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DEVELOPMENT OF ROV FOR ORIENTATION CONTROL

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A report submitted in partial fulfilment of the requirements for the degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

I declare that this report entitles "**DEVELOPMENT OF ROV FOR ORIENTATION CONTROL**" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature	:	....
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Date	:	....

To my beloved mother and father

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ABSTRACT

In the field of underwater unmanned vehicle, Remotely Operated Vehicle (ROV) and Autonomous Underwater Vehicle (AUV) are mobile robots that replace human to do dangerous task such as carrying out operation under the deep ocean with the operator on the surface of the ocean. One of the problems faced by ROV is that the new operator cannot run the ROV perfectly because there is absence of direct orientation control of ROV. So, a steering system that uses the sense of motion to control a ROV is discussed in this project. In designing the ROV, SolidWorks software is used and undergoes various simulation tests such as stress and strain test, sustainability test and stability by referring the center of mass. This project was used MPU6050 sensor as a steering system to control the angle of rotation of ROV in yaw, pitch and roll. In this research, the performance of the ROV with steering system was evaluated in terms of manoeuvrability and ease of handling. The experiments are carried out in the lab pool to test the orientation control of the ROV through the communication between the ROV and the steering system using Arduino MEGA 2560. The result obtained from SolidWorks simulation tests was that the design of ROV has good stability in water due to its center of gravity. The drifting angle on pitch and roll was filtered by using Kalman Filter coding. The ROV was able to move in pitch and roll direction but not yaw because the angle of the rotation on yaw was drifted too much. The only solution for the drift angle on z axis is by replacing the MPU 6050 with MPU 9150.

ABSTRAK

Dalam bidang kenderaan tanpa pemandu bawah air, kenderaan kawalan jauh (ROV) dan kenderaan autonomi bawah air (AUV) adalah robot bergerak yang menggantikan manusia untuk melakukan tugas yang berbahaya seperti menjalankan operasi di bawah laut dalam dengan pengendali di permukaan lautan. Salah satu masalah yang dihadapi oleh ROV adalah bahawa pengendali baru tidak dapat menjalankan ROV dengan sempurna kerana tidak ada kawalan orientasi langsung ROV. Jadi, sistem pemanduan yang menggunakan isyarat gerakan untuk mengawal ROV dibincangkan di dalam projek ini. Untuk mereka bentuk ROV, perisian SolidWorks digunakan dan menjalani pelbagai ujian simulasi seperti tekanan dan ujian terikan, ujian kelestarian dan kestabilan dengan merujuk kepada pusat jisim. Projek ini digunakan sensor MPU6050 untuk mengawal sudut putaran ROV dan kayuria. Dalam kajian ini, ROV hanya bergerak dalam yaw, padang, dan roll. Eksperimen dilakukan di kolam lab untuk menguji kawalan orientasi ROV dari komunikasi antara ROV dengan sistem pemanduan menggunakan Arduino MEGA 2560. Hasil yang diperoleh dari ujian simulasi SolidWorks adalah bahwa desain ROV mempunyai kestabilan yang baik di dalam air ke pusat graviti. Sudut drifting di padang dan gulung ditapis dengan menggunakan pengekodan Kalman Filter. ROV dapat bergerak di arah padang dan gulung tetapi tidak mengecil kerana sudut putaran pada lekukan terlalu banyak. Satu-satunya penyelesaian untuk sudut drift pada paksi z adalah dengan menggantikan MPU 6050 dengan MPU 9150.

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LIST OF ABBREVIATION

ROV - Remotely Operated Vehicle

AUV - Autonomous Underwater Vehicle

PID- Proportional Integral Derivative

FLC- Fuzzy Logic Controller

FYP- Final Year Project

CG- Center of Gravity

CB- Center of Bouyancy

DOF- Degrees of Freedom

CFD- Computational Fluid Dynamics

PMM- Planar Motion Mechanism

SMC- Sliding Mode Controller

CAD - Computer-Aided Design

FEA- Finite Element Analysis

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

On the Earth's surface, 71 percent covered by the oceans and it still has plenty of resources that not yet been explored and extracted [1]. Underwater vehicles are used to replace diver that works in the hazardous environment such as explore, investigate or recovery of the item under the deep ocean. There are 2 types of underwater vehicles which are unmanned vehicles and manned vehicles. Autonomous Underwater Vehicle (AUV) and Remotely Operated Vehicle (ROV) are categorized under unmanned vehicles. A ROV is a tethered underwater robot that allows the operator to stay above the ocean and give the command to ROV, whereas AUV is controlled by pre-programmed instructions set by the operator on the controller which is equip with sensors of the robot [2]. The overview of underwater vehicles is shown in Figure 1.

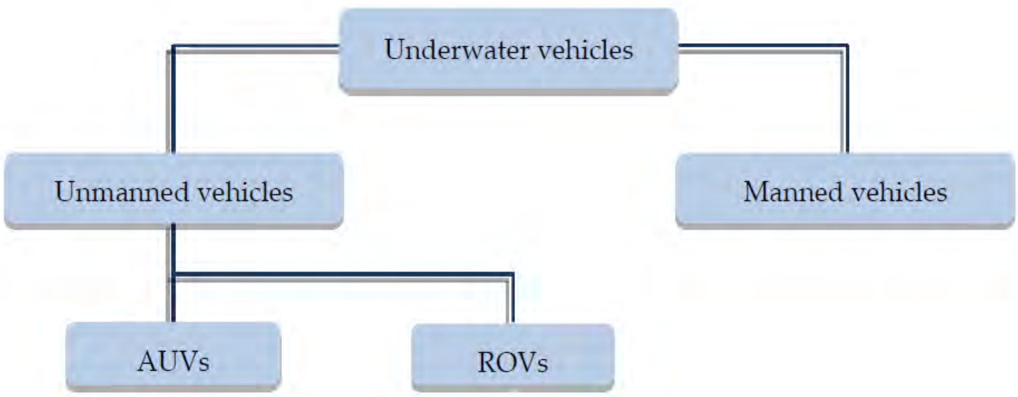

Figure 1.1: Overview of Underwater Vehicles. [3]

1.2 MOTIVATION

The demand for ROV is high in drilling support, construction support, repair, and maintenance. According to World ROV Operations Market Forecast, Douglas-Westwood expected annual expenditure on ROV operations has increased from USD 1.6 billion in 2013 to USD 2.4 billion in 2017. In the year between 2013 and 2017, drilling support of exploration has occupied 75% of the total expenditure while the construction support occupies for 20% and repair and maintenance for 4%. The majority of global ROV demand is from Africa [4].The expenditure in global work-class ROV operations from 2008 to 2017 is shown in Figure 1.2.

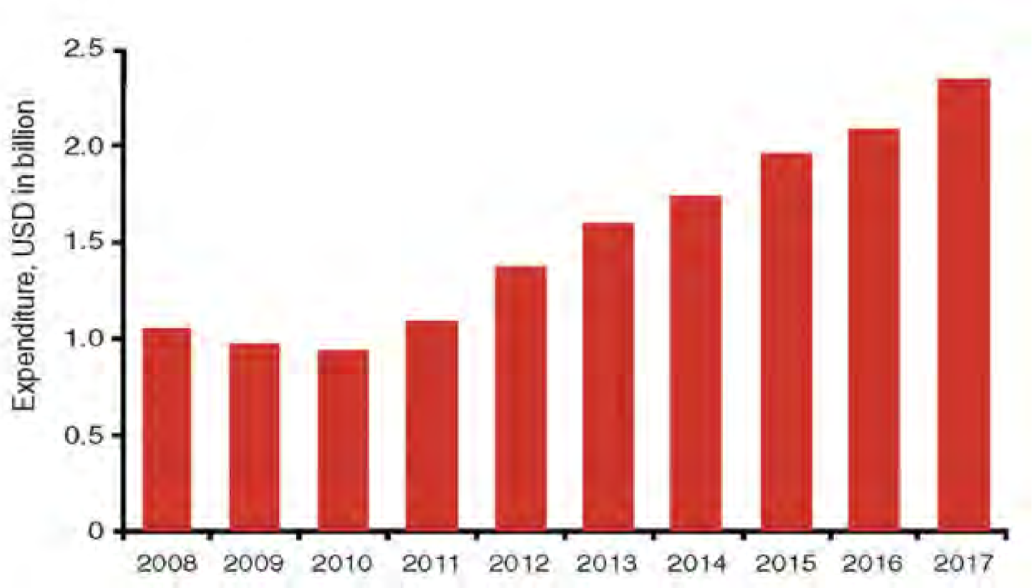

Figure 1.2: The expenditure in global work-class ROV operations from 2008 to 2017. [4]

There are many researchers and engineers in western countries that try to design and develop the unmanned vehicles for underwater exploration. In Malaysia, the research of underwater technology is much lagging behind those western countries such as German, Japan, and the USA. As a result of unable to develop the underwater unmanned vehicle, tragedy of Malaysia Airlines flight MH370 submerge into the Indian Ocean occurred and gave a serious warning to everyone about the vital sign of ROV technology in Malaysia. Malaysia required paying about $20 million to $70 million to Ocean Infinity US Company for the trace of missing Malaysia Airlines flight MH370 [5].

1.3 PROBLEM STATEMENT

Recently, ROV started to grow as an important tool in various operation such as exploring, investigating, cleaning, latching or recovery of the item to protect our ocean resources. With the aid of ROV, human cognition of the ocean become higher. This application requires ROV to be able to navigate to a given point and controllable from the surface of the ocean [6] .Besides that, stability in orientation control is an important issue for ROV. On the ocean, the waves disturb the underwater vehicle severely. The change in direction and speed of currents in an irregular water has caused the operation of ROV become harder. Moreover, the operator of ROV needs to control the orientation of a ROV with the need to control the thrusters directly. The body of the ROV must be waterproof and able to withstand certain deep water pressure. It is not easy to fully seal the electronic components. Once the water entered the component, the circuit will then short circuited. The stability of ROV due to its center of gravity and center of buoyancy will also affect the performance of the ROV. The center of buoyancy should be slightly higher than the center of gravity for stable orientation control of ROV.

This project was developed in order to solve the difficulty in control a ROV using traditional button type joystick. New operator cannot run the ROV perfectly because there is absence of direct orientation control of ROV. The controller which sensing the motion will ease the user in controlling the ROV. Therefore, a steering system for ROV can make the user handle the movement easily without looking at the manual of control. Besides that, the control system is needed for the ROV to move in the desired position. There are various advanced techniques such as Proportional Integral Derivative (PID) controller and Fuzzy Logic controller (FLC) to be used as a controller of ROV. From the controller, a control algorithm can be made. A control algorithm not only built for flexible movement in various direction but also maintain the stability of orientation and move with constant velocity.

1.4 OBJECTIVE

There are three objectives that required to be achieved during this FYP

1. To design and develop a ROV for orientation control in yaw, pitch and roll.
2. To develop a steering system for ROV orientation which are yaw, pitch and roll using MPU 6050 sensors.
3. To evaluate the performance of a steering system developed in terms of maneuverability and ease of handling.

1.5 SCOPE

The scopes and limitations of this project are:

1. The ROV is required in small size, dimension less than 70cm x 50cm x 30cm and lightweight less than 5kg.
2. The orientation of ROV involves only yaw, pitch and roll.
3. Arduino Mega is used as microcontroller due to it has the high processing power and up to 54 General Purpose Input Output pins.
4. 6 DOF MPU 6050 sensors are used on the joystick and the body of the ROV to measure the angle of rotation.
5. The maximum depth for ROV is 2 meters.
6. MPU 6050 sensor is used as input to control the orientation of ROV.
7. Test on working space which are yaw, pitch and roll.
8. Test on time response when using MPU 6050 sensor to control orientation of ROV.

1.6 ORGANIZATION OF REPORT

For the content of chapter 2 on literature review, it involves the theoretical background that needed for this project. It also discussed the factors of choosing the design of ROV for this project. Lastly, it summarises the design proposed by the journals and the conclusion made from the review. Furthermore, chapter 3 methodology includes the block diagram and flowchart of operation and prototype of a ROV. The method of doing the design is also mentioned in this chapter. Moreover, chapter 4 for results and discussion has described several simulations using SolidWorks Simulation. Besides that, the value that the sensor detects is also recorded in this chapter. Last but not least, chapter 5 on conclusion and recommendation, future work reviews the whole information in details for this project. There are some suggestions for future work and recommendations.

1.7 SUMMARY

This chapter concludes that the importance of a ROV in the underwater application. The development of this technology is needed to further exploration of the ocean. This project is focused more on designing a control system to stabilize the orientation of the ROV.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and basic principles

2.1.1 Centre of gravity

The center of gravity is the average position of the weight of an object whereas the center of buoyancy is the center of mass of the floating or submerged body that caused by a displaced fluid. Most ROVs are designed to be as stable as practical. Most common design of ROV is open frame type. The open frame configuration also aids the stability of the vehicle which is related to the distance where both the center of gravity and the center of buoyancy intersect is known as metacentric height. The longer the distance between the center of buoyancy and the center of gravity, the more stable the vehicle and vice versa but the more maneuverable [7]. In order to prevent the ROV from rotating itself, the center of buoyancy should be located above the center of gravity [3]. Figure 2.1 shows the center of buoyancy located above the center of gravity.

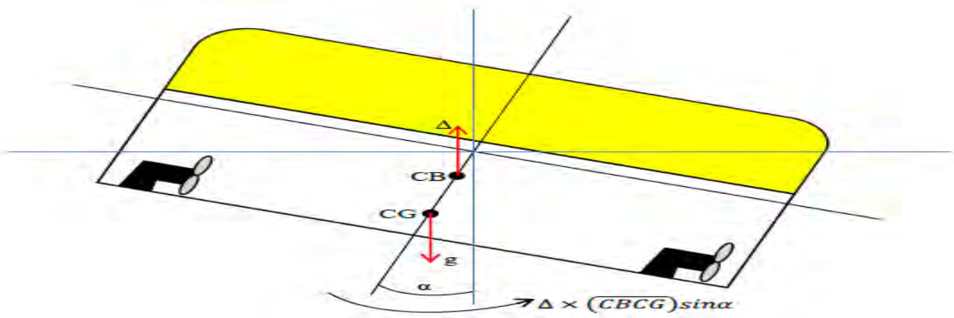

Figure 2.1: Righting moment of stable ROV. [3]

2.1.2 Stability of ROV

Passive Stability

The stability of ROV is the ability of ROV to return to original position when tipped or flipped by a disturbance such as a wave. BG is an important term in stability of underwater vehicles. BG is the distance between the center of gravity (CG) and center of buoyancy (CB). In Figure 2.2, the position of BG is shown [7].

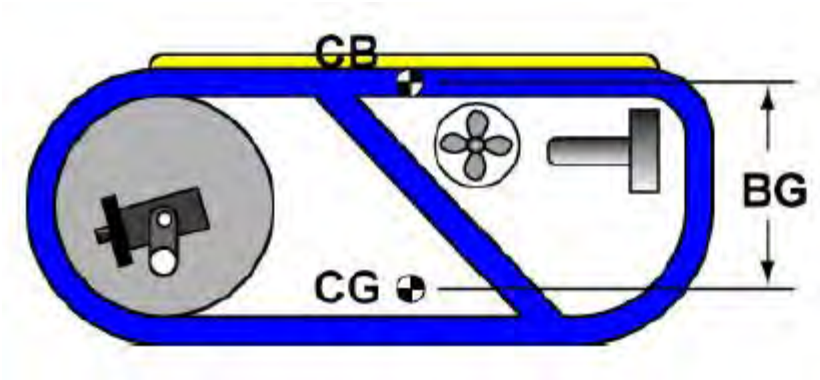

Figure 2.2: The distance between CB and CG is BG.

According to a special case of moments, the couple is consist of two equal but opposite forces that act upon a body [8]. It is about the same that happens on ROV during operation. When the BG increases, d will increase and produce a larger turning torque. From the formula of torque [9]:

$$\tau = F \times d \tag{2.1}$$

$$\tau = F_W \times BG \sin\theta \tag{2.2}$$

Where τ = Torque,

F_w = Force of weight,

BG = distance between the center of buoyancy and center of gravity,

Θ = pitch or roll angle.

In Figure 2.3, the similar of couple force on ROV is shown. The stability of ROV will increase when larger BG produces a larger torque [9].

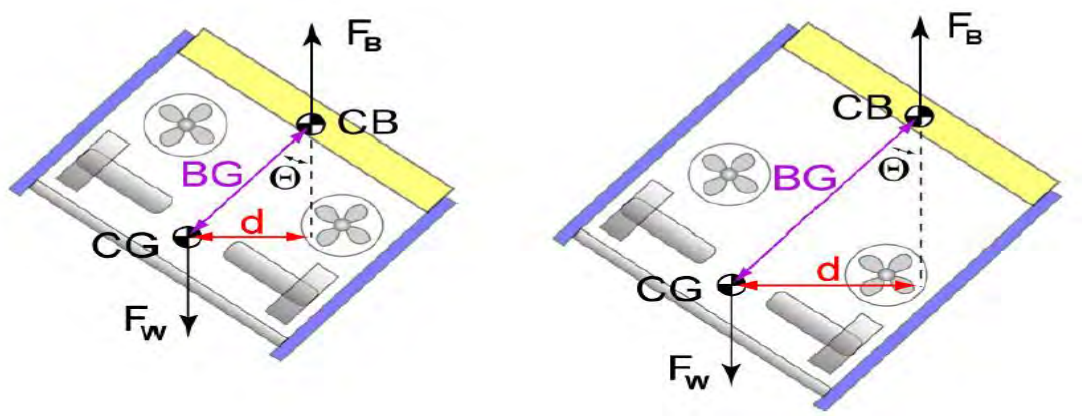

Figure 2.3: Couple force on ROV. [7]

Active Stability

The thruster configuration is also an important factor for having a good stability of ROV. The vectored thruster configuration gives a better performance as mentioned in 2.2.2The equation 2.3 and 2.4, it shows that the thrust force for x and y axis. From these equation, it is known that if any absence of the thruster will make the ROV become unbalance in thrust force. Therefore, it will affect the stability of ROV on motion to oppose the force.

2.1.3 Ballast System

Ballast is the adding or removing of weight on an underwater vehicle to improve its stability [7]. A ROV requires both floatation and weight to carry out the operation for the diving purpose. There are 2 types of ballast systems that can be used by ROV which are the static and dynamic ballast. For static ballast system, the ROV will be pre-set with the desired ballast and remain unchanged throughout the operation. For dynamic ballast system, the ROV will change its ballast during the operation. It allows the ROV to be heavy when diving in the high current situation. However, the disadvantage of this system is the air in the tank changes in volume as the ROV dive to a different depth. Therefore, it is uncommon for most ROV. The most common material used for ballast system is syntactic foam. This is because of its low density and ability to withstand high pressure [9, 10]. In Figure 2.4, it shows the float block and ballast weights added to ROV to increase its stability.

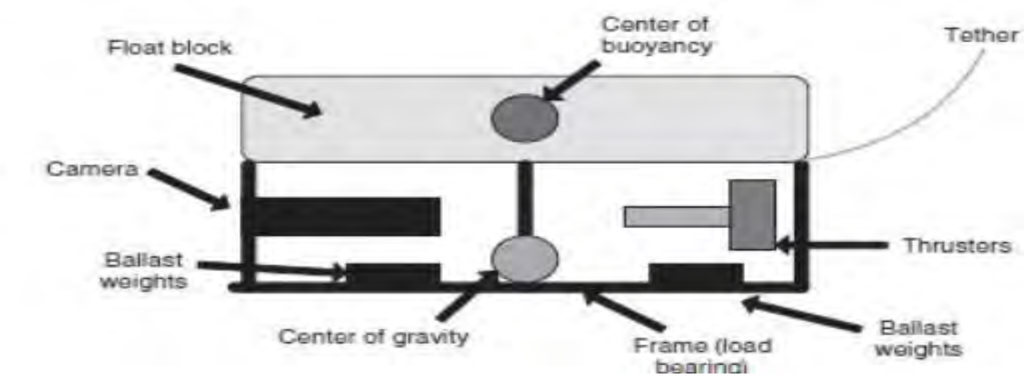

Figure 2.4: Ballast system on ROV. [11]

2.1.4 Buoyancy (Archimedes' Principle)

Buoyancy is a force that exerted by the liquid on an object that is fully or partially submerged on it. Archimedes' principle indicates that the upward buoyant force that exerted on an object is equal to the weight of the fluid displaced by the object [11]. ROV need to neutralize the negative buoyancy effect of heavier than water materials on the submersible for example frame and pressure housing with lighter than water materials. A slightly positive buoyant is the goal of ROV [7]. This is because it allows the ROV to float to the surface when the propeller is damaged. Moreover, it is easier to make any modification when the ROV stay at the surface. Most of the material of frame used by the ROV is polymer type. Metal is not recommended to be used as the material of the frame of ROV due to its increase in weight and degradation after long periods of contact with seawater [3].

2.1.5 Control System

A Proportional-Integral-Derivative controller is a control algorithm that widely used in industrial control system [12]. The most common tuning method of PID used is Ziegler-Nichols rule. The Ziegler-Nichols rule is a method of PID tuning rule that try to produce good values for the three PID gain parameters which are the controller path gain (K_p), controller's integrator time constant (T_i) and controller's derivative time constant (T_d) [13]. The period T_u of the oscillation frequency at the stability limit and the gain margin K_u for loop stability are the two measured feedback loop parameters derived from the measurements [13]. The advantage of this tuning method is that it only need to change the P controller. Moreover, it gives a better illustration on how the system is behaving. By using the values of K_u and T_u, the values of PID gain setting can be determined as shown in Table 2.1 [13].

Table 2.1: Tuning Rule

Rule Name	Tuning Parameters
Classic Ziegler-Nichols	Kp = 0.6 Ku Ti = 0.5 Tu Td = 0.125 Tu
Pessen Integral Rule	Kp = 0.7 Ku Ti = 0.4 Tu Td = 0.15 Tu
Some Overshoot	Kp = 0.33 Ku Ti = 0.5 Tu Td = 0.33 Tu
No Overshoot	Kp = 0.2 Ku Ti = 0.5 Tu Td = 0.33 Tu

2.1.6 Propulsion and Thruster Configuration

ROV propulsion system is divided into 3 types which are electrical, hydraulic, and ducted jet propulsion. The size of the vehicle, type of operation and location of work can affect the type of propulsion system used. The electrical type propulsion system is used when there is required to change energy from electrical to mechanical. For hydraulic type, it is needed when the vehicle requires huge work tooling for intervention. Moreover, the vehicle that operated under the condition that can cause waste to pull into the thrusters needs to use ducted jet propulsion system. The main target of the design of ROV is to obtain a high thrust to physical size and power input ratios [11].

The propeller is divided into 2 main groups which are fixed pitch propeller and controllable pitch propeller. For the fixed pitch propeller, the position of the blades is fixed. For controllable pitch propeller, there is a large hub for a mechanism to control the pitch of the blades when hydraulically activated. Figure 2.5 shows the types of propeller [14]. A number of propeller blades are different for certain operation. It can be made of 2 to 6 blades. However, the lesser the propeller blade, the greater the propulsion efficiency.