DESIGN AND FABRICATION OF
SELF-DRIVING DELIVERY ROBOT

Submitted in partial fulfilment of the requirements for the award of
Bachelor of Engineering degree in Mechanical Engineering

By

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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Accredited with Grade "A" by NAAC

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BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **SHALOM TIRKEY (37150176) and THOTAKURA AYYAPPA (37150195)** who carried out the project entitled **"Design and Fabrication of Self-Driving Delivery Robot"** under our supervision from **M.PURUSOTHAMAN**

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(Name in Capital letters
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DECLARATION

We **SHALOM TIRKEY (37150176), THOTAKURA AYYAPPA (37150195)** hereby declare that the Project Report entitled **"DESIGN AND FABRICATION OF SELF-DRIVING DELIVERY ROBOT"** done by me under the guidance of **Mr. M.Purusothaman, M.E., (Ph.D.,)** is submitted in partial fulfilment of the requirements for the award of Bachelor of Engineering degree in Mechanical Engineering.

DATE: **SIGNATURE OF THE CANDIDATE**

PLACE: CHENNAI

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ABSTRACT

In the present age delivering parcel is quite a usual thing/process. Most of the population orders product online and then the product travels till it reaches the consumer who ordered. Travelling through a vehicle consumes a lot of fuel which causes pollution. We cannot stop pollution due to fuel but we can reduce it, SELF-DRIVING DELIVERY ROBOT can help to reduce pollution and at the same time deliver the parcel who stays near the starting point. Self-Driving Delivery Robot local delivering the parcel from the hub station to the short-range consumer who are nearly 6 km from the hub. When the product comes to the delivery centre then it will notify the consumer and will send an OTP on their phone which will help then to open the lid of the robot where they can collect their parcel. This can also use inside a building like hospital or any other office to transfer some things from one place to another.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Do you order products or food online? At the modern age people are flooded with opportunity to buy any product without going out of their houses and receiving it without going anywhere which is quite amazing. Delivery is one of the essential process of online order. Though delivery is done by delivery executives even so for close range delivery, a delivery robot can be use as it saves time and more parcels can be delivered. Self-delivery robot is expected to revolutionize delivery system, yielding with low-priced and efficient way of delivering.

1.1. SELF-DELIVERY ROBOT

Self-Delivery Robot is an intelligent machine which is capable of executing task by themselves, without explicit human control or otherwise stated Self-Delivery Robot is battery powered motorised robot that can deliver items or packages to consumer without the interference of a delivery person. They are not only used for long distance delivery but also used inside office buildings for transferring some items. Through Self-Delivery Robot better control of transport management can be handle within the city. Organization such as hotel, airport and private organization or university with extensive ground of their own have a good opportunity to use this product to deliver items within their building area such as snacks, documents, books, stationary items any many more items to guest, student and staff. The ease of delivering the items have drastically increased due to Self-Delivery Robot as there is no need to assign a person for delivery.

Self-Delivery Robot is not a big industry but it’s a growing as people are slowing adopting this product as it is mainly driven by increasing cost-efficient and flexible for automated fulfilment which helps to reserve time and bring down the human error. As there is a growth in e-commerce as well as online food orders Self-Delivery Robot can help to reduce the time of delivery and at this pandemic era it is best as no human contact will occur while receiving the parcel.

1.2 NEED FOR SELF-DELIVERY ROBOT

Delivery can be achieved by delivery executives but in hard time like pandemic it’s very risky for every human being to have contact to each and every customer and still we need to fulfil the demand of the supply chain. Here’s how Self-Driving Robot are poised to change the game.

Self-Driving Robot can help in various ways like:

- It reduces human error and rework caused due to errors.
- It increases efficiency and productivity for supplying.
- It improves safety of workforce in precarious work environment.
- Amplify revenue, by improving perfect order fulfilments rates, fast delivery and eventually customer satisfaction.
- It reduces man power on mundane task so employees can concentrate on strategies efforts that can’t be automated.
- It can collect the data and analyse data for providing best service in the near future.
- It reduces employee injuries.

Self-Driving Robot are helping define the supply chain of the future by aiding companies shrink long-term costs, supply labour as well as utilization stability worker’s productivity is increased, the error is reduced, optimize pickup, sorting and deliveries and possibility of delivery to difficult location is increased. Since Self-Driving Robot can potentially move items, they have a strong grip potential to make deliveries further convenient and efficient.

These days pollution in a major problem all over the world. Yes, we cannot stop it but there are some possibilities to reduce pollution. Self-Driving Robot uses batteries as well as solar panel as source of power to run which does not discharge and residue, this helps to maintain clean and healthy environment.

CHAPTER 2

LITERATURE SURVEY

Thomas Hoffmann and Gunnar Prause (1 August 2018) Self driving delivery robots are developed all around the world, and the first prototypes are tested already in last-mile deliveries of packages. Estonia plays a leading role in this field with its, start-up Starship Technologies, which operates not only in Estonia but also in foreign countries like Germany, Great Britain, and the United States of America (USA), where it seems to provide a promising solution of the last-mile problem. But the more and more frequent appearance of delivery robots in public traffic reveals shortcomings in the regulatory framework of the usage of these autonomous vehicles—despite the maturity of the underlying technology. The related regulatory questions are reaching from data protection over liability for torts performance to such mundane fields as traffic law, which a logistic service provider has to take into account. This paper analyses and further develops the regulatory framework of autonomous delivery robots for packages by highlighting legal implications. Since delivery robots can be understood as cyber-physical systems in the context of Industry 4.0, the research contributes to the related regulatory framework of Industry 4.0 in international terms. Finally, the paper discusses future perspectives and proposes specific modes of compliance.[2]

Devang Dave, Parth Parsana and Aarjav Ajmera (Oct 2020) The self-delivery robot is meant to be a substitute for a goods delivery person. The delivery robot is capable of navigating through a cluttered space environment from a home location to a destination point while avoiding obstacles in the process. It uses an ultrasonic sensor to detect if anything has been placed inside the bin and only once when something is placed inside, the robot starts moving from a position to another. Bluetooth beacons are used to represent the start, end and mid-point which will be used by the robot to differentiate the specified locations. Bluetooth beacons will act as a terminal for the robot to detect. The autonomous robot will move on an undesignated path i.e., an unmarked route unlike the archaic robots only capable of moving inside a marked black lane. The robot will be trained and multiple simulations are run on it with the help of the Donkey Car library so it can successfully avoid obstacles and relay the path with efficacy, making the delivery fast and efficient. A Pi camera is used which will help rectify the unmarked desired path over which the robot has to move.[3]

Nils Boysen, Stefan Fedtke & Stefan Schwerdfeger (21 September 2020) In the wake of e-commerce and its successful diffusion in most commercial activities, last-mile distribution causes more and more trouble in urban areas all around the globe. Growing parcel volumes to be delivered toward customer homes increase the number of delivery vans entering the city centers and thus add to congestion, pollution, and negative health impact. Therefore, it is anything but surprising that in recent years many novel delivery concepts on the last mile have been innovated. Among the most prominent are unmanned aerial vehicles (drones) and autonomous delivery robots taking over parcel delivery. This paper surveys established and novel last-mile concepts and puts special emphasis on the decision problems to be solved when setting up and operating each concept. To do so, we systematically record the alternative delivery concepts in a compact notation scheme, discuss the most important decision problems, and survey existing research on operations research methods solving these problems. Furthermore, we elaborate promising future research avenues.[6]

Dylan Jennings, Miguel Figliozzi (16 May 2019) E-Commerce and package deliveries are growing at a fast pace and there is an increased demand for same-day deliveries. Established delivery companies and new startups are investing in technologies that reduce delivery times or increase delivery drivers' productivity. In this context, the adoption of sidewalk automated (or autonomous) delivery robots (SADRs) has a growing appeal. SADRs are pedestrian sized robots that deliver items to customers without the intervention of a delivery person. Because SADRs travel on sidewalks they have been the subject of increasing regulation by local agencies in the U.S. The three research questions that guide this research effort are: (a) What are the limitations imposed by existing regulations in the U.S.? (b) What are the technical capabilities of existing SADRs? and (c) Given the existing capabilities and regulations, what are the time/cost savings and efficiencies that SADRs can bring about? The first part of the research discusses current U.S. regulations on SADRs and reviews existing SADR devices and their capabilities. Building on this knowledge, the second half of the research presents a novel model to estimate delivery time and number of customers served utilizing a combination of SADRs and a special delivery van. These results are compared with a baseline (or prevailing) delivery system utilizing only a conventional delivery van and human driver. Results, insights, and potential implications are discussed. The results show that SADRs can provide substantial cost and time savings in some scenarios. Furthermore, the introduction of SADRs may significantly reduce on-road travel per package delivered.[1]

Ryosuke Murai, Tatsuo Sakai (Dec. 2012) Control systems for Autonomous mobile delivery robots have been described before. However, the control they provide is limited, leaving potential for serious errors. The current mobile robot systems concentrate on position accuracy and operational function but leave open management of safety hazards such as entering the dangerous and not intended areas as stairway. In order to increase the safety of the robot, it is as important to work with sensors installed in the external environment as the sensors installed on the robot. For this purpose, visible light communication (VLC) is a promising device to be used with the robot system. VLC creates an in-house GPS system by installing special LED lights that can replace standard lighting in key locations in the hospital. We have developed an in-hospital transportation robot, called HOSPI in which the control system has been enhanced by combining the navigational sensors of the robot and a VLC using installed lighting in the building. By using VLC, robots can obtain more information about the environment. As the first step for the practical application of VLC to robot system, we use VLC to overcome problems in conventional localization approaches, and to provide an additional line of defence in the case of catastrophic failures. This paper also describes experimental and actual operational results in detail of robots equipped, in an actual hospital, with the described process.[7]

Dongil Choi (02 Jan 2020) This paper introduces the concept of motion planning of delivery robot in an autonomous driving mode using an inverted pendulum model that can effectively control disturbance. The inverted pendulum model exhibits the non-minimum phase characteristic caused by the right half-plane zero. An effective method of reducing this characteristic is examined. A motion platform with 3-degree-of-freedom motion and a touch sensor are installed on a wheeled omnidirectional mobile platform. A steel ball is placed on the touch sensor and controlled to be located at the centre. As the autonomous delivery robot moves, the steel ball is subjected to various disturbances and goes off the centre. The influence of disturbance can be predicted by measuring the distance the steel ball moves away from the centre. In this paper, linear quadratic regulator, preview control, and model predictive control are applied to the inverted pendulum model for motion planning, and thus the reduction of the non-minimum phase characteristic can be comparatively analysed via simulation. The decrease in the disturbance is experimentally compared according to motion planning. Consequently, this paper proposes an effective motion planning method for an autonomous delivery robot with non-minimum phase characteristic.[4]

Yangyang Li (May 28, 2020) This paper introduces an autonomous robot (AR) cart to execute the last mile delivery task. We use navigation and intelligent avoidance algorithms to plan the path of the automatic robot. When AR encounters a new unrecognizable terrain, it will give control to the customer who can control the AR on its mobile app and navigate to the specified destination. We have initially designed an autonomous delivery robot with the cost of 2774 dollars.[10]

Mingeuk Kim & Dongil Choi (29 November 2019).In this paper, we introduce a variable configuration delivery robot platform named HuboQ. HuboQ is a wheeled mobile platform with 6-DOF manipulator and is the next version of KDMR-1, our previous robot platform. The design of mechanical and electrical systems and the development of overall system are described to illustrate how HuboQ is structured and improved. The variable configuration can overcome the disadvantages of using only one configuration. There are three variable configurations at HuboQ, four-wheel ZMP control configuration, two-wheel self-balancing configuration and two-wheel human-riding configuration. HuboQ can be used as an autonomous delivery robot and also as a human transporter. Experiments have demonstrated dynamic driving performances of the ZMP control and of two-wheel balancing control.[5]

Gryd (2016) In package delivery business the most wasteful part is the last-mile delivery. It means delivering packages from package sorting office to client’s door. This kind of delivery takes a lot of time and energy which also adds on the client’s delivery cost. By using autonomous delivery robots these costs can be brought down to about fraction of the usual cost. Also, clients can have more control over the time the package arrives to the door. [8]

Delivery efficiency is even more increased by fact that robots don’t need to rest like humans and can work 24/7. Robots usually run-on batteries and are thus very environment friendly and can move along sidewalks (UGV) or fly above buildings (UAV). During the exercise we build a simple ground vehicle platform which has the ability to move along people. This kind of robot platform is the basis of a delivery robot. By adding camera, sensors and connectivity the robot can be made fully autonomous and also remotely controllable for difficult to pass through areas.[9]

CHAPTER 3

AIM AND SCOPE

The aim of this project is to develop a robot cart which will deliver the parcel without any human contact to the customers. This robot can be used for many delivery purposes like in any food or item parcel, in any offices, hospitals, airplane for documents, samples and food respectively. Self-Delivery Robot also helps to reduce the pollution as it uses batteries or/and solar panel as a source to run, it also reduces the vehicle which were to be used for delivery. The advent of Self-Delivery Robot is predicted to revolutionize the last mile delivery systems, providing a less expensive and efficient way of delivery. Though delivery robots haven't had high adoption, they're expected to possess high growth within the future, due to various advantages. Due to the outbreak of Covid-19 the demand for contactless delivery has expanded exponentially which can be provided by using this robot. Self-delivery robots are robots that work autonomously and are mainly utilized for delivery and service applications. Their applications and adoption within the healthcare, hospitality, retail, and logistics industries are only considered while evaluating the scope of the end-user segment. The study will also cover the impact of Covid-19 across the self-delivery robot market.

3.1 METHODOLOGY:

This paper highlights the present status of autonomous self-driving package delivery robots that are used for intra-supply chain transport in Industry 4.0 networks, also as for the delivery to the client on the last mile. The research is predicated on semi-structured expert interviews, desktop and secondary data analysis. It is not the aim of this paper to offer a comprehensive overview of the world of autonomous delivery robots, which is impossible thanks to the massive number of developments in this sector. Nevertheless, the paper highlights technical, legal, and regulatory issues that are evolving with the event of autonomous delivery robots. Self-delivery robots are placed in the context of Industry 4.0 and machine to machine systems so that exiting concepts are firstly

applied to case of delivery robots. In the sequel, actual issues that are associated with liability and data protection are discussed. Finally, social-technical aspects and possible legal solutions are discussed and an outlook for tentative developments is discussed. Therefore, the research questions are:
RQ 1: How do autonomous delivery robots work, and how are they defined in the context of liability?

RQ 2: Which regulatory frameworks apply on delivery robots?
RQ 3: Where does the current use of delivery robots' conflict with these frameworks, and what shall users be advised to prevent violations?
Literature review reveals a search gap within the listed research questions. In addition, a case study of 1 of the foremost important start-ups for delivery robots is given to debate and to empirically verify the research. For this purpose, the empirical evidence during this paper is predicated on the qualitative research style. Here, the complexity of the research question requires personal interviews and a qualitative approach. The willingness to answer questions during a greater depth and in an open discussion can only be achieved by personal and individual conversations with selected interview partners. Furthermore, the sector of delivery robots addresses a quickly developing innovative sector, in order that an outsized a part of the knowledge is confidential; the research has got to balance between novelty of science and therefore the business secrets of the investigated companies.

CHAPTER 4

MATERIAL METHODS AND ALGORITHMS USED

The major parts that are effectively employed in the fabrication of the Self-Delivery Robot are described below.

- Batteries
- D.C. Motors
- Wheels
- Ultrasonic Sensors
- Arduino
- Bluetooth Module
- Global Positioning System (GPS)
- Servo Motor
- Solar Panel
- Acrylic Sheet

4.1 BATTERY

A battery is a device consisting of 1 or more electrochemical cells with external connections for powering electrical devices like flashlights, mobile phones, electric cars etc. When A battery is supplying electrical power, its positive terminal is that the cathode and its negative terminal is that the anode. The terminal marked negative is that the source of electrons which will flow through an external circuit to the positive terminal. When A battery is connected to an external electric load, a redox reaction converts high-energy reactants to lower-energy products, and therefore the free-energy difference is delivered to the external circuit as electricity. Historically the term "battery" specifically mentioned a tool composed of multiple cells, however the usage has evolved to incorporate devices composed of one cell.

Batteries seem to be the only technically and economically available storage means. Since both the photo-voltaic system and batteries are high in capital costs. It is necessary that the overall system be optimized with respect to available energy and local demand pattern. To be economically attractive the storage of solar electricity requires a battery with a particular combination of properties:

(1) Low cost

(2) Long life

(3) High reliability

(4) High overall efficiency (5) Low discharge

(6) Minimum maintenance

(A) Ampere hour efficiency

(B) Watt hour efficiency

We use lead acid battery for storing the electrical energy from the solar panel for lighting the street and so about the lead acid cells are explained as shown in the Fig 4.1.

Fig 4.1 Batteries

4.1.1 Battery Specification

Battery capacity: 9V, 0.5Ah

Number of Battery used: 2 units

Battery Type: Alkaline Battery

4.1.2 Connector

The battery has both terminals during a snap connector on one end. The smaller circular terminal is positive, and therefore the larger hexagonal or octagonal terminal is that the negative contact. The connectors on the battery are an equivalent as on the load device; the smaller one connects to the larger one and the other way around. The same snap-style connector is employed on other battery types within the electrical converter series. Battery polarization is usually obvious, since mechanical connection is usually only possible in one configuration.

A problem with this sort of connector is that it's very easy to attach two batteries together during a short, which quickly discharges both batteries, generating heat and possibly a fire. Because of this hazard, nine-volt batteries should be kept within the original packaging until they're getting to be used. Battery Connector is shown in the fig 4.2.

Fig: 4.2 Battery Connector

4.2 D.C MOTOR

The electrical motor is an instrument, which converts electrical energy into mechanical energy. According to faraday’s law of Electromagnetic induction, when a current carrying conductor is placed in a magnetic field, it experiences a mechanical force whose direction is given by Fleming’s left-hand rule.

Constructional a dc generator and a dc motor are identical. The same dc machine can be used as a generator or as a motor. When a generator is in operation, it is driven mechanically and develops a voltage. The voltage is capable of sending current through the load resistance. While motor action a torque is developed. The torque can produce mechanical rotation. Motors are classified as series wound shunt wound motors.

4.2.1 Principles of Operation

The basic principle of Motor action lies in a sample sketch.

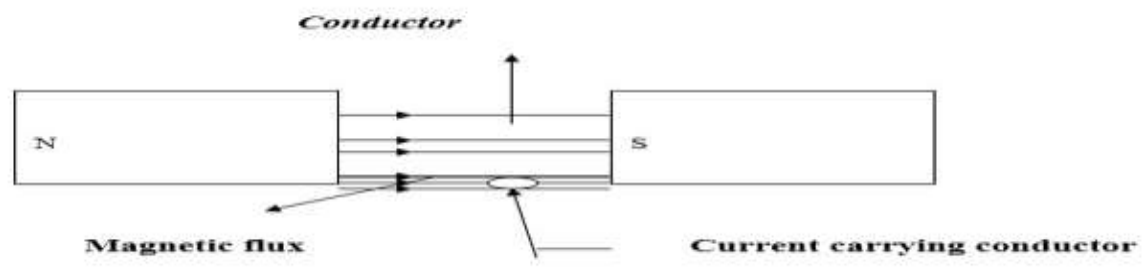


Fig: 4.3 Current Carrying Conductor

The motor run's according to the principle of Fleming's left-hand rule. When a current carrying conductor is placed in a magnetic field is produced to move the conductor away from the magnetic field. The conductor carrying current to North and South poles is being removed.

In the above stated two conditions there is no movement of the conductors. Whenever a current carrying conductor is placed in a magnetic field. The field due to the current in the conductor but opposes the main field below the conductor. As a result, the flux density below the conductor. It is found that a force acts on the conductor to push the conductor downwards. If the current in the conductor is reversed, the strengthening of the flux lines occurs below the conductor, and the conductor will be pushed upwards

As stated above the coil side A will be forced to move downwards, whereas the coil side B will be forced to move upwards. The forces acting on the coil sides A and B will be the same coil magnitudes, but their directions will be opposite to one another. In DC machines coils are wound on the armature core, which is supported by the bearings, enhances rotation of the armature. The commentator periodically reverses the direction of current flow through the armature. Thus, the armature rotates continuously.

An electric motor is all about magnets and magnetism: a motor uses magnets to create motion. So, the 2 bar magnets with their ends marked north and south, then the North end of one magnet will attract the South end of the other. On the other hand, the North end of one magnet will repel the North end of the other (and similarly south will repel south). Inside an electric motor these attracting and repelling forces create rotational motion.

In the below fig 4.4 there are two magnets in the motor, the armature (or rotor) is an electromagnet, while the field magnet is a permanent magnet (the field magnet could be an electromagnet as well, but in most small motors it is not to save power).

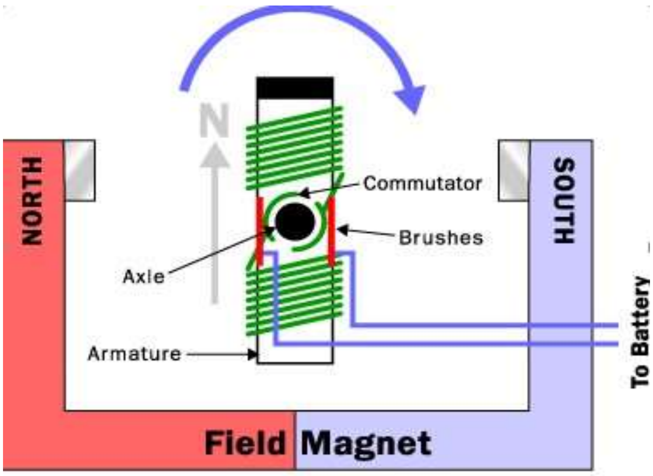


Fig 4.4 Field Magnet

4.2.2 Electromagnets and Motors

To understand how an electric motor works, the key is to understand how the electromagnet works. An electromagnet is the basis of an electric motor.it can be understand by how things work in the motor by imagining the following scenario.

It is created by a simple electromagnet by wrapping 100 loops of wire around a nail and connecting it to a battery. The nail would become a magnet and have a North and South Pole while the battery is connected. Now say that take a nail electromagnet, run an axle through the middle of it, and suspended it in the middle of a horseshoe magnet as shown in the figure below.

It is attached to a battery to the electromagnet so that the North end of the nail appeared as shown, the basic law of magnetism tells what would happen The North end of the electromagnet would be repelled from the north end of the horseshoe magnet and attracted to the south end of the horseshoe magnet.

The South end of the electromagnet would be repelled in a similar way. The nail would move about half a turn and then stop in the position shown the half-turn of motion is simple and obvious because of the way magnets naturally attract and repel one another. The key to an electric motor is to then go one step further so that, at the moment that this half-turn of motion completes, the field of the electromagnet flips.

The flip causes the electromagnet to complete another half-turn of motion. the magnetic field is flipped simply by changing the direction of the electrons flowing in the wire. If the field of the electromagnet flipped at just the right moment at the end of each half-turn of motion, the electric motor would spin freely.

4.2.3 The Armature

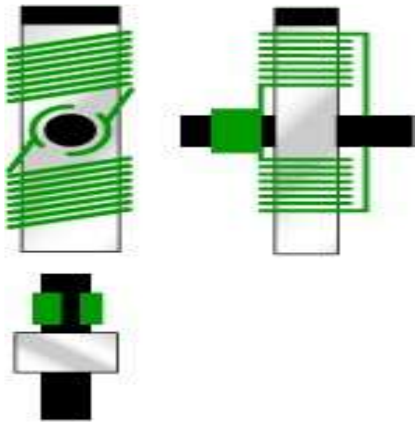


Fig :4.5 The armature

The armature takes the place of the nail in an electric motor. The armature is an electromagnet made by coiling thin wire around two or more poles of a metal core. The armature has an axle, and the commentator is attached to the axle. In the diagram above the three different views of the same armature: front, side and end-on. In the end-on view the winding is eliminated to make the commentator more obvious. the commentator is simply a pair of plates attached to the axle. These plates provide the two connections for the coil of the electromagnet as shown in the fig 4.5.

4.2.4 The Commentator and Brushes

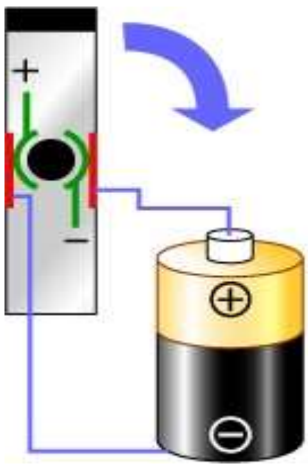


Fig: 4.6 commentator and brushes

The "flipping the electric field" part of an electric motor is accomplished by two parts: the commentator and the brushes. The diagram at the right shows how the commentator and brushes work together to let current flow to the electromagnet, and also to flip the direction that the electrons are flowing at just the right moment.

The contacts of the commentator are attached to the axle of the electromagnet, so they spin with the magnet. The brushes are just two pieces of springy metal or carbon that make contact with the contacts of the commentator as shown in the fig 4.6.

4.2.5 Putting It All Together

When all these parts together, it will constitute a complete electric motor as shown in the fig 4.7.

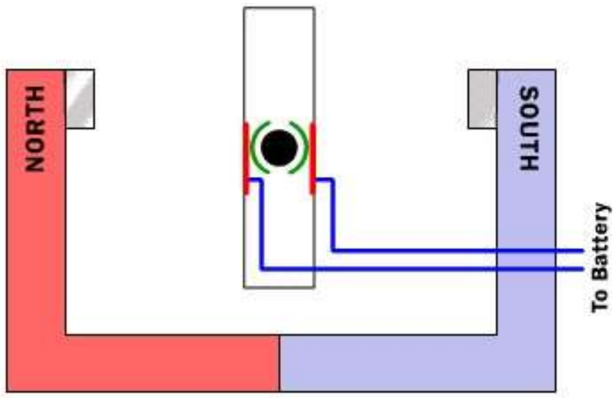


Fig: 4.7 armature winding

In this figure, the armature winding has been left out so that it is easier to see the commentator in action. The key thing to notice is that as the armature passes through the horizontal position, the poles of the electromagnet flip.

Because of the flip, the North Pole of the electromagnet is always above the axle so it can repel the field magnet's North Pole and attract the field magnet's South Pole.

The electric motor is taken apart so as to find that it contains the same pieces described above: two small permanent magnets, a commentator, two brushes and an electromagnet made by winding wire around a piece of metal. Almost always, however, the rotor will have three poles rather than the two poles as shown in this article. There are two good reasons for a motor to have three poles:

It causes the motor to have better dynamics. In a two-pole motor, if the electromagnet is at the balance point, perfectly horizontal between the two poles of the field magnet when the motor starts; you can imagine the armature getting "stuck" there. That never happens in a three-pole motor.

4.3 WHEELS

A wheel is a circular component that is intended to rotate on an axle bearing. The wheel is one of the main components of the wheel and axle which is one of the six simple machines. Wheels, in conjunction with axles, allow heavy objects to be moved easily facilitating movement or transportation while supporting a load, or performing labour in machines. Wheels are also used for other purposes, such as a ship's wheel, steering wheel, potter's wheel and flywheel.

Common examples are found in transport applications. A wheel greatly reduces friction by facilitating motion by rolling together with the use of axles. In order for wheels to rotate, a moment needs to be applied to the wheel about its axis, either by way of gravity, or by the application of another external force or torque. The representation of wheel is shown in the fig 4.8.

Fig: 4.8 Wheel

4.4 ULTRASONIC SENSOR (HC-SR004)

The human ear can hear sound frequency around 20HZ ~ 20KHZ, and ultrasonic is the soundwave beyond the human ability of 20KHZ. Ultrasonic transmitter emitted an ultrasonic wave in one direction, and started timing when it launched. Ultrasonic spread in the air, and would return immediately when it encountered obstacles on the way. At last, the ultrasonic receiver would stop timing when it received the reflected wave. As Ultrasonic spread velocity is 340m / s in the air, based on the timer record and then we can calculate the distance (s) between the obstacle and transmitter, namely: s = 340t/ 2, which is so- called time distance measurement principle

The principle of ultrasonic distance measurement used the already-known air spreading velocity, measuring the time from launch to reflection when it encountered obstacle, and then calculate the distance between the transmitter and the obstacle according to the time and the velocity. Thus, the principle of ultrasonic distance measurement is the same with radar. Distance Measurement formula is expressed as: (L= C * T) in the formula, L is the measured distance, and C is the ultrasonic spreading velocity in air, also represents time (T is half the time value from transmitting to receiving). Ultrasonic sensor is shown in the fig 4.9.

Ultrasonic Application Technology is the thing which developed in recent decades. With the ultrasonic advance, and the electronic technology development, especially as high-power semiconductor device technology matures, the application of ultrasonic has become increasingly widespread

- Ultrasonic measurement of distance, depth and thickness
- Ultrasonic testing;
- Ultrasound imaging;
- Ultrasonic machining, such as polishing, drilling;
- Ultrasonic cleaning;
- Ultrasonic welding;

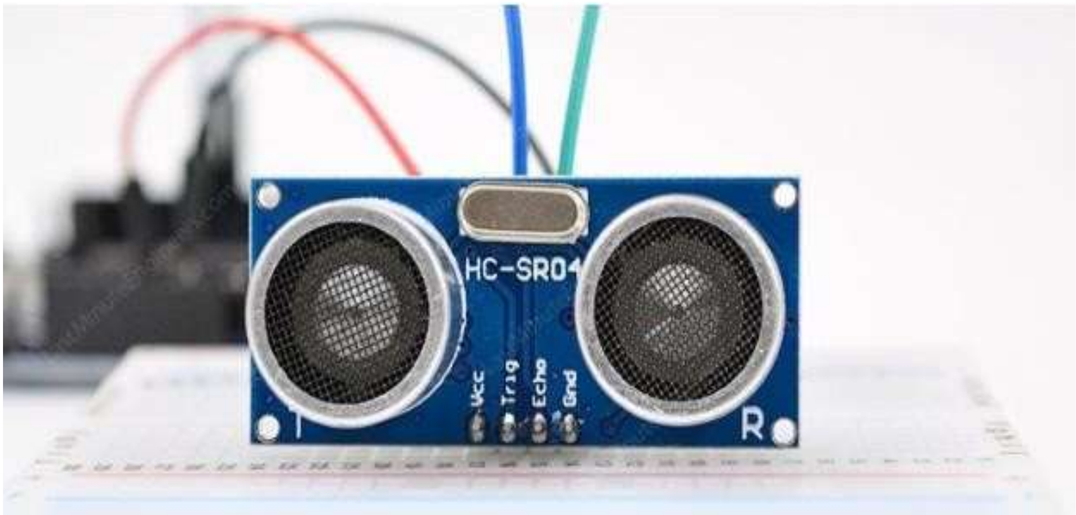


Fig: 4.9 Ultrasonic Sensor

4.5 ARDUNIO UNO AND ITS PROGRAMING

- Arduino is a tool for making computers that can sense and control more of the physical world than your desktop computer. It's an open-source physical computing platform based on a simple microcontroller board, and a development environment for writing software for the board.

- Arduino can be used to develop interactive objects, taking inputs from a variety of switches or sensors, and controlling a variety of lights, motors, and other physical outputs. Arduino projects can be stand-alone, or they can be communicating with software running on your computer. The boards can be assembled by hand or purchased preassembled; the open-source IDE can be downloaded for free.
- The Arduino programming language is an implementation of Wiring, a similar physical computing platform, which is based on the Processing multimedia programming environment which is shown in the fig 4.10.

Fig: 4.10 Arduino

4.5.1 Overview

The Arduino microcontroller is an easy to use yet powerful single board computer that has gained considerable traction in the hobby and professional market. The Arduino is open-source, which means hardware is reasonably priced and development software is free. This guide is for students in ME 2011, or students anywhere who are confronting the Arduino for the first time.

For advanced Arduino users, prowl the web; there are lots of resources. This guide covers the Arduino Uno board (Spark fun DEV-09950, $29.95), a good choice for circuits to read switches and other sensors, and to control motors and lights with very little effort.

The Demilune board features an Atmel ATmega328 microcontroller operating at 5 V with 2 Kb of RAM, 32 Kb of flash memory for storing programs and 1 Kb of EEPROM for storing parameters. The clock speed is 16 MHz, which translates to about executing about 300,000 lines of C source code per second. The board has 14 digital I/O pins and 6 analogue input pins.

There is a USB connector for talking to the host computer and a DC power jack for connecting an external 6-20 V power source, for example a 9 V battery, when running a program while not connected to the host computer. Headers are provided for interfacing to the I/O pins using 22 g solid wire or header connectors. The Arduino programming language is a simplified version of C/C++. If you know C, programming the Arduino will be familiar. If you do not know C, no need to worry as only a few commands are needed to perform useful functions.

An important feature of the Arduino is that you can create a control program on the host PC, download it to the Arduino and it will run automatically. Remove the USB cable connection to the PC, and the program will still run from the top each time you push the reset button. Remove the battery and put the Arduino board in a closet for six months. When you reconnect the battery, the last program you stored will run. This means that you connect the board to the host PC to develop and debug your program, but once that is done, you no longer need the PC to run the program.

The Arduino Uno is a microcontroller board based on the ATmega328.It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, 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.

Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.

4.5.2 Summary

- Microcontroller ATmega328
- Operating Voltage 5V
- Input Voltage (recommended) 7-12V
- Input Voltage (limits) 6-20V
- Digital I/O Pins 14 (of which 6 provide PWM output)
- Analog Input Pins 6
- DC Current per I/O Pin 40 mA
- DC Current for 3.3V Pin 50 mA
- Flash Memory 32 KB (ATmega328) of which 0.5 KB used by bootloader
- SRAM 2 KB (ATmega328)
- EEPROM 1 KB (ATmega328)
- Clock Speed 16 MHz

4.5.3 Pin Configuration

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically. External (non-USB) power can come either from an AC-to-DC adapter (wall- wart) or battery. The adapter can be connected by plugging a 2.1mm centre-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.

The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts. The power pins are as follows:

- *VIN.* The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.

- 5V. this pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board.
- *3V3*. A 3.3-volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- *GND*. Ground pins.
- *IOREF*. This pin on the Arduino board provides the voltage reference with which the microcontroller operates. A properly configured shield can read the IOREF pin voltage and select the appropriate power source or enable voltage translators on the outputs for working with the 5V or 3.3V.

4.5.4 Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM.

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pin Mode (), digital Write (), and digital Read () functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull- up resistor (disconnected by default) of 20-50 ohms. In addition, some pins have specialized functions:

- Serial: 0 (RX) and 1 (TX). Used to receive (RX) and Transmit (TX) TTL serial data.
- These pins are connected to the corresponding pins of the ATmega8U2 USB-to- TTL Serial chip.
- External Interrupts: 2 and 3. These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attach Interrupt () function for details.
- PWM: 3, 5, 6, 9, 10, and 11. Provide 8-bit PWM output with the analog Write () function.

- SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK). These pins support SPI communication using the SPI library.
- LED: 13. There is a built- in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.
- The Uno has 6 analog inputs, labelled A0 through A5, each of which provide 10 bits of resolution (i.e., 1024 different values). By default, they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analog Reference () function. Additionally, some pins have specialized functionality
- TWI: A4 or SDA pin and A5 or SCL pin. Support TWI communication using the Wire library.
- There are a couple of other pins on the board:
- AREF. Reference voltage for the analog inputs. Used with analog Reference ().
- Reset. Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

4.5.5 Communication

Microcontrollers depend on a host computer for developing and compiling programs. The software used on the host computer is known as an integrated development environment, or IDE. For the Arduino, the development environment is based on the open-source Processing platform (www.processing.org) which is described by its creators as a “programming language and environment for people who want to program images, animation, and interactions. “The Arduino programming language leverages an open-source project known as Wiring (wiring.org.co). The Arduino language is based on good old- fashioned C. If you are unfamiliar with this language, don’t worry; it’s not hard to learn, and the Arduino IDE provides some feedback when you make mistakes in your programs.

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides

UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).

A Software Serial library allows for serial communication on any of the Uno's digital pins. The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. For SPI communication, use the SPI library. As you go through the list of programming statements available in the Arduino IDE (choose Help->Reference), you might think there isn’t much power for doing things like running servos, operating stepper motors, reading potentiometers, or displaying text on an LCD. Like most any language based on C, the Arduino supports the notion of “libraries” code.

4.6 BLUETOOTH MODULE

HC-05 Bluetooth Module is an easy-to-use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Its communication is via serial communication which makes an easy way to interface with controller or PC. HC-05 Bluetooth module provides switching mode between master and slave mode which means it able to use neither receiving nor transmitting data. The representation of Bluetooth module is shown in the fig 4.11.

Specification

- Model: HC-05
- Input Voltage: DC 5V
- Communication Method: Serial Communication
- Master and slave mode can be switched

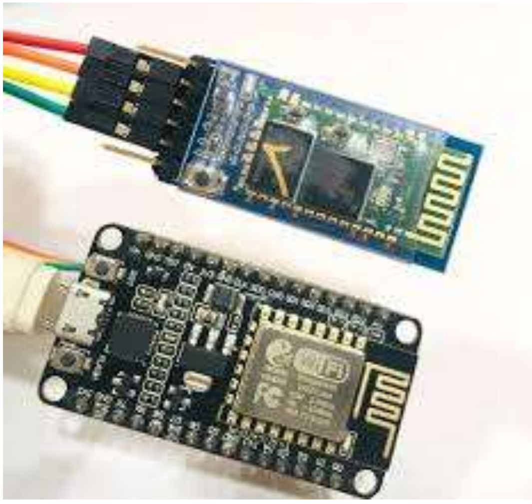


Fig: 4.11 Bluetooth Module

4.6.1 Where to Use Hc-05 Bluetooth Module

The Bluetooth Module HC-05 is an amazing module which can add two ways wireless functionality to the project. HC-05 module can be used to interface between two different microcontroller such as Arduino or interface with any other device with Bluetooth functionality like laptop or a phone. There are many android applications that are already available which makes this process tons easier. The module communicates with the assistance of USART at 9600 baud hence it's easy to interface with any microcontroller that supports USART. Default values of the module can be configured by using command mode.

4.6.2 How to Use Bluetooth Module

The HC-05 has two operating modes, one is that the Data mode during which it can send and receive data from other Bluetooth devices and therefore the other is that the default device setting of AT Command mode can be changed. We can operate the device in either of these two modes by using the key pin.

Paring HC-05 Module with microcontroller is quite easy because it operates using the Serial Port Protocol (SPP). Supplying power to the module with +5V and connecting Rx pin of the module to the Tx pin of the microcontroller and Tx pin of the module to the Rx pin of the microcontroller.

While supplying power the key pin has to be grounded to enter into command mode, if it is left free it will by default enter into the data mode. As soon as the module is powered, we can acknowledge the Bluetooth device as 'HC-05' then connect it with using the default password 1234 and start communication with it.

4.6.3 Pin Configuration

Pin Number	Pin Name	Description
1	Enable / Key	This pin is used to toggle between Data Mode (set low) and AT command mode (set high). By default, it is in Data mode
2	Vcc	Powers the module. Connect to +5V Supply voltage
3	Ground	Ground pin of module, connect to system ground.
4	TX – Transmitter	Transmits Serial Data. Everything received via Bluetooth will be given out by this pin as serial data.
5	RX – Receiver	Receive Serial Data. Every serial data given to this pin will be broadcasted via Bluetooth
6	State	The state pin is connected to on board LED, it can be used as a feedback to check if Bluetooth is working properly.

7	LED	Indicates the status of Module • Blink once in 2 sec: Module has entered Command Mode • Repeated Blinking: Waiting for connection in Data Mode • Blink twice in 1 sec: Connection successful in Data Mode
8	Button	Used to control the Key/Enable pin to toggle between Data and command Mode

Table 4.1 Pin configuration

4.7 GLOBAL POSITIONING SYSTEM (GPS)

The Global Positioning System (GPS) is a navigation system using satellites, a receiver and algorithms to synchronize location, velocity and time data for air, sea and land travel. The satellite system consists of a constellation of 24 satellites in six Earth-cantered orbital planes, each with four satellites, orbiting at 13,000 miles (20,000 km) above Earth and traveling at a speed of 8,700 mph (14,000 km/h). While we only need three satellites to supply a location on earth's surface, a fourth satellite is usually wont to validate the knowledge from the opposite three. The fourth satellite also moves us into the third-dimension and allows us to calculate the altitude of a tool.

4.7.1 Three elements of GPS

- *Space (Satellites)*

  The satellite moves around the earth, transmitting signals to user on geographical position and time of the day.
- *Ground Control*

The Control Segment is made up of Earth-based monitor stations, master control stations and ground antenna. Control activities include tracking and operating the satellites in space and monitoring transmissions. There are monitoring stations on almost every continent within the world, including North and South America, Africa, Europe, Asia and Australia.

- *User equipment:*

  GPS receivers and transmitters including items like watches, smartphones and telematic devices.

4.7.2 GPS Working Principle

GPS works through a technique called trilateration, it used to calculate location, velocity and elevation, trilateration collects signals from satellites to output location information. It is often mistaken for triangulation, which is employed to live angles, not distances.

Satellites orbiting the earth send signals to be read and interpreted by a GPS device, situated on or near the earth's surface. To calculate location, a GPS device must be ready to read the signal from a minimum of four satellites. Each satellite in the network circles the earth twice a day, and each satellite sends a unique signal, orbital parameters and time. At any given moment, a GPS device can read the signals from six or more satellites.

A single satellite broadcasts a microwave signal which is picked up by a GPS device and want to calculate the space from the GPS device to the satellite. Since a GPS device only gives information about the space from a satellite, one satellite cannot provide much location information. Satellites don't give off information about angles, therefore the location of a GPS device might be anywhere on a sphere's area. When a satellite sends a sign, it creates a circle with a radius measured from the GPS device to the satellite.

When we add a second satellite, it creates a second circle, and therefore the location is narrowed right down to one among two points where the circles intersect. With a third satellite, the device's location can finally be determined, as the device is at the intersection of all three circles. That said, we sleep in a three-dimensional world, which suggests that every satellite produces a sphere, not a circle. The intersection of three spheres produces two points of intersection, therefore the point nearest Earth is chosen.

4.7.3 Uses of GPS

GPS may be a powerful and dependable tool for businesses and organizations in many various industries. Surveyors, scientists, pilots, boat captains, first responders, and workers in mining and agriculture, are just a couple of the folks that use GPS on each day to day for work. They use GPS information for preparing accurate surveys and maps, taking precise time measurements, tracking position or location, and for navigation. GPS works in the least times and in most weather.

There are five main uses of GPS:

1. Location — Determining a position.
2. Navigation — Getting from one location to another.
3. Tracking — Monitoring object or personal movement.
4. Mapping — Creating maps of the world.
5. Timing — Making it possible to take precise time measurements.

4.8 SERVO MOTOR

A servo motor may be a sort of motor which will rotate with great precision. Normally this sort of motor consists of an impact circuit that gives feedback on the present position of the motor shaft, this feedback allows the servo motors to rotate with great precision. If you would like to rotate an object at some specific angles or distance, then you employ a servo motor. It is just made from an easy motor which runs through a servo mechanism. If motor is powered by a DC power supply then it's called DC servo motor, and if it's AC-powered motor then it's called AC servo motor. For this tutorial, we'll be discussing only about the DC servo motor working. Apart from these major classifications, there are many other sorts of servo motors supported the sort of drugs arrangement and operating characteristics.

A servo motor usually comes with a gear arrangement that allows us to get a very high torque servo motor in small and lightweight packages. Due to these features, they're getting used in many applications like toy car, RC helicopters and planes, Robotics, etc.

Servo motors are rated in kg/cm (kilogram per centimetre) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm tells you ways much weight your servo motor can lift at a specific distance. For example: A 6kg/cm Servo motor should be ready to lift 6kg if the load is suspended 1cm faraway from the motors shaft, the greater the space the lesser the weight carrying capacity. The position of a servo motor is set by electrical pulse and its circuitry is placed beside the motor. Servo Motor are shown in the fig 4.12.

Fig: 4.12 Servo Motor

4.8.1 Servo Motor Working Principle

A servo consists of a Motor, a potentiometer, gear assembly, and a controlling circuit. First of all, we use gear assembly to scale back RPM and to extend torque of the motor. Say at initial position of servo motor shaft, the position of the potentiometer knob is such there's no electrical signal generated at the output port of the potentiometer. Now an electrical signal is given to a different input terminal of the error detector amplifier. Now the difference between these two signals, one comes from the potentiometer and another comes from other sources, are going to be processed during a feedback mechanism and output are going to be provided in terms of error signal. This error signal acts because the input for motor and motor starts rotating. Now motor shaft is connected with the potentiometer and because the motor rotates therefore the potentiometer and it'll generate a sign. So, because the potentiometer’s position changes, its output feedback signal changes. After sometime the position of potentiometer reaches at an edge that the output of potentiometer is same as external signal provided. At this condition, there'll be no output from the amplifier to the motor input as there's no difference between external applied signal and therefore the signal generated at potentiometer, and during this situation motor stops rotating.

4.8.2 Servo Motor Working Mechanism

It consists of three parts:

- Controlled device
- Output sensor
- Feedback system

It is a closed loop where it uses a regeneration system to regulate motion and therefore the final position of the shaft. Here the device is controlled by a feedback signal generated by comparing output and reference input. Here reference input is compared to the reference output and therefore the third signal is produced by the feedback system. And this third signal acts as an input to the control the device. This signal is present as long because the feedback signal is generated or there's a difference between the reference input and reference output. therefore, the main task of servomechanism is to take care of the output of a system at the specified value at presence of noises.

4.9 Solar Panel:

The term solar panel is employed colloquially for a photo-voltaic (PV) module. A PV module is an assembly of photo-voltaic cells mounted during a framework for installation. Photo-voltaic cells use sunlight as a source of energy and generate DC electricity. A collection of PV modules is named a PV Panel, and a system of Panels is an Array. Arrays of a photovoltaic system supply solar electricity to electrical equipment shown in the fig 4.13.

Fig 4.13 Solar Panel

4.9.1 About Solar Panel

Photovoltaic modules use light energy (photons) from the Sun to get electricity through the photovoltaic effect. Most modules use wafer-based crystalline silicon cells or thin-film cells. The structural (load carrying) member of a module are often either the highest layer or the rear layer. Cells must be shielded from mechanical damage and moisture. Most modules are rigid, but semi-flexible ones supported thin-film cells also are available. The cells are connected electrically serial, one to a different to the specified voltage, then in parallel to extend amperage. The wattage of the module is that the product of the voltage and therefore the amperage of the module. The manufacture specifications on solar panels are obtained under standard condition which isn't the important operating condition the solar panels are exposed to on the installation site. A PV junction box is attached to the back of the solar panel and functions as its output interface. External connections for many photovoltaic modules use MC4 connectors to facilitate easy weatherproof connections to the remainder of the system. A USB power interface can also be used.

Order of module connection

Module electrical connections are made in series to achieve a desired output voltage or in parallel to provide a desired current capability (amperes) of the solar panel or the PV system. The conducting wires that take the present off the modules are sized consistent with the ampacity and should contain silver, copper or other non-magnetic conductive transition metals. Bypass diodes could also be incorporated or used externally, just in case of partial module shading, to maximise the output of module sections still illuminated. [citation needed] Some special solar PV modules include concentrators during which light is concentrated by lenses or mirrors onto smaller cells. This enables the utilization of cells with a high cost per unit area (such as gallium arsenide) during a cost-effective way.

4.9.2 Efficiency

Each module is rated by its DC output power under standard test conditions (STC) and hence the on-field output power might vary. Power typically ranges from 100 to 365 Watts (W). The efficiency of a module determines the earth of a module given an equivalent rated output – an 8% efficient 230 W module will have twice the earth of a 16% efficient 230 W module. Some commercially available solar modules exceed 24% efficiency. Currently, the simplest achieved sunlight conversion rate (solar module efficiency) is around 21.5% in new commercial products typically less than the efficiencies of their cells in isolation. The most efficient mass-produced solar modules [disputed – discuss] have power density values of up to 175 W/m2 (16.22 W/ft2).

Scientists from Spectro lab, a subsidiary of Boeing, have reported development of multi-junction solar cells with an efficiency of quite 40%, a replacement record for solar photovoltaic cells The Spectro lab scientists also predict that concentrator solar cells could achieve efficiencies of quite 45% or even 50% within the longer term, with theoretical efficiencies being about 58% in cells with more than three junctions.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 ANALYSIS

- The analysis is the numerical simulation of any particular physical event using the Finite Element Method (FEM). Engineers use it to minimise the number of actual samples and tests, as well as refine parts during the design process, in order to create better goods faster.

- Mathematics is needed to fully comprehend and measure any physical phenomenon, such as structural or fluid behaviour, thermal transport, wave propagation, and so on. Partial Differential Equations are used to explain the majority of these systems (pdes). Numerical techniques have been developed over the last few decades to allow a machine to solve these problems, and one of the most well-known is

- Differential equations can be used to explain not just natural processes but also physical phenomena in engineering mechanics. These partial differential equations (pdes) are difficult equations that must be solved in order to calculate related structural quantities (such as stresses (), strains (), and so on) in order to predict the behaviour of the investigated variable under a given load. It's important to remember that FEA only provides an approximate solution to the problem and is merely a numerical method for obtaining the real solution to these partial differential equations. Simply put, FEA is a numerical method for predicting how a part or assembly will behave under certain conditions.

- It acts as the base for advanced simulation applications, aiding engineers in detecting blind points, places of tension, and other structural shortcomings. The outcomes of a simulation using the FEA method are normally represented by a color scale that represents the pressure distribution over the target, for example.

- FEA can be traced back to Euler's work as early as the 16th century, depending on one's point of view. The first mathematical papers on Finite Element Analysis, however, can be found in Schellbach's (1851) and Courant's (1943) works.

• FEA was independently developed by engineers in different companies and industries to address structural mechanics problems related to aerospace and civil engineering. The development for real life applications started around the mid-1950s as papers by Turner, Clough, Martin and Topp [1956], Argyris [1957] and Babuska and Aziz [1972] show. The books by Zienkiewicz [1971] and Strang and Fix [1973] also laid the foundations for future developments in FEA.

5.1.1 Geometric Modelling

• Geometry simulation in the ANSYS Workbench framework is highly automated, and users may configure it according to the form of research or application they're operating on. The parametric, feature-based The ANSYS Design Modeler program can be used to construct parametric geometry from scratch or to study CAD geometry that already exists. It has automatic simplification, clean-up, maintenance, and defeaturing solutions.

• Simulation also necessitates modelling capability not found in traditional computer-aided design (CAD) operations. As a result, these features are either missing from CAD programs or applied in an inefficient manner for simulation.

• ANSYS Design Modeler offers simulation-specific modelling functions such as parametric geometry development, concept model formation, CAD geometry adjustment, automatic clean-up and repair, and other custom methods for fluid flow, structural, and other analyses.

5.1.2 Mathematical Modelling

• ANSYS FLUENT combines the ability to model dynamic geometries with a wide variety of mathematical simulations for transport processes (such as heat transfer and chemical reactions). Laminar non-Newtonian flows in process equipment; conjugate heat transfer in turbomachinery are examples of ANSYS FLUENT applications.

• Multiphase in bubble columns and fluidized beds; pulverized coal combustion in service boilers; external aerodynamics; movement by compressors, motors, and fans; and external aerodynamics. The turbulence models presented cover a wide variety of applications and take into account the effects of other physical processes like buoyancy and compressibility. Using expanded wall functions and zonal models, special attention has been paid to issues of near-wall precision.

- We prefer geometric modelling over mathematical modelling because we can get finite elemental analysis and finite elemental volume at a particular point of any metals and this cannot be obtained for mathematical modelling. The geometric modelling helps in generation of balanced system architecture that concurrently incorporate representations of system behaviour, structure, and physical layout

5.1.3 Geometrical Modelling

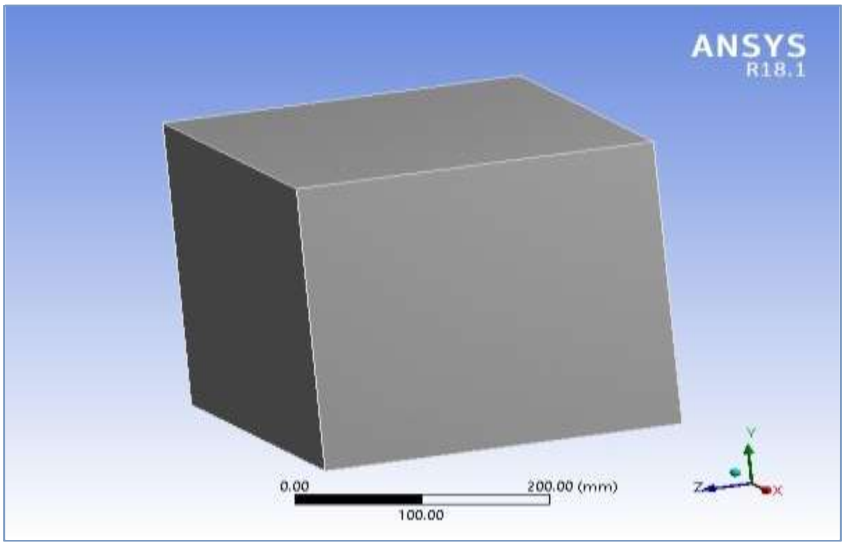


FIG 5.1 Solid Prototype

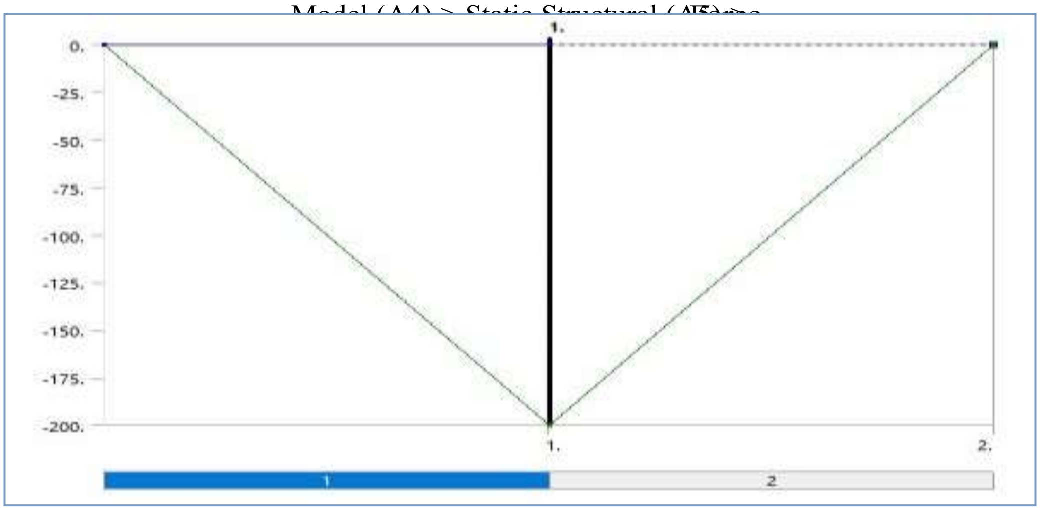


TABLE 10

Fig 5.2 Static Structural Graph

5.2 BOUNDARY CONDITIONS

Force, strain, and temperature are the three major forms of loading present in FEA. These can be used on points, surfaces, borders, nodes, and components, or they can be implemented remotely from the future. The way the model is constrained has a big impact on the outcomes, so it's important to think about it. Models that are above or under constrained 34 will provide tension that is so off that it is useless to the engineer. We may have large assemblies of modules all attached to each other with communication elements in a perfect universe, but this is out of most people's budgets and resources. We should, therefore, make the most of the computing hardware we have, which requires an understanding of how to use it properly.

Table 5.1 Comparison of Forces

Object Name	Directional Deformation	Maximum Principal Stress	Maximum Principal Elastic Strain
State	Solved		
Scope			
Scoping Method	Geometry Selection		

Geometry	All Bodies		
Definition			
Type	Directional Deformation	Maximum Principal Stress	Maximum Principal Elastic Strain
Orientation	Y Axis		
By	Time		
Display Time	Last		
Coordinate System	Global Coordinate System		
Calculate Time History	Yes		
Identifier			
Suppressed	No		
Results			
Minimum	-3.4707e-021 mm	-1.0662e-016 MPa	0. mm/mm
Maximum	4.7437e-021 mm	2.6237e-016 MPa	0. mm/mm
Minimum Occurs On	Solid		
Maximum Occurs On	Solid		
Minimum Value Over Time			
Minimum	-3.2628e-006 mm	-1.6784e-003 MPa	-5.6469e-015 mm/mm
Maximum	-3.4707e-021 mm	-1.0662e-016 MPa	0. mm/mm
Maximum Value Over Time			
Minimum	0. mm	2.6237e-016 MPa	0. mm/mm
Maximum	4.7437e-021 mm	6.9846e-004 MPa	1.0066e-008 mm/mm
Information			

Time	2. s	
Load Step	2	
Substep	1	
Iteration Number	28	
Integration Point Results		
Display Option		Averaged
Average Across Bodies		No

5.6 ANALYSIS FOR DEFORMATION

The review of all solid mechanics problems begins with a deformation analysis. Solid mechanics equations are normally written by watching a volume of fluid as it travels, rotates, and deforms. In contrast to the Eulerian formulation used in many other areas of physics, such as fluid flow analysis, this is known as a Lagrangian formulation. The flux into and out of a fixed-in-space control volume is at the heart of an Eulerian formulation.

1. Two related variants of Lagrangian formulations are widely used in finite element analysis. In the total Lagrangian formulation, the equations are based on the original configuration of the body

2. In the updated Lagrangian formulation, the equations are based on the current configuration of the body

These two formulations are mathematically similar in the sense that they can be converted into each other using a set of transformations. When it comes to the computational utility of finite element formulations, however, the formulations vary. The theory's development suggests that solid matter can be viewed as a continuum. The length dimension is considerably greater than the molecular scale, resulting in homogeneous properties that are small enough to be rendered infinitesimal mathematically.

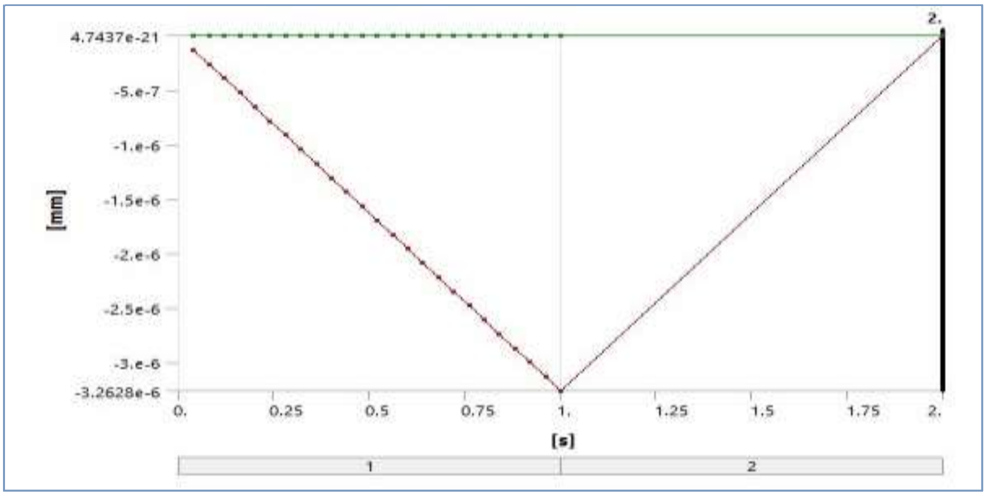


Fig 5.3 Directional Deformation Graph

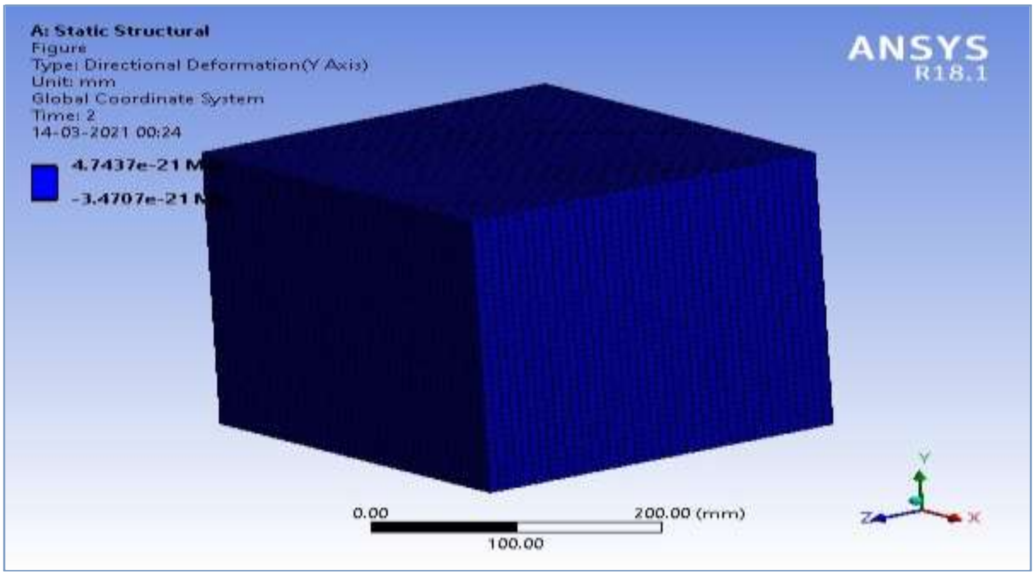


Fig 5.4 Directional Deformation

5.4 ANALYSIS FOR STRESS

Stress–strain analysis (also known as stress analysis) is a field of engineering that utilises a range of techniques to assess the stresses and strains of materials and systems that have been exposed to forces. Stress analysis is also used in the repair of these systems, as well as in the investigation of structural defects.

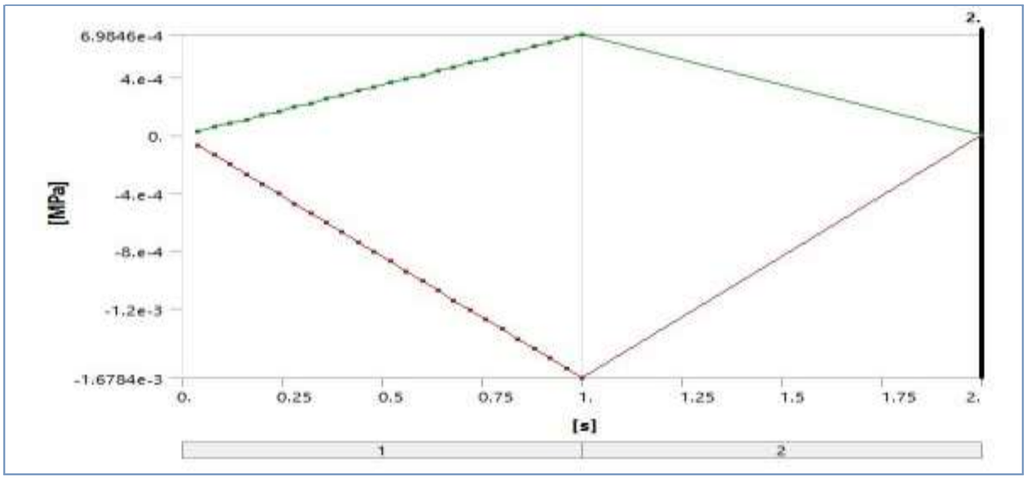


Fig 5.5 Maximum Principal Stress Graph

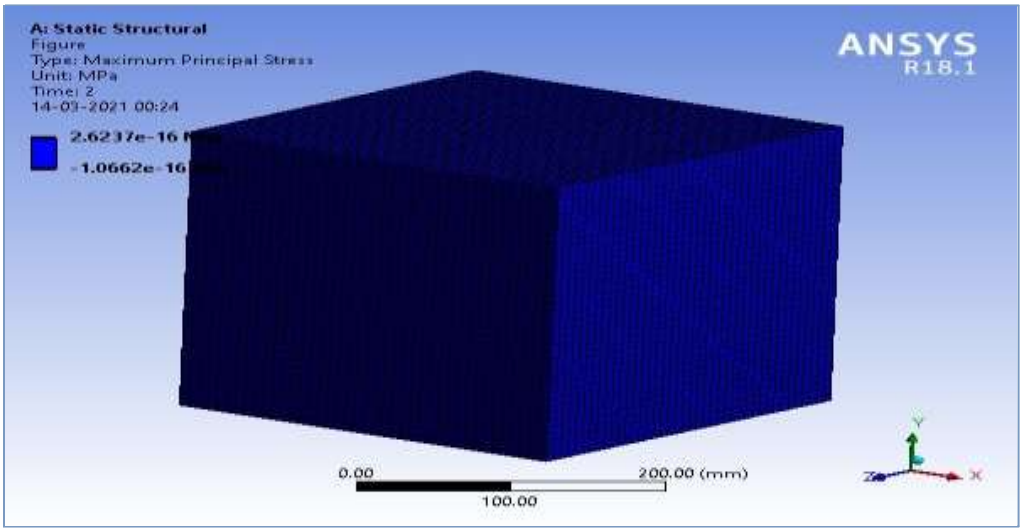


Fig 5.6 Maximum Principal Stress

5.5 ANALYSIS FOR STRAIN

Indirect stress or strain analysis is a flexible tool for determining whether a product or part is likely to fail or has already failed. Externally added stress or residual (moulded-in) pressures will both cause failure. A component may fail prematurely due to both external stress and moulded-in strain (or a combination of both). Failures caused by faulty construction or unnecessary service forces are easier to spot. Residual tensions and pressures, on the other hand, are a whole different story. Bad moulding techniques can create residual strain almost anywhere, at any time. Photo elastic inspection will identify frozen-in strains, causing fault to be identified, and the process will expose the act.

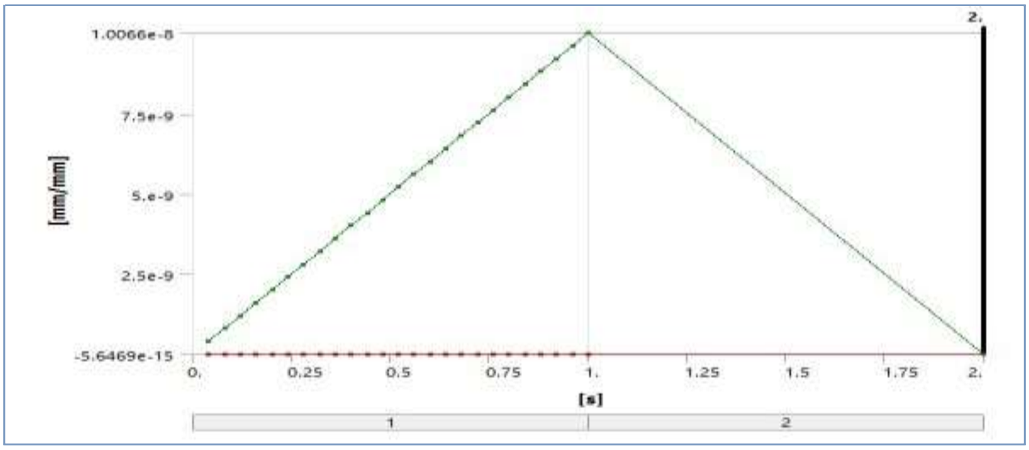
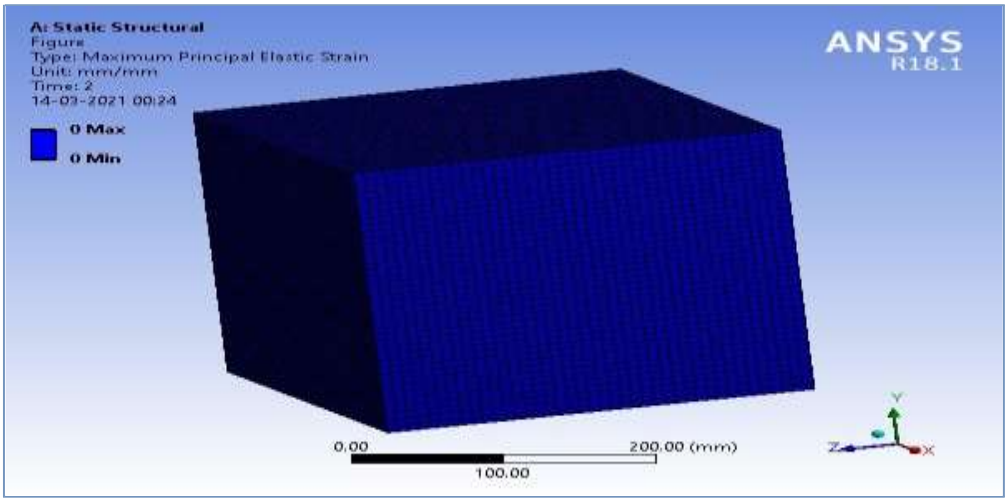


Fig 5.7** > **Maximum Principal Elastic Strain Graph



Material Data

Fig 5.8** > **Maximum Principal Elastic Strain

CHAPTER 6

SUMMARY AND CONCLUSIONS

We need this system to be involved in every individual life since consumption of various product has been increased and it's difficult to fulfil the demand without the help of self-delivery robot.

Based on the results on ANSYS we can conclude the performance of the self-delivery robot is efficient. The fabricated system can result in non-pollution/minimising environmental degradation due to the usage of batteries and solar panel which supplies electrical energy as source of energy and saves money.

The robot can deliver light weight items and is best for office buildings, hospitals and airplane for delivering the documents/ files, samples and food respectively. Self-delivery robot can also be used for food and item deliveries from restaurant and e-commerce as well.

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APPENDIX

Appendix 1: Coding

```
#include <LiquidCrystal.h>
#include <SoftwareSerial.h>
#include <TinyGPS.h>
float lat = 28.5458,lon = 77.1703;
SoftwareSerial gpsSerial(9,10);

TinyGPS gps;
#include<Servo.h>
Servo Myservo1;
int pos1;
Servo Myservo2;
char inputByte;
int pos2;
#define echoPin1 2
#define trigPin1 3

long duration1;
int distance1;

int relay_pin1 = 8;
int relay_pin2 = 9;
void gps();
void relay_SR();
void relay_SL();
void relay_STOP();
void servo1();
void servo2();
void ultra1();
void setup()
```

```
{
  Serial.begin(9600);
gpsSerial.begin(9600);
lcd.begin(16,2);
  digitalWrite(relay_pin1,HIGH);
digitalWrite(relay_pin2,HIGH);
  pinMode(relay_pin1,OUTPUT);
  pinMode(relay_pin2,OUTPUT);
  Myservo1.attach(4);
  Myservo2.attach(5);

  Serial.begin(9600);
  pinMode(trigPin1,OUTPUT);
  pinMode(echoPin1,INPUT);
  Serial.begin(9600);

 Serial.begin(9600);
}
//bluetooth
void loop() {
while(Serial.available()>0){
  inputByte= Serial.read();
  Serial.println(inputByte);
  if (inputByte=='1')
  {
  relay_SR();
}
  else if (inputByte=='2')
  {
  relay_SL();
```

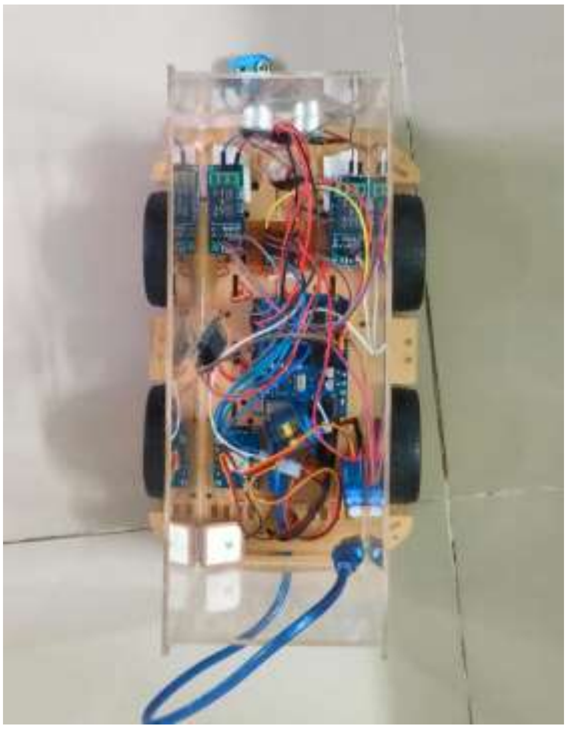
```
 }
  else if (inputByte=='0')
  {
  relay_STOP();
  }
  else if (inputByte=='4')
  {
servo1();
  servo2();
  }
}
}
void relay_STOP(){

  digitalWrite(relay_pin1,HIGH);
  digitalWrite(relay_pin2,HIGH);
  delay(500);
}
  void relay_SR(){
  ultra1();
  digitalWrite(relay_pin1,LOW);
  digitalWrite(relay_pin2,LOW);
  ultra1();
  delay(3000);
  digitalWrite(relay_pin1,HIGH);
  digitalWrite(relay_pin2,LOW);
   delay(1000);
   digitalWrite(relay_pin1,LOW);
  digitalWrite(relay_pin2,LOW);
  ultra1();
  delay(2000);
```

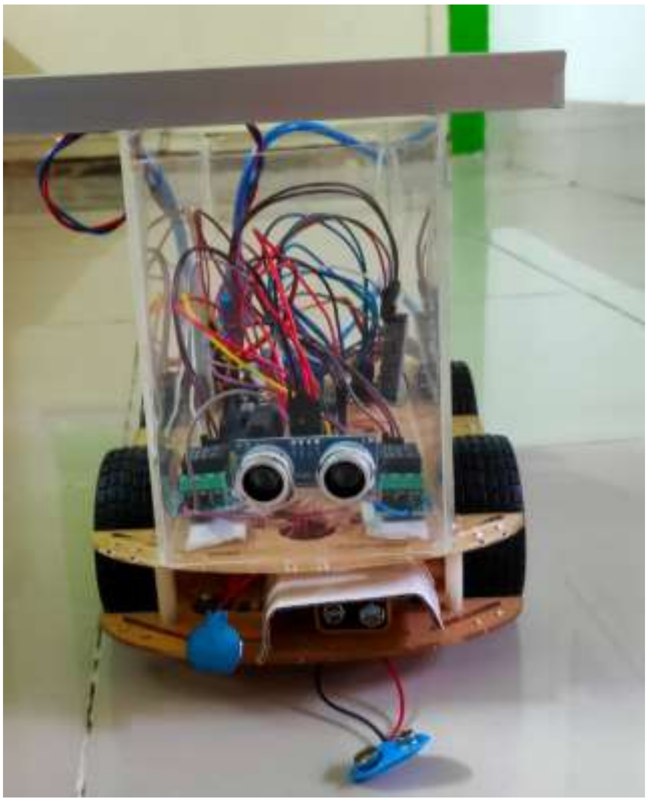
```
 digitalWrite(relay_pin1,HIGH);
  digitalWrite(relay_pin2,HIGH);
  delay(500);
   digitalWrite(relay_pin1,LOW);
  digitalWrite(relay_pin2,HIGH);
  delay(500);
   digitalWrite(relay_pin1,HIGH);
  digitalWrite(relay_pin2,HIGH);
}
void relay_SL(){
 digitalWrite(relay_pin1,LOW);
  digitalWrite(relay_pin2,LOW);
  ultra1();
  delay(3000);
  digitalWrite(relay_pin1,LOW);
  digitalWrite(relay_pin2,HIGH);
   delay(1000);
   digitalWrite(relay_pin1,LOW);
  digitalWrite(relay_pin2,LOW);
  ultra1();
  delay(2000);
   digitalWrite(relay_pin1,HIGH);
  digitalWrite(relay_pin2,HIGH);
}
void servo1()
{
for(pos1=0;pos1<=180;pos1++){
Myservo1.write(pos1);
delay(15);
}
```

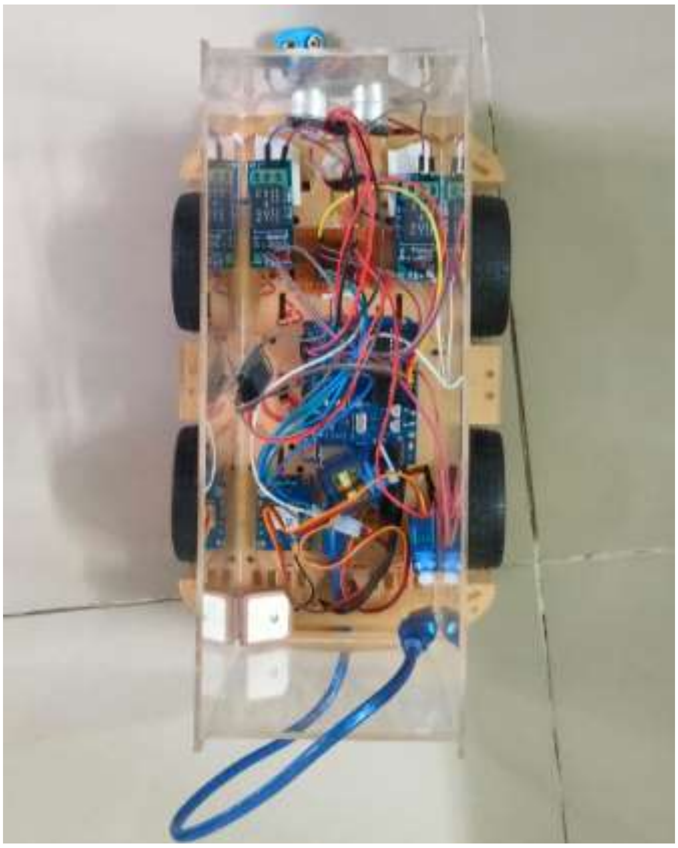
```
 delay(1000);
  for(pos1=180;pos1>=0;pos1--){
Myservo1.write(pos1);
delay(15);
}
}
void servo2()
{
for(pos2=0;pos2<=180;pos2++){
Myservo2.write(pos2);
delay(15);
}
  delay(1000);

  for(pos2=180;pos2>=0;pos2--){
Myservo2.write(pos2);
delay(15);
}
}
void ultra1()
{
  digitalWrite(trigPin1,LOW);
  delayMicroseconds(2);
  digitalWrite(trigPin1,HIGH);
  delayMicroseconds(10);
  digitalWrite(trigPin1,LOW);

 duration1=pulseIn(echoPin1,HIGH);
  distance1=(duration1*0.034/2);
  Serial.print("Distance1 : ");
  Serial.print(distance1);
```

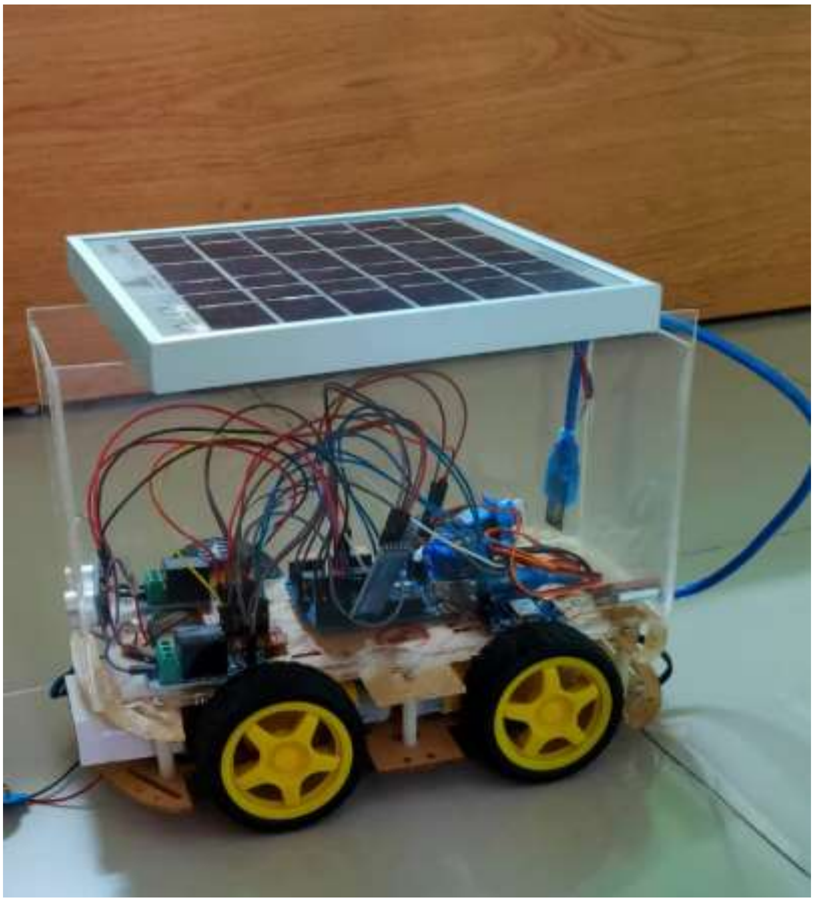
```
Serial.println(" cm ");
   if (distance1<15)
  {
  relay_STOP();


  }
  delay(100);
  }
void gps()
{
    while(gpsSerial.available()){
    if(gps.encode(gpsSerial.read()))
    {
    gps.f_get_position(&lat,&lon);
    lcd.clear();
    lcd.setCursor(1,0);
    lcd.print("GPS Signal");
    lcd.setCursor(1,0);
    lcd.print("LAT:");
    lcd.setCursor(5,0);
    lcd.print(lat);
    lcd.setCursor(0,1);
    lcd.print(",LON:");
    lcd.setCursor(5,1);
    lcd.print(lon);
   }
  }
  String latitude = String(lat,6);
    String longitude = String(lon,6);
  Serial.println(latitude+";"+longitude);
  delay(1000);
}
```

Appendix 2: Images









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