DESIGN AND DEVELOPMENT OF SPHERICAL AMPHIBIAN VEHICLE (SAV) – FOCUSING ON TERRESTRIAL ENVIRONMENT

MOHAMAD SHAFIQ BIN ANUAR
B011710155
980122-87-5021

BACHELOR OF MECHATRONICS ENGINEERING WITH HONOURS
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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MOHAMAD SHAFIQ BIN ANUAR

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DECLARATION

I declare that this thesis entitled "DESIGN AND DEVELOPMENT OF SPHERICAL AMPHIBIAN VEHICLE (SAV) – FOCUSING ON TERRESTRIAL ENVIRONMENT" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Mohamad Shafiq Bin Anuar

Date : 6/7/2021

APPROVAL

I hereby declare that I have checked this report entitled "Design and Development of Spherical Amphibian Vehicle (SAV) – Focusing on Terrestrial Environment" and in my opinion, this thesis it complies the fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : ……………………………………

Supervisor Name : Prof. Madya. Dr. Mohd Shahrieel Bin Mohd Aras

Date : 6/7/2021

DEDICATIONS

To my beloved mother and father

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ABSTRACT

This project focuses on the design and development of Spherical Amphibian Vehicle (SAV), focusing on terrestrial elements for the vehicle. Most vehicles today mainly conform to a rectangular/cuboid shape, so what if vehicles of the future change its shape to a circular/spherical shape? This project is to research on the potential of a spherical type vehicle and learn if it is viable for future vehicles. The objectives of the project are to design the SAV using 3D modelling software such as SolidWorks and to evaluate the stability of the SAV when performing basic movements. The SAV prototype for this project would only consider the terrestrial aspect, and would not exhibit any aquatic qualities. The main drive system for the SAV uses a motorized drive shaft and a pendulum to steer. A gyroscopic IMU sensor is placed within the SAV to transmit the SAVs stability performance by showing its rolling and pitching angles during idle and any movement. The design for the prototype was successfully modelled in SolidWorks. For the performance evaluation, a movement stability test is done to quantify the overall stability of the SAV. Results were taken with a specification of stability; the tolerated angles should be within range of -5° to 5° of the expected angles. Results show that the SAV prototype is very stable based on averaging angles but by viewing the minimum and maximum data recorded were off the tolerated angle range. Therefore, the SAV prototype developed is considered as partially stable.

ABSTRAK

Projek ini memfokuskan pada reka bentuk dan pengembangan Kenderaan Amfibia Sfera (SAV), yang memfokuskan pada elemen daratan untuk kenderaan tersebut. Sebilangan besar kenderaan pada masa ini terutamanya sesuai dengan bentuk segi empat tepat / kuboid, jadi bagaimana jika kenderaan masa depan mengubah bentuknya menjadi bentuk bulat/sfera? Projek ini adalah untuk meneliti potensi kenderaan jenis sfera dan mengetahui sama ada kenderaan tersebut layak digunakan untuk kenderaan masa depan. Objektif projek adalah untuk membuat reka bentuk SAV menggunakan perisian pemodelan 3D seperti SolidWorks dan menilai kestabilan SAV ketika melakukan pergerakan asas. Prototaip SAV untuk projek ini hanya akan mempertimbangkan aspek daratan, dan tidak akan menunjukkan kualiti air. Sistem pemacu utama untuk SAV menggunakan poros pemacu bermotor dan pendulum untuk mengemudi. Sensor IMU giroskopik diletakkan di dalam SAV untuk memancarkan prestasi kestabilan SAV dengan menunjukkan sudut putaran dan nada semasa tidak bergerak dan pergerakan apa pun. Reka bentuk untuk prototaip berjaya dimodelkan di SolidWorks. Untuk penilaian prestasi, ujian kestabilan pergerakan dilakukan untuk mengukur kestabilan keseluruhan SAV. Hasil diambil dengan spesifikasi kestabilan; sudut bertoleransi hendaklah berada dalam lingkungan -5 ° hingga 5 ° dari sudut yang diharapkan. Hasil kajian menunjukkan bahawa prototaip SAV stabil berdasarkan sudut rata-rata tetapi dengan melihat data minimum dan maksimum yang dirakam berada di luar julat sudut yang ditoleransi. Oleh itu, prototaip SAV yang dikembangkan dianggap stabil sebahagiannya.

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mm	-	Millimeter
°	-	Degree

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter would explain the motivation, the problem statement, Objectives and scope of the project in design and development of Spherical Amphibian Vehicle, focusing on terrestrial environment. This project is primarily focusing on the terrestrial environment aspect of the SAV.

The Spherical Amphibian Vehicle is a vehicle that could be used on land, can enter bodies of water and submerge underwater. It can be classified as an all-terrain vehicle, capable of movement on rugged land like normal land vehicles with added features of a submarine, submerging deep into the ocean depths.

1.2 Motivation

Vehicles have been a part of human engineering since the usage of animals for transport and then the invention of the wheel. Vehicles have many applications from transporting people, cargo, goods and many more across distances with time. They came in many forms from land-based vehicles such as cars and lorries, air-based vehicles such as aeroplanes and helicopters, and water-based vehicles such as boats, jet skis, and submarines.

Among these vehicles, there are vehicles that are amphibious in nature. Able to be used on land and in water. One such vehicle is the hovercraft. Hovercrafts, also known as Air-Cushion Vehicles, are capable of travelling on water, land, ice, and many other types of surfaces. It is an all-terrain vehicle that utilizes blowers that produce a very large volume of air underneath it inside a cushion which allows the vehicle to float above a contacted surface. Amphibious vehicles have been in use in many types of applications most notably in military activities such as surveillance systems, scientific research, search and rescue missions, and Ocean exploration. The various activities that amphibious vehicles can be utilized in could be beneficial for the progress of human evolution.

The surface of the Earth has various structures from valleys and fields, jungles and forests, hills and rocky-mountains, rivers and lakes, to vast oceans that are unreachable by humankind. 71% of the Earth is covered by water/ocean, and only a fraction of it has been explored. Ocean exploration is still a growing field for researchers. Earth is also prone to Natural Disasters that comes in many forms; Land base disasters such as Earthquakes, Landslides, and Volcanic Eruptions; Water based disasters includes Floods and Tsunamis; Wind based disasters such as Hurricanes, Tornados, and Typhoons; Search and Rescue missions must be done as soon as possible to help victims from losing their lives

Vehicles comes in many forms. Normal vehicles such as cars, vans, buses and lorries would conform to a rectangular shape as it would be natural and contain high stability. But what if vehicles are spherical? Spherical vehicles have been shown in concept arts and researches of how future vehicles would look like. Researchers worldwide have made an astonishing lot of research on trying to create a real-life spherical vehicle and have proven it is possible. Spherical Vehicles could have many potential applications in the field of Scientific research, exploration, search and rescue activities and military applications.

1.3 Problem Statement

The main issue of Spherical robots/vehicle is its stability. With a spherical body, the contact surface on the ground is very minimal. Having a well-balanced mass would be a challenge.

1.4 Objectives

These are the few objectives that is to be achieved at the end of this project. The objectives of this project are as followed:

1. Design and develop a prototype of Spherical Amphibian Vehicle in small scale as a Robotic system using 3D Design applications (Fusion360/SolidWorks)

2. Evaluate the Spherical Amphibian Vehicle's stability when moving on a flat surface in basic directions; Forwards, Forward-right, and Forward-left

1.5 Scope

For this project's scopes,

- The design process of the robot is only considering the terrestrial aspect of the Spherical Amphibian Vehicle.

- Design the prototype using 3D Modelling software such as Fusion 360 or Solidworks

- The prototype is able to have movement in basic directions; Forwards, Forward-Left, Forward-Right; with a limit of 2-Degrees of freedom while on land (Terrestrial Environment).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Literature review is an important part to reviewing past research on the relevant subject and to view past problems. This chapter will cover past projects that have been done on Spherical Robots and Amphibious vehicles, the requirements of driving principles for the spherical robot, and how to control the Spherical robot’s stability while it is performing basic movement.

2.2 Spherical Robots and Driving Principles

Spherical robots are ball-shaped mobile robots, uses a spherical external shell as its body with an internal driving mechanism that provides the mobile robot its movement features and control. The most common movement for spherical robots is by rolling on its spherical shell performed using its drive mechanism. The internal driving mechanism of spherical mobile robots comes in various ways. The main three driving principles are centre of mass manipulation, Variable gyrostatic momentum generation, and shape deformation.

Centre of mass manipulation is the most common of all the driving principles. The driving principle works by changing the location of the internal mass of the mobile spherical robot from a point to another point. This principle can be divided into three main mechanisms; Cart-based, Rotating Pendulum-based, and Advance Pendulum Base. Each of the mechanisms have its own way of changing the spherical robot’s centre of mass. Figure 2.1 shows the several types of center of mass manipulation drive mechanisms (Bazli *et al, 2018).*

Figure 2.1 Centre of Mass Manipulation drive mechanisms

2.3 Center of Mass Manipulation Drive Mechanisms

Cart-based centre of mass manipulation was proposed by several researchers in their respective papers. S. Addanki et al [1], and Nakasima et al [2] designed a spherical robot utilizing an internal cart that uses two or more motors connected to tires to control the motion of the spherical shell. The internal cart would be weighted at the entire bottom half section of the mobile spherical robot which makes it centre of mass as low as it can be. This would make it very stable compared to other drive principles. Figure 2.2 shows an internal cart system utilized by Virgo Series Robot. Though the movement of these type of drive system is the most agile of all drive principles, the internal cart system has issues of tire slipping. Tire slipping occurs when the internal cart is moving too fast, the tires would just slip on the internal surface of the sphere.

Figure 2.2 Virgo Series Robots

The internal cart design was then further developed by Y. Huang et al [3] and Y. L. Karavaev et al [4]. Figure 2.3 shows the newly designed internal cart utilizing omnidirectional wheels or a version of “Mechanum” wheels with additional elastic support for the wheels to be more in contact with the internal sphere surface. The omnidirectional wheels provide more manoeuvrability for their spherical mobile robot, allowing it to strafe left and right while moving forwards and backwards. The addition of the elastic support has proven to be a substantial improvement of the previous design but does not eliminate the slipping issue entirely.

Figure 2.3 Improved Internal Cart-Based drive mechanism

A different driving mechanism for centre of mass manipulation is using rotating pendulums inside of the mobile spherical robot. Proposed by G. Rigatos et al [5], M. Yue et al [6], and L. Wang et al [7], weighted pendulums located inside the robot hangs from the centre and is connected to a motor, either a DC motor or a servo motor. The rotation of the pendulum using the motor would change the spherical robot’s centre of mass, thus providing a rolling moment for the sphere shell. This type of drive mechanism is not the best for rolling up steep surfaces as the rolling moment is just not enough to provide the essential speed. Though it has less continuous speed of rolling, it can however allow the spherical robot to perform a leaping motion by swinging the internal pendulum rapidly in a specified direction, a kind of surging motion. Further development was made by B. P. Dejong et al [8], by adding multiple pendulums inside their Spherical Robot, pictured in Figure 2.4. Using multiple pendulums improves the robot’s locomotion. Multiple angled yaw motion was achieved and allows the robot to have higher torque than its predecessor’s design, allowing for better movement on rough surface travel.

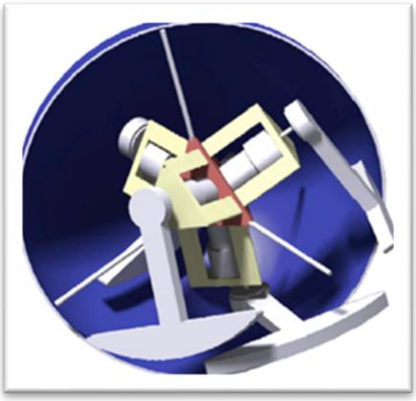

Figure 2.4 Multiple Pendulum-Based Robot by B.P. Dejong et all [8]

Another driving mechanism for manipulation of centre of mass is an Advance Pendulum-based drive mechanism. This drive mechanism has its similarities to the previous drive mechanism, utilizing a pendulum, in addition to another mechanism that allows for better control, speed, and torque additions. S. Moazami et al [9], and Joochim et al [10] proposed a sliding Pendulum base drive mechanism pictured in Figure 2.5. This mechanism allows the spherical robot to move the pendulum to the sides using the shaft utilising a belt with motor perpendicular to the pendulum which allows it to roll sideways.

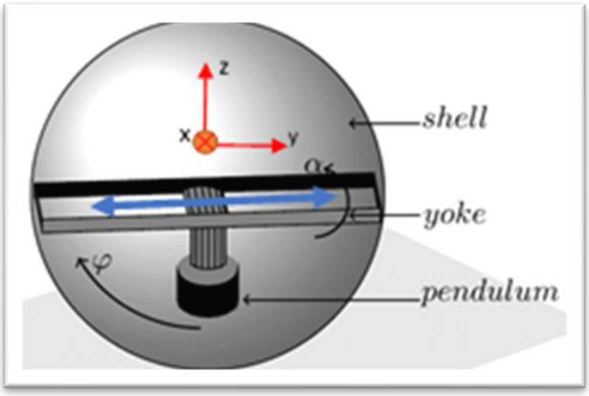

Figure 2.5 Sliding Pendulum Drive mechanism

Furthermore, J.V. Raj et al [11], Y. Ping et al [12], and Q. Zhan et all [13] proposed a spherical robot that uses a rotating pendulum with a motorized drive shaft as shown in Figure 2.6. This robot uses two types of motors, one motor to rotate the pendulum for steering the spherical robot, and one motor for rotating the spherical robot forwards and backwards. This configuration allows for better performance in terms of its movement potential, allowing it to have high torque and speed, better control on rough surface travel and has high stability. Although the spherical robot utilizing this drive mechanism has good performance, it takes a lot of space for the pendulum to move in.

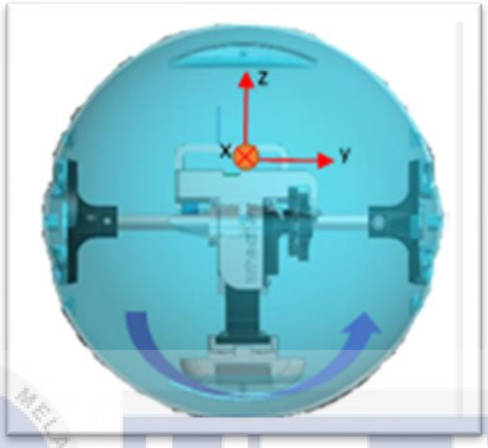

Figure 2.6 Rotating Pendulum with motorized drive shaft

2.4 Mobile Robot Operation

Mobile robots have many ways of communication to perform actions and tasks intended for its design. Different types of robots require a specific type control system. The Spherical Amphibian Robot to be made for this project is a mobile robot. For mobile robots, there are multiple options; Remote controlled, Autonomous operated, and Semi-Autonomous operated. Each type of operation has its advantages and disadvantages

Remote controlled mobile robots use an external controller that requires human input to be operated. Remote operated mobile robots commonly use Radio Control (RC) transmitters and receivers for control of the robot at a distance. Popular systems that use the conventional RC transmitter and receiver system are Unmanned Aerial Vehicles or UAVs, commonly known as Drones. Radio-controlled aircrafts and quadcopters are in use today for many activities such videography and photography usage, military surveillance, and search and rescue efforts. UAVs and drones mainly