International Journal of Engineering & Technology, 7(4.16) (2018) 302-307

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research paper

Image-based Coral Reef Formation Detection and Change Assessment System

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Abstract

Coral reefs play an essential role in marine biodiversity as they provide protection and shelter for marine species. Coral reefs also take a major part in maintaining the amount of carbon dioxide and filtration of coastal waters. The destruction and decrease of coral reefs may lead to an imbalance in marine biodiversity. Hence, the coral reefs have to be protected through monitoring and surveillance.
In this study, an image-based system that monitors coral reef formation detection and assess coral reef changes was implemented. Image Differencing and Post Classification Methods were used to perform detection and recognition of coral reef formation. Foreign objects such as coins, metal rod and stones were dropped to the experimental set-up. Significant changes in the coral reef environment as well as the significant changes in the formation of the coral reefs after the appearance of foreign objects were assessed. The average accuracy of the system relative to the foreign objects considered is 88.75%.
Overall, the study proved that both algorithms are effective in underwater image processing of the coral reef formation. Statistically, there is no significant difference between the results of the two algorithms as used in this study in terms of recognition and detection.

Keywords: *Coral Reef; Image Differencing; Post Classification; Significant Change .*

1. Introduction

Humans are more capable of identifying the three-dimensional structure of the objects in their surroundings as compared to artificial computer vision capabilities. Artificial vision algorithms are continually being developed as they become promising techniques for machines to perceive the three-dimensional structure of the environment. Underwater machine vision is one of the many applications of computer vision. Underwater observation of plants, animals and other species is an essential aspect of marine ecosystem because it is a way to explore the vast ocean resources [1], [2]. Human divers are limited by their oxygen supplies when they do underwater explorations and there is a limited depth in which humans can dive. In addition, they have limited camera memory capacity to monitor or record the behavior of the corals and other marine lives [3], [4]. Hence, a 24/7 monitoring activity is an impossible thing to do.
The development of underwater vision systems is a growing interest to many researchers. The main goal is to enhance capabilities, increase effectiveness and provide automation [5]. Underwater monitoring includes the observation of a variety of marine species which mostly includes coral reefs. Corals are classified into a wide range of colors, textures and shapes. Coral classification and recognition may differ with fingerprints and face recognition in terms of the degree of similarities and common features. With a change in perspective and scale, corals can appear in different ways [6].
Corals have survived for thousands of years even in the event of natural calamities. Human activities lead some of the coral reefs to be damaged and destroyed by means of destructive fishing practices such as dynamite fishing and muro-ami. Coral mining where live corals were detached and used as aesthetic for buildings also contributes to its destruction. Large fishing vessels can also damage the coral reefs if they sail in shallow waters. Statistics show that approximately one-quarter of coral reefs worldwide are damaged while two-thirds are in serious threat [7].
Round the clock manual coral monitoring is facing difficulty due to human capacity limitations in diving given the large area of water concerned. Recent studies proposed both surface and underwater surveillance robots to observe the biodiversity at the bottom of the sea [8]. However, most of these robots are for surveillance purposes only and no further specific applications. In order to monitor the amount of coral reef degradation, the use of surveillance robot that has the capability of determining the change in formation of coral reefs will take a huge role in the prevention of the rapid decrease in the amount of coral reefs. However, due to the absence of light, turbidity conditions and the presence of particulates in the water, the visibility and the interpretability of the acquired data or image becomes limited.
This study aims to design and implement an image-based coral reef formation detection and change assessment system. Specifically, the study aims to create an algorithm that detects the coral reef formation; determine significant changes in the coral reef environment with or without the presence of foreign objects; determine significant changes in the coral reef formation after the appearance of foreign objects; create a notification and investigate two different change detection algorithms which best applies to the proposed system.

2. Materials and methods

The recognition and detection of the coral reef formation was determined first in order to separate it from the other elements present in the background. Next, the significant changes in the coral reef environment was identified as to whether there is or there is no foreign objects present. The underwater coral reef formation was also classified whether there is a significant or no significant change in the formation due to the appearance of foreign objects. The foreign objects considered in this paper are coins, metal rod, stones and fishing net. The foreign objects were dropped into the coral setup in a random manner. In order to determine the level of significant change in the coral reef formation, two algorithms were used; these are the Image Differencing Method (IDM) and Post-Classification Method (PCM). The results of these two were statistically compared to determine which best suits the proposed application.

The coral formation setup is inside an aquarium filled with clear tap water. The aquarium is a 30 gallon tank with the dimension of 36” x 13” x 16”, an optimum size for coral reef formation given the parameters needed by the system such as still water, depth of the water and the position of the cameras. The cameras are partially submerged into the water for real time capturing of coral images.

Other marine creatures and aquatic resources are disregarded. In addition, liquid elements like oil and other chemical substances are not considered in this study. Only one formation of coral reef was used. The set-up is limited to still waters because in real time capturing, the motion of the water will be considered as a noise that can affect the results. The use of the aquarium will lessen water movements since the area is enclosed and no other external factors are present. Tap water was used since sea or salt water requires expensive maintenance because it requires complex filtration systems during the duration of the study.

The system is constricted to a shallow area. The target object will not be clearly seen if it is located on a deep area since the presence of light will become poor as the objects goes deeper on water. The coral reef formation can only be found either at the shallow part or at the deepest part of the ocean. Also, the system requires that the cameras be placed inside an acrylic box with supporting brackets for waterproofing and stability.

2.1. Block diagram of the system

Figure 1 shows the block diagram of the proposed system. A camera will capture a reference image first. After which, detection of the coral reef formation will be traced. Then, the system will capture a test image. If there is an appearance of the foreign object, the system will detect it. In this way, the object can be classified as either touching or not touching the coral reef formation. The output will be displayed in the Graphical User Interface.

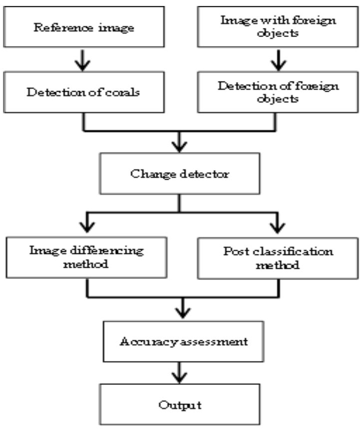
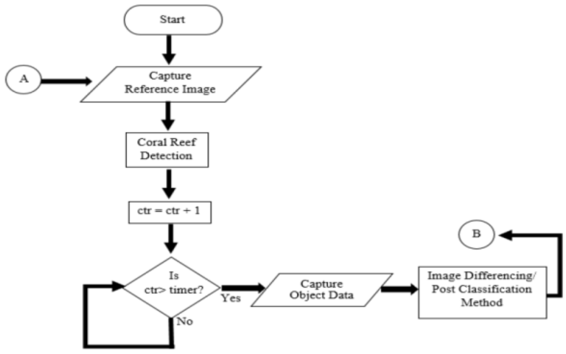


Fig. 1: Block diagram of the system

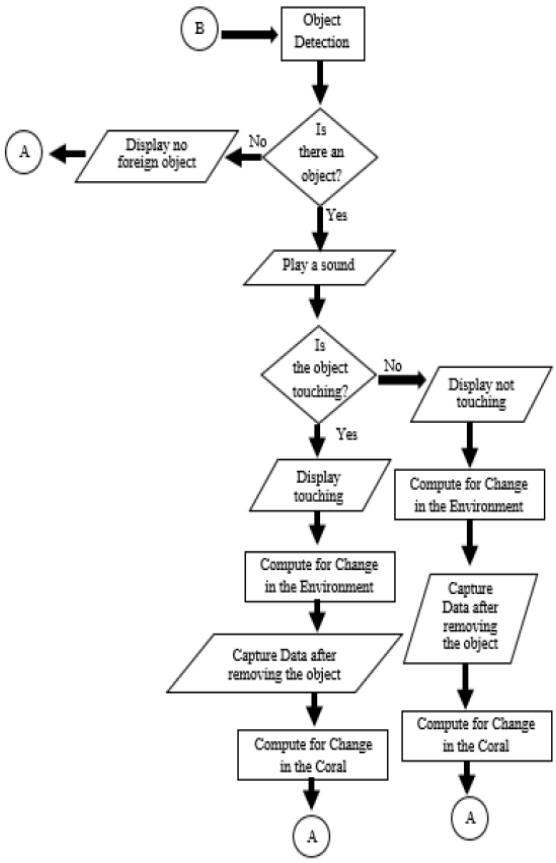
2.2. System flow chart

Figure 2 shows the flowchart of the system. The system is intended to determine whether there is a change in the coral’s environment or in the coral reef formation.

The system will capture its reference image. A counter was included so that increments will be generated until it becomes greater than the inputted monitoring period. Every time this happens, the cameras are triggered to take an image of the coral formation. The captured images will proceed to either IDM or PCM. Detection and classification will then follow as to whether there is or there is no foreign object and if there is an object, it will determine whether it is touching or not touching the coral formation. A sound alarm will be played when there is an object detected. Notifications will be displayed such “Object Detected and Touching the Coral”, “Object Detected and not Touching the Coral” or “No foreign object”, whatever the case may be. After the detection of the object, a change assessment in the environment is determined statistically.



(a)



(b)

Fig. 2: (a) System Flow Chart Part 1, (b) System Flowchart Part 2

2.3. Coral reef detection block diagram

Figure 3 shows the block diagram of coral reef detection. With the use of MATLAB built-in functions, the system starts with capturing a reference image using *getsnapshot*.

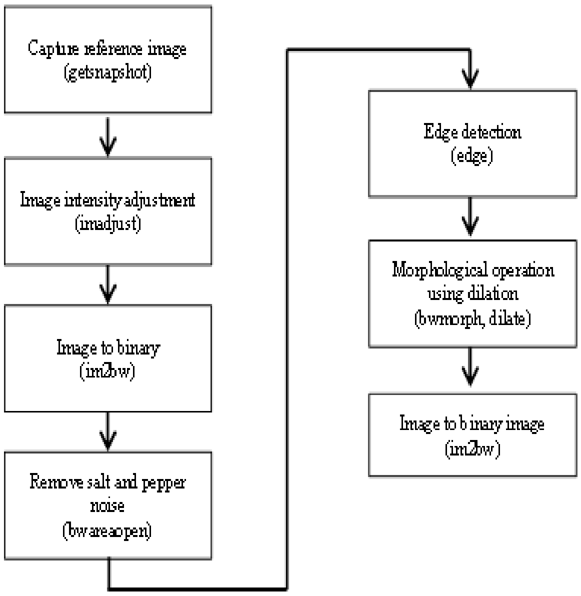


Fig. 3: Coral reef detection block diagram

The raw image undergoes image adjustment using *imadjust* to get the desired intensity of the output. The processed image will be converted to its binary equivalent with the use of *im2bw.* The output of which has salt and pepper noise which can be removed by *bwareaopen*. Afterwards, the coral can be easily detected. The Canny edge detection algorithm was used and was also dilated in order to emphasize the edges of the coral.

2.4. System GUI

Figure 4 shows the actual GUI display in which the user can indicate the time when the system will monitor the coral reef formation. In addition, the use can have a choice to use either of the two image-differencing methods.
The operator will press the "Start/Stop Monitoring Button" to signify the start of monitoring. A count down timer is included to que the user about the time when the camera will take an image. A pop-up message will be displayed and tell the user about the status of the coral reef environment or the coral itself. Text displays will show the summary of the results for the whole monitoring period.

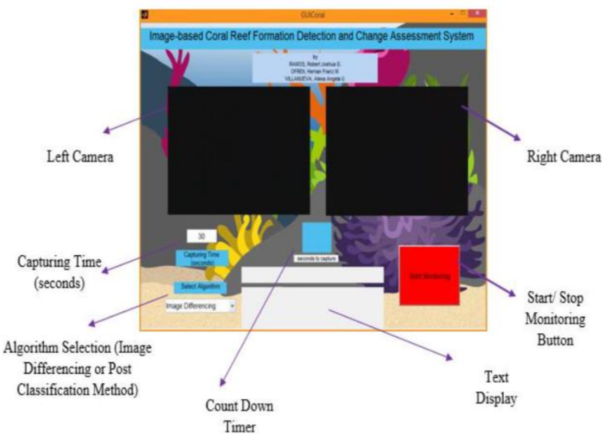


Fig. 4: Graphical user interface display

2.5. Overview of the hardware

Figure 5 shows the experimental setup of the project which is basically composed of a 36" x 13" aquarium, a coral positioned at the center of the aquarium, two cameras which are partially submerged into the water (about 3-inch deep) and are connected to a desktop computer.

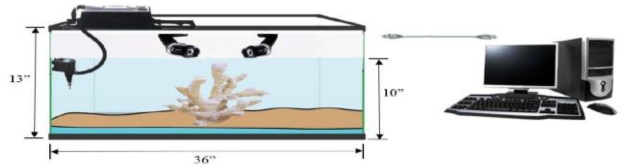


Fig. 5: Experimental set-up

The resulting images were processed by two algorithms and their results were compared in order to determine which of the two is better when it comes to underwater image processing. An alert sound is played if there is a significant change in the coral reef environment with or without the presence of foreign objects and when there is a significant change in the formation of the coral reef due to the occurrence of the foreign object

3. Results and discussion

A total of 90 tests were conducted. Four foreign objects (coin, metal rod, stone and fishing net) were used and scenarios when these objects are touching or not touching the coral formation were considered. Sensitivity, sensitivity and accuracy were calculated in order to statistically measure the performance of the two proposed algorithms.

3.1. Coral reef detection algorithm

Figure 6 shows the block diagram for the coral reefs formation detection algorithm. In order to detect the coral reef formation in a given image, the captured image went through different processes. The first is to capture the coral reef and save it to the two variables namely *imgReferenceRaw* and *imgReferenceRGB*. Using the image saved in *imgReferenceRaw*, the next step is to use image stretching in order to transform the contrast color into the set limits where the limits are lowin = 0.5, highin = 0.51, lowout = 0, highin = 1. In an input image, the colors equal to the value of 0.5 is interpreted with a value of 0 indicative of darker pixels, and colors equal to the value 0.51 is interpreted with a value of 1 indicative of brighter pixels. The next step is to convert the adjusted image into binary. Brighter pixels represent 1 and darker pixels represent 0. This results into a black and white image. The next step is to clean the small regions of white in the image so that the blob of the coral will remain on the picture. Edge detection (Canny method) was used in order to find the edges of the blob of the coral reef. Morphological operation was used in order to get the traces of the coral reef and dilate it for emphasis. The final step is to get the image saved from the *imgReferenceRGB* variable and overlap it to the result of the morphological operation. With this, the edge of the coral reef is emphasized with a green line.

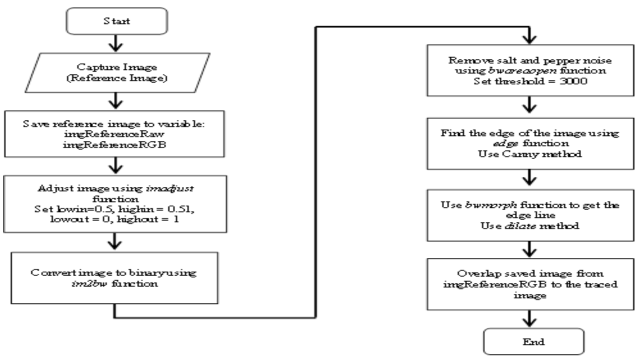


Fig. 6: Coral reef formation detection block diagram

The system is 65% accurate in detecting the coral reef formation. Since the system cannot adapt to the changes in the lighting, the detection is not applicable if the sun light is directed towards the coral or if the sand reflects on the camera.

3.2. Foreign object detection

The data were divided into three scenarios. These are whether the foreign object is touching the coral reef formation, foreign object not touching the coral reef formation and no presence of a foreign object. The classification was assessed by means of sensitivity and specificity and accuracy. On the other hand, t-test was used to determine which foreign objects have a significant change in the coral reef environment as well as on the coral itself with the use of pre-tests and the post-tests.

There are two cameras used specifically Camera A and Camera B. All the foreign objects are processed in the same way. The coral reef formation can be located and traced by the proposed algorithm. As shown in Figure 7, the edges of the coral reef formation were traced with green lines using the Canny method. The accuracy of the detection relies on the intensity of the image since Canny method detects edges by locating strong and weak edges. Weak edges are included only if they are connected to the strong edges. Since not every noise in the reference images can be removed by the system, the detection system finds it hard to identify the coral reef formation.

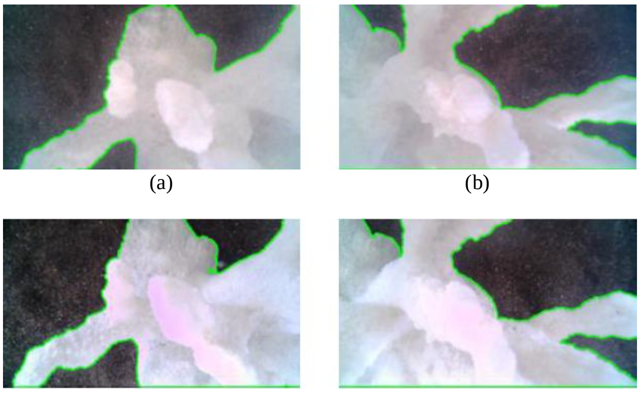

(a) (b) (c) (d)

Fig. 7: Sample of detected coral reef formation

The detection of foreign objects also relies on the Canny method. Figures 8 and 9 show the edges of the coin are traced using both methods. This is similar to Figures 12 and 13 for the stones. However, it was observed that the detection of the foreign object also has flaw. Unlike with the coral reef detection, the foreign object detection has a disfigured trace. As shown in Figures 10 and 11 for the metal rod and Figures 14 and 15 for the fishing net, the edges are not exactly traced. Cases like these are due to the background of the image. There were only two regions in the image in coral reef detection; the coral reef itself and the sand. Here, coral reef can be easily distinguished from the sand since the pixel values of the coral reef are much higher compared to the coral reef. With that, the location of the weak edges and strong edges can be certainly defined. In the case of the foreign object, the coral reef serves as the background of the foreign object if the object is within the formation of the coral reef. The pixel values of some part of the metal rod are nearer the values of the coral reef. Therefore, when background subtraction is performed, some portion of the metal rod does not count as change. As a result, the detection of the foreign object is limited to certain portions. However if the foreign object is beyond the coral reef formation, the object can be detected entirely

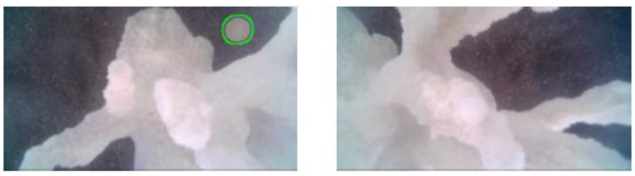

(a) (b)

Fig. 8: Image differencing with a coin for (a) Camera A, (b) Camera B

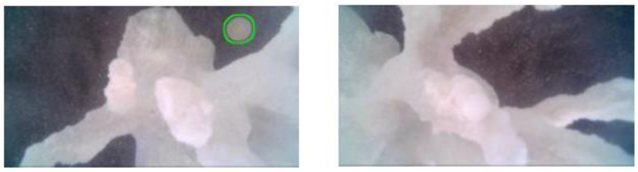

(a) (b)

Fig. 9: Post classification with a coin for (a) Camera A, (b) Camera B

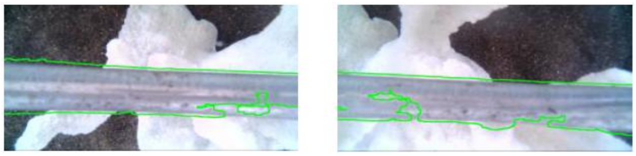

(a) (b)

Fig. 10: Image differencing with a metal rod for (a) Camera A, (b) Camera B

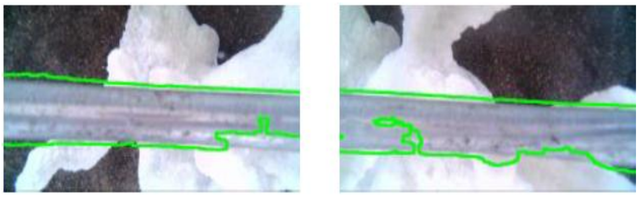

(a) (b)

Fig. 11: Post classification with a metal rod for (a) Camera A, (b) Camera B


(a) (b)

Fig. 12: Image differencing with a stone for (a) Camera A, (b) Camera B

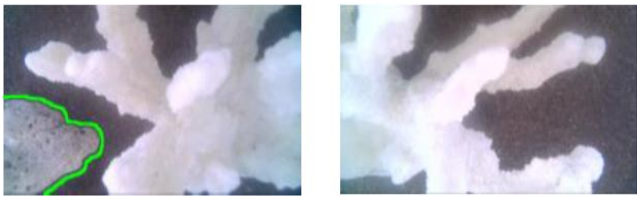

(a) (b)

Fig. 13: Post classification with a stone for (a) Camera A, (b) Camera B

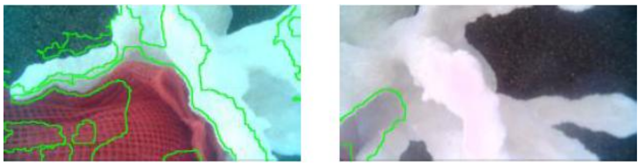

(a) (b)

Fig. 14: Image differencing with a net for (a) Camera A, (b) Camera B

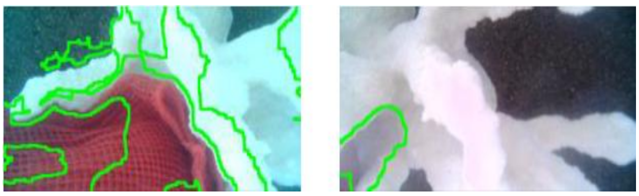

(a) (b)

Fig. 15: Post classification with a net for (a) Camera A, (b) Camera B

The disfigured trace of the foreign object can be lessened by filling up the holes in the image where holes are represented by an area of dark pixels surrounded by the bright pixels. Not every dark portion in the foreign object is filled up since some parts are not surrounded by lighter pixels therefore, dark portion remains in zero value of pixel.

3.3. Change assessment in the coral reef environment

A series of tests was conducted to assess the accuracy of the system in terms of sensitivity and specificity. Based on the computation for sensitivity, specificity, and accuracy for the given data there is a high probability that the system will have correct conclusion for both image differencing and post classification method if there is an object in the actual scenario. On the other hand, if there is no object in reality then, there is 50% possibility that the system will be negative for image differencing while 75% possibility for post classification method. Hence, the system is 90% accurate for both methods.

Table 1: Classification results

Task	Method	Sensitivity	Specificity	Accuracy
Coin Detection	IDM	100%	50%	90%
	PCM	100%	75%	90%
Metal Rod Detection	IDM	100%	100%	100%
	PCM	100%	100%	100%
Stone Detection	IDM	100%	75%	95%
	PCM	100%	75%	95%
Fishing Net Detection	IDM	57.14%	100%	70%
	PCM	57.14%	100%	70%
AVERAGE	IDM	89.29%	81.25%	88.75%
	PCM	89.29%	87.50%	88.75%

For the metal rod, both methods show similar results. If there is an object in the actual scenario, there is high probability that the system will have correct classification. However, if there is no object then, there is 100% chance that the system will be negative. Hence, the system is high in accuracy. Meaning, in both scenarios, the system can classify correctly if the object is a metal rod.
If the foreign object is a stone, both methods results to similar sensitivity, specificity and accuracy on the given data. There is high probability that the system will have correct classification. Yet, if there is no object present then, there is 75% chance that the system will be negative. Thus, the system is 95% accurate.
If the foreign object is a fishing net, both methods also show similar sensitivity, specificity and accuracy. There is 57.14% probability that the system will have correct classification and if there is no object then, there is 100% probability that the system will be negative. The system's accuracy is 70%.
On the average, the two methods used have similar accuracies of 88.75%.

3.4. Statistical comparison

The t-test was used to determine which foreign objects have had a significant effect which resulted to a change in the environment of the coral reef as well as on the coral itself. A null hypothesis was considered wherein there is a significant change in the coral's environment using the pre-test and post-test. Results are shown in Table 2.

Table 2: Statistical results for changes in coral reef environment

Foreign Object	Method	t-stat	t-critical 1-tail	t-critical 2-tail	Remarks
Coin	IDM	-3.9200	1.7291	2.0930	with significant change
	PCD	-3.0755			
Metal Rod	IDM	-4.8436			
	PCD	-4.3803			
Stone	IDM	-8.6267			
	PCD	-8.8728			
Fishing Net	IDM	-3.4548			
	PCD	-3.4570			

All foreign objects contribute significant changes in the environment of the coral reef as the t-stat values exceed the t-critical on both one-tail and two-tail tests.

Table 3: Statistical results for changes in coral reef

Foreign Object	Method	t-stat	t-critical 1-tail	t-critical 2-tail	Remarks
Coin	IDM	-1.7046	1.7291	2.0930	without significant change
	PCD	-1.0895			without significant change
Metal Rod	IDM	-1.6008			without significant change
	PCD	-1.6245			without significant change
Stone	IDM	-3.5200			with significant change
	PCD	-2.8626			with significant change
Fishing Net	IDM	-2.7133			with significant change
	PCD	-2.8082			with significant change

Coin and metal rod do not contribute significant changes since t-stat does not exceed t-critical values of both one-tail and two-tail tests. However, stone and fishing net contribute significant changes in the environments since values of t-stat exceed the values of t-critical on both one-tail and two-tail tests.
A notification system was made available. After the coral reef change assessment result is shown, the system will then send notifications if significant changes are detected either in the coral reef environment or in the coral itself. On the other hand, the system will get new reference images and continue the process of monitoring. Without the appearance of foreign objects, there will no notification and the system will get new reference image and continue the process.

4. Conclusion

There is a need to monitor the coral reefs to assess its formation, growth and even destruction. Hence, this study provides an image-based coral reef formation change assessment system. The system can possibly determine whether the corals are removed or if its initial position was changed. Moreover, the system can also recognize the presence of foreign objects that could affect the formation of the corals.

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