Development of Underwater Object Detection Method Base on Color Feature

Tri Susanto
Department of Electrical Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
trisusanto1988@yahoo.com

Ronny Mardiyanto
Department of Electrical Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
ronny@elect-eng.its.ac.id

Djoko Purwanto
Department of Electrical Engineering
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia
djoko@ee.its.ac.id

Abstract— ***The aim of this research is to overcome human limitation of ability when they are underwater. Thus, they need certain device to see objects in the water. This study aims to develop detection object system using color detection. The objects will be distinguished based on the selected color. Underwater robot, or commonly known as ROV (remotely operated underwater vehicle), is a kind of robot that is able to perform many activities underwater. The design of this object used ROV as a robot that is able to detect and track objects. The control system in this ROV is based on Arduino Mega, and Raspberry was used as the microprocessor in image processing system, and were processed using Open CV. RGB color detection and HSV color detection were the references in this research. Several samples that were drawn showed the detection error of HSV was 44.83% and RGB was 62.41%. This detection error has little effect on detection, only that the detected range is reduced from the desired result.***

.Keywords— Object detection, navigation, **ROV**

I. INTRODUCTION

Indonesia is an archipelago state surrounded by oceans. This condition leads to many accidents occur in Indonesian territorial water like river, lake, and ocean. The accidents that happened are also vary such as vessel capsize and aircraft crash. Among maritime accident cases that have happened is AirAsia plane crash in 2015[1]. In search and evacuation the victims of those maritime accidents, the SAR team usually uses human assistance from diver team. However, human has limitations underwater, such as the lack visibility, time, and oxygen. ROV is used to find the crash site before the divers were deployed. The most recent case happened in 2018 is a vessel capsize in Toba Lake with 450m depth [2]. ROV the underwater robot (remotely operated underwater vehicle), performs better ability underwater than human. It is able to dive several meters below the water, and it has better vision ability compared to human vision.

Yet, there is good possibility that ROV can be used in all fields, different weather and location. The weather condition may constraint ROV visibility, meanwhile different location such as sea and river, its turbidity may also effect the visibility.

Several methods have been used by previous researchers in designing ROV. Some researchers implemented the autonomous system in ROV using weighted template matching as the object tracking method [3]. Meanwhile, other researchers used sonar data as the real-time search data[4][5][6][7][8]. By combining optical flow measurements and disparity measurements, the robot tracking system is proven to be improved [9].

In this research object detection will be applied using RGB and HSV basic color features. It also discusses the comparison between RGB and HSV tracking methods. The detection system applied to this ROV is designed for tracking systems or tracking the intended object.

II. RELATED WORK

Pritpal Singh and friends make automatic detection object use color feature method and motion. Median filtering is used in image processing to remove nois during real-time object detection and tracking. [12]

Donghoon Kim and friends developed an object detection using template machine. The mean shift tracking algorithm was implemented to track the color histogram of the detected objects using proposed template matching method. Low light caused the object can't be detected [3]. Color detection approach is stable and effective. But the proposed method effective to detect in short time not be applied for the real-time [13].

The next research is tracking underwater object using real-time image filtering using optical flow and disparity stereo camera. And the result is in the form of video image. The experiment from Richard L. Marks and friends show that optical flow tracking can be used to single object. While disparity is better in result because the speed of the object could effect the tracking. The weakness of the vehicle caused the optical flow can't identify high speed objects. The vehicle was unable to track objects with large constant acceleration ($> \approx 1\ m/s^2$) [14].

The next research from Ming Yiju and friends compare the conventional mean shift tracking algorithm with mean shift tracking using fuzzy color histrogram. Modified mean shift algorithm based on the fuzzy color histogram is intended for object tracking. It reduced noisy interference such as lighting changes and quantization error [15].

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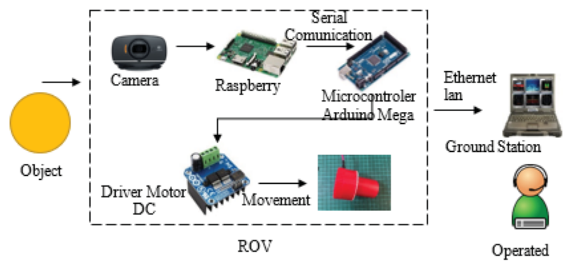


Fig. 1. Underwater ROV Design System

Zdenek Kalal developed Tracking-Learning Detection looked like a template machine, but it estimates the target's motion between consecutive frame under assumption that frame-to-frame motion is limited. LTD is able to update the tracking results by capturing frames to the frame. But if the object moves very fast, the camera may fail to track. Besides, TLD does not perfom well in of full out of-planerotatioin condition [16].

III. COMET-2 UNDERWATER ROV

COMET-TWO ROV is the advanced version of COMET-ROV, in which the PID controller in prior research was implemented for holding the ROV's altitude [10]. COMET-TWO ROV is rather similar to COMET ROV, with additions of several DC motors and the Raspberry controller for images processing. Fig. 1. displays the process of creating ROV. For a split second the system from Comet-2 Rov, which is the captured object will appear on GUI in the groundstation and will be processed through raspberry. Then, the image processing will generate a coordinate in the x- and y-axis, which is forwarded to the microcontroller that controls the ROV's maneuver.

A. Desain Modeling

Comet-two ROV design modelling was completed in 3D software that generate ROV model as illustrated in Fig. 2. Unlike the previous version, Comet-two ROV has additional It still uses the same system of two buoyancy in the ROV's front and rear.

B. Frame

The frame of COMET-TWO ROV is shaped by the upper and bottom sides. The upper frame is focused on buoyancy, and the bottom one is designed for thruster settlement. The two-sided design will make maintenance and repairs easier. The middle part of the ROV uses aluminum profile with 2cm profile size.

The side and the bottom bases of the ROV were made from 5 mm thick acrylic. Acrylic was used because it is cheap and it has adequate strength required for frame making. CNC was used to cut the frame into the form as is displayed in Fig.3.

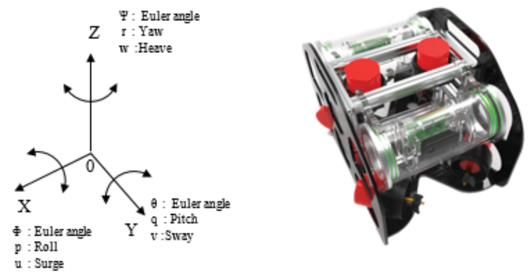


Fig. 2. Model Design Comet-2 ROV

Fig. 3. Rendering of COMET-2 ROV Frame

C. Buoyancy

To compensate the frame weight and components, a buoy is necessary to keep neutral buoyancy. The buoys were installed at the top, front, and rear of the ROV.

The buoy was made of acrylic tube with 100mm diameter as can be seen in Fig. 4. The buoy tube also serve as the main component of the ROV. The rear has ROV's core microcontroller, and the front has microprocessor and camera.

D. Propulsion

COMET-TWO has six DC motors designed as the motor pump in the hull of a vessel. These motors were selected due to their easy maintenance and affordable price. The ROV also has

CW and CCW propellers made from 3D special material, which was PLA material. Four motors at the bottom are mounted horizontally and adjusted to 40° angle. These four motors not

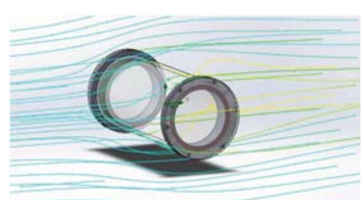


Fig. 4. Flow Simulation of COMET-2 ROV Buoyancy Tube

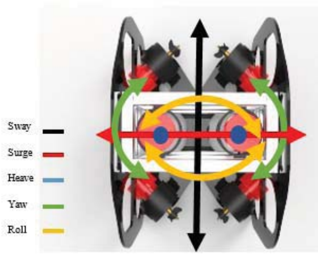


Fig. 5. COMET-Two ROV 5 Degrees of Freedom

Fig. 6. GUI COMET-TWO ROV

only aimed to increase the thrust but also to make the ROV able to move in all directions. Next, the two other motors are mounted on the vertical axis to produce heave or roll motion. The whole motion pattern generated by the motors is five degrees of freedom as shown in Fig.5.

E. *Desain interface*

The interface design used was web-based interface as seen in Fig.6. LAN connection was used to make the user easily understand. The visual interface used was GUI (Graphical User Interface), which was used for data retrieving and processing, and as FPV (first person view).

IV. Object Detection Design

Automatic system in underwater ROV uses camera as the visual sensor. Fig.7 shows a block diagram of ROV system that was developed This Underwater ROV will move automatically by following the color that has been detected. The color detection is obtained through the experiment of HSV color detection method. Then, to decide the HSV value, the RGB value will be concerted usig the following formulation [17]:

$$r = \frac{R}{R+G+B}, g = \frac{G}{R+G+B}, b = \frac{B}{R+G+B}, \qquad (1)$$

$$V = max(r, g, b) \qquad (2)$$

$$S = \begin{cases} 0, & if\ V = 0 \\ 1 - \dfrac{\min(r,g,b)}{V}, & V > 0 \end{cases} \qquad (3)$$

$$H = \begin{cases} \dfrac{60(g-b)}{(V-\min(r,g,b)} if\ V = r \\ \dfrac{120+60(g-b)}{(V-\min(r,g,b)} if\ V = g \\ \dfrac{240+60(g-b)}{(V-\min(r,g,b)} if\ V = b \end{cases} \qquad (4)$$

Value (V) : determining the RGB clarity

Saturation (S) : determining color density percentage

Hue (H) : the true color

A. *Object Selection*

The process of object selection is carried out to distinguish objects which are detected by other objects. The color from the detected object will be cropped to obtain the minimum and the maximum values from HSV to be made as parameters in the threshold. When the objects threshold value recognized, the form of contour can be found.

In this process, the procedure is done using the simple contour approximation method and the contour retrieval list mode. Through this stage, the object will be described based on the countour obtained. Fig.9 shows the object with the countour that has been obtained.

From the form of cuntour, the height and width of the object can be detected. The positions of x1 and x1 can be obtained as well. The center point will then be determined as the xactual value that will be the reference for the ROV movement.

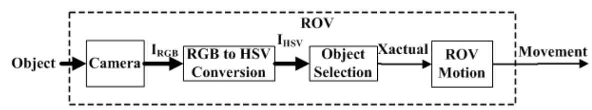


Fig. 7. Block Diagram ROV

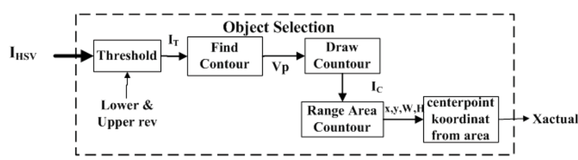


Fig. 8. Block Diagram Object Selection

Fig. 9. Image Color to Grayscale

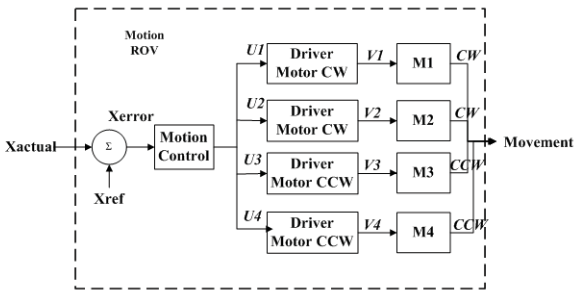


Fig. 10. Block Diagram Posision Control

B. ROV Motion

For ROV movement, actual X and actual Y values can be used as the parameter. In this research, the ROV movement will be carried out using the X axis. When the object moves to the left, ROV will tail the left motion. Fig.11 shows the system design of the ROV control system. To determine the motion control, this research can be formulated in 5 equations.

$$u = \frac{(X_{act} - Pixel_{min})x(PWM_{maks} - PWM_{min})}{(Pixel_{max} - Pixel_{min}) + PWM_{min}} \tag{5}$$

u = value speed control
$Pixel_{min}$ = minimum value of coordinate X
$Pixel_{mac}$ = maximum value of coordinate X
PWM_{min} = minimum value of Pulse Width Modulation 8bit
PWM_{max} = maximum value of Pulse Width Modulation 8bit
X_{act} = Pixel X value of object detect

There is X axis that has target value (setpoint) at 240 px (Xref), in which the value is the result of the large frame of the image in X axis which is 480px in size. The target value is used as the reference to the desired object position.

In this case, object tracking requires control of rotary direction and motor speed so that they can always be in the target position. The value of the detected object position on X axis is the actual value of the object (Xactual) so that Equation 5 is used, which later was used as the value in determining the speed and direction of motor motion.

If the Xactual > Xref, the ROV rotates clockwise, whereas if the Xactual < Xref then the the ROV rotates counter-clockwise against the Z axis. The speed of each motor is determined by the calculation of the equation.
The minimum limit for CW motor control is 160 of Pix range and Pix maximum of 320, with minimum Pix value is 0 and Pix maximum is 255. Hence, to determine CW motor with Xact greater than Xref can be seen in Equation 6

ROV Rotate CW

$$Speed = \frac{(X_{act}-160)x(255-0)}{(320-160)+0} \tag{6}$$

Limitation for CCW motor control the range of Pix minimum 0 and Pix maximum 160. With Pix minimum Pix 0 and Pix maxium 225. So to determine the CCW rotating motor if Xact is smaller than Xref, Equation 7 determines the CCW rotational speed,

ROV Rotate CCW

$$Speed = \frac{(X_{act}-0)x(255-0)}{(160-0)+0} \tag{7}$$

Fig.12 shows ROV movement pattern that rotates to the left and right. In which ROV will be distinguished from the combination of each motor rotation. Fig. 13 is illustrate ROV movement to the intended object.

V. EXPERIMENT

The first object detection experiment was done by using objects in red and orange as shown in Fig.14. Then from the results of the experiment shown in Fig. 15 it is known that the device made few errors in color detection. To ensure the number of errors, the next experiment was carried out by comparing the error rate on detection using RGB and HSV. This experiment was carried out on a pond with clear water, by adding dim light around 29Lux and bright light 945Lux. This experiment is shown in Table.1 for RGB and Table 2 for HSV.

The third experiment, the ROV movement experiment using HSV was conducted according to the results of the comparison between the HSV and RGB value in Table 1 and 2. The movemnent of this ROV is show in Table3.

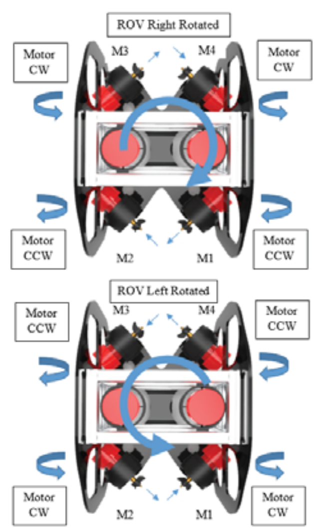


Fig. 11. Motion System ROV

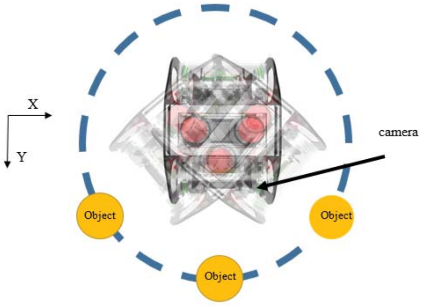


Fig. 12. Ilustration of ROV Movement to Object

Fig. 13. Object Example

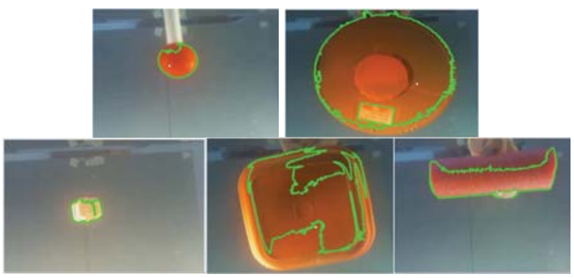


Fig. 14. Detection Color Result

TABLE I. RESULT RGB

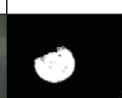
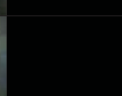
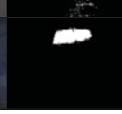
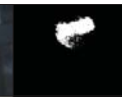
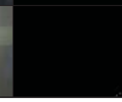
Lux	Range	Image	threshold	Size Object Reference	Size Detection	error
945	R=0-245 G=54-255 B=0-43			Pixel=35458 Height =219 Width =217	Pixel=27476 Height =184 Width =211	22.51%
29	R=0-245 G=54-255 B=0-43			Pixel=31495 Height =191 Width =210	Pixel=1847 Height =196 Width =291	94.14%
29	R=52-93 G=21-44 B=10-34			Pixel=37575 Height =312 Width =442	Pixel=24973 Height =169 Width =217	33.54%
945	R=52-93 G=21-44 B=10-34			Pixel=34084 Height =244 Width =208	Pixel=0 Height =0 Width =0	100%
945	R= 0-160 G=91-255 B=0-79			Pixel=33090 Height =233 Width =222	Pixel=17054 Height =231 Width =328	48.46%
29	R= 0-160 G=91-255 B=0-79			Pixel=27987 Height =173 Width =210	Pixel=12352 Height =92 Width =205	55.87%
29	R=67-122 G=54-116 B=24-54			Pixel=30900 Height =180 Width =217	Pixel=17064 Height =170 Width =208	44.78%
245	R=67-122 G=54-116 B=24-54			Pixel=29837 Height =199 Width =215	Pixel=0 Height =0 Width =0	100%
					Average Error	62.41

TABLE II. RESULT HSV

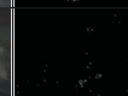
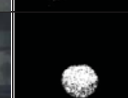
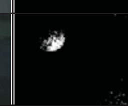
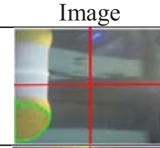
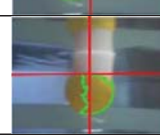
Lux	Range	Image	Threshold	Object size Reference	Size detect	error
945	R=6-17 G=50-255 B=50-255			Pixel=33541 Height=190 Width=225	Pixel=24955 Height =197 Width =226	25.6%
29	R=6-17 G=50-255 B=50-255			Pixel=28319 Height =166 Width =217	Pixel=140 Height =201 Width =252	99.51%
29	R=18-28 G=50-255 B=50-255			Pixel=28769 Height =172 Width =220	Pixel=32517 Height =239 Width =266	-13.03%
945	R=18-28 G=50-255 B=50-255			Pixel=23485 Height =245 Width =327	Pixel=5399 Height =164 Width =196	77.01%
945	R= 1-7 G=50-255 B=50-255			Pixel=24246 Height =169 Width =181	Pixel=22966 Height =220 Width =210	5.28%
29	R= 1-7 G=50-255 B=50-255			Pixel=27976 Height =181 Width =205	Pixel=19090 Height =173 Width =192	31.76%
29	R= 2-8 G=48-255 B=48-255			Pixel=16206 Height =149 Width =143	Pixel=8406 Height =124 Width =152	48.13%
245	R= 2-8 G=48-255 B=48-255			Pixel=28956 Height =200 Width =198	Pixel=4521 Height =90 Width =110	84.39%
					Aerage Error	44.83

TABLE III. MOTION TRACKING

Frame	Image	Error
25		-97,3%
48		-32,7%
76		15,2%

97		47,3%
121		83,4%
145		58,1%
167		11,2%

Not all forms of objects have the same shape as the original shape. Furthermore, in the second experiment it was found that HSV had the least error which was around 44.83%. Table 3 shows the movement of ROV based on object detected. In frame 25 show error -97%, is that the object is to the left of the ROV. The ROV moves to the left so that at frame 48 the object position is close to the reference limit and at frame 97 and frame 121, there is an overshoot, and frame 145 ROV moves to minimize the error, so that at frame 167 has error of 11.2%.

VI. Conclusions

From the results of the experiment, it was found that the error of color detection using RGB was 62.41% and the error detected in HSV mode is 44.83%. Some of the errors is caused by the amount of light refracted to the object. Yet basically this detection is still categorized as successful in short distance of 30 cm to 1m in calm and clear water conditions.

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