UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DESIGN AND DEVELOPMENT OF A SPHERICAL ROBOT

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the the Bachelor's Degree in Electrical Engineering Technology (Industrial Automation & Robotics) (Hons.)

by

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DECLARATION

I hereby, declared this report entitled "Design and Development of a Spherical Robot" is the results of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the Bachelor's Degree in Electrical Engineering Technology (Industrial Automation & Robotics) (Hons.). The member of the supervisory committee is as follow:

………………………………….

(En Aminurrashid Bin Nordin)

ABSTRAK

Robot sfera mempunyai dua hemisfera yang saling berhubung dengan dua sendi putar dan satu sendi prisma. Projek ini adalah mengenai mereka bentuk dan membangunkan sebuah robot sfera yang boleh dikawal menggunakan protokol tanpa wayar. Projek ini memberi tumpuan kepada prestasi robot semasa ia melakukukann pergerakan. Sebuah robot sfera direka dan dikawal oleh telefon pintar melalui komunikasi tanpa wayar Bluetooth. Dengan menggunakan Bluetooth had penggunaan kawalan berasaskan berwayar boleh diatasi. Robot sfera terdiri daripada cengkerang sfera, Arduino Uno, L289P motor perisai pemandu, modul Bluetooth, Micro DC motor gear dan antara muka pengguna grafik (GUI). Robot sfera menggunakan prinsip mekanisme roda yang dipandu dimana pusat graviti adalah tertumpu di bahagian bawah bahagian mekanikal robot. Oleh itu, mekanisme yang digunakan membolehkan robot berada pada kedudukannya apabila robot sfera melakukan sebarang pergerakan. Dari eksperimen yang dijalankan, robot sfera ini mampu untuk melakukan pergerakan diatas pelbagai bentuk rupa bumi yang berbeza seperti jalan tar, permukaan rumput, permukaan simen dan permukaan mozek. Robot sfera juga juga mempunyai keupayaan untuk mengelak halangan yang terdapat di hadapannya. Permukaan jenis tar merupakan permukaan yang terbaik untuk robot sphere melakukan pergerakan.

ABSTRACT

A spherical robot is a two interconnected hemisphere with two rotary joints and one prismatic joint. This project is about designing and developing a spherical robot that can be controlled using wireless protocol. This project focuses on the performance of the robot while it performs the locomotion. A Spherical robot is designed to follow instructions from the smartphone via Bluetooth wireless communication. By using Bluetooth the limitation of using wired based control can be overcome. The spherical robot consists of spherical shells, Arduino Uno, L289P motor driver shield, Bluetooth module, Micro DC gear motor and graphic user interface (GUI). The mechanism of a spherical robot is using the wheel driven principle which the center of gravity is focuses at the bottom of the mechanical part. Thus, the mechanism used is still on its position when the spherical robot performs the locomotion. From the experiment, this spherical robot is capable to perform the locomotion in different terrains such as tar road, grass surface, cement surface and mosaic surface. The spherical robot also has also the ability to avoid the obstacle which obtains in front of it. The spherical robot is best performing on the tar road surface.

.

DEDICATION

Specially..

To my beloved mother

To my kind brothers and sisters

To my kind lectures

And not forgetting to all friends

For their

Love, Sacrifice, Encouragements and Motivation

ACKNOWLEDGEMENTS

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LIST OF SYMBOLS AND ABREVIATIONS

PC	-	Personal Computer
GUI	-	Graphic User Interface
PID	-	Proportional-Integral-Derivative Controller
PD	-	Proportional-Derivative Controller
A/D	-	Analog To Digital
RF	-	Radio Frequency
R/C	-	Radio Controller
RP	-	Rapid Prototype
ABS	-	Acrylonitrile Butadiene Styrene
DC	-	Direct Current
GPS	-	Global Positioning System
UART	-	Universal Asynchronous Receiver/Transmitter

CHAPTER 1

INTRODUCTION

Recently, the spherical robot was really accustomed to many people because of the growth in technology. Many researchers and highest education institutions also show their interests in the growth development of the new innovative spherical robot with special characteristics and functions. What is a spherical robot exactly? The spherical robot is a robot consisting of two type of joints which are rotary joint and prismatic joint. An arm attached to the spherical robot forms a spherical coordinate system. The spherical coordinate system is a coordinate system for the three-dimensional space. Regardless of the characteristics of the spherical robot, the mechanical and control component of the robot were compressed inside the spherical shell and it provides great advantages to it. The spherical robot is proficient to accomplish the omnidirectional locomotion due to its spherical shape and geometrical symmetry. The variations of the design and purposes of the spherical robot show the attractiveness to the new researcher. This project is simply to design the spherical robot with the capability to perform omnidirectional locomotion and capable to control the motion of the robot using Bluetooth which applies to a smartphone.

1.1 Project objectives

The objectives of this project are as follows:

a. To design a spherical robot that can be controlled wirelessly using Bluetooth.
b. To develop a graphic user interface (GUI) to control a robot locomotion using a smartphone.
c. To analyze the locomotion of the spherical robot.

1.2 Project Scopes

By narrowing the needs for this project, a few guidelines are proposed to ensure that this project will achieve its objectives. The scopes covered for this project are:

i. To design a 12cm diameter of spherical robot that can be controlled wirelessly using Bluetooth by utilize the serial communication protocol and using Arduino Uno as a controller to control the robot.

ii. To develop graphic user interfaces (GUI) of MIT app inventor to control the locomotion using a smartphone

iii. To analyze the locomotion of the spherical robot on five different surfaces and tabulate the data.

1.3 Problem statements

The mechanical issues are very important in a spherical robot especially for its locomotion due to its spherical shape, arrangement of the components and the size of the robot itself. There are several principles can be used to implement the mechanical part for the spherical robot such as the wheel driven principle, the gear and pulley principle and pendulum principle. For this project the principles of wheel driven principle was used to ensure the locomotion of the robot due to its application and more practical.

Another important issue is the robot communication. Since the mechanical part and control element were located inside the robot, the communication interface used to control the locomotion of the robot is very important. There are two methods of communication that can be implemented which are by cable and wireless. In order to build the locomotion controller, the wireless method is more rational and more convenient for this project.

1.4 Project Overall System

At the input block, there are a power supply unit, a Bluetooth module and L289P driver motor shield. This project uses Arduino Uno as a controller and it control two DC motor as illustrated at output block. Figure 1.1 shows the overall block diagram for this project.

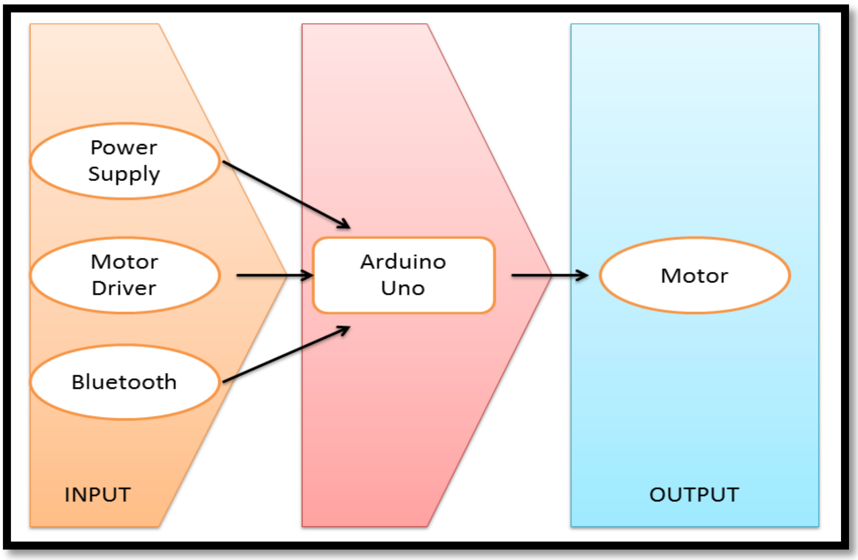


Figure 1.1: Overall Block Diagram

The spherical robot is controlled by GUI which was developed into a smartphone which communicate using Bluetooth module as it transmitter. The developed GUI controls the movement of the spherical robot. The overall system flow is shown in Figure 1.2.

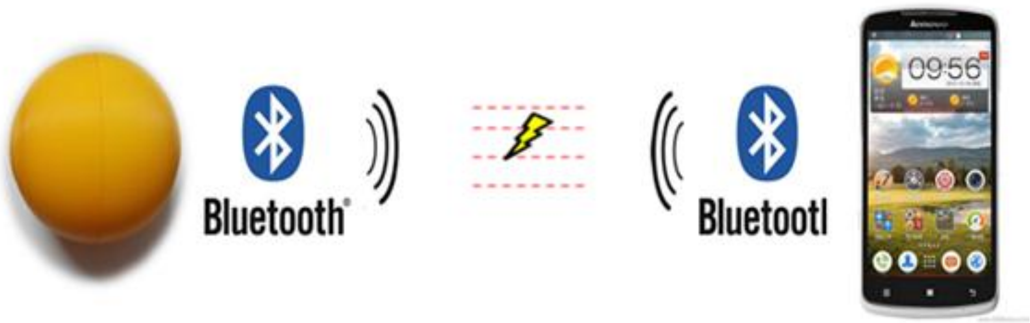


Figure 1.2: Overall System Flow

1.5 Thesis Outline

The structure and layout of the thesis are as follows:

Chapter 1 – Introduction: This chapter discusses a short introduction on the project which covers the objectives, scopes of the project and the problem statements.

Chapter 2 – Literature Review: This chapter describes what is a spherical robot and the existing spherical robot which have been developed by the previous researchers. It also consist of the information which will be the parameter for developing this project

Chapter 3 – Methodology: This chapter discourses the methods used for developing the project and also approach taken in order to complete the project.

Chapter 4 – Project Development: This chapter deliberates about the early conceptualization stage in designing of the robot until it completion. The hardware parts, electrical and electronics parts and the software used will be highlighted.

Chapter 5 – Results and Discussion: This chapter expresses the result and findings of the experiment. The findings results were analyzed and discussed. The problem encountered in this project will be highlighted as well.

Chapter 6 – Conclusion and Recommendations: This chapter concludes the entire project and converse the augmentation that can be done for future project.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the articles and journals related to this project. Similar products have been developed by researchers in other higher learning institutions previously. The theory and implementation of the components, equipment and programming language used in the previous project are discussed here.

2.1 Spherical Robot Design

Deepak Pokhrel et al. (2013) stated that the spherical robot may be the most significant design due to its easy maneuverability, holonomic nature and omnidirectional movement. The pendulum-based drive system is used as a driving mechanism due to its relatively simple design. There are boundless restrictions on how the shell is made. The design consists of three basic units which are namely as an outer shell, inner drive unit and pendulum arrangement as shown in Figure 2.1. The gear drive is used in order to keep the mechanical design simple and powerful. Two halves of spherical shell design is used to ease the manufacturing and assembly.

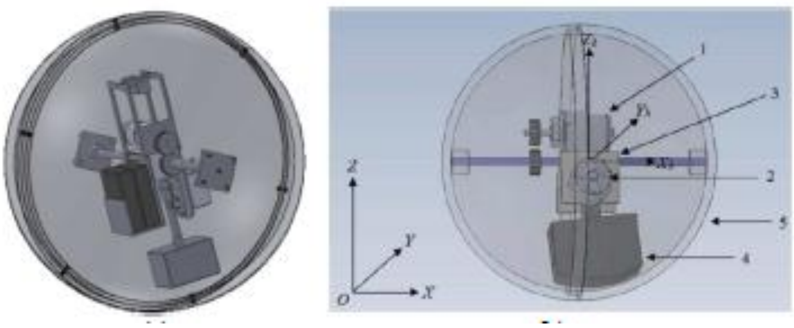


Figure 2.1: 3D CAD view of assembly

Jayoung Kim et al. (2009) introduced the pendulum–driven spherical mobile robot. The glass fiber sticks are chosen as an external frame of the robot due to their good elastic characteristics. All the control modules are embedded into the spherical mobile robot and the Atmega 2560-based embedded system is used as the main controller to drive the robot. The implementation of PID controller is verified based on good mobility of the robot. The pendulum-driven spherical robot was a dynamic model for steering motion and analyzing driving. The driving mechanism of the pendulum-driven type robot is shown in Figure 2.2.

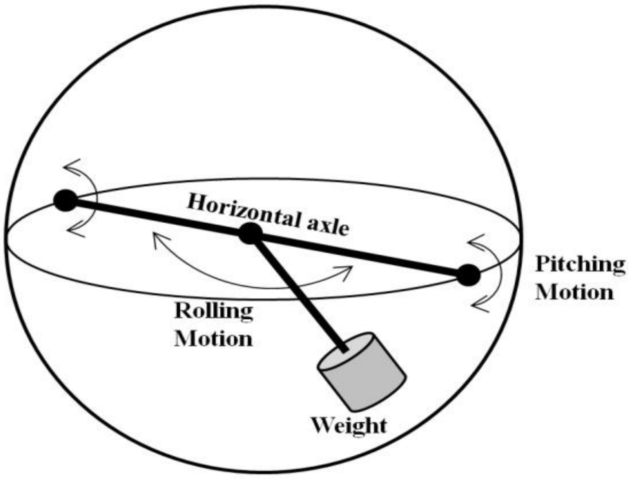


Figure 2.2: The driving mechanism of the pendulum-driven type robot

Petch Jearanaisilawong et al. (2009) introduced the novel mechanical design of three-legged reconfigured robot. The robot body consists of two hemispherical shells and three legs. The outer hemispherical shell is made of acrylic glass based on its durability and light weight. The outer shell is designed to accommodate the internal control board, power source, folded legs and additional space for mission related. The robot can transform from dominant form to reconfigured robot and the transformation process is driven by the motor at each of the joint segment. The dominant form of the robot is shown in Figure 2.3 and the robot which undergoes transformation is shown in Figure 2.4.

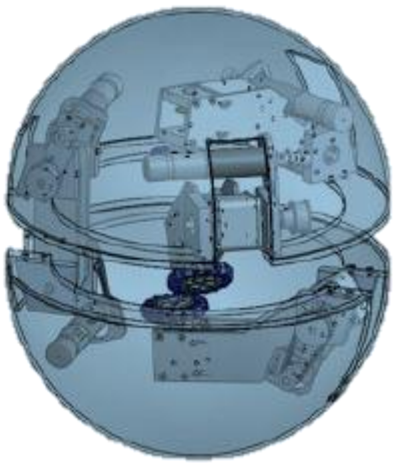


Figure 2.3: Dominant form

Figure 2.4: Reconfigurable robot after transformation

Design and kinematic analysis of an amphibious spherical robot is the novelty by Shuxiang Guo et al. (2012). A mother-son multi-robot cooperation system named GSL system is introduced to solve the locomotion velocity and enduring time. The amphibious robot is the mother robot while the several micro-robots are the son robots. The GSLMom robot is designed as an amphibious spherical one with fixed hemisphere hull and two opened quarter ball hull shape as shown in Figure 2.5. Four units of locomotion were equipped by the robot and each unit consists of a water jet propeller and two servo motors.

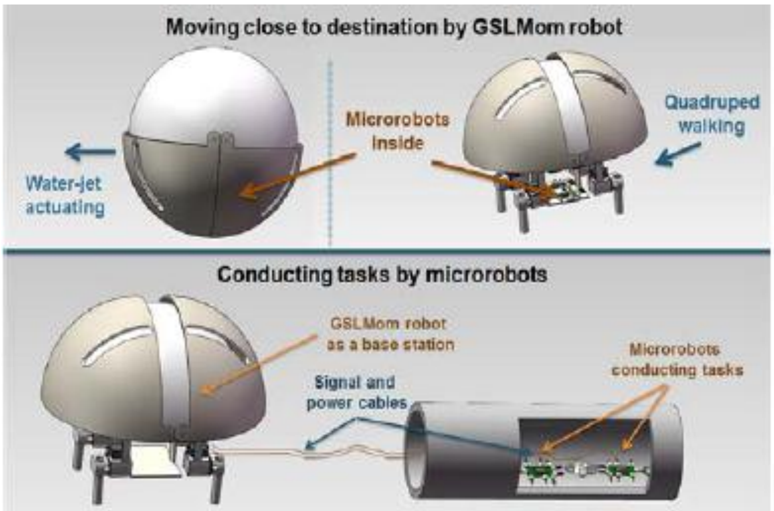
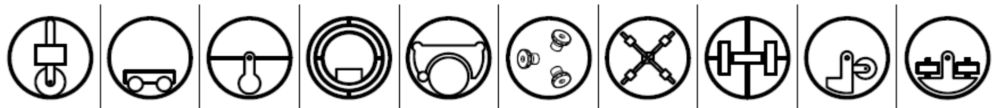


Figure 2.5: The GSL mother-son robot system

2.2 Locomotion of Spherical Robot

Qiang Zhan et al. (2011) designed a novelty spherical robot with omnidirectional which composed of a lucent ball-shaped shell and an internal driving unit. To attain the omnidirectional motion of the robot, two motors were installed on the internal driving unit. One motor was used to perform straight movement and another one was used to make it steer. The spherical robot was used barycenter principle offset to drive the center of gravity which deviates from the static position. By applying that, it can break the system balance when the gravity moment were produced and cause the robot to roll.

Design and implementation of an omnidirectional spherical robot *Omnicron* were designed by Wei-His Chen et al. (2012). Three omnidirectional wheels were used instead of using wheels or flywheels which installed inside the spherical shell and controlled independently. Without any singularity condition of the 3 degree of freedom planar omnidirectional mobility of the robot can be done by the simple forward 3-to-3 kinematic mapping. The characteristics of the developed spherical robot are shown in Figure 2.6.



Robot Configuration	Single wheel	Hamster car	Pendulum on rotating axis	Gimbal mechanism	Single ball	Omni wheels	Mass movement	Orthogonally mounted flywheels	Flywheel on pendulum	Parallelly mounted flywheels
Driving mechanism	D	D	D		D	D	G	A	D/A	A/G
Input needed/ Output DOFs	2/2	⩾ 2/2	2/2		2/2	3/3	4/2	2/2	3/2	2/2
Sharp turn	V	V	V*		V	V	V	V*	V	
Omnidirectional locomotion			V*		V	V	V	V*		

Figure 2.6: Characteristics of the developed spherical robot

Ya-Fu Peng et al. (2009) implemented an omnidirectional spherical robot using fuzzy control. The robot can move directly in any direction with no constraint and the fuzzy control is introduced to control the locomotion of the robot. Fuzzy control can deal with the unknown nonlinearities and external disturbance. Fuzzy control method was based on the human experience to understand the behavior of the system and fuzzy control was simple in designing. Fuzzy control systems were designed around personal computer and comprise same hardware components. The block diagram of the Fuzzy control system is shown in Figure 2.7.

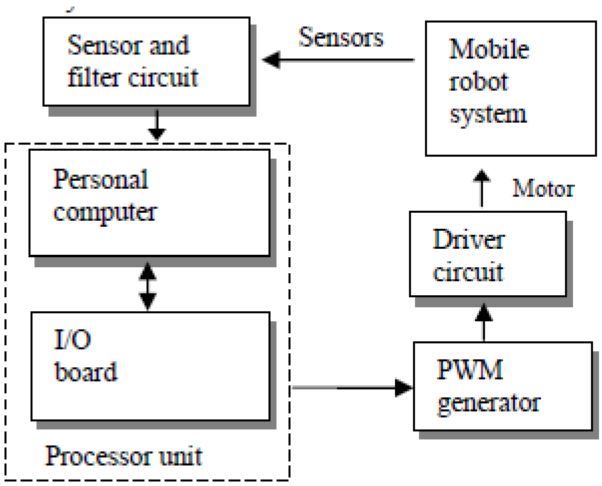


Figure 2.7: Block diagram of the robot system

Zheng Yili et al. (2008) designed an omni-directional rolling spherical robot with telescopic manipulator (BYQ-IV) as shown in Figure 2.8. Other than performing straight line motion, circular motion, zero turning radius and obstacle avoidance it is also capable to carry out the tasks by grabbing and delivering assemblies. The robot was allotted into three subs-systems which are the motion driving system; the manipulator system and the stability maintain system. The ARM processor and wireless communication system are pioneered as the distributed control system.

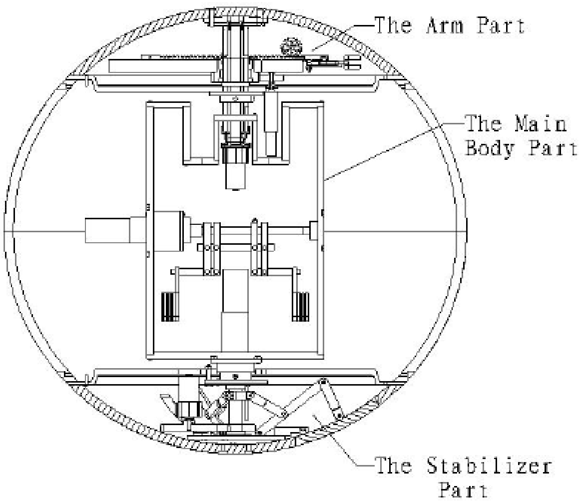


Figure 2.8: The plane view of BYQ-IV

2.3 Control Motion

Control motion of a novel spherical robot equipped with a flywheel was designed by Jia Qingxuan et al. (2008). It mainly composed of four mechanical structures which are a gyro case, a flywheel, a telescopic camera holder and a spherical shell. The constrained Lagrangian method was used as a dynamic model and the model was simplified under some assumptions. A LQR controller and PD controller were designed for pose and velocity control of the robot. Three separated actuators were used as actuation mechanism which is drive motors, a steer motor and a flywheel motor. The drive and steer motor are perpendicular to the main axes.