IMPLEMENTATION OF SPHERICAL ROBOT USING ARDUINO

Mini project report submitted in partial fulfilment of the requirements for the degree of

Bachelor of Technology

in

Electronics and Communication Engineering

Submitted by

T ASHMITHA (18B81A0404)

ADUWALA SAI PREETH (18B81A0434)

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Department of Electronics & Communication Engineering

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(An Autonomous Institution & Affiliated to JNTUH)

Ibrahimpatnam (M), Ranga Reddy (D), Telangana

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CERTIFICATE

This is to certify that the project titled "**IMPLEMENTATION OF SPHERICAL ROBOT USING ARDUINO"** submitted to the **CVR College of Engineering,** affiliated to **JNTU, Hyderabad** by **T ASHMITHA (18B81A0404), ADUWALA SAI PREETH (18B81A0434), VANAPARTHI SRIRAM SANTHOSH (18B81A0443)** is a bonafide record of the work done by the students towards partial fulfilment of requirements for the award of the degree of **Bachelor of Technology in Electronics & Communication Engineering**.

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Mr. Shakeel Ahmed	Dr. K. Lalithendra
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ABSTRACT

Robots are the growing technological device in the world that perform many functions ranging from space exploration to entertainment**.** The main aim of the project is to design a Spherical robot that is easily affordable. It is typically made of spherical shell serving as the body of the robot and an internal driving unit (IDU) that enables the robot move by rolling over the surface.

Since a sphere has very less surface contact it's very unstable to be stationary. To resolve this, we made use of weights that keep the sphere stationary and also provide movement. Spherical robot uses Arduino UNO, nRF 24 module as main components. RF module transmits instructions to Arduino and moves the bot according to the received instructions. To provide high voltage to DC and Servo motors, a motor driver is used. For rotation motion robot's centre of mass is changed by weights.

This robot emulates the unique spherical movement pattern, and has extra feature, like manual control by using remote controller. This robot can be used for surveillance, entertainment, planetary exploration, etc. The proposed model is completed and the result are satisfactory.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER – 1
INTRODUCTION

Among diverse types of robots, spherical robots have become increasingly attractive in the last decade. 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.

First, they have only a single contact point with the ground with minimal friction for locomotion. Therefore, they would be able to save energy for locomotion. Second, the spherical exoskeleton can protect the inner structure against external shocks or dust. It is even possible to move even in tightly constrained spaces.

Spherical robots have begun to be used in underwater experiments, child development studies, and security reconnaissance. The current research direction of spherical robots is heavily focused on developing the dynamic model, developing a prototype robot and proposing control methods for supporting manual control. However, there are numerous ways, but each method has its own set of obstacles. Some of these systems are simple, and some have complicated designs with even more complicated control algorithms. The early and current majority of designs are based on the principle of shifting the equilibrium of a sphere, the most common of which is shifting the sphere’s centre of gravity.

This project is simply to design the spherical robot with the capability to perform Bidirectional locomotion and capable to control the motion of the robot using remote controller. They normally generate only little amount of torque to rotate themselves. This makes it difficult for the robots to overcome obstacles and climb uphill. Therefore, this study focuses on spherical robots operating on smooth flat floors for indoor use.

1.1 Project objectives

The objectives of this project are as follows:

i. To design a 32cm diameter of spherical robot that can be controlled wirelessly using NR24L01 by utilize the serial communication protocol and using Arduino Uno as a controller to control the robot.
ii. To analyse the locomotion of the spherical robot.

1.2 Project Overall System

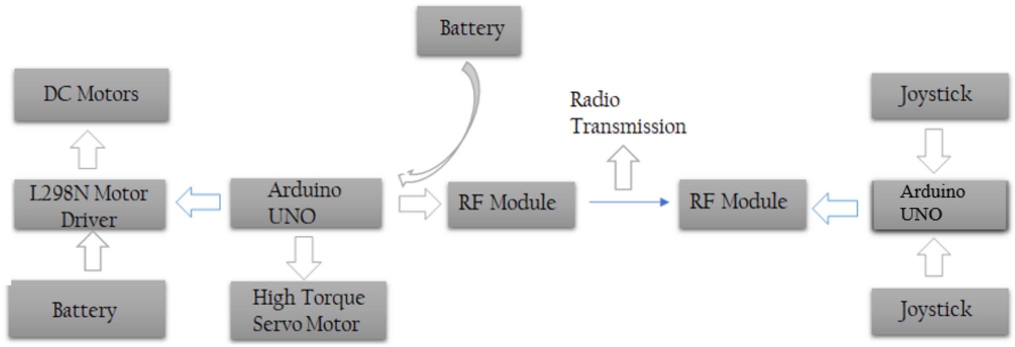


Figure 1.1: BLOCK DIAGRAM

Input is taken from user through joystick and sent to Arduino. The received signals are sent to main robot using radio modules at receiver and transmitter ends. Depending on the received instructions the motor driver takes signals from Arduino and controls DC Motors and servo motors.

1.3 Report 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 of the project and project overall system.

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 – Proposed Work: 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 analysed 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 reviews the articles and journals related to the project. Similar products have been developed by researchers in other 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

A spherical robot, known as a ball-shaped robot. It is typically made of a spherical shell serving as the body of the robot and an internal driving unit (IDU) that enables the robot to move. The rolling motion is commonly performed by changing the robot's centre of mass (i.e., pendulum-driven system), but there exist some other driving mechanisms.

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.

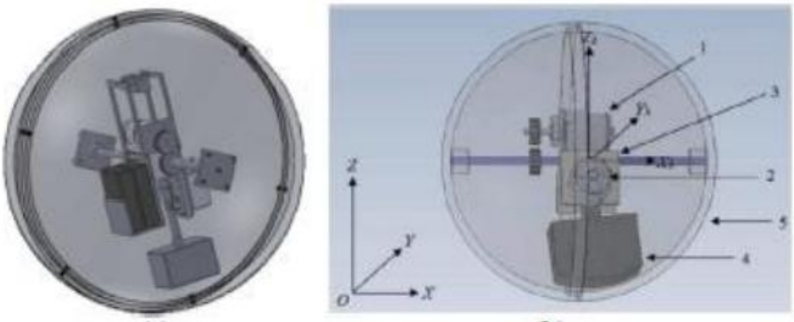


Figure 2.1: 3D CAD view of assembly

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 pendulum-driven spherical robot was a dynamic model for steering motion and analysing driving. The driving mechanism of the pendulum-driven type robot is shown in Figure 2.2.

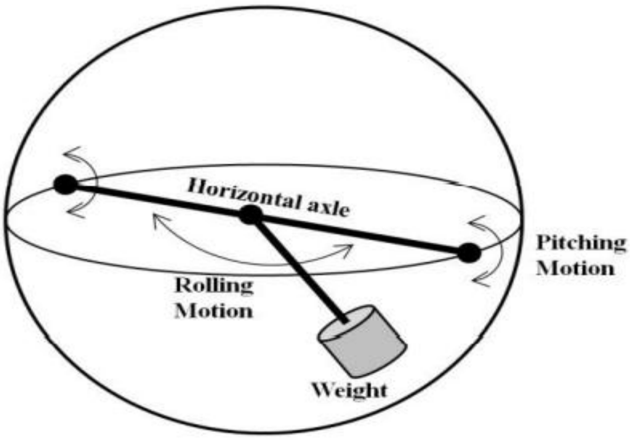


Figure 2.2: The driving mechanism of the pendulum-driven type robot

To attain the Bidirectional 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 barycentre principle offset to drive the centre 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 role.

2.2 Principles of Locomotion

2.2.1. Using an IDU (Inside Driving Unit)

One locomotion method is to use an IDU, or a box with wheels, which moves on the inner surface of the spherical body. One example of an IDU-driven spherical robot is the Rollo robot 2^{nd} generation developed at TKK in 1988. Its IDU has two driving wheels sideways and two un-driven wheels on the top to ensure a tight fit in the sphere. This robot employed electronics, such as sensors, motors, a transceiver, and a computer. Those components are necessary to ensure the smooth control of the robot.

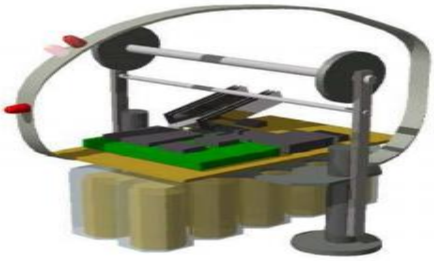


Figure 2.3: IDU of the Rollo robot 2nd generation developed at TKK

It has encoders, a gyro, and an inclinometer. Since the locomotion system utilizes an IDU, two encoders for both wheels are equipped. Without any reference pose information, the accuracy of the data has not been evaluated. Instead, the data was just used for estimating rough dynamic motions, such as the vibration, of the robot. The sensor data is not even used for the control.

The 3rd generation Rollo following the 2nd generation has the different design of an IDU. Its IDU can turn itself by rotating along the rim gear on the spot. The driving motion is generated by swinging up the main mass of the IDU. This driving strategy is same as that of pendulum-driven type spherical robots mentioned in next section. This study, however, classifies Rollo as an IDU-driven robot.

Figure 2.4: IDU of the Rollo robot 3rd generation

One limitation, however, of IDU-driven robots is their size constraint. As a matter of the fact, this type of robot requires a smooth and hard spherical body in order to let the IDU drive on the inner surface. Hard spherical bodies can easily be employed for small robots, such as the robots mentioned above. Furthermore, large plastic hard bodies require thick shells for structural strength, which leads to significant increase in weight. This could be critical in space missions where prohibitively high launch costs greatly depend on the weight of a payload.

2.2.2. Pendulum Driven

A popular design used by industry and academia is a pendulum-driven design (Figure 2.2.2). The pendulum model consists of a fixed shaft through the centre of the outer shell of the robot, with a pendulum and bob that rotates around the shaft. Rotating the pendulum shifts the centre of mass outward from the centre and the shell begins to roll. Shifting the pendulum left or right along the equator will shift the centre of mass left or right, and the robot will begin to turn in the corresponding direction.

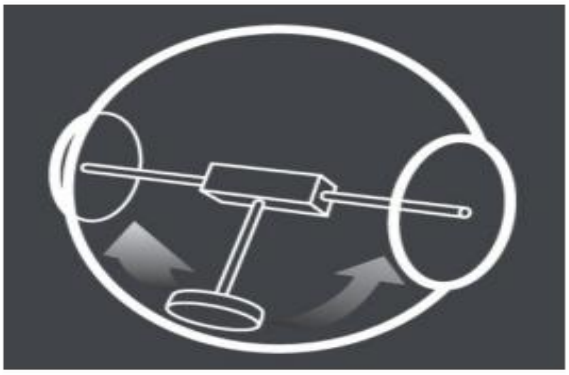


Figure 2.5: A commercialized pendulum-driven robot, Rotundus

As the weight of the bob increases, so does the amount of torque that can be used to drive the robot. However, a heavier bob means a heavier robot. However, in practice, a well designed spherical robot can usually only go up about a 30◦ slope. A spherical robot that can traverse an incline greater than 30◦ may require design techniques that are not commercially or economically practical. Even though there are some limitations to the pendulum drive, it is a low-power easy-to-implement design that allows the shell to be sealed. Rotundus can roll at speeds of 6mph, through snow, ice, mud, and sand, and can float.

It is also important to consider that as the radius of the shell becomes larger and the pendulum bob becomes more massive, the output torque increases. However, as these items become larger, the energy required to move them also becomes larger. There is a delicate balance of design when considering material compositions and the physical sizes of the internal elements.

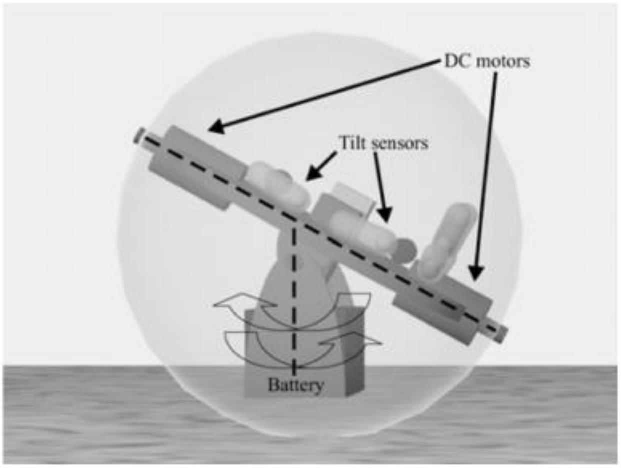


Figure 2.6: Rear view of Roball's steering mechanism.

Onboard sensors allow the robot to navigate its environment autonomously. All elements are placed on a plateau of the robot (the equator), and steering is done using a counterweight. In this particular model, the counterweight is a battery. In this design, the counter weight is designed to stay at the bottom of the shell, and the shell moves around it, causing propulsion.

2.3 Applications

Our Spherical robot can be used in the following ways:

- Playing Toy
- Surveillance
- Space Exploration
- Entertainment
- Reconnaissance

2.3.1 Playing Toy

A spherical toy robot, which is implicitly appealing for children because they are used to playing with ball-shaped objects.

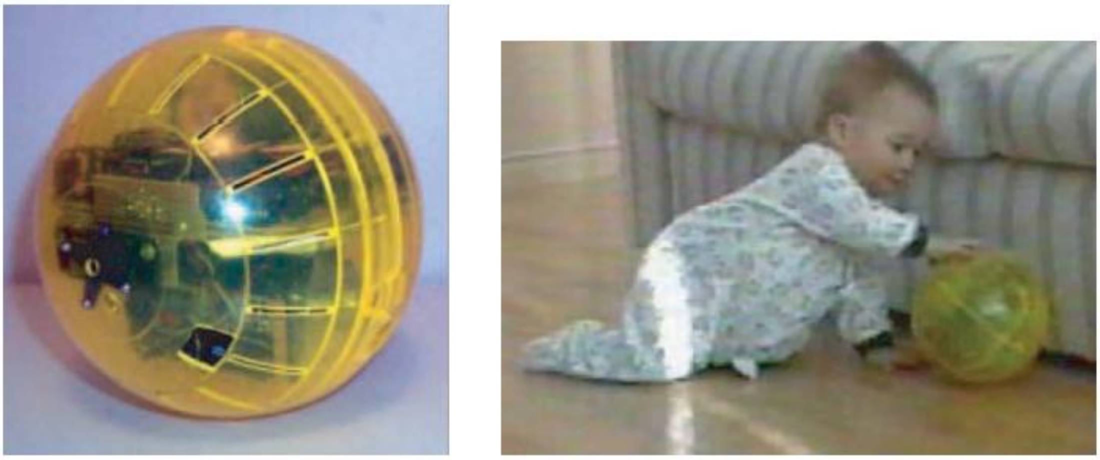


Figure 2.7: (i) Spherical Robot as a toy (ii) A boy playing with ball

2.3.2 Surveillance

Another application for spherical robot is surveillance. Surveillance robots, able to navigate all types of terrain, such as mud and snow. Spherical robots offer great advantages for those terrain types.

Figure 2.8: Surveillance robot

2.3.3 Space Exploration

Spherical robots that can move by bouncing and rolling. These robots can be sent to other planets arranged altogether in an egg-cart on-like container.

The advantage of using dozens of micro robots is that they can cooperate to achieve their collective goal. For example, given correct positioning, they can relay messages back to the central unit even from deep within cave.

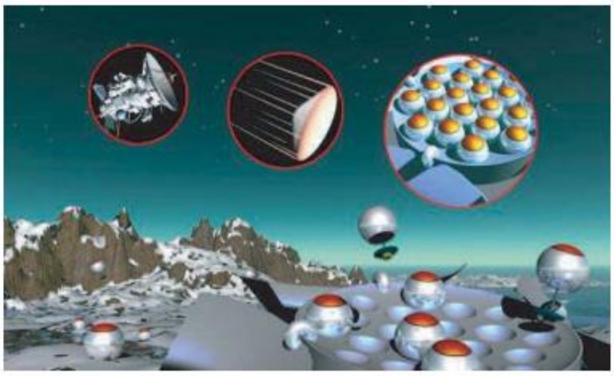


Figure 2.9: Spherical Micro Robots

2.3.4. Entertainment

Spherical robot for entertainment purpose – “Action Robot”. In this application they start to communicate and cooperate with each other.

Figure 2.10: Entertainment Robot

2.3.5 Reconnaissance

Spherical Robot is designed for remote surveillance and reconnaissance in an urban area. Remote surveillance enables people to survey a dangerous situation from a far.

Figure 2.11: Spherical Robot for Reconnaissance

CHAPTER – 3
METHODOLOGY

3.1 Driving

The driving motion of the robot depends on the power of the motor used as well as the weight of the pendulum attached to the robot. If the weight of the pendulum is more then, the motors have to provide more energy for the robot to move in a direction.

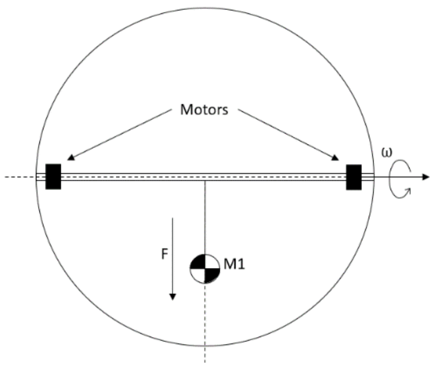


Figure 3.1: Modelling of the ball (driving)

3.1.1 Uphill and Downhill Motion

The motion of spherical robot is restricted to certain angle of inclination of the ground. At certain angle the robot cannot move in desired direction as the force exerted by the motors is less than the gravitational force on the robot.

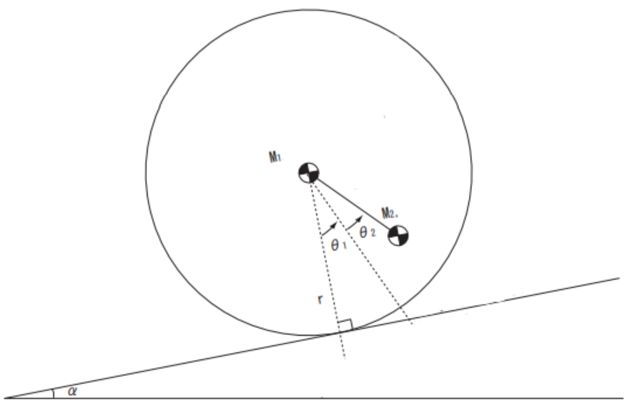


Figure 3.2: Modelling of the ball (uphill / downhill)

This can be avoided to certain extent by using high rpm motors as they provide more force to the robot to move over certain angle of inclination.

3.1.2 Obstacle Crossing

When an obstacle is encountered by the robot it may/may not overcome it depending on the size of the obstacle. For robot to climb up the obstacle, the driving force must be greater than the gravitational force on the pendulum and the size of the obstacle must be less than the small fraction of the radius of the robot.

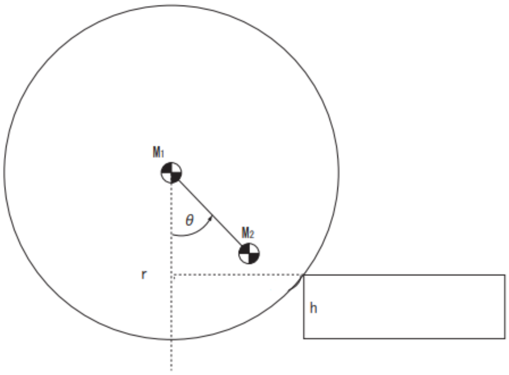


Figure 3.3: Obstacle crossing

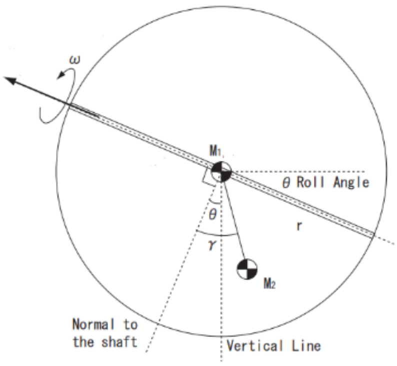
This means obstacle crossing is a critical weakness in the spherical robot motion. This can be overcome by use of momentum of robot or by using additional feature that might allow robot to jump over the obstacle.

3.2 Steering

3.2.1 Modelling

For simplicity, the sideways tilting angle of the pendulum with respect to the ball namely gamma, is called steering angle. Note that the inclination of the main shaft namely theta, is called roll angle.

Figure 3.4: Modelling of steering



3.2.2 Ball Traveling at low speed

The basic principles for this analysis are:

- Equilibrium of force and torque including the centrifugal force of steering.
- The robot follows the circumference where the centre point is the intersection of the floor and the line of the rotating shaft of the robot.

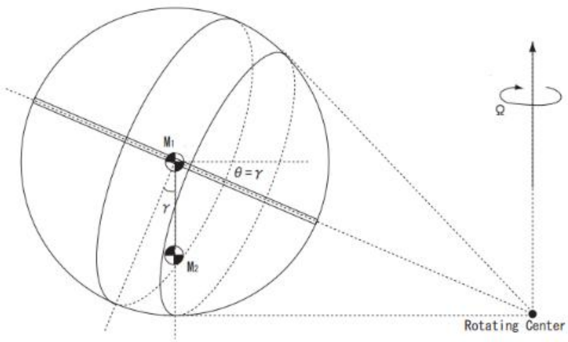


Figure 3.5: Modelling for steering with low speed

Centrifugal force can be neglected when the robot travels at very low speed. In such cases the roll angle theta is same as the steering angle of the pendulum gamma. This representation can be shown in the above figure.

3.2.3 Ball travelling at max speed

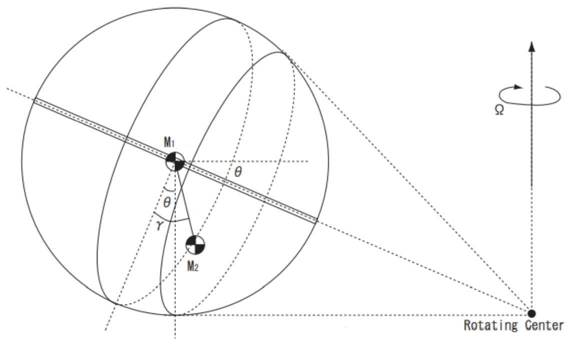


Figure 3.6: Modelling for steering with max speed

When robot travels at max speed, the centrifugal force needs to be taken into consideration. Due to this the angle at which the robot turns in a direction decreases drastically. This representation can be shown in above figure. The most important characteristic of a spherical robot is that the more the steering angle is and less the speed is, the steeper the turning becomes.

CHAPTER – 4

PROJECT DEVELOPMENT

4.1 System Overview

The objective of the development of a prototype robot is to investigate the applied control methods. The system consists of the following two main components: the prototype robot and the remote controller. The prototype robot is equipped with several components, where you will go through a detailed explanation.

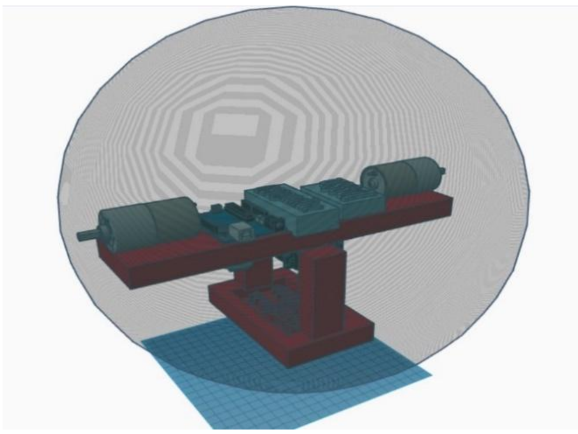


Figure 4.1: 3D Diagram

4.2 Block Diagram and Components

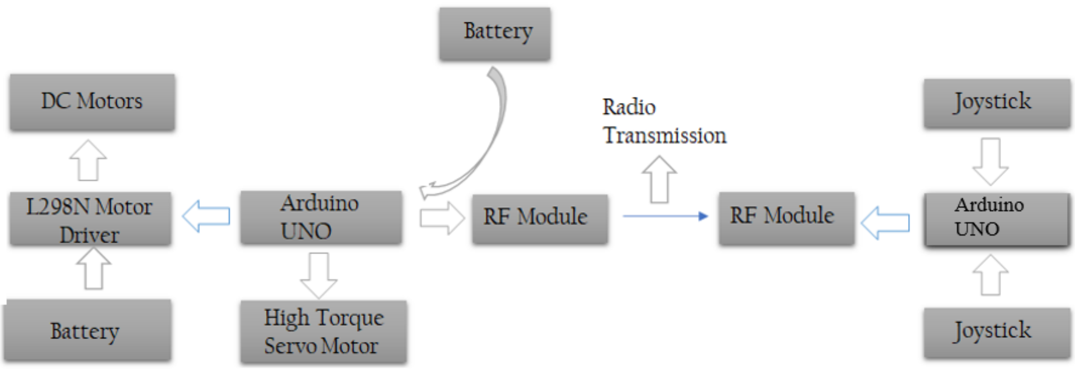


Figure 4.2: Block Diagram

4.2.1 Components of Block Diagram

1. DC Motors:

The DC motors are used to rotate the sphere and was installed at the horizontal center axis of the sphere. The speed controller was used to change the speed and rotational direction of the DC motor, allowing the robot to move forward or backward.

Figure 4.3: DC Motors

This DC Motor with Metal Gear Head is generally used in various robotics applications, It has following electrical and mechanical specifications.

Specifications:

Motor Type	DC with Gear Box, Metal Gears
Base Motor	DC 3000 RPM
Shaft Type	Circular 6mm Diameter with Internal Hole for coupling, 23 mm shaft Length
Maximum Torque:	~3 Kg-cm at 12V
RPM	100 RPM at 12V
Weight	130 grams
Max Load Current:	~330mA at 12V

Table 4.1: DC Motor Specifications

2. L298N Motor Driver

An H bridge is an electronic circuit that enables a voltage to be applied across a load in either direction. These circuits are often used in robotics and other applications to allow DC motors to run forwards and backwards. H bridges are available as integrated circuits, or can be built from discrete components.

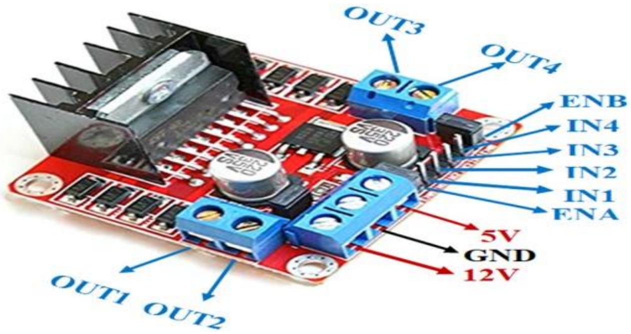


Figure 4.4: L298N Motor Driver

Specifications:

Double H Bridge Drive Chip	L298N
Logical Voltage	5V
Drive Voltage	5V-35V
Logical Current	0-36Ma
Drive Current	2A (Max single Bridge)
Max Power	25W

Table 4.2: Specifications of L298N Motor Driver

3. ARDUINO UNO

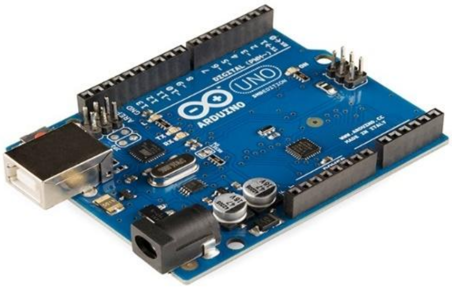


Figure 4.5: Arduino UNO

Arduino Uno is a microcontroller board based on the ATmega328P. It has 14 digital input/output, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

Specifications:

Microcontroller	Microchip ATmega328P
Operating Voltage	5V
Input Voltage	7 – 20V
Digital I/O Pins	14
Analog Input Pins	6
DC Current per I/O Pin	20Ma
DC Current for 3.3V Pin	50mA
Flash Memory	32KB of which 0.5KB used by bootloader
SRAM	2KB
EEPROM	1KB
Clock speed	16MHz

Table 4.3: Specifications of Arduino

4. nRF24L01 Module

The nRF24L01 is a wireless transceiver module, meaning each module can both send as well as receive data. The nRF24L01+ transceiver module transmits and receives data on a certain frequency called Channel.

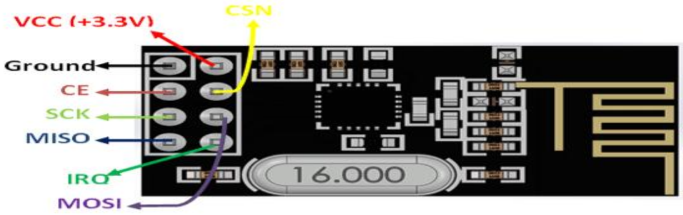


Figure 4.6: 2.4GHz RF transceiver Module

Figure 4.6: Data Channel

Specifications:

Operating Voltage	3.3V
Nominal current	50mA
Range	50-200feet
Operating current	250Ma
Communication Protocol	SPI
Baud Rate	250kbps-2Mbps

Table 4.4: Specifications of nRF24L01

5. MG995 Servo Motor

MG995 is a **servo motor** that is popular for its performance and low price. The motor is used in many applications mainly being robotics and drones.

MG995 has three terminals as mentioned in pin diagram and the function of each pin is given below.

Figure 4.7: MG995 Servo Motor

MG995 Features and Electrical characteristics

- Metal geared servo for more life
- Stable and shock proof double ball bearing design
- High speed rotation for quick response
- Fast control response
- Constant torque throughout the servo travel range
- Excellent holding power

Specifications:

Operating voltage	4.8 V to 7.2 V
Stall torque	9.4kg/cm (4.8v); 11kg/cm (6v)
Operating speed	0.2 s/60º (4.8 V), 0.16 s/60º (6 V)
Rotational degree	180º
Dead band width	5 µs
Operating temperature range	0ºC to +55ºC
Current draw at idle	10mA
No load operating current draw	170mA
Current at maximum load: 1200Ma	1200Ma

Table 4. 5 : Specifications of MG995

6. Joysticks

When we listen the word “**Joystick**” we think of Game controllers. If we talk about Electronics there are many useful applications of Joystick. These modules are mostly used in Arduino based DIY projects and Robot Control. As we know, the module gives analog output so it can be used for feeding the analog input based on direction or movement. It consists of two Potentiometer, each for one axis (X and Y). Both 10k potentiometer are independent to move in their particular direction. SW (Switch) pin is connected to a push button internally.

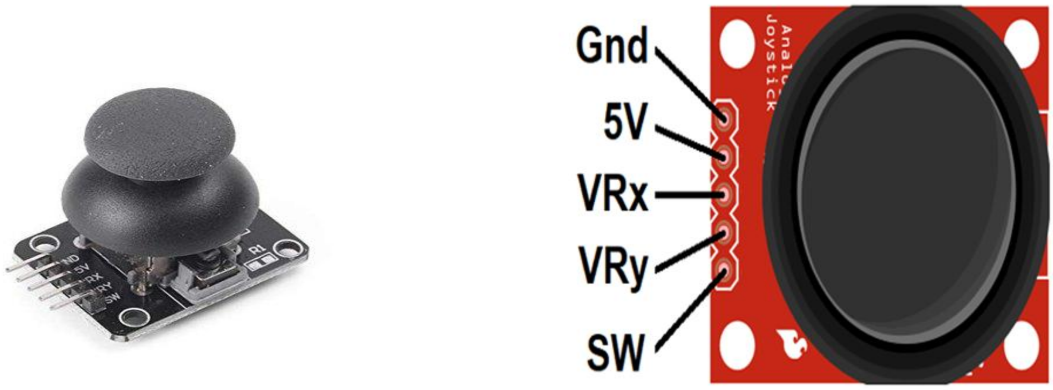


Figure 4.8: Joystick

7. Battery

I. 9V Battery

The nine-volt battery, or 9-volt battery, is a common size of battery that was introduced for the early transistor radios. It has a rectangular prism shape with rounded edges and a polarized snap connector at the top.

Figure 4.9: 9V Battery

II. 12V Battery

These batteries can provide hundreds of amps of electrical current for a short period of time. That is why these batteries are commonly used in automotive applications.

Figure 4.10: 12V Battery

8. Spherical Ball

This is outer shell that is used as spherical structure for the robot.

Figure 4.11: Spherical

Ball

4.3 Circuit diagram:

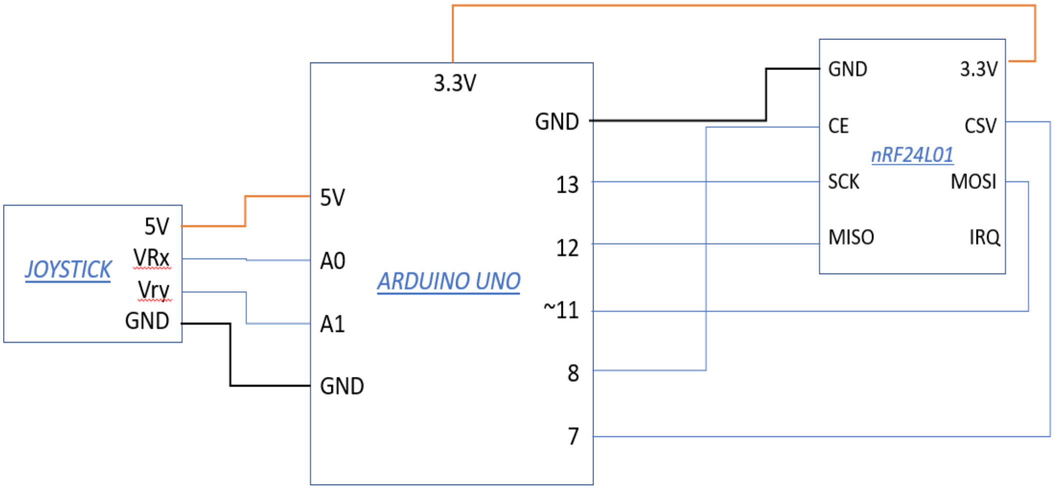


Figure 4.12: Transmitter

Table 4.6: nRF24L01 and Arduino UNO Pin Configuration

nRF24L01	**Arduino**	**Joystick**
GND	GND	GND
VCC	3.3V	
CE	D8	
CSN	D7	
SCK	D13	
MOSI	D11	
MISO	D12	
	5V	5V
	A0	VRx
	A1	VRy

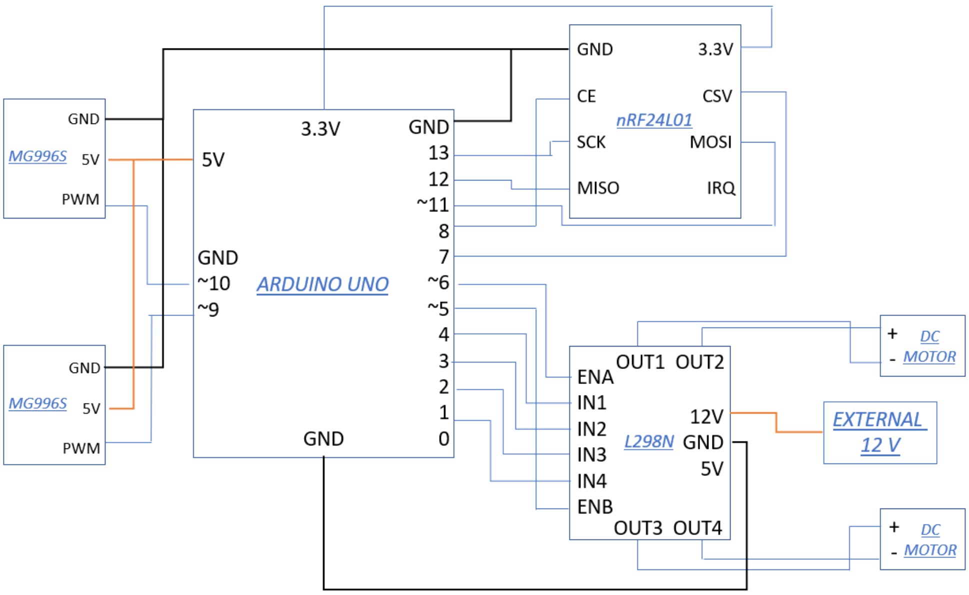


Figure 4.13: Receiver

Table 4.7: nRF24L01, L298N, MG996S and Arduino UNO Pin Configuration

MG996S	**MG996S**	**UNO**	**nRF24L01**	**L298N**	**DC Motor**	**External**
GND	GND	GND	GND	GND		
				12V		12V
5V	5V	5V				
		3.3V	3.3V			
		D13	SCK			
		D12	MISO			
		D11	MOSI			
PWM		D10				
	PWM	D9				
		D8	CE			
		D7	CSN			
		D6		ENA		
		D5		ENB		
		D4		IN1		
		D3		IN2		
		D2		IN3		
		D1		IN4		
				OUT 1 / 4	(-)	
				OUT 2 / 3	(+)	

CHAPTER – 5

RESULT

5.1 Transmitter

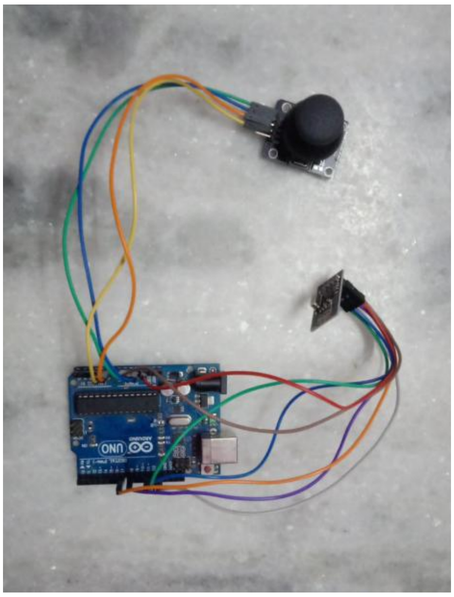


Figure 5.1: Remote Controller

Figure 5.1 is remote controller that controls the robot's motion depending on the input given by the user. It consists of Arduino that takes values from joystick and send the corresponding values to the robot through radio module (nRFL01). Figure 5.2 show that when inputs are provided to joystick the corresponding values varying from 0 to 1023 are sent to robot that can be viewed in serial monitor with COM 7 as transmitter and COM 9 as receiver.

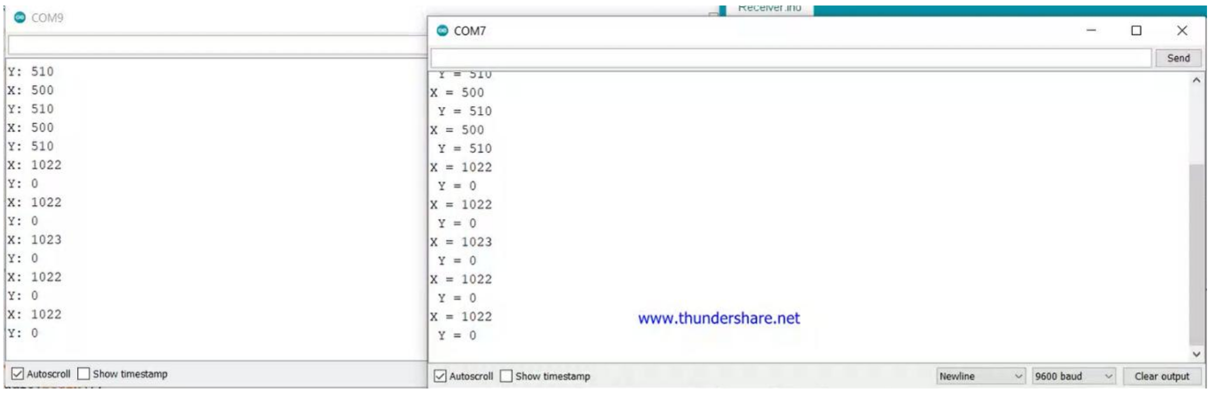


Figure 5.2: Receiver and Transmitter observed values

5.2 Receiver

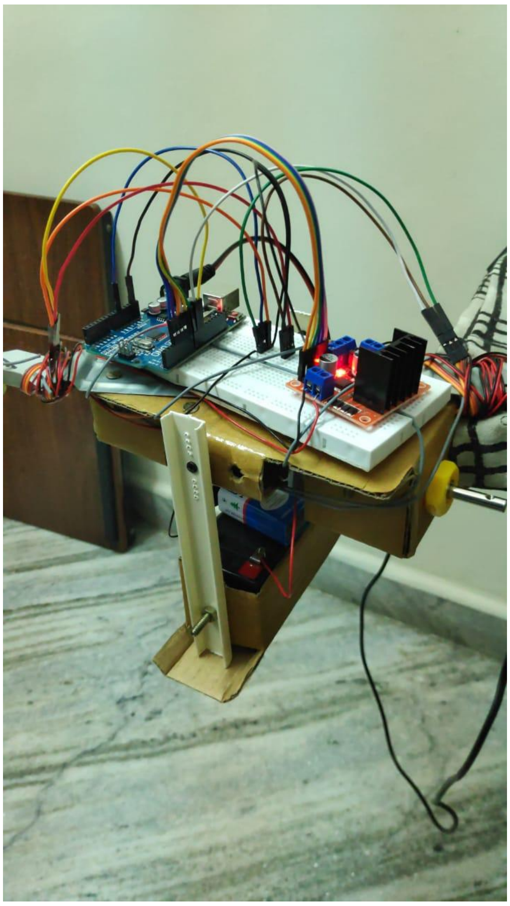


Figure 5.3: Robot Body Part

Figure 5.3 shows the finished model of the robot IDU (Internal Driving Unit) which contains Arduino UNO, motor driver, servo motors, dc motors and batteries to power up components. When the values from the remote controller is received by the robot's receiver module then, depending on the values of the receiver the movement of the robot changes accordingly. Depending on the value of dual axis joystick which changes from 0 to 1023 the dc motor or the servo motor changes its position and speed and the robot moves accordingly.

CHAPTER – 6

CONCLUSION AND FUTURE SCOPE

6.1 CONCLUSION

Spherical robots are a class of mobile robots that are generally recognized by their ball-shaped shell and internal driving components that provide torques required for their rolling motion. The advantage of spherical robots is that, it is completely sealed and they are ideal for hazardous environments. This enables the robot to be operated in snow, mud and different terrains. Spherical robot would be appropriate for many different mobile robotics applications such as surveillance, reconnaissance, hazardous environment assessment, search and rescue, as well as planetary exploration.

These kinds of systems require the most efficient and versatile mechanisms of locomotion for working in rough and uneven terrains. Spherical robot can achieve different kinds of unique motion, such as all-direction driving and motion on rough ground, without losing stability.

Most spherical robots utilize displacement of the centre of mass as their driving force, they can vary in the strategies used for displacing the mass. We discussed locomotion method that is to use an internal driving unit (IDU) that enables the robot to move and another being pendulum-driven spherical robot, a dynamic model for steering motion.

The basic principles for this analysis are, equilibrium of force and torque including the centrifugal force of steering and robot follows the circumference where the centre point is the intersection of the floor and the line of the rotating shaft of the robot.

Our work was an attempt to develop a real-time low-cost spherical robot.

6.2 FUTURE WORKS

6.2.1 HAND GESTURED CONTROL

In this prototype the robot is controlled by a remote controller using Arduino nano. But this robot can also be controlled by hand gesture using Arduino, accelerometer and gyroscope component that can be mounted on glove that can be used by user to control the motion of the robot depending on the angle the user rotates his hand.

6.2.2 NAVIGATION

Navigation method of robot can also be implemented which is needed for pure automated control.

6.2.3 SURVELIENCE

Camera can be mounted on the robot and sent to cloud so that the user can operate the robot from distance giving user the visuals of the robot's surroundings.

6.2.4 AUTOMATION

By adding few more sensors, the robot can be given more sense of its surroundings and allowing it to navigate on its own.

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