Remotely Operated Vehicles (ROV) With Manipulator to Plant Coral Reefs

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***Abstract*— Coral reefs in the sea of Indonesia have been damaged. The efforts are made by re-planting coral reefs and can be done by Remotely Operated Vehicle (ROV). The process of planting by putting the seeds of coral reefs in captivity. The ROV needed with a robot manipulator that can hold the coral reef seeds and put it into place already provided. The ROV will be designed using a paralon pipe to be easily formed and can move with the joystick controller. A robot manipulator will be designed using a kinematic inverse method. This method will be easier to determine the position of the robot manipulator to put the coral reef seeds. The navigation system used in this ROV uses an accelerometer, compass, and camera. Kompas aims to display the direction of the ROV heading, while the accelerometer sensor to determine the distance traveled by the ROV. The camera placed on the ROV is used to monitor conditions around the ROV and is designed as a Surveillance Camera that can move up, down, left, and right. The movement of ROV in the water is forward, backward, turn right, turn left, up, and down. The movement of ROV will be tested on the speed of ROV in the water.**

Index Terms*— Robot Manipulator, ROV, Joystick. Accelerometer, Kompas, Surveillance Camera.

I. Introduction

Lately, there has been a lot of coral reef damage spread throughout the waters of Indonesia. Siti Nurbaya as the Minister of Environment and Forestry said that "13,522 square meters in KLHK count that is on the coral reef field in Raja Ampat is damaged" [1], this is caused by foreign ships entering into shallow waters.

The damage effects that already happened need to be handled by replanting damaged coral reefs. This planting is usually done by divers, who will dive into the sea to plant coral reefs. However, it has many risks such as shark attack, according to data in 2015, there is a shark attack on divers and surfers 98 times [2].

In recent years there is an underwater robot technology called ROV (Remotetly Operated Vehicles). ROV is an underwater robot that used to perform underwater research activities with operator control which is above the sea. ROV used for research is very diverse depending on the purpose of the ROV itself.

The research chaired by Tirza H. Samosir [3] using ROV to monitor underwater conditions around the waters of North Sulawesi and Biak Papua which includes oxygen levels, seawater temperature, and the diversity of marine biota around it. In 2005 there was ROV developed for underwater research purposes, for example, to monitor real-time fish activity around coral reefs [4]. Inspection and investigation of large underwater structures such as dam embankments with the depth of more than 40m, offshore, and port structures by human divers are the challenging tasks from the viewpoint of safety and efficiency [5]. Ref. [6] presented the complete design and operation of IRIS-SP, also known as Swimming Pool (SP) model which was a prototype ROV for operation at about 30 meters of depth. The design also demonstrates an effective hardware-software combination that can assist a human operator to control the ROV from a platform for underwater search and housing equipment used for surveillance, monitoring as well as data collection depending upon the situation at hand.

In this research, the ROV will be made that can dive up to 2 meters in the water, can withstand the pressure, and can protect the electrical components from the water. The underwater robot has a system called the ballast system that serves to manipulate the weight of objects in the water. The ballast system in the ROV uses a DC motor that can be controlled in the direction of rotation by a joystick. The ROV is designed with 4 DC motors placed on the right-hand side of the ROV to move forward and backward. Then to float and sink, it is required DC motor which is placed upwards from the ROV. To assist in coral reef plastering tasks, this ROV is equipped with a manipulator robot.

A visual servoing control system was proposed for a two-link electrically actuated underwater manipulator [7]. In the research by Mizuho Shibata and his team, the robot manipulators were operated underwater using a mechanical joint which was controlled by using hydraulic pressure [8]. While in this research, the actuator is a servo motor. This servo motor was controlled by a joystick and the method used is inverse kinematic.

Ref. [9] presented the design and development of three degrees of freedom (DOF) underwater manipulator gripper for unmanned underwater vehicles. In this research, 3 DOF manipulator robots are placed on this ROV function as a holder and put coral reefs when ROV arrived at the point of captivity. To solve the kinematics analysis required a method called the Denavit Hartenberg parameter (DH-Parameter). This parameter can be done after composing the geometry image of the robot

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manipulator. Furthermore, these values will be input to form homogeneous matrices, and forward kinematic analysis can be done then followed by inverse kinematic analysis [10, 11, 12, 13].

In its operation, ROV has many challenges, especially on its navigation system. Because the operation is under the sea, a suitable sensor is needed to be able to send data in the form of an ROV location. This navigation system itself is used so that the movements of the ROV are monitored and can move according to the control of the user. The navigation system in this study utilizes a compass and accelerometer. The compass displays the heading direction of the ROV, while the accelerometer displays the position and distance of the ROV. Position data is obtained from the results of a dual integral process on the accelerometer output in the form of acceleration.

The ROV condition monitoring system uses Surveillance Camera that can move right, left, up, and down controlled using Joystick, this camera will provide information about conditions around the ROV and also the condition of the coral reef visually sent directly to the computer for further observation.

This research is expected to make divers easier to put coral reefs in the undersea without having to dive and can save time and reduce the risk of divers in the water. The cost of material is low and with the robot manipulator and camera on the ROV make it easier to do monitoring the coral reefs condition. Moreover, it can be developed for other purposes such as for offshore oil drilling or a robot to find a black box lost in aircraft.

II. Design of Robot

The design of this robot has several parts, here is the detail of each part:

A. Main Design of ROV Main Body

The design of the system starts from the hardware then followed by the design of the software. ROV is designed to put coral reef missions. The hardware used such us Arduino Mega, BTS7960 motor driver, bilgepump motor, and PS2 joystick. The sensor used is an MPU 6050 gyroscope to determine the slope of the ROV when moving in the water. The software used such as the Arduino Mega programmed with the Arduino Software. The system is designed with a 12 Volt, 17.5Ah battery with 4 bilgepump motors. The illustration of the system is based on Figure 1. Users or operators will control ROV in the water using a joystick, the movement of ROV in the water can be seen through a monitor that shows the slope of ROV from the gyroscope sensor. ROV can move forward, backward, turn right, turn left, up, and down by using 4 bilgepump motors and set the speed using the BTS7960 motor driver.

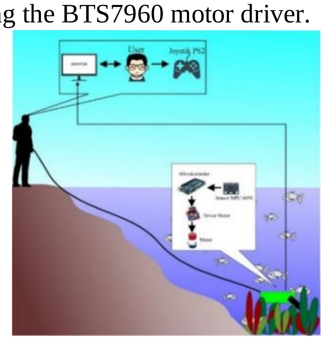

Fig 1. Illustration of System

The Robot is designed with 3D Builder software as shown in Figure 2, then realized by using paralon pipe. The dimensions of the robot are made have a length of 54 cm, a width of 40 cm, and a height of 32 cm. At the foot of the ROV is made by using a paralon pipe with a rectangular shape which has a length of 55 cm and a width of 41 cm. The rectangular shape is expected to make the ROV easier to land on the seabed. At the top, there are two buffers for the tube where the components are placed. They have a length of 19 cm. ROV also has a wing that placed on the right and left with a height of 20 cm and a wing on the top with a total length of 40 cm as shown in Figure 4, it is useful to maintain the balance of ROV when moving and increase power floating of ROV in the water.

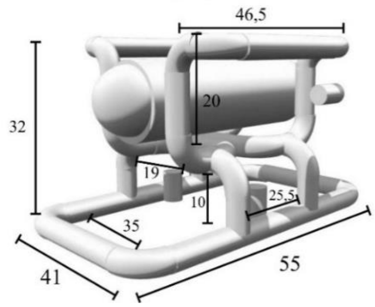

Fig 2. Design of ROV

Placed of electrical components such as motor drivers and MPU 6050 sensors are on tubes that have a diameter of 9 cm and height of tubes of 52 cm as based on Figure 5. The tube will be given an acrylic box that will add protection from water with a length of 5.5 cm, a width of 5,5 cm, and a height of 45cm. While the big tube will be given a paralon lid and make it resistant to water. ROV is equipped with four motors, two motors 1 and 2 are placed vertically at the foot of the ROV, so that ROV can move up and down, two motors 3 and 4 are placed horizontally to the ROV wings so it can move forward, backward, turn left, and turn right as shown in figure 3.

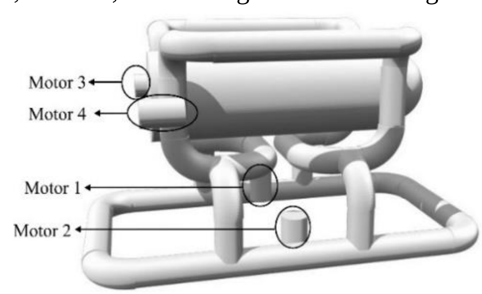

Fig 3. Posisition of Motor

The ROV design will be made when entering into the water in floating conditions. Floating conditions will allow the ROV to sink and float, because the power given the motor is not large and does not burden the motor. To make ROV float, the arcimedes law is applied in Equation 1, where the buoyancy (Fa) is equal to the weight of the object when in water (W).

The mechanical design of robot manipulator is made of aluminum material. This material has been provided in the market and the shape has been adjusted of making robot manipulator. From the model of existing materials in the market, the designed model is shown in Figure 4.

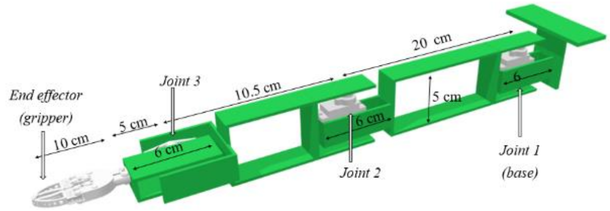

Fig 4. Design of Robot Manipulator

There are 3 servo motors to move the arm and 1 servo motor. They are used to drive the gripper. This robot manipulator will be placed on the bottom of the ROV. The distance between the first servo and the second is 20 cm, the distance between the second and third servo is 10.5 cm and the last length after the third servo is 5 cm. The length of the gripper is 10 cm. Link length is adjusted to ROV shape with the ROV width of 40 cm.

In Figure 5, the design of the camera driver uses 2 DS3218 servos along with the bracket to place the camera. From Figure 5, it is explained about the size of the Surveillance Camera design which has a length of 9.5 cm, then has a height of 9.5 cm and a width of 5.5 cm, the servo motor is used as much as 2 pieces. In the lower servo, the vertical position is used to move the camera to the right and left, and the upper servo is mounted horizontally to make the camera movement up and down. The mechanical design also pays attention to the electrical design by providing a safety hose to all cables both from the camera and the two servo motors to be resistant to water

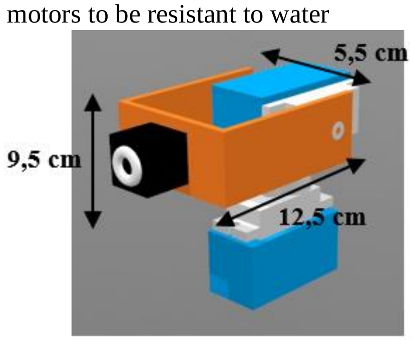

Fig 5. Design of *Surveillance Camera*

B. *Trajectory Planning*

Trajectory planning is used to determine the direction and movement of the robot manipulator from one point to another.

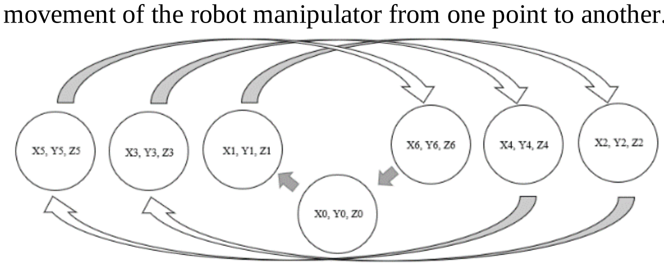

Fig 6. Illustration of *Trajectory Planning*

In figure 6, there are 7 coordinates that must be done by the robot manipulator. The first coordinate is (x0 y0, z0) as the starting position of the robot manipulator. The second coordinate is (x1, y1, z1) which then proceeds to the coordinate of (x2, y2, z2) then to the coordinate of (x3, y3, z3) and continues until the last coordinate of (x6, y6, z6) and backs again to the coordinate of (x0, y0, z0). The three left circles are illustrated as the starting position of the coral reef before being moved and the three right halves are the coordinates or positions of the coral reef after being moved to captivity. Each of these coordinates will be input for the kinematic inverse method. The coordinate point (x0, y0, z0) becomes the starting position of the robot manipulator, the angle formed for θ1 = -70°, θ2 = -90°, and θ3 = 30°.

TABLE I
CORDINATES OF MOVEMENT ROBOT MANIPULATOR

No	Cordinates Name	Cordinates Location		
		X	Y	Z
1	x1, y1, z1	14	29	-0.5
2	x2, y2, z2	14	-29	-0.5
3	x3, y3, z3	24	23	-0.5
4	x4, y4, z4	24	-23	-0.5
5	x5, y5, z5	-1.5	27	-0.5
6	x6, y6, z6	-1.5	-27	-0.5

The kinematic inverse method finds the angle value of each joint. The angle at joint 1 is called θ1, the angle at joint 2 is called θ2, and the angle at joint 3 is called θ3. The coordinates are entered from the kinematic inverse method based on Table 1. The coordinates are measured from joint 1 as the base.

III. MATERIAL AND METHOD

A. *The Buoyancy Force*

The buoyancy force is the opposite force with gravity, which is downing in the fluid. When influencing all the objects placed in the liquid, the mass of the body presses the fluid or gas, while the upward buoyancy forces the object can be against gravity.

$$Fa = Mf\ x\ g \tag{1}$$

$$Fa = \rho f x\ Vbf x\ g \tag{2}$$

$$Fa = Vt\ x\ \rho\ x\ g \tag{3}$$

Fa = The Buoyant force
Mf = The mass of liquid from the object drowning
g = Gravity of earth
ρf = the density of the liquid
Vbf = the volume of objects drowning in a liquid

The robot uses a tube with a diameter size of 10 cm and a height of 52 cm. The tube volume formula is described in Equation 4.

$$V = \pi\ x\ r\ x\ r\ x\ t \tag{4}$$

π = 3.14
d = diameter of tube
t = height of the tube

Based on the specifications of the robot, the volume of the tube is 3306.42 cm^3. After obtaining the value of volume then the volume value will be included in the buoyancy formula (Fa) in equation 3. Then the value of the floating force of the robot is 3,240 N. The ROV Weight Equation is used to determine the weight of the robot (W). The W can be formulated in equation 5.

$$W = m \, x \, g \qquad (5)$$

W = Weight of Object
m = Mass of Object
g = Gravity

ROV has a mass of 3.3 kg so based on the formula in equation 5 the weight of the robot is 3.234 N. The ROV equation in the floating condition is when the buoyant force (Fa) equals the weight of the object (w). The floating force (Fa) value was 3.240 N while the weight of the object (w) was 3.234 N.

According to the Archimedes equation ie Fa > w then the Archimedes equation for the robot is 3.240 N > 3.234 N. The equation is declared that the buoyant force (Fa) is greater than the weight of the object (w) then the robot is called sink. The difference between the buoyancy and the weight of the object is only 0.007 N so the robot only sinks halfway when the state floats in the water so it can be called ROV already float in the water.

B. *Design Of ROV Movement*

Movement of ROV is controlled by a joystick. First, the program will read joystick then read command from analog joystick. The control configuration of each PS2 joystick button is based on Figure 6 and the functions for the ROV movement are based on Table 2.

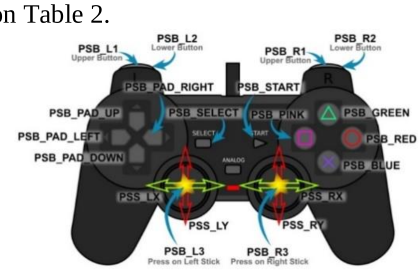

Fig 7. Description of the PS2 Joystick Button

The Programs created based on table 2, when the left analog switch is directed to PSS_LY, then it will move ROV up or down. When the analog right button is directed on the PSS_RY axis, it will move the ROV forward or backward. Then when analog right is directed PSS_RX, it will turn right or turn left.

TABLE II
CONFIGURATION OF JOYSTICK BUTTON

Description of button	Movement ROV
PSS_LY	Up/Down
PSS_RX	Turn Right/Turn left
PSB_RY	Forward/Backforward

C. *Kinematics Model Of Manipulator*

The description of the robot manipulator begins from the design of robotic movement geometry (position) without force influenced on the joints in the robot manipulator. Before doing kinematic analysis on the robot manipulator, it is necessary to build a geometric robot manipulator, according to the position and orientation of each joint.

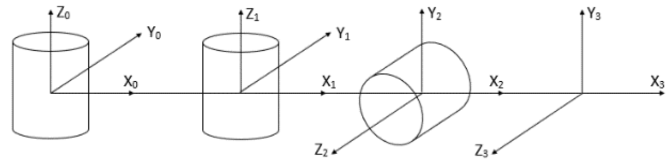

Fig 8. Geometric Robot

To get a robot geometry image (based on figure 8), it begins with selecting Ji to Ji + 1 after getting the value of Li-1 to Li. The Z axis is determined according to the direction of rotation of the joint. After the Z axis is obtained then proceed to find the coordinates X. Where the location of the X coordinates is along the normal line between Zi-1 and Zi (if any). However, if Zi-1 intersects Zi then the direction of Xi is in accordance with the direction of the X axis of the previous joint.

When finished forming the direction of Xi and Zi, Yi's location can be known based on the rule of the right hand. Direction on the end of the end effector with On-1. While the location Xn intersect perpendicular to Zn-1. If the joint at the end of the effector is a rotation, then the direction Zn parallel with Zn-1. But if the joint on the end effector is a prismatic type, then the Zn direction is free. Yn direction corresponds to the right-hand rule.

To create a kinematic model of the robot manipulator using Denavit Hartenberg-Parameter. In table 3 is a Denavit-Hartenberg table of 3 DOF robot manipulator Parameters. Link 1 through link 3 do not have an offset then the values d1 to d3 are zero. In each link has a normal line then the value is obtained, where the value a1 = 20 cm, a2 = 10.5 cm, and a3 = 5 cm. The angular change from the Zi-1 axis to Zi against the Xi axis is the value of α. beacause the type of joint is revolute, the values θ1, θ2, θ3 are variables.

TABLE III
DENAVIT HARTENBERG-PARAMETER ROBOT MANIPULATOR

Link	d_i	a_i	α_i	θ_i
1	0	20 cm	0˚	θ_1(0˚)
2	0	10.5 cm	90˚	θ_2(0˚)
3	0	5 cm	0˚	θ_3(0˚)

From Denavit Hartenberg-Parameter value, faound that the kinematic forward function equation based on equation 6.

$$\begin{bmatrix} p_x \\ p_y \\ p_z \\ 1 \end{bmatrix} = \begin{bmatrix} a_1C_1 + a_2C_1C_2 - a_2S_1S_2 + a_3C_3(C_1C_2 - S_1S_2) \\ a_1S_1 + a_2C_1S_2 + a_2S_1C_2 + a_3C_3(C_1S_2 + C_2S_1) \\ a_3S_3 \\ 1 \end{bmatrix} \quad ...(6)$$

After getting the kinematic forward function, it can be determined the end position of the end effector by giving the specified angle value θ.

D. *Inverse Kinematics*

Inverse kinematic refers to the use of robot kinematics equations to determine the parameters along which gives the desired position at the end or the end position of the effector.

Inverse kinematic changes the motion plan into the value that must be given to actuators or movers in the movement of the robot. Inverse kinematics is a method for calculating the rotational values together with the degrees of individual freedom through a predetermined rotation and position. The fundamental difference from advanced kinematics, inverse kinematics is determined from the movement of links based on the final angle of some joints that define the movement. The kinematic inverse formula is based on Equation 7-9.

$$\theta_1 = atan2(p_y, p_x) \mp atan2(\sqrt{p_x^{\,2} + p_y^{\,2} - k_2^{\,2}}, k_2) \quad (7)$$

$$\theta_2 = atan2(S_2, C_2) \quad (8)$$

$$\theta_3 = atan2(S_3, C_3) \quad (9)$$

Dimana,

$$k_1 = a_2 + a_3 C_3$$

$$k_2 = p_x C_1 + p_y S_1$$

$$C_2 = \frac{p_x^{\,2} + p_y^{\,2} - k_1^{\,2} - a_1^{\,2}}{2 a_1 k_1}$$

$$S_2 = \pm\sqrt{1 - C_2^{\,2}}$$

IV. Implementation Of ROV

A. ROV Movement Testing

ROV movement testing in the water was done by entered ROV into the water which is controlled by a program that has been made. By moving the analog joystick up based on Figure 9 (a) it will move the ROV upward as shown in Figure 9 (b).

(a) **(b)**

Fig 9 (a) Joystick Command Movement Up (b) ROV Movement Up

Down Movement of ROV based on the joystick analog commands from left to bottom as shown in Figure 10 (a) then ROV will move down and sink to the bottom based on Figure 10 (b). The forward movement Figure 11 (a) then ROV will move forward with two motors at the same time rotating based on Figure 11 (b). The reverse movement is based on Figure 12 (a) then the ROV will move backward with two motors at the same time rotating based on Figure 12 (b).

(a) (b)

Fig 10. (a)) Joystick Command Movement down (b) ROV Movement Up

(a) (b)

Fign11. (a)) Joystick Command Movement Forward (b) ROV Movement Forward

(a) (b)

Fig 12. (a) Joystick Command Movement Backforward (b) ROV Movement Backforward

(a) (b)

Fig 13. (a) Joystick Command Movement Turn Right b) ROV Movement Turn Right

The turn right movement is illustrated in Figure 13 (a) then the ROV will move to the right using 1 left-handed motor 13 (b). Turn left movement based on analog command joystick right was directed to the left as shown in Figure 14 (a) then ROV moved turn left using 1 right pusher motor 14 .

(a) (b)

Fig 14. (a) Joystick Command Movement Turn Left (b) ROV Movement Turn Left

From ROV movement testing based on joystick coontroller can be concluded that the movement was in accordance with the expected that ROV can move up, down, forward, backward, turn right and turn left using the joystick control

B. ROV Speed Testing In The Water

Testing the speed of movement and slope of ROV in the swimming pool based on figure 15.

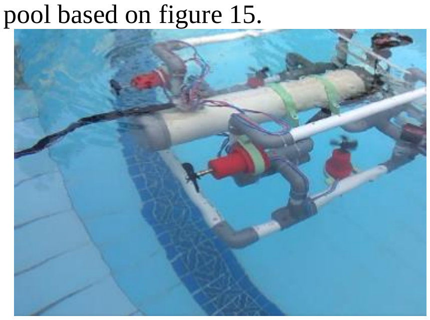

Fig 15. ROV Speed Testing

TABLE IV
ROV TESTING IN THE WATER

ROV Movement	Speed (m/s)	Arc Measurement (deg)	Reading Sensor (deg)	Error Sensor (%)
Forward	0,45	10	9,51	4,9
Backforward	0,33	10	9,78	2,2
Up	0,13	35	38,21	9,1
Down	0,22	5	5,12	4,2
Turn Right	0,18	15	15,34	2,3
Turn Left	0,17	15	17,65	17,6
Average	0,25	15	15,93	6,7

The slope of the ROV when moving up was very different from the previous movement because the load in front of the ROV was a robotic manipulator arm that makes the ROV sideways moves up to 35 degrees. Based on the test results data in table 4 can be concluded that the average speed of ROV movement in water can be up to 0.25 m/s with the average error value of the gyroscope sensor to know the slope of ROV to y axis when moving in water was 6.7%. This high error value is caused by an additional load in front of the ROV in the form of the manipulator arm that deflected to the right of the ROV to lock the movement of the manipulator arm when tested.

C. Trajectory Planning Manipulator Testing

This test was performed in the water using a robot manipulator bringing a 350gr object based on Figure 16.

TABLE V
TRAJECTORY PLANNING TESTING IN THE WATER

Input (cm)			Manual Measurement (cm)			error (%)		
x	y	z	x	y	z	x	y	z
14	29	-0.5	15	28	-0.5	7.14	3.4	0
14	-29	-0.5	13	-31	-0.5	7.14	6.9	0
24	23	-0.5	25.5	21	-0.5	6.25	8.7	0
24	-23	-0.5	22	-25	-0.5	8.33	8.7	0
-1.5	27	-0.5	-1.5	26	-0.5	0	3.7	0
-1.5	-27	-0.5	-1.5	-27	-0.5	0	0	0

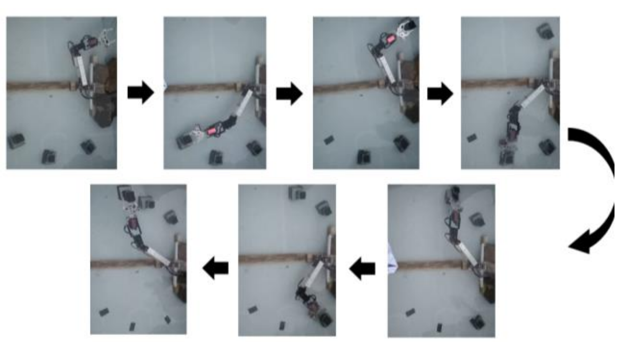

Fig 16. Trajectory Planning Testing

Table 5 shows trajectory planning testing on the robot manipulator in water using 350 gr load. This table shows that the biggest error on y axis was 8.70%. The error value was relatively not too large can prove that manipulators are made capable of putting the coral reefs in the water.

D. Testing of Camera Visibility Against Coral Reefs

This test aims to find out how far the camera is to be able to see clearly the coral reef in front of it. Tests carried out in the water by placing coral reefs ranging from a distance of 30 cm to the position of the camera up to a distance of 130 cm. the first test is shown in Figure 17,

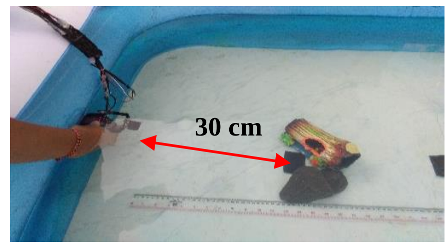

Figure 17. Testing at a distance of 30 cm

These tests are also carried out by placing objects in the form of rocks in addition to coral reefs in the same shape, the purpose of which is to compare the extent to which the camera's vision can clearly see coral reefs so that it cannot be distinguished between coral reefs and rocks. Then the results are displayed on the monitor screen to see the quality of objects seen on the camera shown in Figure 18.

At a distance of 30 cm, coral reefs look very clear and can be distinguished from rocks. The test results for other distances can be seen in table 6.

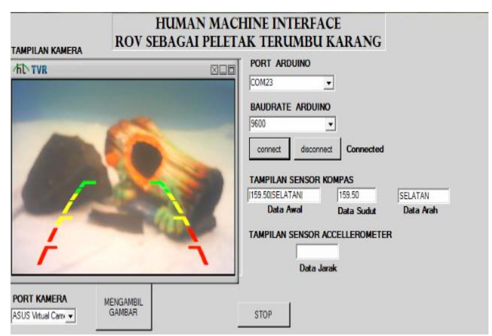

Figure 18. **C**amera View at a Distance of 30 cm

TABLE VI
CAMERA VISIBILITY TEST RESULTS

Distance (cm)	Test result
60	coral reefs are clearly visible and can be distinguished from rocks
90	coral reefs are still clearly seen and can be distinguished from rock, only the image quality has begun to fade
120	coral reefs can still be seen but the picture quality is not clear
135	coral reefs can only be seen in color, because the picture quality decreases, for the shape of the coral reef is no longer visible as well as with the stone only looks black.

From this test, it can be concluded that the camera's visibility of coral reefs at a distance of 30 cm to 120 cm can still be distinguished between the color and shape of coral reefs and rocks, while the distance of 135 cm only shows color while

E. Acquisition of Accelerometer Data Moved Condition

The X and Y axes are shifted linearly to a certain distance. This is done to test how accurate sensors read mileage when the ROV is moving.

TABLE VII
INVERTER ACCELEROMETER POSITION DATA ON THE X AXIS BASED ON DISTANCE

No	Time (s)	Distance (m)		*Error* (%)
		Real	Sensor	
1	20	0	0	0
2	20	0,5	0,6	20
3	20	1	0,95	5
4	20	0,6	0,65	8,33
		Average		8.33

TABLE VIII
ACCELEROMETER POSITION DATA ON THE X AXIS BASED ON TIME.

No	Time (s)	Distance (m)		*Error* (%)
		Real	Sensor	
1	20	0	0	0
2	70	0	0,1	0
3	20	1	0,95	5
4	70	1	2,1	110
5	30	0,8	1	20
6	100	0,8	2,3	187,5
			Average	99,16

TABLE IX
ACCELEROMETER POSITION DATA ON THE Y AXIS BASED ON DISTANCE.

No	Time (s)	Distance (m)		*Error* (%)
		Real	Sensor	
1	20	0	0	0
2	20	0,3	0,32	6,67
3	20	0.5	0,59	18
4	20	1	1.08	8
			Average	8.67

In retrieval of data based on Table 7, testing the accelerometer test data on the X axis based on distance, testing starting from a distance of 0 m to 1m is determined randomly to see the percentage error ratio obtained at the same time. While in Table 8 accelerometer testing on the X axis based on time, testing is done by distinguishing the time of each data taken. From the test, it was found that it turned out that the most determining factor was the time taken. Data obtained at the same time the average error obtained was 8.33%. While at the time of extraction it is made longer which is up to 100 seconds, the average error obtained reaches 99.16%. While in Table 9, the testing of accelerometer testing data on the Y axis based on distance, the average value of errors obtained when data retrieval lasts for 20 seconds is 8.67%. And in Table 10, testing the accelerometer test data on the Y axis based on time, when data collection is extended to 100 seconds the average error obtained is 51%.

TABLE X
ACCELEROMETER POSITION DATA ON THE Y AXIS BASED ON TIME.

No	Time (s)	Distance (m)		*Error* (%)
		Real	Sensor	
1	20	0	0	0
2	100	0	0,06	0
3	20	0.5	0,59	5
4	100	0.5	0,98	96
5	20	1	1.08	20
6	100	1	2	100
		Average		51

Errors from sensor readings can reach up to tens of cm. The longer the time it takes the sensor to go to a certain point it causes even more integrated data. Many times the integration causes the output value on the sensor to continue to rise and increase the reading error value.

For testing in real time alone the sensor is not able to display data that is close to real data. Data has an error of 10 m in only 5 seconds of vulnerable time and continues to increase. The main cause of the magnitude of the error in this test is due to the lack of good sensor components used so that the data displayed is less accurate when used for a long time.

F. Testing on Digital Compass Sensor Data

Digital compass aims to show the direction of the heading of the ROV based on the direction of the wind. Tests are carried out when the sensor is idle and rotated to 360°. From the tests that have been done, the comparison of compass sensors and digital compasses found on mobile phones is shown in Table 11.

TABLE XI
RESULTS OF COMPARISON OF DATA ON COMPASS SENSORS AND DIGITAL MOBILE COMPASSES

No	Angle (°)		Heading		*Error* (%)
	Digital mobile compass	Compass sensor	Digital mobile compass	Compass sensor	
1	345	345	North	North	0
2	307	310	Northwest	Northwest	0,97
3	362	367	West	West	1,38
4	174	175	South	South	0,57
5	146	145	Southeast	Southeast	0,6
6	85	83	East	East	2,3
7	62	62	Northeast	Northeast	0
8	207	210	Southwest	Southwest	1,44

Variation with the error value is due to the inability of the sensor to read at a certain angle. The error value will be greater when the sensor is directed towards the maximum and minimum values in the range of the direction of the wind. And the error value will be smaller when the sensor is in the position between the maximum and minimum values in the range.

V. CONCLUSION

The ROV is an underwater robot which is often used to perform underwater research with operator control over the sea. This robot makes reasearch such as coral reefs easier. ROV is made with a joystick control then the ROV can easily move in accordance with the user. The control has been made based on the data reading joystick control to get the movement.

The design of ROV found that ROV can float with a maximum load of 4-5,5Kg. The control of ROV movements made according to the joystick which is forward at 0.19 m/s, retreating at 0.15 m/s, rising at a speed of 0.11 m/s, down at a speed of 0.16 m/s, then turn right and turn left at a speed of 0.14 m/s. From the test results, the MPU 6050 sensor is able to show the slope of ROV with a sensor error reading value of 0.52% on the land and 6.7% in water, so that the operator can correct the ROV position to balance in the water.

Robot manipulator to move three seeds of coral reef with a determined point. The position displacement from one point to another, the average error value on X axis = 3.26%, the mean error value on the Y axis = 3.27%, and the mean error value on the Z axis = 1.36%.

The distance between the camera and coral reefs at a distance of 30 cm to 120 cm can still be distinguished between the color and shape of the coral reef and stone, while the distance of 135 cm only shows color while the shape cannot be distinguished from stone.

The error value on the accelerometer sensor increases with the length of time the data is retrieved. The average error value reaches 99.16% in 100 seconds on the X axis and 51% on the Y axis. So that the application on the ROV cannot be done, due to the large error value.

The digital compass sensor is able to display the eight wind direction found on the mobile compass. The biggest error is obtained in the Southwest with 3.81% and the smallest in the North West with 0.23%.

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