THREE DIMENSION PIXEL DISTRIBUTION SHIFTING BASED COLOR CORRECTION METHOD FOR DIGITAL IMAGES

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By

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LIST OF ABBREVIATION

2D	Two Dimensions
3D	Three Dimensions
AMBE	Average Mean Brightness Error
CVT	Computer Vision Techniques
FPGA	Fixed Programmable Gate Arrays
GW	Grey World
HVS	Human Vision System
MW	Max White
PSCC	Pixel Shifting Color Correction
SG	Shades of Grey
WB	White Balancing

NEW COLOR CORRECTION ALGORITHM
FOR DIGITAL IMAGES

ABSTRACT

Color correction algorithm for a color digital image is important to reduce the influence of inhomogeneous surrounding illumination in color digital image. Commonly, existing color correction algorithms are divided into two main phases, namely color estimation and color correction. Although there are various color correction algorithms introduced by other researchers, the output images created still face some problems. Some algorithms still produce non-uniform illumination resultant image, while others methods still produce over-corrected problem in the resultant images. Thus, in this study, new color correction algorithm was developed to overcome the weaknesses of those conventional algorithms. The introduced algorithm is named as Three Dimension Pixel Shifting Color Correction (3D-PSCC). There are two variations of 3D-PSCC, which are 3D-PSCC based on RGB color channel and 3D-PSCC based on CIE*Lab color channel. Both proposed algorithms employ color correction process by shifting the pixel distribution based on the 3D three color channels planes. From the qualitative analysis results, the 3D-PSCC algorithm based on RGB color channels is able to produce better resultant images for underwater images. The bluish of the images are reduced significantly and the color of the object captured is able to be determined easily. The 3D-PSCC algorithm based on CIE*Lab color channel, on the other hand, is more suitable to correct the overexposed images. This algorithm ensures loss of information does not occur during image enhancement process. Besides that, the quantitative analysis also proves that the proposed algorithms introduced not only have the ability to correct the color of the image, but are also able to remain the brightness of the image.

ALGORITMA-ALGORITMA WARNA PEMBETULAN BAHARU UNTUK IMEJ DIGITAL BERWARNA

ABSTRAK

Algorithma warna pembetulan untuk imej digital warna adalah penting untuk mengurangkan pengaruh pencahayaan sekeliling yang tidak sekata dalam imej digital warna. Biasanya, algoritma-algoritma warna pembetulan dibahagikan kepada dua fasa utama iaitu penganggaran warna dan proses pembetulan warna. Walaupun terdapat pelbagai algoritma warna pembetulan telah diperkenalkan oleh penyelidik-penyelidik lain tetapi imej yang dihasilkan masih menghadapi beberapa masalah. Beberapa algoritma masih menghasilkan imej berwarna yang tidak sekata, manakala kaedah-kaedah lain masih menghasilkan imej-imej yang terlebih pembetulan. Oleh itu, dalam kajian ini, algoritma warna pembetulan baharu akan diperkenalkan untuk mengatasi kelemahan-kelemahan algoritma konvensional. Algoritma diperkenalkan dalam kajian ini dinamakan sebagai Tiga Dimensi Pembetulan Warna Anjakan Piksel (3D-PWAP). Di dalam kajian ini, dua jenis 3D-PWAP akan diperkenalkan iaitu pertama 3D-PWAP berdasarkan saluran warna RGB dan 3D-PWAP kedua berdasarkan saluran warna CIE*Lab. Kedua-dua algoritma yang dicadangkan menggunakan proses pembetulan warna dengan peralihan pengedaran piksel berdasarkan pada satah 3D tiga saluran warna. Daripada keputusan analisis kualitatif, algoritma 3D-PWAP berdasarkan saluran warna RGB dapat menghasilkan imej yang lebih baik bagi imej di bawah laut. Kebiruan imej dikurangkan dengan ketara dan warna objek yang ditangkap dapat ditentukan dengan lebih mudah. Algoritma 3D-PWAP berdasarkan saluran warna CIE*Lab adalah lebih sesuai untuk membetulkan imej yang mempunyai kawasan terlebih pendedahan. Algoritma ini memastikan kehilangan maklumat tidak akan berlaku semasa proses pembetulan imej. Selain itu, analisis kuantitatif juga menunjukkan bahawa algoritma

yang dicadangkan bukan sahaja mempunyai keupayaan untuk membetulkan warna imej, tetapi juga dapat mengekalkan kecerahan imej.

CHAPTER 1

INTRODUCTION

1.1 Research Background

Nowadays, the computer vision techniques (CVT) are widely used for solving the problems related to an image. These techniques used for analyze image must have high performance to ensure that the results obtained are fast and accurate. Human errors can be minimized by using the techniques are proved in [1]. As an example, the CVT can be applied in industry field to ensure that the manufactured products are in good condition. The techniques help the industry to increase the efficiency of quality checking.

The CVT can be divided into two parts. The first part is the capture of an image and the following part is an analysis of the image. The process of CVT is almost same as our human vision system (HVS). The HVS and CVT can be easily explained by Figure 1.1.

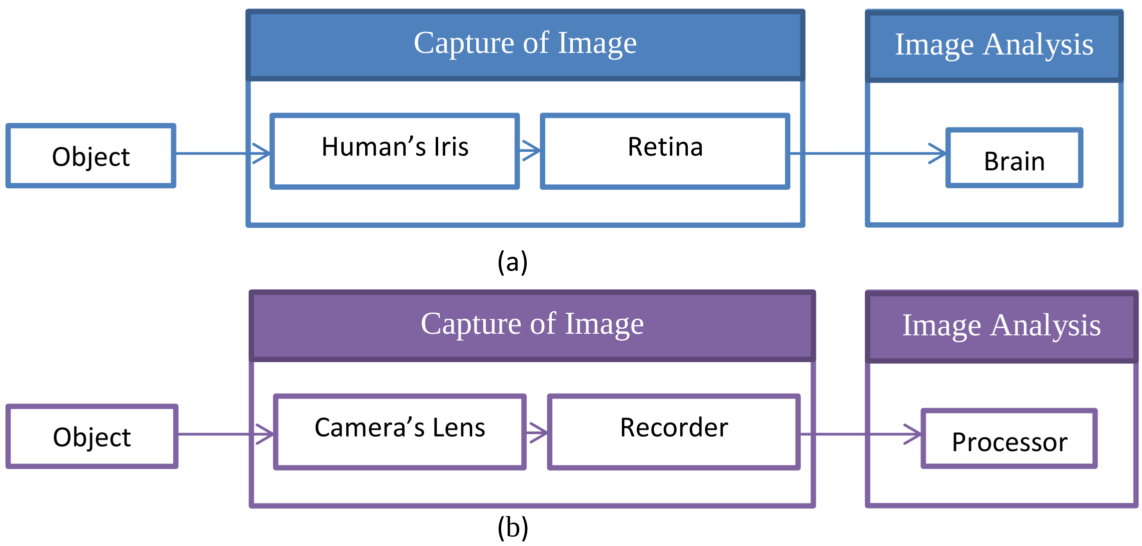


Figure 1.1: The process of capture image and image analysis by (a) HVS, (b) CVT

From the Figure 1.1, the HVS and CVT are started by capturing an object. For HVS, the image of the object is captured by human eyes. The image enters into human's iris and sends to the retina. After that, the image is analyzed by our human brain. However, the image is captured by digital electronics in the CVT. The image enters the lens and then the recorder of the camera. The image is analyzed by the processor in the camera [2].

The advantage of HVS is the light intensity entering the iris can be easily controlled. In the darker condition, the eye lens is opened to a larger size to allow enough light intensity entering into the iris. While in the bright condition, the eye lens is closed to a smaller size to prevent too much light entering to the iris. Consequently, human's neutral system is able to analyze the image with the different light condition. However, the camera lenses do not have this function. The size of the lenses is unable to react in very short time as the human. Hence, the light intensity captured is unstable. The image captured is overexposed when the there is too high light intensity enters to the lens. At the same time, the underexposed image is captured when there is a low light intensity enters to the lens. Figure 1.2 shows the image captured under bright, normal and dark condition.

(a) (b) (c)

Figure 1.2: Image with (a) Overexposed problem (b) Normal (c) Underexposed problem

From the comparison of Figure 1.2 (a) and (c), the differences of the image are obviously detected. In the overexposed image, there are a lot of pixels of the image consist of the maximum value (255). While the number of pixels' value in the underexposed image near to minimum value (0) is a large quantity. The average value in the pixels of the normal image is almost half of the maximum value.

1.2 Problem Statement

There are two steps needed for the image enhancement as shown in Figure 1.3. The first part is the color estimation of the image. This step is carried on for the determination of the light source of the image. After the color estimation, the color channels of every pixel in the image are updated to retrieve the image.

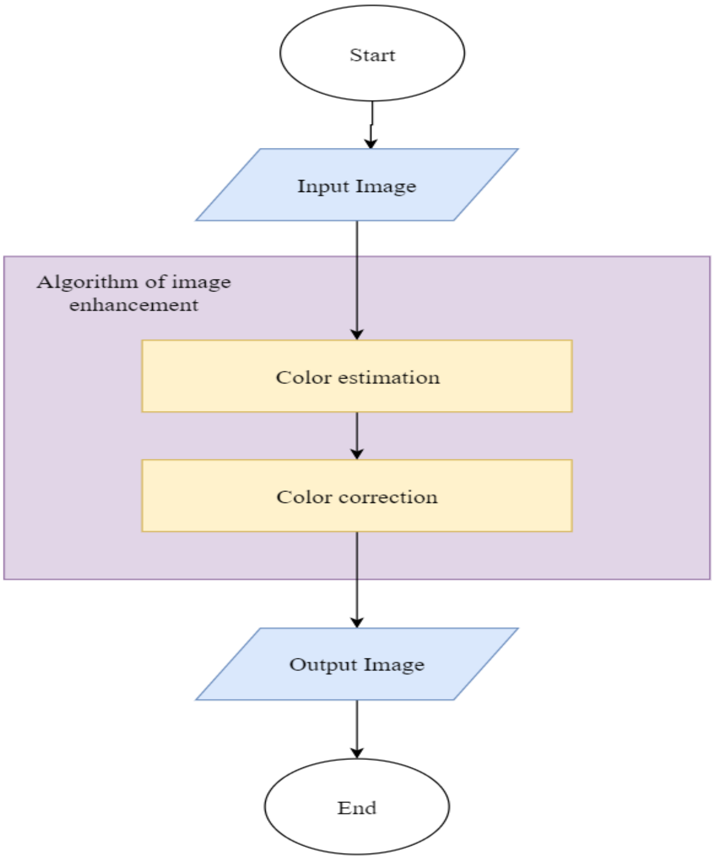
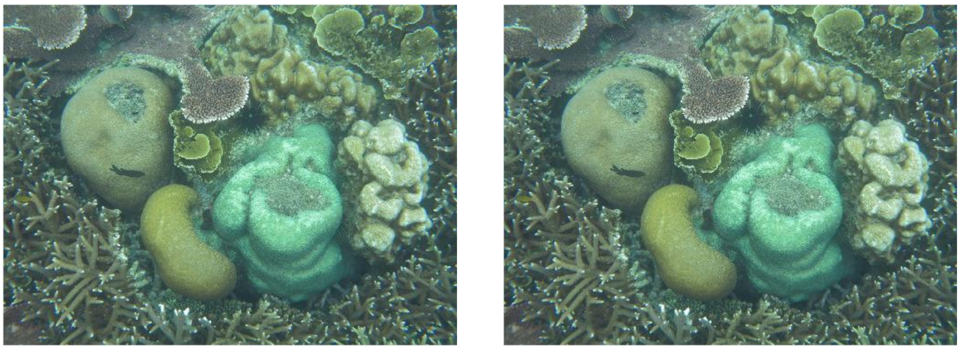


Figure 1.3: The flowchart of algorithm of image enhancement

Although there are some studies had done for enhancing a digital image, the methods proposed still face some problems. On the other hand, the current algorithms introduced also have their own advantages. As an example, the algorithm based on Gray World is simple and the processing time required is short. However, there are some processes should be changed or added to develop a new and better algorithm. By using the hypothesis made by Von Kries [3], reference point for the correction of the RGB channels of the pixel in the image can be obtained. The corrections to the three color channels are linear and affect some pixels are concentrated at maximum or minimum value. For the pixel which originally near to the maximum or minimum value, the corrections done are ineffective because the corrected pixels' value is unable to exceed the maximum or minimum value. Hence the loss information of the digital image occurs. From Figure 1.4, the corrected image shows the weakness of Von Kries hypothesis. The enhanced image is exactly same as the original image. The new algorithm which able to prevent the saturation of color contents should be developed to overcome the problems occurs while only Von Kries Hypothesis is used.



(a) (b)

Figure 1.4: Image with (a) Original (b) enhanced by Von Kries Hypothesis

1.3 Research Objective

To solve the problems mentioned in Section 1.2, there are some tasks needed to be done to overcome those problems. There are two objectives are set as stated below:

(a) To develop an algorithm which is able to enhance the image by using the **3D** Pixel Distribution Diagram.

(b) To develop an algorithm which is able to enhance the image based on **RGB** and **CIE*Lab** color channels.

1.4 Research Scopes

The image processing for a digital image is a large field. There are some scopes set for ensuring the research can be done efficiently. The digital image is able to save in several formats such as RGB, XYZ, HSL, CIE Lab, etc. In this study, images in RGB and CIE Lab formats are studied in this research.

Besides that, the number of bits per pixel consisted in RGB and CIE Lab can be either 24-bits or 48-bits. The second scope is only the 24-bits format is covered in this research. This target set because mostly the images captured nowadays are saved in 24-bits. The 48-bits image is only used in some high-ended systems which are not commercially used. The platform used for the image enhancement technique is QT creator. The programming language used is C++ programming. The algorithm proposed is mainly focus on enhancement of daily life photos and underwater images. 100 daily life photos and 100 underwater images will be tested after the development of the algorithm to ensure that the proposed algorithm is effective to correct the color of the image.

1.5 Chapter Organization

The report consists of five chapters. Chapter 1 is the introduction of the research background, problem statement, objectives, and scopes of this research.

Chapter 2 will focus on the literature review. The theory of the digital image and the common problems occur in a digital image are reviewed and studied. Besides that, the conventional algorithms for color correction of the image developed are analyzed. The strength and the weakness of those conventional algorithms are investigated. The factors that contribute to advantages and weaknesses of those algorithms are reviewed as well.

Chapter 3 presents the steps to develop the proposed algorithms. The details of their implementation are presented in this chapter. Chapter 4 is the chapter to show the results of the algorithms developed. The performance comparisons with conventional algorithms are studied and presented to prove that the new proposed are better than the current algorithm.

The last chapter (Chapter 5) is the summary of the whole research had done. Besides that, the future development of this research is also suggested in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter starts with a review about the process for taking a color digital image. The important characteristics considered for taking an ideal image will be also discussed. After the characteristics of the image discussed, the following part of this chapter will be an introduction to the problems faced by the digital image. The issues faced by the digital image will be described in Section 2.3. There are some methods suggested solving those problems specifically. In this study, the color correction will be focused on improving the quality of the digital image.

Until now, there are algorithms which are proposed to correct the color content in color digital image. The algorithms can be divided into two parts, which are image data acquiring and image data correction. These processes will be discussed further in Section 2.4. Besides that, the advantages and disadvantages of each current algorithm will be also presented after the discussion of the current algorithms used.

2.2 Digital Image

Digital Image is a rectangular array of the intensity value, $\{p_{i,j}\}$. The "i" and "j" is the horizontal and vertical coordinate of the digital image as shown as Figure 2.1. The value $p_{i,j}$ represents the color of the specific pixel in the digital image. It may be a single number (gray image) or a vector of several values (color image). The aim of this study is to correct the color of the image recorded in the RGB-model. In this study, $p_{i,j}$ consists of three values, $\{r_{i,j}\ , g_{i,j}, b_{i,j}\}$ which denote the intensities of red, green and blue at the point $\{i,j\}$ respectively. Normally, the format RGB-24 bit is used to save the data of the image which means that each pixel consists of a number range between 0 and 2^{24}-1.

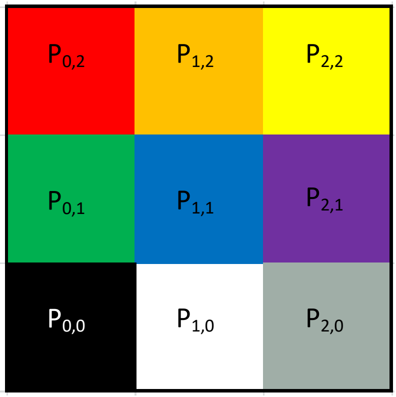


Figure 2.1: Pixels in a color digital image

Besides that, there are several factors that affect the quality of the digital image. First of all, the surrounding environment is the main factor which affects the quality of the image. Based on article about color image analysis with varying camera aperture by Asada and Matsuyama [4], the authors said that color data obtained from a camera are affected by the distribution of the incident light from a point in the scene. Besides that, the noise occurred in the actual camera system also affects the brightness and chromaticity of the color vector. If the image was taken under extremely dark or bright condition, the color data captured is unable to completely analyzed. Thus, the irregular light condition affects and produces wrong objects' color which is different from the original color of the object.

Secondly, the lens of the camera which allows the entering of the light captured also act as an important role during photography. The lens aperture performs like human being's eye iris. The smaller the lens aperture opened, the lesser the light captured in the photo. The light entering to the camera decides the depth of field of the photo [5]. Figure 2.2 shows the image captured using different size of the opening lens.

The aperture of the lens shown in Figure 2.2(a) is set as f/2.8 which means that the opening lens is $\frac{1}{2.8}$ of the lens. While Figure 2.2(b) shows the photo taken under aperture set as f/11. From the images shown, the Figure 2.3 explained the effect to the image base on the size of the opening of the lens.

(a) (b)

Figure 2.2: Image captured in different aperture (a) f/2.8 and (b) f/11 [5]

The larger the opening in the lens,
(i) The lesser depth of field. (ii) The blurrier the background
The smaller the opening in the lens,
(i) The greater depth of field. (ii) The sharper the background.

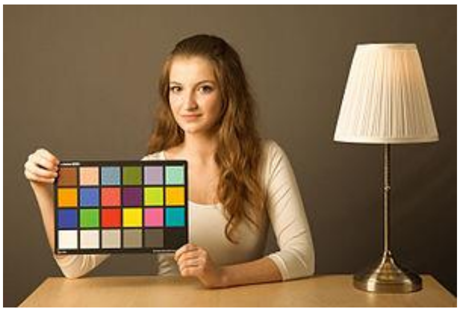
Figure 2.3: Effect of image based on the size of opening lens

2.3 Common Problems of Digital Image

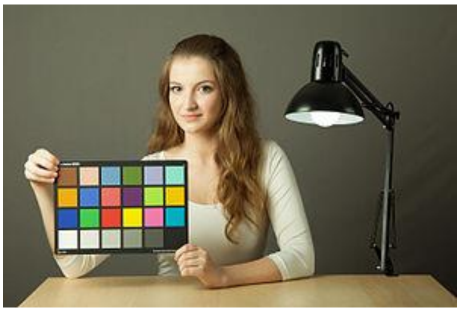
There are always some common problems occur during digital image capturing process. Tone reproduction, color balance, noise removing and sharpening of an image are the techniques used to enhance image that will be discussed later [6]. If the tones are too light or dark, or if the relationship between tones is distorted, the quality of image suffers. For example, if the image reproduced overall is too light, the image will appear washed out and lack of dark shadow. On the other hand, if the image reproduced overall is too dark, the image appears flat and lack separation of shadow details.

The color balance of the image is also important for a digital image. Normally, the color balance problems occur when the primaries are not mixed correctly and are usually most apparent in the neutral tones of an image. The primaries are the color channels in the pixels of the image [6]. When the brightness level is different in three channel (RGB), there will be a color balance problem occurs.

(a)



(b)



(c)

Figure 2.4: The image taken under (a) neutral light, (b) warm light, (c) cold light[7].

Figure 2.4 shows the image taken under different light temperature. The different effects on the image taken under different light temperature can be observed in Figure 2.4. In overall, the image captured under warm light shows yellowish while the image captured under cold light is bluish compared to the image taken under neutral light. The yellowish and bluish of the image represents the color balance problem of an image.

Unwanted noise, in general, gives undesirable effect if it is appeared in a digital image. Noise is described as non-image forming tone variations created by the capture system. Noise can be particularly troublesome if certain image processing is applied to an image. During image processing, every single pixel of an image is analyzed and updated. When the unrepresentative noise pixels are considered, the average or the data calculated will be different from the expected result. In the end, the algorithms used are unable to retrieve the original image.

Lastly, the sharpness of the digital image needs to be increased to perceive the quality of an image. If sharpening was not performed judiciously, it can actually reduce quality by introducing visible artifacts or causing loss of information.

Next few sections will discuss on noise effect, low contrast, non-uniform illumination, lighting conditions and different illumination of an image.

2.3.1 Noise Effect

In general, the digital image is always influenced by the mechanical and electrical properties of digital equipment and imaging environment. Hence, the image is often polluted by different kinds of noise such as composite type noise composed of Gaussian noise and impulse noise [8].

Gaussian noise is a statistical noise having probability density function (PDF) equals to normal distribution. Gaussian noises in the digital image occur normally caused by the high temperature and electronic circuit noises. Unlike Gaussian noise, impulse noise is always independent and unrelated to the image pixels and is randomly distributed over the image. There are black, white or random colors spots are randomly appear on the image [9]. Figure 2.5 shows the image with impulse noises.

From Figure 2.5, there are a lot of pixels in the image consist of the wrong data. The image is unable to be clearly observed due to the loss information of the image. Besides that, the image processing on the image will become a difficult task due to there are large amount of significantly wrong data in the image.

Figure 2.5: Image with impulse noises. [10]

Therefore appropriate noise filters were proposed to remove the noises from the image. As an example, research reported in [11], employed Gaussian noises and impulse noises are able to be removed to ensure the data in the image is corrected.

2.3.2 Low Contrast

Image contrast is the difference in luminance or color that makes the image distinguishable [12]. The contrast ratio of an image is the maximum differences of the color value of an image. Hence, the low contrast image produced due to small contrast ratio of the image. The low contrast image values are concentrated near a narrow range (mostly dark or mostly light). As an example, the image values of an 8-bit data (0-255) image concentrated at the highest value (255) or lowest value (0) will result a low contrast image due to the small contrast ratio. Consequently, an image is able to be improved by transforming the low contrast image into high contrast image.

The image with low contrast decreases the image quality. In Figure 2.6, the color of the flower is not sharp enough which affects the attractiveness of the image. The pixels in the low contrast image have only small differences to each other. Hence, the color difference of the image captured is unable to be significantly observed in low contrast image. Consequently, the observation on the image with low contrast is not easy. The efficiency and accuracy are low if the low contrast image is used. Besides that, the low contrast image is less attractive compared to the high contrast image.

Figure 2.6 Image with low contrast [13]

In some specific fields, the high contrast image is needed for increase the accuracy of the discovery. The small change in the image is easier to be detected in high contrast image. For an example, in the medical field, the image extracted from the different layers of biological organisms must be a high contrast image [14]. The high contrast image helps to increase the accuracy of analysis.

2.3.3 Non-uniform Illumination

Variation in brightness across an image can result to form non-uniform illumination. The overexposed or underexposed image is one of the examples in non-uniform illumination. Besides that, the worst case is the image taken is partially overexposed or/and underexposed. These images with exposure problems normally were taken when the intensity of light entering the camera lens was not properly controlled. The underexposed image makes the photo looks glimmer which caused by the low intensity of light while the overexposed image captured caused by too high light intensity entering the lens of the camera. The difference and effect from overexposed and underexposed image compared to the normal image can be clearly observed in Figure 2.7.

(a) (b) (c)

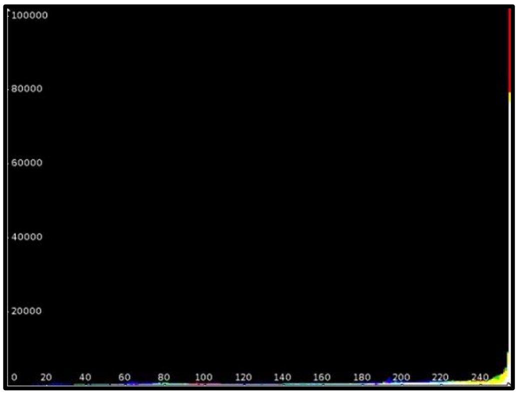
Figure 2.7: Image with (a) Overexposed problem, (b) Original, (c) Underexposed problem [15].

These images are analyzed by using histogram of RGB-models. The RGB-models of the images in Figure 2.7 are shown in Figure 2.8. Every single pixel consists of 24-bit (0-255) RGB data.

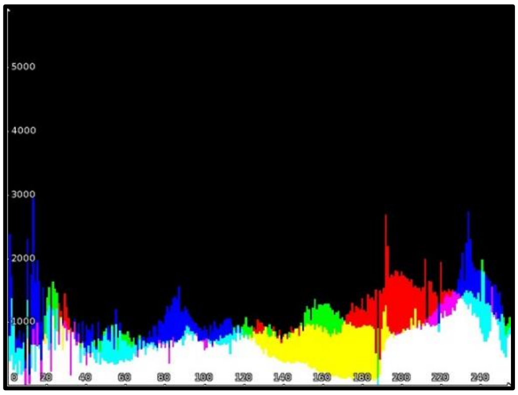
From Figure 2.8, the difference between the overexposed image and underexposed image can be analyzed easily. In Figure 2.8 (a), the color content in overexposed image is saturated at the maximum value (255). This phenomena cause the data acquired during image processing is incorrect. Hence, the image enhanced is less effective.

Figure 2.8 (b) shows the color of the image is balanced. The original image consists of all useful data information which helps the image detecting can be processed in correct pathway. In Figure 2.8 (c), it can be observed that the color contents are saturated at the minimum value (0) and also the maximum color contents is only around 180 which is far from the maximum value. The small differences of the color contents produce the low contrast image. This also influences the users to discover or enhance the image.

In summary, the photo with overexposed or underexposed is confusing human or machine during determining the color image captured. The errors occurred in the image is carried to the next process and hence make the conclusion or decision done is unreliable.



(a)



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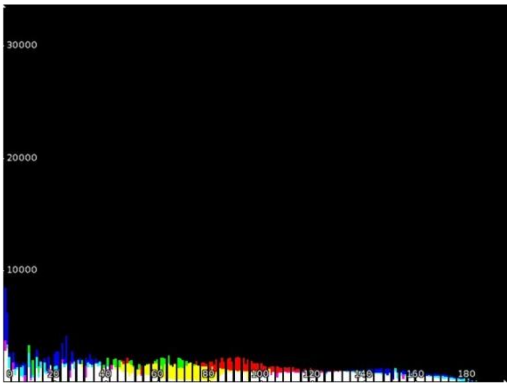

(c)

Figure 2.8: RGB Histogram of (a) Overexposed image, (b) Original image,

(c) Underexposed image.

Besides that, there are some images with partially underexposed and partially overexposed. Figure 2.9 shows the image with both overexposed and underexposed. In Figure 2.9, the outer part of the image is the overexposed part and the middle part in the image is underexposed. The phenomena caused by high light intensity captured in the outer part of the image while there is only low light intensity captured in middle part. Hence, the problem occurs in the image is the brightness of the upper part of the image is too high and users are unable to read the actual image. The problem occurs in middle part of the image is same. The brightness of the middle part in the image is low and users are unable to obtain the useful information from the image captured.

Figure 2.9: Image with overexposed and underexposed region.

2.3.4 Lighting Conditions and Different Illumination

Application of taking photo is a real-time system. The light intensity applied to the camera is different in every millisecond. The changes occur during the moment of taking photo will produce an image with wrong color. Consequently, a good timing and condition is expected for taking a perfect digital image. The environment during capturing the photo must be same and photographer is required to take the photo in a short time. However, the colors of the objects shown in the digital image may not match with the real objects due to the lighting condition. The different kinds of illumination deviates the real colors of the objects [16].

During the process of capturing a digital image, the photo is based on the reflected light of the object. If the white light shoots to the object, the original color of the object is taken. However, if the color of the light shoots to the object is not white in color, the color of the captured object will be the combination of the original color and the color of the light source [17]. Figure 2.10 shows the captured image due to different light source.

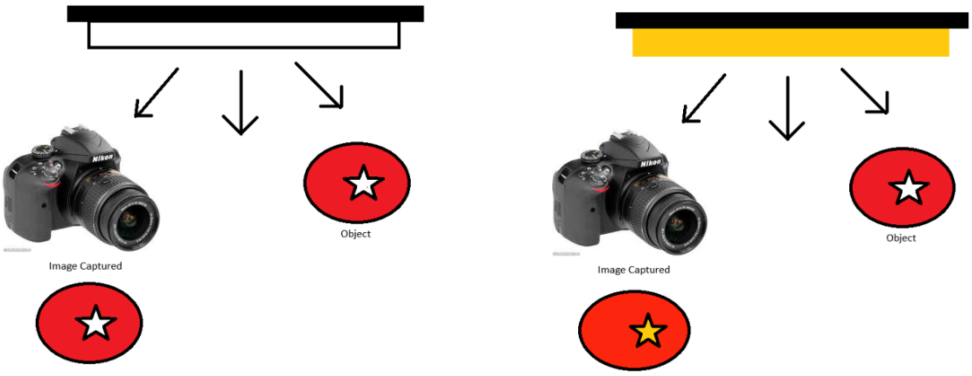

Figure 2.10: Color digital image captured with different light source

From Figure 2.10, the image captured under white light is same as the object. While for the orange light source, image taken shows the yellowish image. This happens because the image captured is the combination of the color of the image and the color of the light source

Figure 2.11 shows the image taken under different color light source. In (a), the wooden model is taken under yellow light and hence the image looks yellowish. While the bluish image in (c) is produced as wooden model is captured under blue light. These different color light source confused the image reader to analyse the actual color of the wooden model. The wrong estimation on the image will cause the discussion or action related to the image in a wrong pathway.

Based on the above mentioned explaination, an image processing step has to be carried on to produce a better image. Color correction or color balancing to the digital image had introduced to retrieve the actual color of the object in the image [18].

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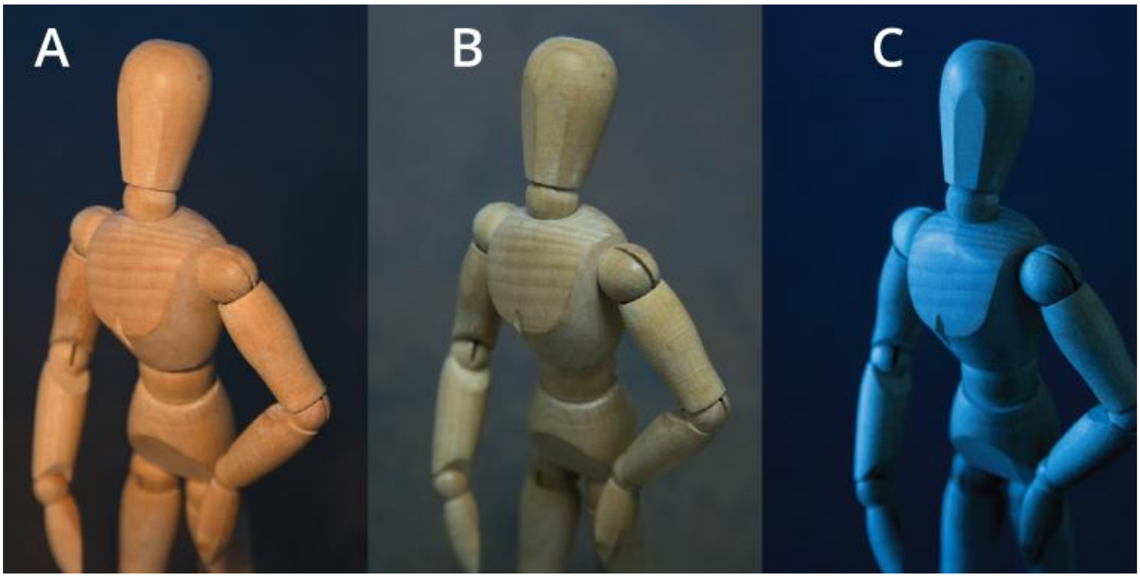


(a) (b) (c)

Figure 2.11: Model Captured in Different Light Souce. (a) Yellow, (b) White, (c) Blue [19]

2.4 State-of-the-art Color Correction Methods for Digital Image

The technique of color correction of a digital image is improving from year to year. Nowadays, this technique is the commonly used for the enhancement of photo (digital image).

There are a lot of research had been done for introducing the new methods for enhancement of a digital image. However, the proposed methods have their own strengths and weaknesses. Hence the most suitable algorithms need to be selected for enhancing the image. From the beginning, the color estimation of an image is required.

Algorithm named Gray World (GW) assumption which is widely used has been proposed since 1980 [20]. The color correction of an image has divided into two parts. The first step is the data acquiring of the digital image. The RGB intensity values of the image are collected and the average of the color contents is calculated. The following step of the algorithms is the data of the image change based on the average obtained from the previous step. The details of the algorithms will be presented in Section 2.4.1.

Besides that, White Balancing (WB) is also commonly used technique for color restoration and retrieval. Based on the Retinex Theory, the perceived white color is associated with the maximum cone signals of Human Visual System [21]. For Retinex-based white balancing algorithm as suggested in [22], only the red and blue channels are updated based on the average of the green channel in the image. The green channel of the faded image is never been changed. Max White White-Balancing Algorithm [23][24] is proposed which assumes all RGB channels are equally affected by all physical and chemical changes occur to the input image. The maximum value (brightest pixel) of the image is recorded and the data of the image are processed based on the maximum values. The details of the method will be discussed in Section 2.4.2. The combination of the Gray World and Max White is introduced in [25][26]. It helps to minimize the disadvantages of the single algorithms and combine the advantages of these two algorithms. Lastly, a new technique, namely Pixel Distribution Shifting Color Correction (PDSCC) introduced in [26] which is able to color correct the image based on the pixel distribution. The algorithm shifts the pixel distribution based on the concept used in the SG algorithm. It is able to reduce the weaknesses of the SG algorithm.

The techniques of color estimation are designed to ensure that the image is able to be enhanced based on the correct references. This helps the research of image processing (image enhancement) will be started in the correct pathway.

2.4.1 Gray World Algorithms

The technique for estimate the light source had introduced since 1900. For the color digital image, the first algorithm proposed for the color correction is gray world (GW) [20]. Algorithms GW used for acquiring and analysis the data of the color image. The pixels of the image are analyzed. The totals of red, green and blue color channels in every pixel of the image are recorded. The average of the color channels (RGB) is calculated as represented by Equation (2.1). After the average of the color channels is obtained from the Equation (2.1), the red color channel and blue color channel of every pixel in the image is updated based on the average green color channel as shown as Equation (2.2)and (2.3) respectively [20].

$$k_c = \frac{\sum_{x=0}^{X}\sum_{y=0}^{Y} I(x,y)}{N} \quad C \in (R, G, B) \qquad (2.1)$$

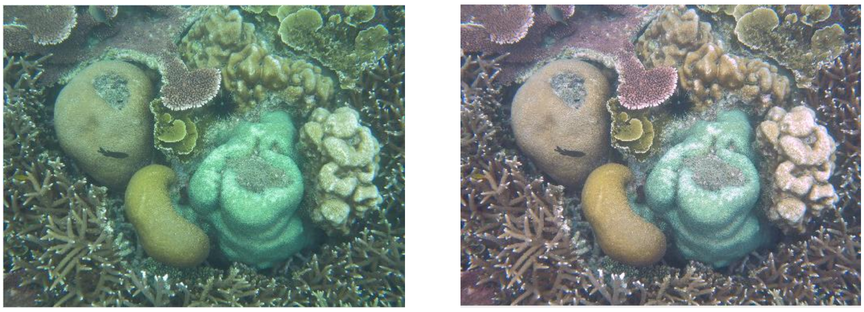
where k_c is the matrix of average value of the RGB channels , x is x-coordinate of the image, y is y-coordinate of the image, X is total number of horizontal pixels of the image, Y is total number of vertical pixels of the image, N is total number of pixels of the image, and $I(x,y)$ is the intensity values of the pixel.

$$\dot{I}_{Red}(x,y) = \frac{k_G}{k_R} \times I_{Red}(x,y) \qquad (2.2)$$

$$\dot{I}_{Blue}(x,y) = \frac{k_G}{k_B} \times I_{Blue}(x,y) \qquad (2.3)$$

where k_G is the average value of the green channels, k_R is the average value of the red channels, k_B is the average value of the blue channels, and, $\dot{I}$ is the corrected color channel.

The advantage of algorithm GW is the time required for the process is short due to the algorithm is based on simple analysis of the statistic of the image. The algorithm works effectively if the color distribution of the image is high. As shown in Figure 2.12, the input image which affected by the water (bluish) with high color distribution is corrected well. The bluish of the image is removed.



(a) (b)

Figure 2.12: (a) Original image (b) GW image

On the other hand, the algorithm GW has the weakness part. The digital image with low color distribution is unable to be enhanced by using the GW. The output image will be over-edited and become less attractive and naturalness due to the weakness of the algorithm. Figure 2.13 shows the image that is unable to be corrected precisely. The reddish of the image is the unwanted effect of the edited image.

(a) (b)

Figure 2.13: (a) Original image (b) GW image

From the example shown in Figure 2.13 as GW faces several weaknesses, thus the problems should be overcome by some new algorithms. The modified algorithms had been introduced to eliminate the limitation. Example of several most popular algorithms is Max White and White Balancing (Section 2.4.2). On the other hand, algorithm named Shades of Gray (Section 2.4.3) is the combination of the algorithms introduced in Section 2.4.1 and 2.4.2 will be discussed.

2.4.2 White Balancing and Max White

The white balancing and the max white method is the method based on the maximum point of the pixels. For the white balancing method, the maximum values of the red, green, and blue channels should be equal. This is the main assumption of the method. Hence, there are only two color adjustment parameters (gain) calculated to change the data of red and blue channel in the faded RGB image [22][24]. The final output image of the technique is decomposed from three layers (I_{Red} , I_{Green} , I_{Blue}) where green channel is kept without changes which satisfied the assumption on Retinex theory. The red and blue channels are corrected as in Equation (2.4-2.7).

$$Red_{Gain} = \frac{max\ [I_{Green}(x,y)]}{max\ [I_{Red}(x,y)]} \qquad (2.4)$$

$$Blue_{Gain} = \frac{max\ [I_{Green}(x,y)]}{max\ [I_{Blue}(x,y)]} \qquad (2.5)$$

$$\dot{I}_{Red}(x,y) = Red_{Gain}\ \times I_{Red}(x,y) \qquad (2.6)$$

$$\dot{I}_{Blue}(x,y) = Blue_{Gain}\ \times I_{Blue}(x,y) \qquad (2.7)$$

While in the Max White [MW] algorithm, the green channel no longer kept unchanged. At the same time, the RGB channels of the faded image are linearly scaled so that the maximum values of the colorimetric layers are equal to 2^N-1. The adjustments of the RGB channels are shown in Equation (2.8) to (2.11).

$$Red_{Gain} = \frac{2^N - 1}{max\ [I_{Red}(x,y)]} \qquad (2.8)$$

$$Green_{Gain} = \frac{2^N - 1}{max\ [I_{Green}(x,y)]} \qquad (2.9)$$

$$Blue_{Gain} = \frac{2^N - 1}{max\ [I_{Blue}(x,y)]} \qquad (2.10)$$

$$\dot{I}_{Color}(x,y) = Color_{Gain}\ \times I_{Color}(x,y) \qquad (2.11)$$

where N is the number of bit represents the color channel.

The Max White algorithms had successfully enhanced the image with certain exposure of light. As the problem stated in Section 2.3.2, the image that polluted by different color light source is able to be recovered by using this algorithms. Figure 2.14 shows the input and output images which are able to be solved by using Max White algorithm.

(a) (b)

Figure 2.14: (a) Original image (b) MW image

There still have some areas that Max White algorithm could not fix it well. If the image was taken under overexposed condition, this algorithm failed to retrieve the original image. As mentioned in Section 2.3.3, the pixels consist of the maximum value (255) and make the image become white in color which means that the following pixels do not consist of the useful information (color of the object).

Hence the Max White Method is unable to enhance the image with overexposed image. Figure 2.15 shows the input and output image which unable to be solved by using Max White method. The output image is exactly same as the input image. From the advantages and disadvantages of algorithm GW, MW and WB, the combination of those algorithms is introduced.