"Smart Solar Grass Cutter"

Submitted in partial fulfillment of the requirement for the award of Degree of Bachelor of Technology in Computer Engineering

Submitted To

Dr. Babasaheb Ambedkar Technological University, Lonere (M.S.)

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DEPARTMENT OF COMPUTER ENGINEERING

P.S.G.V.P. MANDAL'S
D. N. PATEL COLLEGE OF ENGINEERING
SHAHADA, DIST- NANDURBAR (M.S.)

YEAR 2023-2024

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CERTIFICATE

This is to certify that

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Has satisfactorily completed Project Phase-II entitled

"Smart Solar Grass Cutter"

As prescribed by Dr. Babasaheb Ambedkar Technological University, Lonere (M.S.) as a part of syllabus for the partial fulfillment in Bachelor of Technology in Computer Engineering for Academic Year 2023-2024.

GUIDE	**H.O.D.**
Prof. R.A. Shaikh	Prof. V.S. Mahajan
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P.S.G.V.P. MANDAL'S

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TESTING REPORT

This is to certify that the system

"Smart Solar Grass Cutter"

Developed by

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has been successfully tested and is operating as per the specifications.

Date: ___/___/2024

Place: Shahada

GUIDE	PROJECT INCHARGE
Prof. R.A. Shaikh	Prof. V.S. Mahajan/Prof. S.H. Shaikh

H.O.D.

Prof. V.S. Mahajan

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ABSTRACT

In today's era the home decorations' integral part is lawn. The manual grass cutting requires man power, time and it may create non-uniform structure of grass height. Hence to avoid all these issues it is essential to create a system which can cut the grass without any human involvement. This proposed system implements robot which has solar powered mechanism with battery backup which can be charged by solar energy. The system drives robot that works in automatic as well as manual mode. A user has to select initial starting point from which the grass cutting of lawn is to be stared. The robotic system then automatically decides path by detecting obstacles by ultrasonic sensors. The navigation system then decides which direction to go further by internal logic. The system can also be operated using android phone's application. The grass cutter uses a solar based energy source to charge the battery, which is easier to use, more advantageous compared to other energy source especially for gas based source of power.

Keywords— Android, Bluetooth Module, Grass Cutter, Solar Energy, Gear DC Motors, Servo Motor, Ultrasonic Sensor.

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1. INTRODUCTION

1.1 Project Domain

Nowadays pollution is a major issue for whole world. Pollution is manmade and can be seen in own homes. In case of gas lawn mowers due to emission of gases it is responsible for pollution. Also the cost of fuel is increasing hence it is not sufficient. So the solar powered lawn cutters are introduced. There are worked using natural source of energy (solar power). Grass cutter or lawn mowing with a standard motor powered lawn mower is inconvenience, and no one takes pleasure in it. Even though the electronic grass cutters are environmentally friendly, they too can be inconvenience. Along with the motor powered lawn mower, electric lawn mowers are hazardous and cannot be easily used by all. Hence we design to make a grass without any power source due to reduce the power consumption. Design solar powered domestic lawnmowers that utilize solar power as energy source as an energy source is meant to address a number of issues that standard internal combustion engine mowers do not. Electric lawn mowers with solar power can be used easily. It will eliminate the pollution caused due to gas and the noise is reduced along with the cost.

The smart grass cutter system puts forth a completely automated lawn mover mechanism. The robotic vehicle is equipped with a grass cutter blade that allows for grass cutting at high RPM. The system has a smart functionality that allows it to cover the complete area of a lawn or garden by detecting corners using ultrasonic sensor and moving in a zigzag manner in order to cover the entire area. This efficient system uses a microcontroller based circuit in order to achieve this functionality. It is a battery operated system that uses one battery to run the vehicle movement DC motors and the grass cutter motor. Also the system uses a solar panel to demonstrate the charging of vehicle movement battery. The microcontroller operates the vehicle movement dc motors as well as the grass cutter at the same time as monitoring the ultrasonic sensors. The microcontroller smartly operates the dc motors using the motor driver IC to achieve desired movement based on ultrasonic inputs. The system also uses a gyro sensor in order to achieve perfect 180 degree turns in order to achieve complete lawn/garden coverage. Thus this system allows for fully automated grass cutting system without the need for any human intervention.

A smart solar grass cutter with lawn coverage holds significant importance as a modern and sustainable solution for lawn maintenance. By harnessing solar power, it not only reduces environmental impact but also offers cost savings through the use of renewable energy. The autonomous operation of the grass cutter, guided by smart navigation algorithms, ensures precise and consistent coverage, leading to well-maintained lawns. The inclusion of features such as automated scheduling and rain sensing enhances user convenience, allowing for efficient lawn care without constant supervision. With a user-friendly interface and safety measures like collision avoidance, the smart grass cutter combines innovation and efficiency, contributing to quieter and eco-friendly lawn care practices. Beyond the aesthetic benefits of a well-groomed lawn, this technology promotes environmental conservation by reducing chemical dependency and fostering the adoption of green technologies, ultimately offering a sustainable and forward-thinking approach to landscaping.

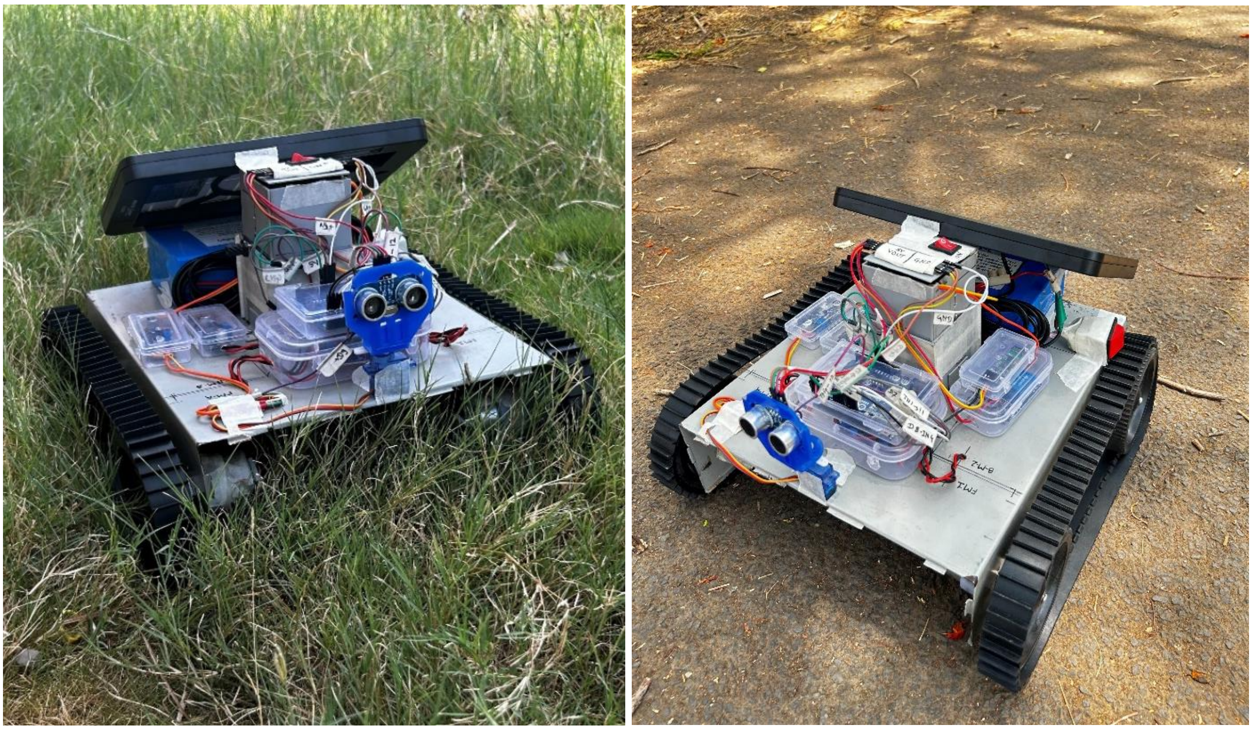

Fig.1.1 Smart Solar Grass Cutter

1.2 Problem Definition

1.2.1 Background

Maintaining a well-groomed lawn is a common yet time-consuming task for homeowners and property managers. Conventional lawnmowers often rely on fossil fuels, contributing to environmental pollution and increased operational costs. The aim is to design and develop a smart solar-powered grass cutter that operates autonomously, efficiently covering the entire lawn area using renewable energy sources.

1.2.2 Problem Statement

Create an intelligent, solar-powered grass cutter that autonomously navigates and efficiently covers a designated lawn area while providing user-friendly control and monitoring features.

1.2.3 Key Objectives

1.2.3.1 Autonomous Navigation and Mapping

- Develop a reliable navigation system that allows the grass cutter to autonomously traverse the lawn.
- Implement mapping capabilities to recognize obstacles, borders, and irregularities in the terrain.

1.2.3.2 Solar-Powered Operation

- Integrate solar panels and an energy storage system to power the grass cutter.
- Optimize the charging and discharging cycles to ensure continuous operation during daylight hours.

1.2.3.4 Efficient Grass Cutting

- Design an effective cutting mechanism capable of adjusting to different grass heights.
- Implement algorithms for intelligent mowing patterns to avoid missed spots and excessive overlap.

1.2.3.5 Lawn Coverage Optimization

- Develop algorithms for efficient lawn coverage, considering lawn size, shape, and potential obstacles.
- Ensure even distribution of cutting efforts to maintain a uniform lawn appearance.

1.2.3.6 User Interface and Control

- Create a user-friendly interface for controlling the grass cutter, setting cutting schedules, and monitoring its status remotely.
- Include safety features and emergency stop functionalities for user reassurance.

1.2.3.7 Safety and Obstacle Avoidance

- Integrate sensors for obstacle detection and avoidance to prevent collisions with objects and people.
- Implement safety protocols to shut down the cutter in case of unexpected events.

1.2.3.8 Low Maintenance and Diagnostics

- Engineer the grass cutter for minimal maintenance requirements.
- Include diagnostic features for self-assessment and early detection of potential issues.

1.3 Available Similar Systems

1.3.1 iRobot Roomba 675 Wi-Fi Connected Robot Vacuum

The Roomba 675 series robot vacuum is a great way to begin cleaning your home smarter. It learns your cleaning habits and then offers up custom cleaning schedules—taking on daily dirt, dust, and debris from carpets and hard floors. It even has an edge-sweeping brush to get into corners and along edges. Google Assistant and Alexa compatibility lets you start a cleaning session with just your voice, or simply by using the iRobot Home App. It is easy to use and has extra cool features once you download and install the app on your phone or tablet. When your area's pollen count is high or during pet shedding season, the Roomba 600 series robot vacuum can even suggest extra cleanings —to help keep your floors clean every day of the year. It helps clean debris, dust and pet hair from your carpets. This iRobot Roomba 675 Wi-Fi Connected Robot Vacuum is a must-have!

Fig. 1.2 iRobot Roomba 675 Wi-Fi Connected Robot Vacuum

1.3.2 Smart and Versatile Cleaner

Students of Mahatma Gandhi Institute of Technology, Gandipet, M Charanlal and U Anil Kumar have invented a solar grass cutting machine which is being run through solar energy. 'It took around 3-4 months to make this' says Charanlal. Due to continuous increase in the cost of fuel and the effect of emission of gases from the burnt fuel into the atmosphere, it was felt appropriate to tap the abundant solar energy available as a source of power to drive a grass cutter. "The project name is 'Smart and Versatile Cleaner' as it is smart because the operations of cleaner are controlled by remote and versatile because it can adapt to cleaning conditions".

A smart and versatile lawn cleaner represents an innovative solution for residential lawn maintenance, combining cutting-edge technologies to deliver efficient and adaptable performance. Equipped with autonomous navigation capabilities, such as GPS or computer vision, the device seamlessly traverses the lawn while employing obstacle detection sensors to avoid collisions. Smart mapping technology allows for the creation of digital maps, optimizing cleaning routes and ensuring comprehensive coverage. Artificial intelligence algorithms enhance the cleaner's functionality by analyzing lawn conditions, adapting to varying grass lengths, and responding to weather changes. Harnessing solar power for energy efficiency, the cleaner incorporates user-friendly controls through a mobile app, enabling remote monitoring, scheduling, and customization. With security features, automated maintenance alerts, and environmentally friendly materials, this smart lawn cleaner offers a holistic and sustainable approach to lawn care, catering to the diverse needs of homeowners.

Fig.1.3 Smart and Versatile Cleaner

1.3.3 Solar Powered Grass Cutter for Domestic Utilization

The solar-powered lawn mower and thus saved energy by decreasing air pollution and reducing labor cost. In the old model, cutting iron was used. Due to its high environmental impact, it was the most expensive cutter used by the engine. We have utilized a microcontroller in our project to control the different lawn mower actions. Two DC gear motors (10,000 RPM, starting current 1.7 A and no load current 1.5 A) are used to move the solar grass cutter, and one DC blade motor (7000–13,000 RPM, starting current 0.7 A and no load current 0.45 A) is used to cut the grass quickly. With current technology, this new prototype is designed as a remotely controlled grass cutter using Arduino UNO. The Smart Solar tracker is controlled via Bluetooth by using a smartphone. The Smart Solar Grass Cutter can run for more than two hours when the battery is completely charged.

Fig.1.4 Solar Powered Grass Cutter for Domestic Utilization

1.4 Objectives of the Proposed System

- To utilize solar power to ensure an eco-friendly and sustainable energy source, reducing dependence on traditional grid electricity.
- To enable the grass cutter to operate autonomously, navigating the lawn, avoiding obstacles, and adjusting cutting patterns without constant manual intervention.
- To provide a user-friendly interface, such as a mobile application, allowing users to control the system.
- To minimize environmental impact by reducing noise pollution, eliminating emissions associated with traditional gas-powered mowers, and promoting sustainable lawn care practices.
- To aim for "Precision Cutting" by utilizing intelligent technique to optimize grass cutting. By analyzing growth patterns and user preferences, the system dynamically adjusts cutting patterns, ensuring uniform and precise trimming, resulting in a well-maintained lawn.

1.5 Proposed Modules

1.5.1 System Architecture

In the Smart Solar Grass Cutter, the Energy Layer harnesses solar power through panels, storing it in rechargeable batteries to fuel the electric motor. The Controller Layer, comprising a microcontroller and sensors, manages obstacle avoidance, cutting patterns, and IoT connectivity for real-time control and monitoring. The User Interface Layer facilitates user interaction, offering interfaces like mobile apps to schedule tasks, monitor the grass cutter's status, and receive alerts. Together, these layers form a seamless integration—solar energy powers the system, the controller ensures smart and autonomous operation, and the user interface provides a user-friendly experience, making the Smart Solar Grass Cutter an efficient and user-centric lawn maintenance solution.

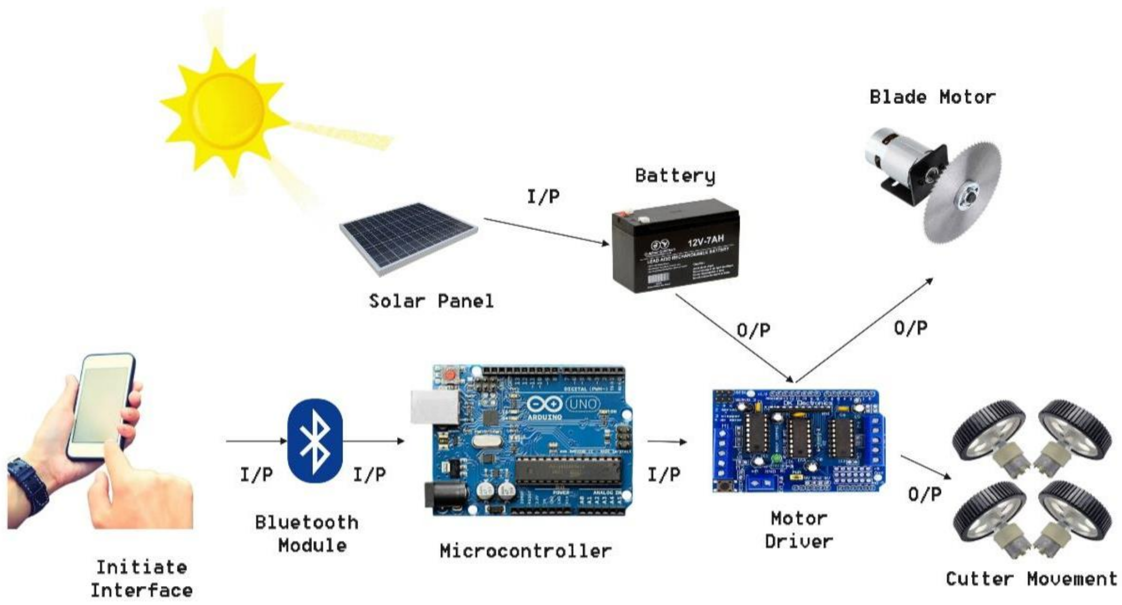

Fig.1.5 System Architecture

1.5.1.1 Energy Layer

This layer includes energy generation, storage, and consumption components such as solar panels, batteries, and electric motors for harvesting sunlight, storing energy, and cutting grass.

1.5.1.2 Controller layer

The controller layer manages and coordinates the operation of the grass cutter, comprising a microcontroller and motor control unit for data processing and decision-making.

1.5.1.3 User Interface Layer

The User Interface Layer involves components that enable interaction between the grass cutter and its user. This may include a mobile app interface, providing users with control options.

Explain how the Energy Layer and controller layer and user Interface Layer is involve in Smart Solar Grass Cutter

1.6 Applicability

1.6.1 Residential Lawn Maintenance

Ideal for homeowners seeking a hassle-free solution for maintaining their lawns. The smart solar grass cutter offers autonomous operation, ensuring a well-manicured lawn without the need for constant manual intervention.

Fig.1.6 Residential Lawn Maintenance

1.6.2 Commercial Landscaping

Perfect for landscaping companies and property managers overseeing large commercial spaces. The system's autonomous navigation and precision cutting make it efficient for maintaining the aesthetic appeal of office complexes, parks, and other commercial properties.

Fig.1.7 Commercial Landscaping

1.6.3 Public Spaces and Municipal Parks

Well-suited for municipalities and local governments looking to automate the upkeep of public parks, gardens, and recreational areas. The smart grass cutter contributes to the efficient maintenance of green spaces in urban environments.

Fig.1.8 Public Spaces and Municipal Parks

1.6.4 Educational Institutions

Ideal for schools, colleges, and universities with extensive lawns. The autonomous operation of the grass cutter ensures that outdoor spaces remain well-groomed without requiring significant manual labour.

Fig.1.9 Educational Institutions

1.6.5 Sports Fields and Facilities

Beneficial for groundskeepers managing sports fields. The precision cutting and autonomous navigation features contribute to maintaining high-quality playing surfaces for sports facilities and complexes.

Fig.1.10 Sports Fields and Facilities

1.6.6 Agricultural Fields

In certain agricultural contexts, the smart grass cutter can be adapted for the maintenance of specific crops or experimental fields. This application can contribute to efficient lawn care in agricultural settings.

Fig.1.11 Agricultural Fields

1.6.7 Golf Courses

Suited for golf courses where maintaining precise and well-groomed grass is crucial. The autonomous operation ensures that the grass cutter adheres to the standards required for golf course maintenance.

Fig.1.12 Golf Courses

1.6.8 Hospitality Industry (Hotels and Resorts)

Valuable for hotels and resorts with landscaped areas. The system enhances the aesthetic appeal of outdoor spaces, providing guests with well-maintained and visually pleasing environments.

Fig.1.13 Hospitality Industry

2. LITERATURE SURVEY

2.1 Fundamental Concepts

G. Rahul describes the application of solar energy to power an electric motor which in turn rotates a blade which does the cutting of grass. Bhosale Swapnil, Khadake Sagar explained that the smart solar grass is automatic system for the purpose of grass cutting. The source is driven from the solar energy by using solar panel from the panel and store the voltage in battery. The automatic grass cutting machine is designed using photovoltaic source and motor speed control. Ms. Yogita D. Ambekar, Mr. Abhishek U. Ghate describes the aim of project is to make the grass cutter which operates on solar energy hence save the electricity and reduces manpower. In this project we use microcontroller for controlling various operation of grass cutter. P.Amrutesh, B.Sagar, B.Venu proposed smart solar grass cutter system in which there is an use of sliding blades to cut a lawn at an even length. Unskilled operations can operate easily and maintain the lawn very fine and uniform surface look.

2.1.1 Alternatives to Gas-Powered Lawn Mowers

Several alternatives to gas-powered mowers offer a more sustainable option for lawn maintenance. Electric mowers emit no pollutants and are much quieter than fossil fuel-based equipment. They also provide the convenience of being able to plug them in and go. Reel mowers are another option that requires no fuel or electricity and produces no emissions, but they require more effort to use and may not be suitable for larger lawns.

Robotic mowers are a newer technology offering an eco-friendly and convenient option. They use rechargeable batteries and produce no emissions or noise pollution. Additionally, since they mow the lawn on a regular schedule, they can help reduce the need for fertilizers and pesticides by keeping the grass at a consistent height. By choosing one of these alternatives, homeowners can reduce their environmental impact and make a more sustainable choice for their lawn maintenance.

2.1.2 The Role of Landscaping Decisions

Landscaping choices can significantly impact your lawn's sustainability as well, and they can reduce the frequency or square footage of mowing. One critical step is choosing plants adapted to your local climate and soil conditions. Native plants, in particular, are often more drought-resistant and require less water, fertilizer, and pesticides than non-native plants. Also, choosing species suited to your soil conditions can reduce the need for fertilizers and other chemicals.

And remember, the more bushes and shrubs, the less mowing! Consider reducing the size of your lawn or incorporating alternative landscaping options, such as vegetable gardens, flower beds, or even permeable paving. These alternatives can lessen the need for mowing and chemical treatments, providing additional benefits such as improved soil health and increased biodiversity.

Fig.2.1 Landscaping Decisions

We can all make landscaping choices that obviate the need for mowing and help make our lawns more sustainable. For example, native shrubs and edibles can turn lawns into productive (and attractive!) land. And, of course, our lawnmowers often significantly impact the environment, particularly gas-powered models. Instead, homeowners can reduce their emissions, noise pollution, and fuel consumption by using electric, reel, or robotic mowers. Sustainable choices like these can go a long way in the fight against climate change.

2.1.3 Types of pollution occurs by gas grass cutter

Gas-powered grass cutters, commonly using internal combustion engines, can contribute to several types of pollution. The primary pollutants associated with gas grass cutters include:

2.1.3.1 Air Pollution:

Fig.2.2 Air Pollution

Carbon Monoxide (CO): Gas-powered engines emit carbon monoxide, a colorless and odorless gas that can be harmful when inhaled in high concentrations. It contributes to poor air quality and poses health risks, especially in enclosed spaces.

Nitrogen Oxides (NOx): Combustion in gas engines generates nitrogen oxides, which contribute to the formation of ground-level ozone and smog. NOx is a respiratory irritant and can lead to air quality issues.

Particulate Matter (PM): Small particles from the combustion process, known as particulate matter, can be released into the air. These particles can have adverse effects on respiratory health and air quality.

Hydrocarbons: Incomplete combustion of gasoline produces hydrocarbons, which can contribute to the formation of ground-level ozone and smog. They also play a role in air quality degradation.

2.1.3.2 Noise Pollution:

Gas-powered grass cutters are often noisy, contributing to noise pollution. Prolonged exposure to high levels of noise can have negative effects on hearing and overall well-being, as well as disturb the peace in residential and recreational areas.

Fig.2.3 Noise Pollution

2.1.3.3 Greenhouse Gas Emissions:

Gasoline combustion releases carbon dioxide (CO_2) and methane, both of which are greenhouse gases. These gases contribute to global warming and climate change by trapping heat in the Earth's atmosphere.

Fig.2.4 Greenhouse Gas Emissions

2.2 Detailed Study of Existing Systems

2.2.1 In paper Design and implementation of automatic solar grass cutter. By B.P. Dilip, N.B. Pagar, V.S. Ugale, S. Wani, M. Sharmila, Int. J. Adv. Res. Electr. (IJARE) (2017) has discussed that The automatic solar grass cutter uses a solar panel for energy harvesting and a rechargeable battery for storage. It uses a DC motor and a rotary blade with adjustable height. A microcontroller manages the system, integrating sensors for obstacle detection. The system is weather-resistant, easy to maintain, and prioritizes efficiency, safety, and environmental sustainability.

2.2.2 In paper Solar based grass cutting. By B.R. Patil, S.S. Patil, Solar based grass cutting. Int. J. Electr. Electron. Eng. (IJEEE) (2017) has discussed that A solar-powered grass cutting system uses solar energy to power an autonomous cutter, powered by a solar panel and rechargeable batteries. The system uses a DC motor, microcontroller, and sensors for obstacle detection, reducing dependence on traditional power sources for sustainable grass maintenance.

2.2.3 In paper Self-efficient and sustainable solar powered robotic lawn mower . By S. Jain, A. Khalore, S. Patil, Self-efficient and sustainable solar powered robotic lawn mower. Int. J. Trend Res. Dev. (IJTRD) 2(6) (2015) has discussed that solar-powered robotic lawn mower uses sunlight to power its autonomous operation, converting it into energy stored in rechargeable batteries. The system, controlled by microcontrollers like Arduino or Raspberry Pi, reduces dependence on external power sources, offering a sustainable and eco-friendly lawn care solution.

2.2.4 In paper Automatic solar grass cutter. By M. D’Souza, V.B. Naik, R.V. Bicholkar, Automatic solar grass cutter. IJSTE Int. J. Sci. has discussed that the solar grass cutter is an eco-friendly lawn maintenance solution that converts sunlight into electrical power, stored in rechargeable batteries. It operates autonomously with a DC motor and a microcontroller, reducing dependence on conventional power sources and providing a low-maintenance solution.

2.2.5 In paper Automated mower robo. By S. V. Tanaji et al., "Automated mower robo", Int. Res. J. of Eng. and Technol, vol. 5, no. 1, Jan. 2018 has discussed that the automated mower robot, equipped with sensors and intelligent algorithms, streamlines lawn maintenance by autonomously navigating and cutting grass without human intervention. This time-saving, low-maintenance solution showcases advancements in robotics and automation for household tasks.

2.2.6 In paper Mobile operated solar powered lawn mower. By S. P. Ganjewar, S. H. Gidde and P. Bhusnar, "Mobile operated solar powered lawn mower", Int. J. Res. in Comp. Sci. and Inf. Technol, vol. 1, no. 3, Dec. 2016 has discussed that the solar-powered mobile lawn mower offers convenience and sustainability in lawn maintenance. It uses solar energy and features a mobile app for remote control. This eco-friendly tool reduces reliance on traditional power sources, making it an efficient and accessible tool.

2.2.7 In paper Automatically controlled energy conservation system for corporate office based on microcontroller. By K. Ahmed et al., "Automatically controlled energy conservation system for corporate office based on microcontroller", IEEE Int. Conf. Adv. Sci. Eng. Robot. Technol, May 3-5, 2019 has discussed that microcontroller-based energy conservation system for corporate offices optimizes energy usage and reduces environmental impact. It regulates lighting, HVAC systems, and electronic devices, adjusting settings based on occupancy and demand. This intelligent system aligns with sustainable practices.

2.2.8 In paper Smart solar grass cutter with sprinkler. By S. V. Patil, N. P. Gawade, A S. Golam, M.M. Kajale and G. R. Yelave, "Smart solar grass cutter with sprinkler", Int. J. Sci. Adv. Res. in Technol, vol. 4, no. 3, pp. 2395-1052, Mar. 2018 has discussed that the smart solar grass cutter with sprinkler is an efficient lawn maintenance solution that uses solar power and automation. It operates autonomously, ensuring precise grass cutting and water efficiency. This eco-friendly system reduces dependence on conventional energy sources, making it an innovative and sustainable approach to green spaces.

2.2.9 In paper Fabrication of solar grass cutter, By P. Malviya, N. Patil, R. Prajapat, V. Mandloi, P. K. Patil and P. Bhise, "Fabrication of solar grass cutter", Int. J. Sci. Res. in Sci. Engg. and Technol, vol. 2, no. 2, 2016 has discussed that a solar grass cutter is an eco-friendly lawn maintenance solution that uses solar energy and efficient cutting mechanisms. It uses a solar panel for sunlight capture and a rechargeable battery for energy storage. The cutter offers a sustainable alternative to conventional mowers.

2.2.10 In paper Design and implementation of solar power wireless battery charger. By A. Shufian et al., "Design and implementation of solar power wireless battery charger", IEEE Int. Conf. Adv. Sci. Eng. Robot. Technol, May 3-;5, 2019 has discussed that a solar-powered wireless battery charger integrates solar energy harvesting, wireless charging technology, and energy storage. The solar panel converts sunlight into electrical energy, while a wireless charging module allows cord-free charging. A rechargeable battery stores solar power for future use. This eco-friendly solution promotes sustainable energy practices.

2.2.11 In paper Modification of solar grass cutting machine. By P. P. Ulhe, M. D. Inwate, F. D. Wankhede and K. S. Dhakte, "Modification of solar grass cutting machine", Int. J. Innovative Res. in Sci. and Technol, vol. 2, no. 11, Apr. 2016 has discussed that the Modifications to a solar grass cutting machine enhance efficiency and performance by upgrading the solar panel, optimizing the cutting mechanism, incorporating advanced sensors, improving durability, weather resistance, and introducing smart features like remote monitoring, thereby making the machine more user-friendly and environmentally sustainable.

2.2.12 In paper Solar Powered Automatic Grass Cutter and Pesticide Spreading Robot. By P. P. Argade, S. B. Bhosale, S. S. Khadke, N. V. Phadtare and R. U. Kale, "Solar Powered Automatic Grass Cutter and Pesticide Spreading Robot", International Research Journal of Engineering and Technology, vol. 4, no. 5, pp. 3372-3375, May 2017has discussed that the solar-powered automatic grass cutter and pesticide spreading robot is a sustainable and eco-friendly solution for efficient agricultural practices. Equipped with a solar panel for energy harvesting, it navigates fields, cuts grass, and spreads pesticides, reducing reliance on traditional power sources.

2.2.13 In paper A Fully Automated Lawn Mower Using Solar Panel. By V. Kubendran, S. G. Fernandez, K. Vijayakumar and K Selvakumar, "A Fully Automated Lawn Mower Using Solar Panel", Journal of Advanced Research in Dynamical & Control Systems, vol. 10, no. 07, pp. 977-982, May 2018 has discussed that the fully automated solar-powered lawn mower offers a sustainable and efficient solution for lawn maintenance. It operates autonomously, eliminating the need for manual intervention and self-charging. This eco-friendly system reduces dependence on traditional power sources, providing a hassle-free and energy-efficient solution for maintaining green lawns.

2.2.14 In paper Solar based Robot for Garden Grass Cutting and Watering Plants. By T. S. Gokul and C. Arunkumar, "Solar based Robot for Garden Grass Cutting and Watering

Plants", GRD Journals Global Research and Development Journal for Engineering, pp. 19-22, May 2019 has discussed that the solar-powered robot for garden grass cutting and watering plants offers a sustainable, multifunctional solution for garden maintenance. It operates autonomously, efficiently cutting grass and optimizing water usage, promoting environmental sustainability and making it an eco-conscious choice.

2.2.15 In paper Grass Cutting & Sprayer Machine Using Solar Energy. By K. Harshhal, K. Ganesh, R. Akshay, B. Pravin, P. Swapnil and B. Radhika, "Grass Cutting & Sprayer Machine Using Solar Energy", IJSRSET, vol. 4, no. 4, pp. 806-809, March-April 2018 has discussed that the grass cutting and sprayer machine, powered by solar energy, is an eco-friendly solution for agricultural and lawn maintenance tasks. It features a cutting mechanism and a sprayer for pesticide application, reducing reliance on traditional power sources.

2.2.16 In paper Automatic Irrigation System using Fuzzy Logic. By J. Anand and J. R. P. Perinbam, "Automatic Irrigation System using Fuzzy Logic", AE International Journal of Multidisciplinary Research, vol. 2, no. 8, pp. 1-9, August 2014 has discussed that The automatic irrigation system uses fuzzy logic to optimize water usage in agriculture. It uses real-time data from sensors to make precise irrigation decisions. This sophisticated, automated system enhances crop yield and conserves water resources, ensuring the appropriate watering schedules and amounts are used.

2.2.17 In paper Solar Powered Intelligent Grass Cutter Robot. By D. S. Ajay, J. M. Sahil, R. S. Pratik and R. P. Saurabh, "Solar Powered Intelligent Grass Cutter Robot", International Journal of Scientific Development and Research, vol. 5, no. 4, pp. 229-234, April 2020 has discussed that the Solar Powered Intelligent Grass Cutter Robot is a sustainable, energy-efficient lawn maintenance solution that uses solar panels to cut grass with precision. Its intelligent sensors and algorithms reduce reliance on traditional power sources, promoting eco-friendly practices and continuous operation.

2.2.18 In paper The Solar Operated Multipurpose Agriculture Machine is a sustainable, versatile solution for modern farming, utilizing solar energy for plowing, seeding, and harvesting. Its solar-operated design reduces reliance on conventional power sources, enhancing agricultural efficiency and sustainability. By S. K. Sumeet, B. P. Rahul, D. K. Shrikrushna, A. D. Pravin and S.P. Deepak, " The Solar Operated

Multipurpose Agriculture Machine is a sustainable, versatile solution for modern farming, utilizing solar energy for plowing, seeding, and harvesting. Its solar-operated design reduces reliance on conventional power sources, enhancing agricultural efficiency and sustainability. ", International Journal Of Innovative Research In Science Engineering and Technology, vol. 7, no. 2, pp. 1623-1627, February 2018 has discussed that The Solar Operated Multipurpose Agriculture Machine is a sustainable, versatile solution for modern farming, utilizing solar energy for plowing, seeding, and harvesting. Its solar-operated design reduces reliance on conventional power sources, enhancing agricultural efficiency and sustainability.

2.2.19 In paper TRAWA – An Automated Solar Grass Cutter. By H. Hiba, P. V. Krishna, F. S. Naina, U. Upasana and J. Divya, "TRAWA – An Automated Solar Grass Cutter", Int. J. of Innovative Research In Management Engineering and Technology, vol. 4, no. 6, pp. 162-168, June 2019 has discussed that TRAWA, an Automated Solar Grass Cutter, is a cutting-edge lawn maintenance solution powered by solar energy. Equipped with smart sensors and navigation algorithms, it operates autonomously, reducing environmental impact and promoting sustainable practices in lawn care.

2.2.20 In paper Solar Operated Grass Cutter with Inbuilt Fertilizer Sprayer. By P. Lavkesh, K. Kamlesh, S. Yashraj and S. Rushikesh, "Solar Operated Grass Cutter with Inbuilt Fertilizer Sprayer", Ijsrd - International Journal for Scientific Research & Development|, vol. 6, no. 02, pp. 235-238, 2018 has discussed that The Solar Operated Grass Cutter with an Inbuilt Fertilizer Sprayer is a solar-powered lawn maintenance tool that uses solar panels to convert sunlight into energy. It features an inbuilt fertilizer sprayer for simultaneous grass cutting and targeted fertilization, promoting eco-friendly practices.

2.2.21 In paper Solar Powered Automatic Grass Cutter & Pesticide Spreading Robot. By M. C. Prashant, V. K. Dhiraj, N. A. Sushant, S. K Shubham and R. K. Dipannita, "Solar Powered Automatic Grass Cutter & Pesticide Spreading Robot", International Research Journal of Engineering and Technology, vol. 07, no. 09, pp. 2275-2279, Sep 2020 has discussed that the Solar Powered Automatic Grass Cutter & Pesticide Spreading Robot is a groundbreaking agricultural technology that uses solar energy to efficiently cut grass and spread pesticides, promoting sustainability and eco-friendliness, while enhancing lawn maintenance and farming practices.

2.2.22 In paper Solar Grass Cutter With Linear Blades By Using Scotch Yoke Mechanism. By P. Amrutesh, B. Sagar and B. Venu, "Solar Grass Cutter with Linear Blades By Using Scotch Yoke Mechanism", Int. Journal of Engineering Research and Applications, vol. 4, no. 9, pp. 10-21, September 2014 has discussed that the Solar Grass Cutter with Linear Blades uses solar panels to convert sunlight into energy, ensuring eco-friendly and sustainable operations. Its smart sensors and Scotch Yoke mechanism enhance efficiency and reduce mechanical complexities, demonstrating a commitment to environmentally conscious and efficient grass-cutting practices.

2.2.23 In paper Solar Economical Grass Cutter. By A. D. Akshay, B. B. Dipali, M. M Ashwini, R. T. Nurmohammad and G. K. Shubhangi, "Solar Economical Grass Cutter", International Research Journal of Engineering and Technology, vol. 06, no. 04, pp. 2446-2449, Apr 2019 has discussed that the Solar Economical Grass Cutter is a sustainable, cost-effective lawn maintenance tool powered by solar energy. It uses smart sensors for precise cutting and minimizes energy costs, making it an eco-friendly and budget-conscious choice for green space upkeep.

2.2.24 In paper Automated grass cutter robot based on IoT. By Neha et al., "Automated grass cutter robot based on IoT", International Journal of Trend in Scientific Research and Development (IJTSRD), vol. 2, no. 5, August 2018 has discussed that the Automated Grass Cutter Robot, integrated with IoT, offers real-time connectivity for efficient lawn maintenance. It provides insights into grass height, performance, and operational status, demonstrating the convergence of robotics and IoT, enhancing green space maintenance.

2.2.25 In paper Design and fabrication of lowcost portable lawn mower. By R. Sivagurunathan, L. Sivagurunathan and J. C. J. Hao, "Design and fabrication of low cost portable lawn mower", Scholars Journal of Engineering and Technology, vol. 5, pp. 584-591, 2017 has discussed that the low-cost portable lawn mower is a practical and affordable solution for small-scale lawn maintenance. Its lightweight construction ensures efficient coverage, while its design enhances maneuverability. This innovative tool democratizes lawn care technology, making it accessible to a wider audience.

2.2.26 In paper Development and evaluation of a remote controlled electric lawn mower. By D. A. Aponte-Roa, X. Collazo, M. Goenaga, A. A. Espinoza and K. Vazquez, "Development and evaluation of a remote controlled electric lawn mower", 2019

IEEE 9th Annual Computing and Communication Workshop and Conference (CCWC), 2019 ha discussed that the development and evaluation of a remote-controlled electric lawn mower is a significant advancement in lawn maintenance technology, offering convenience and control. The electric power source ensures eco-friendliness and reduced noise levels. The evaluation phase assesses performance under various conditions.

2.2.27 In paper A technical review of lawn mower technology. By P. P. Dutta, A. Baruah, A. Konwar et al., "A technical review of lawn mower technology", ADBU Journal of Engineering Technology, vol. 4, 2016 has discussed that Lawn mower technology is undergoing significant advancements, focusing on efficiency, sustainability, and user convenience. Electric and robotic mowers offer cleaner operations and reduced noise. Smart technologies like IoT and mobile applications enable remote control. Innovations in blade design, cutting height adjustment, and self-sharpening enhance performance and user experience.

2.2.28 In paper Automatic Solar Tracking System . By J. Ghosh and P. Das, Automatic Solar Tracking System, Maulana Abul Kalam Azad University of Technology, 2019 has discussed that the Automatic Solar Tracking System is a technology that optimizes solar energy collection by adjusting solar panels' orientation based on the sun's position. This technology increases energy output, maximizes sunlight utilization, and promotes sustainability, making it a valuable solution for solar installations.

2.2.29 In paper Design and fabrication of low cost portable lawn mower. By R. Sivagurunathan, L. Sivagurunathan and J. C. J. Hao, "Design and fabrication of low cost portable lawn mower", Scholars Journal of Engineering and Technology, vol. 5, pp. 584-591, 2017 has discussed that the low-cost portable lawn mower is a practical and affordable solution for small-scale lawn maintenance. Its lightweight construction ensures efficient coverage, while its design enhances maneuverability. This innovative tool democratizes lawn care technology, making it accessible to a wider audience.

2.2.30 In paper Development and evaluation of a remote controlled electric lawn mower. By D. A. Aponte-Roa, X. Collazo, M. Goenaga, A. A. Espinoza and K. Vazquez, "Development and evaluation of a remote controlled electric lawn mower", 2019 IEEE 9th Annual Computing and Communication Workshop and Conference (CCWC), 2019 ha discussed that the development and evaluation of a remote-controlled electric lawn mower is a significant advancement in lawn maintenance technology, offering convenience and control. The electric power source ensures eco-friendliness and reduced noise levels. The evaluation phase assesses performance under various conditions.

2.2.31 In paper A Multipurpose Agricultural Robot for Automatic Ploughing Seeding and Plant Health Monitoring. By R Chandana, M Nisha, B Pavithra and R N Nagashree, "A Multipurpose Agricultural Robot for Automatic Ploughing Seeding and Plant Health Monitoring", International Journal of Engineering Research & Technology (IJERT) has discussed that the Multipurpose Agricultural Robot is a revolutionary innovation in modern agriculture, automating key tasks like ploughing, seeding, and monitoring plant health. It enhances efficiency, contributes to sustainable farming practices, and optimizes resource usage, improving crop yield and health.

2.3 Survey of components required for our system:

2.3.1. Microcontroller (Arduino UNO)

Fig. 2.5 Microcontroller (Arduino UNO)

The Arduino UNO is the best board to get started with electronics and coding. If this is your first experience tinkering with the platform, the UNO is the most robust board you can start playing with. The UNO is the most used and documented board of the whole Arduino family.

Main Features

Arduino UNO is a microcontroller board based on the ATmega328P. 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 a AC-to-DC adapter or battery to get started. You can tinker with your UNO without worrying too much about doing something wrong, worst case scenario you can replace the chip for a few dollars and start over again.

Tech Specification

- Board Name- Arduino UNO R3
- SKU- A000066
- Microcontroller- ATmega328P
- USB connector- USB-B
- Built-in LED Pin- 13
- Digital I/O Pins- 14
- Analog input pins- 6
- PWM pins- 6
- UART- Yes
- I2C-Yes
- SPI-Yes
- Power- I/O Voltage- 5V
- Input voltage (nominal)- 7-12V
- DC Current per I/O Pin- 20 mA
- Power Supply Connector- Barrel Plug
- Main Processor- ATmega328P 16 MHz
- USB-Serial Processor- ATmega16U2 16 MHz
- Memory- ATmega328P- 2KB SRAM, 32KB FLASH, 1KB EEPROM
- Weight- 25 g
- Width- 53.4 mm
- Length- 68.6 mm

2.3.2 Obstacle sensor (Ultrasonic sensor)

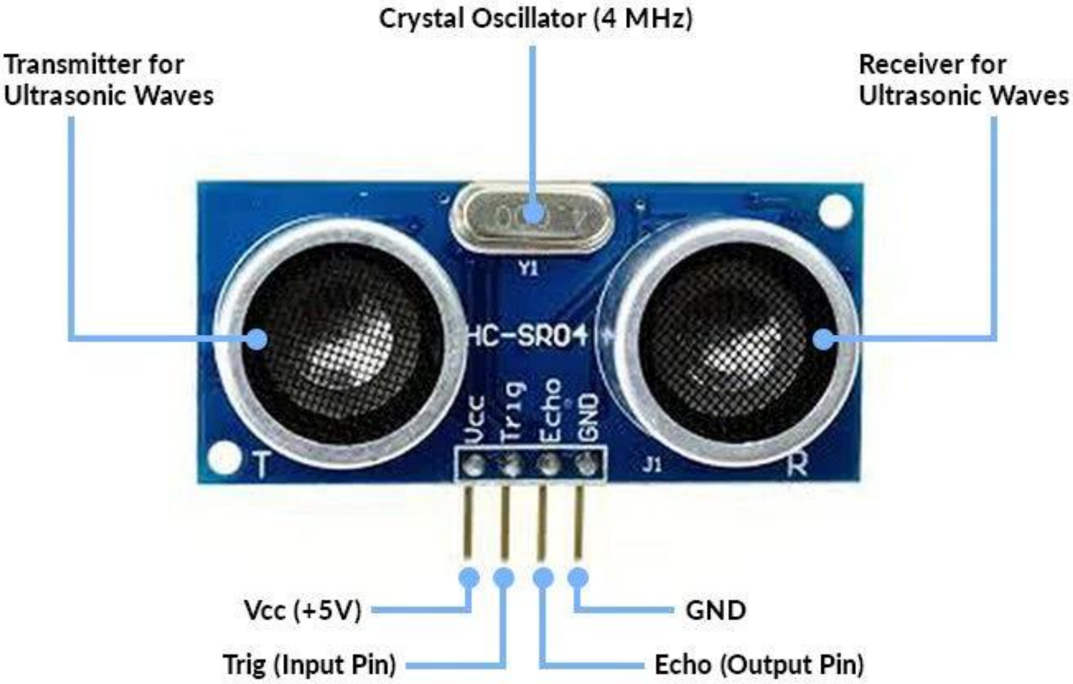

Fig.2.6 Ultrasonic Sensor

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target).

In order to calculate the distance between the sensor and the object, the sensor measures the time it takes between the emission of the sound by the transmitter to its contact with the receiver. The formula for this calculation is D = ½ T x C (where D is the distance, T is the time, and C is the speed of sound ~ 343 meters/second). For example, if a scientist set up an ultrasonic sensor aimed at a box and it took 0.025 seconds for the sound to bounce back, the distance between the ultrasonic sensor and the box would be: D = 0.5 x 0.025 x 343 or about 4.2875 meters.

2.3.3 Battery

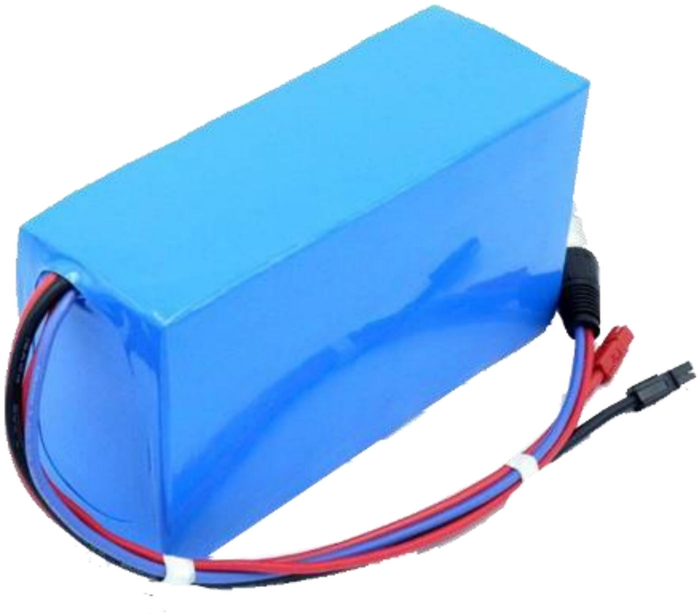

Fig.2.7 Battery

12V 8 Ah Lead Acid Battery

A 12V lithium battery is a rechargeable power source known for its high energy density, lightweight design, and long lifespan. It is commonly used in various applications including electric vehicles, solar energy storage systems, and portable electronic devices. Lithium batteries offer superior performance compared to traditional lead-acid batteries, providing consistent voltage output, low self-discharge rates, and enhanced safety features.

Specifications

- Type - DC
- Output Power - 12V 6Ah
- Weight - 700 grams
- Voltage: 12V (nominal)
- Capacity: 6Ah (Ampere-hours)
- Chemistry: Lithium Iron Phosphate (LiFePO4)
- Charge Voltage: 12.8V (LiFePO4)

2.3.4 L298N Motor Driver Shield

Fig.2.8 L298N Motor Driver Shield

The L298N is a popular dual H-bridge motor driver integrated circuit (IC) used to control the speed and direction of DC motors and stepper motors. It allows for the independent control of two motors, making it ideal for robotics and various automation projects. The L298N can drive inductive loads such as relays, solenoids, and motors, and it can be interfaced with microcontrollers, Arduino boards, and other control systems.

Features:

- Dual H-Bridge: Controls two DC motors or one stepper motor.
- High Voltage and Current: Operates up to 46V and 2A per channel (4A peak).
- PWM Control: Supports Pulse Width Modulation (PWM) for precise speed control.
- Thermal Shutdown: Includes thermal shutdown protection to prevent overheating.
- Overcurrent Protection: Protects the circuit from excessive current.
- Diode Protection: Integrated diodes for back-EMF protection.
- Compact Design: Available in a small, easy-to-integrate package.

L293D Motor Driver Shield Specifications

- Operating Voltage: 5V to 46V
- Output Current: 2A per channel (continuous), 4A peak
- Logic Voltage: 5V

- Control Inputs: TTL/CMOS compatible
- Output Pins: 4 output pins for connecting to motors
- Heat Sink: Built-in heat sink for better heat dissipation
- Dimensions: Typically around 43mm x 43mm x 27mm (board dimensions may vary)
- Weight: Approximately 30 grams (board weight may vary)

2.3.5 Solar panel

Fig.2.9 Solar Panel

A 12-volt solar panel is a commonly used component in various applications, especially in off-grid systems, recreational vehicles (RVs), boats, and other small-scale setups. This type of solar panel is designed to produce electrical energy at a voltage suitable for charging 12-volt batteries, making it an ideal choice for powering devices or systems that operate on this voltage. When integrating a 12-volt solar panel into a system, it's crucial to ensure compatibility with the connected batteries. Additionally, employing a solar charge controller is recommended to regulate the charging process, preventing overcharging and optimizing battery performance. The wattage of the solar panel should be chosen based on the specific power requirements of the intended application, with higher wattage panels delivering more power under similar sunlight conditions. Proper orientation towards the sun and regular maintenance contribute to the efficient operation of the 12-volt solar panel system, providing a reliable and sustainable source of clean energy.

2.3.6 Gear DC Motors

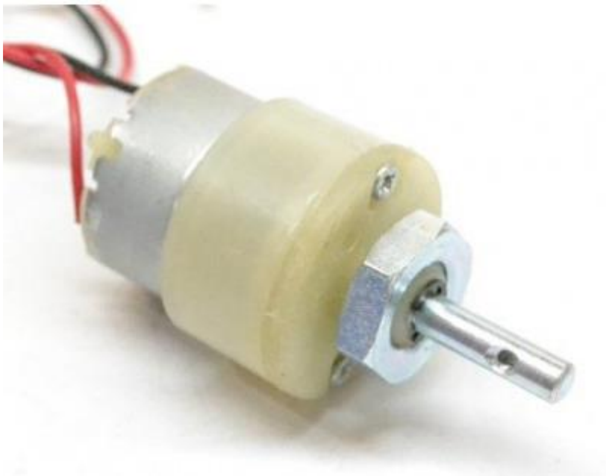

Fig.2.10 Gear DC Motor

A gear motor is an all-in-one combination of a motor and gearbox. The addition of a gearbox to a motor reduces the speed while increasing the torque output. The most important parameters in regard to gear motors are speed (rpm), torque (lb-in) and efficiency (%). In order to select the most suitable assembly for your application, you must first compute the load, speed and torque requirements for your application.

ISL Products offers a variety of small or miniature gear motors including Spur Gear Motors, Planetary Gear Motors and Worm Gear Motors to meet all application requirements. Most of our DC motors can be complemented with one of our unique gearboxes, providing you with a highly efficient inline solution. Pairing the proper motor and gearbox reduction ratio is critical when designing in a gear motor.

Specifications

- RPM: 100
- Operating Voltage: 12V DC
- Gearbox: Attached Plastic (spur)Gearbox
- Shaft diameter: 6mm with internal hole
- Torque: 2 kg-cm
- No-load current = 60 mA(Max)
- Load current = 300 mA(Max).

2.3.7 Blade Motor

Fig.2.11 Blade Motor

A blade motor for cutting grass is a vital component in lawn mowers and similar grass-cutting equipment. This motor is responsible for powering the rotation of the cutting blades, enabling them to efficiently trim and maintain the grass at a desired length. Whether in traditional gas-powered lawn mowers or electric models, the blade motor's performance directly influences the cutting effectiveness and overall efficiency of the equipment. These motors are designed to handle the demands of grass cutting, providing the necessary torque and rotational power to tackle various grass types and terrains. In electric models, the blade motor often operates quietly and may offer features like adjustable cutting heights for customized lawn maintenance. Regular maintenance of the blade motor, including blade sharpening and motor lubrication, ensures optimal performance and longevity. In essence, the blade motor is a key element that transforms electrical or combustion energy into the mechanical force required to keep lawns well-manicured and visually appealing.

Specifications

- Motor Type- DC Motor (775 Series)
- Operating Voltage- 12V DC
- No-load Speed- 10,000 RPM (rotations per minute)
- Bracket Dimensions- 8 cm x 10 cm x 5 cm (L x W x H)
- Blade Length- 20 cm
- Weight- 300 grams (approximate)

2.3.8 Servo Motor

Fig.2.12 Servo Motor

A servo motor is a type of motor that can rotate with great precision. Normally this type of motor consists of a control circuit that provides feedback on the current position of the motor shaft, this feedback allows the servo motors to rotate with great precision. If you want to rotate an object at some specific angles or distance, then you use a servo motor. It is just made up of a simple motor which runs through a servo mechanism. If motor is powered by a DC power supply then it is called DC servo motor, and if it is AC-powered motor then it is called AC servo motor. For this tutorial, we will be discussing only about the DC servo motor working. Apart from these major classifications, there are many other types of servo motors based on the type of gear 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 are being used in many applications like toy car, RC helicopters and planes, Robotics, etc.

Servo motors are rated in kg/cm (kilogram per centimeter) most hobby servo motors are rated at 3kg/cm or 6kg/cm or 12kg/cm. This kg/cm tells you how much weight your servo motor can lift at a particular distance. For example: A 6kg/cm Servo motor should be able to lift 6kg if the load is suspended 1cm away from the motors shaft, the greater the distance the lesser the weight carrying capacity. The position of a servo motor is decided by electrical pulse and its circuitry is placed beside the motor.

2.3.9 HC05 Bluetooth Transceiver Module

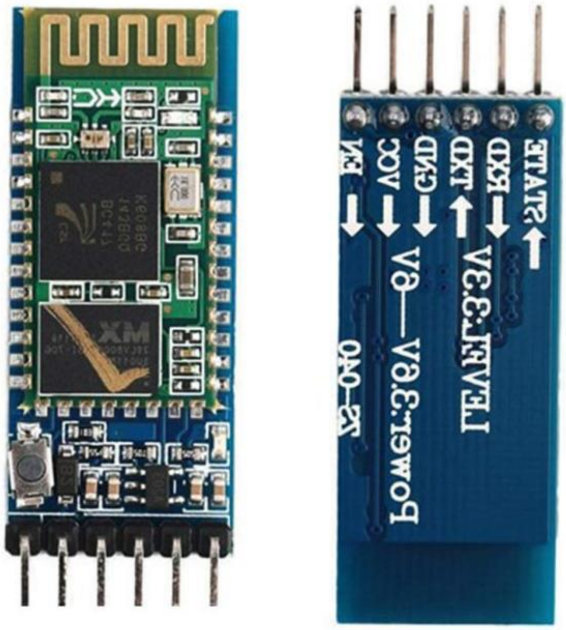

Fig.2.13 HCO5 Bluetooth Transceiver Module

The Bluetooth Transceiver HC-05 TTL Module with enable/disable button Breakout is the latest Bluetooth wireless serial cable! This version of the popular Bluetooth uses the HC-05/HC-06 module. These modems work as a serial (RX/TX) pipe. Any serial stream from 9600 to 115200bps can be passed seamlessly from your computer to your target.

The remote unit can be powered from 3.3V up to 6V for easy battery attachment. All signal pins on the remote unit are 3V-6V tolerant. No level shifting is required.

Do not attach this device directly to a serial port. You will need an RS232 to TTL converter circuit or Arduino XBee USB Adapter if you need to attach this to a computer. You can either solder a 6-pin header or individual wires. The unit comes without a connector. Please see related male and female pins below. And now, we provide HC-05/06, HC-05 could be set to Master or Slave by a user. HC-06 just be Master or Slave, that could be customized.

2.3.10 DC-DC step-down Module

Fig.2.14 DC-DC step-down module

A DC-DC step-down module, also known as a buck converter, is an electronic circuit that converts a higher input voltage to a lower output voltage. This type of module is essential for applications where a stable and lower voltage is required from a higher voltage source. It is widely used in power supply systems for electronic devices, enabling efficient voltage regulation and distribution.

Specifications

- Input Voltage Range: Typically 4V to 60V
- Output Voltage Range: Typically 1.25V to 36V
- Output Current: Typically ranges from 1A to 10A, depending on the module
- Efficiency: Up to 95% or higher
- Switching Frequency: Typically around 150kHz to 1MHz
- Dimensions: Varies by module, generally compact
- Weight: Light, typically a few grams

2.3.11 Relay Module (Single Channel Relay)

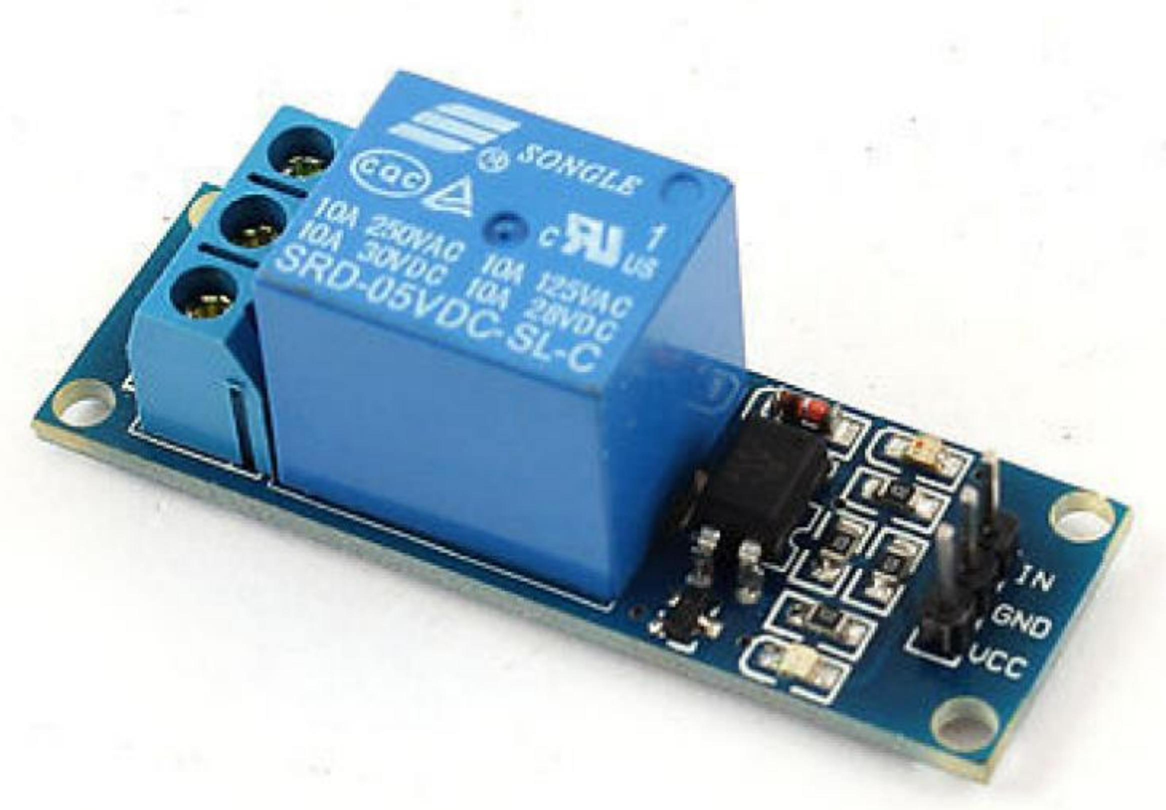

Fig.2.15 Single channel relay

A single channel relay module is an electronic switch that allows you to control high-voltage devices using low-voltage signals. It is commonly used in automation, home appliances, and DIY projects to switch electrical loads, such as lights, motors, and other devices, with a microcontroller or other control system.

Specifications

- Control Voltage: Typically 3.3V to 5V (compatible with most microcontrollers like Arduino, Raspberry Pi, etc.)
- Relay Voltage: Supports high voltage, usually up to 250V AC or 30V DC
- Current Rating: Typically 10A at 250V AC or 10A at 30V DC
- Trigger Current: 15-20mA
- Switching Capacity: 10A at 250V AC or 10A at 30V DC
- Dimensions: Generally compact, around 5cm x 2cm x 2cm
- Weight: Light, typically a few grams

3.1 System Development Requirements

3.1.1 Hardware Requirements

Table 3.1 Minimum Hardware Requirements

Hardware Type	Minimum Requirement
Processor	Intel Core i3-1135G7 @ 2.40GHz or above
Primary Memory	4GB RAM or above
Secondary Memory	50GB
Internet Connection	Not Applicable
Other Hardware	Arduino UNO, Ultrasonic Sensor, Servo Motor, Bluetooth Module, Gear DC Motors, Blade Motor, Motor Driver Shield, Step-down module, Relay, Battery, Solar Panel.

3.1.2 Software Requirements

Table 3.2 Minimum Software Requirements

Software Type	Minimum Requirement
Platform (OS)	Windows Family (7/8/9/10/11)
Front End	C/C++
Back End	Not Applicable
Design Tool	RSA (Rational Software Architect), Edraw 6.1
Development Tool (IDE)	Arduino IDE, MIT app inventor
Browser	Not Applicable
Other	Photoshop, Cirkit Designer, Adobe XD

3.2 System Deployment Requirements

3.2.1 Hardware Requirements

Table 3.3. Minimum Hardware Requirements

Hardware Type	Minimum Requirement
Android Version	Android 5.0 (Lollipop)
Primary Memory	2GB RAM or above
Secondary Memory	16GB
Internet Connection	Not Applicable
Other Hardware	Arduino UNO, Ultrasonic Sensor, Servo Motor, Bluetooth Module, Gear DC Motors, Blade Motor, Motor Driver Shield, Step-down module, Relay, Battery, Solar Panel.

3.2.2 Software Requirements

Table 3.4. Minimum Software Requirements

Software Type	Minimum Requirement
Platform (OS)	Android
Android App	SSGC (Smart Solar Grass Cutter)

3.3 Functional Requirements

3.3.1 Autonomous Navigation

The system shall autonomously navigate the lawn, avoiding obstacles and covering the entire mowing area.

3.3.2 Solar-Powered Operation

The system should be powered by solar energy, utilizing solar panels to charge the onboard battery.

3.3.3 Obstacle Detection

The system shall Implement sensors to detect obstacles and adjust the grass cutter's path to avoid collisions.

3.3.4 Real-Time Data Feedback

The system shall Provide real-time feedback to users, including battery levels, cutting progress.

3.3.5 Mobile App Integration

The system shall Enable remote monitoring and control through a mobile app, allowing users to start/stop, schedule, and receive notifications.

3.3.6 Low-Noise Operation

The system shall Design for low-noise operation to minimize disturbances to the environment and users.

3.3.7 Automatic Charging

The system shall Include an automatic charging feature where the grass cutter returns to its charging station when the battery is low.

3.4 Non-functional Requirements

3.4.1 Maintainability:

The system should be easily maintainable, allowing for straightforward repairs, component replacements, and software updates.

3.4.2 Power Efficiency:

Optimize the power consumption to maximize the efficiency of solar energy utilization and minimize the need for frequent charging.

3.4.3 Performance:

The grass cutter should operate efficiently, covering a specified area within a reasonable time, and responding promptly to user commands.

3.4.4 Usability:

The user interface, whether on the grass cutter itself or through a mobile app, should be intuitive and user-friendly.

3.4.5 Cost-Effectiveness:

Strive for a cost-effective design, considering the affordability of the grass cutter without compromising quality and performance.

3.5 Functional Modelling

3.5.1 Data Flow Diagram – Level 0

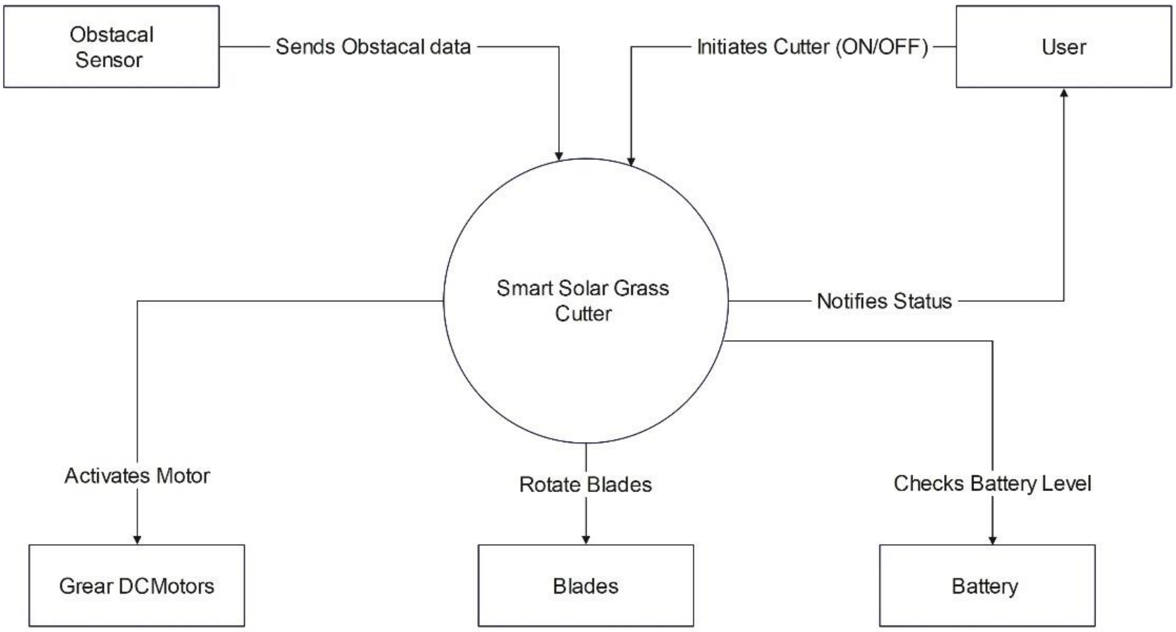

Fig.3.1 Data Flow Diagram: Level 0

3.5.2 Data Flow Diagram – Level 1

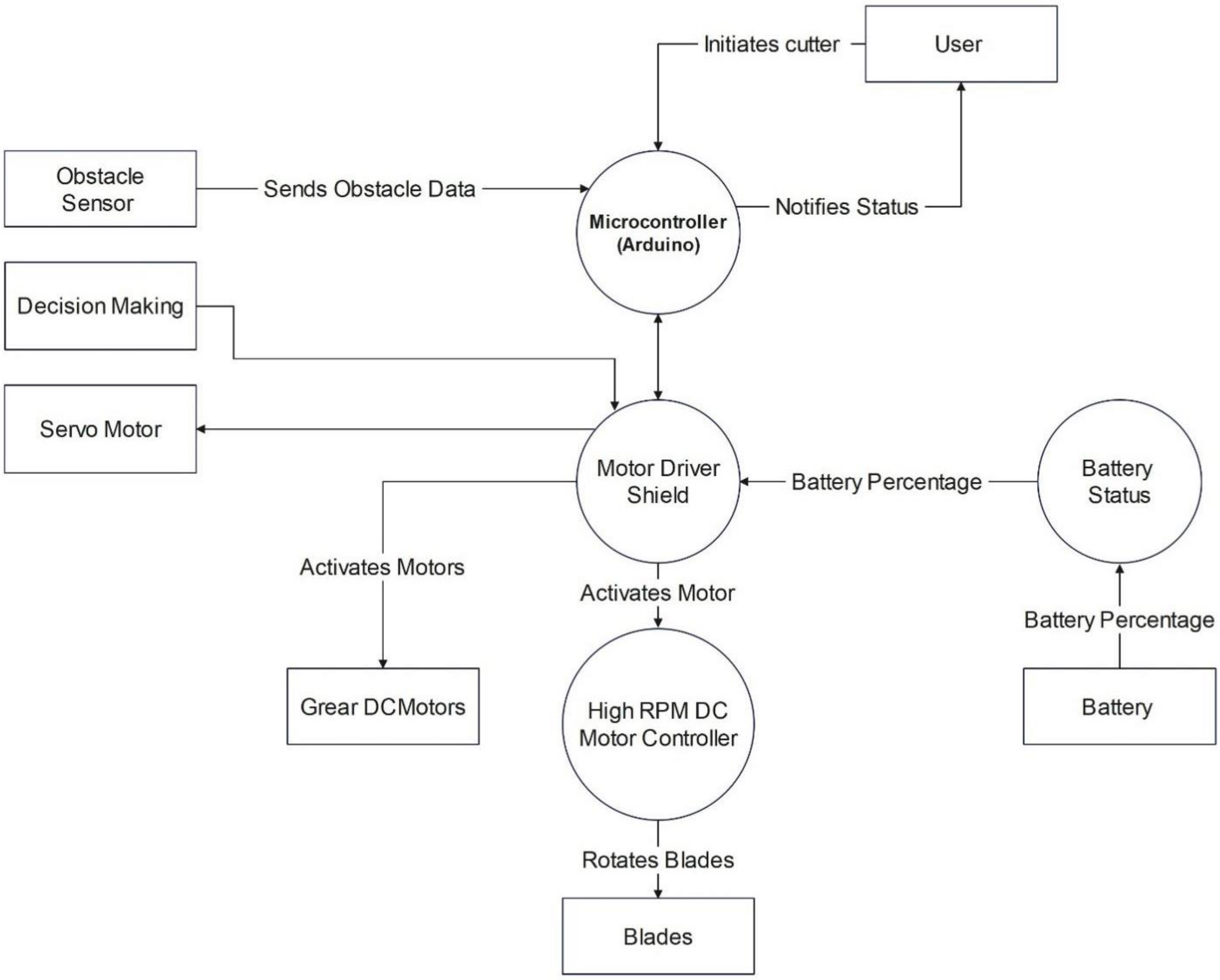

Fig.3.2 Data Flow Diagram: Level 1

3.5.3 Data Flow Diagram – Level 2

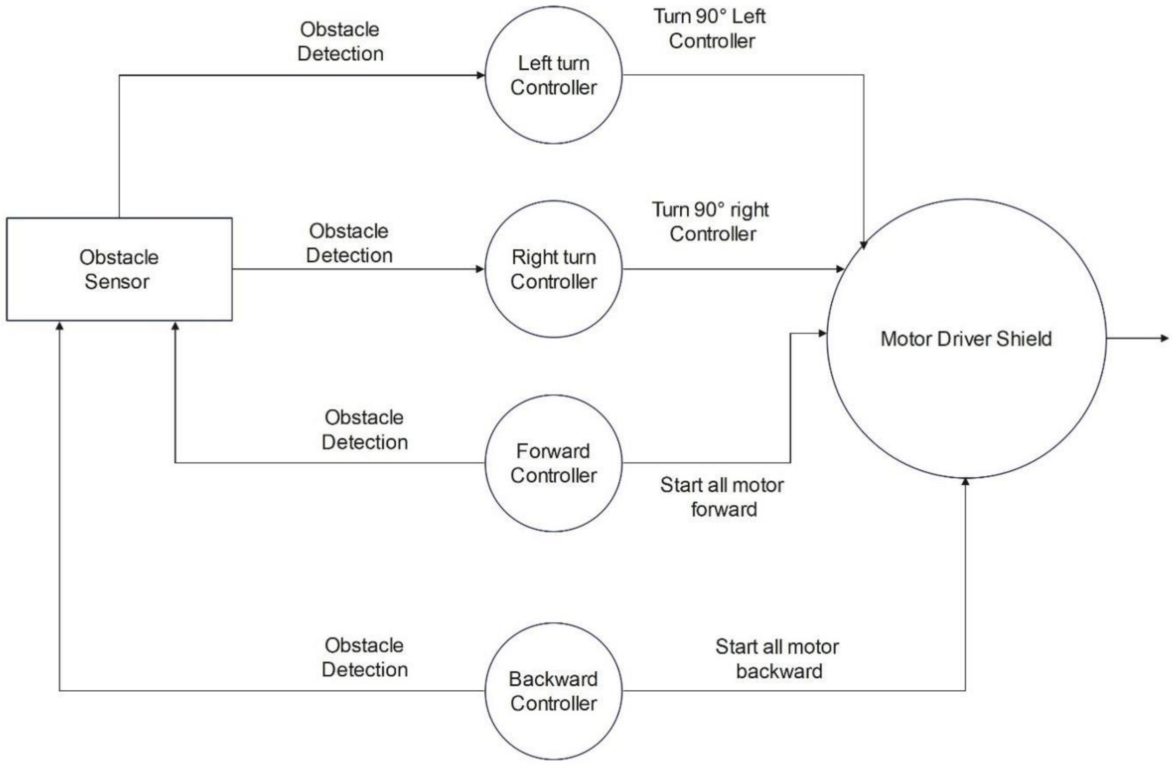

Fig.3.3 Data Flow Diagram: Level 2

4. PLANNING

4.1 Software Process Model

4.1.1 Description of Selected Model

In a waterfall model, each phase must be completed before the next phase can begin. There is no overlapping in the phases. The waterfall model is the earliest SDLC approach used for software development. The waterfall Model illustrates the software development process in a linear sequential flow; hence it is also referred to as a linear-sequential life cycle model.

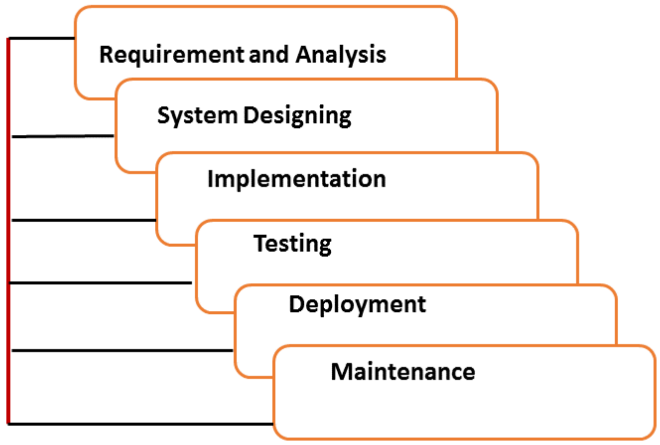

Fig.4.1 Classical Waterfall Model

The sequential phases in the Waterfall model are:

Requirement Analysis: All possible requirements of the system to be developed are captured in this phase and documented in a requirement specification doc.

System Design: The requirement specifications from the first phase are studied in this phase and the system design is prepared. System Design helps in specifying hardware and system requirements and also helps in defining overall system architecture.

Implementation: With inputs from system design, the system is first developed in small programs called units, which are integrated into the next phase. Each unit is developed and tested for its functionality, referred to as Unit Testing.

Integration and Testing: All the units developed in the implementation phase are integrated into a system after the testing of each unit. Post integration the entire system is tested for any faults and failures.

Deployment of the system: Once the functional and non-functional testing is done, the product is deployed in the customer environment or released into the market.

Maintenance: Some issues come up in the client environment. To fix those issues patches are released. Also, to enhance the product some better versions are released. Maintenance is done to deliver these changes in the customer environment.

4.1.2 Reason for selection

Water quality monitoring helps evaluate the nature and extent of pollution control required. Every software developed is different and requires a suitable SDLC approach to be followed based on internal and external factors. We choose the **Waterfall, model,** as a software process model, because

- It is useful for projects in which the requirements are well understood.
- It has sequential nature.
- The effectiveness of pollution control measures already in existence.
- We select this project because we are freshers.
- The project size is less than 50,000.

4.2 Cost Estimation using Basic COCOMO Model

4.2.1 Historical Data

We have referred to the project titled IoT-Based Crop Monitoring Using Arduino.

Table 4.1. Size Estimation of Historical Data

Software Module	**LOC**
Graphical User Interface	2000
Embedded c	2000
Total Estimated Lines of Code (LOC)	**4000**

We are here considering the approximate size of our product as 4000 LOC.

4.2.2 Estimation Technique

COCOMO (**Co**nstructive **Co**st Estimation **Mo**del) was proposed by Boehm [1981]. COCOMO predicts the efforts and schedule of a software product based on the size of the software. According to Boehm, software cost estimation should be done through three stages: **Basic COCOMO, Intermediate COCOMO,** and **Detailed / Complete / Advanced COCOMO.** [8,16]

Basic COCOMO: It is a single-valued, static model that computes software development effort (and cost) as a function of program size expressed in estimated thousand delivered source instructions (KDSI) i.e., Lines of code (LOC).

Intermediate COCOMO: an extension of the Basic model that computes software development effort as a function of program size by adding a set of "cost drivers," that will determine the effort and duration of the project, such as assessments of personnel and hardware.

Detailed COCOMO: an extension of the Intermediate model that adds effort multipliers for each phase of the project to determine the cost drivers impact on each step (analysis, design, etc.) of the software engineering process.

In our project, we are going to use the "Basic COCOMO" model for estimations. Basic COCOMO categorizes projects into three types:

Organic Mode: (**Application Programs** such as data processing, scientific, etc.) Development projects typically are not complicated and involve small, experienced teams. The planned software is not considered innovative (i.e., little innovation) and requires a relatively small number of DSI (typically 2000 to 50,000 LOC). Organic projects are those developed in a stable development environment and do not have tight deadlines or constraints.

Semidetached Mode: (**Utility Programs** such as compilers, linkers, analyzers, etc.) Development projects typically are more complicated than in Organic Mode and involve teams of people with mixed levels of experience. The software requires no more than 50,000 to 300,000 DSI. The projects require minor innovations and have some deadline & constraint restrictions where the development environment is not much stable. Examples of this type are developing a new database management system.

Embedded Mode: (**System Programs** such as: operating system, etc.) Development projects must fit into a rigid set of requirements because the software is to be embedded in a strongly joined complex of hardware, software, regulations, and operating procedures. Contains a large highly experienced project team that is required to do some highly innovative work with very tight deadlines and severe constraints. The project requires no more than 300,000 DSI.

The Basic COCOMO formula takes the form:

Effort, E = a(KLoC/KDSI)^{b} person months

Duration, D = c(E)^{d} months

Person, P = E/D persons

where **E** is the effort applied in person-months, **KLoC** is the estimated number of thousands of delivered lines of code for the project, **D** is the total time duration to develop the system in months, and **P** is the number of persons required to develop that system.

The coefficients **a, c,** and the exponent **b, d** are given in the following table.

Table 4.2. Coefficient/Exponent Values of Basic COCOMO

Project Type	a	b	c	d
Organic	2.4	1.05	2.5	0.38
Semi-Detached	3.0	1.12	2.5	0.35
Embedded	3.6	1.20	2.5	0.32

This system will fall in the "**Embedded Mode**" category.

4.2.3 Cost Estimation

4.2.3.1 Size Estimation

Table 4.3. Size Estimation of Current System.

Software Module	**LOC**
Arduino UNO	1000
Obstacle Sensor (Ultrasonic Sensor)	500
Navigation System	500
Bluetooth Module	1000
Total Estimated Lines of Code (LOC)	3000

The total lines of code for the proposed system will be approximately **3000**.

4.2.3.2 Effort Estimation

The system falls into the embedded category.

Effort (E) = a $(KLOC)^b$ [Person-Month]

The value ab and bb according to the embedded system is:

a=3.6 and b=1.20

The total LOC (approx.) of the project is: 3000 LOC=3 KLOC

$E = (3.6) * (3.0)^{1.20}$

E=3.6*3.73

E=13.42≈14 Persons

4.2.3.3 Duration Estimation

The values c and d according to the embedded system c = 2.5 and d = 0.32

Duration (D) = $c\,(E)^d$

$D = 2.5*(14)^{0.32}$

$D = 2.5 * 2.32$

D = 5.8 ≈ 6 Months

4.2.3.4 Person Required

Person Required = Effort Applied (E) / Development Time (D)

= 13.42/6

= 2.23≈ 3 Persons

4.2.3.5 Estimated Cost of System

We assume each team member charges ₹1000/- per month, ₹8000/- required for other resources. Thus, parts include in project are Arduino UNO, Ultrasonic Sensor, Servo Motor, Bluetooth Module, Gear DC Motors, Blade Motor, Motor Driver Shield, Battery, Solar Panel etc.

Estimated Cost of System = ((Person Charges * Person Required) + Resource Charges) * Duration [+ Hardware Cost]

= ((1000 * 3) + 1000) * 6 + 8000 = **₹32,000**/-

4.2.3.6 Estimation Summary

Table 4.4 Summary of different estimations.

Estimation	Value
Size of the Project	3000 LoC
Effort Required	14 Person Months
Duration Required	6 Months
Person Required	3
Cost Required	₹32,000/-

4.3 Team Structure

Team structure addresses the issue of organization of the individual project teams. As per the estimation, the project team will consist of **three** members. The effort assignment, duties, and details of each member are given below:

Table 4.5 Team Members

Sr. No.	Name of Team Member	Phase – I Role	Phase - II Role	E-mail ID
1.	Pawar Mayur Rajubhai (Group Leader)	Analyst	Coder	mayurpawar4908@gmail.com
2.	Patil Lalit Mahendra	Designer	Documentation	lp613408@gmail.com
3.	Panpatil Laukik Santosh	Documentation	Tester	panpatilaukik@gmail.com

4.4 Project Scheduling

Project scheduling involves plotting project activities against a time frame. The process aims to ensure that various project tasks are well coordinated, and they meet the various project objectives including timely completion of the project. The Project Table is a popular way to perform project scheduling.

Table 4.6 Project Table

Activity Name	Start Date	End Date	Effort Assignment
Introduction	16/10/2023	20/10/2023	Mr. Mayur Mr. Lalit
Literature Survey	20/10/2023	3/11/2023	Mr. Mayur Mr. Laukik
Analysis	3/11/2023	17/11/2023	Mr. Mayur Mr. Lalit
Planning	17/11/2023	24/11/2023	Mr. Mayur Mr. Lalit Mr. Laukik
Design	24/11/2023	01/12/2023	Mr. Mayur Mr. Lalit
Phase-I Documentation	01/12/2023	04/12/2023	Mr. Mayur Mr. Lalit, Mr. Laukik

Implementation	04/12/2023	10/04/2024	Mr. Mayur Mr. Lalit
Testing	10/04/2024	05/05/2024	Mr. Laukik
Phase-II Documentation	05/05/2024	26/05/2024	Mr. Mayur Mr. Lalit Mr. Laukik

5. DESIGN

5.1 UML Modelling

The unified modeling language (UML) is a Graphical Language for visualization, Specifying, constructing, and documenting the artifacts of a software-intensive system. The UML gives a standard way to write a system's blueprints, covering conceptual things, such as Business Processes & system functions, as well as concrete things, such as classes written in a specific programming language, database schemas, and reusable software components.

5.1.1 Use Case Diagram

A use case defines the behavioral features of a system. Each use case is named using a verb phrase that expresses a goal of the system. A use case diagram shows a set of use cases and actors & their relationships. Use case diagrams address the static use case view of a system. These diagrams are especially important in organizing and modeling the behaviors of a system. It shows the graphical overview of the functionality provided by the system intents actor.

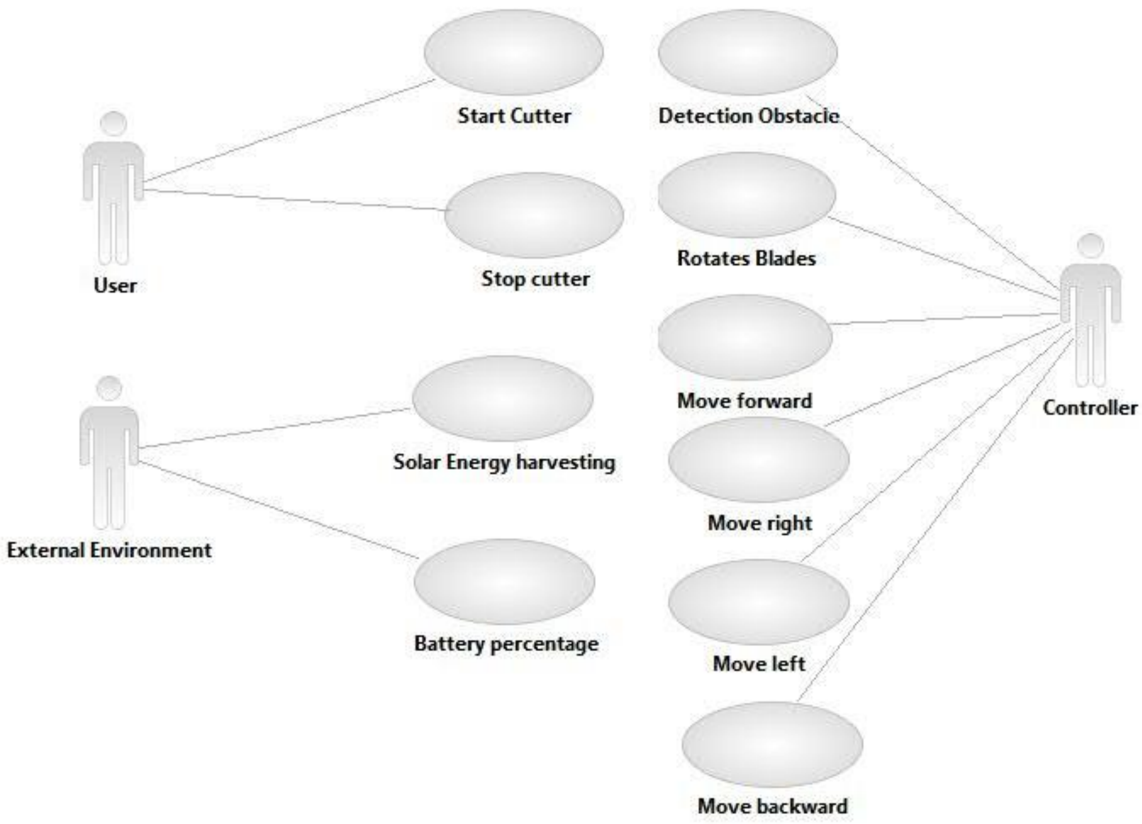

Fig.5.1 Use Case Diagram

5.1.2 Activity Diagram

An activity diagram of a special kind of state chart diagram that shows the flow from activity within a system. An activity addresses the dynamic view of a system. The activity diagram is often seen as part of the functional view of a system because it describes logical processes or functions. Each process describes a sequence of tasks and the decisions that govern when and when they are performed. The flow in an activity diagram is driven by the completion of an action.

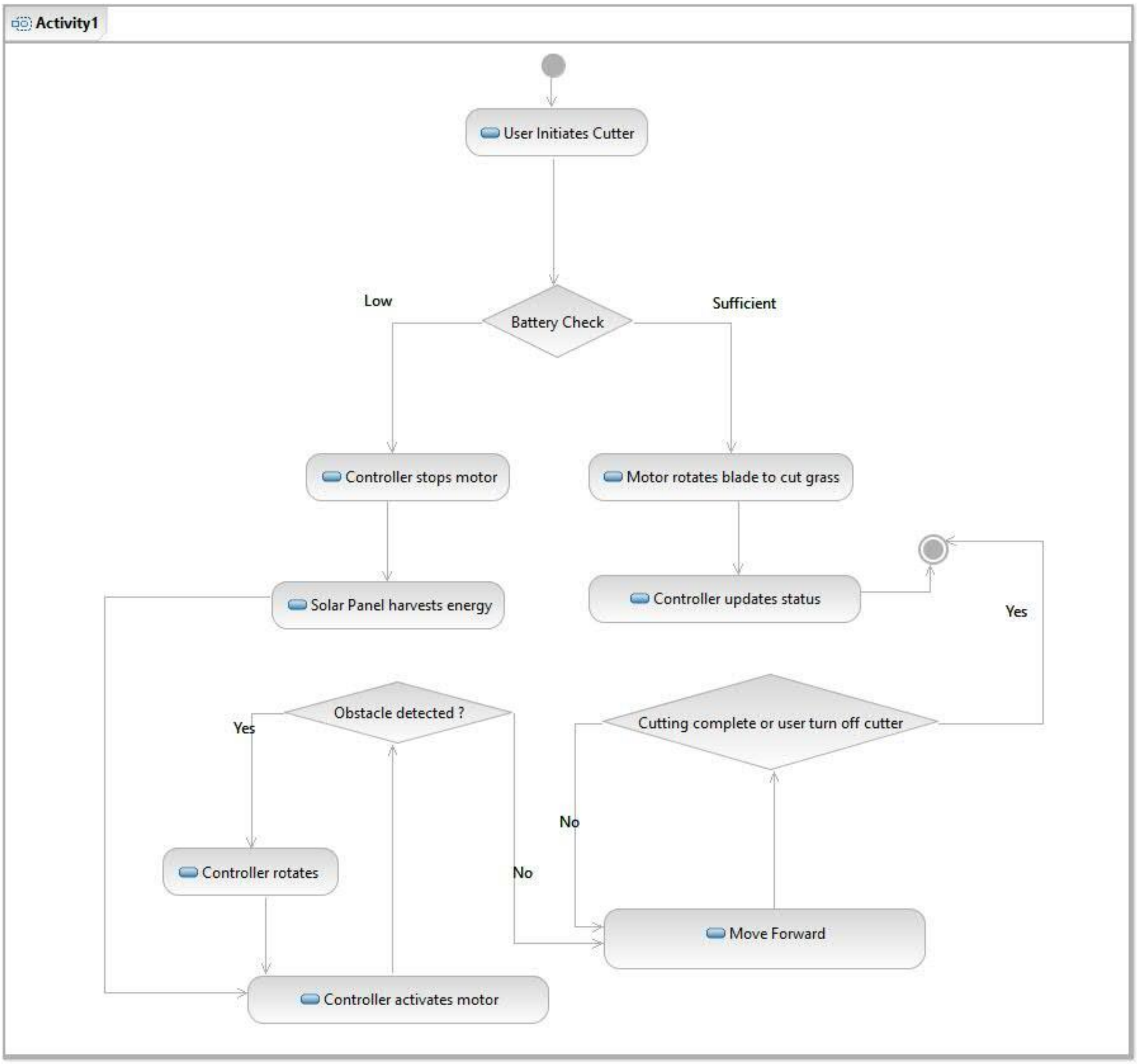

Fig.5.2 Activity Diagram

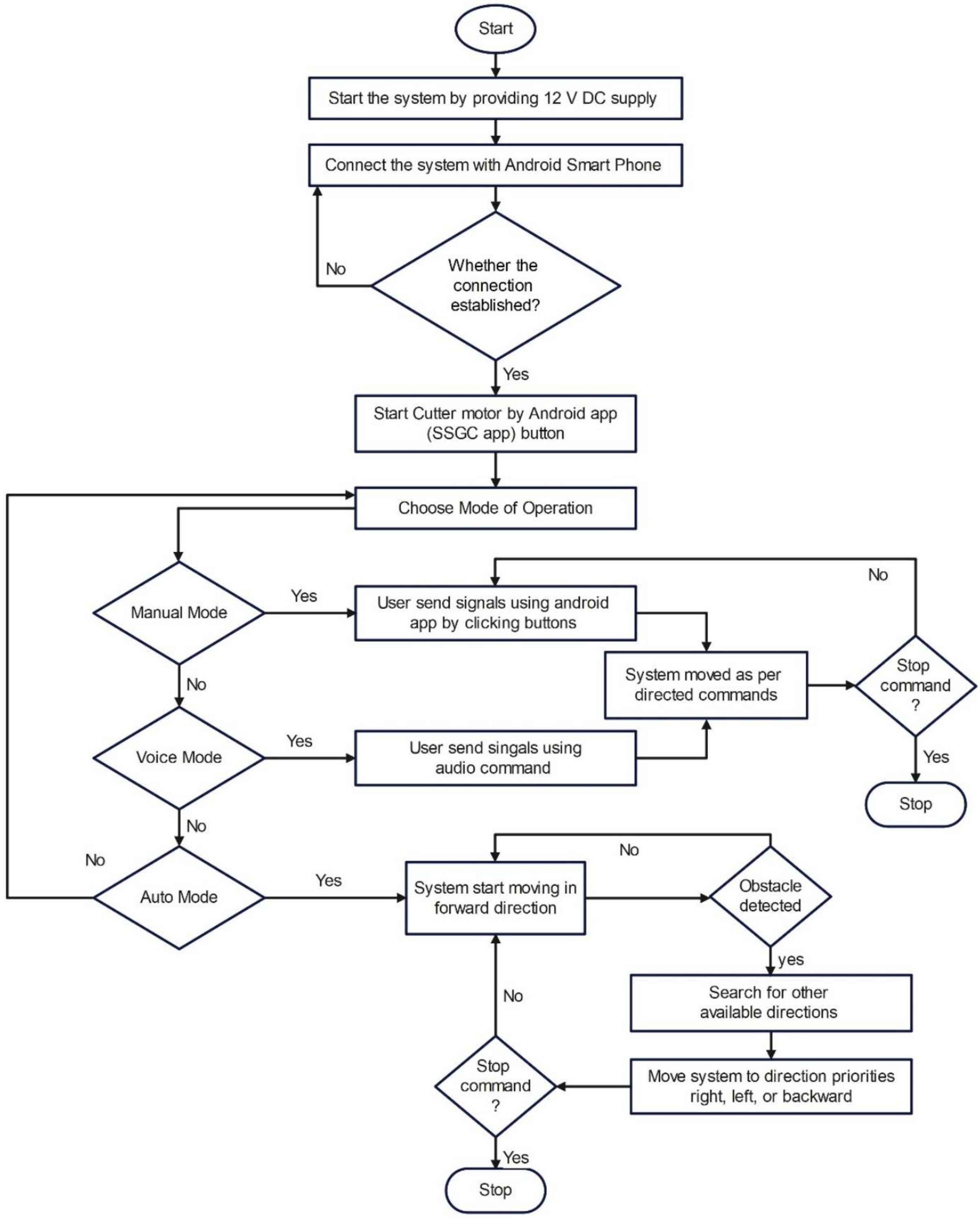

Fig.5.3 Flow Chart

5.1.3 Sequence Diagram

A sequence diagram is a kind of interaction diagram. It shows an interaction, consisting of a set of objects and their relationships, including the message that may be dispatched among them. A sequence diagram emphasizes the time ordering of messages. As shown in the figure we can form a sequence diagram by first placing the objects that participate in the interaction at the top of our diagram. The object that initiates the interaction at the left and increasingly more subordinate objects to the right. The messages that these objects send and receive along the Y-axis, in order of increasing time from top to bottom. This gives the reader a clear visual cue to the flow of control over time.

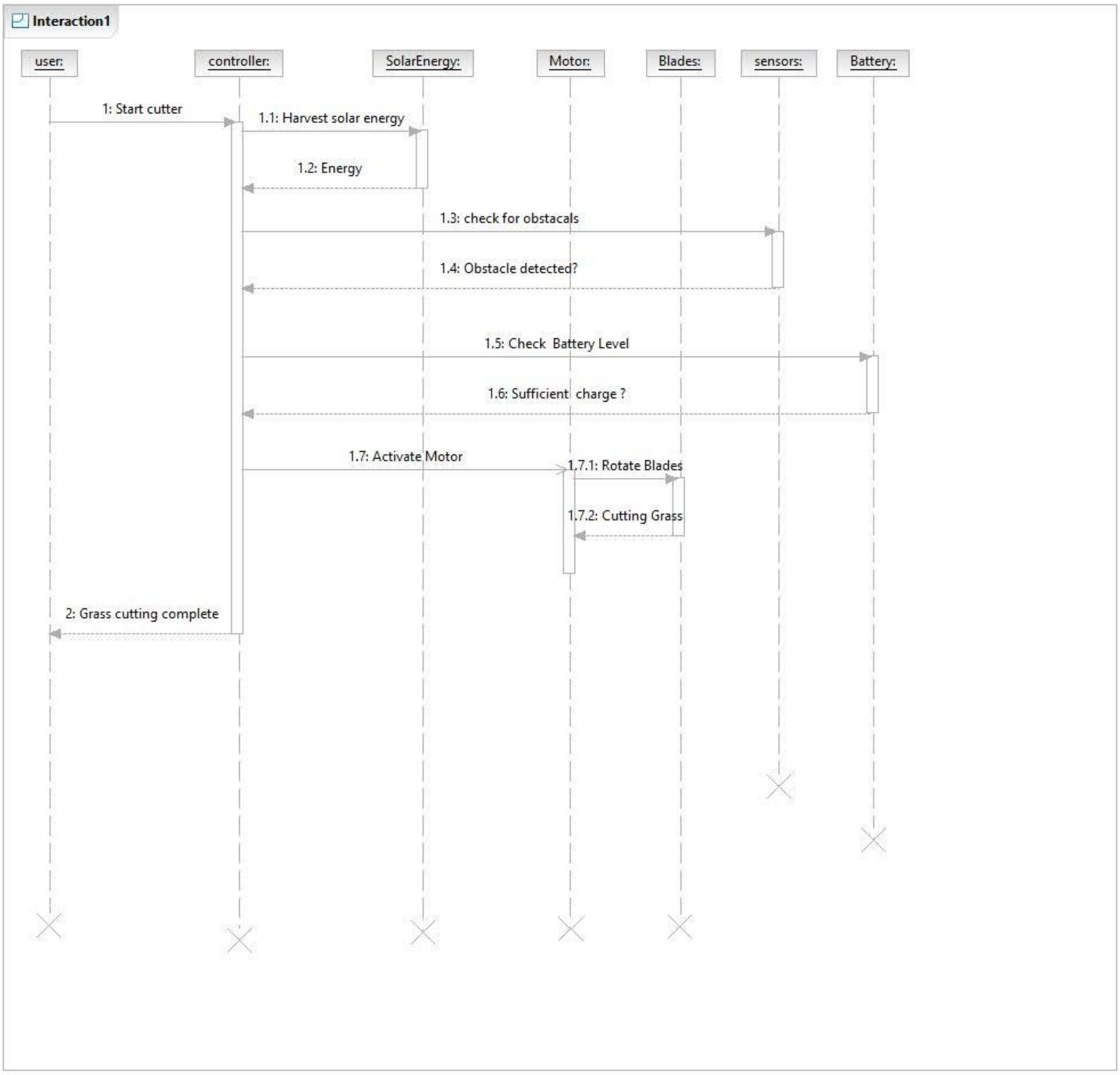

Fig.5.4 Sequence Diagram

5.1.4 Class Diagram

A class diagram shows a set of classes, interfaces, and collaborations and their relationship. These diagrams are the most common diagram found in modeling object-oriented systems. Class diagrams addressed the static design view of a system.

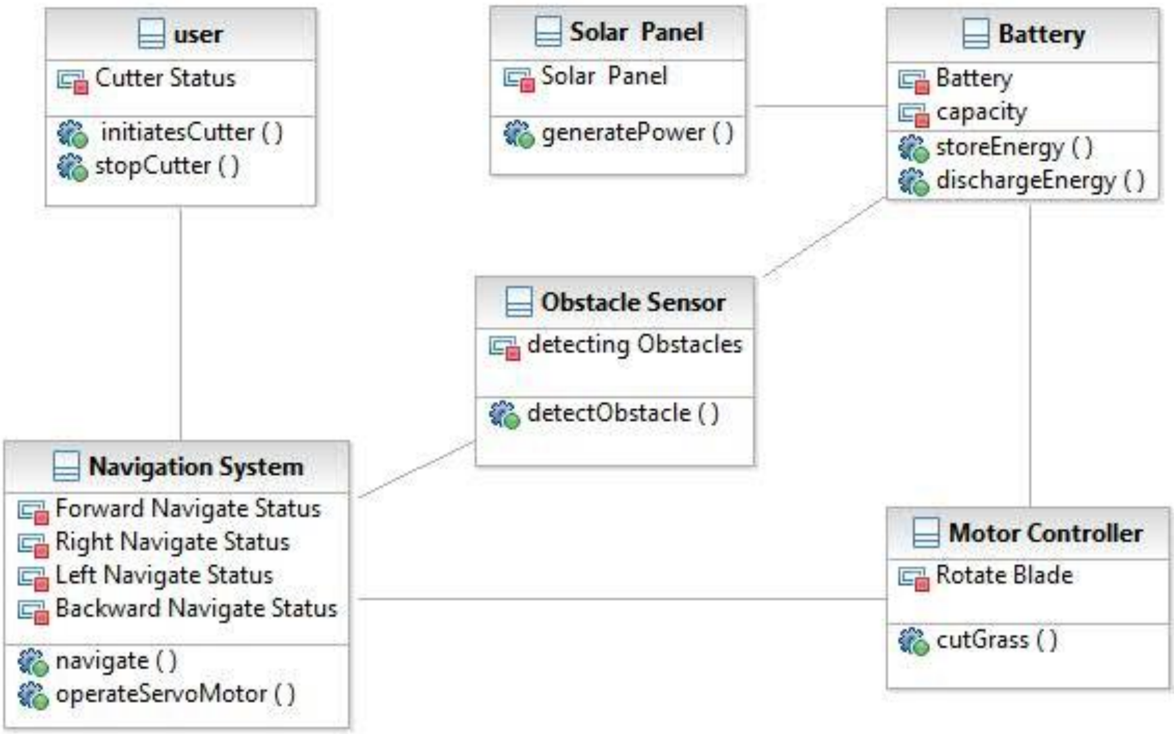

Fig.5.5 Class Diagram

5.1.5 Component Diagram

A component diagram shows the organization and dependencies among a set of components. Component diagrams address the static implementation view of a system. Component diagrams are one of the two kinds of diagrams found in modeling the physical aspects of object-oriented systems. A component diagram shows the organization and dependencies among a set of components. You can use component diagrams to model the static implementation view of a system.

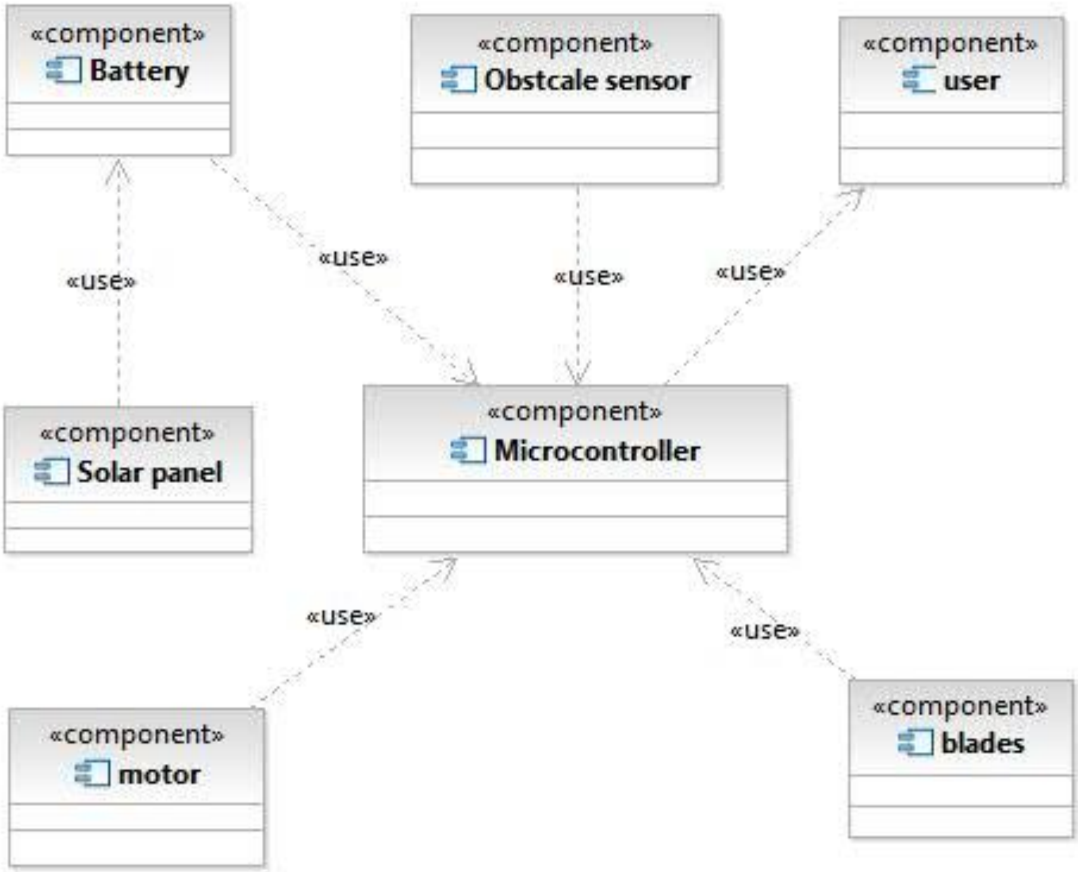

Fig.5.6 Component Diagram

5.1.6 Deployment Diagram

The deployment diagram shows the configuration of run-time processing nodes and components that live on them. The deployment diagram addresses the static deployment view of architecture. A deployment diagram shows the configuration of run-time processing nodes and the components that live on them. Deployment diagrams address the static view of architecture. They are related to the diagram of the components in that a node typically encloses one or more components.

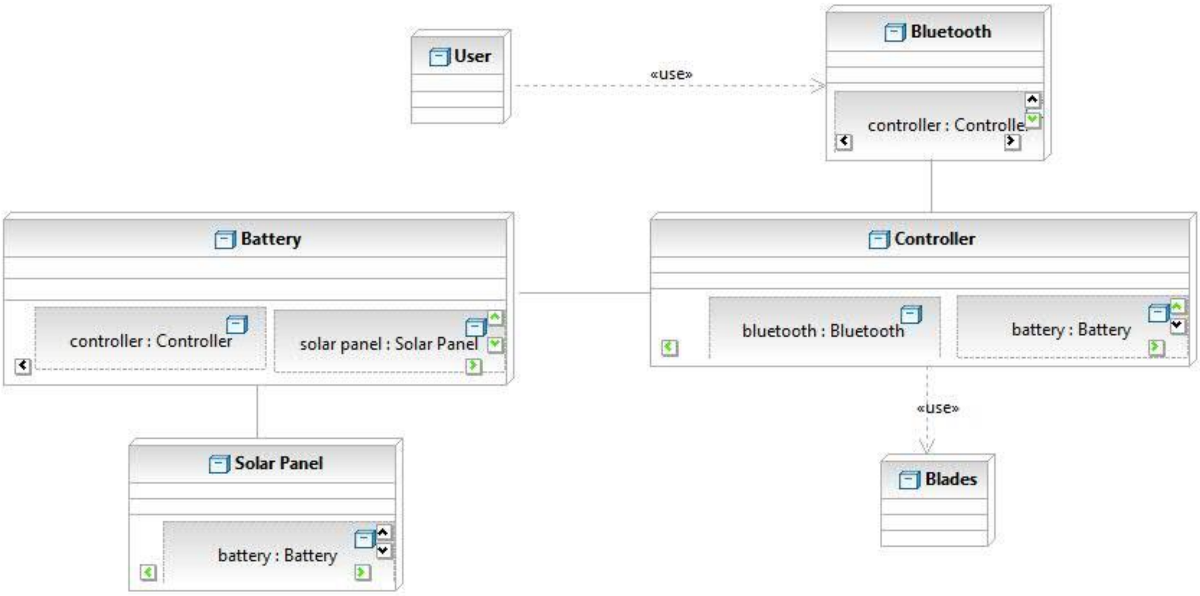

Fig.5.7 Deployment Diagram

5.2 Circuit Diagram

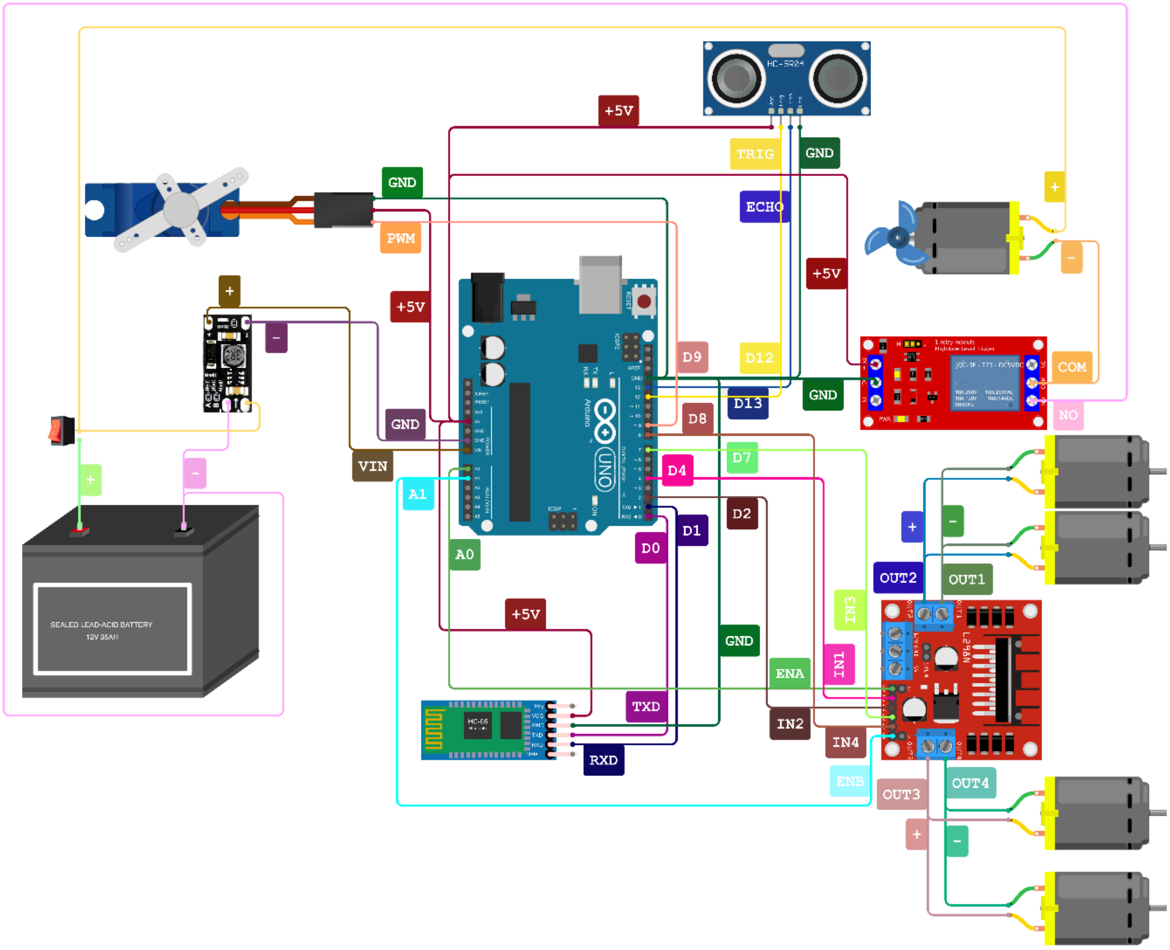

Fig.5.8 Circuit Diagram

5.3 Connections

5.3.1 Ultrasonic Sensor Connections

Table 5.1 Ultrasonic Sensor with Arduino Uno

Arduino Uno	Ultrasonic Sensor
5V	VCC
GND	GND
D12	TRIG
D13	ECHO

5.3.2 Servo Motor Connections

Table 5.2 Servo Motor with Arduino

Arduino Uno	Servo Motor
D9	PWM
5V	VCC (+)
GND	GND

5.3.3 HCO5 Bluetooth

Table 5.3 HC05 Bluetooth with Arduino Uno

Arduino Uno	HCO5 Bluetooth
5V	VCC
GND	GND
D0	TXD
D1	RXD

5.3.4 DC-DC Buck Converter

Table 5.4 DC-DC Buck Converter with Arduino Uno

Arduino Uno	DC-DC Buck Converter
+5V	Vout
GND	GND

5.3.5 Battery

Table 5.5 DC-DC Buck Converter with Battery

Battery	DC-DC Buck Converter
+12V Battery	Vin
GND Battery	GND

5.3.6 DC Gear Motor's

Table 5.6 DC Gear Motor's with Moter Driver

Motor Driver	DC Gear Motor's
OUT1	Motor 1 / Motor 2
OUT2	Motor 1 / Motor 2
OUT3	Motor 3 / Motor 4
OUT4	Motor 3 / Motor 4

5.3.7 Motor Driver

Table 5.7 Motor Driver with Arduino Uno

Motor Driver	Arduino Uno
IN1	D4
IN2	D2
IN3	D7
IN4	D8

5.3.8 Relay

Table 5.8 Relay with Arduino Uno

Arduino Uno	Relay
+5V	DC+
GND	DC-
D11	NI

5.3.9 Blade Motor

Table 5.9 Blade Motor with Relay

Motor	Relay
+12V battery	COM
GND	ON

6. IMPLEMENTATION

6.1 Implementation Language: Arduino Language

6.1.1 Features

The Arduino programming language is used to program microcontroller boards such as the Arduino Uno to interact with sensors, actuators, and other devices connected to the board. The language is based on C++, and it is designed to be easy to use for beginners and non-programmers. Arduino code is written in C++ with an addition of special methods and functions, which we'll mention later on. C++ is a human-readable programming language. When you create a 'sketch' (the name given to Arduino code files), it is processed and compiled into machine language.

- **Object-Oriented Language (OOPs):** C++ is an object-oriented language which means it has properties like classes, objects, polymorphism, inheritance, encapsulation, abstraction, data hiding, etc. The OOPs help in solving problems effectively, prevent data redundancy, and ensure the flexibility of the code.
- **Compiler Based:** C++ is a compiler-based programming language, which means C++ programs need to be compiled, and their executable files are used to run; that's why it is faster than Java and Python.
- **Dynamic Memory Allocation:** In C++, memory can be allocated dynamically, i.e., during run time. Most of the time programmer is not aware of how much memory would be required to store the particular information in the defined variable, so in this case, the size of required memory can be defined at run time.

6.1.2 Reason for Selection

We have selected the name of Arduino language to implement the system because of the following reasons:

- **C++ is an Efficient and Fast Language:** C++ is an advanced language that supports various programming methods like functional, procedural, and object-oriented programming. It is a fast language; its compile-time and execution time is faster than other programming languages.
- **Suitable for Big Projects**: C++ programming language is very well suited for big projects. Many projects, including compilers, cloud storage systems, databases, game

development, graphic designs, etc., are built using C++. C++ is also used for making 3D visual projects, these projects require control over huge amounts of data efficiently, and C++ is one of the best choices for that.

- **Community Support of C++:** C++ is an old language and is being studied and learned by most programmers around the globe, so it has huge community support. The large community of C++ means it will be easier and more flexible to learn this language. Community plays a very important role for a learner. If someone needs any help or guidance regarding C++, many programmers and experts are out there on different platforms creating resources for C++.
- **Embedded Systems**: An embedded system is a microprocessor-based software and hardware system that is used to design a specific function. Developing these embedded systems requires fast and efficient languages like C++. C++ is widely used in embedded systems because it is an intermediary language. It has both the features of the high-level and low-level language, which gives C++ an edge over other languages because it can directly access the hardware part without sacrificing the high-level part.

6.1.3 Comparison with Python

Table 6.1 Comparison of C++ with Python

Criteria	C++	Python
Code	C++ tends to have long lines of code	Python has fewer lines of code
Compilation	C++ is precompiled	Python is interpreted
Speed	C++ is faster once compiled as compared to python	Python is slower since it uses an interpreter and also determines the data type at run time
Nature	C++ is statically typed	Python is dynamically typed
Extension	C++ programs are saved with the .cpp extension	Python programs are saved with a .py extension

6.2. Hardware: Arduino

6.2.1. Features

Arduino is an open-source software and hardware company that designs and manufactures single-board microcontrollers and kits to build digital devices. The boards developed by them are termed Arduino boards, capable of reading inputs like – dept info using radar, light on a sensor, press of a button, etc. can convert them into an output like activating the led light, motors, buzzers, etc.

6.2.2. Reason for Selection

We have selected Arduino to implement the system because of the following reasons:

- It is open source both in terms of hardware and software.
- It can perform serial communication with the computer using USB.
- It only needs 5V to power up.
- It can work with Digital and Analog signals, sensors, and Actuators.
- The recommended input voltage is 7-12V, while the operating voltage is 5V for most Arduino boards.
- For Easy Prototyping.
- Controlling Motors.
- Robotics and Control System.
- Designing Basic Circuit Diagrams.
- Home and Industry Automation.
- Standalone Projects.

6.2.3 Comparison with Raspberry-pi

Table 6.2 Comparison of Arduino with Raspberry-pi

Criteria	Arduino	Raspberry-pi
Control Unit	The Control Unit of the Arduino is from the ATmega family	The Control Unit of the Raspberry Pi is from the ARM family.

Basis	Arduino works based on a microcontroller.	Raspberry Pi works based on a microprocessor
RAM	2kB	1GB
Processing Speed	16MHz	1.4GHz
Cost Efficiency	It has higher cost-efficiency	It has a lower cost-efficiency
Power Consumption	200 MW	700MW

6.3 Implementation Tool: Arduino IDE

6.3.1 Features

The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions, and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them.

6.3.2 Reason for Selection

We have selected Arduino IDE to implement the system because of the following reasons:

- The Arduino IDE is an open-source software
- Is used to write and upload code to the Arduino boards.
- The IDE application is suitable for different operating systems such as Windows, Mac OS X, and Linux.
- It supports the programming languages C and C++.

6.4 Code Snippet

6.4.1 Robot Control in Manual mode

```
void manual() {

  if (input == 'G') {
    forward();
  }
  else if (input == 'H') {
    backward();
  }
  else if (input == 'I') {
    left();
  }
  else if (input == 'J') {
    right();
  }
  else if (input == 'K') {
    stop();
  }
}
```

Figure 6.1 Robot Control in manual mode

6.4.2 Robot Control in Automatic mode

```
void automatic() {
  findDistance();

  while (true) {
    if (distance > safeDistance) {
      Serial.print("Forward?");
      setForward();
      findDistance();
    }
    else if (distance < safeDistance) {
      stop();
      delay(300);
      servoScan();
    }
  }
}
/* Finding distances on both sides using servo motor and ultrasonic sensor*/
void servoScan() {
  modeChange();
  delay(100);
```

```
  if (flag == 1) {
    Serial.print("Scan?");
    delay(100);

    /* Finding distance on left side */
    ultrasonicServo.write(180);
    delay(100);
    findDistance();
    delay(300);
    leftDistance = distance;
    delay(300);

    ultrasonicServo.write(90);
    delay(100);

    /* Finding distance on right side */
    ultrasonicServo.write(0);
    delay(100);
    findDistance();
    delay(300);
    rightDistance = distance;
    delay(300);

    ultrasonicServo.write(90);
    delay(100);
    safeZone();
  }
}
/* Comparing distances recieved after scanning by servo motor */
void safeZone() {
  modeChange();
  delay(100);

  if (flag == 1) {
    if ((leftDistance > rightDistance) && (leftDistance > safeDistance)) {
      left:
      setBackward();
      delay(200);
      setLeft();
      findDistance();

      while (true) {
        if (distance > safeDistance) {
          setForward();
          findDistance();
        }
        else if (distance < safeDistance) {
          goto stopA;
```

```
        }
      }
      stopA:
      stop();
      delay(300);
      servoScan();
    }
    else if ((rightDistance > leftDistance) && (rightDistance > safeDistance))
{
      right:
      setBackward();
      delay(200);
      setRight();
      findDistance();

      while (true) {
        if (distance > safeDistance) {
          setForward();
          findDistance();
        }
        else if (distance < safeDistance) {
          goto stopB;
        }
      }
      stopB:
      stop();
      delay(300);
      servoScan();
    }
    else if ((leftDistance && rightDistance) > safeDistance) {
      goto right;
    }
    else if ((leftDistance && rightDistance) < safeDistance) {
      setBackward();
      delay(300);
      servoScan();
    }
  }
}
```

Figure 6.2 Robot Control in Automatic mode

6.4.3 Robot Control in Voice mode

```
void voice() {
  if (input == 'F') {
    voiceForward();
  }
  else if (input == 'B') {
    voicebackward();
  }
  else if (input == 'L') {
    voiceLeft();
  }
  else if (input == 'R') {
    voiceRight();
  }
  else if (input == 'S') {
    Serial.print("Stop?");
    stop();
  }
}
/* When voice input is "Forward" */
void voiceForward() {
  ultrasonicServo.write(90);
  delay(100);
  findDistance();

  while (true) {
    if (distance > safeDistance) {
      Serial.print("No obstacle detected?");
      setForward();
      findDistance();
    }
    else if (distance < safeDistance) {
      goto stop;
    }
  }
  stop:
  stop();
  Serial.print("Obstacle detected?");
}
/* When voice input is "Backward" */
void voicebackward() {
  backward();
  delay(1500);
  stop();
}

/* When voice input is "Left" */
```

```
void voiceLeft() {
  ultrasonicServo.write(180);
  delay(100);
  findDistance();
  delay(200);
  ultrasonicServo.write(90);
  delay(100);

  if (distance > safeDistance) {
    Serial.print("No obstacle detected?");
    setBackward();
    delay(200);
    setLeft();
  }
  while (true) {
    if (distance > safeDistance) {
      setForward();
      findDistance();
    }
    else if (distance < safeDistance) {
      goto stop;
    }
  }
  stop:
  stop();
  Serial.print("Obstacle detected?");
}
/* When voice input is "Right" */
void voiceRight() {
  ultrasonicServo.write(0);

  delay(100);
  findDistance();
  delay(200);
  ultrasonicServo.write(90);
  delay(100);

  if (distance > safeDistance) {
    Serial.print("No obstacle detected?");
    setBackward();
    delay(200);
    setRight();
  }
  while (true) {
    if (distance > safeDistance) {
      setForward();
      findDistance();
    }
```

```
    else if (distance < safeDistance) {
      goto stop;
    }
  }
  stop:
  stop();
  Serial.print("Obstacle detected?");
}
```

Figure 6.3 Robot Control in Voice mode

6.4.4 DC Motor Movement's

```
/* Forward movement */
void forward() {
  modeChange();
  delay(100);

  if (flag == 1) {
    digitalWrite(motorMovement_1, HIGH);
    digitalWrite(motorMovement_2, LOW);
    digitalWrite(motorMovement_3, HIGH);
    digitalWrite(motorMovement_4, LOW);
  }
}
/* Forward movement for auto and voice modes*/
void setForward() {
  modeChange();
  delay(100);

  if (flag == 1) {

    digitalWrite(motorMovement_1, HIGH);
    digitalWrite(motorMovement_2, LOW);
    digitalWrite(motorMovement_3, HIGH);
    digitalWrite(motorMovement_4, LOW);
  }
}
/* Backward movement */
void backward() {
  modeChange();
  delay(100);

  if (flag == 1) {
    digitalWrite(motorMovement_1, LOW);
    digitalWrite(motorMovement_2, HIGH);
    digitalWrite(motorMovement_3, LOW);
    digitalWrite(motorMovement_4, HIGH);
```

```
  }
}
/* Backward movement for auto and voice modes*/
void setBackward() {
  modeChange();
  delay(100);

  if (flag == 1) {
    Serial.print("Backward?");
    digitalWrite(motorMovement_1, LOW);
    digitalWrite(motorMovement_2, HIGH);
    digitalWrite(motorMovement_3, LOW);
    digitalWrite(motorMovement_4, HIGH);

    delay(700);
    stop();
  }
}
/* Left movement */
void left() {
  modeChange();
  delay(100);

  if (flag == 1) {
    digitalWrite(motorMovement_1, HIGH);
    digitalWrite(motorMovement_2, LOW);
    digitalWrite(motorMovement_3, LOW);
    digitalWrite(motorMovement_4, HIGH);
  }
}
/* Left movement for auto and voice modes*/
void setLeft() {
  modeChange();
  delay(100);

  if (flag == 1) {
    Serial.print("Left?");
    digitalWrite(motorMovement_1, HIGH);
    digitalWrite(motorMovement_2, LOW);
    digitalWrite(motorMovement_3, LOW);
    digitalWrite(motorMovement_4, HIGH);
    delay(1500);
  }
}
/* Right movement */
void right() {
  modeChange();
  delay(100);
```

```
  if (flag == 1) {
    digitalWrite(motorMovement_1, LOW);
    digitalWrite(motorMovement_2, HIGH);
    digitalWrite(motorMovement_3, HIGH);
    digitalWrite(motorMovement_4, LOW);
  }
}
/* Right movement for auto and voice modes*/
void setRight() {
  modeChange();
  delay(100);

  if (flag == 1) {
     Serial.print("Right?");
    digitalWrite(motorMovement_1, LOW);
    digitalWrite(motorMovement_2, HIGH);
    digitalWrite(motorMovement_3, HIGH);
    digitalWrite(motorMovement_4, LOW);
    delay(1500);
  }
}
/* Stopping robot */
void stop() {
  modeChange();
  delay(100);

  if (flag == 1) {
   digitalWrite(motorMovement_1, LOW);
    digitalWrite(motorMovement_2, LOW);
    digitalWrite(motorMovement_3, LOW);
    digitalWrite(motorMovement_4, LOW);
    ultrasonicServo.write(90);
  }
}
```

Figure 6.4 DC Motor Movement's

6.4.5 Cutter Motor Control

```
void cutter() {
     if (input == 'N') {
      startCutter();
    }
  else if (input == 'M') {
    stopCutter();
  }
}
```

```
 /* Start Cutter movement */
void startCutter() {
  delay(100);
  digitalWrite(motorRelay, HIGH);
}
 /* Stop Cutter movement */
void stopCutter() {
  delay(100);
  digitalWrite(motorRelay, LOW);
}
```

Figure 6.5 Cutter Motor Control

6.4.6 Android Application

Our app, created using MIT App Inventor, is designed to automate eco-friendly lawn care using solar power, smart navigation, and multiple control modes for efficient, user-friendly operation. The app includes features such as automated scheduling, voice control, and a user-friendly interface for manual control via smartphone. The app allows users to detect and avoid obstacles automatically, control the grass cutter via voice commands, and manually operate the cutter through a smartphone interface. **The code behind the app was created using visual programming blocks in MIT App Inventor, which allowed us to easily design and implement the desired functionality without the need for traditional coding.** Overall, our app provides a user-friendly experience.

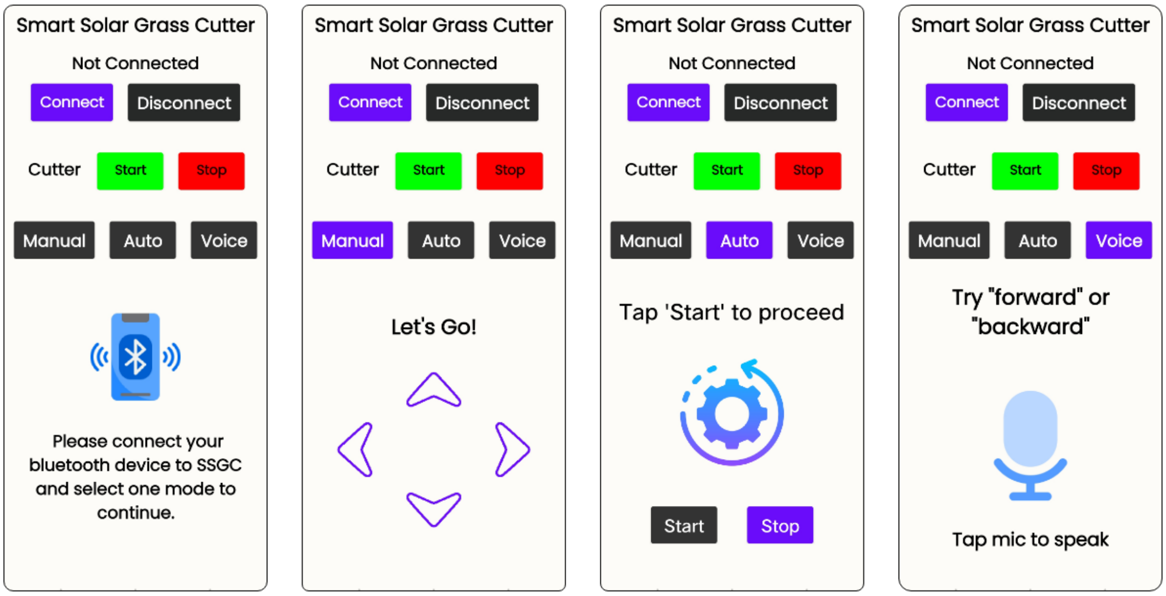

Figure 6.6 Android Application

7. TESTING

Testing is an investigation conducted to provide stakeholders with information about the quality of the product or service under test. Software Testing also provides an objective, independent view of the software to allow the business to appreciate and understand the risks in the implementation of the software. Test techniques include, but are not limited to, the process of executing a program or application with the intent of finding software bugs.

Software Testing, depending on the testing method employed, can be implemented at any time in the development process. However, most of the test effort occurs after the requirements have been defined and the coding process has been completed. As such, the methodology of the test is governed by the Software Development methodology adopted.

7.1 Testing Approach: Manual Testing

7.1.1 Features

- Offers more flexibility in adapting to changes - Doesn’t require scripting skills.
- Helps improve quality, reliability and users' satisfaction before its release.
- It can be performed at any stage of the development lifecycle, allowing for quick feedback and iterative improvement.
- It is more cost effective for small scale projects or projects with changing requirements, as it doesn’t require significant upfront investment in automation infrastructure.

7.1.2 Reason for Selection

- Manual testing leverages human insight to detect subtle issues, especially important for user experience.
- Allows for on-the-spot decision-making and adaptation to unexpected scenarios.
- Ensures the robot is tested under natural conditions, critical for functionalities like obstacle detection and solar charging.
- Provides qualitative insights into performance and usability that automated tests might miss.
- Facilitates quick issue identification and direct communication with the development team.

7.2 Test Plan[1]

A test plan documents the strategy that will be used to verify and ensure that a product or system meets its design specifications and other requirements. A test plan is usually prepared by or with significant input from Test Engineers.

Table 7.1. Test Plan

Sr. No.	Name of Tester	Test Item	Planned Date
1.	Mr. Laukik Panpatil	Power On	10/04/2024
2.	Mr. Laukik Panpatil	Forward Movement	10/04/2024
3.	Mr. Laukik Panpatil	Backward Movement	10/04/2024
4.	Mr. Laukik Panpatil	Left Turn	10/04/2024
5.	Mr. Laukik Panpatil	Right Turn	10/04/2024
6.	Mr. Laukik Panpatil	Obstacle Detection and Avoidance	15/04/2024
7.	Mr. Laukik Panpatil	Stop Command	16/04/2024
8.	Mr. Laukik Panpatil	Remote Control (Android App) Connectivity	18/04/2024
9.	Mr. Laukik Panpatil	Autonomous Mode Activation	18/04/2024
10.	Mr. Laukik Panpatil	Bluetooth Connectivity	18/04/2024
11.	Mr. Laukik Panpatil	Grass Cutter Motor Activation	22/04/2024
12.	Mr. Laukik Panpatil	Grass Cutter Efficiency	25/04/2024
13.	Mr. Laukik Panpatil	Grass Cutter Safety Mechanism	28/04/2024
14.	Mr. Laukik Panpatil	Solar Panel Charging	30/04/2024
15.	Mr. Laukik Panpatil	Solar Panel Angle Adjustment	04/05/2024

7.3. Test Case Design

A test case in software engineering is a set of conditions or variables under which a tester will determine whether an application or software system is working correctly or not. It may take many test cases to determine that a software program or system is functioning correctly. Test cases are often referred to as test scripts, particularly when written. Written test cases are usually collected into test suites.

Table 7.2. Test Case (Manual Testing)

Sr. No.	Test Item	Purpose	Input(s)	Output(s)	Validation(s)
1.	Power On	To ensure the robot powers up correctly.	Power button press.	Indicator lights turn on.	Confirm the robot is powered on by checking the indicator lights and any startup sounds.
2.	Forward Movement	To verify that the robot can move forward.	Forward command from the remote control.	The robot moves forward in a straight line.	Observe and confirm the robot moves forward without deviation.
3.	Backward Movement	To ensure the robot can move backward.	Backward command from the remote control.	The robot moves backward in a straight line.	Observe and confirm the robot moves backward without deviation.
4.	Left Turn	To check the robot ability to turn left.	Left turn command from the remote control.	The robot makes a left turn.	Observe and confirm the robot turns left accurately.
5.	Right Turn	To verify the robot ability to turn right.	Right turn command from the remote control.	The robot makes a right turn.	Observe and confirm the robot turns right accurately.
6.	Obstacle Detection	To ensure the robot can detect	Forward command from the remote	The robot stops or changes	Observe and confirm the robot detects

	and Avoidance	and avoid obstacles.	control with an obstacle placed in its path.	direction to avoid the obstacle.	the obstacle and avoids it appropriately.
7.	Stop Command	To verify the robot stops when commanded.	Stop command from the remote control.	The robot stops moving.	Observe and confirm the robot stops immediately upon receiving the stop command.
8.	Remote Control (Android App) Connectivity	To verify the robot responds to remote control commands.	Commands from the remote control.	The robot responds to the commands.	Observe and confirm the robot executes the commands received from the remote control.
9.	Autonomous Mode Activation	To check the autonomous navigation functionality.	Activate autonomous mode.	The robot navigates autonomous ly.	Observe and confirm the car moves and avoids obstacles without manual input.
10.	Bluetooth Connectivity	To verify that the robot can connect to a Bluetooth device and receive commands.	Bluetooth pairing request from a smartphone.	Successful pairing and the ability to control the robot via the Bluetooth-connected device.	Confirm the device pairs successfully with the robot car and can send commands such as move forward, backward, left turn, right turn, and stop.
11.	Grass Cutter Motor Activation	To ensure the grass cutter motor activates and operates correctly.	Command to start the grass cutter motor.	Grass cutter motor starts running.	Observe and confirm that the grass cutter motor starts without any issues.

12.	Grass Cutter Efficiency	To verify the grass cutter's efficiency in cutting grass.	Command to start the grass cutter motor and navigate over a patch of grass.	Grass is cut evenly and efficiently.	Observe and confirm that the grass cutter cuts the grass evenly and effectively without leaving uncut patches.
13.	Grass Cutter Safety Mechanism	To check the safety mechanisms of the grass cutter motor.	Obstruction in the grass cutter's path while running.	Grass cutter motor stops or avoids the obstruction.	Observe and confirm that the grass cutter motor stops or avoids the obstacle safely to prevent damage or injury.
14.	Solar Panel Charging	To verify that the robot's battery charges via the solar panel.	Exposure to direct sunlight.	Battery charge level increases.	Confirm the battery level increases when the robot car is exposed to direct sunlight.
15.	Solar Panel Angle Adjustment	To verify the ability to adjust the solar panel angle for optimal sunlight exposure.	Adjust the angle of the solar panel.	Solar panel maintains the new angle and charges efficiently.	Confirm that the solar panel angle can be adjusted easily and it remains in the set position, charging the battery efficiently.

7.4. Test Results

Table 7.3. Test Results

Sr. No.	Test Item	Errors	Bugs	Remark
1.	Power On	None	None	Successfully powered on
2.	Forward Movement	None	None	Moves forward correctly
3.	Backward Movement	None	None	Moves backward correctly
4.	Left Turn	None	None	Turns left as expected
5.	Right Turn	None	None	Turns right as expected
6.	Obstacle Detection and Avoidance	Detected late	Bug001: Delayed stop	Needs improved detection sensitivity
7.	Stop Command	None	None	Stops immediately
8.	Remote Control (Android App) Connectivity	None	None	Connects and responds to commands
9.	Autonomous Mode Activation	None	None	Navigates autonomously
10.	Bluetooth Connectivity	None	None	Connects and controls via Bluetooth
11.	Grass Cutter Motor Activation	None	None	Motor activates correctly
12.	Grass Cutter Efficiency	Uneven cut	Bug002: Cutting uneven	Cutting uneven Needs adjustment for even cutting
13.	Grass Cutter Safety Mechanism	None	None	Stops for obstructions
14.	Solar Panel Charging	None	None	Charges in sunlight
15.	Solar Panel Angle Adjustment	None	None	Angle adjusts and holds position

8. PROJECT COST AND EFFORT

8.1 Estimation Technique: Detailed COCOMO

For the initial estimation of our project, we have used the first stage of COCOMO i.e., Basic COCOMO, now since our work is completed, we have all the necessary and actual information required for the cost calculation, hence here we will use Detailed COCOCMO.

Detailed COCOMO incorporates all characteristics of the intermediate version with an assessment of the cost driver's impact on each step (analysis, design, etc.) of the software engineering process.

The detailed model uses different effort multipliers for each cost driver attribute. These Phase Sensitive effort multipliers are used to determine the amount of effort required to complete each phase. In detailed COCOMO, the whole software is divided into different modules and then we apply COCOMO in different modules to estimate effort and then sum the effort.

Detailed COCOMO incorporates the set of "cost drivers" that include subjective assessment of the product, hardware, personnel, and project attributes. The 17 cost drivers are multiplicative factors that determine the effort required to complete our software project. Each of the 17 attributes receives a rating on a six-point scale that ranges from "very low" to "extra high" (in importance or value).

After assigning a rating to each of the cost drivers the ratings are multiplied together to yield **Effort Adjustment Factor (EAF)**.

The Detailed COCOMO formula takes the form:

$$\textbf{Effort, } E = a(KLoC)^{b} * EAF \textbf{ person months}$$

$$\textbf{Duration, } D = c(E)^{d} \textbf{ months}$$

$$\textbf{Person, } P = E/D \textbf{ persons}$$

where **E** is the effort applied in person-months, **KLoC** is the estimated number of thousands of delivered lines of code for the project, **D** is the total time duration to develop the system in months, and **P** is the number of persons required to develop that system.

The coefficients **a, c,** and the exponent **b, d** are given in the following table.

Table 8.1 Coefficient/Exponent Values of Detailed COCOMO

Project Type	a	b	c	D
Organic	3.2	1.05	2.5	0.38
Semi-Detached	3.0	1.12	2.5	0.35
Embedded	2.8	1.20	2.5	0.32

8.2 Effort and Cost Calculation

8.2.1 Project Size

Table 8.2. Final Project *Size*

Software Module	LOC
Arduino UNO	1100
Obstacle Sensor (Ultrasonic Sensor)	650
Navigation System	550
Bluetooth Module	950
Total Estimated Lines of Code (LOC)	3250

8.2.2 Cost Drivers Selection

Table 8.3 Cost Drivers Selection

Cost Drivers	Ratings					
	Very Low	Low	Usual	High	Very High	Extra High
Personnel Factors						
Analyst Capability **(ACAP)**	1.46	**1.19**	1.00	0.86	0.71	---
Applications Experience **(APEX)**	1.29	1.13	1.00	**0.91**	0.82	---
Programmer Capability **(PCAP)**	1.42	1.17	**1.00**	0.86	0.70	---
Platform Experience **(PLEX)**	1.21	**1.10**	1.00	0.90	---	---

Language and Tool Experience **(LTEX)**	1.14	1.07	**1.00**	0.95	---	--
Personnel Continuity **(PCON)**	1.29	**1.12**	1.00	0.90	0.81	---
Project Factors						
Use of Software Tools **(TOOL)**	1.24	**1.10**	1.00	0.91	0.83	---
Multisite Development **(SITE)**	**1.24**	1.10	1.00	0.91	0.82	---
Development Schedule **(SCED)**	1.23	**1.08**	1.00	1.04	1.10	---
Platform Factors						
Execution Time Constraint **(TIME)**	---	---	**1.00**	1.11	1.30	1.66
Main Storage Constraint **(STOR)**	---	---	**1.00**	1.06	1.21	1.56
Product Factors						
Platform Volatility **(PVOL)**	---	**0.87**	1.00	1.15	1.30	---
Required Software Reliability **(RELY)**	0.75	0.88	**1.00**	1.15	1.40	---
Database Size **(DATA)**	---	**0.94**	1.00	1.08	1.16	---
Product Complexity **(CPLX)**	0.70	0.85	**1.00**	1.15	1.30	1.65
Required Reusability **(RUSE)**	---	**0.95**	1.00	1.07	1.15	1.24
Documentation Match to Lifecycle Needs **(DOCU)**	0.81	0.91	**1.00**	1.11	1.23	---
Effort Adjustment Factor (EAF)	1.19*0.91*1.00*1.10*1.00*1.12*1.10*1.24*1.08* 1.00*1.00*0.87*1.00*0.94*1.00*0.95*1.00 = **1.52**					

8.2.3 Effort Calculation

The system falls into the **embedded** category. The values a and b according to the embedded system are a = **2.8** and b = **1.20**.

The total LOC (approx.) of the project is **3250LOC = 3.25 KLOC**

Effort (E) = $a(\text{KLoC})^{b}$ * EAF

E = 2.8*$(3.25)^{1.20}$ * 1.52

E = 17.50 ≈ 17 Person Months

8.2.4 Duration Calculation

The values c and d according to the embedded system c = **2.5** and d = **0.32**.

Duration (D) = $c\,(E)^{d}$

$D = 2.5*(17.50)^{0.32}$

D = 6.24 ≈ 6 Months

8.2.5 Person Required

Person Required = Effort Applied (E) / Development Time (D)

= 17.50/6.24

= 2.80 ≈ 3 Persons

8.2.6 Total Cost

Each team member charges ₹1000/- per month, ₹12000/- spent for other resources. Thus, parts include in project are Arduino UNO, Ultrasonic Sensor, Servo Motor, Bluetooth Module, Gear DC Motors, Blade Motor, Motor Driver Shield, Battery, Solar Panel, Relay, Step-Up, Step-Down etc.

Total Cost of System = ((Person Charges * Person Required) + Resource Charges) * Duration [+ Hardware Cost]

= ((1000 * 3) + 1000) * 6 + 12000 = **₹36,000**/-

8.3 Calculation Summary

Table 8.4 Summary of different calculations.

Calculation	Value
Size of the Project	3250 LoC
Effort Required	17 Person Months
Duration Required	6 Months
Person Required	3
Total Cost	**₹36,000**/-

9. ADVANTAGES & DISADVANTAGES

9.1 Advantages

Environmentally Friendly

The use of solar power reduces carbon footprint, making the grass cutter eco-friendly and contributing to sustainable lawn maintenance.

Autonomous Operation

The smart grass cutter navigates autonomously, saving users time and effort while ensuring comprehensive lawn coverage.

Energy Efficiency

Solar-powered operation optimizes energy use, providing consistent and efficient performance without relying on non-renewable energy sources.

Real-Time Monitoring

The integrated mobile app allows users to adjust settings remotely, and receive real-time notifications, enhancing user convenience.

Quiet Operation

Designed for low-noise operation, the grass cutter minimizes disturbances to the environment and neighbors during lawn maintenance.

Safety Features

The grass cutter includes safety features like obstacle detection and emergency stops, prioritizing user safety during operation.

Modern and Sustainable Design

The overall design aligns with modern sustainability practices, incorporating eco-friendly materials and addressing the demand for environmentally conscious lawn maintenance solutions.

9.2 Disadvantages

Initial Cost

The upfront cost of a smart solar grass cutter can be higher compared to traditional gas-powered mowers, potentially limiting accessibility for some users.

Limited Operation in Low Light

The dependence on solar power means the grass cutter's efficiency may be reduced in low-light conditions, such as during cloudy days or at night.

Limited Power in Large Lawns

In extensive lawn areas, the solar-powered system might face challenges in maintaining sustained power levels, potentially requiring longer charging times or supplementary power sources.

Battery Degradation

Over time, the performance of the battery may degrade, potentially reducing the overall efficiency of the grass cutter and requiring battery replacement.

Limited Load Capacity

Smart solar grass cutters may have limitations in carrying additional tools or attachments, limiting their versatility compared to larger, traditional mowers.

10. APPLICATION

Residential Lawns

Efficiently maintains lawns with autonomous and customizable cutting features.

Public Parks and Gardens

Ideal for municipal authorities to optimize lawn maintenance in public spaces.

Commercial Landscaping

Provides efficient grass cutting for commercial properties and landscaped areas.

Educational Institution

Maintains school, college, and university lawns with precision and autonomy.

Hospitals and Healthcare Facilities

Enhances green spaces around healthcare facilities for a pleasant environment.

Sports Fields and Stadiums

Ensures well-kept sports fields with precise cutting patterns.

Hotels and Resorts

Enhances the aesthetic appeal of hospitality properties with eco-friendly lawn care.

Golf Courses

Maintains fairways and greens efficiently for optimal playing conditions.

Green Roofs and Urban Spaces

Suitable for maintaining green roofs and green spaces in urban environments.

Residential Complexes and Condominiums

Manages communal lawns and green areas in housing complexes.

Environmentally Sensitive Areas

Minimizes impact on ecosystems in areas with environmental conservation concerns.

Smart Cities Initiatives

Aligns with smart cities' sustainability goals for advanced lawn maintenance practices.

11. CONCLUSION

The device with different combinations of technology this will helps to reduce the human effort and give maximum efficient output for the work. The device can be the possible replacement for the gasoline powered grass cutter. In order to enhance the beauty of home lawns and gardens, smart solar grass cutter device is the best option. People can easily maintain gardens without any problem. By using this system one can preserve the non-renewable sources of energy such as petrol, gasoline etc. System can also reduce various forms of pollutions such as air pollution and noise pollution. Electricity is saved as we utilize solar energy that is renewable source of energy and is present in abundance. The Smart Solar Grass Cutter, an IoT-enabled solution, optimizes its path based on monitored coverage, enhancing efficiency and user control, thereby simplifying lawn maintenance.

12. FUTURE SCOPE

Improvements in AI and machine learning will make smart solar grass cutters smarter and more efficient. Better solar panels and batteries will provide longer running times and quicker charging. If we consider the soil and grass conditions, we can equip the smart solar grass cutter with a humidity sensor and a sprinkler system. This setup will allow the grass cutter to monitor the soil's humidity levels and activate the sprinkler to water the ground as needed, based on the programmed instructions. The advanced navigation systems incorporating GPS and mapping technologies will improve the devices' navigation, efficiency, and coverage.

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