An Image Color Gradient preserving Color Constancy

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Outline

Introduction

- We present a color gradient.
- The approach does not need a priori information or changes in color space.
- It is based on the angular distance between pixel color representations in the RGB space.
- It is naturally invariant to intensity magnitude, implying high robustness against bright spots produced be specular reflections and dark regions of low intensity.

Outline

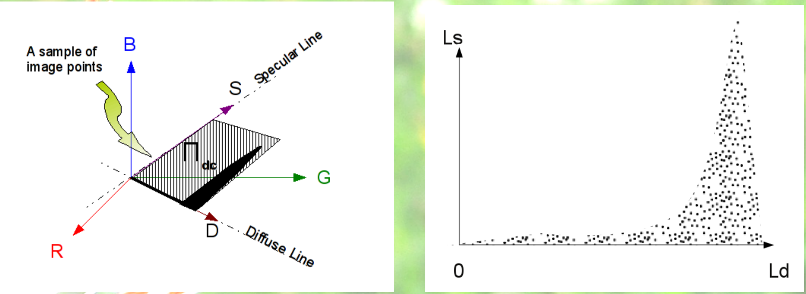
Dichromatic Reflection Model

The mathematical expression of the model

$$I(x) = m_d(x)D + m_s(x)S \quad (1)$$

- The Dichromatic Reflection Model (DRM) was introduced by Shafer .
- It explains the perceived color intensity of each pixel in the image as addition of two components
  - one diffuse component D
  - and a specular component S
- The diffuse component refers to the chromatic properties of the observed surface
- The specular component refers to the illumination color.

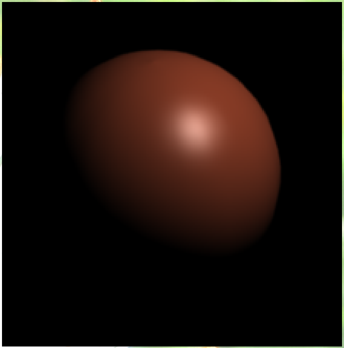
Dichromatic Reflection Model



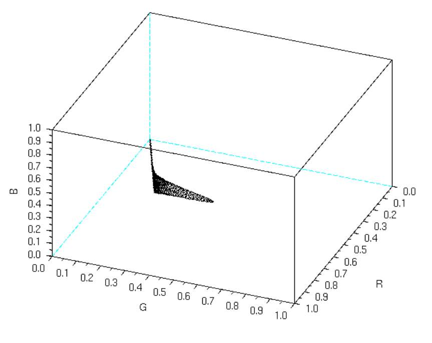
(a) (b)

Figure: Expected distribution of the pixels in the RGB cube according to DRM for a single color image.

Dichromatic Reflection Model



(a)



(b)

Figure: Distribution of pixels in the RGB space

Dichromatic Reflection Model

The mathematical expression of the model

For an scene with several surface colors, the DRM equation assumes that the diffuse component may vary spatially:

$$I(x) = m_d(x)D(x) + m_s(x)S \quad (2)$$

Finally, assuming several illumination colors we have the most general DRM

$$I(x) = m_d(x)D(x) + m_s(x)S(x) \quad (3)$$

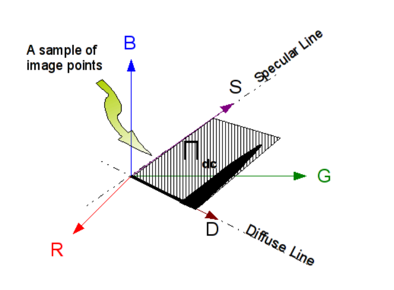
where the surface and illumination chromaticity are space variant.

Outline

Color Constancy

- CC is the mental ability to identify chromatically homogeneous surfaces under illumination changes.
- CC property is inversely proportional to the color discontinuity represented by the CE
- In essence, given a chromatic image gradient, low intensity gradient magnitude corresponds to CC and high magnitude to CE.

Color Constancy



- We have observed that chromaticity in the RGB space is characterized by a straight line crossing the RGB space's origin, determined by the ϕ and θ angles of the spherical coordinates of the points over the line. We denote L_d this *diffuse line*.
- If the image has surface reflection bright spots, the plot of the pixels in these regios appear as another line L_s intersecting L_d

Color Constancy

- For diffuse pixels (those with a small specular weight $m_s(x)$) the zenithal ϕ and azimuthal θ angles are almost constant, while they are changing for specular pixels, and dramatically changing among diffuse pixels belonging to different color regions.
- Therefore, the angle between the vectors representing two neighboring pixels I_p and I_q, denoted $\angle(I_p, I_q)$, reflects the chromatic variation.
- For two pixels in the same chromatic regions, this angle is $\angle(I_p, I_q) = 0$ because they will be colinear in RGB space.

Outline

Gradient

Definition of the image gradient

- To set the stage for our chromatic gradient proposition, we must recall the definition of the image gradient

$$G[I(i,j)] = \begin{bmatrix} G_i \\ G_j \end{bmatrix} = \begin{bmatrix} \frac{\partial}{\partial i} I(i,j) \\ \frac{\partial}{\partial j} I(i,j) \end{bmatrix}, \quad (4)$$

where $f(i,j)$ is the image function at pixel (i,j). For edge detection, the usual convention is to examine the gradient magnitude:

$$G(I) = |G_i| + |G_j|. \quad (5)$$

Gradient

Problem: The intensity approach

- For color images, the basic approach to perform edge detection is to drop all color information, computing the intensity $Intensity = (Red + Green + Blue)/3$ (sometimes computed as $Intensity = .2989 * Red + .587 * Green + .114 * Blue$)
- To take into account color information, the easiest approach is to apply the gradient operators to each color band image and to combine the results afterwards:

$$G(I) = [G(I_r) + G(I_g) + G(I_b)]/3$$

Gradient

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

(a)

$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

(b)

Figure: Convolution kernels for the (a) Sobel and (b) Prewitt edge detection operators.

Gradient

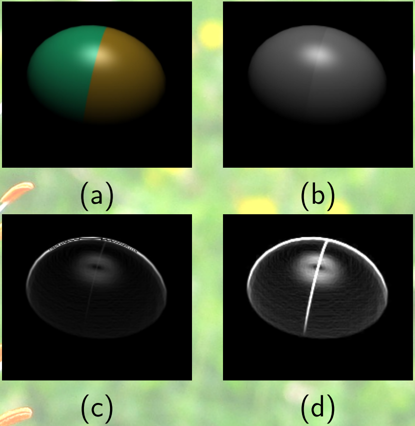


Figure: (a) Original synthetic RGB image, (b) Intensity image, (c) Gradient magnitude computed on the intensity image, (d) gradient magnitude combining the gradient magnitudes of each color band

Proposed Method

Outline

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2. Background
   - Dichomatic Reflecion Model
   - Color Constancy
   - Gradient Operators
3. Proposed Method
   - A chromatic coherent distance
   - Chromatic coherent gradient operators
4. Results
   - Syntetic Image 1
   - Syntetic Image 2
   - Natural Image
5. Conclusions

A chromatic coherent RGB pixels distance

Notation

- First, we convert the RGB cartesian coordinates of each pixel to polar coordinates, withe the black color as the RGB space origin.
- We denote the cartesian coordinate image as $I = \left\{ (r, g, b)_p ; p \in \mathbb{N}^2 \right\}$
- And the spherical coordinate as $P = \left\{ (\phi, \theta, l)_p ; p \in \mathbb{N}^2 \right\}$, where p denotes the pixel position.
  - In this second expression, we discard the l because it does not contain chromatic information.

A chromatic coherent RGB pixels distance

Chromatic distance

- For a pair of image pixels p and q, the color distance between them is defined as:

$$\angle(P_p, P_q) = \sqrt{(\theta_q - \theta_p)^2 + (\phi_q - \phi_p)^2}, \tag{6}$$

  that is, the color distance corresponds to the euclidean distance of the Azimuth and Zenith angles of the pixel's RGB color spherical representation.
- This distance is not influenced by the intensity and, thus, will be robust against specular surface reflections.

Outline

Chromatic coherent gradient operators

Chromatic Gradient

- We will formulate a pair of Prewitt-like gradient convolution operations on the basis of the above distante.
- Note that the $\angle(P_p, P_q)$ distance is always positive.
- Prewitt masks

$$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$$

Chromatic coherent gradient operators

Chromatic Gradient

- The row convolution is defined as

$$CG_R(P(i,j)) = \sum_{r=-1}^{1} \angle(P(i-r, j+1), P(i-r, j-1))$$

- And the column convolution is defined as

$$CG_C(P(i,j)) = \sum_{c=-1}^{1} \angle(P(i+1, j-c), P(i-1, j-c))$$

- The color gradient image is computed as:

$$CG(P) = CG_R(P) + CG_C(P) \quad (7)$$

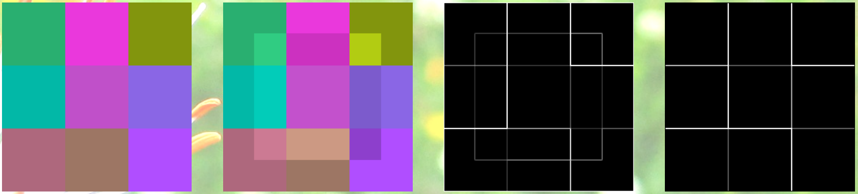
see Eq. 5

Experimental Results

- To demonstrate the efficiency of our proposed approach, we will show three experimental results.
- Two of the experiments are done on synthetic images whose ground truth is know.

Outline

Experimental Results I



(a) (b) (c) (d)

Figure: Results of the color edge detection on a synthetic image with nine uniform chromatic regions and a variation of intensity. (a) Original color distribution, (b) lower intensity central square, (c) Prewitt detection on RGB bands, (c) our approach in equation (7).

Outline

Experimental Results

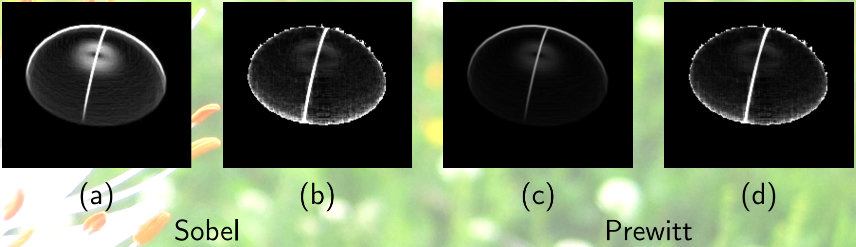


Figure: Color edge on the synthetic image of fig. 4(a) with two color regions. (a) The Sobel operator over the RGB bands with specular component, (b) our approach in a Sobel-like structure, (c) the Prewitt linear operator, (d) our approach in a Prewitt like structure.

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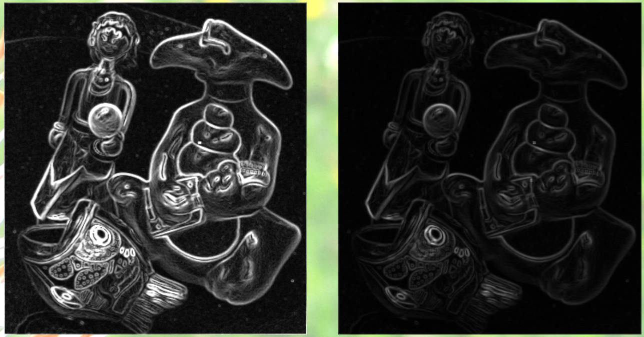
Experimental Results

Figure: Natural image

Experimental Results



(a) (b)

Figure: Results of the linear operators on the natural image (a) Sobel detector, (b) Prewitt detector

Experimental Results


(a)


(b)

Figure: Resuls of our approach on the natural image (a) taking 8 neighbors, (b) taking 4 neighbors

Conclusions

- We have presented an innovative chromatic gradient computation, which is chromatically coherent, preserves the Color Constancy and gives good detection of Color Edges.
- The method is grounded in the DRM which is a widely accepted image model for reflectance analysis.
- Our method is intensity invariant, and, thus, is robust against the bright spots of specular reflections.
- It does not imply or need color segmentation, on the contrary can provide good color region separation with little assumptions.
- It works on the RGB space, which the most common color processing space.

Further works

- In the future we will try to apply this approach to robust reflectance analysis, helping to provide good separation of color regions as the starting point for diffuse and specular component separation.
- It can provide the basis to build good a priori mappings for Bayesian methods using Random Markov Field modeling tools.

Thanks:)

Thanks ;)