Using Illumination Information in Color Balance Adjustments

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ABSTRACT

This article discusses the relationship between lighting conditions of a natural scene and the reproduction of colors in a picture of that scene. Possibilities to use metadata concerning the origins of a picture to an advantage in color balance adjustments were studied at the Laboratory of Media Technology (Helsinki University of Technology). A prototype application for estimating the prevailing illumination conditions on the basis of source information and for utilizing the information in color balance adjustment was developed as a part of the research. The goal of the adjustments performed by the application is to produce images whose color balance is approximately in keeping with the original scene as seen in specified illumination conditions.

INTRODUCTION

Effective algorithms for automatic digital image enhancement have been developed at the Laboratory of Media Technology (Helsinki University of Technology). In a majority of photographic images these algorithms are able to correct possible deficiencies in color and contrast so as to nearly optimize the visual quality of a given image in a matter of seconds. The work described here concentrates on color balance adjustments of digital pictures. Unwanted color casts, which can be caused by many factors (such as improper scanning parameters, wrong film or filtering in traditional photography, or failure to set the white balance of a digital still or video camera properly for given illumination conditions), often severely degrade image quality. This is the case in the water-skier picture seen below. Here the greenish color cast can be easily identified and automatically corrected, resulting in the more natural-looking picture seen next to the original one.

Figure 1.   Original picture.

Figure 2.   Automatically corrected picture.

In the example above the image data (the pixel values of the digital image) was analyzed and corrected by an algorithm, with no knowledge of the image above the pixel values. While often beneficial, treating all color shifts as errors to be corrected is not always the best possible approach. Sometimes it is necessary to consider the illumination-induced variation to the human

perception of colors in the original scene to be able to recreate the feel of the scene in a picture. For instance, candle-lit scenes are seen and remembered as warm and more reddish than scenes seen in average daylight. Indeed, in the picture of the fireplace wall below, removing the red glow of the burning logs can be said to have produced a picture lacking all the mood of the original scene.

Figure 3.   Original fireplace picture.   *Figure 4.*   Automatically corrected picture.

Outdoor scenes lit by the warm light of setting sun are another good example of cases where the atmosphere desired of a picture can be ruined by completely canceling illumination-induced color shifts. Here the original picture in Figure 5, though possibly overly yellow, can even be said to be a better representation of the original scene at the time the picture was taken than the automatically adjusted picture, which has a feel of a colder midday light.

Figure 5.   Original picture.   *Figure 6.*   Automatically corrected picture.

What if we knew the prevailing illumination conditions at the time a photograph was taken? This article describes a prototype application that estimates illumination conditions based on given source information and uses this knowledge to adjust colors so as to produce pictures faithful to the mood of the original scene.

ESTIMATING LIGHTING CONDITIONS

A parameterized model of atmospheric optics can be used to estimate the spectral irradiance incident on given location at given date and time under prevailing weather conditions. Thus we can have an approximation of the illumination at the moment a photograph was taken.

Input parameters of the model include cloud type and cloud coverage, and the sun polar angle. The solar coordinates and the scattering geometry used in the model are illustrated in Figures 7 and 8. The sun position can be calculated when date and time, and geographical location are known. Thus kind of source information could be stored in image file headers and used by image processing applications.
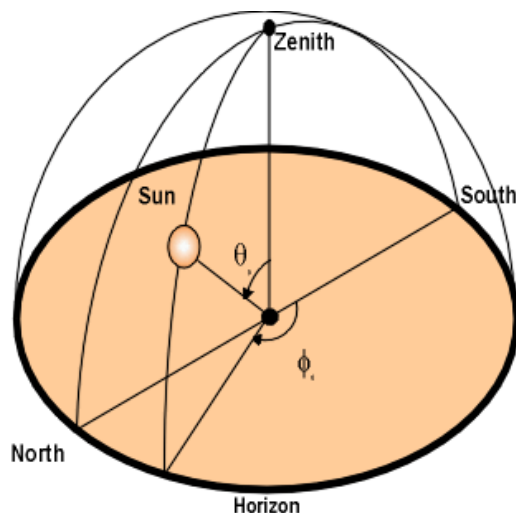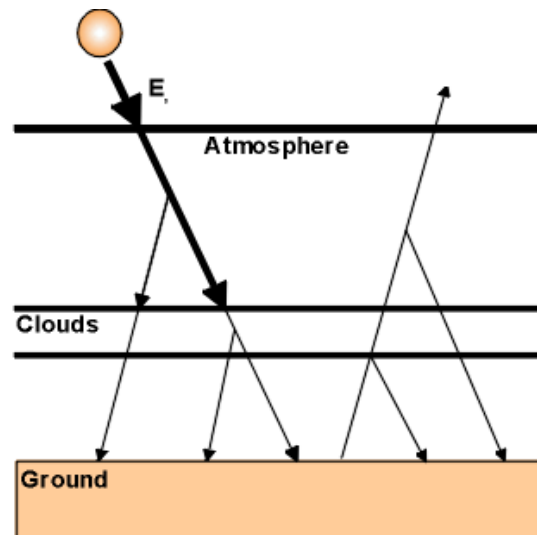

Figure 7.   Solar coordinates.

Figure 8.   Atmospheric optics.

ILLUMINATION-BASED COLOR BALANCE ADJUSTMENT

A degree of adaptation factor, D, known from the chromatic adaptation transforms of color appearance models such as CIECAM97, is used by the application to control the amount of color shift towards the color of the specified illumination in the adjusted picture. In other words, if the adaptation of the observer of the original scene to the illumination is assumed to have been incomplete, a picture with an intentional shift towards the illumination color is produced. Finding the proper value of D for natural scenes is seldom a trivial task. When the illumination color is approximately uniform across the scene, as is the case in indoor scenes lit by only one type of artificial illumination, good results can be obtained by setting the D according to the average illumination level as suggested in CIECAM97 and performing the same global adjustment for every pixel. In the case of pictures of outdoor scenes on clear conditions the task is made more difficult by variations in illumination across the scene: shadow areas receive only diffuse bluish skylight, while other parts are also illuminated by direct sunlight. The approach

taken here is to analyze and adjust the colors according to the brightest areas of the image, which are presumably those lit by direct sunlight. However, it has been observed that using only the estimated average luminance level of the scene as a guide to set the D parameter results in values corresponding to nearly 100% adaptation even in dimmer daylight; this in turn results in a too neutral reproduction of colors especially in the case of scenes lit by a sun low in the sky.

In the interactive mode the user can adjust the parameter while observing the effects on the picture; an initial estimate can be provided by the application. An example of this is given in Figure 9. The pictures have been adjusted using different degrees of adaptation; the sun was assumed to have been 2 degrees above the horizon, and the light was therefore estimated to have been quite yellow. The differences between direct sunlight and diffuse skylight can be used as further clues when setting the degree of adaptation automatically.

Figure 9.   Assumed degree of adaptation from left to right: 0%, 25%, 50%, 75%, 100%.

A REAL-LIFE EXAMPLE

The fruit composition below was photographed with a digital camera in late afternoon sunlight, producing the overly orange picture seen in Figure 10. In Figure 11 the color cast has been automatically removed, but gone are also all traces of the warm feel of the scene: the picture has neutral highlights typical of midday scenes and cold blue shadows. When the date and time, the geographical location, and weather conditions were given to the application, the spectral power distribution of the prevailing illumination at the time the picture was taken was estimated to have been as shown in Figure 13, i.e. containing more energy in the longer wavelengths associated with yellow and red colors. Armed with this information, the degree of adaptation parameter was set to an intermediate value and the picture shown in Figure 12 was produced.

Figure 10.   Original picture.

Figure 11.   Automatically corrected picture.

Figure 12.   *Picture* adjusted using the knowledge of the illumination.
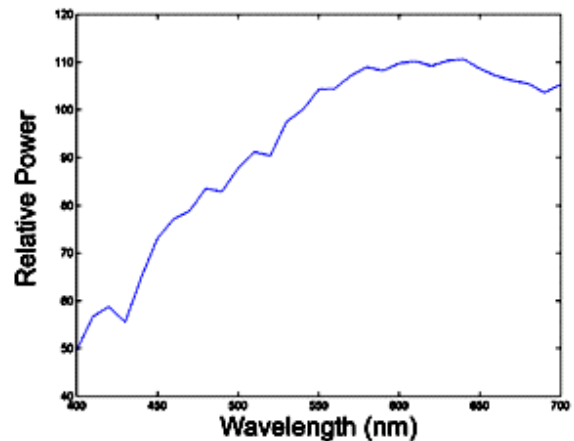

Figure 13.   Estimated relative spectral power distribution of the light at the time the picture was taken.

CONCLUSION

Although the goal of conveying in a picture the feel of certain illumination conditions cannot always be solved as a purely scientific problem, an application such as described above could prove to be a valuable tool in a number of color balancing tasks. On the interactive mode of the application, the user can manually adjust the parameters to achieve either a picture matching her mental recollection of the original scene or an illumination-based artistic effect to her liking; the color of the illumination can be exaggerated to emphasize the mood of a picture, for instance. The central question in fully automatic processing is the state of adaptation of the human visual system in varying illumination conditions; there is still a lot to be learned of human perception of illumination in complex scenes.

REFERENCES

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