ESTIMATION OF SAND DISTRIBUTION IN CORAL REEF ENVIRONMENT USING COLOUR SEGMENTATION AND COLOUR THRESHOLDING METHODS

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Abstract: At present, marine scientists employ manual method to estimate the components in coral reef environment, where Coral Point Count with Excel extensions (CPCe) software is used to determine the coral reef components and substrate coverage. This manual process is laborious and time consuming, and needs experts to conduct the survey. In this paper, a prototype for estimating the distribution of sand cover in coral reef environment from still images by using colour extraction methods was introduced. The colour segmentation called delta E was used to calculate the colour difference between two colour samples. Another method used was colour threshold by setting the range of sand colour pixels. The system was developed by using a MATLAB software with image processing toolbox. The developed system was semi-automatic computer-based system that can be used by researchers even with little knowledge and experience to estimate the percentage of sand coverage in coral reef still images.

Keywords**:** Colour segmentation, delta E, colour threshold and image processing.

Introduction

Corals are marine animals from the class of Anthozoa. All corals have the same simple structure of anemone-like polyps and typically live in colonies of many identical individuals. Corals secrete calcium carbonate to form the hard skeletons which hold the diverse and valuable underwater ecosystem together to form coral reefs. From the perspective of human beings, coral reefs provide many benefits in many aspects including coastline protection, environment for marine species, economy as well as tourism spots.

In coral reef environment, it consists of several components that can be classify into different categories such as live coral, soft coral, hard coral, dead coral and reef rubble, just to name a few. Marine scientists will always need to estimate the components in coral reef environment to know the coral coverage at a particular time. From the estimation, they can deduce whether a reef ecosystem is either healthy, in the process of dying or at certain risk. Marine scientists can take action in conservation of coral reef to stop the bleaching of coral reef from happened. Protection of coral reef is very important to prevent reef ecosystem that are at risk.

From the study of past researches, people had started the surveys on coral reef environments. Several ways of classification methods to classify coral reefs components and deduce the coral reef health have been proposed and implemented. The coral reef survey may apply several different image processing based methods including on feature extraction and classification. Coral reef components can be classified through their

colour, texture and shape features.

Soriano *et al*. (2001) have made a comparison of methods on colour, texture and colour-texture combination on the classification of five types of coral reef using video transect, i.e. dead coral, live coral, dead coral with algae, algae and abiotics. They found that the use of texture features lead to better classification accuracy performances as compared to using only colour features or colour and texture features combined. In their experiment, the local binary patterns was used as a texture feature extraction method and *k*-nearest neighbor as a image classifier. In another study by Marcos *et al*. (2005), they have used a combination of colour and texture features for classifying three type of coral from an underwater video; live coral, dead coral and sand. They found that the use of three-layered neural network classifier performs better and provides a higher recognition rate than a decision tree classifier.

One of the methods to separate the object from the background is by using image segmentation technique. Kulkarni (2012) proposed a manual multi-threshold colour segmentation technique on each colour band to separate the desired object from the background. The experimental results showed that by manually selecting specific colour threshold at each colour band, the algorithm is able to segment desired object of interest. However, the process of manually selecting the region of interest although may be able to work well for some type of image but it could not perform well in all test set images. Kumar *et al*., (2016) investigated and compares the performances of six segmentation algorithms namely the *k*-means, Otsu, quad tree, delta E, region growing and fth algorithms. Their results showed that the Delte E algorithm produced better segmentation results as compared to the other five popular segmentation algorithms.

This paper is mainly focus on estimating the distribution of sand cover from coral reef images by using image processing technique. In the past, different methods have been used to estimate and classify the coral reef components. Hamylton (2011) used a hyperspectral remote sensing image data to estimate four types of benthic components. She successfully demonstrated that an unmixing image analysis method could provide an accurate estimation of the benthic components coverage. However, remote sensing itself also have some limitations; the scope of which is beyond this paper to discuss.

In this project, classification of sand in coral reef environment from colour properties is estimated using digital still images. Sand is usually white in colour. It is achromatic and has a stochastic texture. So, through colour, we can differentiate it from other coral reef components.

At present, marine scientists classify the components in coral reef environment manually. This manual process takes sometimes for them to estimate the distribution of the coral reef components. This process may also results in low accuracy estimation, incorrect record and the results vary between experts.

Recently, marine scientists are using Coral Point Count with Excel extensions (CPCe) software (Kohler & Gill, 2005) to estimate the coverage of coral reef components. This software is basically a Visual Basic computer code programmed in a Microsoft Excel software to calculate statistical coral reef coverage based on some selected random points on the given image marked by a user. By using the CPCe software, marine scientists are able to perform their tasks faster and in a more systematic manner. However, the process is still a manual procedure and need an expert operator to identify and mark the coral reefs type.

In this paper, image processing based technique is used to estimate the distribution of sand in coral reef environment using still images. Specifically, this paper focuses on developing a computer-based system for user to estimate the percentage of sand in coral reef environment through the classification of components in coral reef environment. The

classification will be based on the colour property of the sand.

Materials and Methods

The estimation of sand distribution in coral reef environment images was a semi-automated method where the user circled an obvious sand region and the system would automatically calculate the sand percentage from the whole image. The coral reef still images for estimating the sand distribution were acquired from the Institute of Oceanography and Environment (INOS) of Universiti Malaysia Terengganu. We experimented with several methods in image processing and applied them for sand estimation in coral reef still images. The method with the best results was used to develop a system for estimating the distribution of sand in coral reef environment. The experimented methods included colour segmentation, colour thresholding, local binary pattern (LBP) and Canny edge detection. The combination of colour segmentation and colour thresholding methods were chosen as the method to be used in the system. Firstly, colour feature was extracted from the still images. After that, different classifier was used to classify the colour features extracted. The estimated sand area results were obtained by overlapping the results of classification from colour segmentation and colour thresholding methods to obtain the area of sand coverage. The result of estimated sand coverage area in the coral reef still image was displayed as percentage coverage due to no direct scaling of the actual area cover at ground truth available from the image sample.

Colour Segmentation

The process of colour segmentation started with reading the RGB coral reef still image into an array and obtain its image dimensions. The original image was then displayed for user to outline the sand region over RGB image. The image was later masked followed by conversion from RGB colour model to Lab colour model. Lab colour model was used in this study because it was designed to approximate the human lightness perception. Thus, by adjusting the appropriate L, a and b components, it can accurately match the colour segmentation of the desired objects (Baldevbhai & Anand, 2012). Next, the colour bands were extracted from the original image into three separate 2D arrays, one for each component. From there, the average Lab colour value was calculated and a uniform image was computed on one single Lab colour. This was followed by the calculation of delta E image value by using delta E algorithm. Finally, the pixels within the delta E values were extracted which resulted in black and white image. The results were later put through morphological closing operation followed by erode operation with length of 3 degree and 45 degree for four times to get better quality image results.

According to Baldevbhai & Anand (2012), before converting the RGB colour space to Lab colour space, the RGB values must be converted into a specific absolute colour model. The conversion process involved data transformation into the CIE 1931 colour model before it could be converted in Lab colour model. The formula for the colour space conversion is as follows:

$$L^* = 116 \, f\left(\frac{Y}{Y_n}\right) - 16 \qquad\qquad (3.1)$$

$$a^* = 500 \left[f\left(\frac{X}{X_n}\right) - f\left(\frac{Y}{Y_n}\right)\right] \qquad\qquad (3.2)$$

$$b^* = 200 \left[f\left(\frac{Y}{Y_n}\right) - f\left(\frac{Z}{Z_n}\right)\right] \qquad\qquad (3.3)$$

Where,

$$f(t) = \begin{cases} t^{\frac{1}{3}} & \text{if } t > \left(\frac{6}{29}\right)^3 \\[2em] \frac{1}{3}\left(\frac{29}{6}\right)^2 t + \frac{4}{29} & \text{otherwise.} \end{cases}$$

Here, the X_n, Y_n and Z_n are the CIE XYZ values of the reference white point and the subscript n means its value was normalized.

Delta E means "a difference in sensation" (Baldevbhai & Anand, 2012). The units of measure that calculated the difference between two colours were based on Lab coordinates, the two colours being a reference colour and a sample colour that attempted to match it.

The delta E algorithm used in this work was according to the formula defined as follows which calculates the Euclidean distance between (L*1, a*1, b*1) and (L*2, a*2, b*2) of two colours.

$$\Delta E_{ab}^* = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2} \qquad\qquad (3.4)$$

This was followed by matching the delta E in the mask region and obtaining their mean and standard deviation values. Lastly, the pixels within that delta E were found and the result was in black and white image.

Colour Thresholding

Firstly, the input RGB coral reef still image was split into RGB channels. From there, the histogram values for each channel could be determined. Next, the average range of pixel values of sand regions for 20 coral reef still images was calculated. After the average range of pixel values was determined, it would be set as the range of pixel value of sand regions in the coral reef still images. Finally, the result was presented in black and white image. The result was processed by filling the holes in the resulted image two times and later eroded by using morphological operation on binary image two times to obtained a better result.

Local Binary Pattern (LBP)

For texture feature extraction, the input RGB coral reef still image was converted to grayscale image. In this work, local binary pattern (LBP) method was chosen as the texture extraction method. LBP is an operator introduced by Ojala *et al*. (2002) and has been shown to be an effective descriptor in texture classification process. Marcos *et al*. (2005) showed that LBP is an excellent method in recognizing tilted 3D textures compared to the other texture-based methods. The LBP method was used to extract relevant features from coral reef images which later would be used to calculate image similarity. After the conversion of RGB image to grayscale image, the

dimensions of the image were calculated and the array for the local binary pattern was instantiated. Then, the image was converted into binary image by manual threshold. Next, the LBP code was calculated for every pixel element of a given coral reef image. Therefore, the LBP texture of the input grayscale image was calculated and produced an LBP code. The LBP texture was calculated as follows:

$$LBP_{P,R(X_C,Y_C)} = \sum_{P=0}^{P-1} s(g_p - g_c)2^P \qquad (3.5)$$

where

$$s(x) = \{_{0,}^{1,} \quad \begin{matrix} x \geq 0 \\ x < 0 \end{matrix}$$

and,

P = the points on the edge of the circle.
R = Radius distance from the centre pixel.
P, R = The total number of pixels in 3 × 3 neighbourhoods and the radius of the neighbourhood, respectively.
For a matrix of 3 × 3 neighbourhood, the value of P is 8.
(x_c, y_c) = Coordinates of the centre pixel.
g_c = Gray level value of centre pixel.
g_p = Gray level value of neighbour.
$s(g_p - g_c)$ or $s(x)$ = The threshold value of LBP operation where 1 is assigned to the point on the circle with a same or higher gray value than the center pixel, or else o is assigned.
2^p = A binomial weight.

For an efficient representation of the sand, the image was first divided into regions. Next, a regional histogram was constructed. The feature vector was then constructed by concatenating the regional histograms to an overall histogram that represented the image contents. After all of these processes, the LBP features were extracted from the image. The result of LBP would be black and white image.

Canny Edge Detection

For shape feature extraction, the input RGB coral reef still image was converted to grayscale image. In this study, Canny edge detection was used for shape feature extraction. Canny edge detection was chosen because according to Vijayarani & Vinupriya (2013), it can produce good edge quality. After grayscale image conversion, the image was converted into double precision. Next, the value for threshold and the Gaussian filter coefficient were set. Then, convolution of image by Gaussian coefficient and filter for horizontal and vertical direction was performed. This was followed by performing convolution of image by horizontal and vertical filter and then calculation of the directions. After that,

adjustment for negative directions was made, making all directions positive. This adjustment was achieved by adjusting the directions to the nearest 0, 45, 90 or 135 degrees. Next, the calculation of magnitude and hysteresis threshold was made. This process produced a black and white image.

Combination of Colour Segmentation and Colour Thresholding Method

Figure 1 shows the overall combination of colour segmentation and colour thresholding method. The results of colour segmentation and colour thresholding methods were both in binarized image. Therefore, logical OR operator as shown in Table 1 was used to combine colour segmentation and colour thresholding results by overlapping them together. For logical OR operator, it will return logical 1 (true) if even a single condition in the expression is true. In Table 1, the number 0 means area with sand while number 1 means area without coral.
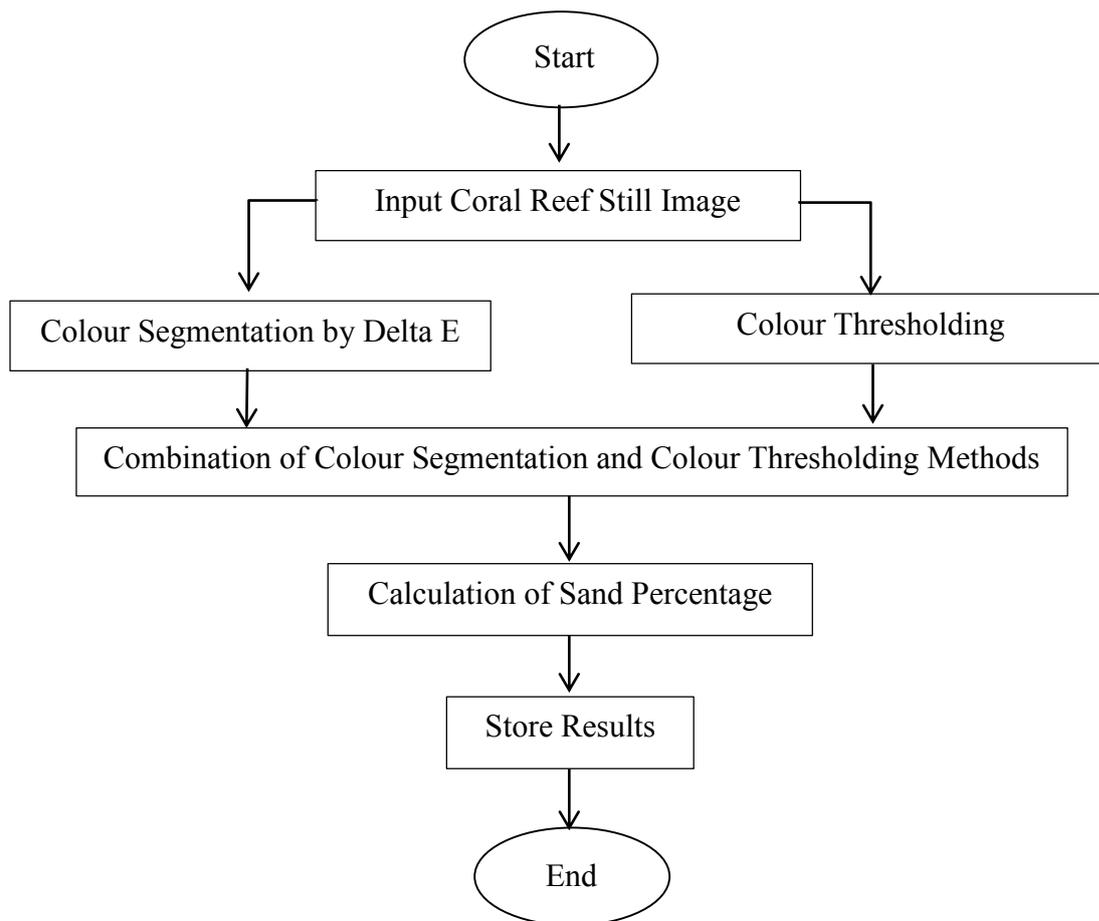
Figure 1: Flowchart of the combination of colour segmentation and colour thresholding methods

Table 1: Example of truth table for logical OR operator

Input A	Input B	OR Operator A	B
0	0	0
0	1	1
1	0	1
1	1	1

From the logical OR operator, the percentage of sand coverage in the still image was estimated. Sand cover area could be calculated by computing the total number of number 1 (i.e. number of bins) over the total number in the matrix. The percentage of sand in every image would be stored in a file. The total number of sand percentage for each coral reef image was also stored in a file and the average percentage of total number of images stored would be displayed in the system. The data stored in the file would be deleted when the user clicked "reset data".

Results and Discussion

In this work, three basic feature extraction methods were carried out to determine the most suitable methods to estimate the sand distribution in coral reef environment. For colour feature extraction, colour segmentation by delta E method and colour thresholding method were carried out. For texture feature extraction, local binary pattern (LBP) was

carried out, while Canny edge detection was used for shape feature extraction. After carrying out all these methods, the strengths and weaknesses of these methods in estimating sand coverage in coral reef environment were identified. The most suitable and best method would be used to develop the system. From the experimental results, the colour segmentation and colour thresholding method were chosen and combined by overlapping them using logical OR operator to get better results. The percentage of sand in the image was then calculated.

In coral reef environment, there are several elements that need to be differentiated from sand in order to get the sand area. The elements can be classified as black corals, white corals, rubble, sand on corals and shadows. The experimental results of these methods were studied and are shown in Table 2.

Table 2: Comparison of different techniques.

Elements / Method Used	Differentiate Element from Sand				
	Black Coral	White Coral	Rubbles	Sand on Coral	Shadow
Colour Segmentation by Delta E	√	×	√	Some	×
Colour Thresholding	√	Some	√	×	×
Local Binary Pattern (LBP)	Some	Some	Some	×	×
Edge Detection by CANNY	Some	Some	√	×	×
Combination of Colour Segmentation and Colour Thresholding	√	Some	√	Some	×

From Table 2, it can be observed that the combination of colour segmentation and colour thresholding methods produced the best results. This is because they could differentiate most of the elements from sand. They could clearly show the difference between black corals and rubble from sand. Besides, some of the white corals and sand on coral reefs could also be distinguished out from sand. Only the sand area with the shadow could not be distinguished. However, there were some exceptions for some of the images to get the same result as in Table 2. Therefore, further improvement can still be made in the future to get better results by studying on more methods and classifiers besides methods studied here. Furthermore, the system only can be applied to some of the dataset collected from the Institute of Oceanography and Environment (INOS) in University Malaysia Terengganu (UMT) but not all the dataset obtained from the other reef areas around the world. So, the system can be improved by including more dataset from other areas around the world.

Conclusion

As a conclusion, the system for estimating sand distribution in coral reef environment using colour segmentation and colour thresholding methods is a semi-automated computer-based system that can be used by people even with little knowledge and experience to estimate the percentage of sand coverage in coral reef environment. In this study, image processing toolbox in MATLAB was used as the platform to run this system. Besides, this system only uses the combination of colour segmentation and colour thresholding image processing methods and the result is combined with the logical OR operator to extract and classify the sand regions in the coral reef still images in order to obtain the percentage of sand. This is because the combination of colour segmentation and colour thresholding methods can produce more accurate results compared with previous experimental methods in this work. The system can further be improved by running more dataset from other areas around the world. Moreover, although using the

combination of colour segmentation and colour thresholding methods may lead to acceptable results, it will not guarantee to produce the best results for all the images. Therefore, further investigations by using other methods or different classifiers can be performed in the future to produces more accurate results.

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