Dr. AMBEDKAR INSTITUTE OF TECHNOLOGY
(An Autonomous Institute, Affiliated to Visvesvaraya Technological University, Belagavi, Accredited by NAAC, with 'A' Grade)
Near Jnana Bharathi Campus, Bengaluru – 560056

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

A Project Report on

"Ball – E using C++ (IoT)"

Submitted in partial fulfilment of the requirement for the award of the Degree of

Bachelor of Engineering
In
Computer Science and Engineering

Submitted by

ADWAITH.V	1DA16CS003
AKASH	1DA16CS005
AKSHAY.R	1DA16CS007
HARSHAL.U	1DA16CS050

For the academic year 2019-20

Under the Guidance of

Ms. Madhu.B
Assistant Professor, Dept. of CSE,
Dr.AIT, Bengaluru – 560056.

Visvesvaraya Technological University
Jnana Sangama, Belagavi, Karnataka 590018.

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CERTIFICATE

Certified that the Project work entitled **"Ball-E using C++ (IoT)"** carried out by **ADWAITH.V** bearing the USN **1DA16CS003** is a bona fide student of **Dr.Ambedkar Institute of Technology, Bengaluru,** in partial fulfilment for the award of **Degree in Bachelor of Engineering in Computer Science and Engineering** of Dr. Ambedkar Institute of Technology during the academic year 2019-20. It is certified that all the corrections/suggestions indicated during Internal Assessment have been incorporated in the Project report deposited in the department. The Project report has been approved as it satisfies the academic requirements in respect of Project work prescribed for the said Degree.

Signature of the Guide
Ms. Madhu.B,
Assistant Professor,
Department of CSE,
Dr.AIT, Bengaluru -56.

Signature of the HOD
Dr.Siddaraju,
Dean (A),
Professor and HEAD,
Department of CSE,
Dr.AIT, Bengaluru – 56.

Signature of the Principal
Dr.C.N.Nanjundaswamy,
Principal,
Dr.AIT, Bengaluru – 56.

Viva-Voce Examination

Name of the Examiners   Signature with Date

1.

2.

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ADWAITH.V
1DA16CS003

ABSTRACT

Our project aims to develop a multi-purpose robot, controlled by gestures of the movements of our hand. This will be done with the help of an automated glove which will be created so as to move the robot around and the camera gives a live feed on its current position & what the robot sees. This feed will be provided to us in our daily day to day use smartphones or to a display which is linked to the robot.

The robot feature set can be used for a variety of purposes such as a home companion, security support by threat detection & surveillance, delivery robot, garbage collection etc. & move around with the help of hand gestures. With so many opportunities, we can produce a versatile robot capable of helping humans in multiple fields. The benefits of this robot is it that it is not tied to any field and hence, can be used for multiple purposes which gives it a wide range of capabilities for helping in daily life activities.

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1. Introduction

1.1. The Basics

1.1.1. The dawn of Robotics

The industrial revolution paved the way for new advances in the area of science and technology. This was also the time when “robotics” was established as a study of science and usage of robots. Technology is all set to make us, not only physically, but also emotionally dependent on robots. Technological singularity is said to be that hypothetical point in time at which machines grow up to be so intelligent that it is no longer possible to differentiate between them and humans.

A robot is a man made device or machine, especially one programmable by a computer, capable of carrying out a complex series of actions automatically. Robots can be guided by an external control device or the control may be embedded within. Their motions are modelled, planned, sensed, actuated and happen in a controlled fashion. Robots may be constructed on the lines of human form, but most robots are machines designed to perform a task with no regard to their aesthetics.

1.1.2. The era of Internet of Things (IoT)

The Internet of things (IoT) is a system of interrelated computing devices, mechanical and digital machines provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

The definition of the Internet of things has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems. Traditional fields of embedded systems, wireless sensor networks, control systems, automation and others all contribute to enabling the Internet of Things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "smart home", covering devices and appliances that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as smartphones and smart speakers.

1.1.3. The Internet of Robotic Things (IoRT)

The IoT and robotics communities are coming together to create The Internet of Robotic Things (IoRT). The IoRT is a concept in which intelligent devices can monitor the events happening around them, fuse their sensor data, make use of local and distributed intelligence to decide on courses of action and then behave to manipulate or control objects in the physical world. This attempt at emulating human behaviour can be influenced by "programming" to achieve the motto of developing "intelligence" for safe interaction in open environments.

1.2. The Inspiration

The robot we have chosen to build takes inspiration & tries to replicate one of the classic robots from the visual media industry, Star Wars. Among the numerous robots present in the film, we found a very intriguing one; BB-8. The BB-8 robot along with the iconic R2-D2 robot were the most recognizable and were synonymous to the movie franchise.

Fig 1.1. BB – 8

Fig 1.2. R2 – D2

BB-8 is a ground-based holonomic robot with a free-moving domed head. Holonomic robots are those which can instantaneously move in any direction on the horizontal plane. That makes them incredibly responsive. The one in the movies shows it as white, with orange and silver accents and a black optical lens on its headpiece. BB-8 is also shown to possess multiple panels containing various tools or ports. BB-8's body rolls independently from the head, which always stays near the vertical axis of the droid.

The patent presents several variants of the invention, but one which stands out is a configuration in which the body contains a drive system that always keeps a relative position with respect to the sphere. The system uses omni wheels to make the sphere roll in any direction. Each of those wheels is connected to a motor. The robot uses sensors (gyroscopes and accelerometers) to determine its position and dynamics. The drive system can be manoeuvred using a remote controller. The base plate acts as a counterweight, keeping the centre of gravity close to the ground. That keeps the wheels' traction on the inner shell of the body.

Fig 1.3. The Patent

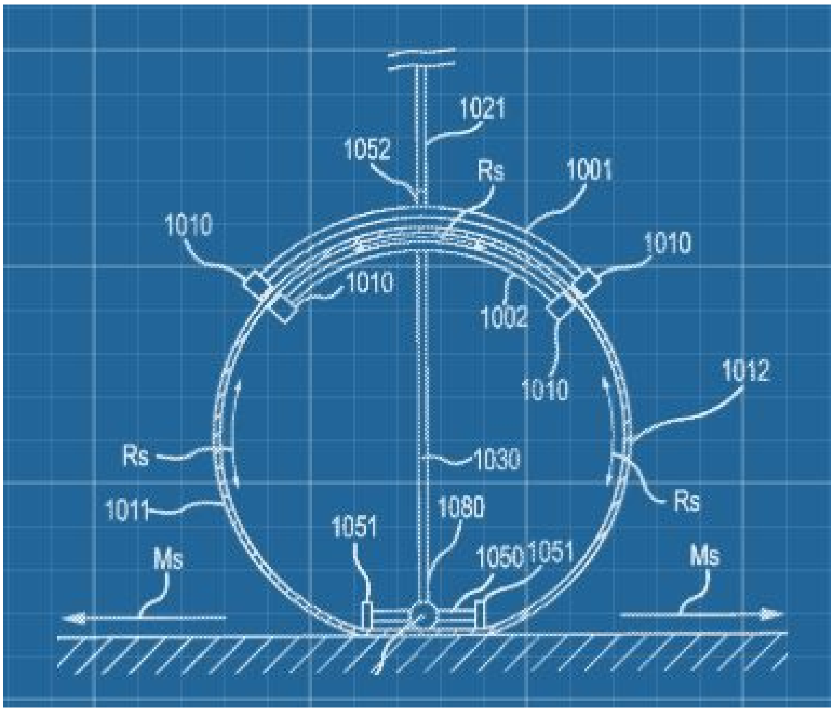
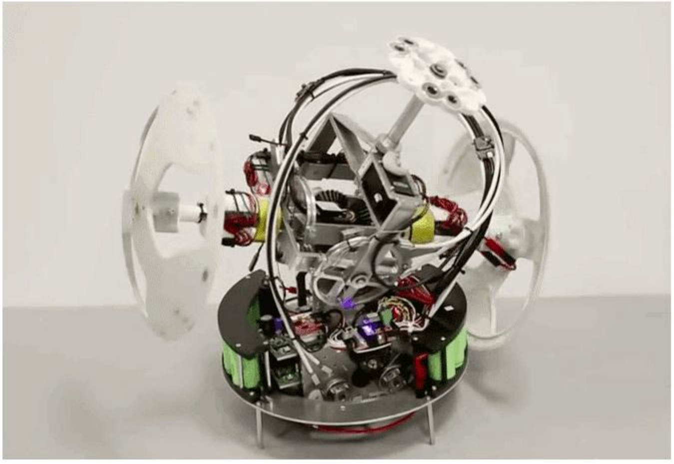


Fig 1.4. A pictorial representation of the mechanism

The practical cost of development of such a droid would practically be very high if we are to follow the original patent. Instead, our project helps to achieve creation of these robots at a much cheaper price. This cuts down a few aesthetic properties but increases the ease of access to the common public. Due to this, we can use these as cheap replaceable drones and can be easily deployed. The following diagrams shows the drastic differences in complexity between the original robot and the one made in this project.



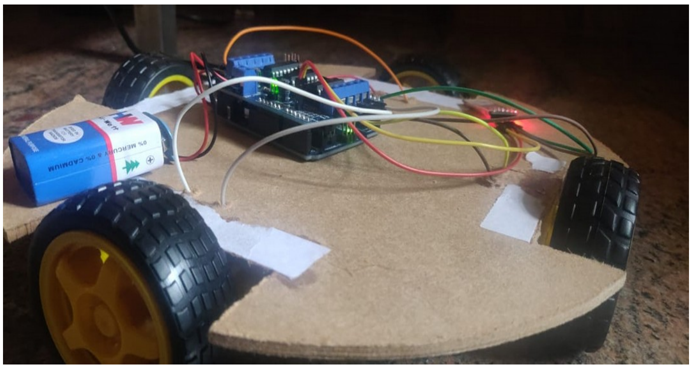


Fig 1.5. The original design of BB – 8 **Fig 1.6. The inspired design of Ball – E**

The inspired design has 2 pairs of wheels symmetrically aligned inside the body. This is controlled by the Arduino UNO board which interprets the commands received from the HC-05 Bluetooth module and send these instructions to the L293D motor driver module. The motor driver module commands the metal gearbox, effectively controlling the motors attached to the wheels. The wheels inside, create friction on the inner surface of Ball-E, which translates into motion of the body of Ball-E. The head is replaced with a simple mechanism for visual data acquisition using an ESP CAM module which transmits data in real time over Wi-Fi.

1.3. Problem Statement

Can a robot be created which is not restricted to traditional movement? Can this provide real time interaction with it's environment? How can this be done with minimum expenditure so as to have the ability to be mass produced and keep cost low?

1.4. Objective

Creating a multi-purpose robot running on motion gesture commands with the ability to traverse with a holonomic motion. Provide video information in real time for remote operation. Provide capabilities of remote surveillance, exploration, product delivery etc.

1.5 Organization of Project

The project needed meticulous planning and consideration in order to succeed. We hit a few rough patches along the way, learned from our experience and incorporated it into our scientific approach by re-evaluating core aspects and correcting as required.

2. Literature Survey

The study by Meng et al. [1] published in 2016, mentions the different holonomic robot systems. These spherical robots fall into six different categories based on their propulsion mechanisms:

- wheel-based
- two independent hemispheres
- pendulum-based
- relocation of centre of gravity (COG)
- wind powered
- deforming

The first study on spherical robots though, was that of Halme et al. [2] in 1996, which described a spherical robot driven by a wheel inside. The wheel can be rotated to roll the robot and steered to make the robot turn. The wheel is balanced by a stabilizing wheel at a symmetric position inside the sphere.

Another study by K. Husoy [3] adopted two symmetric wheels to drive a spherical robot. The robot goes straight when the two wheels are rotating at the same speed and turns when the wheels rotate at different speeds. A wheel-based mechanism uses the friction between the wheels and shell. This has been implemented in this undertaking.

Francisco Cuellar [4] in his work deals with the understanding of the kinematic equations and design of a wheeled mobile robot based on holonomic omnidirectional robot. The paper focuses on the robot's offers of exceptional mobility because it could perform translation and rotation at the same time. This technology may displace existing wheeled mobile robots because it is more efficient and dexterous.

Laura Dipietro et al. [5] works involve hand movement data acquisition i.e. glove-based systems, which represent one of the most important efforts aimed at acquiring hand movement data. This paper surveys such glove systems and their applications. It also analyses the characteristics of the devices, provides a road map of the evolution of the technology, and discusses limitations of current technology and trends at the frontiers of research. This paper allows us to scale the project according to the available resources by changing the type of control and precision available to robot.

3. Requirement Specification

3.1 Hardware Requirements

The hardware required for the project is divided into 7 parts :

3.1.1 Robot / Receiver Electronics :

- Arduino UNO
- L293D 4 Geared Motor Driver Module
- Pololu 50:1 35D Metal Gearbox
- HC05 Bluetooth Module
- 4 Cell Lithium Battery Pack (2x)
- Switch, DC Jack, Wires, Solder

3.1.2 Transmitter Electronics

- App Designer
- Java IDE
- Mobile App

3.1.3 Camera System

- ESP32-CAM module
- FTDI 232RL / TTL Connector

3.1.4 Ball-E's Body :

- Globe (made of plastic)
- Old Newspaper Strips
- Cut out wooden board
- 4 small wooden pillars
- 2 Bottles of PVA Glue (a.k.a Elmer's Glue)
- 1 Bottle of Wood glue
- White, Grey and Orange Spray Paint
- Roll-on Deodorants / Wheels
- Strong Magnets
- Ball Bearings

3.1.5 Ball-E's Head

- Wi-Fi Antenna (Increasing Range)
- Roll-on Deodorants
- White, Grey and Orange Spray Paint
- Strong Magnets
- Ball Bearings

3.1.6 Miscellaneous :

- Superglue
- Neodymium Magnets
- Gloves

3.2 Software Requirements

- Java 8
- Windows 10 / 8 / 7 / Vista SP2
- Arduino IDE 1.8 +

4. System Design

The system design phase involved the research and design of circuits which each targeting a specific functionality, which come together to make the robot unique. Therefore, it is necessary to understand each of these and has been categorised according to the roles they play in the following sections.

4.1 Transmitter Design

A simple app which can be downloaded for hassle-free interfacing. This section introduces how the transmitter app works

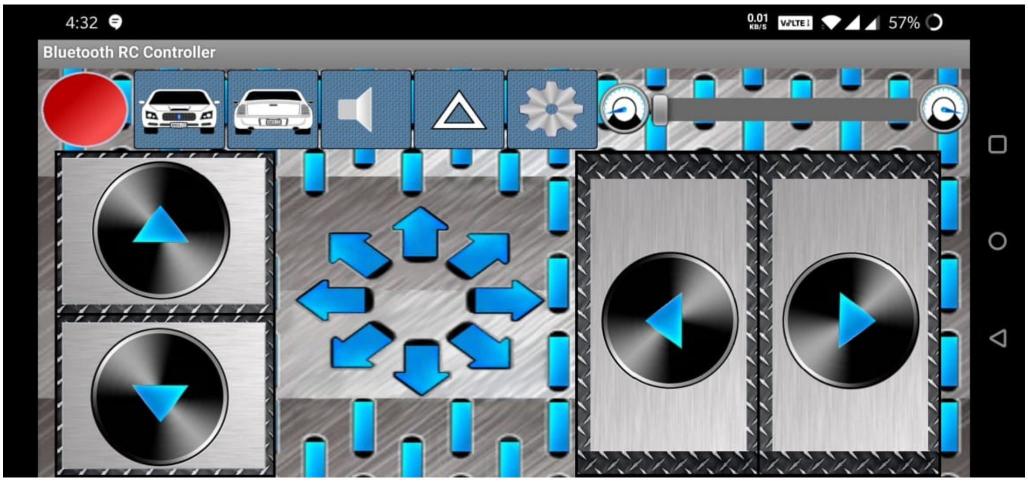


Fig 4.1.1 Application Interface

Step 1 : When the Bluetooth is not connected it will flash red on the left topside of the app. (Fig 4.1.1)

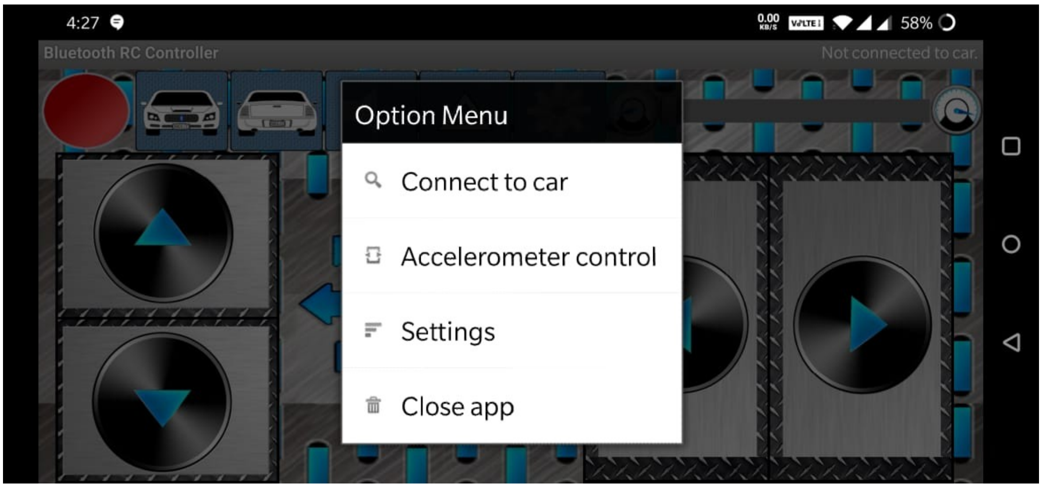


Fig 4.1.2 Connection Option Menu

Step 2 : Press on the settings icon and press on connect to car to open the pairing window. (Fig 4.1.2)

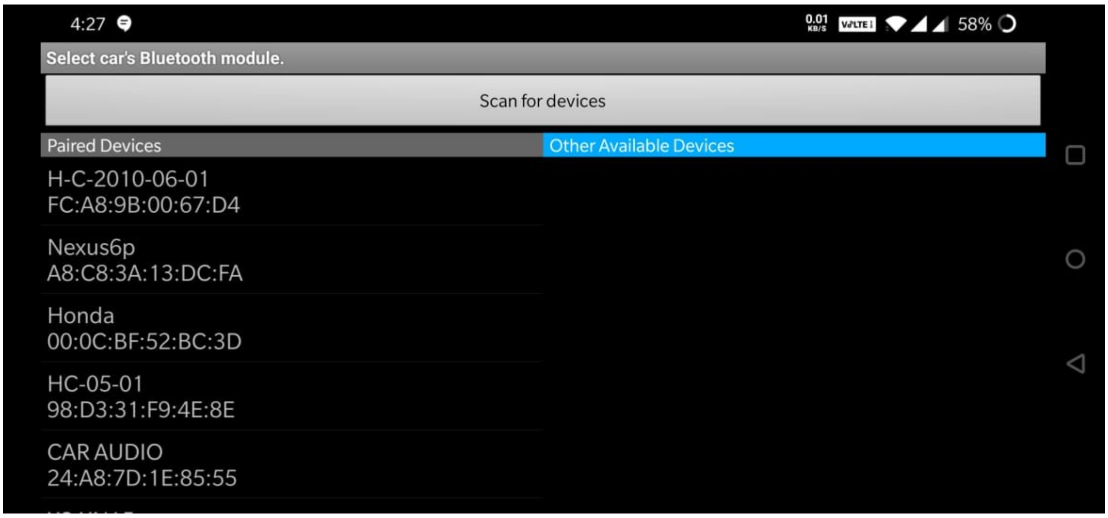


Fig 4.1.3 List of available devices for Bluetooth pairing

Step 3 : Scan for devices and pair the Bluetooth module (if asked for password it will be set to default as 0000/1234). (Fig 4.1.3)

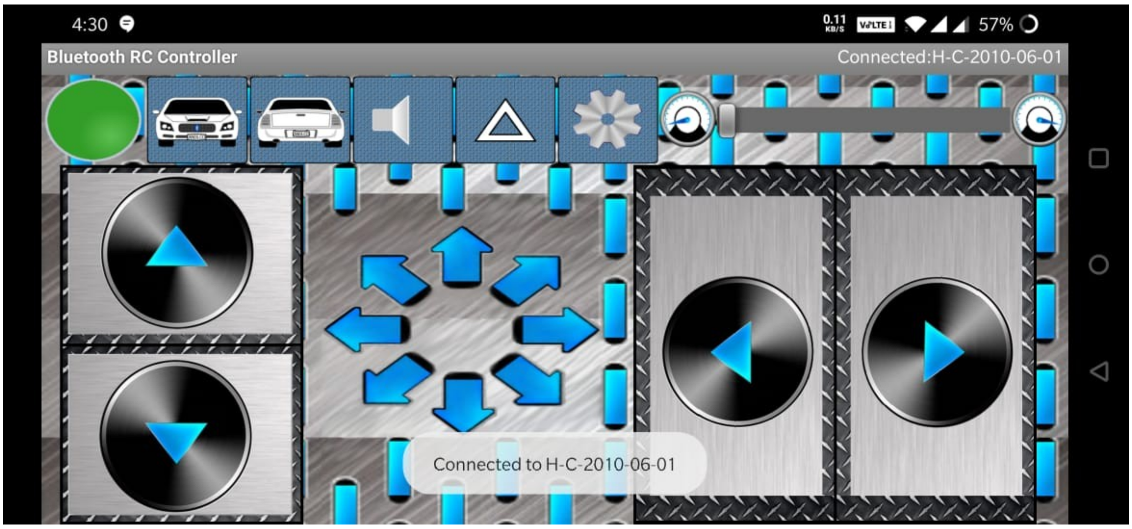


Fig 4.1.4 Connection Success Screen

Step 4 : After connected you get a notification saying connected to the Bluetooth module. (Fig 4.1.4)

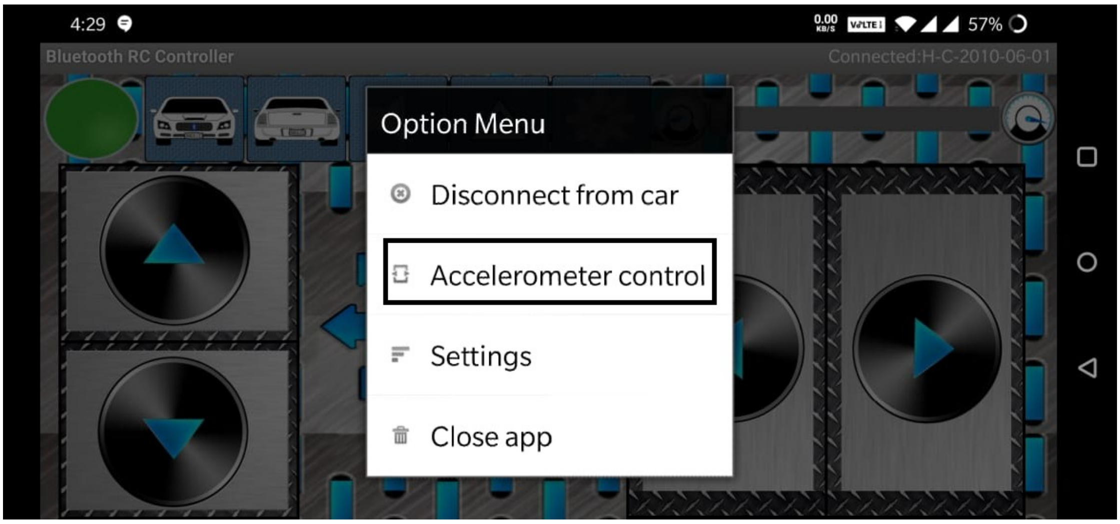


Fig 4.1.5 Control Scheme selection

Step 5 : Press on setting menu and Accelerometer control in order to change it to gesture mode.(Fig 4.1.5)

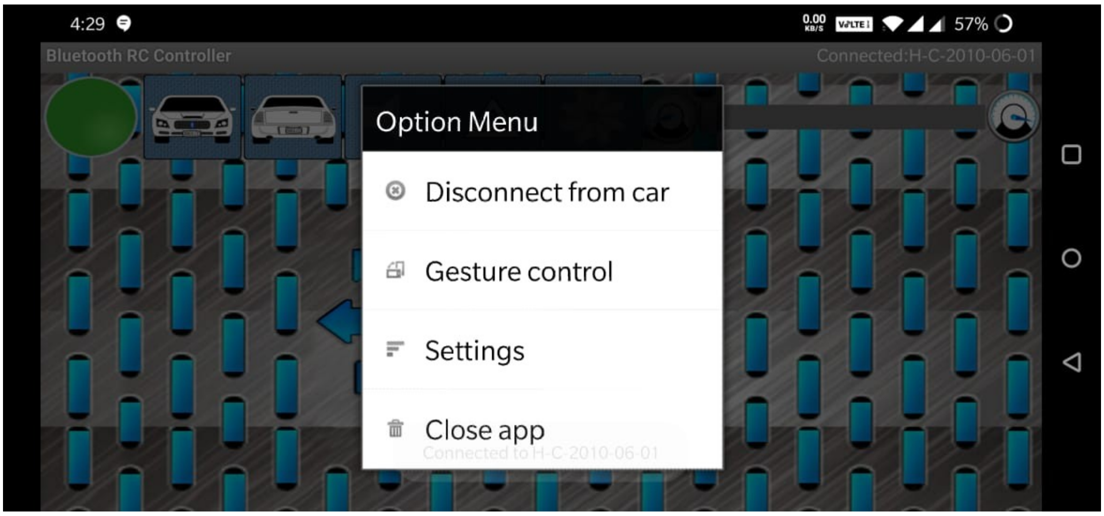


Fig 4.1.6 Options Menu

Step 6 : Press on gesture control in order to go back to remote control. (Fig 4.1.6)

Step 7 : Press in disconnect in order to disconnect the car and close app in order the close the app. (Fig 4.1.6)

4.2 Receiver Electronics

The receiver module is made up of 4 components :

1. HC-05 Bluetooth Module

Helps in recieving of instructions from the glove to Ball-E. The RX line recieves instructions and TX line transmits it.

2. Arduino UNO

The brain of Ball-E, which is responsible for sending necessary instructions from the sensed data provided to it.

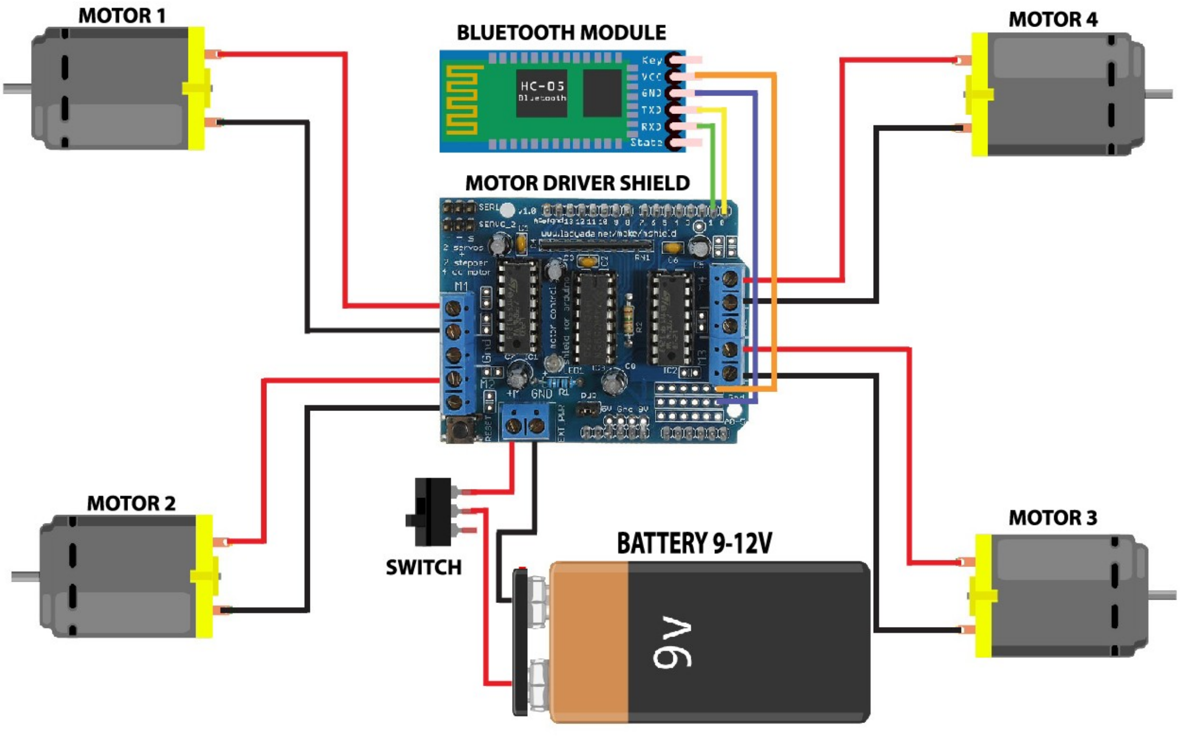


Fig 4.2 Schematic of Reciever Module

3. L-293D 4 Geared Motor Driver Module

It is a high power motor driver module for driving DC and Stepper Motors which helps move the wheels accordingly to the signals given by the Arduino. The module consists of an L293D motor driver IC. It can control up to 4 DC motors, or 2 DC motors with directional and speed control.

4. Pololu 50:1 35D Metal Gearbox

It is a miniature, high-power, 12 V brushed DC motor which has a long lasting carbon brushes & extended motor shaft which helps in the actual movement of Ball-E.

4.3 Camera System

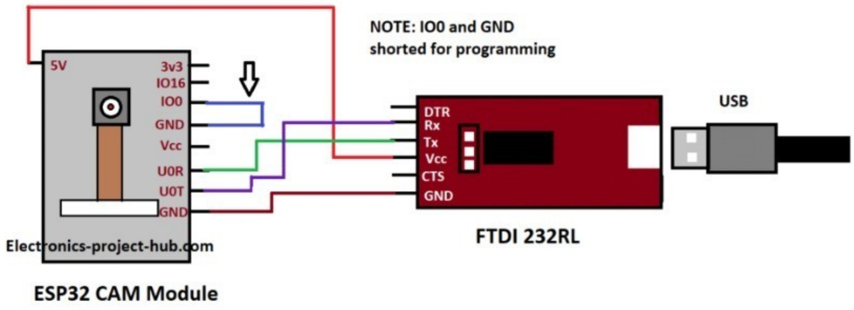


Fig 4.3 Schematic of Camera Module

The camera system is made up of 2 components :

1.ESP32-CAM

A small lens which acts as a camera for our robot. The module contains a built in interface which helps in detecting faces. It is lightweight and compact which are additional benefits.

2. FTDI 232RL / TTL Connector

This module helps in connecting to the Wi-Fi & also acts as a power source for the camera module. It contains the source code for the camera which helps in face detection and video streaming.

4.4 Design Flow

All the modules follow the specific logic flow in order to achieve the complete mechanism designed to be achieved by Ball-E.

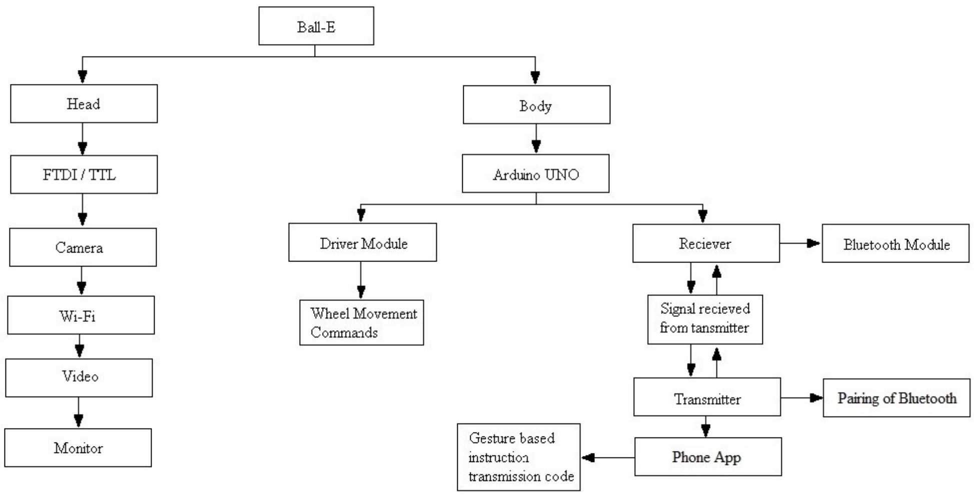


Fig 4.4 Design Flow Chart

5. Implementation

As we have charted the design and system involved in making Ball-E we can now start putting the robot together.

Step 1: Gather the Parts and Materials

Procurement of materials. As the parts needed sourcing from different vendors, a planned acquisition was executed.

Step 2 : Prepare the globe

The globe was cut and hollowed. The internal measurements were taken for creating the base on which the mechanical parts will reside, which will be placed inside the body of Ball-E.

Step 3 : Smooth the surface

Any roughness present inside & outside was smoothed.

Step 4: Draw details and outlines on Ball-E's Body

Used figures & pictures from the internet as reference. Circular shapes were drawn using a compass. While straight lines which falls on the curved surface of the body were traced with a tailor's tape measure.

Step 5 : Mask the Body

Used lots of masking tape to mask the areas that need not be painted on.

Step 6 : Paint Ball-E's Body

Painted Ball-E's body with 3 different colours of spray paint: white, grey and orange. Dried it overnight under the fan.

Step 7 : Peel the Mask

Masks were carefully pealed off to reveal Ball-E’s new body

Step 8 : Making Ball-E's Head

Using a smaller globe cut in half, we make the head for Ball-E ready.

Step 9 : Draw the details on Ball-E's Head

Used the same techniques used to draw details on Ball-E’s body.

Step 10: Paint Ball-E's Head

Painted Ball-E's head with the same 3 different colours of spray paint: white, grey and orange. Dried it overnight under the fan.

Step 11: Make Ball-E's Eye

Clear a smaller plastic globe/ball by wiping it out with Acetone to leave an area so as to place the electronics for live feed.

Step 12: Integrate Ball-E’s Eye into the Head

Place the Eye inside the head of Ball-E and make adjustments as necessary.

Step 13: Build the mechanism on the base plate

Using wood as the base of the robotic mechanism, putting the mechanical parts together & connected on this base plate.

Step 14 : Build a makeshift Lithium Battery Pack

Assembling our own Lithium-ion battery pack. In this project we’re using a 4 cell battery pack. Simply just soldering four 18650 (3.7v 2000mAh) Lithium-ion batteries in series which are rechargeable (which are very cheap and common). We made two sets of these and connected them in parallel for a total of 14.4v (4,000mAh).

Step 15 : Mount the Metal Gearbox

Mount the metal gearbox together with the brackets on the wooden platform using nuts & bolts.

Step 16 : Establish the Electronics in Ball-E’s body

Characters via Bluetooth would be passed every time a gesture is understood and sent as instruction. The Bluetooth module receives the data while the Arduino interprets and processes these data. The Arduino sends signals to the Motor Driver shield to give a go signal for the switching off the motors. The following steps explain in detail the connections:

1) Mount the Arduino to the platform
2) Stack the Motor Driver Shield
3) Connect the left motor's wires to M1A & M1B
4) Connect the right motor's wires to M2A & M2B
5) Mount The Lithium-Ion Batteries

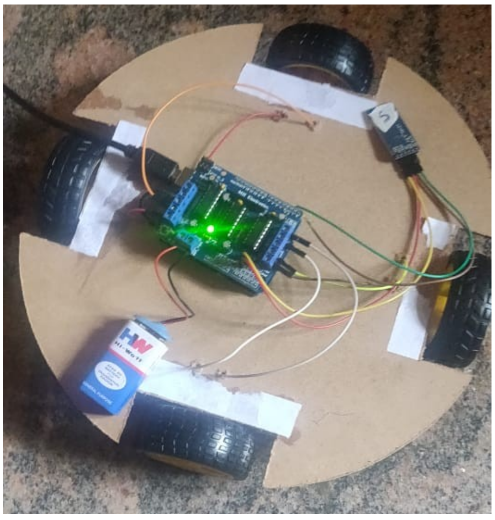


Fig 5.1 Ball-E’s Electronics

Step 17 : Add the Bluetooth & Receiver Module

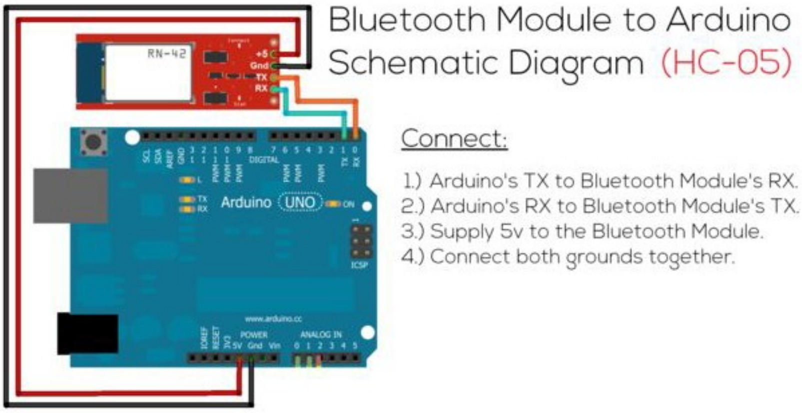


Fig 5.2 Connecting Bluetooth Module to Arduino

Step 18 : Program the Robotic Mechanism

Before uploading the code/program to the Arduino UNO board, be sure to install the Pololu Motor Driver Library. Also, please do not forget to disconnect the TX-RX lines of the Bluetooth module from the Arduino. This is done to prevent the Bluetooth module from interfering with the Arduino during the programming process.

Step 19 : Develop the program code

Development of the code for the body movement, gloves instruction recognition, display of video and writing the related code.

Step 20 : Cut Ball-E's Body in half

Use a hacksaw to cut BB8's body in half.

Step 21 : Build makeshift Rollers

Using the roll-on mechanism form deodorants.

Step 22 : Building Ball-E's Internal Magnetic Head Mechanism

Ball-E has a magnetic mechanism that keeps the head upright. He has an Internal and External one. In this design, we hot glued four magnets on pillars (work as makeshift rollers). The four elongated wooden shafts are mounted to the base using hot glue to hole these pillars are upright.

Step 23 : External Magnetic Mechanism - Adding Magnets to the Head

Use the 4 pillars to mount the magnets on which the internal mechanism rests. Then again, use magnets as ball bearings for the makeshift rollers. Install one half of Ball-E's body (above the internal mechanism) and then use the magnets to locate each other from either side by letting them attract each. You don't have to take measurements in order to find the exact position of the other the magnets from the either end. Finally hot glue the magnets to the pillars and then hot glue the other set of magnets to the head of Ball-E.

Step 24 : Establish the Interface with the app

Start the interface to check if the modules are working together and interfacing well.

Step 25 : Sealing The Robot

Encapsulate the robotic mechanism and use superglue or wood glue to seal BB8's body together.

Step 26 : Testing, Debugging & Validation Phase

Debug any errors encountered during the operation of Ball-E. Recurrent testing of the code by running Ball-E through multiple scenarios, monitoring performance and fine tuning code. After being satisfied with the finesse of Ball-E's operation, validate it's use cases and performance.

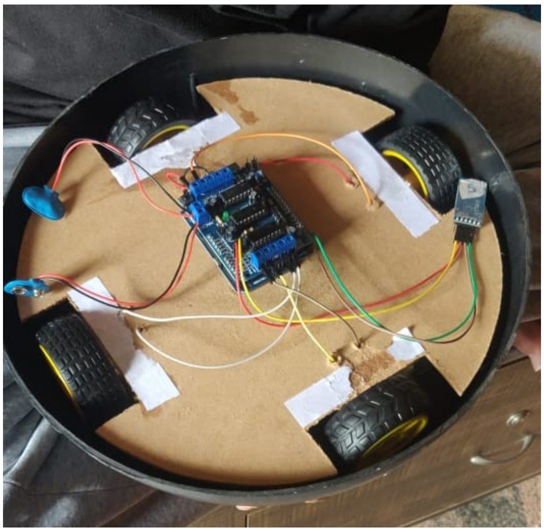


Fig 5.3 Completed Ball-E internals

Fig 5.4 Ball-E's Body

6. System Testing

6.1 Facial Recognition

Objective - Perform tests to determine whether Ball-E could recognise faces.

Test - Multiple faces and pictures scanned in order to determine;

i) if Ball-E could differentiate between a picture and a human

ii) if Ball-E could recognise different human subjects

Results -

i) when encountered with a picture of a human being, Ball-E occasionally recognises it as a human & produces a positive result. This is due to lack of biometric recognition.

Fig 6.1.1 Result

ii) Ball-E can easily determine the differences in humans and give accurate results

Fig 6.1.2 Recognisable Face Result

Fig 6.1.3 Unrecognisable Face Result

Improvements -

i) inclusion of more powerful AI & ML techniques for facial recognition can be included with an upgrade in equipment used.

ii) a better camera & lens system can help improve the quality of image capture, in turn helping in better recognition.

6.2 Ball-E's motion

Objective – Test the speed of movement of Ball-E

Test - The program allows us to take control of the motor speed individually. The max value that can be set in the program is 255. Hence, 255 is the max value for an individual motor to run the wheel at 100% power or max RPM.

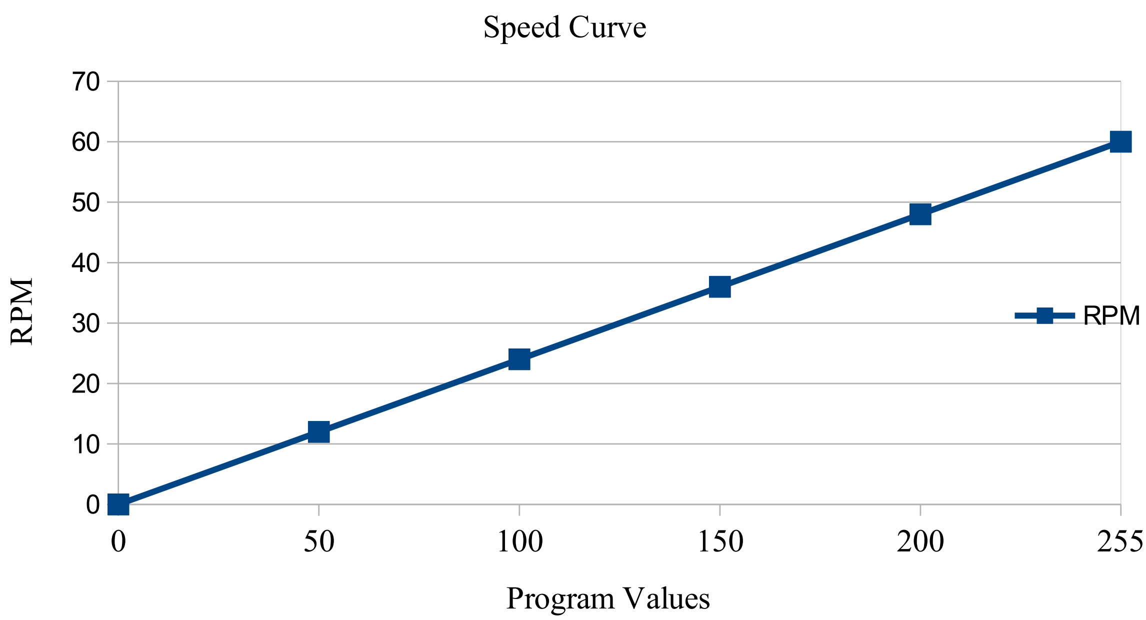


Fig 6.2 Speed Curve for Ball-E

Results -

The results plotted in a graph which relaters to speed of Ball-E indirectly. The max speed of Ball-E in this setup is around 1 m/s.

Improvements -

i) Inclusion of better motor

ii) Improved battery pack for better power delivery

7. Results and Discussion

The following figures show the application interface when the robot interacts successfully to the commands it is given. Once the control scheme is changed to gesture, we can use the following gestures.

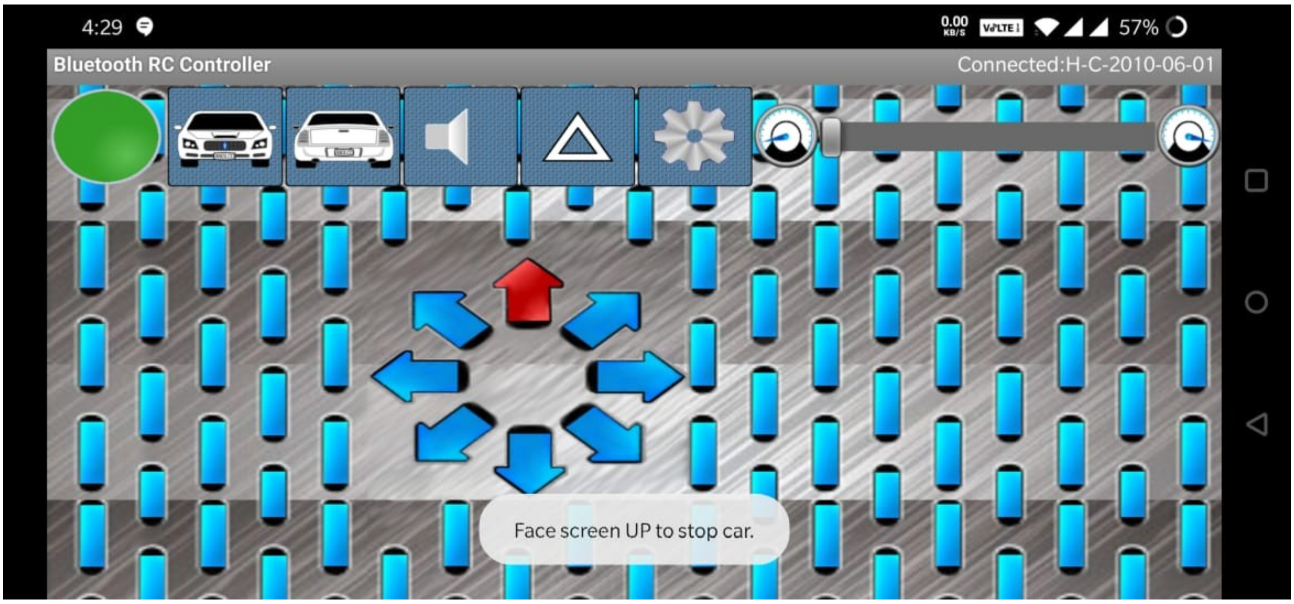


Fig 7.1 Tilt phone forward in order to go in the forward direction

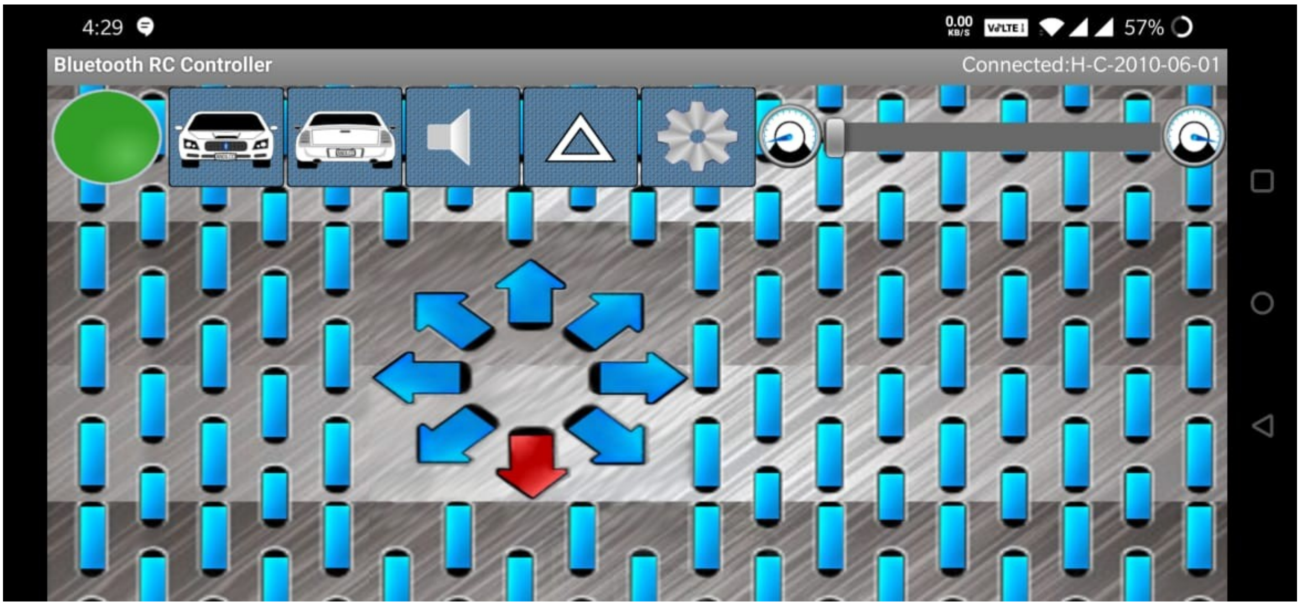


Fig 7.2 Tilt phone backward in order to go in the backward direction

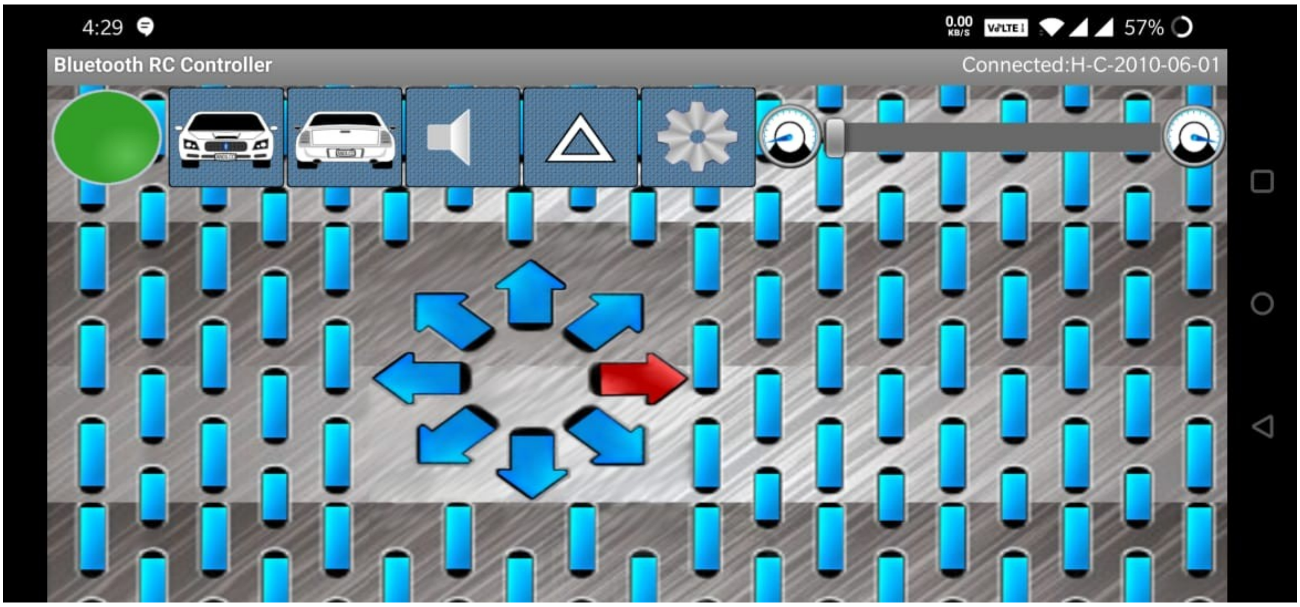


Fig 7.3 Tilt phone right in order to go in the right direction

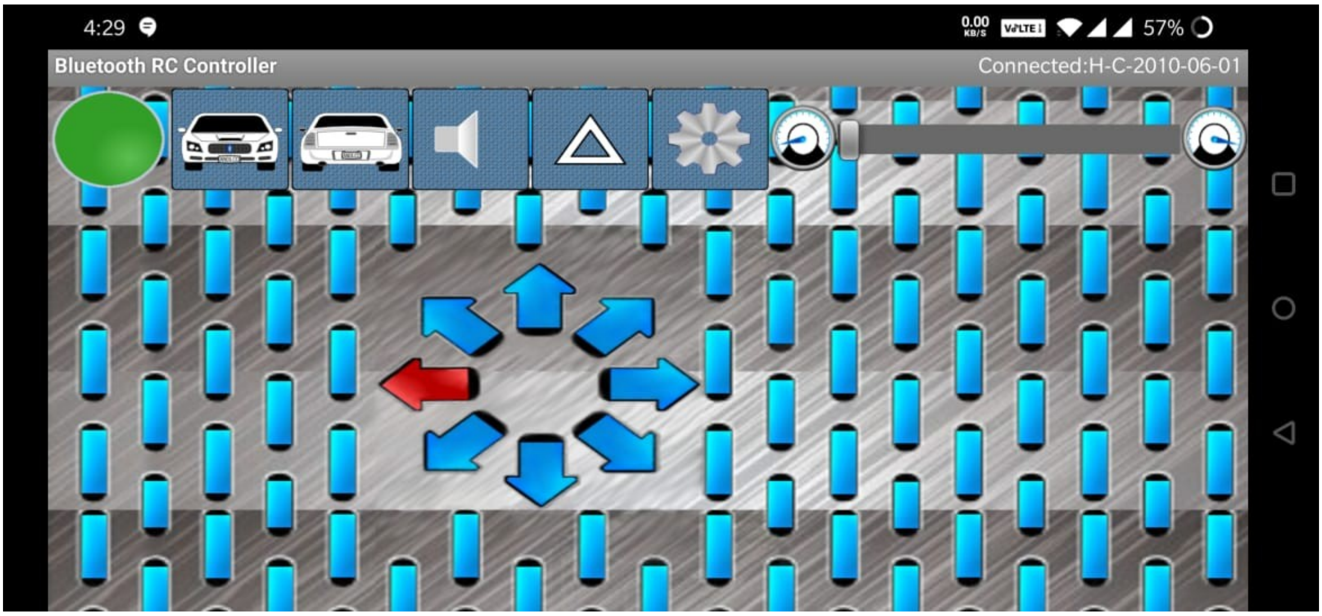


Fig 7.4 Tilt phone left in order to go in the left direction

We're happy with the results as t was a learning experience and this endeavour turned out to be a fruitful one. Ball-E is as a versatile holonomic robot which can extend it's capabilities and serve greater purposes when augmented with the right tools.

Conclusions and Future Enhancements

Holonomic robots are very versatile and have vast deployment scenarios. The simplicity of gestures allows a wider audience to make best use of Ball-E. The robot can be used for a varied purposes such as a home companion, security support by threat detection & surveillance, delivery robot, garbage collector etc. & move around with the help of hand gestures. With so many opportunities, we can produce a versatile robot capable of helping humans in multiple fields.

Future enchantments could include the inclusion of but not exclusively :

1) Arms to facilitate interaction with instruments and environment.
2) More powerful motors and bigger battery.
3) Improved camera systems which bring in the ability for thermal imaging, night vision etc.
4) Improvement to battery system
5) Improvement by including higher powered motors for better speed

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