The von Kries Hypothesis and a Basis for Color Constancy

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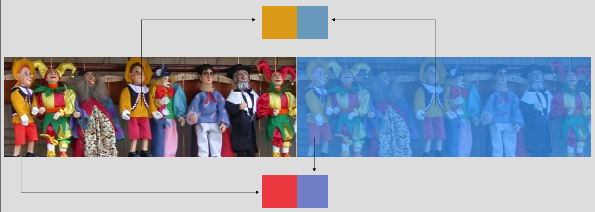
Introduction and Motivation

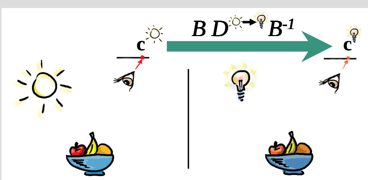
- Color constancy refers to the stable perception of object color--despite changes in overall illumination



- Color constancy should generally not be possible

Background

- ***Generalized diagonal (von Kries-like) color constancy***:



- D is a diagonal matrix with entries independent of material
- B is a globally constant matrix

Goals

1) Derive necessary and sufficient conditions for {sensors, illuminants, materials} to support generalized diagonal color constancy.

2) Compute an optimal global color basis (i.e., an optimal B matrix)

Definitions

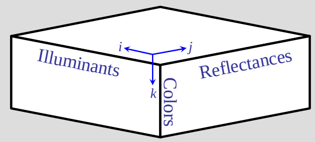
Define ***measurement tensor*** $M_{kij} := \int \rho_k(\lambda) E_i(\lambda) R_j(\lambda) d\lambda$

λ = wavelength

ρ_k = sensor response function

E_i = spectrum of i[th] illuminant

R_j = spectrum of j[th] material



An order 3 tensor (3D data block), T, has ***tensor rank N*** if N is the smallest integer allowing decomposition as the sum of outer products:

$$T = \sum_{n=1}^{N} \vec{c}_n \circ \vec{a}_n \circ \vec{b}_n$$

Theorem : *A measurement tensor supports generalized diagonal color constancy if and only if its* tensor rank *is at most 3.*

Algorithm (for determining color basis)

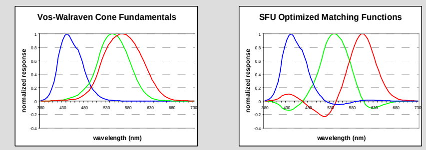
1) Create measurement tensor from input data (database of illuminant and material spectra).

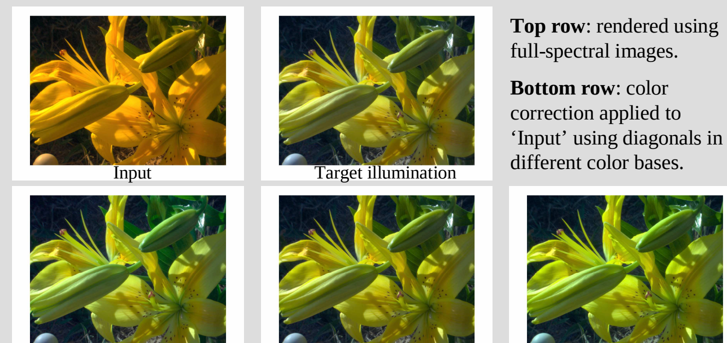
2) Run a nonlinear least squares optimization (TALS) to get closest rank 3 tensor (in Frobenius norm)

3) Algorithm allows us to read off color basis that gives perfect constancy for this approximate tensor

Results and Discussion

Color Matching Functions – normalized so that 1 is the max response.



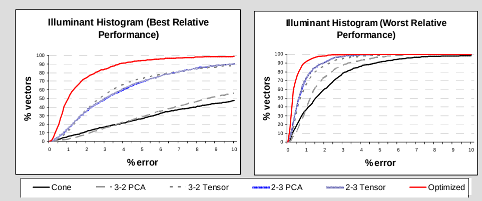


Input | Target illumination | Cone | Optimized | 2-3 Tensor

Top row: rendered using full-spectral images.

Bottom row: color correction applied to 'Input' using diagonals in different color bases.

Each histogram curve plots the % of color vectors obeying diagonal color constancy (under a specified color basis) versus the % allowable error.



- Additional details on experiments can be found at: http://www.people.fas.harvard.edu/~hchong/color.html
- Source of full-spectral image:

Foster, D.H., Nascimento, S.M.C., & Amano, K. (2004) "Information limits on neural identification of coloured surfaces in natural scenes", *Visual Neuroscience*, 21, 331-336