"I hereby declare that I have read through this report entitle "**Remotely Amphibian Vehicle**" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Mechatronics Engineering.

Signature : .....

Supervisor"s Name : DR MOHD SHAHRIEEL MOHD ARAS

Date : .....

REMOTELY AMPHIBIAN VEHICLE

YEOH EIK KEONG

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

I declare that this report entitle "**Remotely Amphibian Vehicle**" 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 candidature of any other degree.

Signature : .....

Name : YEOH EIK KEONG

Date : .....

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ABSTRACT

This project is mainly focusing on the development of the Remotely Amphibian Vehicle (RAV). RAV is considered as a drone or vehicle that can operate autonomously or remotely controlled by a user. The term “amphibian” is referring to a vehicle that is capable of functioning in dual environments, which is in aerial and aquatic. In order to achieve that purpose, the ability of flying and submerging are being implemented into this RAV. This innovation mends to assist and help human in aquatic operation as well as aerial activity. However, this is still a very recent concept with numbers of limitation and challenge. Challenges like transition in medium has limited and affected the performance of the vehicle in terms of flying capability or submerging ability. Available model in the market is either robust in flying, but imperfect in submerging and vice versa. Hence, this project is to design and develop a remote control amphibian vehicle that can fly and submerge in order to overcome the challenge mentioned. The denser material is preferable for body frame fabrication because a body design with low volume and lesser drag is recommended to achieve a better performance in transition medium. To validate and verify the performance of this RAV, a series of simulation and experiment will be carried out. This RAV is tested and verified of able to fly in the air as well as submerge into underwater and capable of hovering like a normal quad-copter up to a height of 200 cm and submerge about 50 cm of depth. The RAV has successfully achieved the aim of travel in both mediums.

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ABSTRAK

Fokus utama bagi projek ini adalah pembanguan Kenderaan Amphibia Tanpa Pemandu (RAV). RAV dianggap sebagai sejenis kenderaan atau „drone" yang boleh berfungsi autonomi ataupun secara kawalan dari jarak jauh. Istilah "amfibia" ini merujuk kepada kenderaan yang mampu berfungsi dalam dua persekitaran seperti udara dan aquatik. Dalam usaha untuk mencapai tujuan tersebut, keupayaan terbang dan tenggelam telahpun diimplikasikan ke atas RAV. Inovasi ini dapat membantu manusia dalam operasi akuatik serta aktiviti udara. Walau bagaimanapun, ianya masih satu konsep yang baru dengan mempunyai kekurangan dan cabaran. Cabaran seperti peralihan dalam pelbagai medium sangat terhad dan menjejaskan prestasi kenderaan tersebut dari segi keupayaan terbang dan menenggelam. Model yang terdapat di pasaran yang upaya terbang udara dengan mudah, tetapi tidak boleh menenggelamkan didalam air dan sebaliknya. Oleh itu, matlamat projek ini adalah untuk mereka bentuk dan membina sejenis kenderaan yang berupaya dan lebih baik untuk terbang dan tenggelam berbanding dengan model yang sedia ada. Untuk mengatasi cabaran yang disebut, bahan yang lebih kukuh adalah lebih sesuai digunakan untuk fabrikasi badan kenderaan. Isipadu badan kenderaan yang kurang dan keheretan yang rendah membolehkan kenderaan tersebut beralih dengan baik di antara persekitaran. Untuk menjayakan projek ini, pelbagai ujian, percubaan dan simulasi telah dijalankan untuk menelitit prestasi. RAV ini diuji dan disahkan boleh terbang di udara serta menenggelamkan ke dalam air yang mampu bergerak seperti *quad-copter* biasa hingga ketinggian 200 cm dan menenggelamkan kira-kira 50 cm ke dalam air. RAV telah berjaya mencapai matlamat untuk perjalanan dalam kedua-dua medium.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.0 Introduction

At this ever-changing era, the technology of robotics is undeniably getting more and more advanced from day to day. The usage of remote control robot and unmanned drone can be found at every corner of modern country. A leading country like America has already started to utilize the capability of robot and drone to aid in their daily routine. Other than daily routine, this promising technology is being applied on medical field as well. For an instance, a Dutch Engineer had designed an unmanned drone, called Ambulance Drone. This drone has built in webcam and loudspeaker which allow remote doctors to monitor the situation of the victim and instruct the people to help the victim at incident spot.

Knowing that drone comes in very handy in many situations, a lot of engineering experts have already started to design and improve the performance and functionality of drone to a better level until what we are seeing today. One of the famous type of drone can be seen today is Unmanned Underwater Vehicles (UUV). UUV is a kind of drone which is able to operate underwater remotely controlled by human. A drone with this capability gives a big hand to the related field to carry out some dangerous mission underwater. There are two categories under this UUV drone, which are Remotely Operated Underwater Vehicles (ROVs) and Autonomous Underwater Vehicles (AUVs). The difference between these two categories is that ROVs works based on operator command while AUVs operates independently of the operator‟s command. The ROV is widely used

by the underwater researcher to gather some info and data under the sea. Besides, it is also being used for the seabed cleaning purpose.

Seeing that this tech brings a lot of advantages, field experts start coming up with idea applying flying capability to the drone so that it can viable in the aerial as well as in aquatic. Therefore, the term of Remotely Amphibian Vehicle (RAV) starts being used to refer to drone that able to navigate and operate in two different mediums, which is in the aerial and aquatic. In order to enable the vehicle to travel in two mediums, there are quite a few limitations and challenges faced by most engineers during their design stage. Engineers need to solve those limitations such as the design of the body, waterproof issue, thrust required to move the body in both medium and controller issues, so that the vehicle can function well in both mediums. However, experts managed to eliminate and overcome one by one until now what we can find in the market. As this idea is still very recent, not much prototype can be found in the market or being used for any practical application yet.

In order to keep pace with the technology, this idea has been brought into University Teknikal Malaysia Melaka for development purpose. This development includes design and fabrication of the hull of the vehicle, controller design and also thruster design. In year 2014, UTeM has successfully developed an unmanned amphibian vehicle which able to navigate in vertical direction in both mediums. It was a big breakthrough for the vehicle. The vehicle succeeded in sealing the crucial part from water invasion and designing the suitable propellers for the usage in both mediums. This project has not only gained the attention of the university, but also the concern from engineering field and to be believed that this project will be carried forward by other researchers to continue the development.

1.1 Motivation

From what we learnt from history, Malaysia is a country that owns a very strategic position which turned it into one of the most famous and important international trading center. This not only catalyst the growth of the economy of the country, it also creates a lot of investment opportunities. Seeing that Malaysia is a land rich of natural resources, the number of foreign investors never ceases to increase from day to day. Besides natural resources, this historic land is full of hidden treasures buried underground and under the seabed. Until today, groups of archaeologist are still searching and savaging the historical heritages left by the ancients. All these heritages are very expensive in value and protection and maintenance is highly needed. In Figure 1.0, this is one of the famous sunken ships at Selat Melaka, Malaysia. According to the article written by those archeologists, this ship contains a lot of jewelry that value up to billion in price. They stated that anyone would be one of the richest people in the world if they found this.

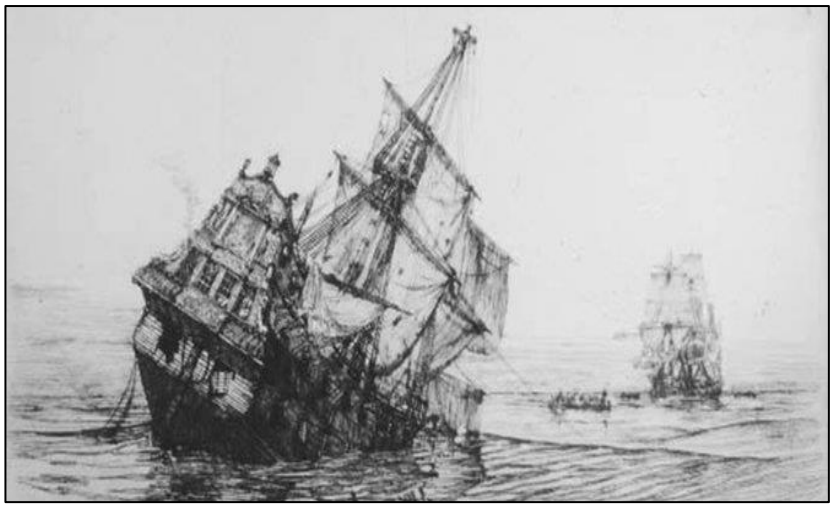

Figure 1.0: Kapal Flor de la Mar.

(Source: http://www.merdeka.com/peristiwa/flor-de-la-mar-kapal-berisi-harta-di-selat-malaka-jadi-rebutan.html)

Somehow, our technique and technology haven‟t reached the requirement to discover this entire heritage by ourselves. With the assists from other, the heritages don‟t fully belong to our country as they took some of the treasures in return for their help. Without proper law enforcement, these value heritages are not secure. A lot of them had been raided earlier by illegal antique collector. All the related fields know these precious

gifts needed to be protected and secured. Thus, some responds have been made to countermeasure all the illegal act of them.

In order to secure all these belongings, our engineers can do nothing but to improve the technology being used to salvage and secure these heritages. Hence, they start to utilize drone to replace the human to work underwater for this heritages‟ salvaging and also patrol the seabed. At here, they feel the urge that they might need to design a better technique and technology to help in these missions. The idea of remotely amphibian vehicle can help to secure the sea from above the sea and also under the seabed.

Apart from that, maintenance of the water dam and bridge makes the job of the worker becomes more risky. Previously, a diver is deployed to examine the wall status of the dam. It is very risky to have a diver to go underwater and check the wall status. Despite strong water current, the diver might put himself in danger when the oxygen going to used out. This situation can be found during the maintenance of the bridge. It is advisable to come with a less risky method to do the maintenance.

The invention of this remotely amphibious vehicle will be big hand for this maintenance job. By just deploying the vehicle, it can help the worker to examine the wall status as well as the bridges. This not only minimizes the job risk, it has also made the maintenance job go smoother and effortless.

1.2 Problem Statement

Remotely Amphibian Vehicle (RAV) is considered a new technology in this era, which not much ready model exists in the market now. The existing models possess several flaws which need to be improved. The existing models face some challenges during the transition in mediums. Several forces acted on the body of the model have been limiting the performance of the vehicle. Buoyant force acted on the body during aquatic, while friction force acted on the body during aerial. Friction force acted on the body can be neglected because it is too small to affect the flight capability. Buoyant force is so strong to be neglected as it creates a force push the vehicle upward. This makes the speed of the vehicle become slower to submerge or transit from aerial to aquatic. Buoyant force defined as the upward force experienced by the body when it submerges partially or completely in liquid.

$$F_b = \rho\, g\, v \tag{1.1}$$

Equation (1.1) of the buoyant force stated the relation between the volume of the vehicle and the density of the water. The gravity has a constant value of $9.8 m/s$, so it is not one variable that will affect the buoyant force. So does the value of density of water, which is $1000 kg/m^3$. The only variable that will affect the buoyant force here is the volume of the vehicle itself. On the other hand, the volume of the object can be related as in Equation (1.2).

$$\rho = \frac{m}{v} \tag{1.2}$$

From the Equation (1.2), the value of density of an object is inversely proportional to the volume of the object. In here, we can see those available models tend to have a smaller density, which contribute to a large buoyant force, which makes the transition in medium becomes challenging. Although some of the models have a denser body, but the ability of withstanding water pressure is not as good as expected. Therefore, the range of operation in water is limited. Furthermore, there is a density change from aerial to aquatic as illustrated in Figure 1.1.

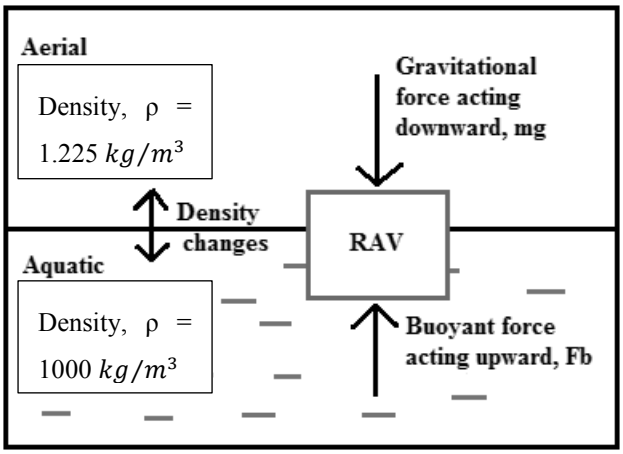

Figure 1.1: Density Changes

Some of the ready models tend to have a robust performance in movement speed and transition in between mediums, but the operating range of the controller in aquatic is shorter than expected. This limitation caused by the operating frequency of the controller.

Higher range of operating frequency is being used for a larger operating distance. But, transmission of frequency serves different in both aerial and aquatic. Operating range of controller becomes shorter in aquatic due to the attenuation of radio waves. From the equation 1.3, the relationship between radio signal attenuation and conductivity of the medium is stated.

$$Attenuation(\alpha) in \frac{dB}{metre} = 0.0173\left(\sqrt{f\sigma}\ \right) \tag{1.3}$$

Attenuation is affected by the conductivity of medium, σ and operating frequency, *f*. Transition from a less conductivity medium into a more conductivity medium which is from aerial to aquatic. Attenuation of radio signal increases significantly in transition in the mediums.

Next, previous models are using different types of mechanism for different mediums. Hence, to operate in two mediums required two different techniques can induce several drawbacks such as decrease in speed and battery lifetime due to increased weight. Yet, to achieve the best range of both mediums is quite impossible due to several reasons. It is only desired to improve one of the ranges of operation without affecting the other one significantly.

1.3 Objectives

There are objectives for this project listed as follow:

1. To design and develop a Remotely Amphibian Vehicle (RAV) that can operate in both aerial and aquatic based on selected design.
2. To analyze the performances of the RAV in terms of robustness and durability.

1.4 Scope

There are few scopes and challenges for this project are listed as follows:

1. The hull design has to be negatively buoyant and low volume body. The negatively buoyant body is to reduce the time taken for transition in medium, while the low volume body is to create a denser body that will contribute to performance of transition.

2. The vehicle needs to submerge about 0.5 meter depth and fly about 2 meter height in the air in vertical direction, z-axis. Motion in vertical direction along z-axis is the main focus for this vehicle. The movement speed of the vehicle will be examined. Vehicle‟s performance is based on the body structure design. A light weight solid body structure design is favored to create less drag and resistance during movement in both mediums.

3. The vehicle need to be tested in both aquatic and aerial, to see if the vehicle able to travel in underwater as well as in the air. Test will be carried out in a large water tank with volume of $15m^3$ in the lab and also in an open area which is safe for experiment purpose.

1.5 Summary

All the fundamental information about this project are included. In order to provide a more efficient solution for all the problems stated, concept of drone that able to travel in both mediums is implemented. A Remotely Amphibian Vehicle (RAV) is to be designed and developed. Objectives are stated clearly so that project can be done successfully within due. Scopes and challenges are listed such as hardware design expectation, operational range and so on. Its purpose is to ensure the performance of the RAV hit the expectation. All these elements are very important in completing this project.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter will cover the analysis and evaluation of the journals and studies related to the RAV. Several selected journals will be compared and studied and the outcome will be recorded in this chapter. The criteria to be studied are the architectural design of the main hull, the design of the propeller and the operating frequency of the controller. Designs will be compared and take what‟s best to be implemented into RAV. Most interests are placed on previous studies such as an unmanned underwater vehicle, hybrid unmanned aerial underwater vehicle, quad-copter and triple tilting rotor unmanned aerial vehicle. All the designs will be discussed and a simple evaluation will be made.

2.1 Architecture of Platform

This section discusses about how to utilize some of the conceptual design and implement it into the development of the RAV. From journals, the method and idea used by the authors to improve the device or vehicle‟s performance found to be very helpful in designing amphibious vehicle. Method like water-sealing is important to design an amphibious vehicle because the controller part needed to be sealed from contacting with water. Besides, it is important to design an architecture that can provide a better experience of movement in both mediums. In order to design a robust RAV, it is required to refer and extract some beneficial design concept from previous success example. Things go differently when the vehicle goes in aquatic from aerial. Therefore, at here the most

suitable and compatible fuselage for the RAV will be determined and designed to solve and improve our problem statement.

2.1.1 Architecture Design

As explained in [1], the developer chosen the architectural concept of a torpedoes-shaped for their vehicle for several purposes. The vehicle they design is a Small Unmanned Underwater Vehicle (SUUV), which able to navigate and perform tasks underwater. This torpedo-shaped body is mends to achieve the objective of light weight, smaller in size, better in mobility and also a wider range of activities. Studies show that water resistance and drag can be lowered with this body shape, which possessed some positive contribution to the vehicle traveling speed. With this cylindrical body, the vehicle has a better endurance towards the pressure. Talking about diving, the main frame of the vehicle is made of nylon. Nylon can provide a better diving condition as it is very close to neutrally buoyant where the body will have an equal body density to the density of fluid when it‟s immersed. The movement of the vehicle is supported by the level thruster mounted on its rear part. The level thruster comprised of several parts and that make the vehicle owns a degree freedom up to six. The main advantage of this design is it has a robust body design and also better adaptability with six degrees of freedom. However, this design only suitable for shallow and stable water task as its hull is very light. It might not able to remain stable when it comes to a turbulent flow of water.

From [2], it is an Unmanned Underwater Vehicle, (UUV) that mostly found to be used for seabed scouting and the sea chest cleaning purpose for sea bio-security. This vehicle designed based on the architectural concept of torpedoes and submarine, which is why the vehicle has the bulky size of a submarine and a cylindrical hull of a torpedo. This is a low cost design and development vehicle. All the materials and components that used to develop this vehicle possessed optimum performance and spec, but also come in a very reasonable price. This UUV is equipped with several types of sensor used for underwater mission. The developer chose to apply the simplest method to provide the vehicle mobility. By applying two propellers and four thrusters to the vehicle, it now can move in a forward and backward direction. The thrusters are to ascend and descend the vehicle. This combination of motors makes the vehicle have more degree of freedom in the water. It can carry out any desired mission freely in the underwater now. The main benefit of this

vehicle is that its hull can fit in quite a number of components such as sensors, batteries, electronic components and so on. The cylindrical hull design has a strong endurance towards load or pressure underwater. It has no concern carry a number of components with it underwater. However, the bulky design of the vehicle doesn‟t really allow the vehicle to work in a narrow or limited space. Besides, two propellers and four thrusters consume a big amount of power. The power will be drained out shortly.

All the two previous journals are mentioning a topic related to UUV, while in [3] will bring in a new different topic. In this journal, the authors will introduce about the combination of technology of both aerial and aquatic into one vehicle. Hybrid Unmanned Aerial Underwater Vehicle (HUAUV) is completely a new achievement in this field. This vehicle is to be deployed for underwater and aerial operation. The design of this vehicle enables it to have the capability to navigate in both environments without any mechanical adaptation. It is designed based on a quad rotor-like aerial platform. The only difference between this vehicle and quad copter is just the thruster part. This vehicle used four aerial propellers and four aquatic propellers. It has considered several factors that will affect the performance of the thrusters such as the density of the medium. These eight propellers are specially designed and manufactured so that it can sustain the weight of the vehicle in both mediums. Obviously, the main advantage of this design is that it can travel freely in both medium and perform the desired task and mission. The battery capacity is always a limiting factor to all these vehicles. Seeing it needs to operate eight propellers at once, which is a very high power consuming activity. The consequence of this HUAUV will be the same as the previous design. The battery will be drained out shortly.

Based on what‟ve been stated in [4], the Authors are targeting a multifunction and a high-adaptive small scale indoor Unmanned Aerial Vehicle (UAV). The design of the vehicle found to be very common and just a slightly different from others. The objective of development is to deploy this vehicle into multiple tasks and missions such as searching, investigating and so on. For military uses, the vehicle might need to carry out mission under a critical and highly dangerous environment. Some need to work under an environment which exposed to high number of radioactive objects. To be able to work against all these resistances, a corresponding component needs to be added. Thus, the weight of the vehicle will increase, which might affect the performance of it. This paper mainly focuses on the overall system design and detailed design in each specific system. Besides, the Authors also includes few existing algorithms which aid in stable flying of the

traditional quad-copter. The overall design is just as simple as other UAV. The shielding applied to vehicle might act as a protection to the controller part of the vehicle. Their foremost advantage of this UAV is that it can be modified accordingly to the environment it‟s going to work in. Furthermore, it is provided with the shielding where we cannot see in other UAV. This improves the safety level of the vehicle. The only disadvantage is that it doesn‟t have protection on the propeller part. Flying indoor might faces a lot of physical obstacles such as walls. Collision with any of this obstacle might bring damage even malfunction of the whole vehicle.

The structural design of the vehicle somehow shares a minor contribution to the maneuverability of the vehicle. From [5], it is discussing about a different kind of unmanned aerial vehicle. It is a three-rotor configuration of rotorcraft. Instead of four rotors, it only consists of three which help to develop a more compact and miniature vehicle. This UAV is called as Delta. The Authors have utilized some certain structural advantages to achieve a better performance in attitude stabilization. The main aim of this developing is to deploy this UAV for reconnaissance and surveillance missions according to the author. In order to provide a better visual perspective of “blind” areas during the mission, such vehicle or device is highly recommended. Furthermore, this UAV is equipped with gyroscopic and piezoelectric sensors to for the purpose of maintaining the horizontal attitude of UAV. The body of the UAV is manufactured with carbon fiber material. It is very robust and appropriate material to fabricate the body. Other than strength, carbon fiber is a very light weight material. This not only reduces the burden of the thruster, but also extends the lifespan of the battery. By comparing current design with the quad-copter, the payload of this UAV has a far more satisfying number. The most auspicious advantage of this vehicle is the maneuverability and the compact design of the fuselage. The only disadvantage is that it might not able to perform heavy task like lifting heavy object due to its compact size.

2.1.2 Comparison on Architecture Design

The following Table 2.0 shows the comparison between the architectural designs of selected different kind of unmanned vehicles. Brief explanation and description are included in the Table 2.0. The advantages and disadvantages of each architecture design are being discussed and evaluated as given.