Basic Optics

Four Models:

1. **Geometric optics**
2. **Scalar wave theory**
2. **Physical optics**
4. **Quantum optics**

Overview

A. **Generation of light**
B. **Interaction of light with matter**
C. ***Display***
D. **Sensing and perception**
E. **Computer representations and calculations**

Spectral Representations

1. Procedural representations
   - Blackbody spectra
   - Rayleigh scattering
   - Reflection from thin films (oil spills)
2. Spectrophotometric measurements
   - Measure spectra every 1, 5, 10, … nm
3. Spectral approximations
   - Approximate with different basis functions
4. Complex procedural models

Spectral Databases

- Krinov Data
  - 350 natural objects
  - Available online
- Munsell Book of Color
  - Covers color gamut
  - Paint mixtures
- Macbeth Color Chart
  - Photographic reproduction
  - "Important, not Representative" colors

Light Sensor

$$R = \int_{\lambda} R(\lambda) S(\lambda)\, d\lambda$$

Spectral Sensitivity Curve

Spectral Sensitivity Curve

Grassman's Laws

Color matching is linear

1. Scaling the color and the primaries by the same factor preserves the match

2. To match the sum of two colors, sum the primaries

=> To match a spectra, match each pure color and sum

What’s Wrong with RGB?

Display

- **Relative vs. absolute gamut**
- **Gamma correction/Tone reproduction**
- **White point**

Physics

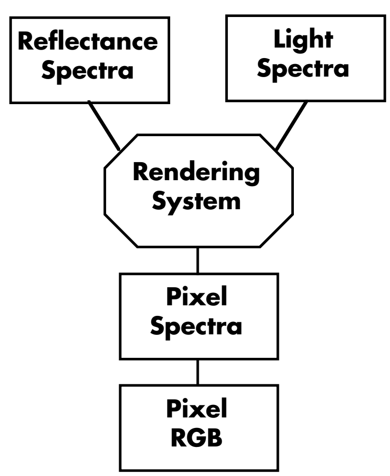
- **Approximate spectrum**
- **Multiplying approximation not the same as multiplying spectra**

Full Spectral Calculations

Hall, Cook

1. How many samples?

2. Where?



Spectral Basis Functions

Observe: Moon experiment implies smooth reflections

Box functions

- Hall

Two cubic splines

- Raso-Fournier

Principal components analysis:

- Find m best vectors give n colors
  Eigenvectors of database
- Cohen '64: Munsell colors highly correlated
- Maloney, Parkkinen: Munsell colors 6-8 parameters
- Peercy: Principal components analysis of R*L

Spectral Quadrature Rules

Most resulting spectra are smooth

Gaussian quadrature for trichromatic basis functions

- Find best wavelengths and weights

Meyer '86

- A C1 C2 coordinate system by PCA of Cones
  - Macbeth colors have low average error w/ 4
  - A C1 C2 better than XYZ better than Cones

Product of Basis Functions

1. Approximate spectra with orthonormal bases

$$S(\lambda) = \sum_{i=1}^{n} s_i B_i(\lambda) \qquad s_i = \int_{\lambda} S(\lambda) B_i(\lambda)\, d\lambda$$

2. Multiply spectra

$$S'(\lambda) = R(\lambda) S(\lambda)$$

3. Project onto basis functions

$$s_i' = r_{ij} s_j \qquad r_{ij} = \int_{\lambda} R(\lambda) B_i(\lambda) B_j(\lambda)\, d\lambda$$