I hereby declare that I have read through this report entitle “Analysis on colour temperature of incident light to inhomogeneous object in industrial digital camera” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Mechatronics with Honors

Signature:………………………..

Supervisor’s Name: Pn.Nurdiana bt Nordin @Musa

Date: 8 Jun 2012

2012

ANALYSIS ON COLOUR TEMPERATURE OF INCIDENT LIGHT TO INHOMOGENEOUS OBJECT IN INDUSTRIAL DIGITAL CAMERA

WAN NOR SHELA EZWANE BT WAN JUSOH

A submitted in partial fulfillment of the requirements for the degree of Bachelor of Mechatronics Engineering with Honors

2012

I declare that this report entitle "Analysis on colour temperature of incident light to inhomogeneous object in industrial digital camera" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree

Signature:………………………..

Supervisor's Name: Wan Nor Shela Ezwane bt Wan Jusoh

Date: 8 Jun 2012

ADKNOWLEDGEMENT

First of and foremost, I thank Allah for giving me mental and physical strength as well as capability to complete this project.

I am sincerely grateful to my supervisor PuanNurDiana bt Nordin@Musa for her guidance, support and invaluable advice in completing this project and this progress report.

I also wish thank to my friends, especially my partners Noraidah Binti Ahmad, Fong Kar Weng, Abdul Rahman Bin Abdul Ghani and Mohd Farhan Bin Ramli for their opinions and ideas in doing the research.

My sincere appreciation also goes to my beloved father Wan Jusoh Bin Wan Daud, my mother Zaumi Binti Omar and all my siblings. A big thank you for their support, encouragement and putting colours in my life, may Allah bless you.

Last but not least, I wish to express my sincere thanks to all who had directly or indirectly helped me in completing my final year project.

ABSTRACT

Visual information is important in the field of robotics to assist object recognition and route mapping. However, variations of lighting fixtures impede the generalization for indoor illumination and therefore require image correction. Hence, the project will analyze on the effect of different white light illumination which produce different reflection on captured image using industrial digital camera. Since most of the object on earth is inhomogeneous, this research mainly focused on samples of inhomogeneous object and studies the reflection characteristic. Three spherical objects painted with three different paints are the objects of study. To maintain the colour constancy of the object, the correction factor is obtained using MATLAB software to ensure the result of the colour image after processing is almost the same with the colour of benchmark image.

ABSTRAK

Imformasi visual adalah penting dalam bidang robotik untuk membantu pengecaman objek dan pemetaan laluan. Walau bagaimanapun, variasi lampu menghalang keseragaman pencahayaan dan oleh itu, ia memerlukan pembetulan imej. Projek ini akan menganalisis kesan pencahayaan cahaya putih yang berbeza yang menghasilkan refleksi yang juga berbeza pada imej yang di ambil menggunakan digital kamera. Oleh kerana kebanyakan objek di muka bumi ini adalah tidak sekata atau mempunyai permukaan yang tidak linear, kajian akan lebih memfokuskan kepada sampel objek yang tidak sekata dan mengkaji ciri-ciri pantulan. Kajian menggunakan tiga objek bulat yang telah dicat menggunakan tiga cat yang berbeza dan untuk mengekalkan kemalaran warna objek tersebut, faktor pembetulan akan diperolehi dengan menggunakan perian MATLAB untuk memastikan hasil imej warna selepas pemprosesan adalah hampir sama dengan imej warna yang di tanda aras.

[128 patah perkataan]

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICED

CHAPTER 1

INTRODUCTION

1.1 Background

Colour of the object is perceptual and human depends on their vision to process what they see and learn. It is also difficult to identify the actual colour of an object when it is exposed to illumination, shadows, highlights, and background clutter on the objects [1]. The inhomogeneous object is one of the factors that make the colour of an object difficult to be identified; the reason being the surfaces are not linear. The analysis is more focused on the effect of colour temperature when the object is situated under different lightings such as indoor illumination, daylight, tungsten or fluorescent; which may cause the changes in the colour of the object. The correction factor will be obtained to ensure the result of the image colour after processing is almost similar with the colour of the benchmark image.

1.2 Problem Statement

Daylight, incandescent, warm white and fluorescent are various typical lighting fixtures which are often used. These lighting fixtures will cause the colour of the image captured to be different from the image's actual colour. Different coating surfaces such as matte, glossy and fluorescent which are painted on the inhomogeneous object may change the characteristic of the reflection. Therefore, these lighting fixtures will produce uncertainness which will impede the recognition.

1.3 Objectives

- To analyze the effect of different white light illumination on coloured objects
- To obtain the generalization of various lighting fixtures on the object
- To obtain the correction factor of the inhomogeneous object colour captured by industrial digital camera with white light illuminants.

1.4 Project Scope

This project focuses on analysis of these factors:

- The objects are inhomogeneous with spherical shapes.
- Three different white light illuminants (Incandescent 60W and 250W, Spotlight, Warm White 20W) with the benchmark (Daylight D65) will be used for analysis.
- Objects are coated with three different type of coating material which is matte, glossy and florescent paints.
- The object colour will be in three colour of traffic light.
- Industrial digital camera is used.

This project however does not include:

- The measure of effectiveness of colour recognition.
- The analysis of surface roughness for inhomogeneous objects.
- The sensor sharpening of the camera

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The object colour is categorized into uniform colour (single colour of object) and multicolour (many colour in one object). Human has a different perceptual on the object colour while the computer vision measures the image colour on this three aspects which are surface roughness, illuminations and sensor characteristic. Of all the three aspects, the illumination is closely related to this project. The illumination is divided into two categories which are coloured illuminant and natural illuminant. The colour illuminant has more colour such as red, green, yellow, blue, and white and so on so forth. The white colour itself possesses variety of lighting fixtures which are daylight (D65), incandescent, warm white and fluorescent (F). This incident white light may change the image of object as below:

In Daylight illuminant (Green Fluorescent)   In Spotlight illuminant (Green Fluorescent)

Figure 2.1: Different image colour in different illuminant

Therefore, this chapter will discuss about colour temperature, the effect on incident light to inhomogeneous object, camera and will explain the methods and the persons who created the solution for the effect of the illumination.

2.2 Colour Temperature

Colour temperature is a way to measure the quality of a light source. It is based on ratio of the amount of blue light to the amount of red light. The unit for measuring this ratio is in degree Kelvin (K). Colour temperature of lamp is very crucial to attune white light using camera. The colour temperature is different under different lightings such as candle, indoor tungsten, indoor florescent, outdoor sunlight, outdoor shade and north sky. The colour temperature scale is shown in Figure 2.2.

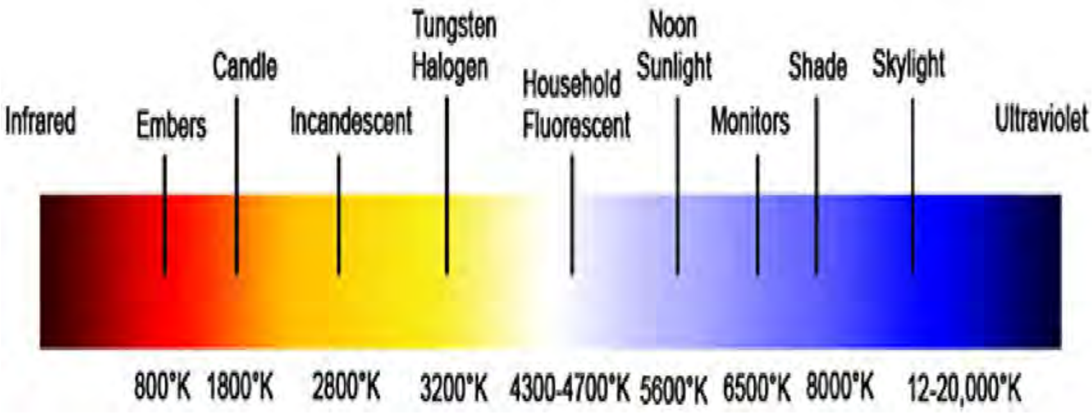

Figure 2.2 Colour Temperatures [2]

A colour temperature may be obtained by using a colour histogram to represent the colour compositions of an image. In this respect, Finlayson [3] claimed that the RB plane is divided into a regular grid with small even intervals. The array of grid has 256x256 with fine regular cells and the value of 256x256 is obtained as binary image. All cells are represented by the filled squares. The array is set as '1' and the other open square is set as '0'. Besides that, the RGB data of the CCD camera image is also represented in scaled RB plane and the original RGB values are normalized with maximal intensity over all pixels in image. As the outcome, the pixel should be stable and making the normalization reliable.

Brian A.Wandell [4] considered the estimation of colour temperature of scene illumination from a single image and acquire less than one illumination can be rendered for viewing in an illumination with a different colour temperature. Bright image region contains more information of illuminant compared to dark image region. The algorithms of illuminant colour temperature are valid for many light source including sunlight, incandescent lamp and fluorescent lamp.

After reviewing these two methods that were suggested by Finlayson [3] and Brian A.Wandell [4], the method that are related and to be employed to this project is from Brian A.Wandell [4] because this particular method used different colour temperature and the algorithm is capable to any illuminations. Therefore, the light meter can be used to get the colour temperature easily when the camera is placed on the right position.

2.3 Analysis on effect colour temperature

Robby Tan Towi [5] had figured out the method for testing his algorithm by using two types of surface which are uniform colour surface and multicolour surface. The first step begins with counting an intersection distribution before obtaining several peaks in which the number depends on the number of illuminant colour. The point on this distribution needs to be observed in three spaces which are inverse intensity chromaticity space, Hough space and illumination chromaticity-count space in order to solve this uniform colour illumination. This method should consider two aspects which are, cluster points that have the same direction in inverse-intensity chromaticity space and finding all peaks of the Gaussian like distribution in histogram (intersection count) space.

The result obtained by Robby Tan Towi [5] shows a real image of green object with uniformly coloured surface. The object was lit by two illuminants which are incandescent lamp and halogen lamp. Under these illuminations, white as references of image chromaticity taken by the camera has chromaticity value of which, for the incandescent light; the value is = 0.503, = 0.298 = 0.199 while for halogen lamp, the value is = 0.371, = 0.318 = 0.310.

Long Yonghong et al. [6] had found that the interface component distributed the illuminant by estimating the spectral power distribution of the illuminant. Firstly, illumination chromaticity needs to be estimated by intersection of two colour signal from two inhomogeneous surfaces to get the illuminant spectral power distribution. Then the original images are able to be recovered to the image with standard illuminant D65 using the finite-dimensional model. Yonghong's solution of estimating the scheme of illumination is based on dichromatic reflection model exploits and finite-dimensional linear model [7] to achieve the colour correction in the second stage of colour recovery. It gives a precise, clear and efficient way to describe relation between illuminants, surface reflectance and reflected lights.

In view of the experiments, the steps for colour recovering start with estimating the illuminant chromaticity by the intersection of two colour signal planes and afterward, estimating the illuminant spectral distributions. After that, image was taken under chromatic illuminant and CIE Standard Illuminant D65 is obtained in which the latter is regarded as the standard images. The original images are transformed to the standard image with CIE Standard Illuminant D65 and lastly the colour difference between original images is computed and image is recovered.

The result [6] shown in table 2.1 which show the recovery result and colour difference between original images and standard images as well as colour differences between recovered image and standard images. From the table, the colour-biased appeared when images are taken under chromaticity illuminant. After processed method, the images are much similar with the standard images taken under standard illuminant D65 and it also has a colour difference is much smaller than the original images.

Table 2.1 Processing result of ten images colour chip

number	color	main wavelength	original images	standard images	recovered images	color difference before recovery	color difference after recovery
1	red	700				51.4409	3.8540
2	orange	600				43.8275	10.0297
3	yellow	585				43.8722	7.9662
4	olivine	570				48.5036	7.6451
5	green	540				51.5311	13.1060
6	turquoise	510				44.8851	9.4167
7	cyan	495				44.6709	10.6643
8	cyanine	485				47.0665	6.2382
9	blue	480				36.5545	10.7949
10	purple	400				50.5197	5.5738

Then process the five couple image of colour chip and each couple of original images is transformed to the standard image which shown in Table 2.2. From that table, the colour difference of each couple of original is much different from those of standard images.

Table 2.2 Processing results of five couple images of similarly colour chip

number	original images	recovered images	standard images	color difference before recovery	color difference after recovery	color difference of standard images
1				7.0395	4.8952	5.5271
2				7.0372	5.4211	5.5638
3				15.8807	12.3193	11.3202
4				7.6971	7.5297	7.9986
5				5.4153	3.8471	3.4457

2.3.1 Comparison table for the two methods

Table 2.3: The comparison table of methods

Title	Illumination colour and intrinsic surface properties	Colour recovering based on dichromatic reflection model and finite dimensional linear model
Author	Robby Tantowi Tan	Long Yonghong et al
Method	• Counting an intersection distribution then obtains the several peaks • Consider cluster points that have the same direction in inverse-intensity chromaticity space • Consider to find all peaks of the Gaussian like distribution in histogram (intersection count) space	• Estimate the illuminant chromaticity by the intersection of two colour signal planes • Estimate the illuminant spectral distributions • Image was taken under chromatic illuminant and obtain CIE Standard Illuminant D65 • Transform the original images to the standard image with CIE Standard Illuminant D65 • Compute the colour difference between original images.
Result	• Shows a real image of object with uniformly colour surface.	• Images are much similar with the standard images taken under standard illuminant D65 and it also has a colour difference is much smaller than the original images.
The method related and why	From this comparison, the method from Long Yonghong is closely related because it emphasizes on the illuminant D65 which is the benchmark for project. However, only few steps are taken similarly to the stated approach as the scope of the project is different. The rest of the steps are self-created to ensure the completion of the project.	

2.4 White Balance

White balance is a process whereby unrealistic colour cast is being removed. [7] When the process is completed, the display image will have the same general appearance as the colour in the original scene. Here, it must be noted that the colour of each pixel in an image captured directly by digital camera does not solely depends on the object, but also the colour temperature light of light source. When the object is illuminated under a low colour temperature light source, the recorded image will appear to be reddish. On the other hand, when the colour temperature of the light source is high, the object will appear to be bluish. The figure shown below is best to describe the example of the colour image with different colour temperature.

Figure 2.3: Example of image with different colour temperature [7]

Nowadays, there are a lot of algorithms that have been proposed by engineers for the purpose of maintaining the colour consistency of image captured from an object under different light sources [7]. Here, the emphasis and attention must be given to the methods of choosing the reference pixel to estimate the illumination. The illumination estimation is one issue that must be given due care and consideration due to numerous factors that control the colour of the display image such as the object shape, illumination geometry, background colour and many more.

2.5 Effect on incident light to inhomogeneous object

Generally objects are of inhomogeneous materials. Hence, the reflection will appear when an incident light is illuminated on these objects and materials. The standard dichromatic reflection model which assumes the surface of inhomogeneous materials or objects when the light is reflected is further decomposed into two preservative components. The independence of wavelength is separated into two which are body refection and interface reflection.

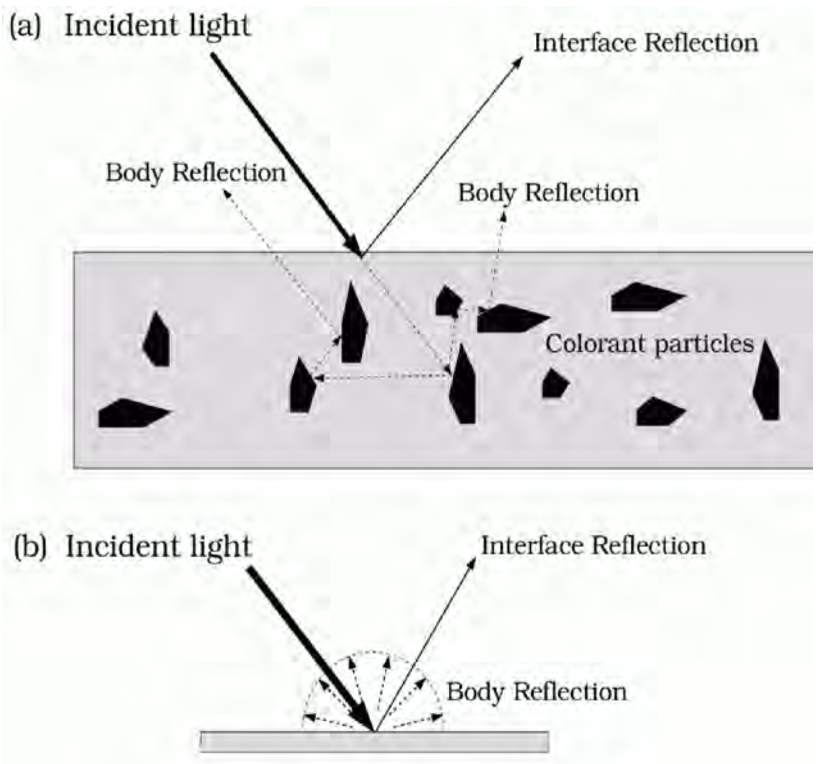

Figure 2.4: Incident Light [8]

Yifan Chen [8] had acquired that the real incident light information is associated to a basic light source and real incident light source which resulted in the buildup of level pixel mapping. Obviously, the same direction of rays from actual light source will light up the same point of the object when the actual light source is at the same position. The ray reflected from the same point has the same direction and light up the same point image with fixed camera.

Inhomogeneous object which has a linear combination of diffuse and specula reflection component evidently shows that these two components need to be separated or decomposed. Most inhomogeneous objects are made of acrylics and plastics which exhibited both diffuse and secular reflections. The diffused reflection is due to varying refractive index in the bodies and object surface, while the specula reflection is primarily due to the refractive index difference between air and the object surface. If the presence of these indexes is very minor, inhomogeneous object will ignore. Unlike diffuse reflection, the location of secular reflection depends on viewing an illumination direction, causing its appearance to be consistent. On the other hand, diffuse reflection is independent from viewing position and is only dependent on illumination direction in terms of its intensity magnitude.

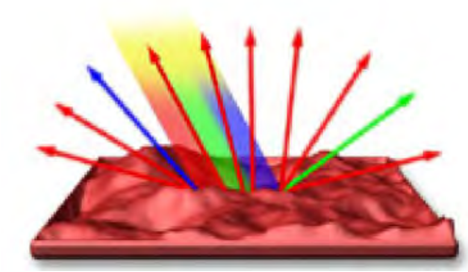

Figure 2.5: Diffuse Reflection [9]

Figure 2.6: Specula Reflection [9]

The characteristic of reflection of inhomogeneous object is depending on the effectiveness of light position selection. Takashi Machida [3] had examined the cause of considering interreflection in surface reflectance parameter estimation using object with uniform and non-uniform surface properties. The image clearly shows that the specula reflectance parameter and also illustrate the surface roughness parameter with grey scale where the largest value is coded as white. This image defined shows that the smaller the value is the smoother the object surface will be.