Hybrid Color Space Transformation to Visualize Color Constancy

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Introduction

- Color constancy (CC) and chromatic edge (CE) detection are fundamental problems in artificial vision.
- In this work we present a way to provide a visualization of color constancy that works well even in dark scenes where such humans and computer vision algorithms have hard problems due to the noise.
- The method is an hybrid and non linear transform of the RGB image based on the assignment of the chromatic angle as the luminosity value in the HSV space.
- This chromatic angle is defined on the basis of the dichromatic reflection model, having thus a physical model supporting it.

DRM in the RGB Space

- It explains the perceived color intensity $\mathbf{I} \in \mathbb{R}^3$ of each pixel in the image as addition of two components, one **diffuse** component $\mathbf{D} \in \mathbb{R}^3$ and a **specular** component $\mathbf{S} \in \mathbb{R}^3$.
- The diffuse component refers to the chromatic properties of the observed surface.
- The specular component refers to the illumination color.
- The mathematical expression of the model, when we have only one surface color in the scene, is as follows:

$$\mathbf{I}(x) = m_d(x)\mathbf{D} + m_s(x)\mathbf{S}, \quad (1)$$

where m_d and m_s are weighting values for the diffuse and specular components, taking values in $[0, 1]$.

- In figure the stripped region represents a convex region of the plane Π_{dc} in RGB that contains all the possible colors expressed by the DRM equation 1.

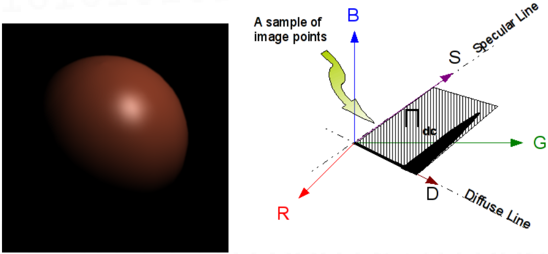


Figure: Typical distribution of pixels in the RGB space according to the Dichromatic Reflection Model

DRM in the RGB Space

- For an scene with several surface colors, the DRM equation must assume that the diffuse component may vary spatially, while the specular component is constant across the image domain:

$$\mathbf{I}(x) = m_d(x)\mathbf{D}(x) + m_s(x)\mathbf{S}. \quad (2)$$

DRM in the RGB Space

- In the HSV color space, chromaticity is identified with the pair (H,S), and the V variable represents the luminosity or light intensity.
- Plotting on the RGB space a collection of color points that have constant (H,S) components and variable intensity I component, we have observed that chromaticity in the RGB space is geometrically 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 this chromaticity line.
- The plot of the pixels in a chromatically uniform image region appear as straight line in the RGB space. We denote L_d this *diffuse line*. If the image has surface reflection bright spots, the plot of the pixels in these highly specular regions appear as another line L_s intersecting L_d.

DRM in the RGB Space

- For diffuse pixels (those with a small specular weight $m_s(x)$) the zenith 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 $\mathbf{I}(x_p)$ and $\mathbf{I}(x_q)$, denoted $\angle(I_p, I_q)$, reflects the chromatic variation among them.
- For two pixels in the same chromatic regions, this angle must be $\angle(I_p, I_q) = 0$ because they will be collinear in RGB space.

DRM in the RGB Space

The angle between I_p, I_q is calculated with the equation:

$$\angle(I_p, I_q) = \arccos\left(\frac{\mathbf{I}(x_p)^T\,\mathbf{I}(x_q)}{\sqrt{\left\|\mathbf{I}(x_p)\right\|^2 + \left\|\mathbf{I}(x_q)\right\|^2}}\right) \tag{3}$$

An Approach for Regular Region Intensity

- The basic idea of our approach is to assign a constant luminosity to the pixels inside an homogeneous chromatic region.
- To do that we must combine manipulations over the two color space representations of the pixels, the HSV and RGB.
- The process is highly non linear and it is composed of the following steps:

An Approach for Regular Region Intensity

1. Isolate the diffuse component removing specular components ($m_s = 0$): we are interested only in the diffuse component because it is the representation of the true surface color.
2. Transform the diffuse RGB image into the HSV color space.
3. Compute for each pixel in the image the chromaticity angle as the angle between pure white line in the RGB space, and the chromaticity line of the pixel.
4. Assume the normalized chromaticity angle as the new luminosity value in the HSV space pixel representation.

An Approach for Regular Region Intensity

- In an homogeneous chromatic region, all pixels fall on the same diffuse line $L_d : (r, g, b) = \mathbf{O} + s\sigma; \forall s \in \mathbb{R}^+$ where $\mathbf{O} = [0, 0, 0]$ and $\sigma = [\sigma_r, \sigma_g, \sigma_b]$ is the region chromaticity.
- The chromatic reference is the pure white line L_{pw} which is defined as $L_{pw} : (r, g, b) = c + s\mathbf{u}; \forall s \in \mathbb{R}^+$ where $\mathbf{O} = [0, 0, 0]$ and $\mathbf{u} = [1, 1, 1]$.
- Therefore, if all pixels is a region belong to the same chromatic line, the angle between each pixel and the line L_{pw} must be the same, and the result of this angular measurement is a constant for whole region.

An Approach for Regular Region Intensity

- Our strategy is to normalize this measure in his domain of definition (the RGB cube) and assume it as the constant luminosity value V. This method is expressed with the equation:

$$V^{new}(x) = \frac{\angle(\mathbf{I}(x), \mathbf{u})}{\arccos(\vartheta)} \tag{4}$$

- where the denominator $\arccos(\vartheta)$ is the normalization constant corresponding to the maximum angle between the extreme chromatic lines of the RGB space (red, green or blue axes) and the pure white line.

An Approach for Regular Region Intensity

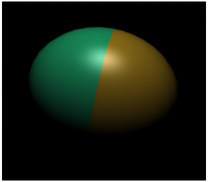
- Algorithm , shows a Matlab/Scilab implementation of the method, where ϑ takes the value $\frac{1}{3}$ and $\arccos(\vartheta) = 0.9553166$.

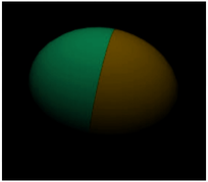
```
function IR = SF3(I)
   Idiff = imDiffuse(I); // look for the diffuse component
   new_intensity = angle(Idiff, [1 1 1]); // matrix of chromatic angles
   Ihsv = rgb2hsv(Idiff);
   Ihsv(:,:,3) = new_intensity; // assign angles as image intensity
   IR = hsv2rgb(Ihsv);
endfunction
```

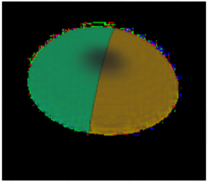
Experimental Results

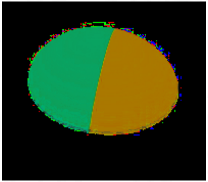
- We present the results from three computational experiments.
- The first one using a synthetic image and the remaining using natural images.

Experimental Results. Synthetic image


Original image


Diffuse image

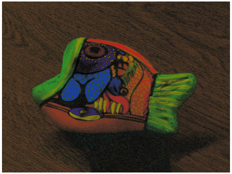

Result on original


Result on duffuse

Experimental Results. Natural images

Original image

Diffuse component of the image



Result on original

Result on diffuse

Experimental Results. Natural images

Original

Diffuse component

Result on original

Result on diffuse

Conclusions and Further works

- In this work we present a color transformation that enables good visualization of Color Constancies in the image, changing only the image luminosity and preserving its chromaticity.
- The result is a new image with strong contrast between chromatic homogeneous regions, and good visualization of these regions as uniform regions in the image.
- This method performs very well in dark regions, which are critical for most CC methods and image segmentation based on color clustering processes.

Conclusions and Further works

- The method could be the basis for such a process, applying the clustering process to the chromaticity angle.
- We have found that specular correction of the image improves the results on highly specular regions of the image, however our approach performs well also on images that have not been preprocessed.
- Future works will be addressed to the computation of color edge detection and color image segmentation based on this approach.

Thanks!!