Colour Constancy using Sub-blocks of the Image

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Abstract— **Colour constancy is the ability to measure the colour of objects independent of the light source, while colour casting is the presence of unwanted colour in digital images. Colour casting significantly affects the performance of image processing algorithms such as image segmentation and object recognition. The presence of large uniform background within the image considerably deteriorates the performance of many state of the art colour constancy algorithms. This paper presents a colour constancy method using the sub-blocks of the image to alleviate the effect of large uniform colour area of the scene. The proposed method divides the input image into a number of non-overlapping blocks, and Average Absolute Difference (AAD) value of each block colour component is calculated. The blocks with AAD greater than threshold values, which are empirically determined for each colour component, are considered to have sufficient colour information. The selected blocks are then used to determine the scaling factors to achieve achromatic values for the input image colour components. Comparing the performance of the proposed technique with the state of the art methods using images from three datasets shows that the proposed method outperforms the state of the art techniques in the presence of large uniform colour patches.**

Keywords- colour constancy; colour balancing; uniform colour; average absolute difference.

I. INTRODUCTION

Human vision is enabled with the ability to perceive and recognise object's colours regardless of different light colours and luminous intensities under which it is observed. This feature of the human eye is called colour constancy [1]. The colour details of a scene in an image acquired by a modern digital image acquisition device like a digital Singe Lens Reflex (SLR) camera, handheld point and shoot camera or a smartphone camera, may not be same as they are perceived by human vision [2]. A digital camera incorporates the functions of reading light intensity and its colour details through a single sensor. The light intensity details are used by the camera software to match with sensor's colour signals for each pixel to form an image. Analogous to human eyes ability to maintain colour constancy, digital cameras are enabled with colour compensation capability called the White Balancing (WB) function [3]. However, the signal's colour dependency on luminous intensity limits the camera's colour compensation ability and it is prone to produce colouration or colour casts due to variations in intensity or colour of the source light that illuminates the object or the scene. Researchers have proposed various algorithms to correct colour casts or colouration of the images such as: the Grey World assumption (GW) [4], Max-RGB algorithm [5], Modified White Patch [6], Shades of Grey [7], 1st order Grey Edge [8], 2nd Order Grey Edge [8] and Weighted Grey Edge [9], over the years. Colour constancy algorithms aim to adjust the colours of the image, to look like as if it is captured from a scene that is illuminated by canonical (white) light source. Colour constancy is usually performed in two stages. In the first stage, the scaling factor for each of the three colour components of the input image is calculated and in the second stage; the resulting scaling factors are applied to the input image to compensate any colour casts or colourations within the image [10, 11].

The Grey World algorithm assumes that the averages of the three colour component of the image, taken from a scene illuminated by a neutral light source are equal. Hence, the performance of this algorithm is dependent on the image scene colour and its processed images are biased towards the dominating colour of the scene [12]. The Max-RGB algorithm is based on the Retinex theory of the human visual system and as per this theory, the perceived white is associated with the maximum cone signal. In practice, this assumption is supplemented by computing the maximum response of the R, G and B colour components of the image. The scaling factor for each image colour component is determined by dividing the average of the maximum of the columns of the image colour component by the average of the maximum values of the columns of that colour component of the image. However, the data dependency of the Max-RGB algorithm could result in inaccurate image colour adjustments [5]. The Max-RGB like colour balancing method, known as Modified White Patch technique, produces superior results to that of the Max-RGB technique by adjusting just the red and blue colour components of the image. However, images produced by this method do not always satisfy the Retinex theory criteria [6]. The Shades of Grey colour constancy algorithm is based on the fact that the Minkowski norm-p (related to the generalised mean or power mean) of a scene is achromatic. The experimental results of Shades of Grey algorithm showed that the best performance of the algorithm is achieved at norm-p equal to 6 [7]. A colour constancy technique, called Grey Edge method, was proposed in [8]. The Grey Edge method uses objects edge information to adjust image colour constancy; it assumes that the average absolute derivatives of the image colour components is achromatic. In this method each colour channel pre-processed by the Gaussian filter with standard

deviations of 1-2 to determine 1st and 2nd order of the Grey Edge assumption. Although smoothing the image before applying the edge detection improves the robustness of the technique to noise but may deteriorates the effectiveness of the technique. The Weighted Grey Edge method uses edge information of the various objects, for instance, shadow and highlight to calculate the scaling factors for different colour components [9]. A colour constancy algorithm based on saturation free white point detection using the dark channel prior method was introduced in [13]. This method is efficient at detecting pure white pixels. However, the dependency of the algorithm on the bright pixels' values leads to an inconsistent estimation of the light source. Consequently, the algorithm fails to accurately colour balance the image. A computationally less intense colour constancy algorithm based on adaptively stretching the histogram information of the image data was proposed in [14]. This method changes the intensity of the image, which is not acceptable in some applications. From the literature, it can be seen that colour constancy algorithms have some levels of data dependency; hence their effectiveness in adjusting the colour constancy of the image is deteriorated in the presence of uniform colour areas within the image.

This paper presents a colour constancy technique, which its performance is less sensitive to uniform colour patches within the image. The proposed method divides the input image into non-overlapping blocks. Each resulting block's colour component is assessed to exclude uniform colour blocks' image pixel values from being used for calculating image colour constancy scaling factors. Experimental results on images of three standard image datasets, shows the effectiveness of the proposed technique to that of state of art techniques. The rest of the paper is organised as follows: Section 2 presents the proposed colour constancy algorithm, experimental results are given in Section 3 and finally Section 4 concludes the paper.

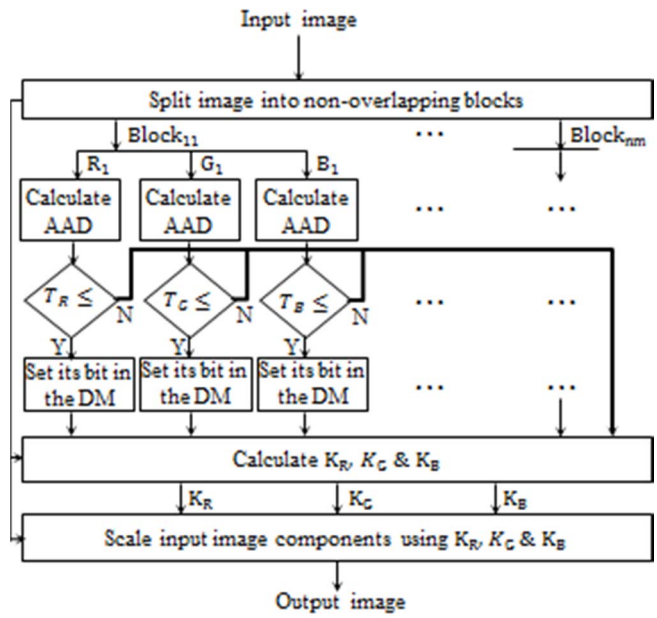
II. Colour Constancy using Sub-Blocks of the Image

A block diagram of the proposed Colour Constancy using Sub-blocks of the Image (CCSI) method is illustrated in Fig. 1(a). The algorithm takes a colour image and divides it into a number of $N \times M$ non-overlapping pixel blocks called B_{11} to B_{nm}, as shown in Fig. 1(b). The rest of the proposed algorithm is as follows:

i. The Average Absolute Difference (AAD) values of R, G and B components of each image block are then calculated using equation 1:

$$ADD_C = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}(|C(i,j)-\bar{C}|)}{N \times M} \quad (1)$$

where C represents R, G or B component of the block; AAD_C is the Average Absolute Difference of the C component's intensity values; $C(i,j)$ is the C component intensity value at position (i,j) of the block; $\bar{C}$ is the average intensity value of the C component of the block's pixels and N and M are the size of the block.



(a)

AAD: Average Absolute Difference
DM: Decision Matrix
T_R, T_G, & T_B: Threshold values for R, G &B components
K_R, K_G K_B: R, G & B components scaling factor

B_{11}	B_{12}	...	...	B_{1m}
B_{21}	B_{22}	...	...	B_{2m}
...	...	B_{ij}	...	...
...	...	...	...	...
B_{n1}	B_{n2}	...	...	B_{nm}

(b)

Fig.1. (a) Block diagram of the Colour Constancy using Sub-blocks of the Image (CCSI) method and (b) non-overlapping blocks of the image.

ii. The resulting AAD_R, AAD_G and AAD_B values are compared with the empirical threshold values for R, G and B components called: T_R , T_G and T_B , respectively. If the AAD_C of the block component is greater than its predefined threshold value, this block's component does not represent a uniform colour area. Hence, it is selected to be used for colour constancy computation.

iii. A bit representing this block's component in the Decision Matrix (DM) will be set to one (A binary Decision Matrix for each image colour component is created to keep a record of the selected blocks. The DMs are initialised to zero.).

iv. The selected blocks that carry sufficient colour information are processed to determine the scaling factors, named: K_R, K_G, and K_B, for R, G and B components of the input image, respectively, using (2):

$$\overline{SB} = \frac{\sum R_{SB} + \sum G_{SB} + \sum B_{SB}}{N_{R_{SB}} + N_{G_{SB}} + N_{B_{SB}}}$$

$$K_C = \overline{SB} \Big/ \frac{\sum C_{SB}}{N_{C_{SB}}} \qquad (2)$$

where $\overline{SB}$ is the average value of the selected blocks' coefficients; $\sum R_{SB}$, $\sum G_{SB}$ and $\sum B_{SB}$ are the total intensity values of the R, G and B pixels of the selected blocks, respectively; $N_{R_{SB}}$, $N_{G_{SB}}$ and $N_{B_{SB}}$ are the total number of the R, G and B coefficients in the selected blocks, respectively; $\sum C_{SB}$ shows the total value of the coefficients in the selected C components, where C can be R, G or B component; $N_{C_{SB}}$ is the number of coefficients in the selected C component and K_C represents the calculated scaling factor for component C of the image.

v. R, G, and B components of the input image are then scaled using the resulting K_R, K_G and K_B scaling factors, respectively, to generate the colour balanced output image.

The performance of the illuminant estimation of the proposed CCSI method as a function of its thresholds values, T_R, T_G and T_B, were investigated using outdoor images from the Ciurea and Funt [15], Photos Futta.NET [16] and Gehler [17] datasets. The empirical value for each block's component was determined as follows:

i. Assign 0.05 to threshold value.

ii. Apply the block selection of the algorithm on the each of the image component's blocks.

iii. Visually inspect the selected blocks.

iv. If blocks containing uniform intensity values are excluded, go to the step vi.

v. If blocks containing uniform intensity values are not excluded, increase the current threshold value by 0.05 and go to step ii.

vi. Assign the current threshold value to the empirical threshold value.

The average of the resulting threshold values for different images were chosen as the general empirical values for the proposed algorithm, which are $T_R = 1.70$, $T_G = 0.75$ and $T_B = 0.5$.

III. Experimental Result and Evaluation

In this section, the experimental results derived by testing the proposed Colour Constancy using Sub-blocks of the Image (CCSI) and Histogram Stretch [14], max-RGB [5], Modified White Patch [6], Shades of Grey [7], Weighted Grey Edge [9], 1st Order Grey Edge [8], 2nd Order Grey Edge [8] and GW [4], methods are given. 11346 images (each image is in is in 240×360 pixels resolution), captured by Ciurea and Funt [15], 3000 images from Japan Photos Futta.NET [16] and 568 images from Gehler datasets [17] were used for assessing the performance of the CCSI technique. The Gehler dataset contains people, places and various objects, from indoor and outdoor scenes, where a Macbeth colour checker is placed in a known location of every scene of the images. For the Gehler dataset, captured images were automatically white balanced by the camera [18].

Colour constancy performance measurement algorithms are grouped into two main categories, called objectives and subjective methods. Objective methods evaluate the performance of an illuminant estimation algorithm by comparing the estimated illuminant to a ground truth. Euclidean distance and the angular error are the two frequently used objective measurements criteria. The value of these two distance criteria shows how close the colour balanced image is to the ground truth. However, it is not clear how these distances correspond to perceived differences between the colour-balanced and ground truth images [19]. Moreover, objective assessment methods always require the ground truth to be known, which is not usually the case [20]. Since human eyes are the final and most reliable judge for assessing the quality of the colour balanced images, many researchers have used subjective methods to evaluate the performance of the colour constancy techniques.

In order to compare the performance of the proposed CCSI algorithm with the state of the art techniques, the proposed method and other state of the art algorithms were applied to the three image datasets. Results show that the proposed technique outperforms the state of the art techniques; in the following some colour compensated images from the proposed algorithm and state of the art techniques are presented. To illustrate the visual quality obtained by using the proposed method in comparison to the state of the art methods, one image from Gehler and another image from Futta.NET datasets with various visual contents, including uniform patches, are chosen and colour balanced. The resulting images are shown in Fig. 2-3. For accuracy, the observations have been done using a 42-inch full high definition screen of 1920×1080 resolution.

Fig. 2a shows a sample image from Gehler dataset, which is shot in daylight with blue-white sky background, with some greenery in the center of the image and a well-illuminated building with a colour checker next to the wall in the foreground.

Fig. 3a shows an image from Futta.NET dataset, which appears to be a fall season morning shot of a street with clear blue sky, trees with dried leaves and sparsely spread dried leaves covering most of the foreground. The blue sky and the road in the mid-ground are well lit by the morning sunlight from the right side of the frame; however the foreground has large paths of tree shadows, which makes it less illuminated than the rest of the image.

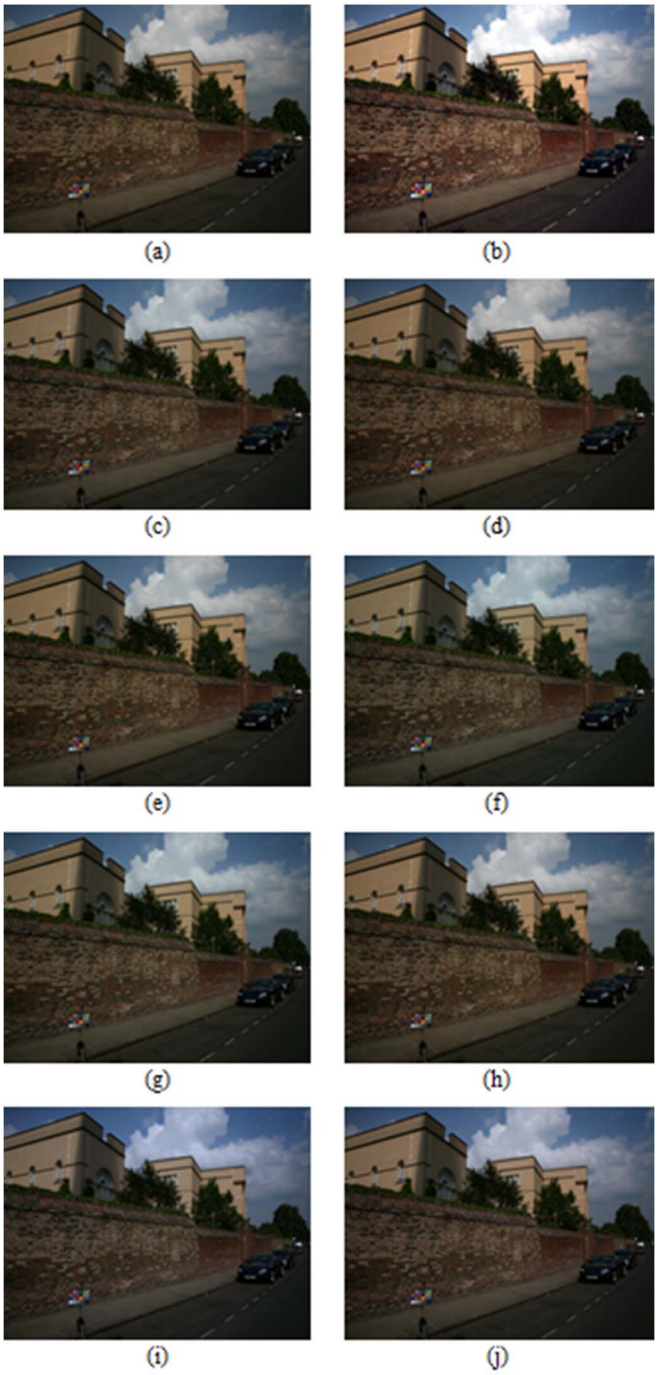


Fig.2. Original and colour balanced images from various techniques: a) Original image from Gehler dataset b) Histogram Stretch c) Max-RGB d) Modified White Patch e) Shades of Grey f) Weighted Grey Edge g) 1st Order Grey Edge h) 2nd Order Grey Edge i) Grey World and j) Proposed CCSI method.

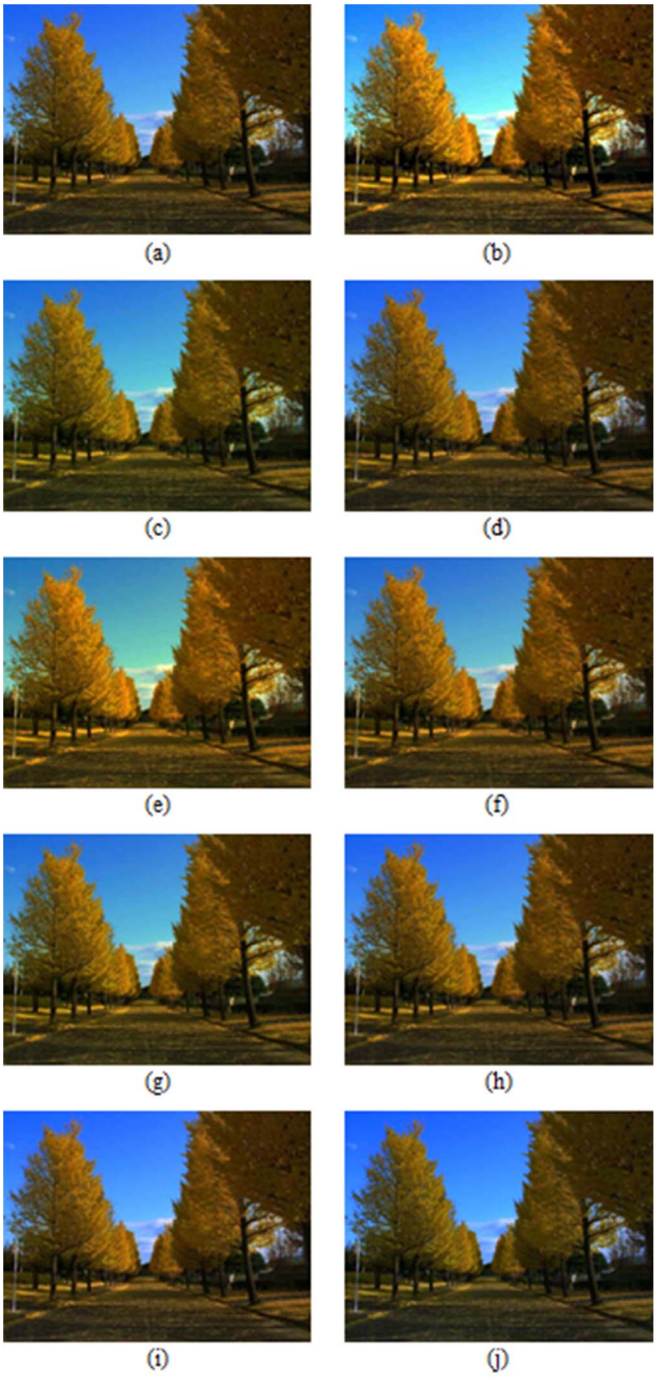


Fig.3. Original and colour balanced images from various techniques: a) Original image from Futta.net dataset b) Histogram Stretch c) Max-RGB d) Modified White Patch e) Shades of Grey f) Weighted Grey Edge g) 1st Order Grey Edge h) 2nd Order Grey Edge i) Grey World and j) Proposed CCSI method.

Fig. 2b-2j and 3b-3j show the colour balanced images using Histogram Stretch [14], max-RGB [5], Modified White Patch [6], Shades of Grey [7], Weighted Grey Edge [9], 1st Order-Grey Edge [8], 2nd Order Grey Edge [8], Grey World [4] and the Proposed CCSI method, respectively.

Fig. 2b and 3b show the colour balance images using the Histograms Stretch method. From these images, it can be seen that mid-tones and shadows of the images have been enhanced with respect to the original images. From the max-RGB algorithm images in Fig. 2c and 3c noticeable colour correction in the foreground objects of both images are obvious. In addition, the images with a very subtle light yellow tint and a mild colour cast on the grey path near the brick wall are evident. The colour constancy performance of Modified White Patch colour balancing method is show in fig. 2d and 3d. Comparing with their respective original images, it can be seen

these images are very similar to their originals. However, fig. 2d exhibits slight yellow colour casting on the buildings and wall area. The Shades of Grey colour compensated images are shown in fig. 2e and 3e. As it can be seen from fig. 2e, the processed image does not exhibit noticeable changes with respect to its original image while the image in fig. 3e shows a warm yellow shade on the tree and pathway. Fig. 2f and 3f illustrate Weighted Grey Edge method images. From these figures, it can be seen that the images demonstrate higher colour constancy in comparison to those of Shades of Grey method images while they show a slight improvement in compare to images of the grey patches. However, these images do not show sufficient colour consistency in the mid-tone and highlight areas of the images. Fig. 2g and 3g show images of the 1st Order Grey Edge method, and it is observed in these images that they exhibit little improvement in the grey parts and mid-tones area of the images. Although, they do not have sufficient colour constancy in the highlights and shadows area of the images. The 2nd Order Grey Edge method images are shown in Fig. 2h and 3h. From these figures, it can be seen that the shadows and mid-tones have been enhanced with a slightly warmer colour tone, but not fully in a neutral tone. However, there is not much noticeable improvement in these images. Grey world images are shown in Fig. 2i and 3i. From these figures, it can be seen that the sky area of the images exhibit near natural blue colours, also the pathway areas of the images are fairly well colour balanced. However, the foreground objects such as buildings and the wall in fig. 2i do not demonstrate convincing colour constancy. Also, the presence of dominant single colour regions has not been well handled by this method, and there is a subtle yellow tone the image, which is more obvious in Fig. 3i. The proposed CCSI method images are presented in Fig. 2j and 3j. These images exhibit distinct natural colours on both images. In comparisons to other presented techniques' images, the proposed method's images demonstrate significantly higher colour consistency and natural looking, 'true' colours, in images while successfully maintaining a neutral colour tone.

IV. Conclusion

This paper presented an effective way of exploiting colour variation among the pixels of an image to solve the colour constancy problem. The aim of the proposed algorithm was to circumvent an over-reliance on the large uniform colour part of the image, which significantly affects the performance of most of the colour constancy algorithms. To furtherance the determination of enriched coloured blocks, the input image was divided into a number of non-overlapping blocks. The average absolute difference value of each block's colour components was calculated and used to determine if the block has sufficient colour information to be used for colour constancy algorithm. The selected image blocks' components were used to calculate the scaling factors for the input image. Results on images of three datasets show a significant performance improvement of the proposed algorithm over the state of the art techniques.

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