CS 112 – Display Considerations
Display

- Image generation
  - Generate digital images
  - Should take care to have non-aliased images

- Image Reconstruction
  - Generate a continuous image on the display
Image Reconstruction

- Each pixel is not a point but an area
- How is that area lighted?

Ideal Case

2D

1D

Spot Width

In practice

Wider spots

Narrower spots
Aliasing artifacts (Right Width)
Wider Spots (Lost high frequencies)
Narrow Width (Jaggies, insufficient sampling)
Quantization

- Digitization of color
- Gray scale – infinite grays between 0 and 1
  - 8 bit representation – 256 levels
  - A range of grays represented by a single value
- Any value is assigned to one of k values
- Choose number of levels and range of each level
Quantization Error

Uniform Quantization

Maximum Error = $\frac{1}{2}$ Step Size
Human Perception

- Use properties of human perception
- Response Compression
- Response Expansion

![Diagram showing magnitude estimates against stimulus intensity with curves for Electric shock, Apparent length, and Brightness.](image)
Steven’s Power Law

\[ P = KS^n \]

P = Perception
S = Stimulus Strength

n > 1.0 (Expansion)

n < 1.0 (Compression)
Steven’s Power Law

\[ P = KS^n \]

- \( P = \) Perception
- \( S = \) Stimulus
  - Strength

- \( n > 1.0 \) (Expansion)
- \( n < 1.0 \) (Compression)
Gamma Function

- Inverse of human response curve for faithful representation of intensities
- Called the gamma function
  - \( O = I^\gamma \)
- Gamma Correction
Non-Uniform Quantization

- Note how quantization changes
- Non-uniform step size
- Maximum Error
  - $\frac{1}{2}$ of maximum step size
- # of levels is the color resolution
  - # of bits

Display Gamma

Graph:
- Output Intensity vs. Input Intensity
- Red line represents Display Gamma
Color Resolution

Analog Image 4 Steps 8 Steps 16 Steps

Quantization Artifacts 64 Steps 32 Steps
Dithering

- What if the color resolution is low?
  - Newsprint – Bi-level, only black and white

- Can we expand the # of colors?
  - Spatial integration of eye

- Trading off spatial resolution for intensity resolution
Dithering

- Represented by a dither matrix
  \[
  \begin{bmatrix}
    0 & 2 \\
    1 & 3
  \end{bmatrix}
  \]
- \(n \times n\) pixels, bi-level intensity, can produce \(n^2 + 1\) intensities
- If more than two levels – k levels
  - \(n^2 \cdot (k-1) + 1\)
  - Used for increasing the color resolution
Dithering

- If more than two levels – k levels
  - \( n^2 \cdot (k-1) + 1 \)
  - For \( k = 4 \) (0,1,2,3) and \( n=2 \)
Examples

Loss of tone and details
(Intensity and Spatial Resolution)