Sampling and Reconstruction

Today:

- Finish up Color
- Tone mapping
- Image representation
- Signal processing
- Sampling
- Reconstruction

Color Theory

- CIE XYZ color space
  - 3 color matching functions: X, Y, Z
  - Y is luminance
  - X and Z are color values

WP user acdx

Color Theory

- xyY color space
  - Since Y is luminance, it carries no color data
  - Chromaticity can be carried in new parameters x and y
\[ x = \frac{X}{X + Y + Z} \]
\[ y = \frac{Y}{X + Y + Z} \]
\[ Y = y \]

\[ X = \frac{Y}{x} \]
\[ Z = \frac{Y}{y} (1 - x - y) \]

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**Color Theory**

- **Gamut**
  - Formed by plotting x,y colors

- Let's mix colors!

The line between two points represents all the mixes possible with those colors.

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**Color Theory**

- sRGB space
Color Theory

Intuitive colors?
RGB is not necessarily intuitive with human color perception.

Color Theory

- RGB model

![RGB Model](image)

Visual Computing, Nielsen et al.

Color Theory

- HSV model
  - Color wheel (hue), saturation, value
Color Theory

- HSV model

Tone mapping

- Images
  - Stored for easy display
  - Not accurate representations
  - Most output devices show 256 brightness levels
  - Most image formats store 256 brightness levels

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Tone mapping

- Humans perceive more than 256 brightness levels
  - 4-5 log units, 100,000 : 1
  - Images are typically 2 log units, 100 : 1
- Your simulation images will have more than 256 brightness levels
  - Likely RGB float values
  - How to store them as standard images? (RGB bytes)

Tone mapping

- High dynamic range
  - This is normal range for humans
  - Images are low dynamic range
  - Must take HDR images and map them into smaller range

Tone mapping

- Clamping
  - Only keep small range (0.0 - 1.0)
  - Clamp low and high values
- Issues?

Can discard large amounts of the image, or even the entire image!

Tone mapping

- Remap values
  - Linear scaling to destination values
- Issues?

\[ n = \frac{L}{L_{\text{max}}} \]

Can remap many colors to the same value, losing detail.
Tone mapping

- Many, many more mappings...
  - Average luminance scale
    \[ n = 0.5 \cdot \frac{L}{L_{avg}} \]
  - Preserve color ratios
  - Separate reflectence and illuminance

Can remap many colors to the same value, losing detail.

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Image representation

- Grid of values
  - Each value is a 'pixel'
- How to store?
  - Single array with map/unmap function
  - 2d array (x,y dimensions)
  - Could be by spatial dimension
  - or channel dimension
Image representation

- What is a pixel?
  - Little box of color?
A pixel stores a single discrete sample result. It is not necessarily the color for the area under the pixel.

### Image representation

- Aliasing
It is impossible to tell an aliased image from an image of an object that is similar to the alias pattern.

**Image representation**

- Aliasing
Anti-aliasing is used to show the original signal more clearly.

**Image representation**

- Aliasing
Today:

- Finish up Color
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Signal processing

- Continuous vs. Discrete

- Frequency

- Maximum represented frequency
  - Two times the sampling rate

Today:

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- Image representation
Sampling

- Sample the signal at some location
- Record value
  - Recording more than 1 value per pixel is called super sampling
- Many, many ways to do this

Sampling

- Uniform sampling
- Regular pattern
- Easy, fast
- Issues?

Sampling

- Random sampling
- Multiple random samplings per pixel
- Generally good distribution
- Issues?

Sampling

- Stratified sampling
- Divide pixel into grid
- Random sample in each grid

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Now that we have samples, we need a value for the pixel
  - We will use a reconstruction filter
  - Again, there are many, many ways to do this

Reconstruction is the process of combining samples to form a representative value. This value corresponds to the original signal.

Filter basics

Support
  - Range of the filter

Weighting
  - Area under filters should sum to 1

Box filter

$$a_{\text{box}, r}[i] = \begin{cases} 
\frac{1}{(2r + 1)} & |i| \leq r, \\
0 & \text{otherwise}.
\end{cases}$$

For the box filter, we include both endpoints. As a

$$f_{\text{box}, r}(x) = \begin{cases} 
\frac{1}{2r} & -r \leq x < r, \\
0 & \text{otherwise}.
\end{cases}$$

Tent filter
Reconstruction

- Gaussian filter

\[ f_g(x) = \frac{1}{\sqrt{2\pi}} e^{-x^2/2}. \]