Development of real-time motion autonomous surface vehicle controlling for coral reef conservation and fisheries

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Abstract. Start Coral reefs are typical ecosystems with underwater beauty. In addition to beauty, there is a function to reduce abrasion, marine biota residence and as well as educational facilities. The current state of coral reef ecosystems in Indonesia is quite alarming, the condition of coral reefs that are in very good condition is 6.39%, good condition is 23.40%, sufficient condition is 35.06% and bad condition is 35.15%. So there needs to be special handling to deal with these damage by using technological developments. Based on these conditions many researches emerged for observation and conservation. One of them is research on the development of conservation aids, the floating of these tools is accompanied by the development of increasingly natural ways of user interaction and tools. Natural interaction is characterized by interactions that transform human movements into direct digital action. Motion Tracking (MT) is one of the implementations of markerless/natural interaction, in which to identify projects is no longer based on certain symbols. MT reads body parts then converted into digital movements. This study aims to develop Real-Time Motion Autonomous Surface Vehicle (ASV) Controlling for Coral Reef Conservation and Fisheries using Fuzzy Algorithms. The tools produced by the study are controlled naturally, so it is expected to facilitate users in operating ASV. This tool is expected to facilitate monitoring and observation for the conservation of marine ecosystems (coral reefs and fisheries).

1. Introduction
Coral reefs are typical ecosystems with underwater beauty. In addition to beauty, there is a function to reduce abrasion, marine biota residence and as well as educational facilities. According to [1] Indonesia is a country that has a total area of 3,257,483 km² of water. Based on the One Map Policy mandated in UU No.4 tahun 2011, the area of coral reefs released in Indonesia is around 2.5 million hectares with 569 types of coral including in 82 genera.

The current state of coral reef ecosystems in Indonesia is quite alarming. According to [1] the condition of coral reefs that are in very good condition is 6.39%, good condition is 23.40%, sufficient condition is 35.06% and bad condition is 35.15%. So there needs to be special handling to deal with these damage by using technological developments. Based on these conditions many researches emerged for observation and conservation. One of them is research on the development of conservation aids, the floating of these tools is accompanied by the development of increasingly natural ways of user interaction and tools.
Natural interaction is characterized by interactions that transform human movements into direct digital action. Motion Tracking (MT) is one of the implementations of markerless/natural interaction [2], in which to identify projects is no longer based on certain symbols [3]. MT reads body parts then converted into digital movements, the application of this technology as in research [4][5][6][7][8]. This study aims to develop Real-Time Motion Autonomous Surface Vehicle Controlling Development for Coral Reef Conservation and Fisheries using Fuzzy Algorithms.

The tools produced by the study are controlled naturally, so it is expected to facilitate users in operating ASV. This tool is expected to facilitate monitoring and observation for the conservation of marine ecosystems (coral reefs and fisheries).

2. Related Work

Natural interaction is characterized by interactions that transform human movements into direct digital action. Motion Tracking (MT) is one of the implementations of markerless/natural interaction [2], in which to identify projects is no longer based on certain symbols [3]. MT reads body parts then converted into digital movements, the application of this technology as in research conducted by [4], brain imaging has a problem in the quality of modeling if you have to use a marker as a reference. This results in readings not being processed quickly by clinic clinics. This study aims to develop a markerless brain modeling tool.

Research conducted by [5] presents a new concept for optical tracking without markers called "tracking with reference images" introduced. The concept is very relevant for outdoor augmented reality applications, its implementation using image matching techniques, which compares current live video images with one or more reference images. Research conducted by [6] proposes a new model-based human motion capture algorithm. The method used no longer requires foreground/markerless segmentation. Similar research was also conducted by [7][8]. This study uses Kinect as a control sensor from ASV, Kinect selection is based on research conducted by [9][10][11].

This study aims to develop Real-Time Motion Autonomous Surface Vehicle Controlling Development for Coral Reef Conservation and Fisheries using Fuzzy Algorithms. The novelty shown by the research is the implementation of natural controls on ASV [13] that are intended for monitoring and observing the oceans, especially coral reefs. Monitoring and observation of coral reefs using ASV has a high level of difficulty, so with the tools developed in this study it is expected to simplify the process of monitoring and observation. The final result of the implementation of this tool is the condition of coral reefs that are getting better, because its growth can be monitored properly.

3. Research Methods

![Figure 1. Research Methods]
The stages of the research are shown in Figure 1. The first stage of the study is the literature review, this stage is very important because it relates to the novelty raised by the study [14]. In addition this section is also used research to find the best methods for solving control problems in Low-Cost ASV.

The next stage Kinect has a skeletal tracking feature by capturing the movements of human limbs captured by the RGB camera and IR (Infra-Red) Camera found in Kinect by reading and recognizing human bones in each of its movements. At this stage the research will look for the best configuration to get the best control capabilities.

The next stage is the implementation of Fuzzy, at this stage will be examined about the motor response (PWM) to the angle captured by Kinect. PWM obtained from the motor will simultaneously be the rule for the system. The next stage is testing, at this stage the results of the reading on the application/ground system to the real movement of the tool. Then the last stage is the discussion and conclusion, the study will observe the results obtained from the testing phase. After being analyzed the research will draw conclusions.

4. Discussion

4.1. Skeletal Tracking
Skeletal Tracking is a SDK feature, which tracks the joints of the human body, this feature uses a depth sensor. The object used in the kinect sensor is a colorframe to embrace the color, skeletonframe for the bone tracking process, depensor in the depth reading of the tracked bone. At the beginning of the process will be tracking in front of the kinect camera there should not be any obstructing objects, if there are obstructing objects then the process of reading frames and skeletal tracking cannot run even though the Kinect is connected to the computer. The user is a human to control the low-cost ASV (Autonomous Surface Vehicle) robot, which is driven by the right and left hand. Kinect reads the coordinate value. The received coordinate value is converted to an angle value using Equation 1.

\[
\theta = \left( \frac{\pi}{180} \right) \times (1)
\]

Body movements that are used as input from this system, joint data from skeleton tracking is required. The data used on the arm right is the shoulderright and wristright joint data, and the arm left data joint is used shoulderleft and wristleft. Joint data from the depth sensor is a coordinate value, the coordinate value is converted to an angle value. The angle value used is 0° to 90°. Coded from an angle is shown in Figures 2 and 3.

![Figure 2. Retrieval of Right Angle Values](image-url)
Hand movements are used to control the speed of movement of the right and left brushless motors. There are instructions for controlling the low-cost ASV (Autonomous Surface Vehicle) robot. Some hand movements as a controller shown by Tabel 1.

| HandMovement (Angle)                                      | ASVMovement     |
|----------------------------------------------------------|-----------------|
| Straight right and left parallel                         | Straight Fast   |
| Right and left in the same middle position/middleangle   | Medium Straight |
| Right and left straight position under/lowangle           | Soft Straight   |
| Right high corner, left in lowangle position             | Sharp Left Turn |
| Right position low right angle, left position highangle   | Sharp Right Turn|
| Right angle medium, left low angle                       | Slight Left Turn|
| Right angle low, left angle medium                       | Slight Right Turn|
| Right angle is high, left angle medium                   | Turnleft        |
| Right corner medium, left corner high                    | Turnright       |

4.2. Fuzzy Calculation

Fuzzy calculation on the development of control systems or control systems of robot low-cost ASV (Autonomous Surface Vehicles) in a marker-less method uses the Sugeno fuzzy method [12].

4.2.1. Fuzzification

Fuzzification process to change systems that have firm values into linguistic variables using membership functions stored in a fuzzy knowledge base. In this process the angular value of the tracking skeleton results of the movement of the right and left hand becomes fuzzification membership. There are 2 variables used, they are right angle and left angle variables, shown by Figure 4 and 5. In each corner variable has 3 linguistic data and a set of membership.

![Figure 4. Right Angle Graph](image_url)
Figure 5. Left Angle Graph

The results of calculations on each angle input will be included in the calculation of rule evaluation or FIS (Fuzzy Inference System).

4.2.2. Rule Evaluation or FIS (Fuzzy Inference System)

The linguistic data of right and left angle variables that produce each set of memberships are then processed in rule evaluation which combines with the motor speed output values. There are two brushless motors, so before forming the rule, then determine the value of the output membership set for each motor. The membership set in the Sugeno fuzzy is formed by Singleton, so each membership set has a constant value (a fixed value). The range of motor speed values is in the form of PWM up to 10 to 255. At each output membership set there are three data that is slow at 10 PWM, 122 PWM, and fast is 255 PWM.

From the two sets of motor speed membership, then combined with the set of variable right and left angle membership in the Fuzzyfication process in the form of evaluation rule. Making this rule is very influential on the results of ASV (Autonomous Surface Vehicles) robot movements. There are nine rules that are made. The following is the elaboration of the nine rules:

[R1] IF ReKa AND ReKi THEN Motor Kanan Pe[10], Motor Kiri Pe [10]
[R2] IF ReKa AND SeKi THEN Motor Kanan Pe[10], Motor Kiri Se[122]
[R3] IF ReKa AND TiKi THEN Motor Kanan Pe[10], Motor Kiri Ce [255]
[R4] IF SeKa AND ReKi THEN Motor Kanan Se[122], Motor Kiri Pe [10]
[R5] IF SeKa AND SeKi THEN Motor Kanan Se[122], Motor Kiri Se [122]
[R6] IF SeKa AND TiKi THEN Motor Kanan Se[122], Motor Kiri Ce [255]
[R7] IF TiKa AND ReKi THEN Motor Kanan Ce[255], Motor Kiri Pe [10]
[R8] IF TiKa AND SeKi THEN Motor Kanan Ce[255], Motor Kiri Se [122]
[R9] IF TiKa AND TiKi THEN Motor Kanan Ce[255], Motor Kiri Ce [255]

Explanation of the nine rules that ReKa is Low Right, SeKa is Medium Right, and TiKa is High Right for right angles, and left corner ReKi is Low Left, SeKi is Medium Left, and TiKi is High Left. In the rule output is motor speed, including Pe is Pelan, Se is Medium, and Ce is Fast.

The process of Fuzzy Inference System (FIS) or fuzzy inference engine is done with the MIN implication to get the α-predicate value with each rule, FIS calculation is done on 9 rules. All α-predicate values are known and found, so these values are used to calculate the output of the inference results for each rule (z1, z2, z3, z4 ... z9). The Equation 2 is calculation of FIS (Fuzzy Inference System).

\[ \alpha \text{ Predicate} = \min (\mu \text{ Right Angle } \cap \text{Left Angle}) \] (2)
4.2.3. **Defuzzyfication**

The defuzzyfication process is done after the inference system process and produces a predicate $\alpha$ value and the output value of the results of inference on each rule, then the total of each value is used in the defuzzyfication process. This defuzzification process produces PWM speed values which will be used to adjust the speed of the brushless motor, the method used is WeightAverage.

Defuzzyfication is the result of calculations on the FIS (Fuzzy Inference System) process that has been combined with the nine rules or motor speed rules. The results of the FIS calculation produce a predicate $\alpha$ value, then it is processed by multiplying the motor rule value. Determine the value of crips by using the weight average method, then add up the value of the product $\alpha$ predicate with the motor rule, the sum is divided by the number of $\alpha$ predicates.

### Table 2. Defuzzyfication of the Right Motor

| No | $\alpha$ Predicate | Rule Motor | $\alpha$ Predicate $\times$ Rule Motor |
|----|-------------------|------------|-------------------------------------|
| 1  | 0                 | 10         | 0                                   |
| 2  | 0                 | 10         | 0                                   |
| 3  | 0                 | 10         | 0                                   |
| 4  | 0.57              | 122        | 68.32                               |
| 5  | 0.43              | 122        | 52.46                               |
| 6  | 0                 | 122        | 0                                   |
| 7  | 0.04              | 255        | 10.2                                |
| 8  | 0.04              | 255        | 10.2                                |
| 9  | 0                 | 255        | 0                                   |
| Sum | 1.09              | 1061       | 144.67                              |
| Average |                  |            | 132.86                              |

The result of defuzzyfication on the right brushless motor is 132.86 which is shown in Table 2. The value is the result of dividing the number of $\alpha$ Predicate $\times$ Rule of the Right Motor is 144.67 and the number of $\alpha$ Predicate is 1.09.

### Table 3. Defuzzyfication of the Right Motor

| No | $\alpha$ Predicate | Rule Motor | $\alpha$ Predicate $\times$ Rule Motor |
|----|-------------------|------------|-------------------------------------|
| 1  | 0                 | 10         | 0                                   |
| 2  | 0                 | 122        | 0                                   |
| 3  | 0                 | 255        | 0                                   |
| 4  | 0.57              | 10         | 5.6                                 |
| 5  | 0.43              | 122        | 52.68                               |
| 6  | 0                 | 255        | 0                                   |
| 7  | 0.04              | 10         | 0.44                                |
| 8  | 0.04              | 122        | 5.42                                |
| 9  | 0                 | 255        | 0                                   |
| Sum | 1.09              | 1061       | 64.23                               |
| Average |                  |            | 58.98                               |
The result of the defuzzyfication calculation on the right motor is 132.86 shown in Table 3. The value is the result of the defuzzyfication calculation on the left motor (58.98). This value is a set of crups from fuzzy. The set of crups is used as input signal values that are sent to ASV (Autonomous Surface Vehicles) using Xbee Pro 2BS, sending the data shown by Figure 6. The data recorded is serial data.

![Figure 6. Data Transmission](image)

The data sent is serial data with integer data type. The value sent is in the form of header value 0, the right result is the right motor crups value, and the left result is the left motor crups value. The three values are sent with the format "0, 132.86, 58.98".

### 4.3. Testing Fuzzy Values with ASV Motion

This test aims to determine the value of fuzzy calculations in accordance with the output values move according to predetermined rules. The test results are shown in Table 4.

| No. | Right Angle | Left Angle | Right PWM | Left PWM | Movement     | Movement Result |
|-----|-------------|------------|-----------|----------|--------------|-----------------|
| 1   | 7.22        | 3.98       | 30.625    | 23.3611  | Soft Straight| Stop            |
| 2   | 61.87       | 66.8       | 177.423   | 166.464  | Medium Straight | Medium Straight |
| 3   | 78.17       | 77.51      | 209.169   | 207.89   | Straight Fast  | Straight Fast   |
| 4   | 38.65       | 77.6       | 96.913    | 210.426  | Sharp Right Turn | Sharp Right Turn |
| 5   | 45.32       | 61.72      | 123.865   | 171.656  | Turn right    | Turn right      |
| 6   | 24          | 47.58      | 68.28     | 135.6818 | Slight Right Turn | Slight Right Turn |
| 7   | 60.04       | 19.8       | 175.285   | 61.1179  | Sharp Left Turn | Sharp Left Turn |
| 8   | 68.11       | 31.02      | 189.602   | 78.4625  | Turn left     | Turn left       |
| 9   | 49.58       | 14.53      | 144.494   | 48.0864  | Slight Turn Left | Slight Turn Left |

From the test results there is a rule that results in the movement of tools that are different from the application output shown in Table 4. The accuracy obtained by the system is 88% with an error rate of 12%.

### 5. Conclusion

The conclusion obtained, the research has succeeded in developing a marker-less teleoperation robot control low-cost for ASV (Autonomous Surface Vehicle) shown by: a) Kinect can track hand movements with the skeleton feature; b) Kinect was successfully developed for a control system or NUI (Natural User Interface) control system with hand movements; and c) The Fuzzy Sugeno method can calculate the speed of a brushless motor by producing motion on a low-cost ASV (Autonomous Surface Vehicle) robot with an accuracy rate of 88%.
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