Light Mixture Estimation for Spacially Varying White Balance

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Human visual system exhibits color constancy - the ability to interpret surface colors by discounting surround illumination. White balance is an image processing technique used to achieve color constancy in photography. Without correct white balance many images show undesirable color casts. For example, a photograph taken under fluorescent light will appear green-bluish. Extensive research has been done in the area of white balance and color constancy in photography. The main differences among various algorithms are the assumptions they made about the image, the ways to retrieve or estimate illuminants from the image, and the color space being used. For example, [Buchsbaum 1980] assumes that there is a single uniform illuminant, and the color of the illuminant can be estimated by examining the color of a white patch in the scene. Some other techniques ([Brainard 1997], [Finlayson et al. 2001]) use statistical knowledge about the scene to estimate illuminant color. In terms of color space, some algorithms ([Levin et al. 2006]) work in chromaticity space and some algorithms ([Chong et al. 2007]) work in more advanced color space.

This paper makes two major assumptions about the image that distinguish it from previous research. First, it assumes that there are exactly two types of illuminant present, and their color is specified by the user. The other major assumption is that scenes can be represented by a small set of material colors. Other assumptions are also made to simplify the problem. For example, it is assumed that illuminants can be represented using RGB instead of spectral power distribution, no color bleeding is present, and no compression on the image is done.

If the observed RGB of a pixel is $\mathbf{I}$ = $\mathbf{R}(k_1\ \mathbf{L_1}$ + $k_2\ \mathbf{L_2})$(*), where $\mathbf{R}$ is the reflectance of the object at the pixel, $\mathbf{L}$ is the illuminant ($\mathbf{L} = \mathbf{1}$ if illuminant is white), and k is a scalar that captures the light intensity, then the white balance problem can be modeled as $\mathbf{WI}$ = $\mathbf{WR}$ ($k_1\ \mathbf{L_1}$+$k_2\ \mathbf{L_2}$) = $\mathbf{R}$ ($k_1\ \mathbf{1}$ + $k_2\ \mathbf{1}$). Define $\mathbf{W}$=diag(W_r, W_g, W_b), then W_c=$1/(\alpha L_{1c} + (1-\alpha)L_{2c})$ where $c \in r, g, b$ and $\alpha = k_1/(k_1 + k_2)$. The goal is to find α for each pixel. There are two major steps in the algorithm: material color estimation [Omer and Werman 2004] and mixture interpolation.

Material color estimation: Given a material color $\mathbf{R_0}$ and observed pixel color $\mathbf{I}$, use (*) to solve for k_1 and k_2. If $\|\mathbf{I}$-$max(0, k_1)\ \mathbf{R_0 L_1}$-$max(0, k_2)\ \mathbf{R_0 L_2}\|$ is less than a threshold (i.e. 0.02), then the pixel *votes* for material color $\mathbf{R_0}$. Repeat the process for another material color, until a small set of colors $\{\mathbf{R_n}\}$ is obtained.

Mixture interpolation: During material color estimation, only a subset of pixels is sampled. By manipulating (*), we can show that image chromaticities are a linear blend of the material chromaticity multiplied by the light chromaticities. The expression is similar to the classical foreground/background mixture problem in image matting. Therefore Matting Laplacian [Levin 2006] is tailored to solve the α in the white balancing problem.

An additional post-processing effects, individual light control, can be achieved by the algorithm. For example, $\alpha\mathbf{WI}$ = $(k_1/(k_1$+$k_2))\ \mathbf{R}$ ($k_1\ \mathbf{1}$ + $k_2\ \mathbf{1}$) = $k_1\ \mathbf{R}$ models the scene only lit by the first light.

The algorithm was applied to several natural and synthetic images. The result of these experiments shows that the algorithm works well for natural images that satisfy the primary assumptions. The synthetic images are created by combining images taken with a single light source. The algorithm fairly successfully identifies each illuminant and produces visually pleasant result.

In the paper, the author well stated the assumptions made in the algorithm. He also explicitly addressed the main contributions of the paper. The proposed algorithm was innovative but most of the image processing techniques were borrowed from other research paper. Furthermore, previous research([Delahunt 2004][1], [Arend 1986][2]) have shown that color constancy is closely related to human perception. This paper did not take into account any issues in the perception aspect of color constancy. It tried to achieve color constancy purely from image processing perspective. The author proposed that in the future, the algorithm could be fully automated. While it is feasible to estimate the illuminant when only a single, uniform illuminant exists, I fail to see the possibility of estimating two distinct illuminants from an image with zero knowledge beforehand. I believe that without user specification, the assumptions made about the image composition and illumination condition will be too great to generalize the algorithm.

[1] Does Human Color Constancy Incorporate the Statistical Regularity of Natural Daylight? *Journal of Vision*, 2004
[2] Simultaneous Color Constancy, *J.Opt.Soc.Am.A*, 1986