UNDERWATER IMAGE ENHANCEMENT USING INTEGRATED CONTRAST CORRECTION AND WHITE BALANCE METHODS

by

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ICM	Integrated Colour Model
WBA	White Balance Adaptive
GW	Gray World
APHE	Adobe Photoshop Histogram Equalisation
WP	White Patch
avg	Average
max	Maximum
RGB	Red, Green, Blue
HSI	Hue, Saturation, Intensity
YCrCb	Y - Luminance, CrCb - Chrominance
ACE	Automatic Colour Equalization
MLGD	Maximum Likelihood Gamma Distribution
DHS	Dynamic Histogram Specification
WB region	White Balance region
CIE	Commission Internationale de l'Éclairage (Colour International Commission on Illumination)

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PENINGKATAN IMEJ DALAM AIR MENGGUNAKAN KAEDAH PEMBETULAN KONTRAS BERSEPADU DAN KAEDAH IMBANGAN PUTIH

ABSTRAK

Kejelasan imej-imej dalam air dijejaskan oleh penyerapan cahaya, penyerakan cahaya dan kekeruhan air. Disebabkan itu, imej-imej dalam air dipengaruhi oleh kas warna kebiruan, kontras yang rendah dan pencahayaan yang kurang terang. Tesis ini menyarankan dua pendekatan iaitu “Model Warna Bersepadu” (Integrated Colour Model - ICM) dan “Pendekatan Penyesuaian Imbangan Putih” (White Balance Adaptive Approach - WBA) untuk menerangkan punca serta faktor yang mempengaruhi kejelasan imej.

ICM adalah berasaskan keseimbangan warna, pembetulan kontras terhadap model warna RGB dan pembetulan kontras terhadap model warna HSI. Pertama, kas warna dikurangkan dengan persamaan nilai warna. Kedua, peningkatan pada kaedah pembetulan kontras digunakan untuk meningkatkan warna merah dengan merenggangkan histogram merah ke tahap maksimum (i.e., sebelah kanan), begitu juga dengan warna biru dikurangkan dengan merenggangkan histogram biru ke tahap minimum (i.e., sebelah kiri). Ketiga, komponen Ketepuan dan Keamatan model warna HSI telah digunakan untuk pembetulan kontras untuk meningkatkan warna yang sebenar menggunakan Ketepuan dan menyatakan masalah pencahayaan menerusi Keamatan.

Pendekatan WBA berasaskan pada algoritma pembetulan kontras dan algoritma imbangan putih. Proses baru yang berkesan untuk menyesuaikan warna kas diperkenalkan yang mana bergantung kepada pengiraan statistik . Ini dilaksanakan dengan menentukan kas warna, pengiraan kadar keamatan antara komponen-

komponen RGB dan membetulkan imej yang dipengaruhi dengan menggunakan dua faktor tambahan (i.e., Merah dan Hijau).

Kedua-dua model ICM dan WBA telah dinilai menggunakan kaedah yang sedia ada: Persepsi Manusia, Pengesan Tepi dan Histogram. Penggunaan tiga kaedah berbeza memastikan model yang dikemukakan dinilai dengan lebih mendalam. Pendekatan yang dikemukakan: ICM dan WBA dibandingkan dengan kaedah-kaedah yang sedia ada (i.e., Dunia Kelabu, Persamaan Histogram dan Tampalan Putih) dan kaedah penyelidikan terbaru. Keputusan menunjukkan kedua-dua ICM dan WBA lebih baik berbanding kaedah sedia ada pada sudut peningkatan warna, kontras dan pencahayaan.

Kaedah-kaedah penyelidikan terbaru: (i) menggunakan pencahayaan buatan untuk menangkap imej rujukan yang jelas; (ii) menggunakan nilai takrif ambang ; (iii) melibatkan pengiraan tempatan padat dan proses peningkatan global dan; (iv) menghasilkan semula panjang gelombang cahaya yang diserap menggunakan kejadian kedalaman yang diketahui. Dalam kebanyakan kes, kaedah penyelidikan terbaru telah mencapai keputusan yang lebih baik disebabkan fakta yang mana mereka telah menggunakan maklumat tambahan (i.e., pencahayaan buatan, nilai takrif ambang dan imej rujukan) tetapi penggunaan maklumat tersebut akan mengurangkan pengadaptasian kaedah. Tambahan pula, WBA juga telah memberikan keputusan yang lebih baik apabila diaplikasikan pada video dalam air dan imej-imej di darat.

UNDERWATER IMAGE ENHANCEMENT USING INTEGRATED CONTRAST CORRECTION AND WHITE BALANCE METHODS

ABSTRACT

The clarity of underwater images is degraded by light absorption, scattering of light and turbidity of water. Due to this, underwater images are affected by bluish colour cast, low contrast and reduced illumination. This thesis proposes two approaches “Integrated Colour Model” (ICM) and “White Balance Adaptive Approach” (WBA) to address factors affecting image clarity.

The ICM is based on colour balancing, contrast correction of RGB colour model and contrast correction of HSI colour model. Firstly, the colour cast is reduced by equalizing the colour values. Secondly, an enhancement to a contrast correction method is applied to increase the Red colour by stretching red histogram towards the maximum (i.e., right side), similarly the Blue colour is reduced by stretching the blue histogram towards the minimum (i.e., left side). Thirdly, the Saturation and Intensity components of the HSI colour model has been applied for contrast correction to increase the true colour using Saturation and to address the illumination problem through Intensity.

The WBA approach is based on contrast correction and white balance algorithms. A new efficient process for colour cast adjustment is introduced which relies on statistical calculations. This is performed by determining the colour cast, calculating the intensity ratio between RGB components and correcting the affected image by applying two gain factors (i.e., Red and Green).

Both the ICM and WBA models have been evaluated using the three well-known methods: Human Perception, Edge Detection and Histogram. The use of three different methods ensures that the proposed models are comprehensively evaluated. The proposed approaches: ICM and WBA are compared with the established methods (i.e., Gray World, Histogram Equalisation and White Patch) and the latest research methods. The results show that both the ICM and WBA have outperformed against the established methods in terms of colour enhancement, contrast and illumination.

The latest research methods: (i) use artificial illumination to capture clear reference image; (ii) use predefine threshold values; (iii) involve computationally intensive local and global enhancement process and; (iv) regenerate the absorbed wavelength of light using known depth of the scene. In some cases, the latest research methods have achieved better results due to the fact that they have used additional information (i.e., artificial illumination, predefined threshold values and reference image) but the use of such information can reduce the adaptability of the methods. Additionally WBA shows significant results when applied to underwater videos and land images.

CHAPTER 1

INTRODUCTION

1.1 Introduction

Image is better than any kind of information for human perception. Vision helps us to perceive and understand nature (Sonka *et al.,* 1999). In other words, images are invaluable as they provide an efficient means of communication, recording and storing of information (Gonzalez, 2002). Digital image processing techniques contain different ways for the manipulation of digital images and its enhancement, modification and analysis (Russ, 1995; Parker, 1996). Image enhancement is such a technique which helps to improve the quality of the image using software tool (Ebrahim, 2005).

Image enhancement techniques can be applied to general as well as underwater images in order to improve their quality. Unlike underwater images, ordinary or general images, most of the time, are balanced properly and do not have any colour cast but unfortunately, underwater images are always affected by predominant and non-uniform colour cast, low contrast and illumination problem due to absorption (Torres-Mendez, 2005a & 2005b) and scattering of light in an aquatic environment (Anthoni, 2005). Due to this fact, it is difficult to process the underwater images as compared to the ordinary or land images (Garcia *et al.*, 2003). Importantly, this difficulty lies in the pre-processing stage which distinguishes the underwater image processing from the ordinary image processing.

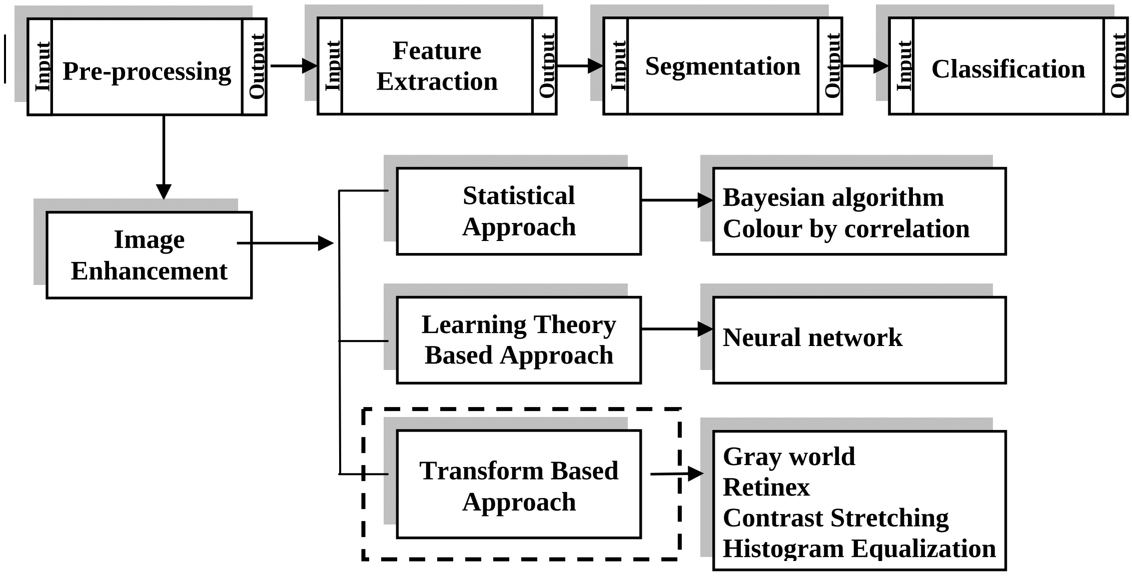

Figure 1.1: Image Enhancement Techniques

In general, image processing involves several stages: pre-processing, feature extraction, segmentations and classification as shown in Figure 1.1. Applying different image enhancement methods or techniques to pre-processing stage ensures the removal of unnecessary characteristics from the image. Image enhancement includes several methods such as statistical, learning and transform. Statistical and learning methods are based on prior information or training and they are limited in their scope because they rely on prior information of the domain and they are also time consuming. On the other hand the transform based approaches are based on point processing techniques, which directly perform operations on the pixel values therefore they are rapid and required less time and resources. This research mainly focuses on 'Transform Based Approach', which contains Gray World, Retinex, Contrast Stretching/Correction and Histogram Equalisation methods as shown in Figure 1.1.

Contrast stretching and histogram equalisation are commonly used to improve the contrast of the image by stretching a range of intensity values to enhance the image by removing the undesired properties. Gray world and Retinex (white patch) are used to remove the colour cast. Many researchers have combined gray world and white patch methods in white balanced approaches (Chikane and Fuh 2006a, 2006b; Gasparini *et al.,* 2004). Generally image enhancement techniques use different colour models such as RGB, HSI and YCrCb, which contain different colour and luminance channels.

1.2 Motivation

A large part of the earth's surface, more than 70%, is covered with ocean which has a great importance to the health of our planet (Bryant *et al.,* 1998). In order to get benefit of it, a lot of discoveries are needed to explore the mysterious creatures live at the bottom of the ocean, but unfortunately the ocean is still barely explored.

Another important aspect is that the sea species such as plants, coral reefs and fishes are dying in many parts of world's ocean due to land based activities which are adversely affecting the water quality (Wilkinson, 2004). Therefore, it is essential to preserve such species for the economy and also for food supply for millions of people.

Many researchers have proposed different approaches to monitor the sea species. Most of these approaches are based on image processing techniques. Unfortunately, advanced research in the field of image processing, in particular, underwater image enhancement, has not yet reached an appropriate level of success due to the nature of underwater problems such as light reflection (Anthoni, 2005), light absorption (Torres-Mendez, 2005a & 2005b) and wavelength of light (Hung, 2006). Underwater images become progressively darker with increasing depth. Not only is the amount of light reduced when we go deeper, but also colours drop off in the order of the wavelength of the colour (Heit, 2004).

In order to address the above mentioned problems, it is important to develop an image enhancement technique that can improve the quality of the underwater images. Many researchers have attempted to address problems related to underwater image enhancement with varying degree of success. However, their approaches have their own limitations as described in Chapter 3.

1.3 Problem Statement

In underwater situations, light absorption, scattering of light and turbidity of water are causes of low illumination, low contrast and bluish colour cast. The clarity of underwater images is degraded because blue colour dominates the image. Underwater images do not completely absorb blue colour due to the shortest wavelength of blue colour in visible light (Bazeille, 2006).

Presently, several software tools are available in research and scientific laboratories as well as in the market that can be used to filter-out the undesired properties of an image. Most of the existing image enhancement software tools are semi-automated. Most importantly, these software tools are developed to improve the quality of the normal or ordinary images and therefore they are not able to be used for underwater images. Also, their features do not always work with underwater images. These tools are often very elegant but they are not suitable to apply to the particular phenomena in any specific real world environment. Furthermore, learning to manipulate the colour in underwater images through computer editing software requires patience and expertise. Therefore, an automated method for underwater image enhancement is highly desirable.

Over the last few years, a successful movement has been started towards the direction of building new techniques and methods to be used for image processing but the existing methods are mainly limited to the ordinary images with the exception of a few approaches that have been applied to underwater images (Åhlén *et al.,* 2005a & 2005b; Chambah, 2006; Garcia *et al.,* 2002; Gasparini *et al.,* 2003a, 2003b & 2004; Harsdorf *et al.,* 1999; Rizzi *et al.,* 2003; Schechner and Karpel, 2004; Torres-Mendez, 2005a & 2005b). The existing literature shows that there is no comprehensive and generic approach available for underwater image enhancement.

1.4 **Research Scope and Objectives**

The scope of this research is to enhance the quality of underwater colour images, by focusing on transform based approaches, in order to address the problem of colour cast, low contrast and low brightness. This research seeks to fulfil the following objectives:

1. To investigate the contrast correction techniques to overcome the problem of high bluish colour cast and low red colour for underwater image enhancement.
2. To investigate the possibility of enhancing white balance techniques to address the problem of underwater image enhancement efficiently.
3. To address the low level of brightness of underwater images by investigating the luminance parameter of the HSI and YCrCb colour model.

4. To investigate the feasibility of integrating a number of image enhancement methods into one fully automated model.

5. To evaluate the effectiveness of the proposed algorithms on underwater images, and additionally evaluate their performance on underwater videos and land images

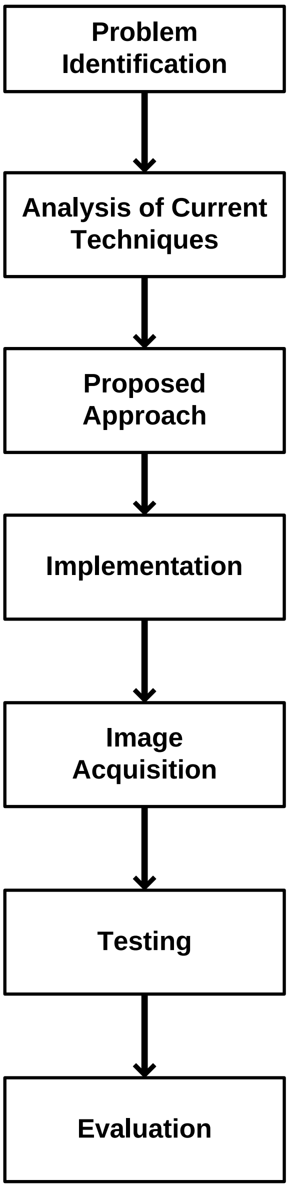

Figure 1.2: Research Methodology

1.5 Research Methodology

In order to address the problem of underwater image enhancement and to achieve the research objectives, a systematic methodology is defined as shown in Figure 1.2.

1.5.1 Problem Identification

In this stage the problem of underwater images is investigated in order to improve the quality of underwater colour images by addressing the problem of high colour cast, low contrast and low illumination.

1.5.2 Analysis of Current Techniques

In this stage current methods and techniques concerning image enhancement are to be investigated by focusing on transform based approaches. By investigating the current literature, this stage intends to perceive limitation of the existing approaches in order to address such limitations in the proposed approach.

1.5.3 Proposed Approach

Following the previous stage in which current methods and techniques are investigated, this stage intends to propose methods to address the limitations of the existing techniques and notably in order to meet the aim and objectives of the undertaken research.

1.5.4 Implementation

This stage is informed by the previous stage. This stage will implement the proposed approach using object oriented programming language such as Java.

Several algorithms will be implemented in an integrated manner in order to enhance the image meeting the aim and objectives of the research.

1.5.5 Image Acquisition

In Image acquisition stage, the image will be obtained through various resources in order to apply colour image enhancement methods. The obtained images will provide input to the system and the system will process these images in order to produce the enhanced images.

1.5.6 Testing

This stage will test the system and its performance. The performance of the system will be assessed based on the quality of the output image in order to ensure that colour cast of the image is removed while contrast and illumination are improved. Based on such testing, the system will further be improved if the enhanced images do not produce satisfactory results.

1.5.7 Evaluation

In this stage the results of the proposed approach are to be evaluated against the existing methods in order to examine the quality of underwater images. In this regard three methods will be used to evaluate the result based on Quantitative, Qualitative and Statistical analysis. The use of the three different methods will ensure that the proposed approach is thoroughly evaluated. The three methods will be used as follows:

1. *Quantitative method:* the edge detection method will be used to examine the quality of images based on number of edges found in the image before and after enhancement.

2. *Qualitative Method:* the human perception method will be used to obtain the opinion of users. In this regard few users will be invited to examine the quality of images based on perception. A set of questionnaires will also be distributed for this purpose.

3. *The Statistical method*: a histogram is to be used to evaluate the images before and after enhancement.

The propose approach will also be compared with the established methods (i.e., Gray World, Histogram Equalisation and White Patch) as well as the latest research methods.

1.6 Research Contributions

This thesis has made two major contributions by proposing two algorithms, an integrated colour model and a white balance adaptive approach, in order to address the problem of underwater image enhancement. The objectives have been achieved in these two methods.

1.6.1 An Integrated Colour Model

An integrated colour model is based on colour balancing, contrast correction of RGB and HSI colour models. Firstly, the colour cast is reduced by equalizing the colour values. Secondly, an enhancement to a contrast correction method is applied to increase the Red colour by stretching red histogram towards the maximum (i.e., right side), similarly the Blue colour is reduced by stretching the blue histogram towards the minimum (i.e., left side). Thirdly, the Saturation and Intensity components of the HSI colour model has been applied for contrast correction to increase the true colour using Saturation and to address the illumination problem through Intensity:

- Contrast correction method has been enhanced to overcome low Red colour problem by stretching to the maximum side to increase the Red colour values. On other hand the problem of high Blue colour cast is addressed by stretching the values to the minimum side in order to decrease the Blue colour cast.

- Saturation and Intensity parameters of the HSI colour model are used in contrast correction method in order to improve the true colour using Saturation and to solve the lighting problem through Intensity parameter. In this research, these parameters are combined with the RGB colour model for underwater image enhancement. Using this method, stretching is carried out towards both directions, minimum and maximum sides.

1.6.2 White Balance Adaptive Approach

The white balance adaptive (WBA) approach is based on existing contrast correction and enhanced white balance algorithm. WBA does not rely on predefined threshold values. A new process for colour cast adjustment is introduced which relies on statistical calculation and efficiently removes the colour cast:

- In order to calculate the colour cast, average values are used due to the fact that majority pixels fall in this range. In the case of using the maximum value, the single outlying pixel having too high value can badly affect the whole image which will eventually lead to unrepresentative scaling.

- Regarding the calculation of ratio, only the maximum value of any pixel affects the image. Therefore the maximum value is used to calculate the ratio. If red colour cast is higher, the red values are used as constant and the other two colours are adjusted. Using this maximum values, the over saturation problem has been addressed. Furthermore, by using the maximum values as divisor, lower values are obtained. This solves the over enhancement problem and helps to adjust illumination of the image at the same level.

- The adjustment of affected image is carried out using the Von Kries hypothesis. The pixel value of every pixel in the whole image is adjusted. The proposed approach has corrected the affected image using two colour channels (i.e., Red and Green) that makes the proposed algorithm more efficient and therefore helps to save computation cost.

1.7 Structure of the Thesis

This thesis is divided into seven chapters. Chapter 1 contains the motivation of this research work and introduces some problems pertaining to this area. It explains the research scope, objectives and methodology. This chapter also discusses the contributions of the research work

Chapter 2 is organised as follows. Firstly, it discusses some of the root problems concerning the underwater image processing. Secondly, it discusses the human visual system and also the importance of light. Thirdly, it discusses different colour models. Fourthly, it discusses different algorithms that have been applied to image

Input

enhancement. Finally, this chapter is concluded by highlighting the main points of this chapter.

Chapter 3 describes several approaches related to colour correction. It explains the contrast enhancement approaches that have been presented by different researchers. It also describes the white balance approaches. Following that, it illustrates the approaches relevant to underwater image and video enhancement. Most importantly, this chapter discusses the limitations of the existing approaches that motivate the proposed research.

Chapter 4 explains the proposed Integrated Colour Model (ICM) and discusses its components. Conclusion of this chapter is also presented.

Chapter 5 describes the second proposed White Balance Adaptive (WBA) approach and explains its steps. Finally, the conclusion of this chapter is given.

Chapter 6 discuses the performance of the proposed approaches by comparing its results with established and latest research methods. Evaluation is carried out based on human perception, edge detection and histogram. It also describes the results achieved by applying the proposed approach to underwater video and land image enhancement.

Chapter 7 concludes this thesis by providing a summary of the work. This chapter also discusses the contributions of the research work and present the future directions that can be further taken from this work.

CHAPTER 2

BACKGROUND

2.1 Introduction

This chapter presents a background of image processing and describes some root problems pertaining to this field, in particular, focusing on underwater image processing. These problems can be classified as transmission, absorption and reflection or scattering of light. This chapter briefly discusses how a human visual system works and how human perceives colours. Following that the importance of colours is described and several colour models are illustrated so that an appropriate colour model can be selected to be used for the proposed approach. Different researchers have implemented these colour models using different algorithms. An overview of these algorithms is given. In addition, the capabilities and limitations of these algorithms are described.

2.2 Problems in Underwater Images

This section briefly discusses some of the root problems concerning underwater images such as transmission, absorption, reflection, and scattering of light. Importantly, some of the problems are related to the physics of the sea surface. This section also discusses the effects of colour cast in underwater images. It is worth noting that most of these problems have to be addressed in the pre-processing stage of the vision systems as discussed in section 1.1. With respect to light reflection, Church *et al.,* (2003) describes that the reflection of the light ray varies greatly depending on the structure of the sea. Another area of concern is related to the angle of incidence of the ray when it hits the water surface that bends the light either to make crinkle patterns or to diffuse, as shown in Figure 2.1. Most importantly, the quality of the water controls and influences the filtering properties of the water such as the presence of fine particulates in the water (Torres-Mendez, 2005a & 2005b).

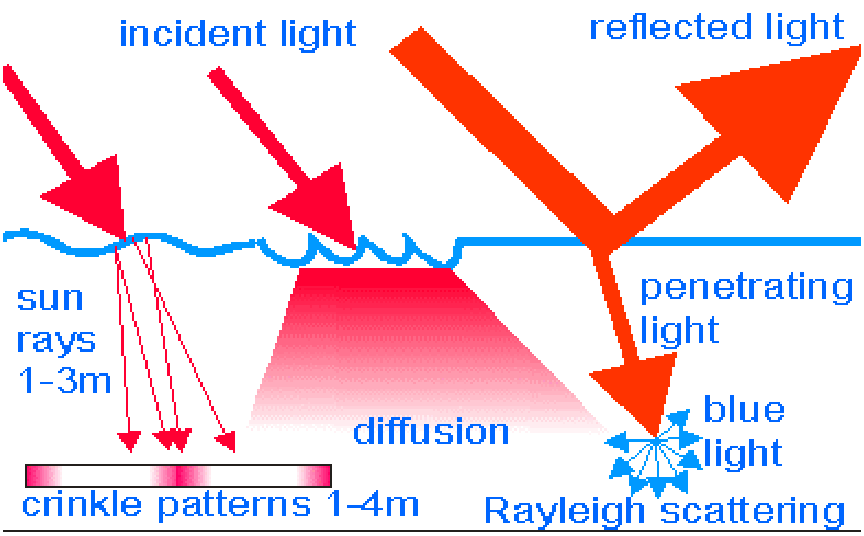

Figure 2.1: The effects of the water surface (Anthoni, 2005)

When a stream of photons or light falls on the surface of an object in the ocean, it reacts differently depending on the characteristics of that object. Light is partly reflected and partly enters the water (Anthoni, 2005). For example, it may react with the atoms of the object and disappear. This is called absorption. Alternatively, it may pass through to the other side of the object that is called transmission, or it may bounce off in a new direction which is known as reflection or scattering.

According to Anthoni, (2005), reflected light is polarised horizontally but polarised vertically when it enters the water. An important characteristic of vertical polarisation is that it reduces the intensity of highlights, which helps capture the deep colours which may not be possible otherwise.

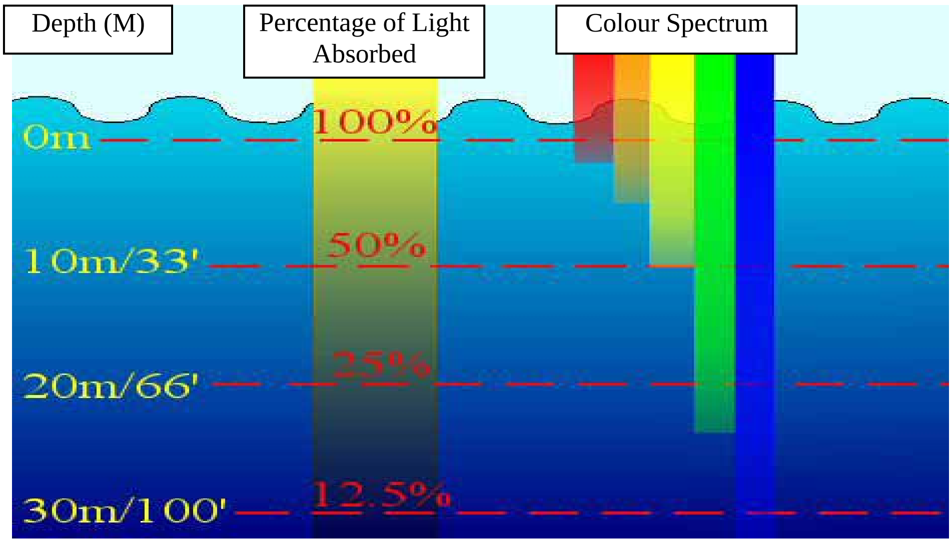

Figure 2.2: Absorption of Colour Spectrum in underwater (Heit, 2004)

Another well-known problem concerning underwater images is related to the density of water. Water is 800 times denser than air. When light enters water, it interacts with the water molecules which absorb a certain amount of light thus reducing the light intensity, changing its colour, creating diffusion, reducing contrast and producing other undesirable effects. The amount of light that enters the water also starts reducing as we go deeper in the sea (Heit, 2004). As a result, the underwater images become progressively darker as depth increases. Not only does the amount of light reduce when we go deeper but the colours also drop off one by one depending on the wavelength of the colours. For example, red colour is absorbed at a depth of 3m. At a depth of 5m, orange is lost, and so on as shown in Figure 2.2 (Torres-Mendez, 2005a & 2005b).

Based on the wavelength, the blue colour travels the furthest in the water due to having the shortest wavelength in visible light. This is what makes underwater images having a bluish colour cast. In addition, due to the predominant amount of blue, underwater images always contain non-uniform blue colour cast, have low contrast and low brightness.

2.3 The Human Visual System and Light

Light or visible light is composed of energy waves that are a segment of the electromagnetic spectrum (Schum, 1994). Our visual system responds to wavelengths in the region of 400 nanometres (nm) to about 700 nm. This is called the visible spectrum of the electromagnetic, as shown in Figure 2.3. Visible light actually consists of many colours, for example, at 400 nm the visual system sees violet but at 700 nm gives the sensation of red. The wavelengths of light are not colour, but produce the sensation of colour. Visible (white) light is not a homogenous component but a mixture of all the colours in the spectrum. Different colours correspond to different wavelengths of visible light. Among them, blue has the shortest and red has longest visible wavelengths ("Southampton Oceanography Centre," 2003).

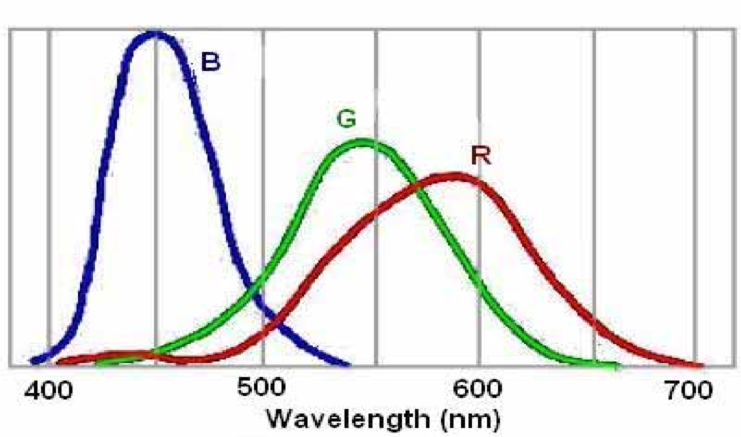

Figure 2.3: Visible portion of the wavelength (Schum, 1994)

Humans perceive colour when light interacts with real objects and also as a result of how humans perceive light, as interpreted by the brain (Hung, 2006). When light enters the eye: it, firstly, passes through the cornea, then crosses the pupil and then the lens. The ray eventually hits the sensitive cells at the back of the eye which form the retina as shown in Figure 2.4. The retina consists of a series of layers of nerve cells including a receptor layer which is made up of rods and cones. The human eye contains three types of light receptor cones such as Short (S), Middle (M) and Long (L). Each cone has different spectral sensitivities (Hung, 2006).

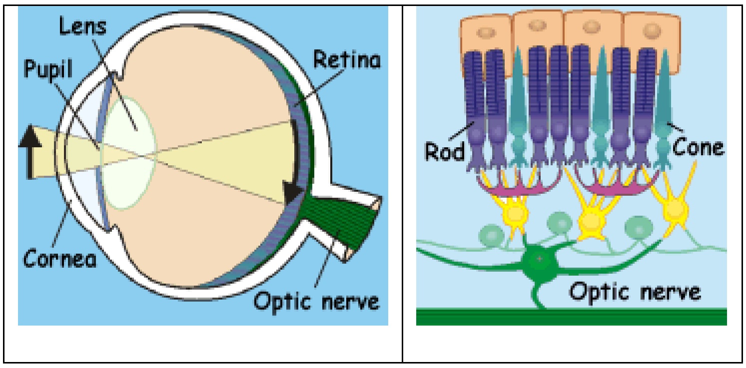

Figure 2.4: Rods and Cones in human eyes ("Southampton Oceanography Centre," 2003)

The human eye senses colour because of the spectral sensitivities which have different wavelength and response values as illustrated in Figure 2.3. The human eye perceives colour by processing the light information triggered by the cones passing through the optic nerves to the brain. There exists about 130 million rods, and 6 or 7 million cones. The rods operate in low light levels and are unable to detect colour. The cones can only operate in bright light conditions and are able to detect colour.

2.4 Colour Models

Colour is considered an important factor in digital colour image processing. The quality of an image is judged by its appearance (Hung, 2006). In fact, a colour image is considered different from a grey-scale image due to its range of colour. In a grey-scale image, the colour space is in the range of 1-dimensional scale ranging from white to grey to black. Due to this factor, a grey-scale image can easily be enhanced by using methods like *histogram equalisation* based on the spatial domain (Russ, 1995). The grey images are constrained to their limited range of colours. In comparison, a colour image has a wider range of colours represented through several colour models, for example, the RGB colour model, the HSI colour model, the CMY colour model, the CIE Lab colour model and the YCrCb colour model. The complex characteristics of a colour image depend on the range of colours of the underlying model. The colour model is also known as the colour system or the colour space that is used to represent the colours numerically or visually for electronic displays. Colour models are briefly discussed in the following sections.

2.4.1 The RGB Colour Model

The most commonly used colour model is the RGB (Red, Green and Blue) colour model. The RGB colour model is an *additive* colour model, which is used to produce a wide range of colours by mixing red, green and blue light. A colour in the RGB colour model can be achieved by mixing varying amounts of red, green, and blue. The amount of the red, green and blue can vary between the minimum (full dark) and maximum (full intensity). For example, if all the colours are at a minimum (0, 0, 0) the result is black; if all the colors at maximum (255, 255, 255), the result is a white (Sonka *et al.*, 1999). In absolute red, the green and blue are at minimum and the red is at maximum (255, 0, 0) as shown in Figure 2.5.

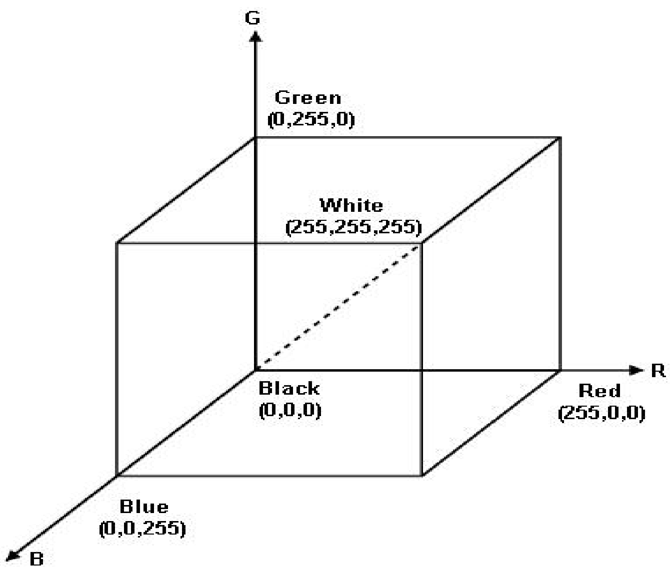

Figure 2.5: RGB colour cube (Sonka *et al.*, 1999)

2.4.2 The HSI Colour Model

In colour image processing, the HSI or HSV colour model is very important because it represents the colour in the same way as humans perceive colour. The components of HSI colour model is Hue (H), Saturation (S) and Intensity (I) as shown Figure 2.6 (Black, 2007).

Hue illustrates colour in the shape of angle. The range of hue is between (0, 360) degree. At 0 degree, it shows red colour; at 120 degree it shows green colour and at 240 degree it shows blue colour. Saturation illustrates the impurity of colour with white colour. The range of saturation component is (0, 1). Intensity shows the lightness of colour. The range of intensity/value is represented by (0, 1) where 0 means black and 1 means white.

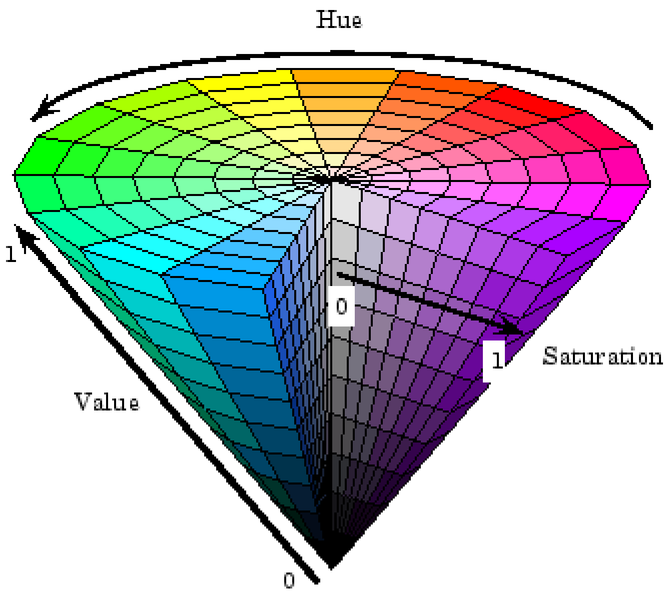

Figure 2.6: HSV colour triangle (Black, 2007)

2.4.3 The YCrCb Colour Model

The YCrCb colour model (also known as YIQ or YUV) is simple, easier and faster to be calculated among the other colour models (Schweng & Detlef, 2006). In the YCrCb colour model, Y represents the luminance and Cr, Cb are the chrominance components. The following matrix operation is used to convert the RGB colour model to the YCrCb colour model:

$$Y = 0.299\,R + 0.587\,G + 0.114\,B \tag{2.1}$$

$$Cr = 0.701\,R - 0.587\,G - 0.114\,B \tag{2.2}$$

$$Cb = -0.299\,R - 0.587\,G + 0.886\,B \tag{2.3}$$

2.5 Colour Constancy Algorithms

In order to address the issues discussed in section 2.2, several algorithms have been developed. This section discusses the most important algorithms in brief. The purpose of this discussion is to investigate the merits and demerits of these algorithms so as an efficient algorithms can be selected to be used for the proposed research.

"*Colour constancy is the perceptual mechanism which provides humans with colour vision which is relatively independent of the spectral content of the illumination of a scene. It may also be referred to as the computation of perceived surface colour*" (Cardei, 2000). The colour constancy algorithms provide colour constant descriptors for the objects. There are two main categories of colour constancy algorithms.

The first category of algorithms includes those that estimate the illuminated area and then correct the given entire image relative to canonical illuminated area. This is a practical approach to colour correction and is closely related to the imaging technologies. It performs two tasks: firstly they determine the illuminated area; secondly, they colour correct the image from one illuminated area to the other. One of the disadvantages of such methods is that they introduce errors in colour appearance (Cardei, 2000).

The second category of algorithms includes those which reduce the specific illuminated area in a scene, which determines the colour constant descriptors for the object. These specific descriptors are similar for a particular scene and are independent of the illuminated area under which they were obtained. These types of algorithms are more suitable for colour based object recognition. They provide illuminate independent colour descriptions implicitly (Cardei, 2000).

2.5.1 Von Kries Coefficient Rule

Johannes Von Kries (1902) proposed a model, known as the Von Kries model, coefficient or hypothesis. As most of the chromatic adaptation theories are based on Von Kries hypothesis, many colour constancy algorithms are built upon the Von Kries model (Fairchild, 2005).

The adaptation rule of Von Kries hypothesis governs that the spectral sensitivity functions of the eye are invariant and independent of each other. In addition, Von Kries argued that the adaptation of the visual system to different illuminants can be done by adjusting three gain coefficients associated with each of the colour channels, thus:

$$L' = kL \times L \quad (2.4)$$

$$M' = kM \times M \quad (2.5)$$

$$S' = kS \times S \quad (2.6)$$

Where L, M and S represent the original tristimulus values, and kL, kM and kS represent the gain coefficients that scale the original tristimulus values into post-adaptation tristimulus values, L′, M′ and S′. In fact, the adaptation models depend on the gain coefficients. The RGB channels are often considered an approximation of L, M and S retinal wavebands, therefore:

$$R' = kR \times R \quad (2.7)$$

$$G' = kG \times G \quad (2.8)$$

$$B' = kB \times B \quad (2.9)$$

Where R, G and B are original pixels values in the image, kR, kG and kB are the gain coefficients and R′, G′ and B′ are the adjusted pixel values.

2.5.2 Gray World

One of the most important approaches to colour constancy is the Gray World algorithm, which is based on the assumption of a given image with adequate number of colour variations. The average value of the Red, Green, and Blue components of an image should average to a common gray value (Buchsbaum, 1980). In a real world image, it is usually true that there are many different color variations. These variations in colour are independent and random.

The simplest approach to colour constancy is to compute a single statistic from the whole scene which is assumed to estimate the illumination uniformly in the region of interest. In physical conditions, the hypothesis indicates that the mean among all the reflectances of the scene is referred to as gray. It is assumed that illuminants and spectral reflectances can be modelled based on the assumption that the entire image can be processed completely with a single reflectance vector (Buchsbaum, 1980)

The human visual systems do not achieve the colour constancy based on the average tristimulus values, even in the case of local surrounds (McCann, 1997). As a result, the author declared that colour constancy must be based on a normalisation process. This is related to the Retinex algorithm described as follows.

2.5.3 Retinex Algorithm

The Retinex based methods are used to solve colour constancy problems through a very simplified but effective model of the human vision system (Land, 1971). The name ‘retinex’ derives from two words ‘retina’ and ‘cortex’. The information attained by the human vision system to observe a subject comes from two distinguishable processes. The first process is performed by the retina that acquires the image, while the second process, operated by the cerebral cortex, concurs to distinguish the objects independent of their illumination. For example the same object can be identified if it is sited in both full sunlight and shadow areas or it is illuminated by an artificial light (Funt *et al.,* 2000).

In this method, light variation is removed based on the assumption that illuminant variation generates small spatial variations on the response, since large variations occur due to changes in the surfaces. The main aim of this method is to estimate the appearance of the colour which is compared with the quantity of the energy obtained for every pixel by applying a statistic computed on a specific region around a pixel. The relationship between these quantities is used in such a way that the method absolutely assumes a diagonal model. Moreover, the variations of method depend on the description of Retinex occur.

The retinex theory deals with compensation for illumination effects in the images (PersComm, 1998). The researcher mentioned that a given image 'S' was decomposed into two different images, the reflectance image R, and the illumination image L, such that at each point (x, y) in the image domain i.e.

$$S(x, y) = R(x, y)\ L(x, y) \tag{2.10}$$

The advantages of this decomposition include: the capability to eliminate illumination effects of lighting and enhance images that involve spatially differing illumination such as images that contain outdoor and indoor regions and to correct them by removing illumination induced colour changing. Recovering the illumination from a given image is known to be a mathematically ill-posed problem. In order to improve the existing problem, further assumptions on the unknowns are needed. A generally used assumption is the spatially smooth parts of 'S' obtained from the illumination image, whereas reflectance in the image produces edges in 'S'.

2.5.4 Statistical Colour Constancy Algorithms

In statistical colour constancy algorithms, the basic assumptions of normal distribution of data are calculated based on statistics. Bayesian's method for colour constancy consists of three steps which are as follows (Freeman *et al.,* 1995):