CS 332 Visual Processing in Computer and Biological Vision Systems

Analysis of Color

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Content-based image retrieval

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CS 332 Visual Processing
Department of Computer Science
Wellesley College
Applications of color image segmentation

medicine, surveillance, inspection, recognition, ...

Color constancy

Color of a surface looks (roughly) the same under different illuminations...

... although colors can be influenced by context

http://www.echalk.co.uk/amusements/OpticalIllusions/Illusions.htm
Surface reflectance

Surface reflectance varies with position and wavelength: \( R(x, y, \lambda) \)

Illumination

Even with uniform scene illumination, cast shadows and reflection of light from other surfaces creates spatially non-uniform surface illumination: \( E(x, y, \lambda) \)
Surface reflectance meets illuminant

\[
L(x, y, \lambda) = E(x, y, \lambda) \times R(x, y, \lambda)
\]

“The Dress” – what color is it?

white-gold? (30%)  ???  blue-black? (57%)

Lafer-Sousa, Hermann, Conway (2015)
It depends on the illuminant...

cool illuminant (blue sky)

warm illuminant (incandescent)

Measuring color by retinal cones

Absorption spectra for S (short), M (medium), L (long) wavelength cones
Luminance meets the cones

\[ L(x, y, \lambda) \]

\[ S(\lambda) \quad M(\lambda) \quad L(\lambda) \]

\[ I_s(x, y) = \int L(x, y, \lambda)S(\lambda)d\lambda \]

\[ I_m(x, y) = \int L(x, y, \lambda)M(\lambda)d\lambda \]

\[ I_l(x, y) = \int L(x, y, \lambda)L(\lambda)d\lambda \]

Land’s color “Mondrian” experiments

Edwin Land

Piet Mondrian

*Composition A*, 1923
Land’s Retinex theory*

\[ L(x, y) = E(x, y) \times R(x, y) \]

- \( L(x, y) \): luminance
- \( E(x, y) \): illuminant
- \( R(x, y) \): surface reflectance

**Goal:** recover surface reflectance

* ignore color for now...

Land’s Retinex theory (1D)

- \( R(x) \)
- \( E(x) \)
- \( L(x) \)

\( \log(L(x)) \)

\( \text{derivative of } \log(L(x)) \)

\( \text{computed } R(x) \)
Retinex theory for 2D color analysis

2D extensions:
- Land & McCann: multiple 1D paths
- Horn: 2D analysis based on Laplacian $\nabla^2 L$
- Jobson, Rahman & Woodell: applied to image enhancement

Color:
- Perform same analysis for $I_S(x, y)$, $I_M(x, y)$, $I_L(x, y)$
- Triplet of values $R_S(x, y)$, $R_M(x, y)$, $R_L(x, y) \Rightarrow$ color

Restrictions (Assumptions):
- Reflectance changes abruptly, illumination changes slowly
- Matte (Lambertian) reflectance characteristics

Image enhancement, Retinex style

Robson, Rahman & Woodell
Morel, Petro & Sbert