Advanced Journal of Technical and Vocational Education 1 (1): 355-363, 2017
eISSN: 2550-2174

Analysis On The Effect Of Colour Temperature Of Incident Light On Inhomogeneous Objects In Industrial Digital Camera On Fluorescent Coating.

Wan Nor Shela Ezwane Binti Wn Jusoh *[1], Nurdiana Binti Nordin @ Musa [2]

[1] *shela@ptsb.edu.my, Politeknik Tuanku Sultanah Bahiyah, Mechanical Department, 09000 Kulim, Kedah, Malaysia.*
[2] *diana@utem.edu.my, Universiti Teknikal Malaysia Melaka,Faculty of Electrical Engineering, 76100 Melaka, Malaysia.*

ARTICLE INFO

Article history:
Received : June 2015
Accepted : August 2015
Available online : January 2017

Keywords:
Colour Temperature, Effect of Different White Light, Inhomogeneous Object and Fluorescent Coat.

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. The spherical objects painted with the fluorescent coats are the object 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.

1. INTRODUCTION

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.

2. LITERATURE REVIEW

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 white light may change the image of object as below:

In Daylight illuminant (Green Fluorescent)

In Spotlight illuminant (Green Fluorescent)

Figure 1: Different image colour in different illuminant

2.1 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.

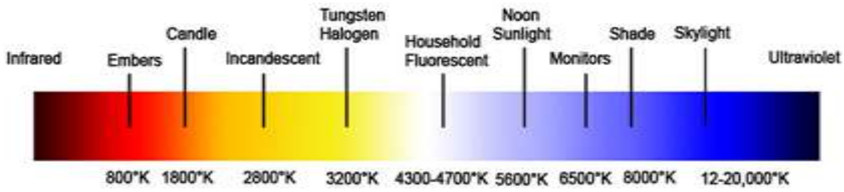


Figure 2: Colour Temperatures [2]

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 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.

2.2 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 $\Gamma_r = 0.503$, $\Gamma_g = 0.298$ $\Gamma_b = 0.199$ while for halogen lamp, the value is $\Gamma_r = 0.371$, $\Gamma_g = 0.318$ $\Gamma_b = 0.310$.

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.

2.3 Comparison table for the two methods

Table 1: 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 [5]	Long Yonghong et al [6]
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 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.

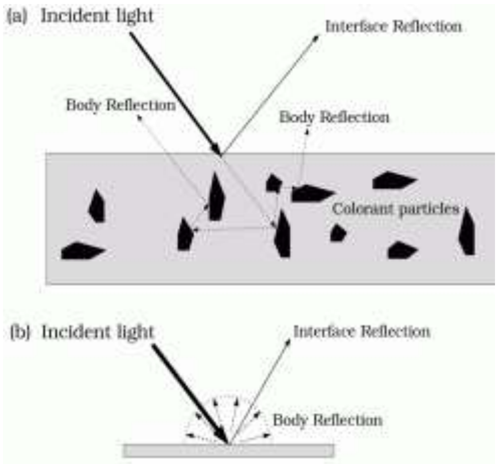


Figure 3: Incident Light [7]

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.

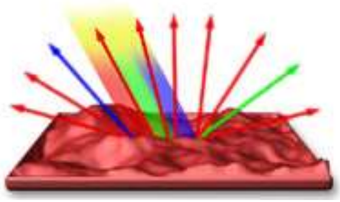


Figure 4: Diffuse Reflection [8]


Figure 5: Specula Reflection [8]

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.

2.5 White Balance

White balance is a process whereby unrealistic colour cast is being removed. [9] 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 6: Example of image with different colour temperature [9]

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 [9]. 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.

3. METHODOLOGY

The sequence of the experiment is shown in methodology flow diagram. The details of the process and procedure will be clearly explained on each experiment below:

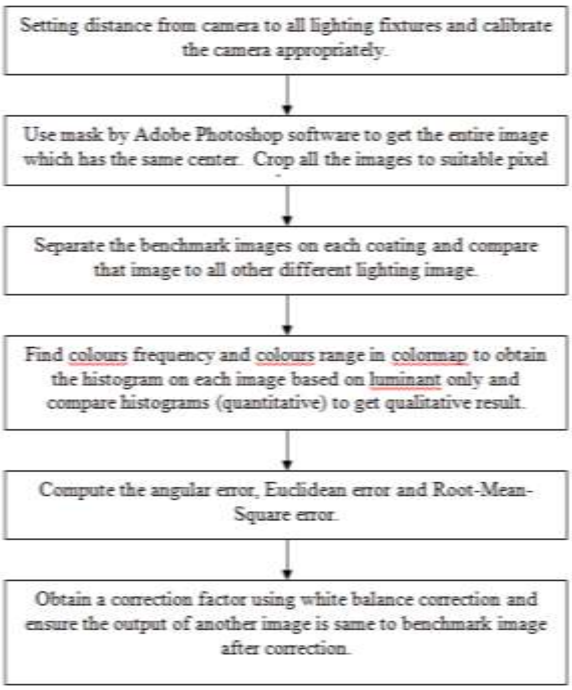


Figure 7: Flow Diagram of the Project method

3.1 Experiment 1: Determination of the differences between benchmark image (D65) with other images under different lighting.

After a mask is completed, the images will be cropped accordingly to the appropriate size. The pictures will be sorted according to colour, fluorescent coating and types of lighting. The sorting was done in such a manner so that comparison between all the images will be easily done. Benchmark image is set as Daylight (D65) and it will be compared with other images captured under different lighting fixture for the purpose of examining the change of colour when the image is captured under different lighting fixtures. For example, the red ball with fluorescent coating has its own benchmark and these benchmarks will be compared with other images captured under different lightings which are spotlight, incandescent and warm white.

3.2 Experiment 2: Determination of the colours frequency and the colours range in colormap and obtaining the qualitative value (histogram).

The colormap will be obtained using the Matlab software. The first step is to load picture and all pixels of the red, green and blue (RGB) will appear. At this stage, the RGB color space needs to be converted into YcbCr color space. After the conversion is made, the pixels will be reshaped to be in one row of YCbCr values. Subsequently, all redundant values will be removed and the new value will then be consolidated to count the number appeared on the same row. This consolidated value has two variables namely yc (colour frequency) and xc (colour range). After that, a mathematic equation is invented to obtain the value of the benchmark and color distance. These steps will be repeated over and over again until the maximum colormap obtained is 255 which is the maximum grey level on unsigned 8-bit integer or less than 255.

3.3 Experiment 3: Comparison of the benchmark histogram with other histogram under different lighting fixture and obtaining the qualitative value.

After noticing that there are differences in each image, the differences must be measured by the qualitative value because the quantitative value only shows the histogram; which cannot provide the real value. In this experiment, the differences between the daylight benchmark with other lighting will be measured in order to obtain the value. The value is called qualitative value as it shows the exact value.

3.4 Experiment 4: Computing the errors

The differences will be calculated to obtain the error between the two histograms and the error will be measured using a benchmark Daylight D65 compared to other image under different lights. There are three errors that should be considered in this project namely Angular Error, Euclidean Error and Root-Mean-Software Error.

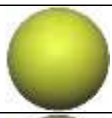
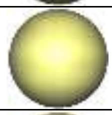
3.5 Experiment 5: Correction by white balance

After identifying all errors, the correction on the image is necessary to ensure that the images accurately correspond with the benchmark image after correction. The correction will focus only on luminant because this project uses white balance correction. Firstly, the correction will be made on benchmark. The output image after the correction should be turned into a brighter image because only luminant lightings used on the ball. After that, the correction will be performed into another image under different lights and the output should be same with benchmark output. Luminant will also give an effect to the background image in which the colour of the background will change from white to blue or yellow or black or other colour.

4. RESULT

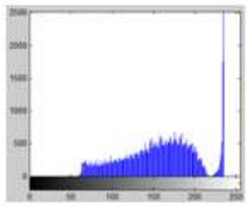
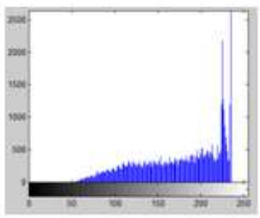
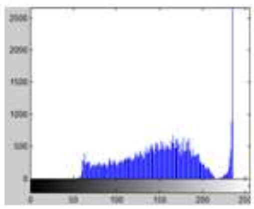
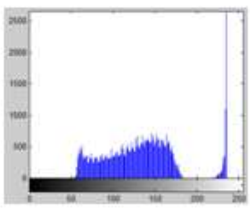
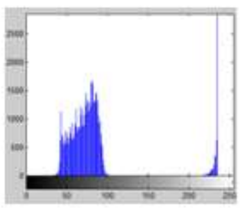
Experiment 1 was conducted to determine the differences between Daylight D65 as a benchmark on fluorescent coating and every colour compared to other images under different lighting fixtures. The main objective is to prove that image will change under difference lighting. The three types of lighting involved are spotlight 150W, incandescent 25W and 60W, warm white 20W and daylight 20W as a benchmark.

Table 2 : Fluorescent coating with different lighting illumination

LIGHTING \ COATING	FLUORESCENT RED	FLUORESCENT YELLOW	FLUORESCENT GREEN
BENCHMARK (DAYLIGHT D65) 20W			
SPOTLIGHT 150W			
INCANDESCENT 60W			
INCANDESCENT 25W			
WARM WHITE 20W			

Experiment 2 was conducted to analyze the colours frequency and the colour range in colormap for each image. The objective is to find the maximum pixel and how many times the pixel is repeated and to find colour centroid (i.e: the most colour frequent colour combination) in the image. This experiment will show the histogram as a quantitative value and it will prove that the changes on experiment 1 by histogram.

Table 3: The histogram (based on luminant only) of different lighting compared to benchmark

THE HISTOGRAM OF YELLOW FLUORESCENT	
 BENCHMARK DAYLIGHT D65 20W	
 SPOTLIGHT 150W	 WARM WHITE 20W
 INCANDESCENT 60W	 INCANDESCENT 25W

This experiment 3 was conducted to determine the value of comparison between benchmark Daylight D65 with others types of lamps. The objective of this experiment is to prove that the differences in histogram from experiment 2 were obtained based on value.

Table 4: Different between benchmark D65 and other lighting fixtures

Different between benchmark D65 and other lighting fixtures		Spotlight 150W	Incandescent 25W	Incandescent 60W	Warm white 20W
Fluorescent	Red	0.0132	0.0072	0.0118	0.0116
	Yellow	0.0050	0.0047	0.0023	0.0020
	Green	0.0086	0.0361	0.0100	0.0091

This experiment 4 was conducted to determine the error in images. The errors are angular error, Euclidean error and root-mean-square error. The objective of this experiment is to obtain the errors occurred in histogram.

Table 5: Error between D65and spotlight 150W

Benchmark (D65) 20W and Spotlight 150W		Angular Error	Euclidean Error	RMS Error
Fluorescent	Red	0.1850	0.0381	30.8861
	Yellow	0.1900	0.0468	37.9465
	Green	0.1344	0.0251	20.2987

This experiment 5 was conducted to determine the correction factor between Daylight D65 images with other images under different lighting using white balance correction. The objective of this experiment is to change each image under different lighting to get the same output image with the benchmark image after correction.

Table 6: Comparison between benchmark with image under difference lighting after correction

Different between benchmark D65 and other lighting fixtures		Incandescent 25W	Incandescent 60W	Spotlight 150W	Warm white 20W
Fluorescent	Red	0.0221	0.0129	0.0159	0.0079
	Yellow	0.0144	0.0045	0.0045	0.0058
	Green	0.0215	0.0162	0.0124	0.0149

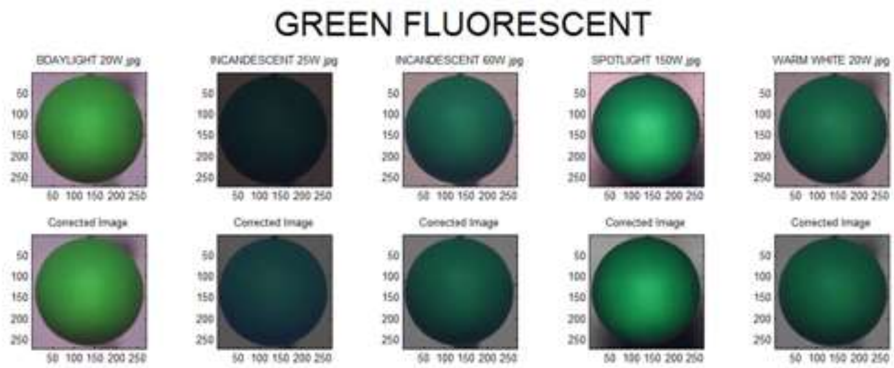


Figure 7: Green image under different lighting is same after correction

5. DISCUSSION AND CONCLUSION

In general, the result of this experiment is the software implementation. In terms of software implementation, it can be concluded as a whole that an excellent and meticulous result had been obtained. The whole Matlab program successfully managed to function in a very exceptional manner during the test run process. For instance, using the image processing method will optimize the output processing of Matlab to a higher performance as expected. Furthermore, vision plays an important role especially when it comes to human perceptions and machine vision. As for the human perception, our eyes is the sensing device which constantly sending the input to the brain in which the latter works as an interpreting device to construe the colour of the objects while in robotics field, the cameras or cctv cameras are being used as a sensing device to capture images or to record the video and sending the captured or recorded data to the computer where the latter will then start to interpret the colour of the objects. This will specifically analyze the effect of different white light illumination which produces different reflection on captured image using industrial digital camera. The most important task is to obtain the correction factor to convert the colours of the image so as to be as similar as the benchmark colour. The white balance is a process to remove unrealistic colour cast and the algorithm of white balance which changes the colour based only on luminat component.

As a conclusion, nowadays, robotic application is increasingly used and widely implemented by numerous industries in Malaysia and has boosted the industries in many ways. One of the widely used applications is vision or image processing to assist the vision of robots. To human eyes, colours is one element that can be easily differentiated, be it green, blue, and so on and so forth. However, a parameter is vital and needs to be intelligently set so that robotic eyes can identify and differentiate colours. Hence, visual information is important in the field of robotics to assist in object recognition and route mapping.

6. REFERENCES

[1]G.Buchsbaum, A spatial processor model for object colour perception, Journal of Franklin Institute, 1980.

[2]William Thompson kelvin, kelvin colour temperature, 19th century

[3]Takashi Machida et all, Surface reflectance modelling of real object with interreflection, 2003.

[4]Brian A Wandell, colour temperature estimation of scene illuminates 2010.

[5]Robby Tantowi Tan, Illumination colour and intrinsic surface properties, Physics based colour analysis from a single image, December 2003.

[6]Long Yonghong et al, Colour recovering based on dichromatic reflection model and finite dimensional linear model, 2009.

[7] Michale W. Daidson, Specular and diffuse reflection, 1998
http://micro.magnet.fsu.edu/primer/java/reflection/specular/index.html

[8] Simone Bianco et all, Combining Strategies for white balance, University a Degli Milano Bicocca, Italy

[9]Brian A. Wandell, Incident light, 1959
http://www.stanford.edu/group/vista/cgi-bin/FOV/chapter-9-color