.
  - Negative values correspond to inverting hues [negative]

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  - Basic operations (3.2 in assignment [10 points]
- *Quantization, Halftoning and Dithering*
  - (3.3 in assignment [10 points])
- Next week: Sampling and Reconstruction
  - Including signal processing and fourier analysis
  - Implementation of simple digital filters, resizing
  - Second half of assignment

Images and Resolution

- Image is a 2D rectilinear discrete array of samples
- There are resolution issues:
  - Intensity resolution: Each pixel has only Depth bits
  - Spatial resolution: Image is only width*height pixels
  - Temporal resolution: Monitor refreshes only at some rate

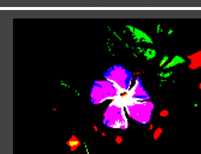
NTSC	640x480	8 bits	30 Hz
PC	1280x1024	24 bits RGB	75 Hz
Film	3000x2000	12 bits	24 Hz
Laser Printer	7000x2000	1 (on or off)	

Some material for slides courtesy Greg Humphreys and Tom Funkhouser

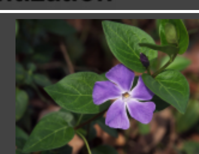
Sources of Error or Artifacts

- Quantization: Not enough intensity resolution (bits)
  Halftoning/dithering: Reduce visual artifacts due to quantization
- Spatial and Temporal Aliasing: not enough resolution
  Sampling and reconstruction to reduce visual artifacts due to aliasing (next week)

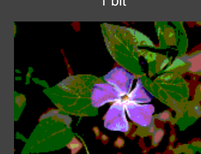
Uniform Quantization



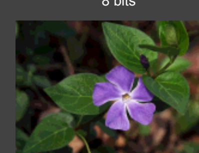
1 bit



8 bits

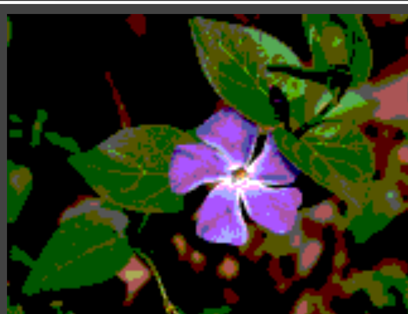


2 bits: NOTE CONTOURS



4 bits

Uniform Quantization



2 bits: NOTE CONTOURS

Reducing Quantization

- *Halftoning*
- Dithering
  - Random Dither
  - Error Diffusion (Floyd-Steinberg)

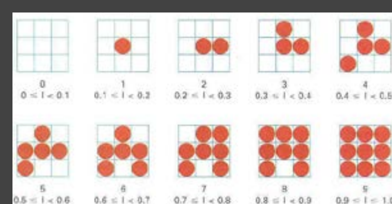
Halftoning

- Motivation: bilevel printing. Trade off spatial resolution for more intensity levels
- Dots of appropriate size to simulate grey levels
- Area of dots proportional intensity

Figure 14-34
An enlarged section of a photograph reproduced with a halftoning method, showing how tones are represented with varying size dots.

Halftone Patterns

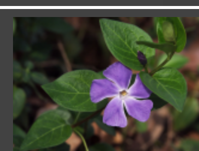
- Cluster of dots (pixels) to represent intensity (trading spatial resolution for increased intensity resolution)
- Exploits spatial integration in eye



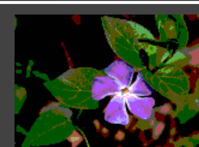
Reducing Quantization

- Halftoning
- *Dithering (distribute errors among pixels)*
  - Random Dither
  - Error Diffusion (Floyd-Steinberg)

Dithering

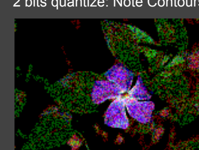


8 bits original



2 bits quantize: Note Contours

2 bits FLOYD STEINBERG



2 bits random dither: noise not contours

Random Dither

- Randomize quantization errors [see assignment for exact details on adding random noise]
- Seems silly (add random noise), but eye more tolerant of high-frequency noise than contours or aliasing
- More complex algorithms (not considered here) are ordered dither with patterns of thresholds rather than completely random noise

Random Dither

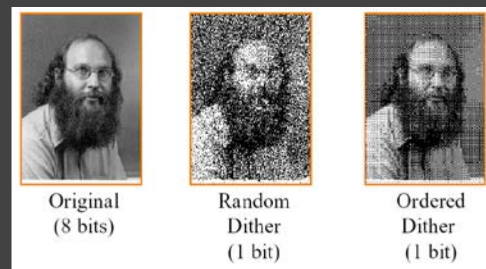
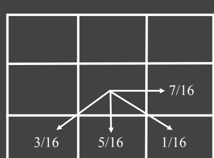


Image and example courtesy Tom Funkhouser

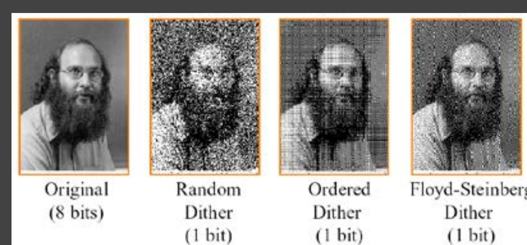
Error Diffusion

- Spread quantization error to neighboring pixels to the right and below (later in the process)
- Reduces net error, gives best results



$$\begin{aligned}
&\text{Error} = \text{pixel}(x,y) - \text{quantize}(x,y);\\
&\text{pixel}(x+1,y) \quad += \alpha \cdot \text{Error};\\
&\text{pixel}(x-1,y+1) += \beta \cdot \text{Error};\\
&\text{pixel}(x,y+1) \quad += \gamma \cdot \text{Error};\\
&\text{pixel}(x+1,y+1) += \delta \cdot \text{Error};
\end{aligned}$$

Floyd Steinberg Results



Quantization (Sec 3.3 Ass 1)

- Simple quantization (should be straightforward)
- Random Dither (just add noise, pretty simple)
- Floyd-Steinberg (trickiest)
  - Must implement a diffusion of error to other pixels (simply add in appropriate error to them)
  - Uses fractions, so must use floating point
  - And possibly negative numbers since error can be minus
  - Boundary conditions (what if no right etc.) toroidal [may not be relevant in this case] or change weights appropriately, but don't darken boundaries