Colour Tone for Image

By

Lim May Chi

A REPORT

SUBMITTED TO

Universiti Tunku Abdul Rahman

in partial fulfilment of the requirements

for the degree of

BACHELOR OF INFORMATION AND COMMUNICATION TECHNOLOGY (HONS)
COMMUNICATION AND NETWORKING

Faculty of Information and Communication Technology

(Perak Campus)

JUN 2015

UNIVERSITI TUNKU ABDUL RAHMAN

REPORT STATUS DECLARATION FORM

Title: ____

____

____

Academic Session: _____________

I ____

(CAPITAL LETTER)

declare that I allow this Final Year Project Report to be kept in
Universiti Tunku Abdul Rahman Library subject to the regulations as follows:

1. The dissertation is a property of the Library.
2. The Library is allowed to make copies of this dissertation for academic purposes.

Verified by,

_________________________ _________________________

(Author's signature) (Supervisor's signature)

Address:

____

____

____

____

Supervisor's name

Date: _____________________ **Date**: ____________________

DECLARATION OF ORIGINALITY

I declare that this report entitled "____" is my own work except as cited in the references. The report has not been accepted for any degree and is not being submitted concurrently in candidature for any degree or other award.

Signature : ______________________________

Name : ______________________________

Date : ______________________________

ACKNOWLEDGEMENTS

Firstly, I would like to express my sincere gratitude to my supervisor, Dr Lau Phooi Yee for the continuous support in my Bachelor of Information Technology (HONS) Communication and Networking study Final Year Project. Knowing that I am not exposed to the area of Image Processing, she still gave me an opportunity to learn and contribute to the study of "Colour Tone for Image". Thanks a lot for her patience, motivation and immense knowledge in guiding me and helping me throughout the research and writing of this report. I could not imaging of having a better supervisor and mentor for my Final Year Project.

Apart from my supervisor, I would like to thank my moderator, Dr Ng Hui Fuang not only for his insightful comments and encouragement, but also for the hard question which allows me to widen my research from various perspectives.

Last but not the least, a million thank to my parents and my family for their continuous support and encouragement throughout my final year project and my life in general.

ABSTRACT

Heavy non-uniform light attenuation in water across visible spectrum causes dramatic hue shifts towards blue, the predominant colour in underwater images and this make capturing underwater imaging a challenging task to do. The motivation for this project is to investigate the underwater images, obtained as low quality images due to imaging scenario or underwater species, which could affect the object recognition in underwater environment, i.e. distinguishing fish species or aquatic life. Image reconstruction goal is to recover the image quality related to specific aquatic environment, including perhaps stock assessment, so that the resultant image can be further used for either object detection or abundance studies i.e. satisfied the user. Resultant images could improve the visual interpretability of human viewers by increase the information acuity within an image.

The proposed work consists of 4 steps, being (1) image acquisition, (2) pre-processing, (3) colour correction, and (4) colour image enhancement. Various methods proposed by others are reviewed and considered in the study. The algorithms that are researched include RGB adjustments, colour balancing, removing blue from image, dehazing and gray world algorithm. These algorithms are colour corrections method. In addition, histogram equalization and contrast stretching are included in the research for image pre-processing and image enhancement.

Colours in image are only affected by the hue or light. Therefore, RGB adjustment method is not suitable for colour correction. Colour balancing algorithm able to enhance the image, i.e producing an image with a higher colour tone of the natural colour of the object as though able to restore the colour of the objects in the image. Dehazing algorithm managed to remove the artificial light that causes colour change and remove hazy condition in images. This method reduces the brightness of an image. Therefore, histogram equalization can be done on the image first to increase the contrast and sharpen the edges of the image. Gray World when used with dehaze and colour balance method it can remove more background blue colour.

Proposed method 1 is the combinations of colour balance, histogram equalization and dehazing algorithm. Proposed method 1 can enhance some of the underwater images while the second proposed method is to process with the histogram equalization, followed by grayworld, dehazing and colour balance. Proposed method 2 managed to remove more predominant blue colour from the underwater images. However, the resultant images are not natural.

Further, MOS was applied, as verification, to check if the image has been recovered. The first MOS is done for proposed method 1 to allow observers to compare between original, pure pre-processed, pure colour correction method and the proposed method. 30 out of the 60 observers preferred the processed image using proposed method 1 than the other 3 images. Then another MOS is done for observers to compare between processed images with proposed method 1 and proposed method 2. 8 out of the 11 observers preferred over proposed method 1 while the other 3 observers chose proposed method 2.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF ABBREVIATIONS

CCI	Colour Colourfulness Index
CIELUV	Commission International de l'Eclairage Luminance U(saturation) Value (hue angle)
CNI	Colour Naturalness Index
CSF	Contrast Sensitive Function
HSB	Hue Saturation Brightness
HSI	Hue Saturation Intensity
HSV	Hue Saturation Value
HVS	Human Visual System
MOS	Mean Opinion Score
RGB	Red Green Blue
SICNI	Satellite Image Colour Naturalness Index
YCrCb / *YCC*	Luminance; Chroma:Red; Chroma:Blue
ACE	Automatic Colour Equalization

1. INTRODUCTION

1.1 – <u>Problem Statement</u>

In Tristan John Lambert's paper (2005, p.4), he stated that in terms of visibility, the images taken underwater environment is poor although there is some use of art equipment. With the aid of modern digital cameras, the colours of the tropical that are seen in the beautiful water appeared to be flat and mostly blue. This is solely because the water has acted as a filter that shifted the colours of the images toward blue, reducing warm reds and yellows. (Lambert, 2005) In a webpage written by Galen Piehl and Nicole Atkins (2006), distance is a factor that causes more colours to be filtered. (Piehl & Atkins, 2006) This report is about reducing the problems existed in images taken underwater with the help of software programs to process underwater image for betterment of the images.

The four photos displayed below showed the scope of this project. As seen in the first photo, the colour of the water has completely filtered the sand colour underneath it. Therefore it is hard to see the sand through the water. The photo next to it is the original sand colour and from the image, it can be seen that the overlapping of water and sand degrades the colour of both water and sand. The next photo is the shows the original colour of the object, the shell when the photo is taken on ground level. It is observed that the colour of the shell changed when it is immersed into water. Hence, it is concluded that water will act as a filter that shifts the colours of images towards blue, the predominant colour in underwater images.

Figure 1: Images showing the colour of water and sand

Figure 2: Images showing the object original colour and its colour in water

1.2 – Background and Motivation

The research area of the project is image processing specifically on underwater images' colour. Image processing has two main purposes which are to improve the visual appearance of images to human observer and prepare images for the features and structures measurement which they reveal. Image processing contains the same amount of data but there is some simple rearrangement of data done to an image. (Russ, 2011)

Colour is a subjective term as human brain can interpret the narrow band of wavelengths of light differently depending on both the wavelengths in the light source and also the absorption of the wavelengths by the reflection of the light of object. (Wikibook, 2013) RGB; red, green, blue is multi-spectral with one band for each RGB colour. Spectral energy is the distribution of energy with wavelength. (Forsyth & Ponce, 2012) The weighted combination of RGB forms three primary colours for each pixel. (Fisher, et al., 2003) RGB is a model approach to colour which the intensity levels of the mentioned three colours will be specified in order to select the wanted colour.

The typical range of intensity values for each colour is 0 to 255 as it takes 32 bits binary number as base where these 32 bits are broken down into four bytes, 8 bits each. 8 bits can hold up to 255 values ranged from 0 to 254. The fourth byte is known as opacity. It portray its role when different colours layers are stacked producing a combined colour when the top layer colour is less than fully opaque or fourth byte less than 255. (Wikibook, 2013) Combining the three primary colours (RGB) can possibly construct almost all visible colours as the human eyes has only three different colours receptors for these three colours. (Fisher, et al., 2003)

Colour space is a useful conceptual tool to aid understanding of colour capabilities in digital file. (McHugh, 2005) McHugh also mentioned that colour spaces can determine whether or not the shadow or highlight detail, colour saturation will be able to retain or how much they will be compromised. Each direction in colour space represents certain aspects such as colour, lightness, saturation and hue depending on its colour space type. (McHugh, 2005) The common type of colour space is RGB and HSV. The diagram on the left in the figure below represents RGB colour space whereas the one on the right is the HSV colour space extracted from the paper written by Ding, X. and Jun, O. (2007, p.59). HSV stands for hue, saturation, value or brightness also known as HSB. It encapsulates colour information in which these colour decomposition into hue; saturation and luminance which are more similar to human perception in colour. (Ding & Jun, 2007)

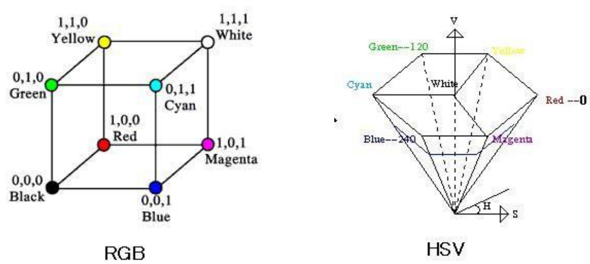


Figure 3: RGB and HSV colour space representation

Blue colour has the shortest wavelength in natural and so it will take the longest time to travel in water. Therefore, blue became the dominant colour in any underwater images. (Iqbal, et al., 2007) Green is the second with shortest wavelength, therefore blue and green is the predominant colour of water.

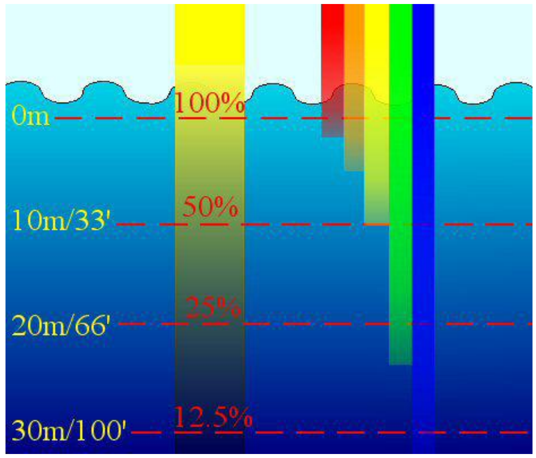


Figure 4: Colour Appearance in Underwater

OpenCV stands for Open Computer Vision which means it is open source software which provides libraries that enable people to use these libraries for programming purpose for free. The libraries has more than 2500 optimized algorithms whereby to summarize the usage of these libraries is that they are used for image processing. OpenCV's primary language is written with C++ programming language. (OpenCV, n.d.) Currently, OpenCV has many image processing and computer vision algorithms and owing to this, it can easily develop advance computer vision applications. (Fernando, n.d.) MATLAB provides a high-level language and interactive environment for numerical computation, visualization and programming. It is often used to analyse data, develop algorithms, create models and applications. It has built-in math functions which is convenient for users to reach a solution more quickly than with spreadsheets or traditional programming languages. Image processing is one of the applications of MATLAB. (Mathworks, 1994-2015)

The motivation behind this project is to get the natural colour of any objects in underwater across underwater imaging where underwater imaging is important to oceanic engineering, surveillance and underwater navigation. Observing colours in water is also important for monitoring and surveillance since there are a lot of studies relating to marine biology studies as well as underwater robots for species identification, ecosystem health and activity monitoring. In addition, projects. Merging of this project with the mentioned related fields may be easier for those projects to work more closely towards theirs objectives. It can reduce the chance of identifying wrongly.

In addition to that, colour can be considered as the most important component in attracting people to see and enjoy an image. However, most of the time, colour appeared in image is not exactly the same as the colour we seen in real life owing to some circumstances such as light attenuation, scattering, absorption and all sorts of sources of performance loss that can distort the transmission of the object to be seen to human observers or cameras. Therefore, it is significant to having an algorithm that can reconstruct and recover image to properly display a better quality image for users.

1.3 – Objectives

1.3.1 – Main Objective

- To propose a method to remove predominant blue and green colour that exists in underwater images which is a constraint to an images using OpenCV and Visual Studio

1.3.2 – Sub-Objectives

- Propose a prototype system for the proposed method in main objective
- Propose a method to evaluate the resultant images
  - Mean Opinion Score (MOS) is the analysis method proposed to justify the processed image

Shadow may exist in any image and affects the quality of the image; however it is not the main concern in this project. In other word, the project ignores shadows that exist in any image. Generally, the project focus is to have a method to display underwater image whereby the images are less filtered by the predominant colours that exist in water. Figure 5 is the example where the shadow (circled in red) has reduced the image quality.

Figure 5: Shadow exist in images

1.4 – Proposed Approach

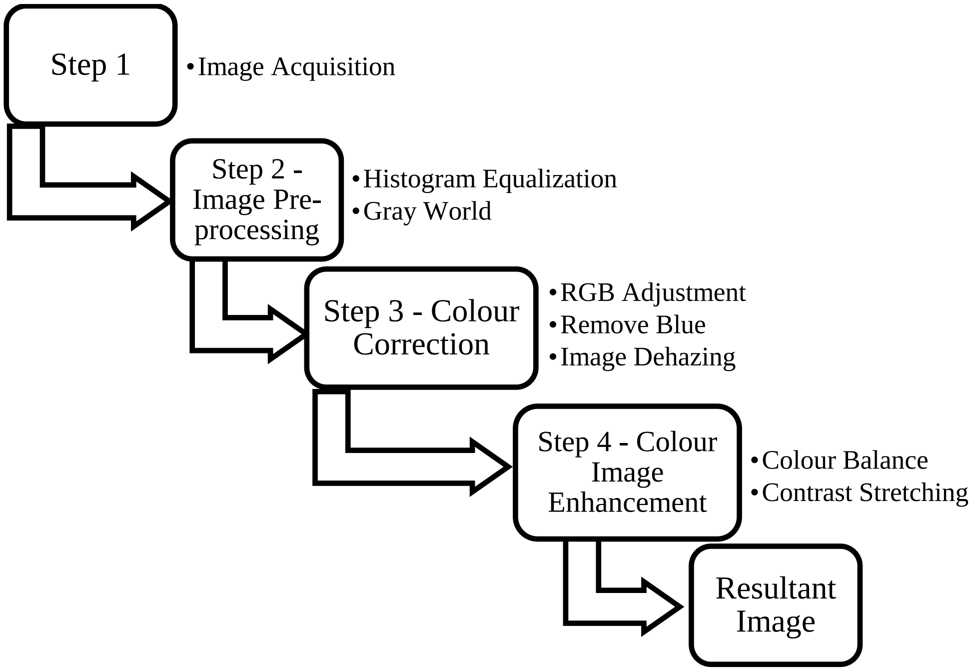


Figure 6: System Flowchart

The first step, image acquisition has been done earlier to acquire data for processing. The image is acquired using a simple yet useful architecture. The design is shown in the following figure. Image pre-processing is performed to improve the image data that contains unwanted distortions or enhances some image features which are important for further processing.

Figure 7: The image of the equipment with tied string

There are a few algorithms and methods as listed in the above flow chart and each of the methods or algorithms are discussed in detail in Chapter 4.3. After underwent these algorithms, a more suitable method or program flow to process underwater images for a better recovered and reconstructed image is produced. Refer to Chapter 4.3.4 (first proposed method) and 4.3.5 (second proposed method).

1.5 – Report Organization

This paper consists of five chapters and is organized as follows. Chapter 1 is the first chapter where the discussion on problem statement, background information and motivation, objectives, proposed approach and achievement of the project are included here. Chapter 2 is literature review of the project. Chapter 3 is the design of the system of the project. Later in Chapter 4 are the details describing the system designs together with the methodology and tools used, requirement, specification: analysis and verification plan as well as implementation and testing of the proposed method. Last chapter which is Chapter 5 concludes this report.

2. LITERATURE REVIEW

Image enhancement goal is processing an image so that the resultant image will be more suitable than the original image that the visual interpretability for human viewers will be improved and also the information acuity contained within the image will be increased mentioned by Leonie and Simon2. (Leonie & Simon2 , 2014)

One of the methods of enhancing the image used is changing the red, green and blue (RGB) value of each pixel to hue, saturation and value (HSV) values as HSV as it allows Human Visual System (HVS) to be able to see it and differentiate it easier. The hue value is not consider to be changed as it represents the colour attribute and it is presumed that changing it will change the original colour of the image as well. (Ding & Jun, 2007)

In a Journal article prepared by Iqbal and others, the method that is proposed by them in order to resolve underwater imaging issues was doing stretching in RGB and HSI or also sometimes known as HSV. Stretching of RGB is to improve the colour contrast whereas stretching of HIS is to increase the true colour while degrading the lighting problem. From doing the mentioned method, Iqbal and partners had managed to get the following result. (Iqbal, et al., 2007)

In Bazeille et al paper, they used four steps to perform four types of processing to the image. They are Homomorphic filtering, Wavelet denoising, Anisotropic filtering as well as contrast stretching and colour correction. These steps are done to reduce problem of illumination, enhance contrast, filter noise and enhance edges and colour compensation to suppress the predominant colour. Homomorphic filtering is to correct non uniform illumination and at the same time sharpens the edges as the image contrast is enhanced. Using these algorithms is good as it is fast; however, the parameters for the functions are pre-adjusted by assumption without prior knowledge to the acquisition conditions. (Bazeille, et al., 2006)

While others convert RGB to HSV for easier luminance enhancement, Bazeille and others convert RGB to YCbCr, Luminance Chrominance because YCbCr enables one channel processing unlike RGB which requires three channels processing. It is stated that by using YCbCr, the processings speed is sped up. However, YCbCr has to be converted back to RGB in order to perform colour correction or to equalize the colours in the underwater image. In Bazeille paper, he stated that the colour correction method that is used will produce a pleasant image rather than only a better segment due to the fact that the colour equalization does not change the gray image like segmentation do. (Bazeille, et al., 2006)

Wavelet transform and Reverse-S-Shape transform are applied to enhance the luminance. Wavelet transform is to decompose the signals into components such that these components are enhanced by reconstructing the brightness or improving the contrast of the image whereas Reverse-S-Shape transform is to enhance the grey-level image. Other than enhancing the luminance, the S component is enhanced to improve the image detail by making use of the high frequency spectral energy. Comparing Reverse S-Shape with Histogram Equalization on RGB Colour Space, the result shown is that the former one will have clear image especially clear in displaying the real colour but the image is not natural enough while the latter causes the image to have a bit of colour change where it turns out to be reddish and it is too sharp that the naturalness of the image is not seen. (Ding & Jun, 2007)

Fang and others have the opinion that the contrast in the underwater image should be increased to overcome the problem of light attenuation. While this raise the issue of colour changed in the image, therefore Fang uses white balance on the original image to recover the distorted colour. The main idea from Fang's paper is about fusion where several images are to be combined into one by selecting only the most significant features among those images. These are done by selecting the appropriate weight maps and inputs. Like others, RGB is not effective to be used for human visual colour; therefore Fang used different weight maps for different area of processing. The three weight maps used are Chromatic weight map which controls the saturation gain in the output image, luminance weight map which manage luminance gain by computing standard deviation between RGB channels and convert them to HSV space for brightness balancing and lastly Saliency weight map for the identification of degree of vividness of the image comparing with the adjacent regions. (Fang, et al., 2013) However, this weigh mapping method is rather complex and confusing compared to RGB to HSV conversion for contrast enhancement. Even so, Fang stated that her proposed solution has the advantage in terms of efficiency in computation.

The next algorithm used is HCCIEE. Referred to the journal article wrote by Kai-Qi Huang, Qiao Wang and Zhen-Yang Wu (2006, pp.53-54) HCCIEE algorithm consist of two stages which are enhancing the texture details as well as avoiding artifacts such as ringing or halo and rendering the colour of image according to natural image quality metrics. HCCIEE first enhance the RGB components with the wavelet enhancement algorithm with CSFs (contrast sensitive functions). Later, the enhanced RGB components are adjusted with respect to the natural image quality metrics until the colour naturalness index (CNI) is what expected and then stretch by the colour colourfulness index (CCI). Then the last step is to do a colour space inverse transform and finally an enhanced colour image is produced. Also in Kai-Qi Huang, Qiao Wang and Zhen-Yang Wu's journal article (2006, p.56) CNI is described as the naturalness in degree of correspondence between human perception and the reality world whereas CCI is describe as the colour vividness degree.(Huang, et al., 2006)

Tristan John Lambert (2005, p.23) mentioned that Schechner & Karpel (2004) has developed an approach based on physics to recover the visibility of image taken in underwater environments. This physics approach is to reduce the poor visibility cause by water turbulence by depending on the raw images taken through different states of a polarizing filter. There will be an increase in colour variation and contrast after performing this approach on the image that has polarization effects because of the light scattering underwater. (Lambert, 2005)

Naturalness Colour Enhancement for THEOS images are also one of the method used for image enhancement. THEOS is optical sensors in satellite which does not cover the whole range of wavelength for RGB spectrums causing the colour of the images emerged to be not natural. Therefore, in this article, another algorithm to enhance the naturalness of a colour image is proposed. The proposed method uses SICNI which is Satellite Image Colour Naturalness Index to measure the colour naturalness of the satellite image. SICNI is new colour naturalness metric according to the article. The SICNI of an image is separated into water, soil and vegetation by classifying them using normalized difference vegetation index (NDVI) which is employing the normalized ration of the NIR (near infrared) and red bands. The whole paragraph is reviewed from Punmanee, Kasetkasem, Chan wimaluang & Nishihara (2013, pp. 523-528). Dividing the image into portion such as water, soil and vegetation can be a great idea to be applied to the project as by differentiating those, the colour of the water and the object to be seen can easily be separated.(Punmanee, et al., 2013)

In Punmanee's paper, apart from the THEOS which is their proposed methods; there is some basic ideas regarding to image naturalness which can be referred and understood for implementation in this project. CIELUV is a standard for colour transformation proposed by Commission International de l'Eclairage with regards to Luminance, Saturation (U) and Value (hue angle). CIELUV is a colour space which is near to human perceptions on colour. Colour naturalness of an image depends mainly on hue and saturation only therefore u-v colour space should be focused on. In order to measure the colour naturalness, CNI can be computed by segmenting of the image into three parts which are skin, sky and grass. (Punmanee, et al., 2013)

In fact, before doing any image processing for betterment of an image, image pre-processing is almost a must for improvement of the image data. As stated in Kumar slideshow, this method is used to suppress the distortions that exist in images and to enhance important features in the image for further processing. (Kumar, 2012) However, image pre-processing will not be good without careful use as it will change the true nature of the raw data. (Verne, n.d.) Direct raw image data may have variety of problems that cause it almost impossible to have the best computer vision results. Therefore, it is fundamental to carefully consider image pre-processing. (Verne, n.d.)

Corrections and enhancements are part of the image pre-processing work. According to Verne, there are 5 types of corrections. They are sensor corrections, lighting corrections, noise, geometric corrections and colour corrections. Colour correction can be helpful to redistribute colour saturation that is to correct for illumination artifacts in intensity channel. Colour hue is one of the difficult attributes to correct as it cannot be corrected using simple gamma curves and RGB colour space. Meanwhile, enhancement is a kind of optimization method and not used to fix problem. It includes sharpening and colour balancing of image. (Verne, n.d.) Morphological operations basically used to clarify underlying structure of objects. Images underwent morphological transformation will give result of the attributes extracted from the images. (Leong, 2013)

Colour changes are caused by the varying degrees of light attenuation when travelling in water with different wavelength. Therefore, John and Ying-Ching had proposed a method to enhance underwater images by using dehazing algorithm to compensate the attenuation discrepancy along the propagation path. This algorithm will first do derivation of d(x) to get the median of the dark channel. This is to get at least one of the colour channel with low intensity at some pixels. The low intensity observed through the dark channel is a consequence of low reflectivity $p_\lambda(x)$. Then, it is essential to compare the artificial light between the foreground and background of the image by segmenting them. The artificial light is removed if it is detected else compensation of light scattering and colour change along the path d(x) is performed to the image to produce haze-free and colour corrected underwater image. (Chiang & Chen, 2012)

In a report written by Chambah et al. about Underwater Colour Constancy, they proposed ACE model which is a colour correction method. ACE is a perceptual approach by some adaptation mechanisms of the human visual system, i.e, lightness constancy and colour constancy. No prior knowledge about the scene is needed to perform ACE. These methods help in the restoration of images when displayed or processed with fish segmentation and feature extraction images. To achieve colour constancy, gray world (GW) and Retinex white patch (WP) are the common colour balancing method. GW and WP are designed to remove the colour cast caused by an illuminant shift. The proposed method, ACE is the merged or hybrid of GW/WP and take spatial distribution of colour information into consideration. ACE can adapt to various lighting conditions and effectively extract visual information from environment. GW method corrects the mid-tones and background of an image based on the mean of the image. This is done by doing an inversion to the colour cast in the foreground, therefore there will be magenta cast in the foreground of the image. (Chambah, et al., n.d.)

As pointed out by Tristan John Lambert (2005, p.4), most of the broad field of computer vision and some underwater projects, the image pre-processing system used to process image and the analysis technique are developed in MATLAB.(Lambert, 2005) However, MATLAB is not open source software and therefore it is not convenient for a student to use it as a development tool as it will be more costly than open source software such as OpenCV.

3. SYSTEM DESIGN

3.1 – Program Flow

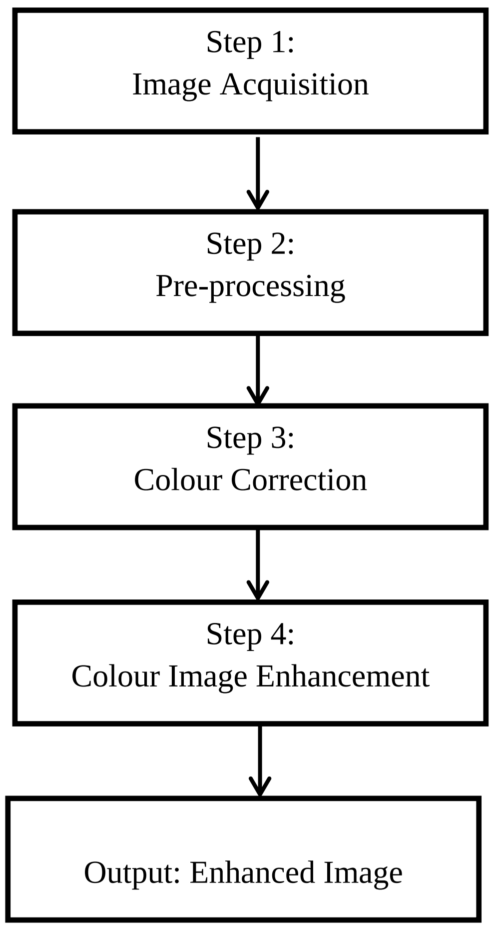


Figure 8: Methodology of reducing predominant colour in underwater images

3.2 – Design Specification

Step 1: Image Acquisition

Figures 7 and 14 were the equipment used to collect data from underwater. Bachok, Kelantan was the destination for data collection. Figure 9 shows how underwater videos were being recorded. The equipment with the camera on and in recording mode was placed into the water and pull by the string to control and measure the depth of the water.

Figure 9: Data Collection

Many videos were taken at different part of the sea. The initial data were taken to test the equipment. The first collections of data cannot be used because the equipment unsteadiness caused the camera to not capture the undersea objects but diagonally up which result in capturing unusable data as shown in Figure 10. After doing some modification on the equipment set up, good data as in Figure 11 were collected. Figure 10 and 11 were parts of the screenshot of one of the videos.

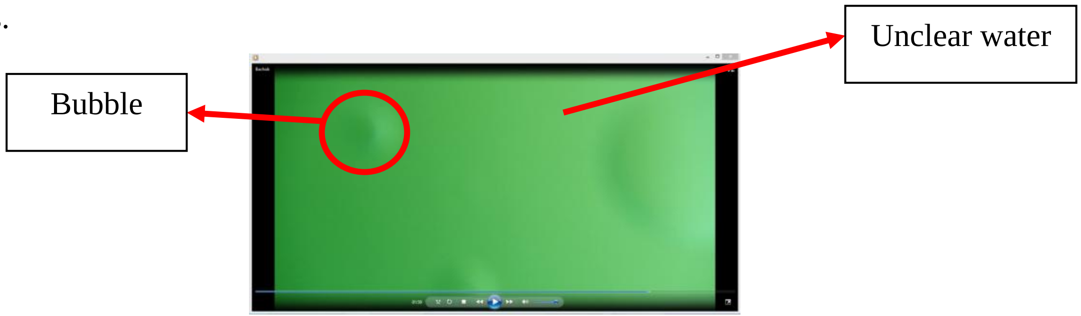


Figure 10: Initial Data for Equipment Testing

Figure 10 shows the bubble that is captured in the video due to the unsteadiness of the camera or equipment set up as stated in previous paragraph. Apart from that, this video was taken at a part of the sea where the sea water is polluted therefore the water was not clear.

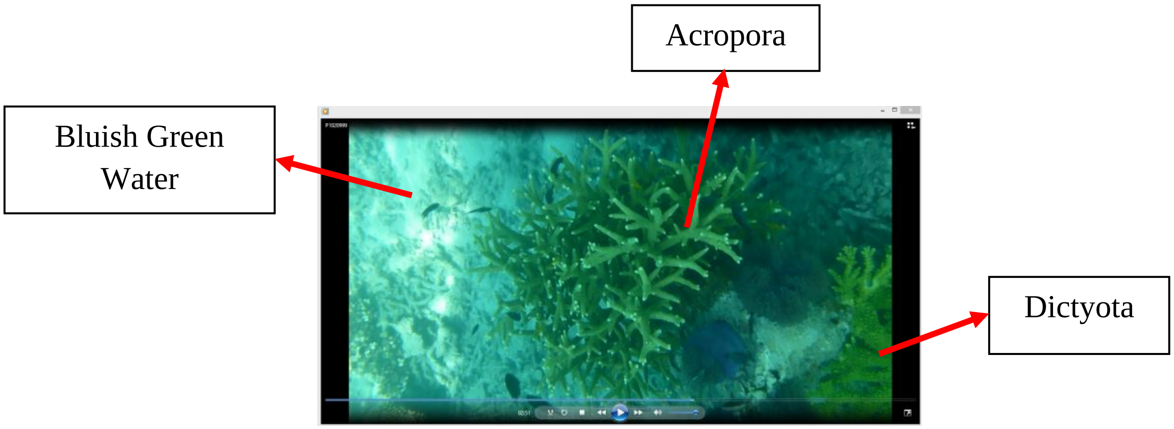


Figure 11: Data Collected

Comparing with (Garrett, 2014) collections of images and details of different Acropora species, the Acropora plant that is labelled in Figure 12 is Acropora Caroliniana. Garrett stated that the plant has a yellow/green colouration. Image below (left side) shows the image of the original colour of this plant found from google. Another species is Acropora tumida which is more to dark green colour. The original colour of Acropora Tumida is as shown on the right side. It is the image captured by Hausi. These images can act as a reference to the data collected after being processed to examine if the colour correction in the image is successful.

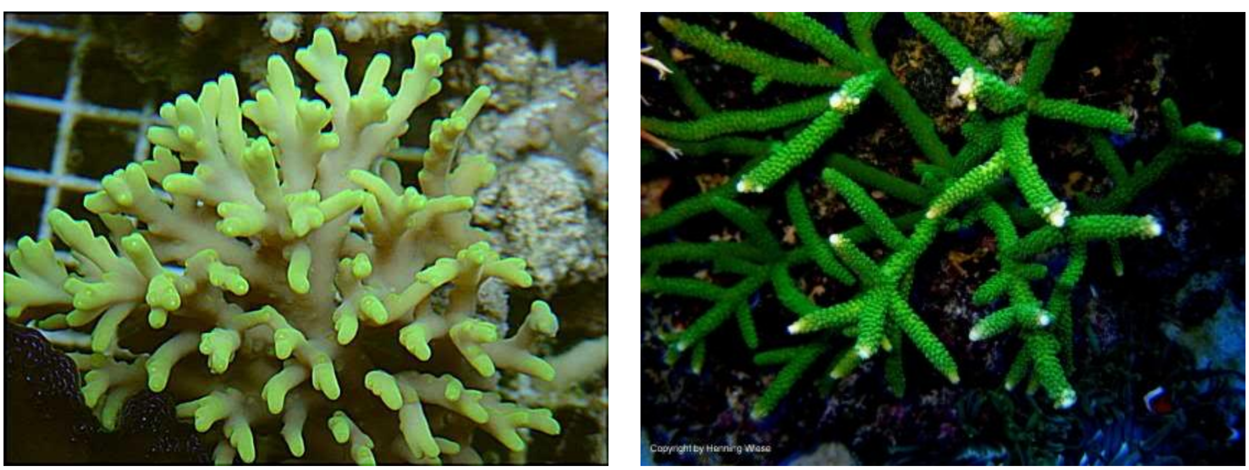


Figure 12: Original Colour of Acropora Caroliniana & Acropora Tumida

Step 2: Pre-processing

Image segmentation was done for RGB adjustments so that the object or the plant colour can be compared to adjust with another image of the same plant (Acropora) in ground level.

Histogram Equalization is an image enhancement method that was used to pre-processed the image so that gray world algorithm can perform at its best. Doing histogram equalization enables the edges of the image to be sharpened to correct the non-uniform illumination of an image. Since gray world is invariant to illuminated colour variations of RGB, histogram equalization which sharpen and enhance the brightness of the image will help to enhance the image processing by gray world algorithm.

Gray world algorithm is a white balance method that makes the assumption that an image is on average a neutral grey. It works best when there is a good distribution of colours in the image that the average reflected colour is presumed to be the colour of the light. Hence, the illumination colour cast can be estimated by comparing grey and the average colour.

Step 3: Colour Correction

For each RGB channel, difference between desired mean value and mean of the channel will be added to each pixel. This step is used to reduce the predominant colour exist in underwater images.

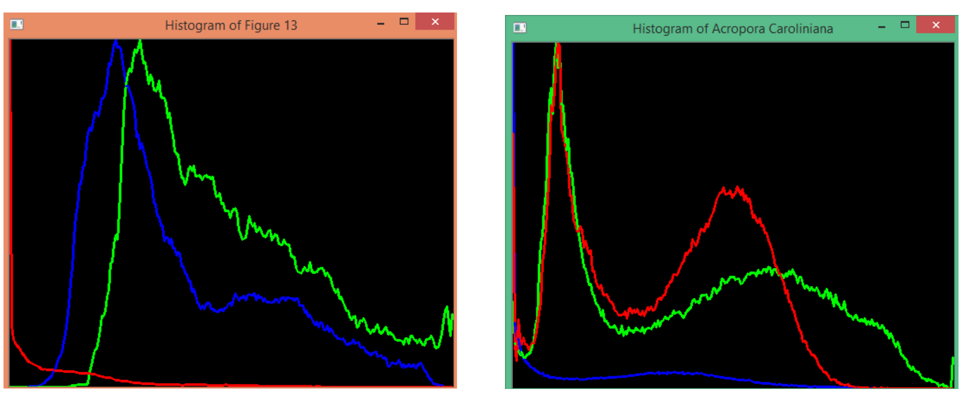


Figure 13: Histogram of Acropora in underwater and Acropora Caroliniana not in underwater

Figure 13, on the left shows the RGB histogram of the screen shot of Acropora plant from the data collected in Bachok, Kelantan. The right one is the original plant colour of Acropora as in Figure 12. As it is clearly displayed, there is excessive blue and green in the collected data due to the presence of water. Therefore, this step is to do some adjustment to the image so that the excessive blue and green colour or the predominant colours will be reduced and RGB channel can be balanced to be as of the Acropora Tumida. Another method is image dehazing or defogging. It is to reduce the predominant colour of an image as it removes the artificial light which is the cause of colour change in images.

Step 4: Colour Image Enhancement

In this step, the underwater image is enhanced by improving the brightness or contrast. Sharpening of the image is also a colour image enhancement method. The method used to enhance the image is Colour Balance. Colour balancing can increase the true colour of the plant by enhancing the colour of the plant. In addition to that, Contrast Stretching is another algorithm taken into consideration to enhance an image.

Resultant Image

The processed image is displayed together with the original image to compare their differences. An enhanced image was achieved with better satisfaction from the observers after the images were processed with the mentioned 4 steps. The output images were used to get MOS from different observers.

4. DESCRIPTION OF METHODOLOGY

4.1 – Methodology and Tools

Underwater videos were collected using underwater camera which was modified in order to be placed into the water to record data. Aluminium together with net was tied with string in order to protect the camera when it is placed in underwater. Weigh are tied to the edges so that the camera can sink into the water to record data and also to capture more steadily in order to have a better quality data. Figure 14 shows the equipment used for data collection.

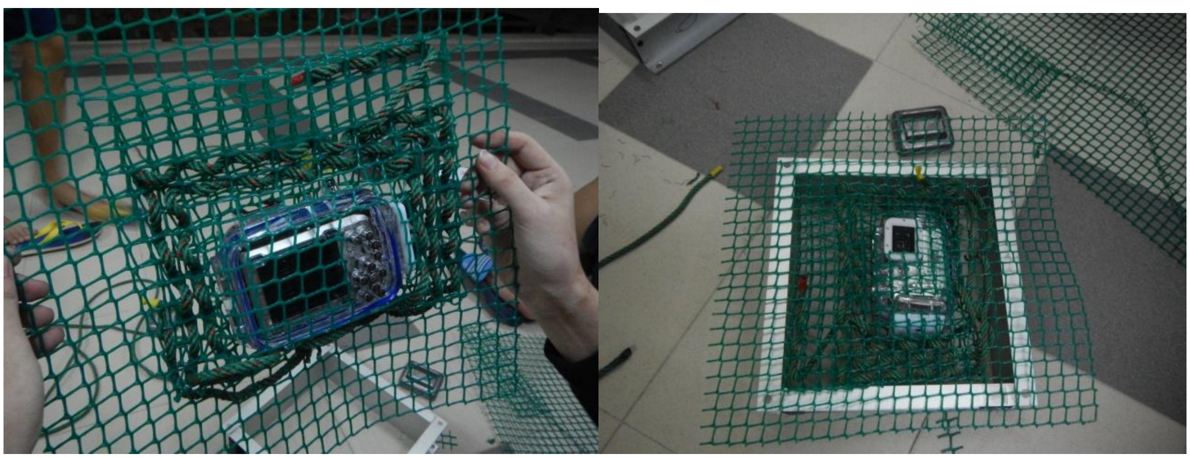


Figure 14: The images of the equipment

Strings were tied in all four ends of the equipment's edges and then placed into water. All 4 ends' strings were tied as one to ease adjustment of the camera position while collecting data. Each one meter of the string were marked with coloured tape and written with the meter number to measure the depth of the data taken in the water. Good data were collected with this equipment. The collected data were processed to achieve the objective of this project. The image processing system was prepared by using both libraries from C++ and OpenCV. MATLAB was also used in one part of the system flow and to plot histogram graph.

Figure 15: The images of needed software

As always, before doing further processing to any image, image pre-processing is almost inevitable. Since underwater image often result in heavy blue that dominant the rest of the colour in the image, colour correction should be done to reduce the blue colour or in other words balance the colour in the image.

The first proposed method consists of 3 algorithms; being (1) colour balance to enhance the image, (2) histogram equalization to increase the contrast and sharpen the edges as well as correcting the non-uniform illuminance, and (3) image dehazing to remove artificial light and hazy condition in an image.

The second proposed method consists of 4 algorithms, which is one extra algorithm namely gray world as compared to the first proposed method. The proposed methods system flow were (1) Histogram equalization, (2) Gray World to do scaling and get the mean value in the R, G and B colour channels to achieve colour correction and colour constancy in image, (3) image dehazing to further improve the effect of gray world and (4) colour balancing.

For first proposed method, all the algorithms were executed in C++ and OpenCV libraries. The resultant images are stored into the respective folder. For instance, step 1 is colour balancing; the resultant image for it will be stored in folder “1) Colour Balance”. To avoid confusion, the resultant image is named according to the algorithm performed. For example, the resultant image that was processed with colour balance, histogram equalization and image dehazing will be named as “image_CB_HE_Dehaze.jpg”. These images are used to compare and analysed. For better comparison, the original image itself is dehazed as well.

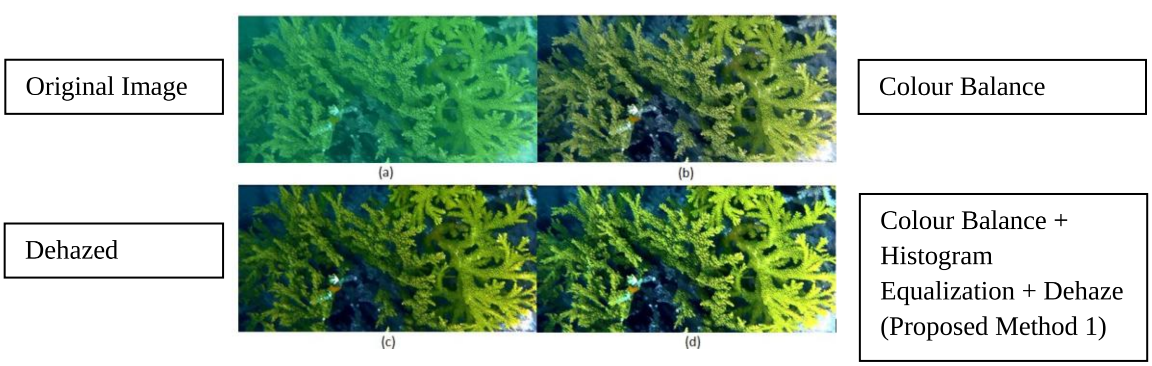


Figure 16: Sample of resultant images (First Proposed Method)

For second proposed method, the idea of storing the files is the same. However, gray world was executed using MATLAB. Therefore, histogram equalization is first executed on the original images using OpenCV and C++ libraries. The resultant images were named “x_HE.jpg” and were placed into MATLAB folder for the execution of Gray World algorithm. Thereafter, “x_HE_GW.jpg” (resultant image after histogram equalization and grayworld) were placed into visual studio working documents for further processing in C++ and OpenCV libraries.

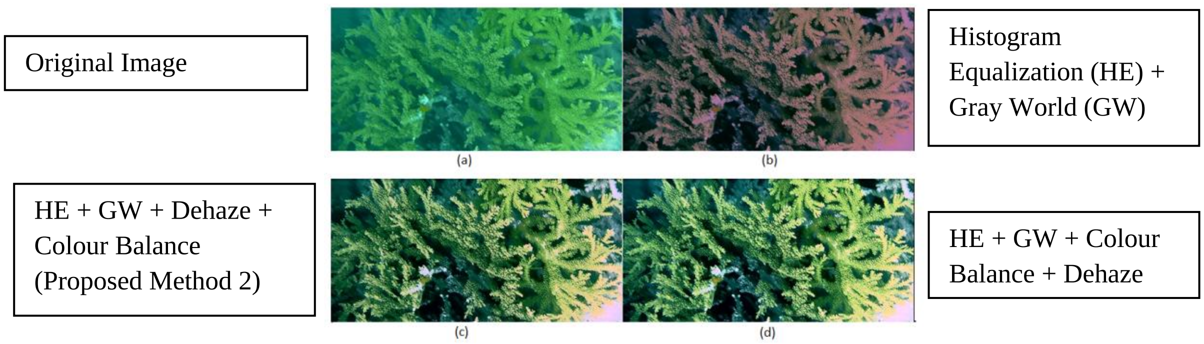


Figure 17: Sample of Resultant Images (Second Proposed Method)

In order to test the image quality between the original and enhanced image, Mean Opinion Score (MOS) was used. This is a test that has been used for human user’s view of quality of something, for example, image quality. The MOS set is placed in Appendix.

4.2 – Requirement

Generally, as described in section 4.1, the essential tools and equipment needed for this project is underwater camera with special architecture design to collect data and Microsoft Visual Studio collaborating with OpenCV library to process the underwater images. MATLAB was used to process image as well.

4.3 – Specification: Analysis, Implementation and Testing

4.3.1 – Pre-processing

Image Segmentation

The image was segmented to do comparison in terms of RGB between the object of the segmented images. This method is known as RGB Adjustment. The segmented plant images are as followed.

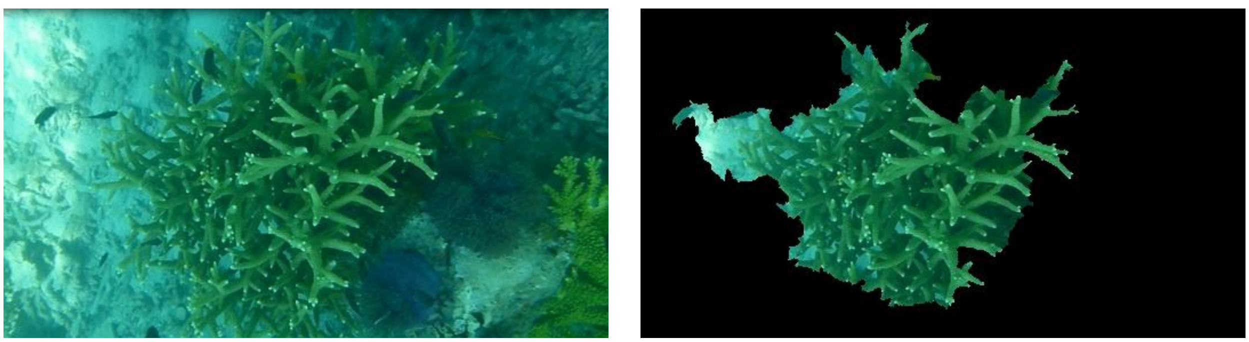


Figure 18: Image Segmentation Result of Acropora from Collected Data

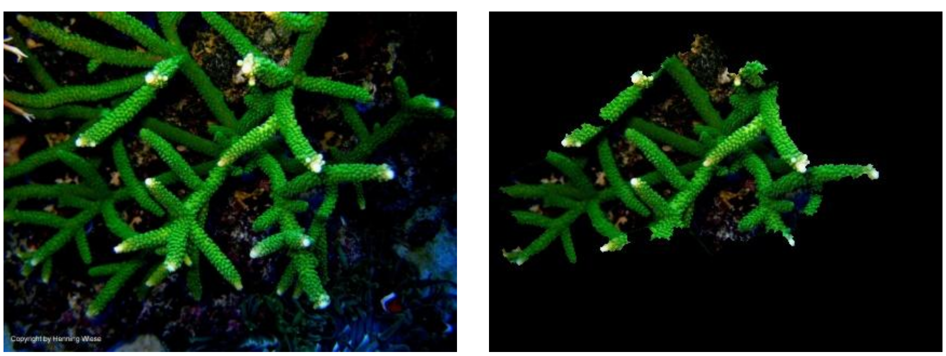


Figure 19: Image Segmentation of Acropora Tumida with Original Colour

Histogram Equalization

Histogram Equalization is done by stretching out the range of intensity that is clustered in an image. This will improve the contrast of an image. This method first converts the image colour channel from RGB to YCrCb format. Then split the channels and use OpenCV's equalizeHist() function to equalize the luminance, Y channel. Generally, the algorithm for histogram equalization is

$$p_n = \frac{number\ of\ pixels\ with\ intensity\ n}{total\ number\ of\ pixels\ n} \quad \text{where } n = 0, 1, \ldots, \mathrm{L} - 1, \text{where}$$

- p – normalized histogram of image represented in a matrix
- L – the pixel intensity of the image represented in a matrix

Then, merge back the channels and convert it back to RGB channel for proper display.

Equalization effect in OpenCV is done by doing remapping on the cumulative distributive function (cdf). The cumulative distribution for histogram H(i) is H'(i) that is $\mathrm{H}'(i) = \sum_{0 \leq j < i} \mathrm{H}(j)$. H'(i) is normalize and the maximum value for the intensity of the image is set to be 255. The remapping procedure used to obtain the intensity values of the equalized image is $\text{equalized}(x, y) = \mathrm{H}'(src(x, y))$. The overall equation for the remapping procedure is

i) Transform the pixel intensity, k of the image
   - $T(k) = floor\ [\ (L - 1) \sum_{n=0}^{k} Pn\ ]$

ii) Assuming transformation as a continuous random variables; it is defined as:
   - $T(X) = (L - 1) \int_0^x px\ (x)\ dx$ where
     - T(X) – cumulative distributive function of X * (L – 1)
     - p_x – probability density function

iii) Assuming T is differentiable and invertible; T(X) is uniformly distributed on [0, L–1] that is $p(X) = \frac{1}{L - 1}$

The following shows the result of doing histogram equalization on different underwater images; on the left is the original image and on the right is the processed image. It can be seen that this method is important for certain image and not suitable for certain image.

Figure 20: Histogram Equalization on Acropora

In Figure 20, the histogram equalization method has made the image to be too bright from the original image. The image appeared to be over enhanced as indicated in the red circle area; the image details are lost. However, in figures 21, the images are enhanced to be better. Some of the details that are blurred in the original images are sharpen and emerged to be clearer as indicated in the yellow circle. However, the same problem in the figure 20 remains a problem (red circle).

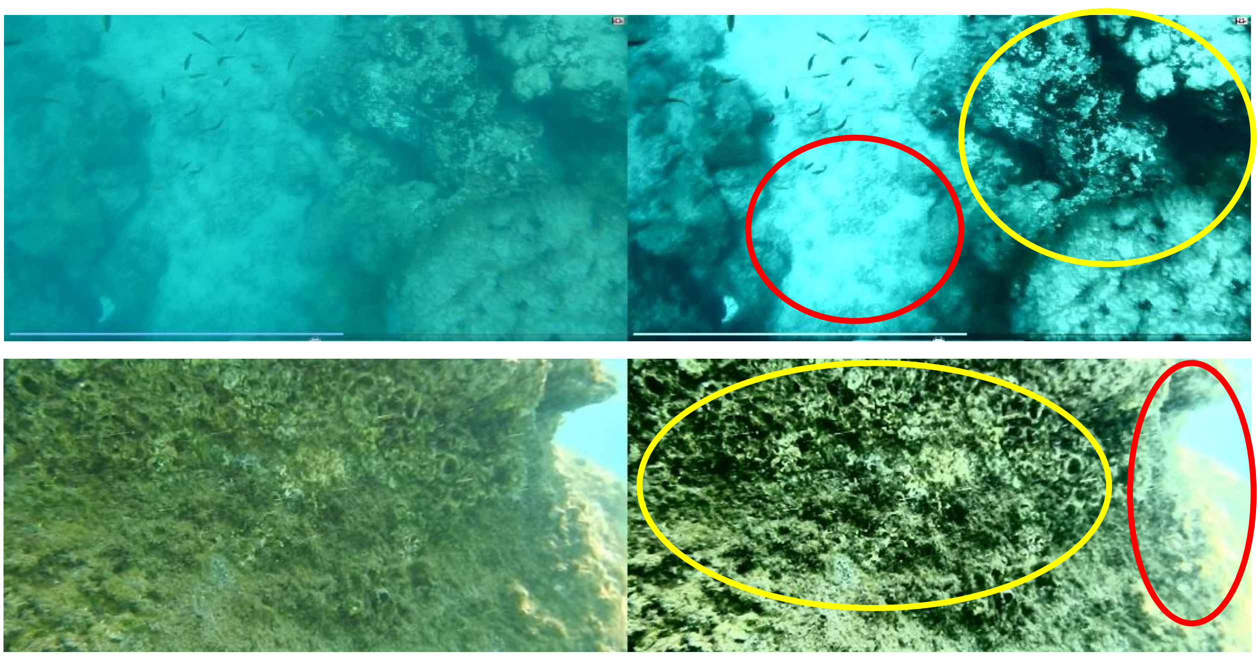


Figure 21: Histogram Equalization on Underwater Image

Following is the histogram graph of Acropora (Figure 20), it shows that the histogram equalization is also doing contrast stretched that stretched the pixels and equalized them for a better result. The colour distributions are better after processed with histogram equalization.

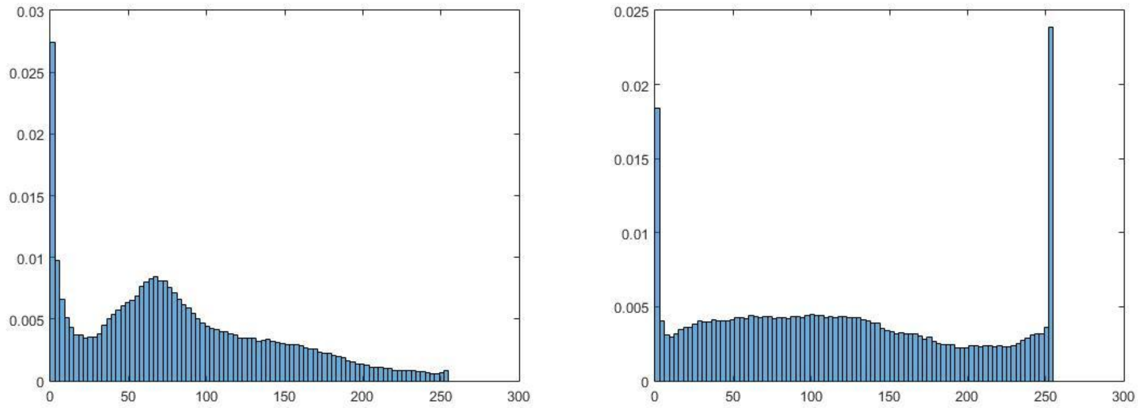


Figure 22: Histogram Equalization - Resultant Graph

Gray World

Gray world algorithm estimates illumination by computing the mean of each channel of an image. The pixel value is scaled by $s_1 = \frac{avg}{avg_i}$ where *avg*avg_i is the channel mean and *avg* is the illumination estimate. The image is normalized by $r_i = \frac{\max(avg_R, avg_G, avg_B)}{avg_i}$. (pi19404, 2013) Dividing each colour channel by its average value can achieve a constancy solution. (Wikipedia, 2015) The image pixels are then scaled by performing multiplication of each and every pixel of the R, G and B by the inverse average values of the R, G and B. Following is the resultant image of performing Gray World algorithm without pre-processed and with pre-processed by Histogram Equalization. Therefore, it is essential to pre-process the image before processing with Gray World.

Figure 23: Gray World Resultant Images

Gray world algorithm can aid in enhancing the image with proposed method 2. It must be used with care because when there is a wrong selection of algorithm to work with; gray world can cause a divergent in the pixels and distort the actual colour value of the image as circled in red. The following 4 images are the distorted images from performing gray world algorithm followed by colour balance and dehaze.

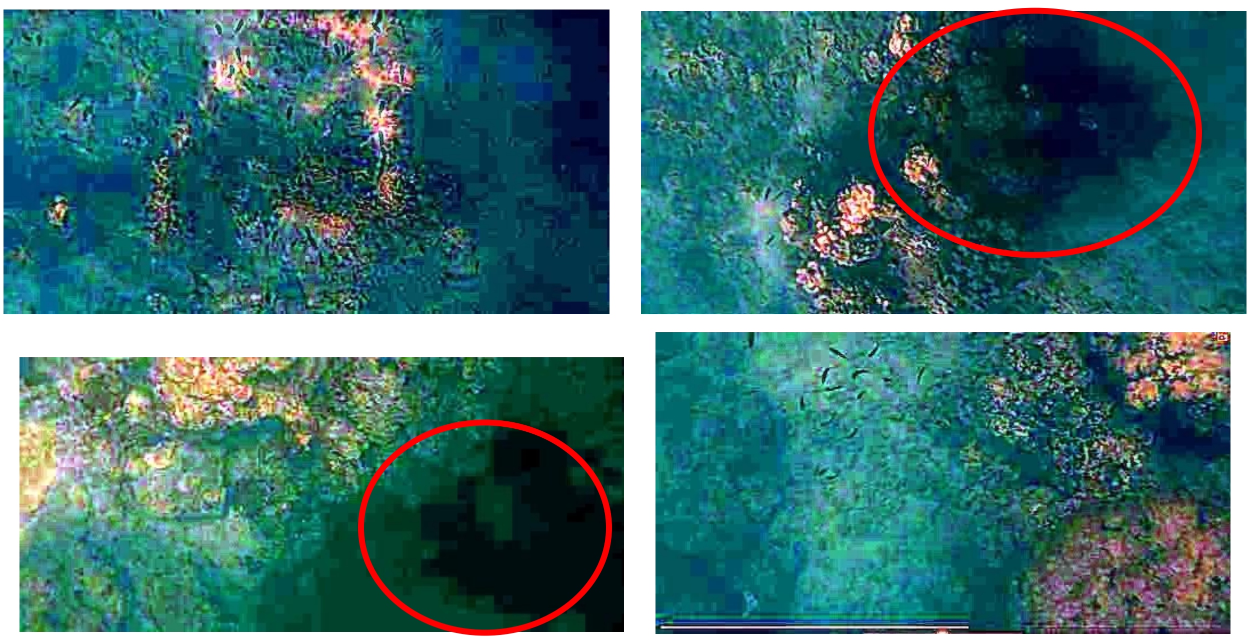


Figure 24: Gray World Caused Distortion

However, the same sequence of processing can result in a good image as well. These 2 images are nicer than proposed method 2. However, proposed method 2 does not have problem of distortion, therefore proposed method 2 is still preferred.

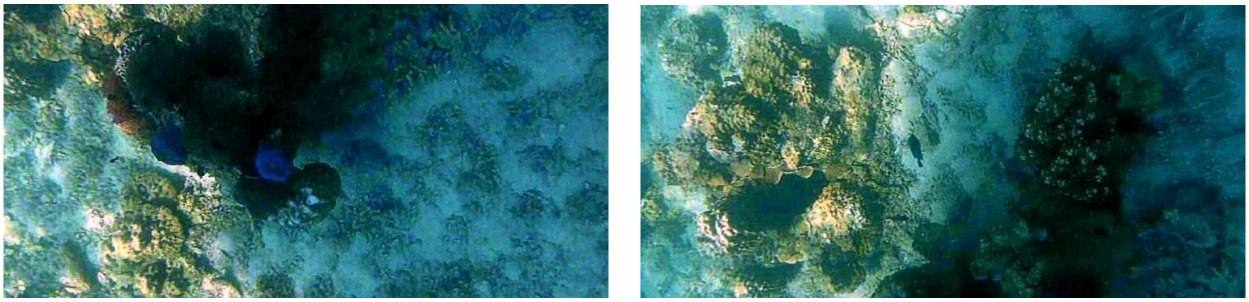


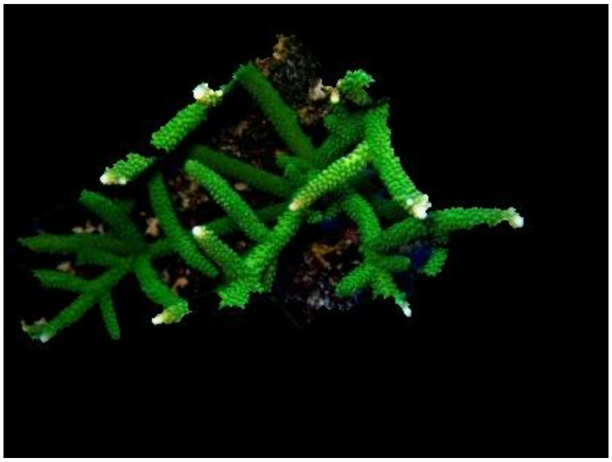
Figure 25: Good Gray World Algorithm Result

4.3.2 – Colour Correction Method

<u>*RGB Adjustment*</u>

The first individual method that is tested is RGB Adjustment. The RGB of 2 cropped images (as of Figure 18 and 19) were compared and adjusted accordingly. This was done by first splitting the image into B, G and R, 3 planes. Blue, Green and Red values of both images were calculated separately. The difference between the BGR values of the plant with natural colour and BGR values of the plant in underwater was computed and then added back to the BGR values of image of the plant in underwater.

After putting this colour correction method to execution, the result does not show any difference between the input and output image. On the left side, is the original cropped image and on the right side is the image of the adjusted RGB values of the plant. Their histogram was compared as well. This method was failed because RGB colour space cannot be used to do colour correction as mentioned in Chapter 2 of Verne's book. (Verne, n.d.)



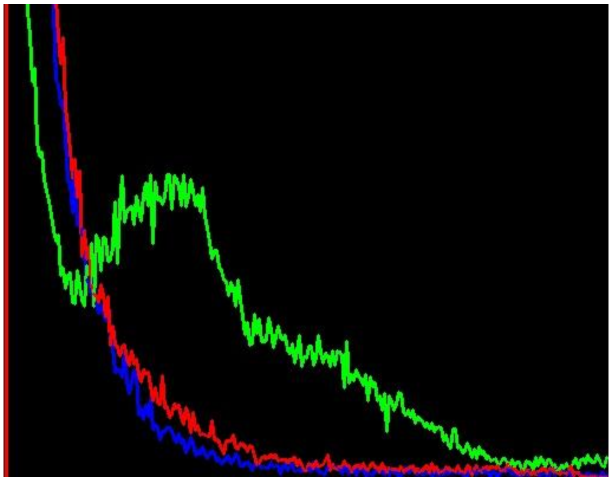


Figure 26: Acropora Tumida on ground and its Histogram

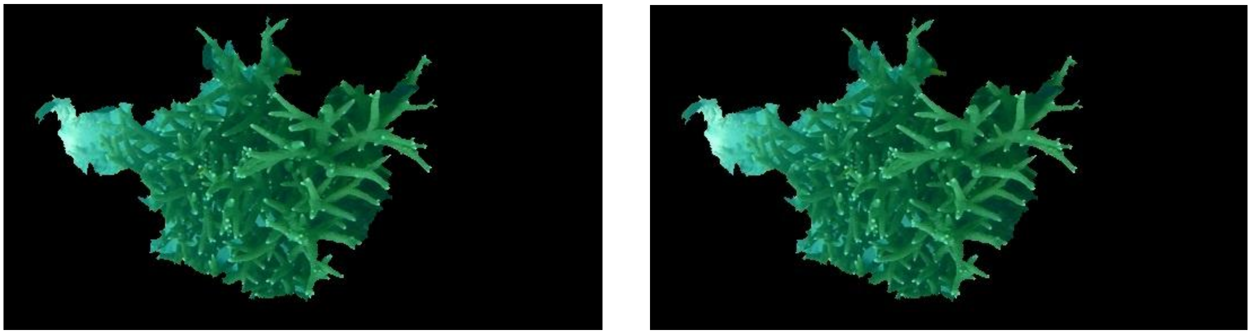


Figure 27: Acropora in underwater (Original (left) & Adjusted (right))

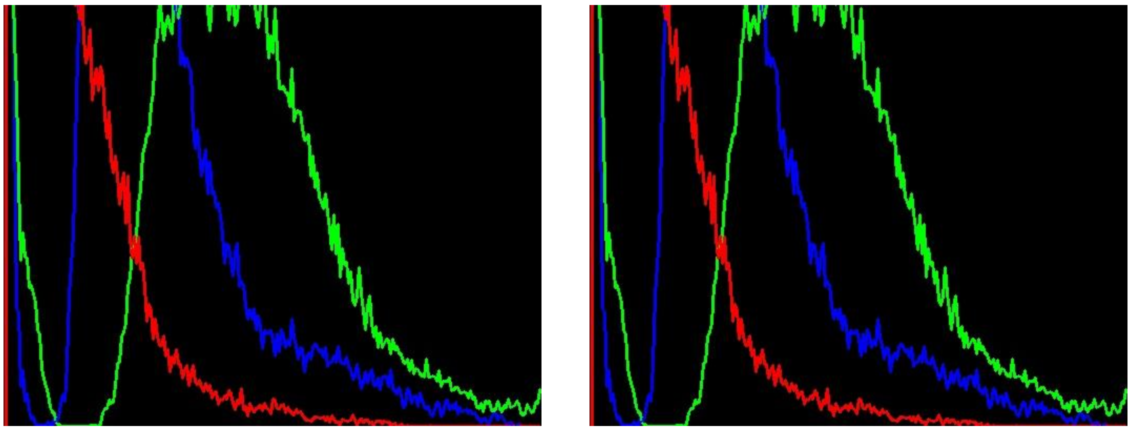


Figure 28: Histogram of Acropora in underwater (Original (left) & Adjusted (right))

Remove Blue

The second individual method is removing blue colour from the image. To do this, first the image was split into RGB channels and then blue channel was set to 0. Hence, the image had no blue colour. The channels were then merged and the image was displayed. Doing this will result in an image having only red and green since blue colour has been set to 0 (removed). This method directly remove blue leaving only green colour, the second predominant colour in the image. Therefore, this algorithm should not be considered.

Figure 29: Underwater Acropora Removed Blue Colour

Image Dehazing

Image Dehazing is a method that can enhance underwater images by taking into consideration of the artificial light which causes the colour change in an image. The method compensates the attenuation discrepancy along propagation path.

Dehazing algorithm will first use the dark channel to estimate the transmission map that is the depth of the image. Before doing this, there is a need to determine the airlight value that is the maximum in the image. All these values are then use to formulate the dehaze algorithm. Given $I(x) = R(x)t(x) + A\ (\ 1 - t(x))$, where I is the observed light intensity vector with RGB values, R is the scene radiance vector, A is the maximum airlight, x is the position of the scene point and t is the transmission along the line of sight which remain constant among the 3 channels. The whole algorithms are as follow:

i) Dark Channel Prior
- Get the minimum value for each R, G and B from the image
- Using $[\min()]^2$ for each B, G and R and to get the dark pixels
  - $Dark(x) = min_{r,g,b}\ [\mathrm{I(x)} - R(x)t(x)] \approx\ min_{r,g,b}(min_{patch}J_c(y))$, where the patch must be odd number and larger than 1 for good effects.
  - J_c is the image to recover and c refer to the colour channel

ii) Filter the image (medianBlur)
- Smoothing – to preserve the edges and remove noise

- Since naturalness of an image often affect by the saturation of the image, therefore filtering can be done in order to sharpen the edges and correct the non-uniform illumination of an image.

  - void medianBlur(InputArray src, OutputArray dst, int ksize)

iii) Estimate the maximum airlight from the processed image (dark channel)

  - void minMaxLoc(InputArray src, double* minVal, double* maxVal) to get the maximum or the brightest pixels from the dark image
  - Brightest_Pixel = max(*Dark(x)*)

iv) Estimate Trans mission Map – Using both Dark Channel and Max Airlight values

  - Get the neighbouring transmission pixels in the whole image by using the transmissions of the wide-spread dark pixels
  - $t(x) = 1 - w * \frac{\text{eq (i)}}{A} * 255$
    - *w* is set to be 0.75 (according to the rates of colour attenuated in water) (refer to Figure 4)
    - different parameters, w for different depth of images are tested for confirmation using a normalized histogram to see how well is the distribution with different parameter

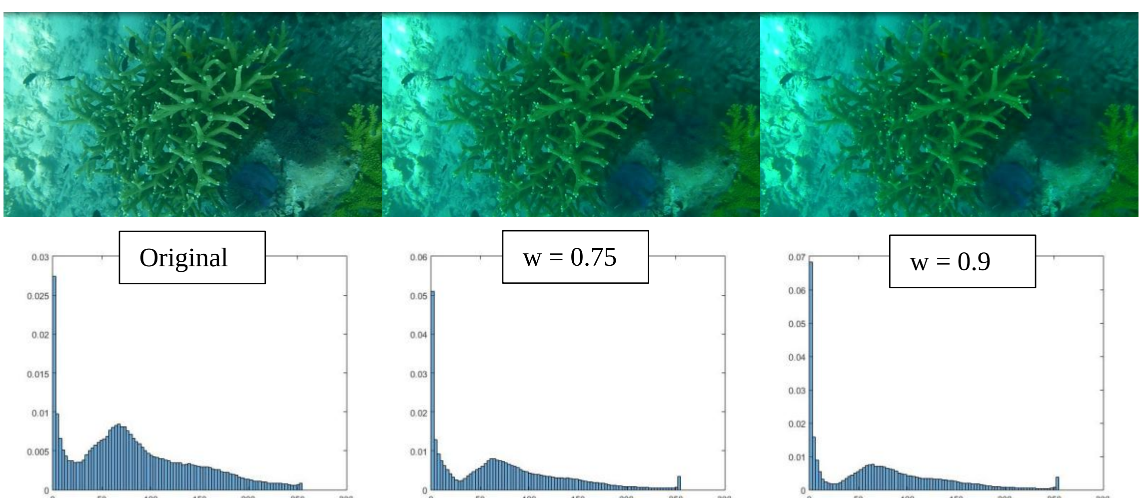


Figure 30: Parameters Testing Transmission Map 1

From above figure, the histogram graph is more well distributed with w=0.75 than the original and w = 0.9. The image processed with w=0.9 appear to be blurred compared with the other two. The histogram graph also shows that certain pixels appeared to be too high and certain pixels to be too low.

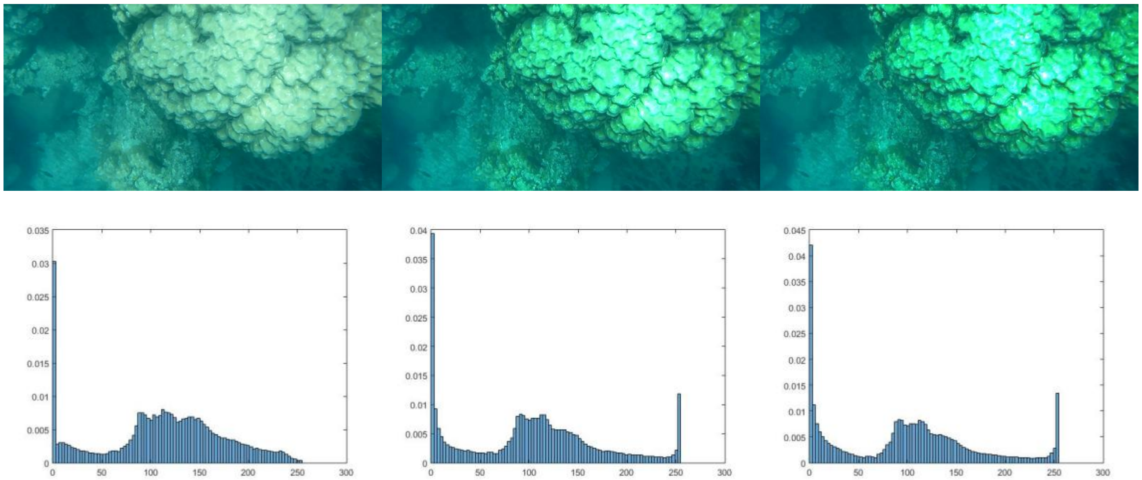


Figure 31: Parameters Testing for Transmission Map 2

From above figure, again the histogram graph is more well distributed with w=0.75 than the original and w=0.9. The image for 0.9 is over enhanced that certain pixels of the plant are lost due to over saturation of light. The resultant image with w=0.9 is not as nice compared to w=0.75 too. The colour of the plant is enhanced with w=0.75 and the side effects is acceptable.

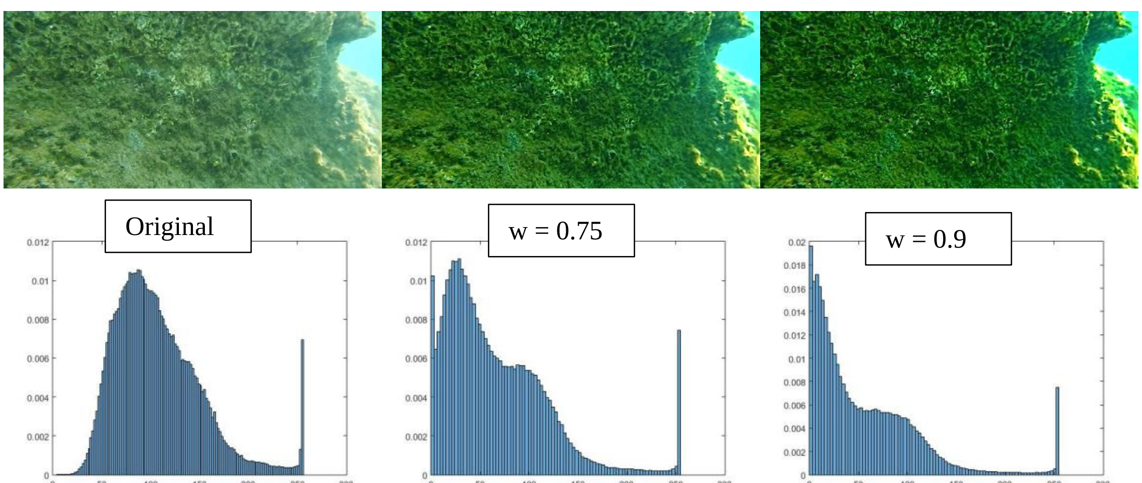


Figure 32: Parameters Testing for Transmission Map 3

From above figure, again w=0.75 has a better distribution of histogram graph. The graph is shifted because the colour change in the image is thorough and the colour in the image has been enhanced.

v) Dehazing algorithm

- Get $\max(t(x))$ is get from the transmission map where the first channel (blue) value is divided by 255
- Using the processed transmission image, get the absolute value for $\frac{(I(x)-A)}{\max(t(x),t_0)} + A$ for whole image of the original image to get a dehazed image.

The following are the images of processed image with image dehazing algorithm comparing with the original one on the left. Image dehazing had enhanced the colour of the plant and it is deduced that removing the hazy bluish of the water effect can colour correct the image.

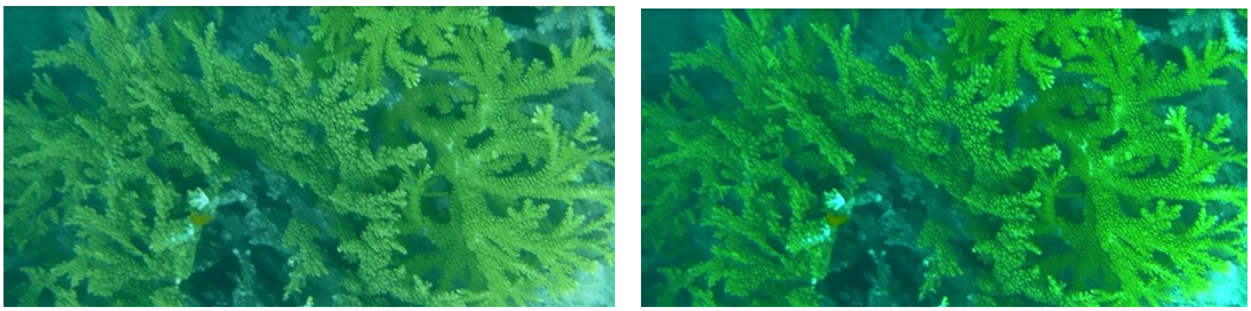


Figure 33: Original (Left) and Dehazed (Right) Underwater Dictyota

4.3.3 – Enhancement Method

<u>Colour Balance</u>

Colour Balance is an enhancement method that can improve the quality of an image being observed. The idea of doing colour balancing is to adjust the low value to lower value and high value to higher value based on the input percentile. This is to say, the brighter side of the image will turn out to be brighter and the dark side of the image will turn out to be darker. Colour balance is performed by first splitting the image into R, G and B. Then the values are sorted in ascending order and the values are adjusted (low to lower and high to higher). These values are then set to the pixels before merging back the 3 channels.

Image processed with colour balance algorithm appeared to be brighter and had sharpened. The plants' colour became clearer and more obvious. Colour balancing is of an image enhancement method – used to optimize specific feature measurement method (Verne, n.d.)

Figure 34: Colour balancing on Acropora Plant

Another enhancement method analysed is Contrast stretching algorithm. It is a piecewise linear function which increase dynamic range of grey level in the image being processed. Following is a linear contrast stretching graph which shows the relationship between the pixels for saturation, s and reflectivity, r of in image with maximum value of 255.

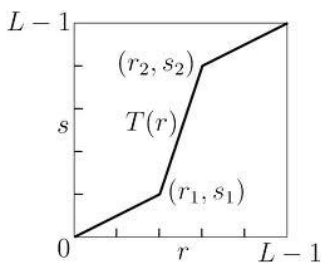


Figure 35: Contrast Stretching Graph

It has 4 parameters, r1, s1, r2 and s2. (r1, s1) and (r2, s2) acts as a control point of the transformation shape. The intensity of output pixel can be calculated with the provided x input pixel as follows:

- for $0 \leq x \leq r1$; the output will be $\frac{s1}{r1} * x$
- for $r1 < x \leq r2$; the output will be $\frac{(s2 - s1)}{(r2 - r1)} * (x - r1) + s1$
- for $r2 < x \leq \mathrm{L} - 1$; the output will be $\frac{(\mathrm{L}-1-\mathrm{s2})}{(\mathrm{L}-1-r2)} * (x - r2) + s2$

The transformation is a linear function when r1 = s1 and r2 = s2 and this will not produce any effect towards the image. This is known as identity transform. When r1=r2, s1=0, and s2=255, a thresholding function is obtained. Thresholding an image is not the concern of this project. It is normally used to do segmentation of an image by separating the important pixels properly and then set a determined value to identify them. For instance, set 0 or 255 to get black or white respectively. (OpenCV, n.d.) Following is a diagram of the underwater Acrpora image that has been processed with the thresholding values.

Figure 36: Threshold Image of an Underwater Acropora

The constraint for the algorithm is that it is a must for $r1 \leq r2$ and s1 $\leq s2$. This constraint is to prevent intensity artefacts in the processed image and ensure the transform function to increase monotonically. Following image is an example of contrast stretch image with r1=70, s1=0, r2=140, s2=255.

Figure 37: Contrast Stretch Underwater Acropora

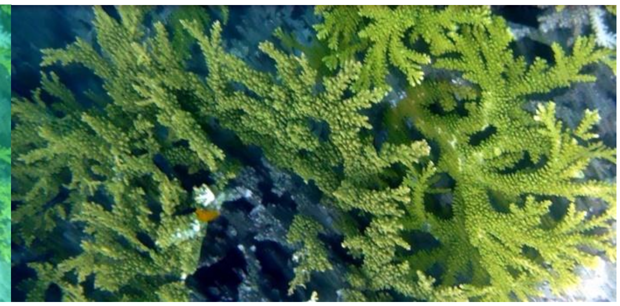
This method is not helpful compared to histogram equalization. Similarly to Colour Balance algorithm, the bright colours become brighter and the dark colours become darker; however, it does not reject any of the very bright or very dark pixels causing the white might be impure. This method is normally used to remove undesirable colour tint from an image which should contain pure white and pure black. (Mattis & Kimball, 2014) In my opinion, it may be useful when use to solve shadow related problem.

4.3.4 – Proposed Method 1

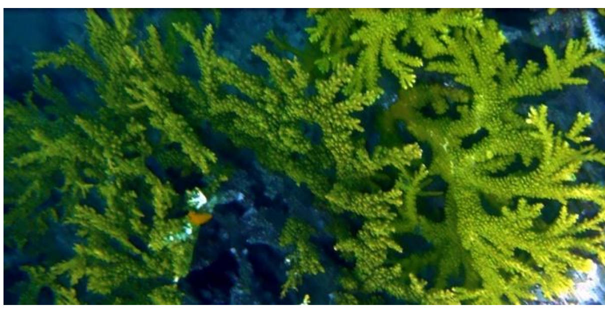
After looking into the few algorithms, it can be seen that by combining them together an enhanced underwater image will be produced.

(a) original image, (b) pre-processed (colour balanced), (c)colour correction (dehazed), (d) proposed method 1 {colour balanced, (image enhancement) histogram equalized, dehazed }

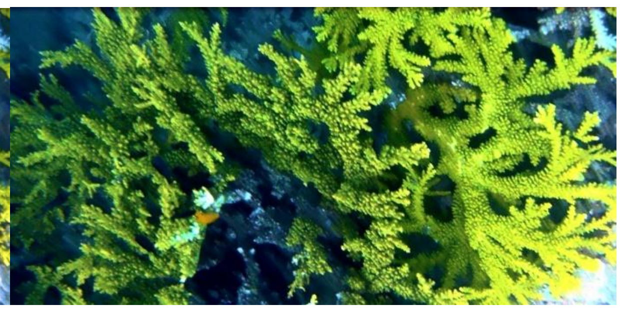
(a)



(b)



(c)



(d)

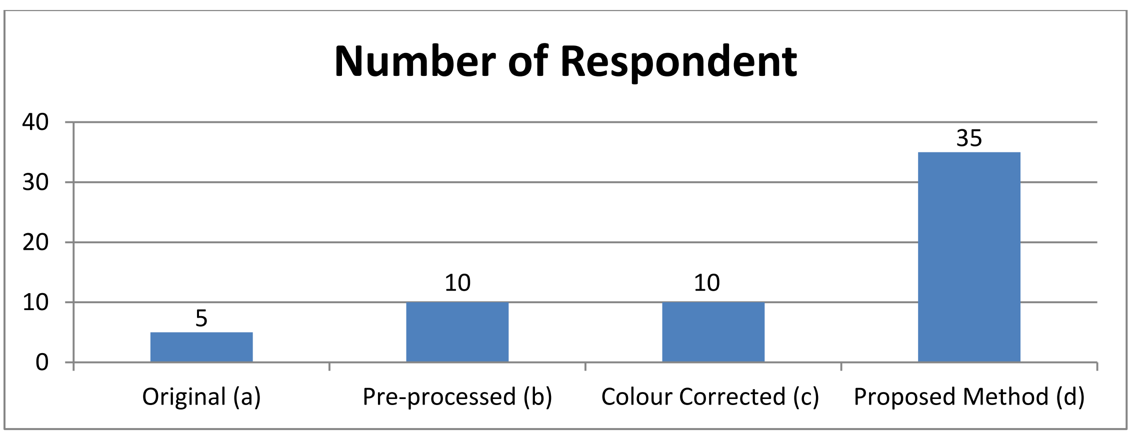
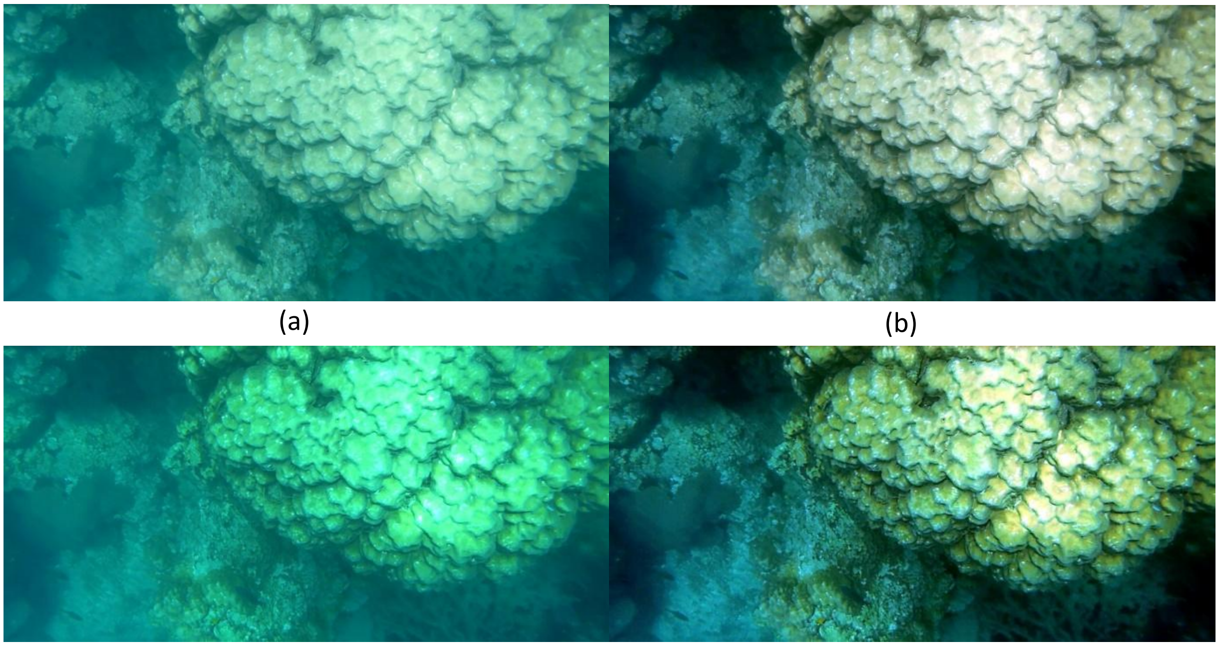


Figure 38: MOS Data Set 1

The original image in set 1 data is Acropora plant in underwater where green is its nature colour. From the graph, they are 5 out of 60 respondents has the opinion that it has better quality. Half of 20 think that the image is better at pre-processing stage or colour corrected stage. The pre-processed image is clear but it has high degree of artificial light that reduce its naturalness while the colour corrected image has a sharp plant colour. It may be because the colour corrected image is not bright enough for people to like it. From the MOS, majority of the 60 respondents which is 35 of them have the opinion that the image processed with proposed method has the best quality among the 4 shown images.



(a) (b) (c) (d)

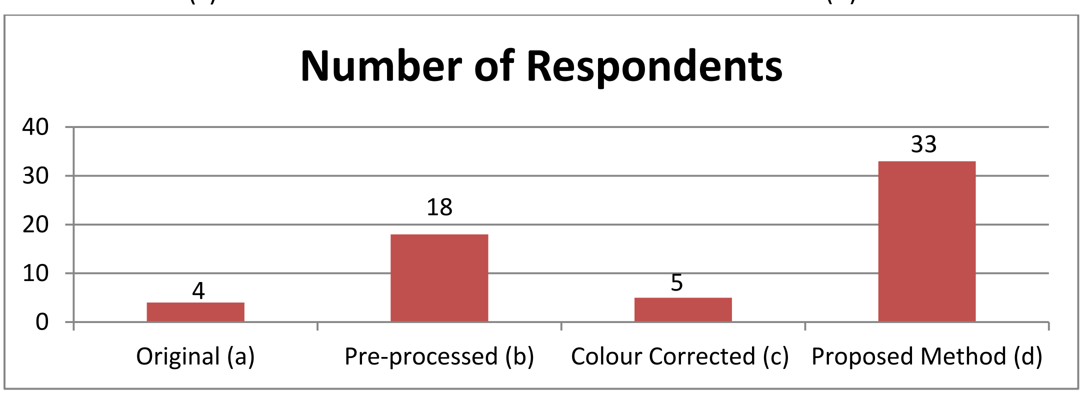
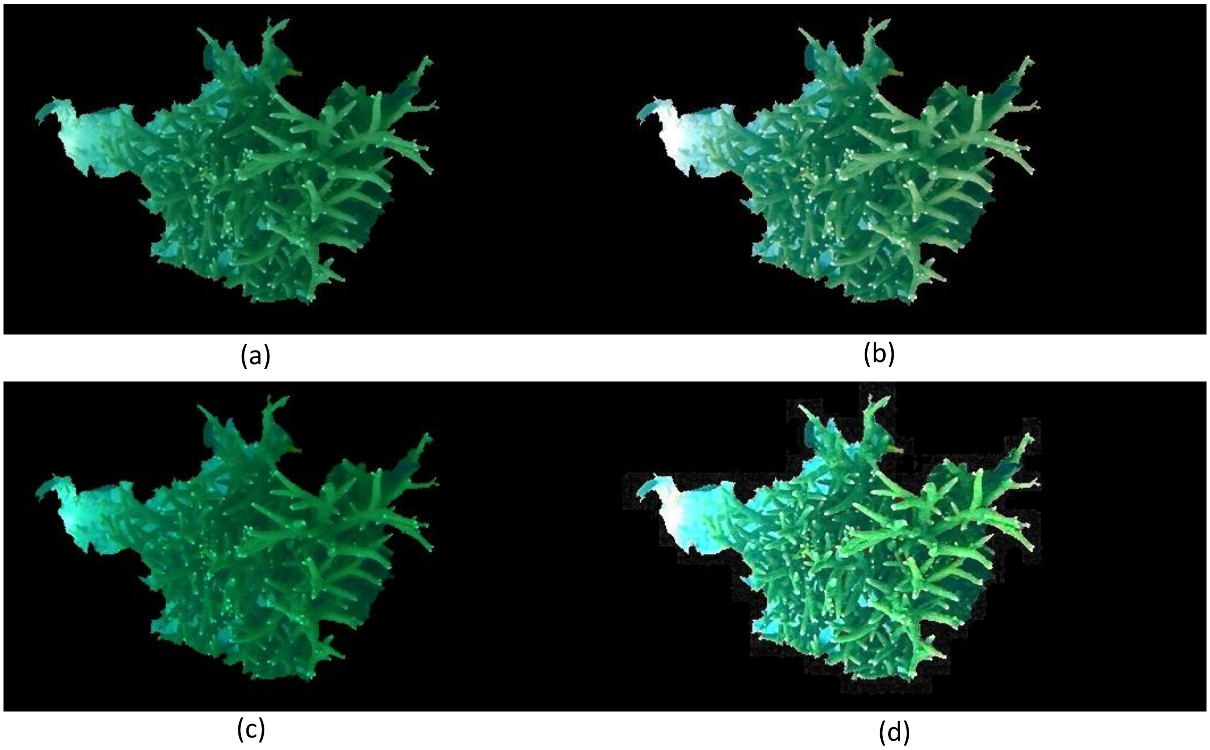


Figure 39: MOS Data Set 2

For set 2, the main object in the underwater image is the plant which is Acropora Caroliana whereby the natural colour of the plant is yellowish green. Only 4 of the respondents prefer the original image. 18 of them like the pre-processed image which is brighter. Another 5 respondents like colour corrected image where the plant natural colour is emerged but the overall image is not natural. 33 out of 60 respondents like the image that is processed with the proposed method. This is because the natural colour of the plant in underwater is more obvious in the image. The processed image is sharper and clearer too.



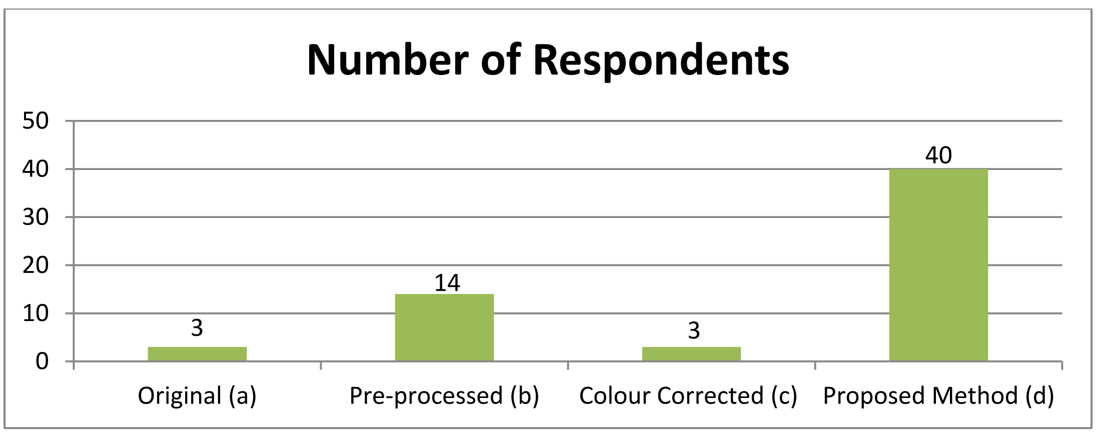


Figure 40: MOS Data Set 3

Third MOS data set refers to the image of the pure plant where the background has been segmented before further processing is performed on the image. The image is segmented so that the processing can focus on the underwater plant. However, when compare to the same image without being segmented, the image will be better enhanced with all full details (compare with MOS Data Set 4 – Figure 35). From the response, it can be seen that observers like bright image than dark image because 14 of them chose pre-processed image which is slightly enhanced compared to the original one and 40 of them chose the image processed with proposed method which is a lot brighter and sharper.

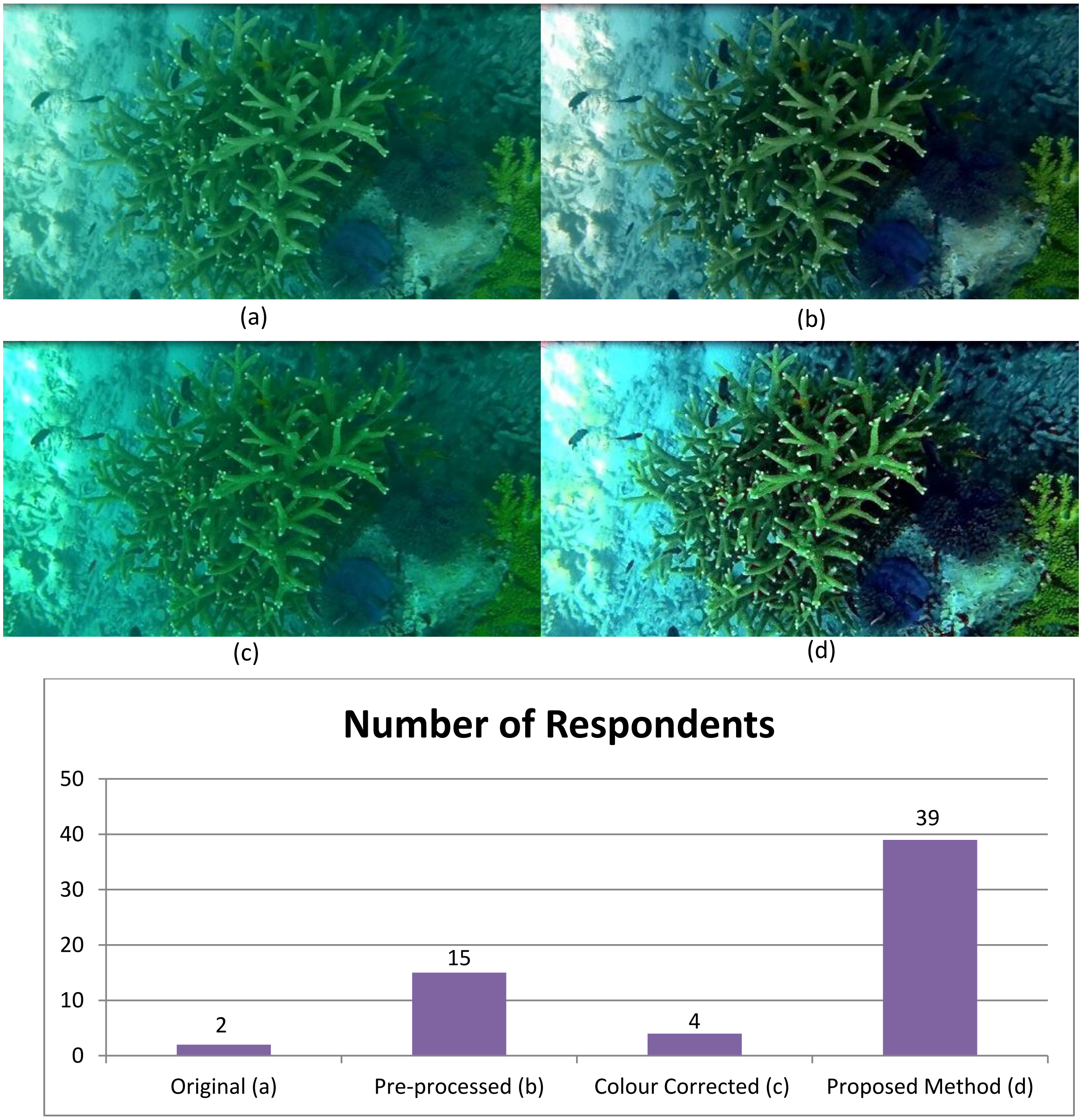


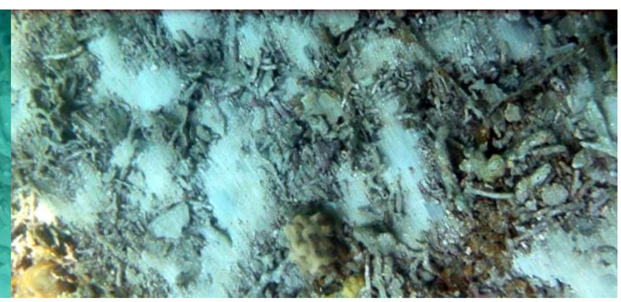
Figure 41: MOS Data Set 4

In this data set, 39 of the 60 respondents share the opinion that the image with proposed method processed is the best among the others. As mentioned most of the observers like bright image and proposed method give the brightest image. However, the image is a bit unnatural and certain part of the image is too bright that some of the image details are lost. Therefore, there are 15 respondents who prefer the darker one which is the pre-processed image. There are 2 and 4 respondents like the original image and colour corrected image respectively.

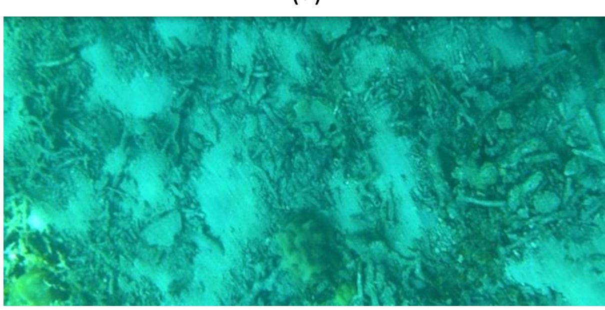
As mentioned earlier, histogram equalization may not be suitable for all images especially are not suitable for image that is originally bright enough. The image in data set 4 is originally bright, therefore the histogram equalization image enhancement method can be omitted to get a better result as shown in the right side of the diagram below.

Figure 42: Omission of Image Enhancement Method

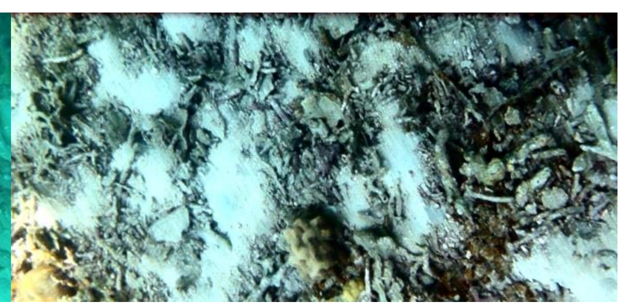
(a)



(b)



(c)



(d)

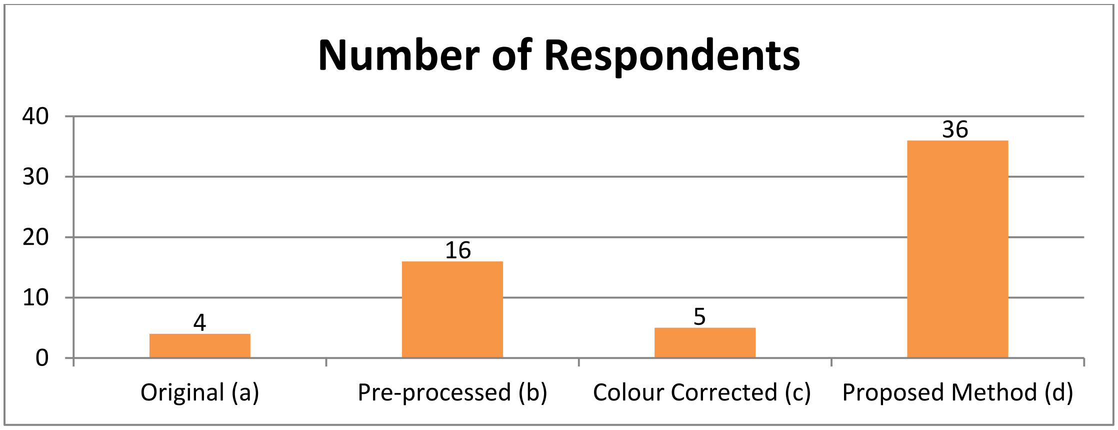
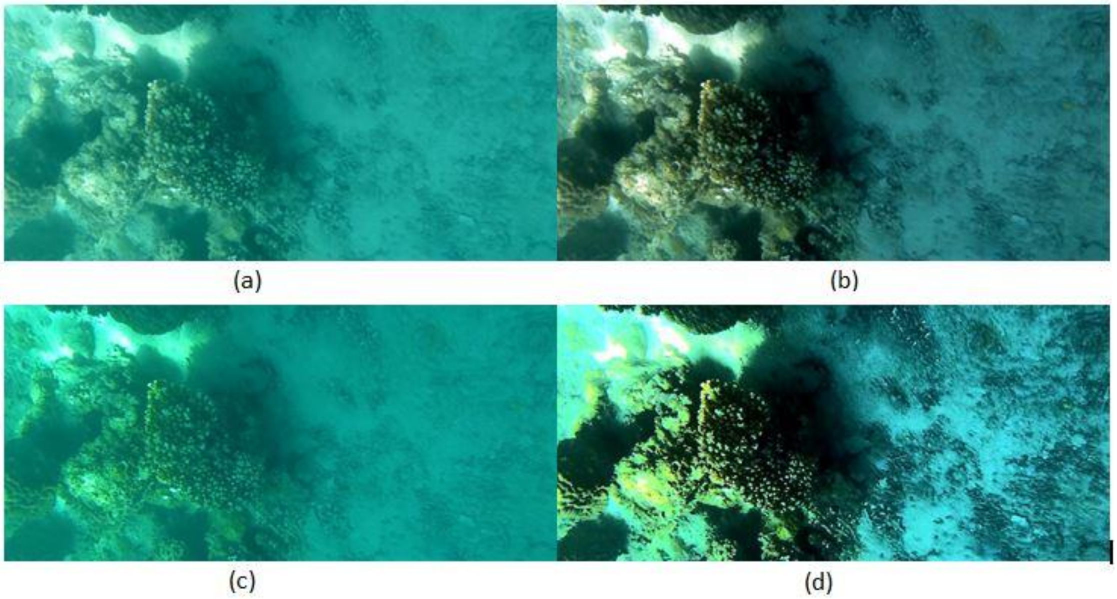


Figure 43: MOS Data Set 5

In set 5, 36 of the 60 respondents prefer the image processed with proposed method as the dominant colour of the water is removed and the image details are sharpen. However, the image appears to be slightly not natural. Therefore, the other 16 prefer the image with blue remove but without sharpening. The other 4 and 5 respondents prefer the original image and colour corrected image. Colour corrected image has only one corner (bottom left) image details has corrected. This may be not obvious enough for the 4 respondents to notice.

However, not all underwater images has good resultant image with the proposed method. MOS data set 8 and 9 has the worst resultant image among the 10 sets of data that is used to get MOS.



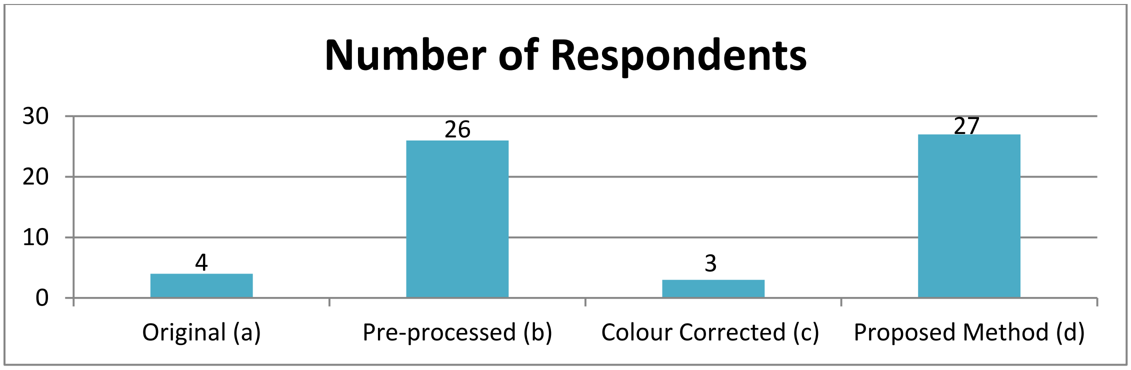


Figure 44: MOS Data Set 8

The number of respondents choosing pre-processed image and proposed method processed image are only one number in difference which is 26 and 27 respectively. Comparing with original image, proposed method did enhance the overall image quality but the object in the underwater has a much lower quality than the original image. The particles on the right side of the image are enhanced and sharpen to be clearer. The pre-processed image does not have enhancement on the particles but the object in underwater appeared to be clearer than original one. In fact, this image is a more severe problem as in set 4 data. The original image is bright enough and therefore doing image enhancement again will cause a loss of details of the bright side of an image.

Following is the result of omitting the image enhancement method (histogram equalization). The object in underwater appear to be clearer with the help of image pre-processing method and the colour of the object is corrected by the colour correction method used. The particles on the right side of the image can be seen though is not as clear as with image enhancement but the overall quality of the image is better.

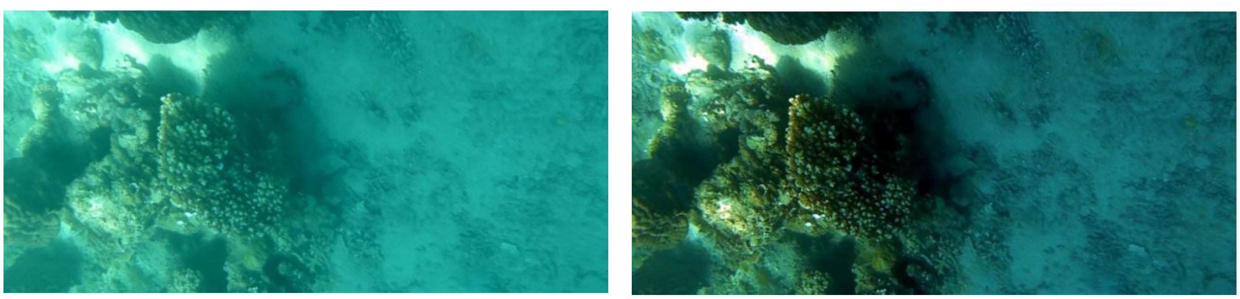


Figure 45: Omission of Image Enhancement Method

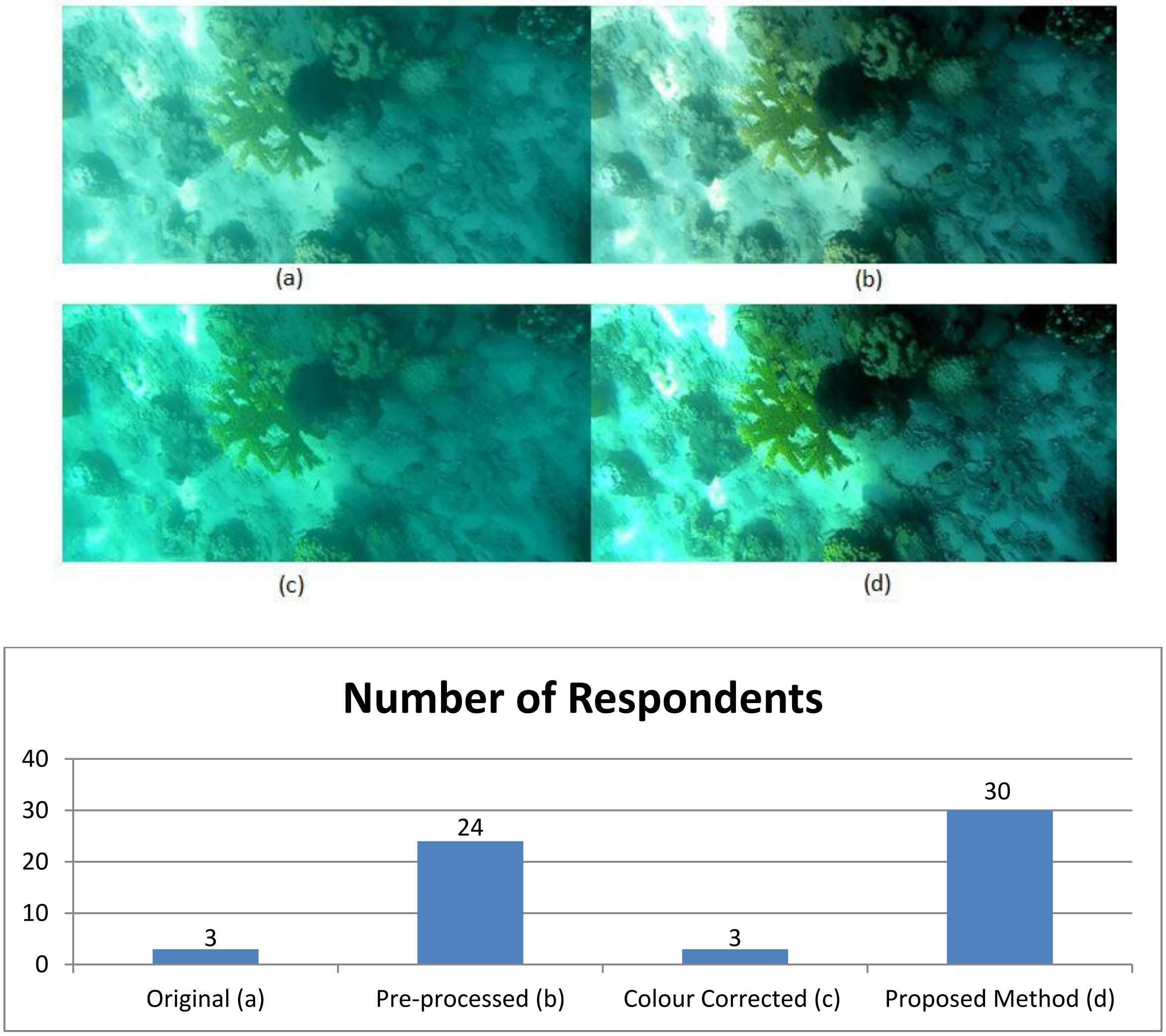


Figure 46: MOS Data Set 9

This underwater image is not fully optimized too. This is because the dominant blue colour is still very obvious in the image and it is not removed. It is deduced that the proposed method can only work best when the object in underwater images are big enough for detection and correction since in the image, the objects and particles are very small. While in MOS data set 1, the image is much optimized and dominant blue colour is removed because the object is big enough. Although set 9 does not have a very good resultant image, the image is still enhanced and there are half of the 60 respondents like it. 24 of them like the pre-processed image more because the dominant blue is lesser compared to proposed method where the blue colour saturation has been increased. 3 of the respondents like original image and another 3 preferred the pure colour corrected image.

4.3.5 – Proposed Method 2

Since proposed method 1 is not able to fit into all underwater images enhancement, another method is proposed. This method adds in gray world algorithm that makes assumption that changes in the lighting spectrum can be modelled by the constant factors of RGB channels. The following 10 images were used to do MOS among 11 observers.

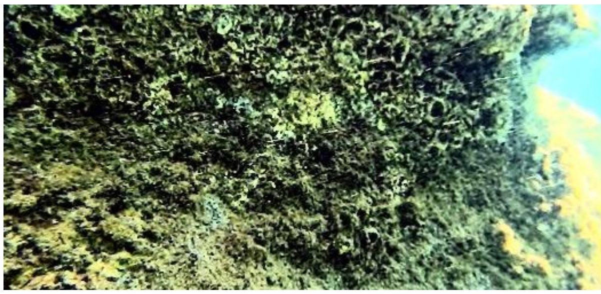
(a) original image, (b) proposed method 1 (c) proposed method 2 {histogram equalized (pre-processed), gray world (pre-processed/colour correction), dehazing (colour correction), colour balance (image enhancement) }

(a)

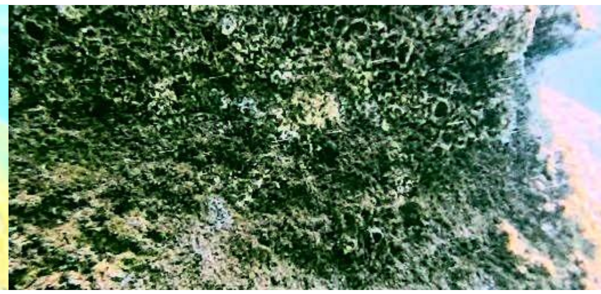
(b)

(c)

(a)

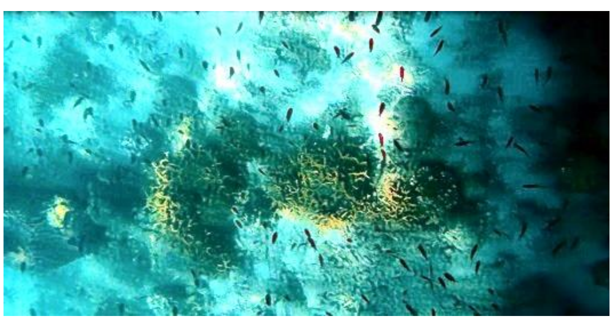


(b)

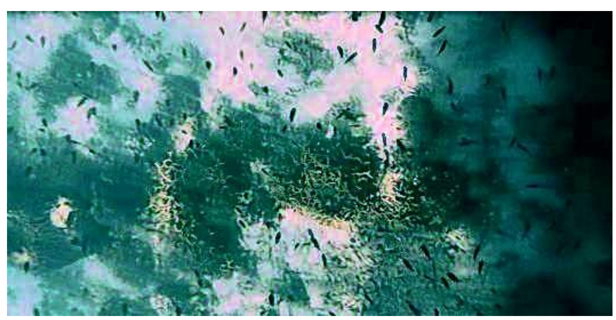


(c)

(a)



(b)

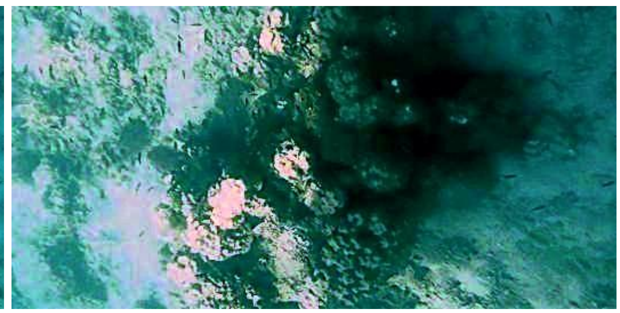


(c)

(a) original image, (b) proposed method 1 (c) proposed method 2 {histogram equalized (pre-processed), gray world (pre-processed/colour correction), dehazing (colour correction), colour balance (image enhancement) }

(a)

(b)



(c)

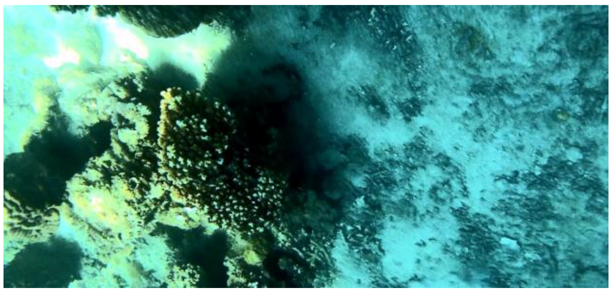
(a)

(b)

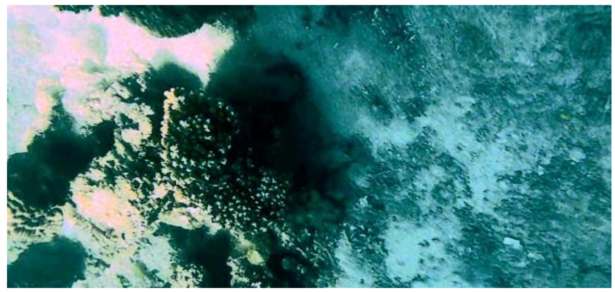
(c)

(a) original image, (b) proposed method 1 (c) proposed method 2 {histogram equalized (pre-processed), gray world (pre-processed/colour correction), dehazing (colour correction), colour balance (image enhancement) }

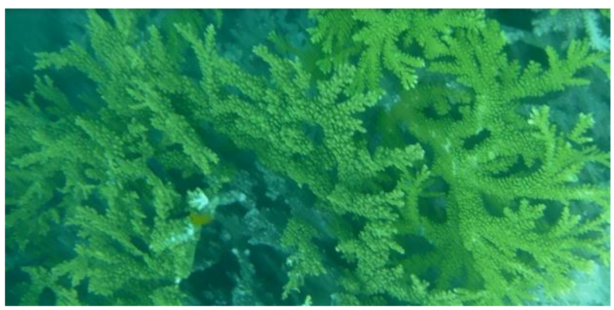
(a)



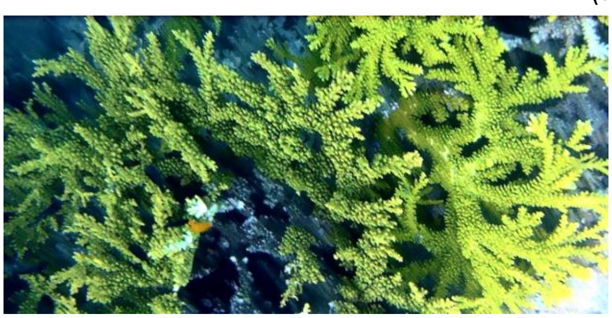
(b)



(c)



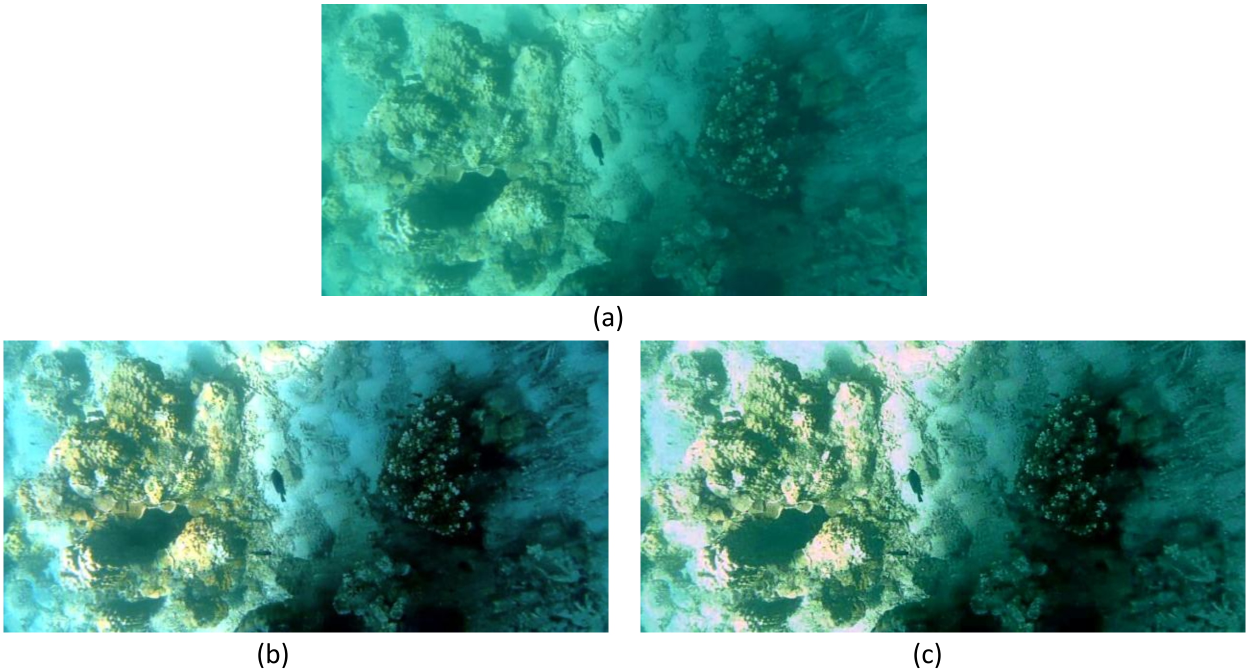
(a)



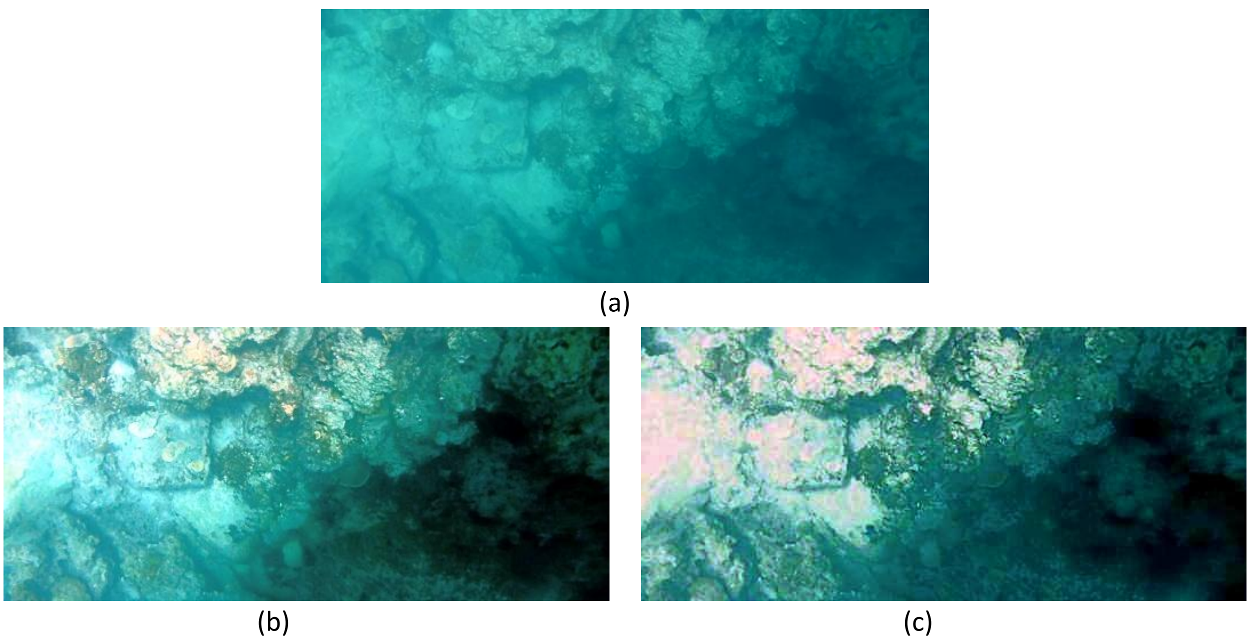
(b)

(c)

(a) original image, (b) proposed method 1 (c) proposed method 2 {histogram equalized (pre-processed), gray world (pre-processed/colour correction), dehazing (colour correction), colour balance (image enhancement) }

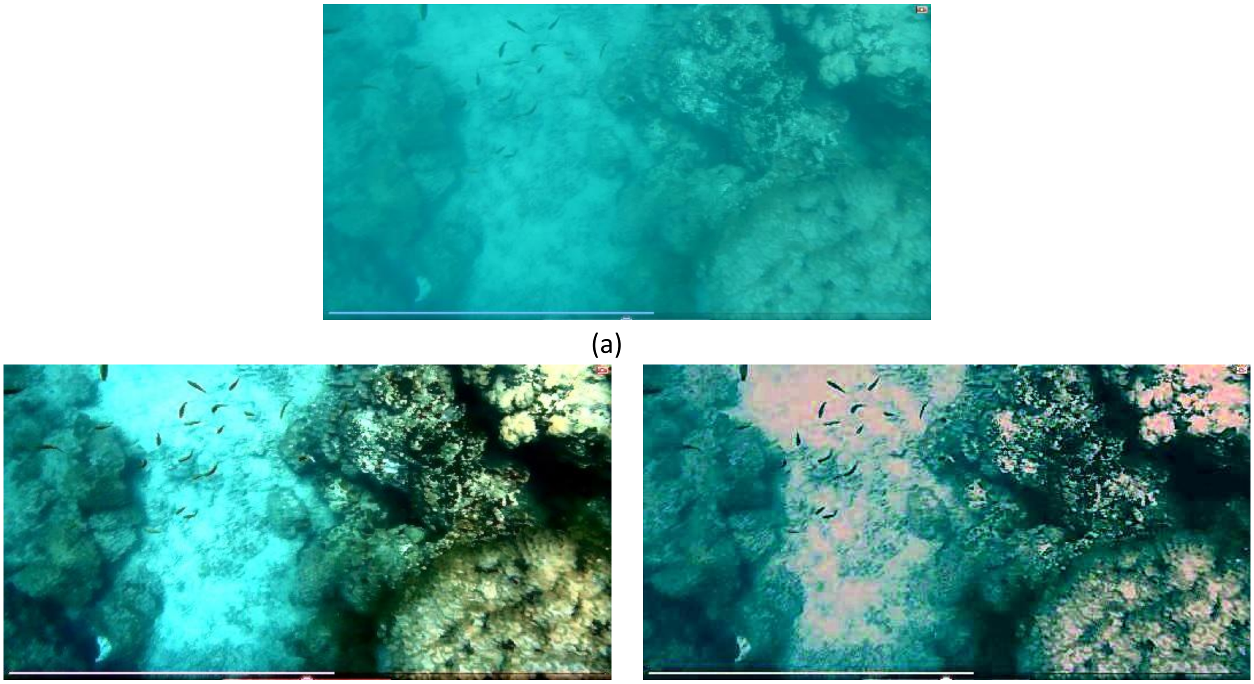


(a) (b) (c)



(a) (b) (c)

(a) original image, (b) proposed method 1 (c) proposed method 2 {histogram equalized (pre-processed), gray world (pre-processed/colour correction), dehazing (colour correction), colour balance (image enhancement) }



(a)

(b) (c)

(a) original image, (b) proposed method 1 (c) proposed method 2 {histogram equalized (pre-processed), gray world (pre-processed/colour correction), dehazing (colour correction), colour balance (image enhancement) }

Figure 47: 10 sets of Images Comparing Original, Proposed Method 1 and Proposed Method 2

From all the images in Figure 40, it is obvious that both proposed method gave better quality images compared to the original images which appear to be hazy and covered by the predominant colour of the water. In my opinion, proposed method 2 have better quality in terms of clarity of the image details and it achieve the objective of the project more as more predominant blue are reduced or removed. However, the image becomes unnatural and there are certain images turned out to be colourless (black and white) where it is very far from the original colour.

Getting the opinion from different human observers, majority (7/9) preferred over proposed method 1 because the images look more real, brighter and clearer. Only minority (2/9) preferred proposed method 2 with the reason that more blue is removed and the resultant image is sharper though it is unnatural. Those who preferred over proposed method 1 critic that proposed method 2 cause the image to be unreal and owing to the high contrast, the image become no longer colourful that is almost equivalent to black and white image. The respondent also mentioned that for certain images, the enhancement of the colour is beyond nice causing the image to be too sharp and fake.

5. CONCLUSION

Underwater imaging possesses predominant colours that filter the other colours in underwater images. Motivation of the project is to research for the development projects related to underwater such as object recognition in underwater environment. Hence, predominant colour in underwater images should be reduced to allow the original colour of an image to be displayed as well as having a better quality underwater image.

C++ platform programming in Visual Studio collaborating with OpenCV libraries and MATLAB are used for the development of this project. RGB adjustment and blue removal methods are the methods that are tested and failed to help in the project. Proposed method 1 resultant image had better quality and enhancement. However, proposed method 2 achieved the objective of this project; remove predominant blue colour. Proposed method 1 can enhance the images while maintaining the image naturalness but proposed method 2 caused the resultant images to look not natural although blue is removed.

The problem of the proposed method 1 is that it does not apply to all underwater images. The algorithm will only work best if there is more underwater plants or rocks with colour in that particular image. This is because colour balancing managed to enhance the plant colour more before the image is further processed. The problem of proposed method 2 is the image emerged to be unnatural and sometimes too different from the original colours. Besides that, there is a chance that there is side effect that the pixels become divergent and not reflect the actual colour value of the image caused by gray world algorithm.

From zero knowledge about image processing, the research has brought out some interesting parts regarding image processing. From the research, a better understanding towards image processing, underwater images and colours are achieved. This project is able to help plant distinguisher project to further clarify the colour of the plant in underwater. However, it may not be useful for object or fish recognition.

Bibliography

Bazeille, S., Quidu, I., Jaulin, L. & Malkasse, J.-P., 2006. *Automatic Underwater Image Pre-Processing.* [Online] Available at: https://www.ensta-bretagne.fr/jaulin/paper_bazeille_CMM06.pdf [Accessed 23 February 2015].

Chambah, M. et al., n.d. *Underwater Color Constancy: Enhancement of Automatic Live Fish Recognition,* France/Italy: s.n.

Chiang, J. Y. & Chen, Y.-C., 2012. Underwater Image Enhancement by Wavelength Compensation and Dehazing. *IEEE Transactions On Image Processing,* Volume 21, pp. 1756-1769.

Ding, X. & Jun, O., 2007. Contrast Enhancement of Colour Images Based on Wavelet Transform and Human Visual System. *Graphics and Visualization in Engineering,* pp. 58-63.

Emami, S., 2013. *HSV Color Conversion.* [Online] Available at: http://shervinemami.info/colorConversion.html [Accessed 28 Febuary 2015].

Fang, S., Deng, R., Cao, Y. & Fang, C., 2013. Effective Single Underwater Image Enhancement by Fusion. *Journal of Computers,* 8(4), pp. 904-909.

Fernando, S., n.d. *OpenCV Tutorial C++.* [Online] Available at: http://opencv-srf.blogspot.com/2010/09/what-is-opencv.html [Accessed 20 February 2015].

Fisher, R., Perkins, S., Walker, A. & Wolfart, E., 2003. *A to Z of Image Processing Concepts.* [Online] Available at: http://homepages.inf.ed.ac.uk/rbf/HIPR2/glossary.htm [Accessed 12 August 2014].

Forsyth, D. & Ponce, J., 2012. Color Image. In: *Computer Vision.* England: Pearson.

Garrett, 2014. *Garrett's Acropolis.* [Online] Available at: http://www.garretts-acropolis.com/Info_Acropora.htm#Acropora prostrata [Accessed 5 March 2015].

Huang, K.-Q., Qiao, W. & Wu, Z.-Y., 2006. Natural Colo Image Enhancement and Evaluation Algorithm based on Human Visual System. *Computer Vision and Image Understanding,* 25 February.pp. 52-63.

Iqbal, K., Salam, R. A., Osman, A. & Talib, A. Z., 2007. Underwater Image Enhancement Using an Integrated Colour Model. *IAENG Internation Journal of Computer Science.*

Kumar, A., 2012. *Image pre processing.* [Online] Available at: http://www.slideshare.net/ASHI14march/image-pre-processing [Accessed 5 8 2015].

Lambert, T. J., 2005. *Digital Enhancement Techniques for Underwater Video Image Sequences.* [Online] Available at: http://eprints.utas.edu.au/253/1/tristanlthesis.pdf [Accessed 12 August 2014].

Leong, C. F., 2013. *Morphological Image Processing.* s.l.:s.n.

Leonie, A. & Simon2 , J., 2014. *Dark Image Enhancement Through Channel Division Using Spectral Decomposition Method.* [Online] Available at: http://www.ijera.com/special_issue/Humming%20Bird_March_2014/Version%20%201/AG3438.pdf [Accessed 12 August 2014].

Mathworks, 1994-2015. *MATLAB Product Description.* [Online] Available at: http://www.mathworks.com/help/matlab/learn_matlab/product-description.html [Accessed 20 August 2015].

Mattis, P. & Kimball, S., 2014. *GNU Image Manipulation Program.* [Online] Available at: http://docs.gimp.org/en/plug-in-c-astretch.html [Accessed 8 August 2015].

McHugh, S., 2005. *Cambridge in Colour.* [Online] Available at: http://www.cambridgeincolour.com/tutorials/color-spaces.htm [Accessed 20 August 2015].

OpenCV, n.d. *OPENCV.* [Online] Available at: http://opencv.org [Accessed 20 February 2015].

pi19404, 2013. *Color Constancy: Gray World Algorithm.* [Online] Available at: http://www.codeproject.com/Articles/653355/Color-Constancy-Gray-World-Algorithm [Accessed 29 Aug 2015].

Piehl, G. & Atkins, N., 2006. *Snorkeling Photography Tips To Create Better Pictures.* [Online] Available at: http://www.tropicalsnorkeling.com/snorkeling-photography.html [Accessed 13 August 2015].

Punmanee, W., Kasetkasem, T., Chanwimaluang, T. & Nishihara, A., 2013. Naturalness Color Enhancement for THEOS Images. *International Symposium on Communication and Information Technologies (ISCIT),* pp. 523-528.

Russ, J. C., 2011. *The Image Processing Handbook.* New York: CRC Press.

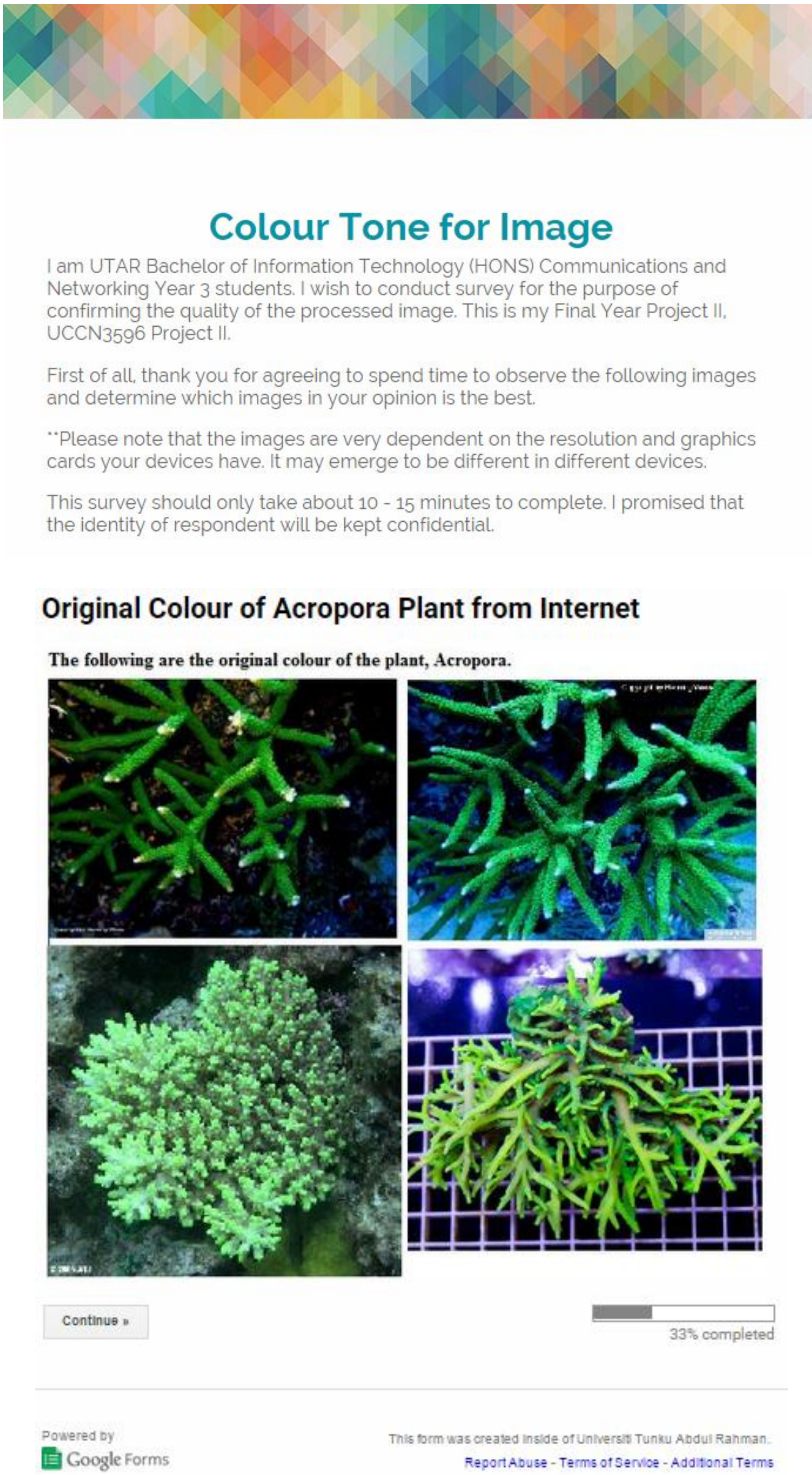
Verne, J., n.d. Image Pre-Processing. In: *Embedded Vision Alliance.* s.l.:s.n., pp. 39-40.

Wikibook, 2013. *Color Models: RGB, HSV, HSL.* [Online] Available at: http://en.wikibooks.org/wiki/Color_Models:_RGB,_HSV,_HSL#Color_Basics [Accessed 12 August 2014].

Wikipedia, 2015. *Color Normalization.* [Online] Available at: https://en.wikipedia.org/wiki/Color_normalization#Grey_world [Accessed 29 September 2015].

Appendix

<u>MOS 1 – Proposed Method 1 Survey Forms</u>



Colour Tone for Image

I am UTAR Bachelor of Information Technology (HONS) Communications and Networking Year 3 students. I wish to conduct survey for the purpose of confirming the quality of the processed image. This is my Final Year Project II, UCCN3596 Project II.

First of all, thank you for agreeing to spend time to observe the following images and determine which images in your opinion is the best.

**Please note that the images are very dependent on the resolution and graphics cards your devices have. It may emerge to be different in different devices.

This survey should only take about 10 - 15 minutes to complete. I promised that the identity of respondent will be kept confidential.

Original Colour of Acropora Plant from Internet

The following are the original colour of the plant, Acropora.

Continue »

33% completed

Powered by Google Forms

This form was created inside of Universiti Tunku Abdul Rahman.

Report Abuse - Terms of Service - Additional Terms

Colour Tone for Image

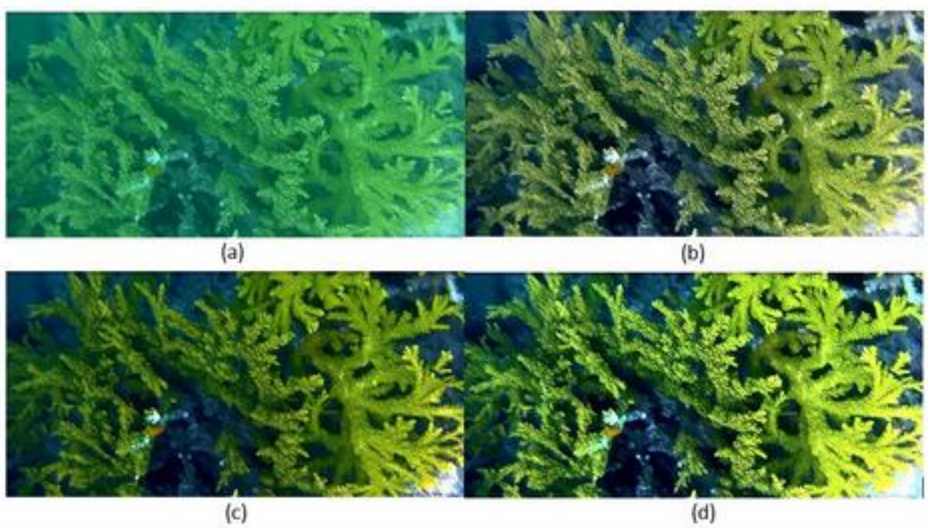
* Required

Data Sets

For each of the following set of images, choose the BEST image and then the SECOND best image.

Considering
1) first priority is the original natural colour of the plant/object and
2) second priority is the image quality.

Set 1



First Best Image *
Top 1 - Choose the one that you think is the most enhanced image
▼

Second Best Image *
Top 2 (Please DO NOT choose the same option as your Top 1)
▼

First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

(a)
(b)
(c)
(d)

est Image *

ease DO NOT choose the same option as your Top 1)

First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

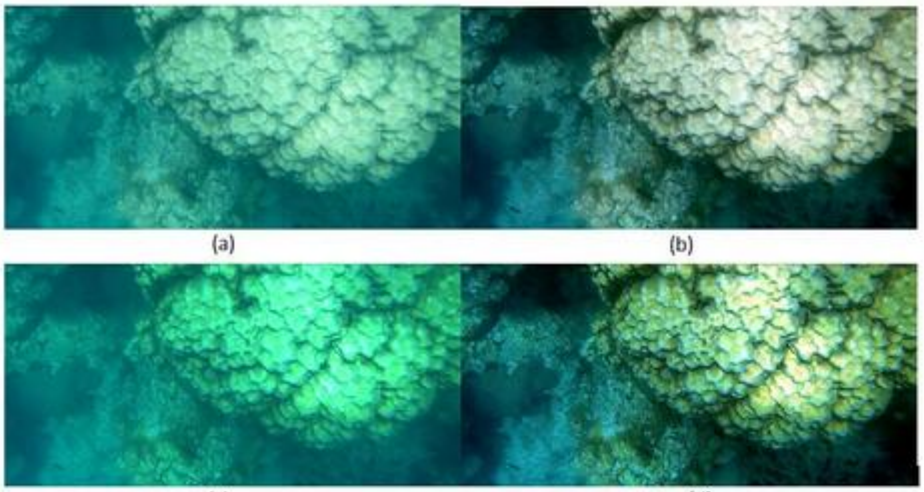
This is a required question

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

(a)
(b)
(c)
(d)

Set 2



(a) (b)

(c) (d)

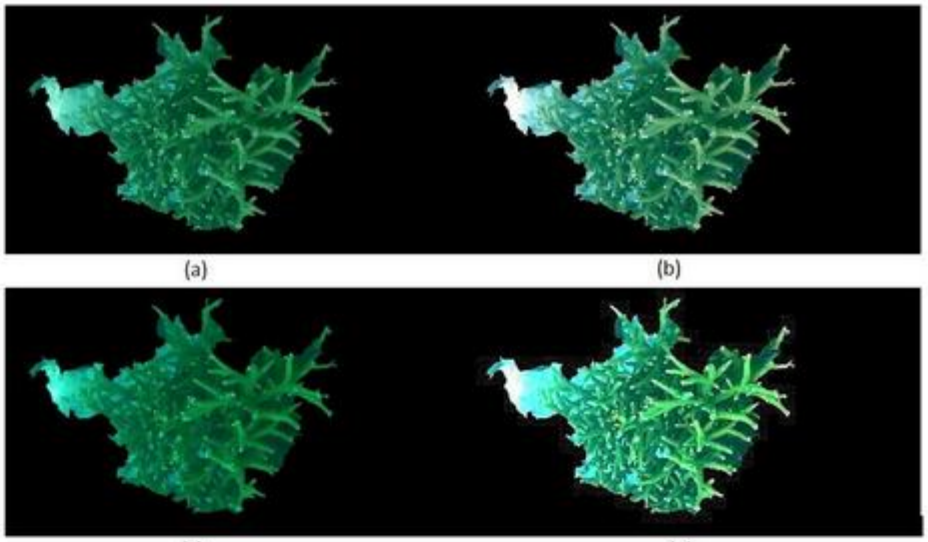
First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

Set 3



(a) (b)

(c) (d)

First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

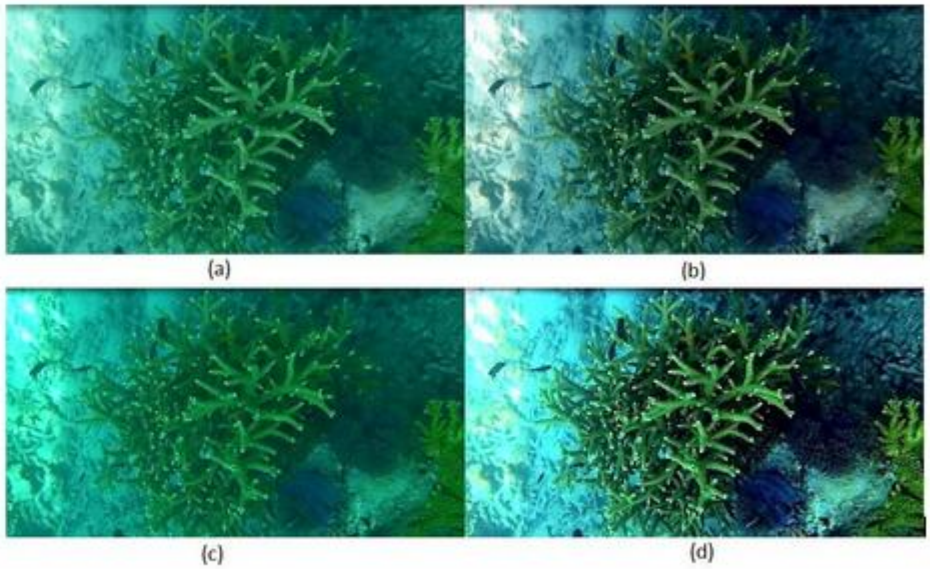
▼

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

▼

Set 4



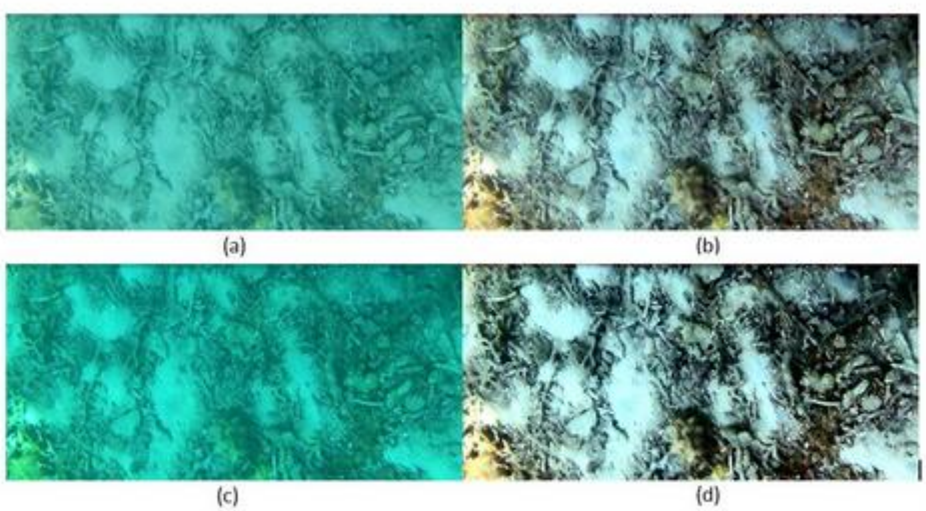
First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

Set 5



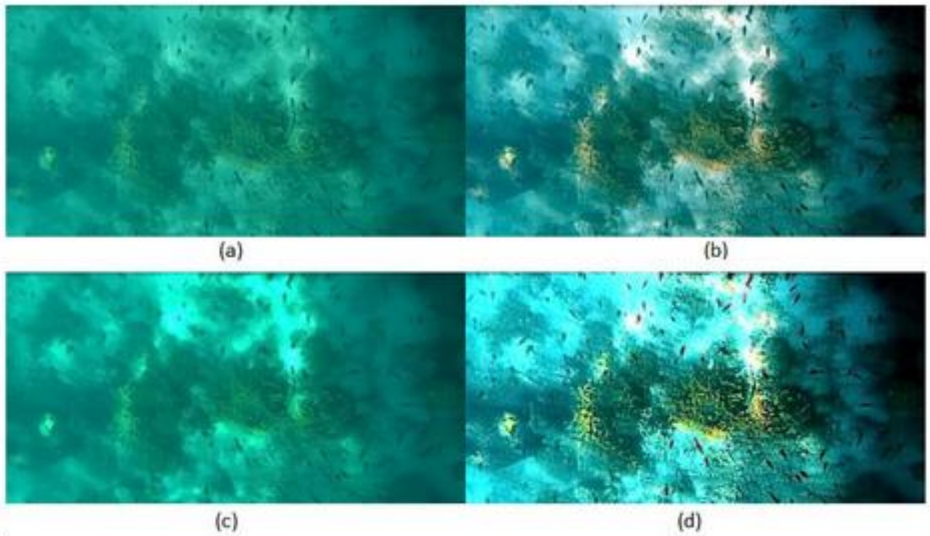
First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

Set 6



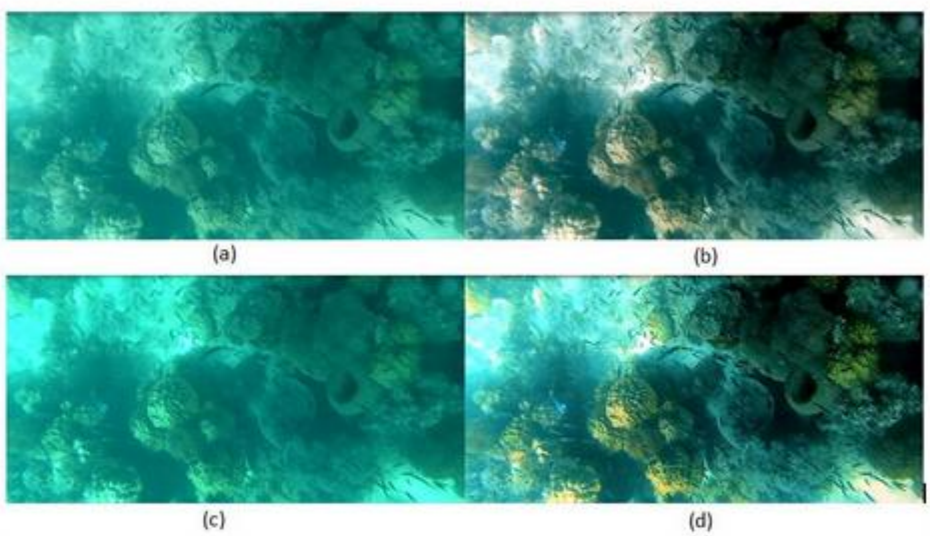
First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

Set 7



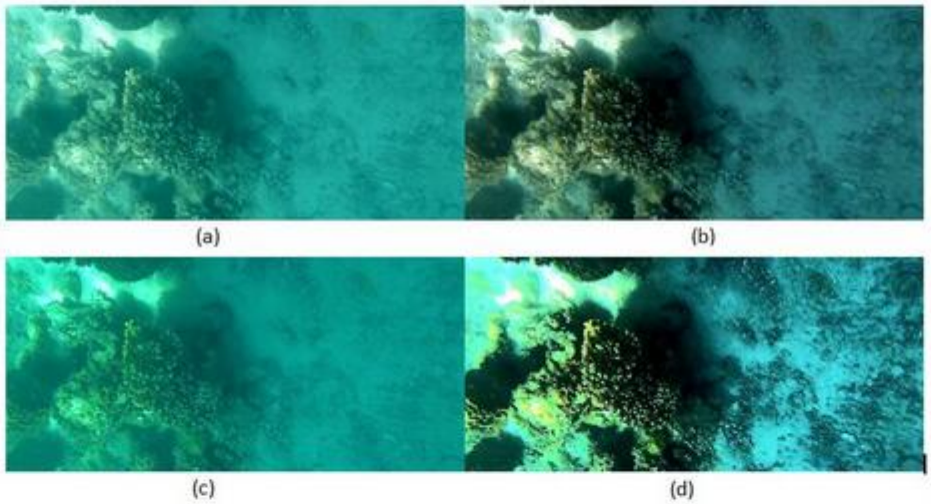
First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

Set 8



First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

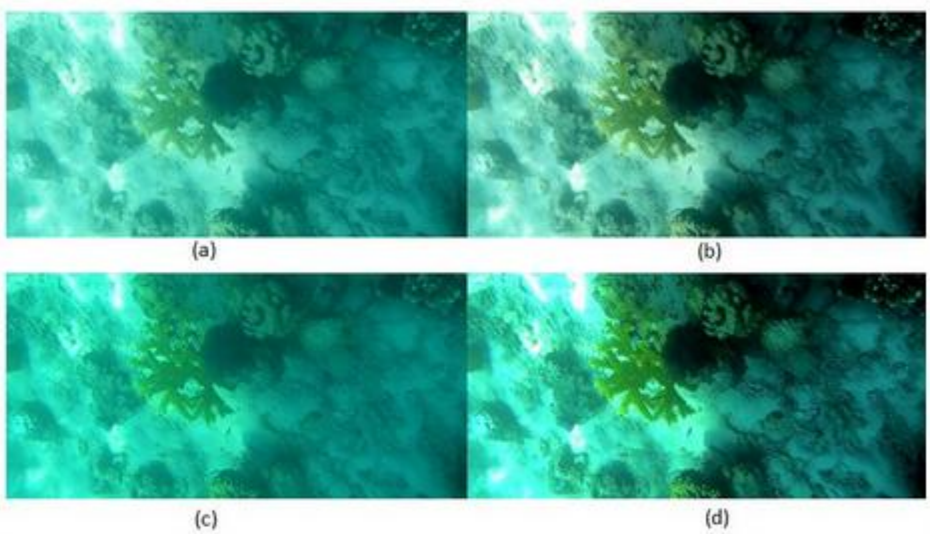
▼

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

▼

Set 9



First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

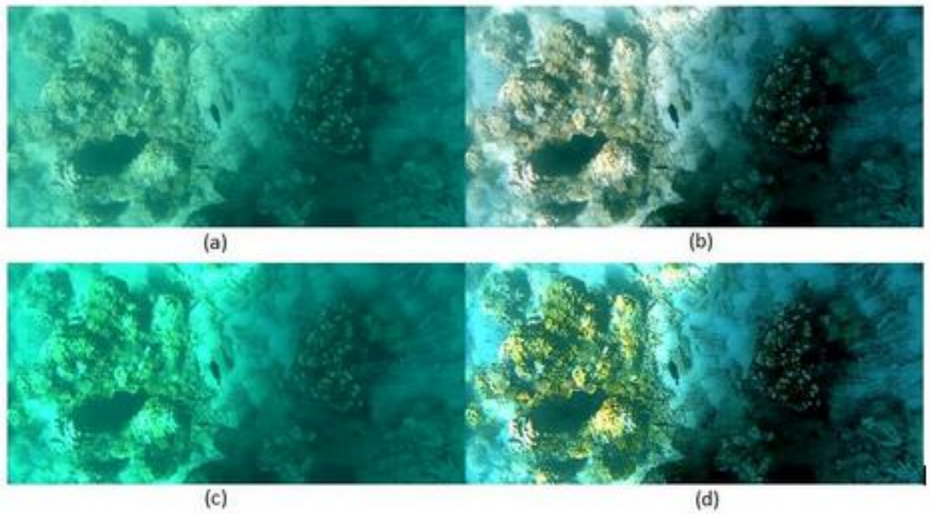
▼

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

▼

Set 10



First Best Image *

Top 1 - Choose the one that you think is the most enhanced image

▼

Second Best Image *

Top 2 (Please DO NOT choose the same option as your Top 1)

▼

General Conclusion

After going through all 10 sets, what's your conclusion?

Overall, do you prefer a, b, c or d processing methods? *

▼

« Back   Continue »

66% completed

Powered by

Google Forms

This form was created inside of Universiti Tunku Abdul Rahman.

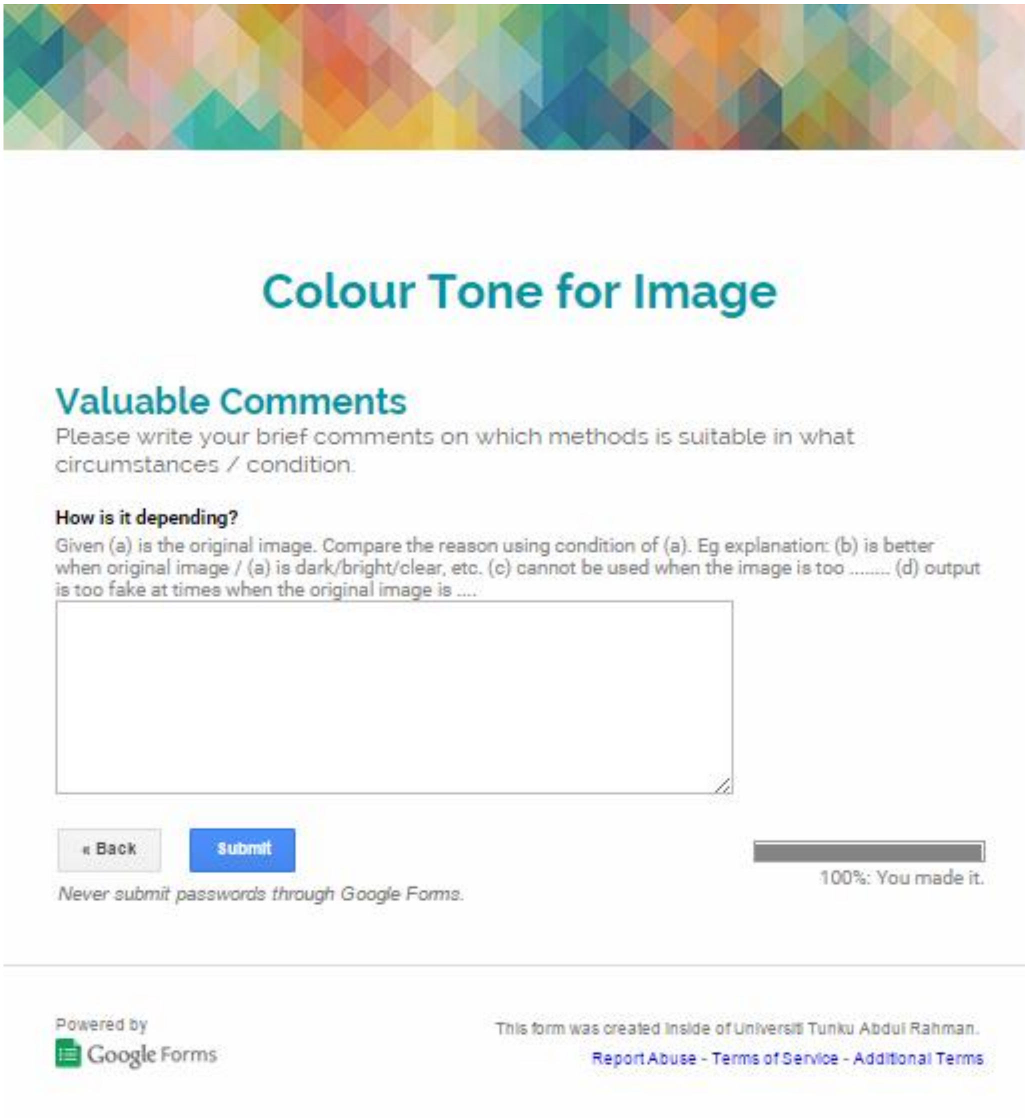
Report Abuse - Terms of Service - Additional Terms

Overall, do you prefer a, b, c or d processing methods? *

▼

(a)
(b)
(c)
(d)
Depends

Continue »



Colour Tone for Image

Valuable Comments

Please write your brief comments on which methods is suitable in what circumstances / condition.

How is it depending?

Given (a) is the original image. Compare the reason using condition of (a). Eg explanation: (b) is better when original image / (a) is dark/bright/clear, etc. (c) cannot be used when the image is too .... (d) output is too fake at times when the original image is ....

« Back Submit

100%: You made it.

Never submit passwords through Google Forms.

Powered by Google Forms

This form was created inside of Universiti Tunku Abdul Rahman.

Report Abuse - Terms of Service - Additional Terms

Survey respond for Proposed Method 1 – Soft Copy Attached to CD.

MOS 2 – Comparing between Proposed Method 1 and Proposed Method 2

Question: Given the objective of the project is to remove or reduce the predominant blue colour that exist in underwater images. Compare the processed images with the original image and select a proposed method (1 or 2) do you think is the best?

<10 sets of Data used for MOS is placed at Chapter 4.3.5)>

Respondents Name	Proposed Method 1	Proposed Method 2
1. Lee Khai Yi		✓ • More blue is removed • Unnatural but sharper
2. Tan Li Jig	✓	• Only good for images a, b, g and i
3. Lum Wai Yin	✓	• Fake
4. Mak Wai Yee	✓	
5. Cheah Sook Theng	✓	**For a,b,c images** • Enhancement of colour too much • Image too sharp, unreal **For f, j images** • Contrast too high, Not colourful – almost become black and white
6. Loh Ke Xin	• Darker blue	✓ • blue color is that not heavy, and the color is sharp also
7. Teh Qin Yong	✓ • Plant looks nicer	• Background blue is removed yet clear
8. Gautamyi Palaniyandi	✓ • Clearer	
9. Than Wai Lim	✓ • Images are more real and brighter	• The object in images c, d, e, f, g, I, j, n, o, p and h is blur • Image e and h more blue is removed but look fake • Image k is better – clearer
10. Tan Woan Pey		✓ • More blue is removed
11. Tan Yen Leng	✓ • Looks cleaner • More beautiful	• Blur and dirty-like
Total	**8**	**3**