Multispectral color constancy: real image tests

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ABSTRACT

Experiments using real images are conducted on a variety of color constancy algorithms (Chromagenic, Greyworld, Max RGB, and a Maloney-Wandell extension called Subspace Testing) in order to determine whether or not extending the number of channels from 3 to 6 to 9 would enhance the accuracy with which they estimate the scene illuminant color. To create the 6 and 9 channel images, filters where placed over a standard 3-channel color camera. Although some improvement is found with 6 channels, the results indicate that essentially the extra channels do not help as much as might be expected.

Keywords: color constancy, illumination estimation, automatic white balancing, multispectral imagery

1. INTRODUCTION

In an earlier study, Mosny and Funt[1] examined the effect of sensor dimensionality on the accuracy of illumination estimation for color constancy. The results reported indicated that increasing the number of sensor channels provided little benefit to the illumination estimation algorithms that were tested. Those results were based on synthetic image data. Do the same results hold for real images? We report on the performance of the same algorithms on data from real images.

Most illumination-estimation methods have been based on analyzing the RGB values from a 3-channel color image; however, two exceptions are the Chromagenic algorithm[2] which uses 6 channels, and the Maloney-Wandell[3] algorithm which is defined for an arbitrary number of channels. It might be expected that the more channels, the better, but the previous synthetic data results showed that using a multispectral camera did not necessarily lead to better illumination estimates than a standard color camera. The algorithms tested were Greyworld, Max RGB, Chromagenic, Maloney-Wandell, and a modified version of the Maloney-Wandell algorithm called Subspace Testing. The original Maloney-Wandell algorithm is not tested here because it requires the spectral sensitivity functions of the camera, and these were not available.

We present real-image tests based on 28 scenes photographed under 10 different illuminants using a standard RGB camera with added filters. The same scene is first imaged three times: once without a filter, then with a brownish 'warming' filter, and finally a bluish 'cooling' filter. Combining the 3-channel RGB images of the same scene taken under the same light but through different filters produces 6-channel and 9-channel images.

2. ALGORITHMS TESTED

Similarly to the synthetic experiments[1], we test the Chromagenic algorithm and the Subspace Testing variation of the Maloney-Wandell algorithm. These 2 methods are specifically intended for use with more than 3 channels. We also include tests of N-channel versions of Greyworld, Max RGB and the 'do nothing' algorithm. Greyworld returns the channel-by-channel means as its illumination estimate. Max RGB finds the channel-by-channel maxima. The 'do nothing' algorithm always estimates the illumination as white (i.e., all channels equal 1). The do-nothing angular error provides a measure of the variation in incident illumination and establishes a benchmark with which to compare other algorithms.

To appear in Human Vision and Electronic Imaging XII, SPIE Vol. 6492, San Jose, Jan. 2007 (Copyright SPIE 2007)

The Chromagenic algorithm[2] exploits the relationship between unfiltered and filtered 3-channel data combined into a 6-channel image. The Chromagenic algorithm first computes a linear mapping from filtered RGB responses to non-filtered RGB responses for each of a set of training illuminants. When given an input image, the Chromagenic algorithm considers each of the training illuminants in turn, and returns the one whose linear mapping best maps filtered responses to non-filtered responses as its estimate of the unknown illumination.

We do not test the Maloney-Wandell algorithm[3, 4] directly because we do not know the spectral sensitivity response functions of our camera, and they are required by the algorithm. However, we do test a modification to the Maloney-Wandell algorithm called Subspace Testing[1]. Subspace testing begins with Maloney and Wandell's observation that the camera responses will lie in a linear subspace of the N-dimensional image input space. The difference between the methods is in the way in which the subspace is identified. The Subspace Testing algorithm is trained for a set of illuminants using many images under each illuminant. For each illuminant, an N-dimensional linear subspace is fitted over the sensor responses from its entire collection of images. This hyperplane represents the gamut of possible camera responses (N-dimensional colors) under that illuminant. Maloney-Wandell fits a subspace to the set of image colors. The subspace defines the illuminant, which is then calculated using some assumptions concerning finite dimensional models of surface reflectance and illumination. Subspace Testing, on the other hand, tests the fit of the image colors to each of the training-derived hyperplanes. The illuminant associated with the best-fitting one becomes the estimated illuminant.

3. DATA COLLECTION

Altogether 28 scenes were photographed under 10 different illuminations through clear lens, warming filter and cooling filter producing a total of 840 images. The 3-channel images of the same scene taken under the same light but through different filters were combined to produce 6-channel and 9-channel images.

Figure 1. Examples of photographed scene types: books and magazines, toys, clothing, household objects, fruits and vegetables, a plant.

3.1. Scenes

All scenes contained a small number of objects placed against a background of colored cardboards. There are 6 scenes of books and magazines, 6 scenes with toys, 6 scenes that contain pieces of clothing, 6 scenes with different objects from a household, 3 scenes of fruit and a single plant scene. The color of the background cardboard was varied in order to prevent the color constancy algorithms from training solely on the background. The left side of all scenes included a Macbeth color checker. The medium grey patches of the color checker were used to determine the illuminant values. The color checker was also included during training phases of the Chromagenic and Subspace Testing algorithms. Only the right half of each image, which contains no portion of the color checker, was used during testing. Figure 1 shows the scenes illuminated with two Sylvania Soft White mini 60 13W CF13EL/MINITWIST/BL/2/CDN fluorescent bulbs.

3.2. Illumination

Illumination was provided by 10 different bulbs. Standard incandescent, tungsten-halogen, and fluorescent lamps were represented: Sylvania 60W frosted incandescent bulb, type T-3 300W clear halogen bulb mounted in a white stand-up Torchiere lamp reflecting off a wooden ceiling, 2x JRD C6010 120V 50W Cool Lamp small halogen bulb, Phillips Daylight 27W Mini Energy Twist BC-EL/MD T27DL fluorescent bulb, 2x Phillips Natural Light Plus 75W 75PAR30/NLP/FL halogen flood lights, 2x Phillips Softone Pastels 60W 60A/STP/PK incandescent bulbs, Phillips Halogen 2000 flood 90W 90PAR38/HAL/FL28 halogen floodlight, 2x Phillips Plant Light 75W 75BR30/AG60 blue frosted incandescent bulbs, 2x Sylvania Soft White mini 60 13W CF13EL/MINITWIST/BL/2/CDN fluorescent bulbs, and finally 2x GE 14W FLE14TBX/827 fluorescent bulbs. Figure 2 shows the spectral power distributions as well as plot of r=R/(R+G+B) vs. g=G/(R+G+B) values of the illuminants.

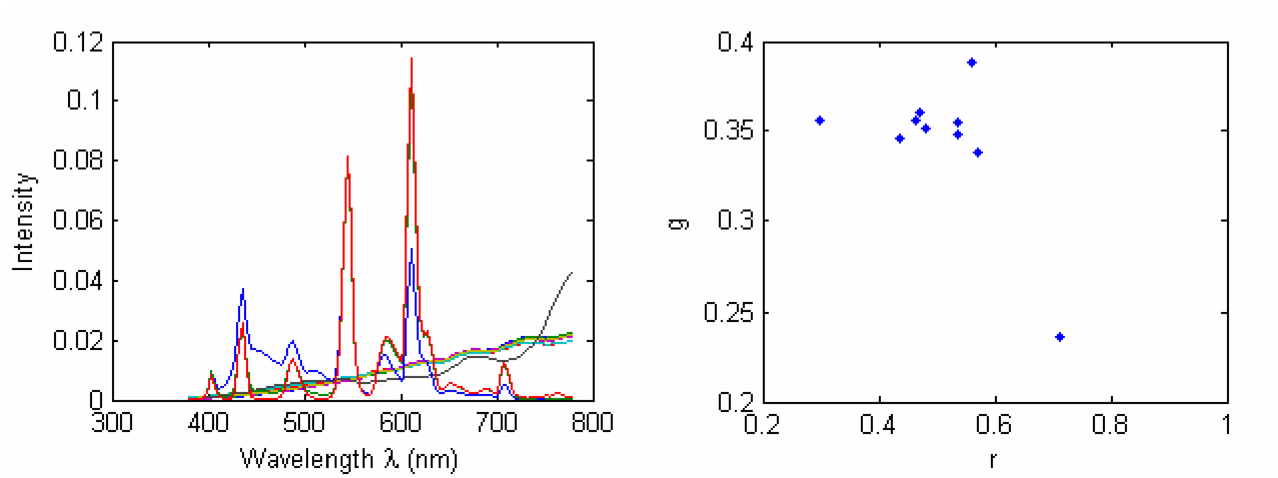

Figure 2. Spectral power distributions of the illuminants (left) and plot of r vs. g values.

3.3. Camera

Sony DSC-V1 camera was set to auto-exposure with no flash and white balance set to daylight. The camera was placed on tripod and fired through a remote control to minimize shaking.

3.4. Filters

Hoya 80A cooling (bluish) filter and Tiffen 81A warming (brownish) filters were used. The scenes were also photographed without any of the filters. Figure 3 shows spectral transmittance of the cooling and warming filters as measured using a Photo Research PR650 spectroradiometer.

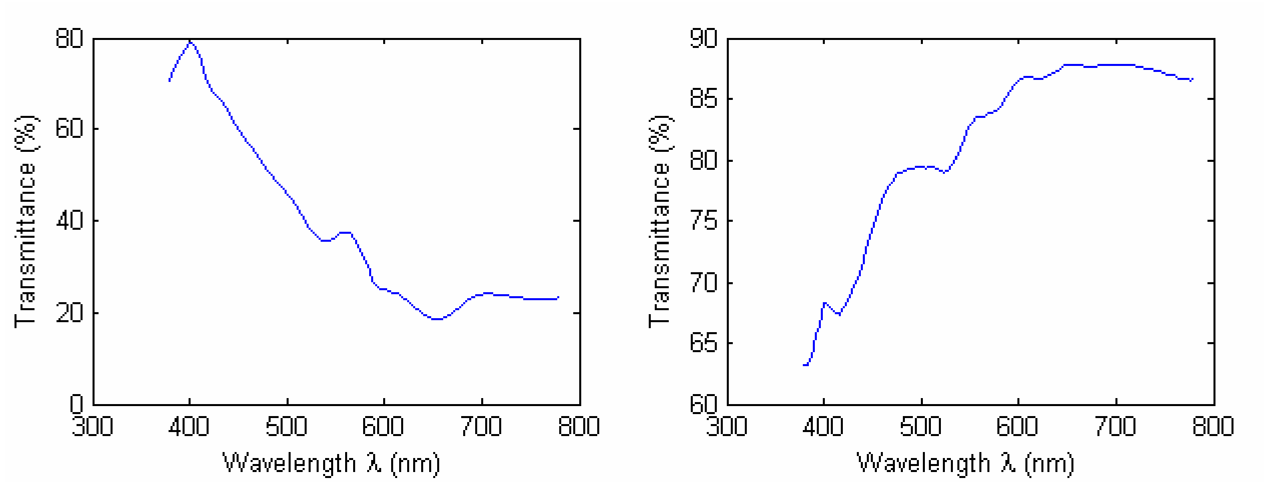

Figure 3. Left: percent spectral transmittance of the cooling filter. Right: percent spectral transmittance of the warming filter.

3.5. Multi-channel image composition

The cooling filter shifts sensor sensitivities towards the shorter wavelengths, and the warming filter shifts sensor sensitivities towards the longer wavelengths. Thus, combining multiple 3-channel images of the same scene taking under different filters amounts to taking a single multi-channel image. The technique of placing filters in front of a 3-channel camera has been used previously to obtain multispectral images[5, 6, 7]. Due to the fact that the camera was mounted on a tripod with very little or no movement, the images taken with different filters could be overlaid to produce multi-channel images. This procedure resulted in images of 3, 6 and 9 channels: a 3-channel image set taken with no filter; two 6-channel image sets constructed by combining no-filter images with cooling filter images, and by combining no-filter images with warming filter images; and a 9-channel image set constructed by combining no-filter images with both the cooling and warming filter images.

4. RESULTS

Table 1 compares the performance of the various algorithms for 3, 6, and 9-channel images as described above. It tabulates the results in terms of the median angular error in image response space (Image), and for illuminant estimates converted to rgb space (Lookup RGB). The angular error is measured between the N-channel camera response to the actual illumination, and the N-channel response to the estimated illumination. For the 'Lookup RGB' case, the N-channel illumination estimate is first converted into an rgb estimate, and then the angle is measured in 3-space. The conversion is done by looking up the closest N-channel illuminant from a database of known illuminants, and using its rgb as the conversion value. Table 1 also shows the maximum error (Max Lookup RGB). Overall, the results in Table 1 indicate a slight improvement in performance of the algorithms in moving from 3-channel to 6-channel images. Adding the cooling filter makes slightly more difference than adding the warming filter. Moving from 6 to 9 sensors leads to no additional improvement.

Table 1. Performance of the various algorithms for 3-channel, 6-channel and 9-channel data.

	3-channel rgb without filters			**6-channel using cooling filter**			**6-channel using warming filter**			**9-channel using cooling and warming filters**		
Algorithm	**Median Angle**	**Median Lookup RGB**	**Max Lookup RGB**	**Median Angle**	**Median Lookup RGB**	**Max Lookup RGB**	**Median Angle**	**Median Lookup RGB**	**Max Lookup RGB**	**Median Angle**	**Median Lookup RGB**	**Max Lookup RGB**
Max RGB	9.30	**7.80**	24.99	7.99	**6.01**	17.90	9.73	**7.93**	26.39	8.74	**6.25**	17.76
Greyworld	8.37	**3.80**	25.27	8.58	**3.81**	24.43	8.52	**4.31**	26.96	8.44	**3.52**	23.49
Chromagenic	n/a	**n/a**	n/a	5.64	**4.98**	36.56	7.86	**8.25**	39.32	6.45	**5.93**	35.42
Subspace Testing	5.54	**5.54**	33.07	5.51	**3.87**	25.22	5.83	**5.61**	29.71	5.33	**3.98**	29.97
Do nothing	24.29	**27.53**	45.91	18.63	**11.97**	28.00	25.42	**27.34**	45.82	21.43	**27.75**	46.23

5. CONCLUSION

Experiments with real image data are similar to the earlier findings on synthetic data, which showed that multispectral imagery does not necessarily benefit illumination-estimation algorithms. In the case of the real data, the subspace testing algorithm is helped somewhat more by going to 6 channels than it was in the synthetic case. Overall, it is surprising that the additional information provided by the additional sensor channels does not lead to substantially more improvement than actually occurs. It is important to note that the experiments reported here do not prove that multispectral data will never help in illumination estimation. They only demonstrate that it does not help for the sensors, scenes and algorithms used in the tests.

ACKNOWLEDGEMENT

This research was supported by a grant from the Natural Sciences and Engineering Research Council of Canada.

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