Toward a Psychophysically-Based Light Reflection Model for Image Synthesis

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Motivation

- Color and gloss both are salient visual aspects of material properties.
- Color is well studied, with multiple physical and perceptually-relevant representations.
- Gloss is described by ad-hoc and physically based models (Phong, Ward, etc.)
- No model for how glossiness is perceived...
Perceptual Aspects of Gloss

- Hunter parameterized the following gloss-related visual phenomena:
  - *specular gloss* – perceived brightness associated with the specular reflection from a surface
  - *contrast gloss* – perceived relative brightness of specularly and diffusely reflecting areas
  - *distinctness-of-image (DOI) gloss* – perceived sharpness of images reflected in a surface
  - *haze* – perceived cloudiness in reflections near the specular direction
  - *sheen* – perceived shininess at grazing angles in
Psychophysical experiments

- Two separate (small) psychophysical experiments to determine:
  - The perceptual dimensionality of gloss
  - The salient axes of glossiness
  - Perceptually uniform gloss space on those axes (linear scale of perceived glossiness)
Experimental setup

- Used Ward’s model to model glossy paints:

\[
\rho(\theta_i, \phi_i, \theta_o, \phi_o) = \frac{\rho_d}{\pi} + \rho_s \cdot \frac{\exp[-\tan^2 \frac{\delta}{\alpha^2}]}{4\pi\alpha^2 \sqrt{\cos \theta_i \cos \theta_o}}
\]
Experiment 1

• Subjects were shown all pairing of the previous inputs, and asked to rate their difference in glossiness on a scale from 0-100

• Using the data garnered, performed MDS analysis to find dimensionality

• Determined axes in the resulting 2D space:
Experiment 1 Results
Experiment 1 results

- Two dimensions: contrast gloss (c) and distinctness-of-image (DOI) gloss (d)
- Higher dimensionality led to less stress, but may be overconstraining to noise

- Clustering by lightness
Experiment 2

- Asked same subjects to estimate gloss magnitude.
- Varied $\rho_s$ and $\rho_d$ in the Ward model for contrast gloss dimension
- Varied $\alpha$ for DOI coordinate
Experiment 2 Results
Experiment 2 Results

- Physical parameters in terms of perceptual ones (L is CIELAB lightness):

\[ \rho_d = f^{-1}(L) \]

\[ \rho_s = \left(c + \sqrt[3]{f^{-1}(L)/2}\right)^3 - f^{-1}(L)/2 \]

\[ \alpha = 1 - d \]
Isogloss Contours

Examples along a given curve is perceptually equidistant in gloss from the reference (bottom left)
Matching Apparent Gloss

Matching physical parameters

Matching apparent gloss
Tool for specifying gloss

• Made a tool for specifying gloss based on $c$ and $d$
Future work

• Extend to other materials (perhaps higher dimensionality/different dimensions)
• Extend to different viewing conditions
• Determine the effect of other object properties (shape, pattern, texture, and color)
• Determine the effect of scene properties (illumination quality, spatial proximity, and environmental contrast)
• Use HDR to capture appearance in trials