# Underwater Image Enhancement Using an Integrated Colour Model

Kashif Iqbal, Rosalina Abdul Salam, Azam Osman and Abdullah Zawawi Talib

*Abstract:*—**In underwater situations, clarity of images are degraded by light absorption and scattering. This causes one colour to dominate the image. In order to improve the perception of underwater images, we proposed an approach based on slide stretching. The objective of this approach is twofold. Firstly, the contrast stretching of RGB algorithm is applied to equalize the colour contrast in images. Secondly, the saturation and intensity stretching of HSI is used to increase the true colour and solve the problem of lighting. Interactive software has been developed for underwater image enhancement. Results of the software are presented in this paper.**

*Keywords*— **Contrast Stretching, Image Enhancement, HSI, RGB**

## I. Introduction

For the last few years, a successful movement has been started towards the direction of the improvement of image processing techniques and methods [1]-[5]. Very little research has been carried out to process underwater images.

The existing research shows that underwater images raise new challenges and impose significant problems due to light absorption and scattering effects of the light and inherent structureless environment.

Exploring, understanding and investigating underwater activities of images are gaining importance for the last few years. Today, scientists are keen to explore the mysterious underwater world. However, the area is still lacking in image processing analysis techniques and methods that could be used to improve the quality of underwater images.

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In the past, research in image processing was mainly limited to ordinary images with the exception of few approaches that have been applied to underwater images. Details can be found in [1]-[5].

For the last few years, a growing interest in marine research has encouraged researchers from different disciplines to explore the mysterious underwater world. A significant amount of literature is available on image processing, '*event detection*', '*detection and tracking of objects*', '*feature detection*' and so forth.

This paper describes the development work on the techniques and methods for image enhancement. The paper is organised as follows: Section 2 describes problems pertaining to underwater images, Section 3 presents relevant literature incorporating different models and techniques used for underwater image enhancement, Section 4 discusses the proposed technique, Section 5 shows the development of the software tool and results and Section 6 concludes this paper.

## II. Problems in Underwater Images

In this section, we briefly discuss a few problems, pertaining to underwater images, such as light absorption and the inherent structure of the sea. We also discuss the effects of colour in underwater images.

With respect to light reflection, Church [6] describes that the reflection of the light varies greatly depending on the structure of the sea. Another main concern is related to the water that bends the light either to make crinkle patterns or to diffuse it as shown in Figure 1. Most importantly, the quality of the water controls and influences the filtering properties of the water such as sprinkle of the dust in water [17].

According to Anthoni [7] the reflected amount of light is partly polarised horizontally and partly enters the water vertically. An important characteristic of the vertical polarisation is that it makes the object less shining and therefore helps to capture deep colours which may not be possible to capture otherwise.

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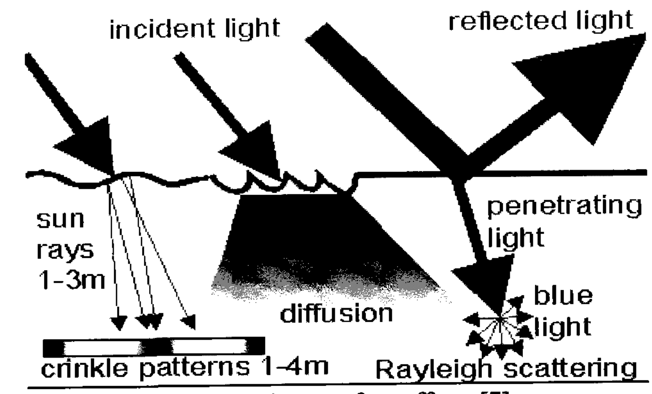


Figure 1: Water surface effects [7]

Another well-known problem concerning the underwater images is related to the density of the water in the sea which is considered 800 times denser than air. Therefore, when light moves from the air to the water, it is partly reflected back and at the same time partly enters the water [7]. The amount of light that enters the water also starts reducing as we start going deeper in the sea [8]. Similarly, the water molecules also absorb certain amount of light [17]. As a result, the underwater images are getting darker and darker as the depth increases. Not only the amount of light is reduced when we go deeper but also colours drop off one by one depending on the wavelength of the colours. For example, first of all red colour disappears at the depth of 3m. Secondly, orange colour starts disappearing while we go further. At the depth of 5m, the orange colour is lost. Thirdly most of the yellow goes off at the depth of 10m and finally the green and purple disappear at further depth [17]. This is shown diagrammatically in Figure 2.

As a matter of fact, the blue colour travels the longest in the water due to its shortest wavelength. This is what makes the underwater images having been dominated only by blue colour. In addition to excessive amount of blue colour, the blur images contain low brightness, low contrast and so forth.

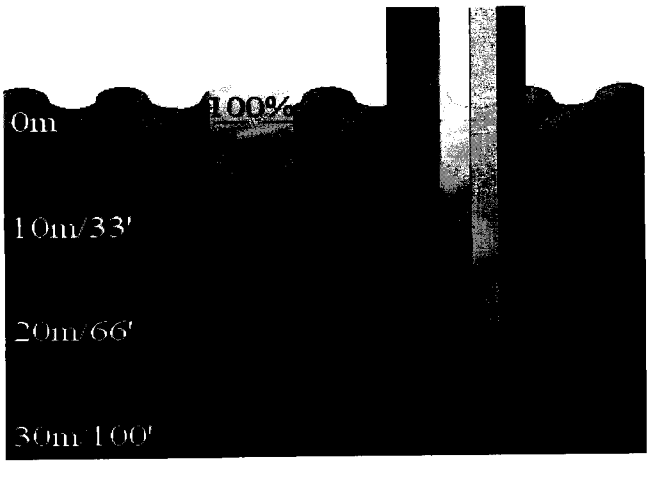


Figure 2: Colour appearance in underwater [8]

## III. RELATED WORK

This section presents related literature concerning underwater image processing.

Gasparini and Schettini [9] have developed a tuneable cast remover for digital photographs based on a modified version of the white balance algorithm. This approach first deducts the presence of a cast using a detector and secondly it removes the cast. The approach has been applied to a set of images downloaded from personal web pages.

Garcia [10] have presented a significant literature addressing the lighting problems in underwater images. The researchers have reviewed several techniques related to image enhancement. They include illumination-reflectance model, local histogram equalization, homomorphic filtering and subtraction of the illumination.

Their approach tends to address the issues concerning the correction of light in homogeneities basis with homomorphic filter. They have attempted to reduce the amount of noise using histogram equalization technique.

Chambah and Semani [1] have proposed an approach in relation to underwater colour constancy enhancement of automatic live fish recognition based on Gray World Automatic Colour Equalization. They have used a combined algorithm based on GW (Gray World), ACE (Automatic Colour Equalization) and WP (Retinex White Patch) for underwater image recognition in real-time. WP method is based on the mean of the image and it does not have any effect on image. ACE enhances the image without supervision. They carried out several steps in order to apply the proposed approach to underwater image recognition. For the sake of segmentation they subtract the background in order to recognise the image (e.g., fish). Using this process, small false detection is found and discarded using threshold. The use of this approach helps to remotely select the fish from the fish tank and choose the fish display on the screen in order to recognise image in real-time.

Andreas [2],[4] have developed an approach for underwater image enhancement by using several algorithms including Histogram Equalization, Gaussian Blur and Log-Gabor. In the first instance, they apply histogram equalization to remove backscattering, attenuation and lighting effect. Applying the histogram methods does not guarantee the removal of noise in the images. In order to address this issue, they further use Gaussian blur, a low pass filtering method. Actually, they select two images from original image using division and subtraction. After fusion, the remaining noise is removed using multi-scale de-noising algorithm based on complex valued Log Gabor wavelets [2].

Cufi [11] have proposed a vision based system using motion detection algorithm. This approach is used to automatically maintain the position of the vehicle when the reference of the corresponding image is lost. In this way, it addresses the issue of image orientation caused by vehicle movement. This approach is twofold. Firstly, this is applied to images to select a set of candidate matches for a particular interest point. Secondly, it uses a texture characterisation of the points for

(Advance online publication: 17 November 2007)

selecting the best correspondence. The contrast operator performs a grey scale differentiation in the region.

Similarly Fairweather [3] have used techniques such as contrast stretching and Markov Random field. They applied bimodal histogram model to the images in order to enhance the underwater image, first of all, they applied contrast stretching techniques. Secondly, they divided the image into two parts; object and background and then applied Markov Random field segmentation method.

Yoav [12] have used a Physics-based model. They developed scene recovery algorithm in order to clear underwater images/scenes through polarizing filter. This approach addresses the issue of backscatter rather than blur. It mainly focused on the recovery of the object. They have applied this approach to analyse and remove the physical effects of visibility degradation which can be associated with partial polarisation of light.

## IV. THE PROPOSED APPROACH FOR UNDERWATER IMAGE ENHANCEMENT

In the previous sections, we have discussed some issues concerning image processing analysis particularly in the context of underwater image enhancement. It has been highlighted that researchers within the field of marine research in general and computer science in particular are facing problems regarding the quality of the underwater images. Such problems need to be addressed in order to perform an effective and rigorous analysis on the underwater images. Most importantly, the problems need to be addressed in the pre-processing stage in the computer vision system.

Given the theoretical and technological perception to marine research, the problem of image enhancement is gaining increasingly importance. One of the most significant issues is how to improve the quality of the underwater images in order to streamline the image processing analysis. The problems related to underwater images come from the light absorption and scattering effects by the marine environment. In order to eliminate this problem, researchers are using state-of-the-art technology such as autonomous underwater vehicles [10], sensors and optical cameras [4], visually guided swimming robot [13]. However, the technology has not yet reached to the appropriate level of success. For example, the movement of autonomous underwater vehicles generates shadows in the scene while the optical camera provides limited visibility when it is used to capture underwater images. It has its own merits and demerits. In order to overcome the limitations of technology, some researchers annotate images manually. However this process is labour intensive and it also requires significant agreement amongst the annotators.

In order to address the issues discussed above, we propose an approach based on slide stretching. Firstly, we use contrast stretching of RGB algorithm to equalize the colour contrast in the images. Secondly, we apply the saturation and intensity stretching of HSI to increase the true colour and solve the problem of lighting. The proposed approach is shown in Figure 3.

The HSI model provides a wider colour range by controlling the colour elements of the image. The Saturation (S) and Intensity (I) are the element that generates the wider colour range. In a situation when we have the blue colour element in the image it is controlled by the 'S' and 'I' value in order to create the range from pale blue to deep blue, for instance. Using this technique, we can control the contrast ratio in underwater images either by decreasing or increasing the value. This is carried out by employing a *histogram* of the digital values for an image and redistributing the stretching value over the image variation of the maximum range of the possible values [14]. Furthermore linear stretching from 'S' value can provide stronger values to each range by looking at the less output values. Here a percentage of the saturating image can be controlled in order to perform better visual displays [15].

The contrast stretching algorithm is used to enhance the contrast of the image. This is carried out by stretching the range of the colour values to make use of all possible values.

The contrast stretching algorithm uses the linear scaling function to the pixel values. Each pixel is scaled using the following function [16]:

$$P_o = (P_i - c) \times (b - c) / (d - c) + a$$

"Where

- $P_o$ is the normalized pixel value;
- $P_i$ is the considered pixel value;
- a is the minimum value of the desired range;
- b is the maximum value of the desired range;
- c is the lowest pixel value currently present in the image;
- d is the highest pixel value currently present in the image " [16]

When the contrast stretching algorithm is applied to colour images, each channel is stretched using the same scaling to maintain the correct colour ratio.

The first step is to balance the red and green channel to be slightly the same to the blue channel. This is done by stretching the histogram into both sides to get well-spread histogram.

In the second step we transform the RGB image into HSI, using the saturation and intensity transfer function to increase the true colour and brightness of underwater images.

Using the transform function we have been able to stretch the saturation and intensity values of HSI colour model.

Using the saturation parameters we can get the true colour of underwater images. Brightness of the colour is also considered to be important for underwater images. The HSI model also helps to solve the lighting problem using Intensity parameters.

## V. IMAGE ENHANCEMENT TOOL AND RESULTS

Based on our methodology, we have developed a software tool to be used for underwater images. We have developed this tool using an object-oriented programming language. Our tool has different stages as discussed above and shown in Figure 3.

A snapshot of this tool is shown in Figure 4. Figures 4 and 5 also show a comparison between images before and after processing. As can be seen, images after enhancements illustrate histogram stretching.

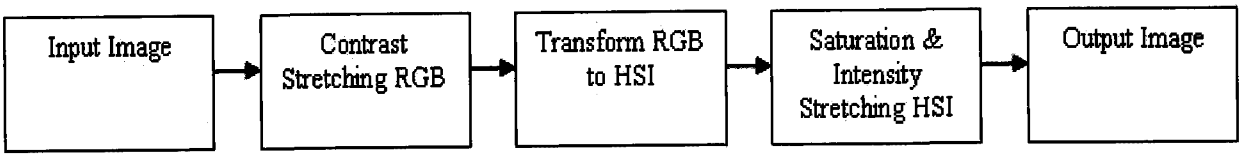


Figure 3: Methodology for Underwater Image Enhancement

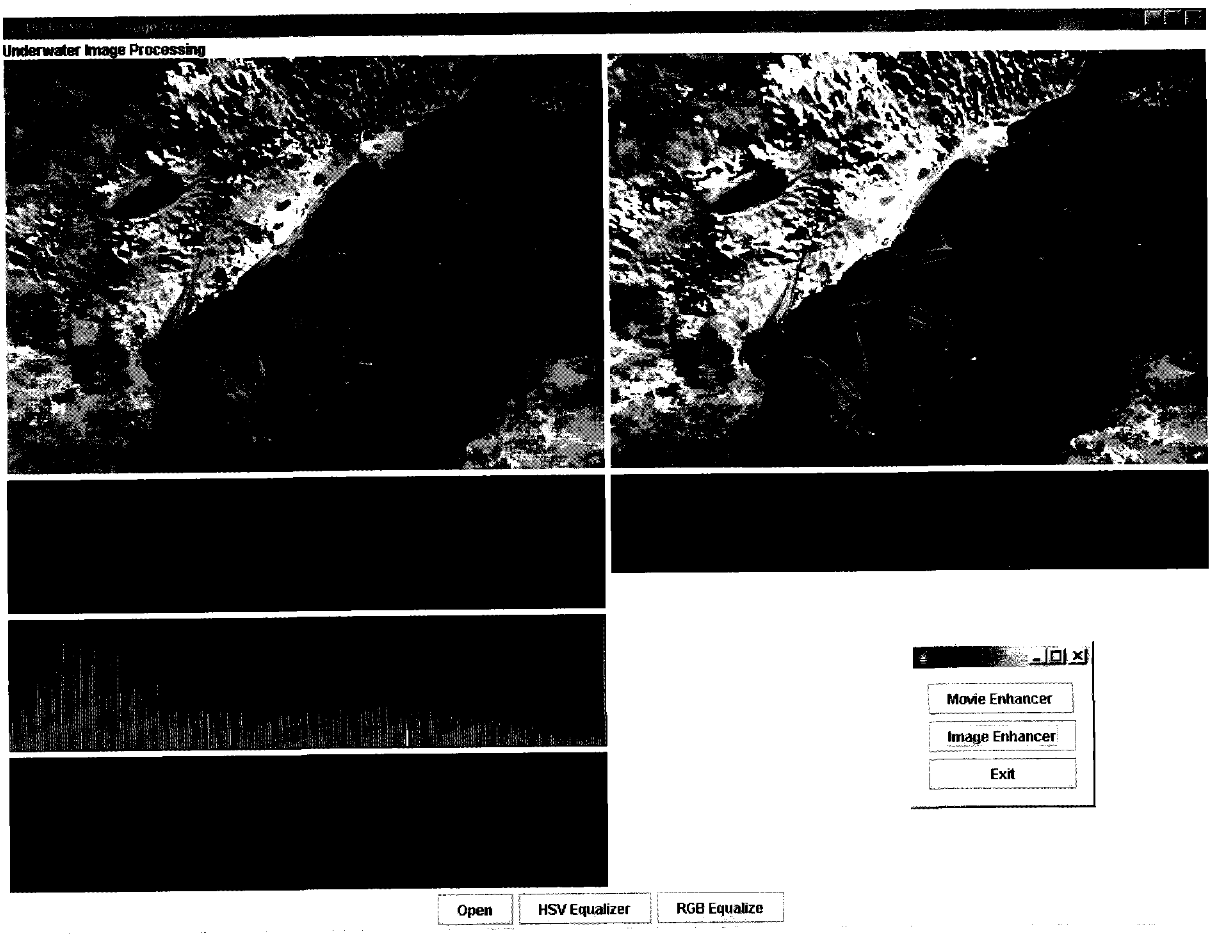


Figure 4 : Snapshot of the Tool

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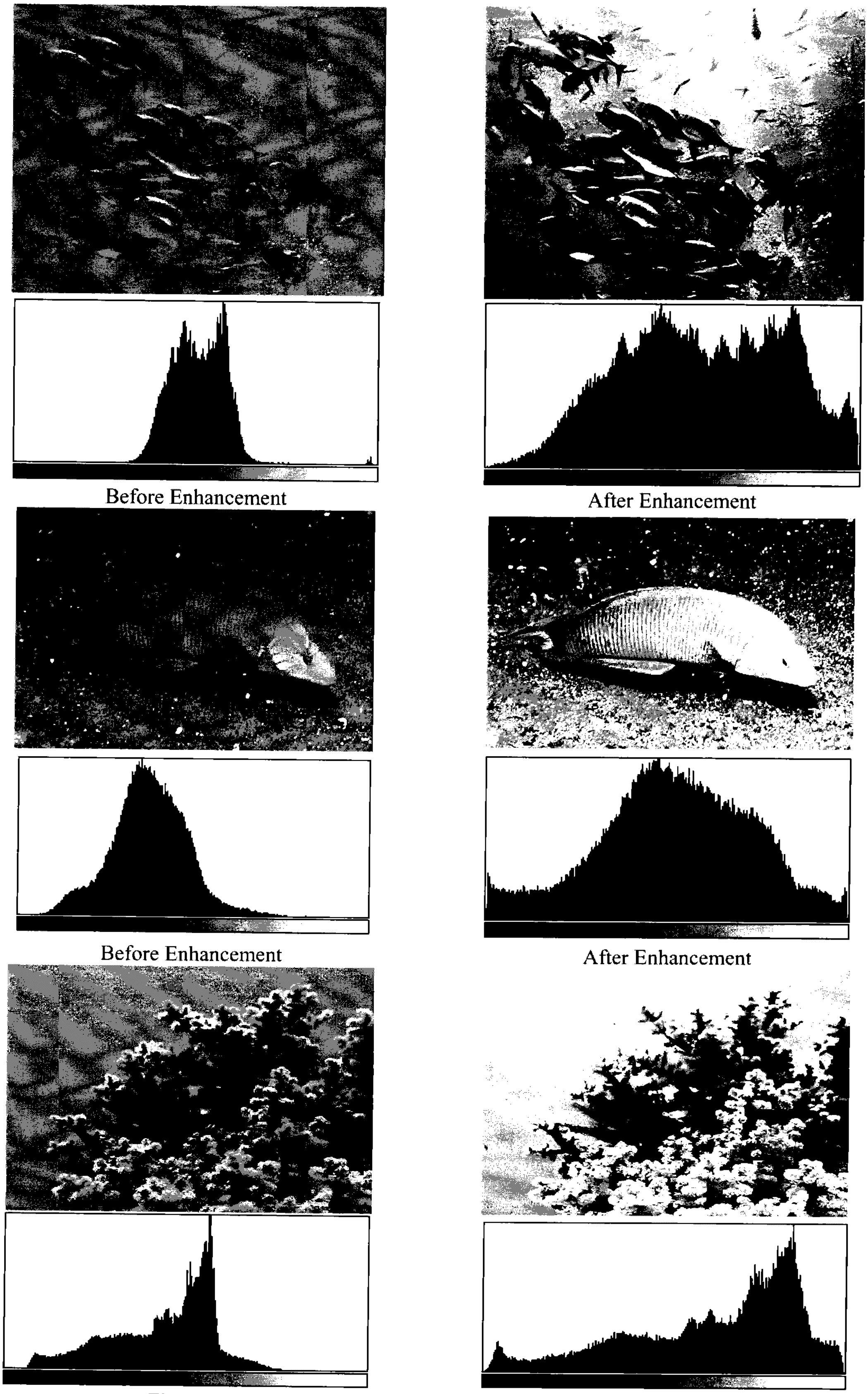


Figure 5 : Comparison of Results Before and After Enhancement

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## VI. CONCLUSIONS AND FUTURE WORK

In this paper, we have used slide stretching algorithm both on RGB and HSI colour models to enhance underwater images. In order to demonstrate the usefulness of our approach, we have developed an interactive software tool to be used for underwater image enhancement. First of all, it performs contrast stretching on RGB colour model. Secondly, it performs saturation and intensity stretching on HSI colour model. The advantage of applying two stretching models is that it helps to equalize the colour contrast in the images and also addresses the problem of lighting. By applying the proposed approach, we have produced promising results. The quality of the images is statistically illustrated through the histograms. Our future work will include further evaluation of the proposed approach.

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