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Coral reef's healthy level measurement system design using digital image processing on Bunaken National Sea Park

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Abstract. The existence of coral reefs have been beneficial for life of living things in the sea. However, their existence today is threatened by some factors which can be seen from its color bleaching. This means that coral reefs' level of healthy is decreasing. This is happening in Bunaken National Sea Park North Sulawesi, which is one of tourism destinations in Indonesia. Data used on this research is 40 reef images collected randomly from 10 diving spots around Bunaken. This research will design a system to analyse coral reefs' healthy level using digital image analysis. Reef healthy observation is accomplished based on Coral Health Chart issued by coralwatch.org. Based on the chart, RGB average is calculated using digital image processing and applying least square method to obtain formula in determining coral reefs' healthy level. Furthermore, the 40 coral reef images collected are classified based on regression equation obtained. This system is built in computer application system. Results show that application system using digital image to determine reef healthy level can be used. Healthy level of coral reefs in Bunaken National Sea Park is 72.8184%.

1. Introduction

Sea is a massive area which makes it interesting to be observed. Moreover, sea is a big source of economic profit of a nation because of its sectors in fisheries and tourism, as well as its coral reefs ecosystem. Coral reefs' existence today has been in a warning level, this is because of increasing earth water temperature, which leads to coral destruction marked by coral's color bleaching. Coral bleaching is a coral's color fading because of the disappearance of symbiotic algae which acts as energy and color suppliers in coral tissues [1]. Less was known in coral bleaching process, however, increasing temperature can interrupt algae's power in photosynthesis and trigger the production of dangerous chemical substance which can harm their cells [2].

Vision is important in human's point of view, this also acts in an image. In this case, unhealthy coral can be observed on its color changing pattern, more brighten the color is, the more it is unhealthy. In 2006 did research about Monitoring Coral Bleaching Using a Colour Reference Card [3]. In that research, images of some reefs were analysed on *Adobe Photoshop V6* using histogram function to determine *hue*, *saturation* and *brightness*. Reef bleaching pattern was then treated to obtain four color classes and generate a *Coral Health Chart* to observe reef's healthy level. The chart was used in fieldwork by comparing reef's color to the colors in the chart, which then continued by listing the



corresponding code. This research use *Coral Health Chart* and digital image processing in obtaining information of colors *RGB* (red, green, blue) points as well as least square method to form formula. From that formula, calculation of coral reefs' healthy level can be completed.

2. Literature Review

2.1 Coral and Coral Health Chart

Coral reef has important role for sea organisms. In a healthy reef, algae (*dinoflagelata simbiotik*) lives in reef's tissues. Algae supplies energy to the reef in form of sugar and amino acid, and gives color characteristics. Severe environment causes algae to be detached from the tissues, so that the reef's color turn into white or well known as reef bleaching [1]. Major cause of massive reef bleaching on these decades corresponds to increasing of sea surface temperature [4]. Increasing average temperature because of climate change causes reefs to be a frequent and extreme subject of bleaching [5]. Mass bleaching in 1998 was the worst in history, because one sixth of reef colonies die every year [1].

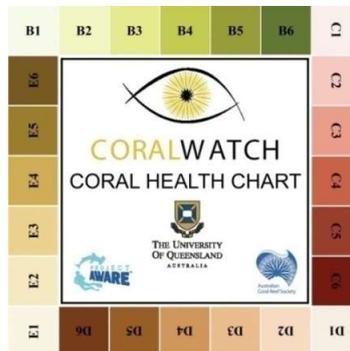


Figure 1. Coral Health Chart

CoralWatch is an organisation started from a research project in Queensland, Brisbane, Australia. *CoralWatch* uses *Coral Health Chart*, an undestructible simple method to observe bleaching and reef's healthy. There are four classification colors in the chart, each represents coral reef, i.e. green, red, brown and brownish [1].

2.2 Digital Image Processing

Digital image processing is a rapidly growing field with improving application in science and technology. Digital image processing term generally refers to two dimensional image processing using digital computer. Digital image processing has important role in application such as remote detecting via satellite and spaceship, image transmission and storage for applications in business, medical process, radar, sonar, acoustic image processing, robotics, etc [6]. Digital *image* is function $f(x,y)$ with size M rows and N columns, where x and y are spatial coordinates and f on coordinates (x,y) is called grey level or intensity of image on that coordinates.

In matrix notation:

$$f(x,y) \approx \begin{bmatrix} f(0,0) & f(0,1) & \dots & f(0,M-1) \\ f(1,0) & f(1,1) & \dots & f(1,M-1) \\ \vdots & \vdots & \vdots & \vdots \\ f(N-1,0) & f(N-1,1) & \dots & f(N-1,M-1) \end{bmatrix}$$

A digital image can be considered as large array of discrete points. These points are called image elements or *pixel*. In *true color*, each *pixel* has specific color which is represented by amount of red, green and blue in it [7]. Each color is produced by mixing of three primary colors or RGB [8].

For *RGB* or red, green, blue, the color has range between 0-255, this gives total $255^3 = 16.777.261$ colors which can be different in the image [7]. Color model *RGB* based on color responded by human eyes which sensitive to wavelength around 400 nm (blue) to 700 nm (red) [9].

Random colors can be produced from the mix of primary colors R, G, B with color specific percentage (W):

$$W = R + G + B \tag{1}$$

2.3 Last Square Method

In science and technology, often appear case in trial which gives sets of data points $(x_i, y_i), \dots, (x_N, y_N)$ where abscissa $\{x_i\}_{i=1}^N$ finite. One of the numerical method goals is determining formula $y = f(x)$ which relates all variables [10]. In this case, linear function is used in the form:

$$y = f(x) = ax + b \tag{2}$$

Sometimes there are errors in measurement, so that the real value of $f(x_i)$ holds:

$$f(x_i) = y_i + e_i \tag{3}$$

Where e_i is error in measurement.

In determining best linear estimation of form (2), it has to be discussed the error

$$e_i = f(x_i) - y_i \tag{4}$$

To measure the length of line $y = f(x)$ on the data, *root-mean-square error*

$$E(f) = \left(\frac{1}{N} \sum_{i=1}^N (f(x_i) - y_i)^2 \right)^{1/2} \tag{5}$$

is used.

Theorem (*Least-squares Line*)

If $\{(x_i, y_i)\}_{i=1}^N$ are points N , where abscissa $\{x_i\}_{i=1}^N$ finite. Coefficient of *least-squares* line

$$y = ax + b$$

is the solution of linear system known as *normal equations*:

$$\begin{aligned} \left(\sum_{i=1}^N x_i^2 \right) a + \left(\sum_{i=1}^N x_i \right) b &= \sum_{i=1}^N x_i y_i \\ \left(\sum_{i=1}^N x_i \right) a + Nb &= \sum_{i=1}^N y_i \end{aligned} \tag{6}$$

with,

$$\begin{aligned} a &= \frac{N \sum_{i=1}^N x_i y_i - \sum_{i=1}^N x_i \sum_{i=1}^N y_i}{N \sum_{i=1}^N x_i^2 - (\sum_{i=1}^N x_i)^2} \\ b &= \frac{\sum_{i=1}^N y_i \sum_{i=1}^N x_i^2 - \sum_{i=1}^N x_i \sum_{i=1}^N x_i y_i}{N \sum_{i=1}^N x_i^2 - (\sum_{i=1}^N x_i)^2} \end{aligned} \tag{7}$$

where,

a = gradient.

b = intercept to vertical axis.

2.4. Bunaken National Park

Bunaken National Park is a sea park located in North Sulawesi Province and part of Manado city territory. This park located on Coral Triangle Reef and is home of 390 coral reef species (http://id.wikipedia.org/wiki/Taman_Nasional_Bunaken) as well as various species of fish, molluscs, sea reptiles and mammals. Bunaken National Park is symbol of Indonesia’s sea ecosystem, including seagrass meadows, coral reefs and beach ecosystems.

This national park was established in 1991 with SK Menteri Kelautan RI No 730/Kpts-II/1991 as its legal document and covers areas of 890.65 km². (<http://www.dephut.go.id/INFORMASI/TN%>

20INDO-ENGLISH/tn_bunaken.htm). Geographic location of National Sea Park is on $1^{\circ} 35' - 1^{\circ} 49' \text{LU}$ dan $124^{\circ} 39' - 124^{\circ} 35' \text{BT}$. Of all habitat in this national park, there are 97% of sea habitat and 3% of land habitat. Bunaken National park covers five island, i.e Bunaken, Manado Tua, Mantehage, Naen and Siladen. For Bunaken Island with its diving point, given in Figure 1.



Figure 2. Diving Spots Map at Bunaken National Park

3. Research Method

Steps:

- 1) Taking digital image Coral Health Chart from CoralWatch.
- 2) Applying digital image processing on Coral Health Chart to calculate RGB average points from the four color classes.
- 3) Determining regression equations from Coral Health Chart with least square method based on RGB average points from the four color classes obtained before with computer application system.
- 4) Taking coral reef image sampel in Bunaken National Park.
- 5) Determining classification of reef's color class.
- 6) Applying digital image processing on coral reefs' image to find RGB average points.
- 7) Determining and concluding reef's healthy level using formula from Coral Health Chart.

In this research, the image was taken directly by diving into the place where the reef was located. The camera used is a camera with a resolution of 10 mega pixels. Also do not consider to the level of turbidity of sea water, lighting and others. This results in the possibility of distortion in taking pictures of the reef and this research has not considered the distortion.

4. Result and Discussion

4.1 Research Data

Coral reef image data is randomly collected from 10 diving spots in Bunaken National Sea Park, i.e. spots 2, 3, 5, 6, 9, 11, 13, 14, 16, 17, with 4 images from each spot. Therefore, data used is 40 images.

4.2. Regression Equations

Regression equations for class B, C, D, and E (from Coral Health Chart) are :

1. Class B : $y = -0.032x + 9.22$
2. Class C : $y = -0.026x + 7.45$
3. Class D : $y = -0.028x + 8.01$
4. Class E : $y = -0.030x + 8.63$

These regression equations become a model for determining the level of coral health in the application system that is built. The value of x is the RGB average of each reef in its class and the y value is the level of freshness of the reef expressed in the interval of values 1- 6, ranging from unhealthy to healthy.

4.3. Application System

Application system is constructed with *Guide User Interface* (GUI) created is as in Figure 3.



Figure 3. Application System Main Menu

In the Figure 4, as application system main menu, there are **program**, **information** and **exit** buttons. **Program** contains application to input coral reef image and determine its healthy level. **Information** contains information about coral health chart as reference to determine reef healthy level. **Exit** is the exit button from main menu.

If the program button is pressed, then the window will appear as in Figure 4.

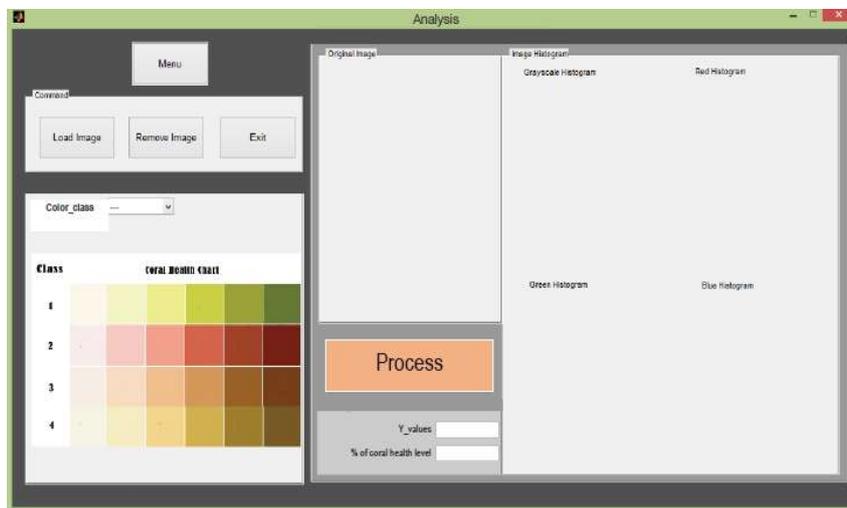


Figure 4. Analysis window

Steps to determine reef healthy level on this program are:

1. Press **Load Image** button then there will appear a window as in Figure 5..
2. Then choose coral reef image file which will be analysed from the image storage folder and press **Open**.

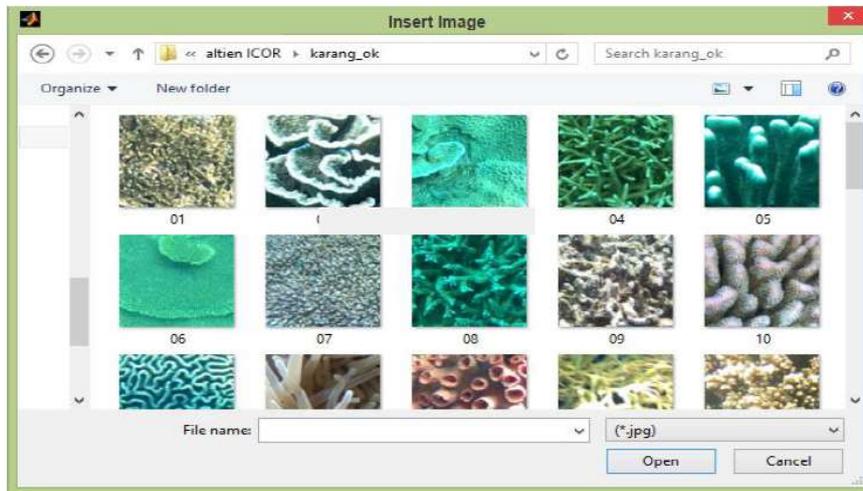


Figure 5. Window to choose coral reef image file

On the analysis window, there will rise appearance as in Figure 6.

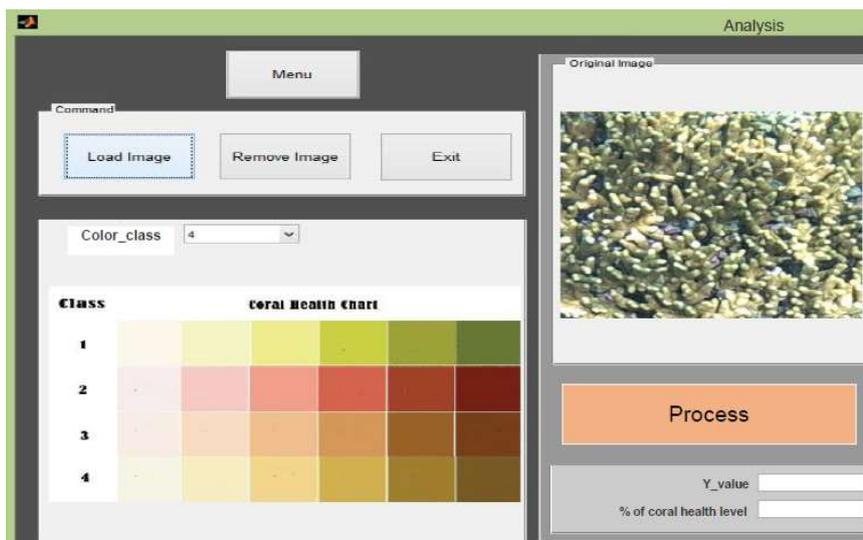


Figure 6. Analysis window after reef image input

3. Choose reef color class corresponding to *coral health cart* (On this case is color class 4)
4. Press **Process** button, then analysis window will give conclusion about the coral reef's healthy level, as in Figure 7.
5. Do the same steps for other reef's images.

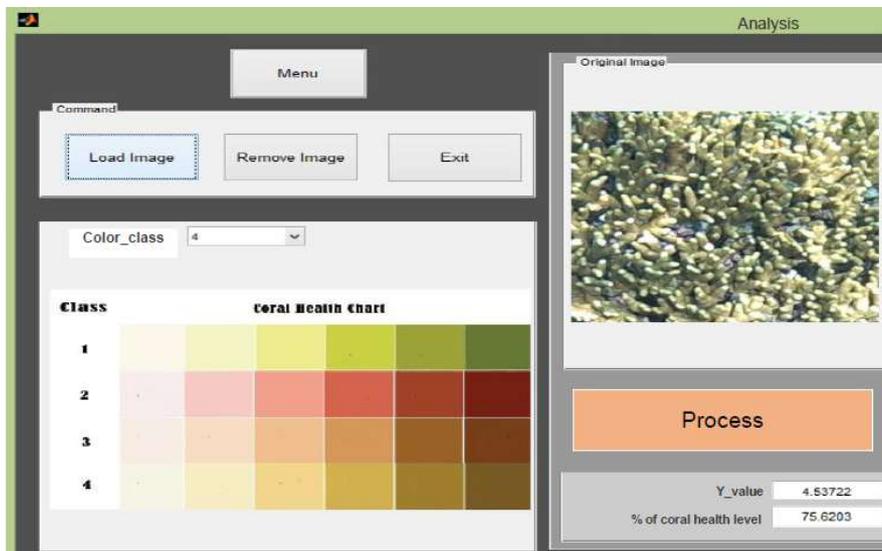


Figure 7. Analysis window with reef image input and conclusion about its healthy level.

4.4. Healthy Level of Reef of Bunaken National Sea Park

Based on system analysis for 40 images of coral reefs in Bunaken National Sea Park, results obtained can be shown on table 1.

Table 1. Healthy Level of 40 Coral Reefs Sample

Sample Number	Healthy Level Points	Healthy Level Percentage	Sample Number	Healthy Level Points	Healthy Level Percentage
01	4.53722	75.6203	21	2.07688	34.6147
02	4.01406	66.9011	22	3.12380	52.0634
03	4.77539	79.5899	23	3.24342	54.0750
04	5.69843	94.9738	24	4.37487	72.9145
05	5.62807	93.8012	25	5.30097	88.3496
06	5.12022	85.3371	26	2.31989	38.6648
07	3.81096	63.5160	27	3.17864	52.9774
08	5.87616	97.9361	28	4.99504	83.2507
09	4.11918	68.6529	29	4.29341	71.5568
10	3.92341	65.3902	30	4.3026	71.7101
11	5.71350	95.2251	31	4.74353	79.0588
12	4.74016	79.0027	32	3.69888	61.6479
13	4.48465	74.7441	33	5.68900	94.8167
14	3.91990	65.3317	34	4.03312	67.2187
15	4.00790	66.7984	35	5.61147	93.5244
16	5.36629	89.4382	36	4.92388	82.0646
17	4.56291	76.0485	37	5.29551	88.2586
18	3.26236	54.3727	38	4.14463	69.0771
19	3.80768	63.4613	39	4.36936	72.8226
20	2.36645	39.4409	40	5.30931	88.4885
Average			4.36908	72.8184	

Based on table 1, it can be seen that the average of healthy level of reefs in Bunaken National Sea Park is 4.36908 or its percentage is 72.8184%. This is fairly at good condition, nevertheless there must be serious concern to preserve or even improve the healthy level.

Descriptively, there are some snorkeling and diving spots where the coral reefs in it have died because of unaware tramples of some beginner snorkelers and divers. The spot is spot number 6

(Tawara). Whereas almost all spots in Eastern Bunaken (number 16 & 17) are still in good and conserved conditions.

Because in taking coral pictures does not consider the effect of camera resolution, the level of turbidity of the sea, light, etc., then there is a possibility of distortion of coral images. This is an opportunity for further research by considering these matters.

5. Conclusion

Based on this research, it can be concluded that:

1. Application system using digital image processing can be used to determine healthy level of coral reefs in Bunaken National Sea Park.
2. Healthy level of Coral Reefs in Bunaken National Sea Park is 72.8184%.

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