iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** IX **Month of publication:** September 2025

DOI: https://doi.org/10.22214/ijraset.2025.74119

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue IX Sep 2025- Available at www.ijraset.com

Automatic Weeding Robot

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Abstract: This project focuses on the design and development of a solar-powered grass-cutting machine capable of performing autonomous cutting while ensuring safety and efficiency. The system is powered by a 12V rechargeable battery that is charged through a solar panel, eliminating the need for an external power supply. The stored energy drives both the grass-cutting motor and the vehicle's motion motors. A microcontroller unit controls the entire system, managing blade rotation, vehicle movement, and obstacle detection.

An ultrasonic sensor is integrated to identify obstacles such as humans, animals, or objects in the path of the machine. Upon detecting an obstacle, the microcontroller halts the blade operation, activates a warning signal, and guides the vehicle towards an alternative route. Once the way is clear, the machine resumes forward motion and continues grass cutting. This design ensures both efficiency and user safety.

The project demonstrates the advantages of renewable energy by reducing reliance on fossil fuels and minimizing environmental pollution. Unlike traditional grass cutters, which are noisy, fuel-dependent, and require frequent maintenance, the proposed machine is eco-friendly, cost-effective, and easy to maintain. With minimal manual intervention, it is suitable for lawns, gardens, and small agricultural fields. The integration of solar

Technology with automation highlights its potential as a sustainable solution for future lawn maintenance systems.

Keywords: Microcontroller, Solar Energy, Grass Cutting, Motor Control, Automation, Renewable Energy.

I. INTRODUCTION

Grass-cutting machines are widely used for maintaining lawns, gardens, parks, and agricultural fields. Conventional machines are either manually operated or powered by electricity or fossil fuels, which makes them costly, labor-intensive, and harmful to the environment. The growing demand for sustainable and user-friendly solutions has encouraged the development of solar-powered machines, which harness renewable energy for grass cutting.

The essential components of such a system include a DC motor for blade rotation, relay switches for motor control, and a rechargeable battery that is charged by a solar panel. The solar panel directly converts sunlight into electrical energy using photovoltaic cells, making the system independent of conventional power sources. High-speed blade rotation provides the necessary kinetic energy for efficient cutting, and the lightweight design ensures easy handling.

One of the key challenges in manual grass cutting is operator fatigue and safety. Accidents often occur due to direct contact with rotating blades, unstable handling, or loss of control while cutting on uneven terrain. To address these issues, the proposed machine incorporates automation through a microcontroller and ultrasonic sensors. The sensor detects obstacles, and the controller ensures immediate safety actions such as stopping the blade, giving an alarm, and redirecting the machine. By incorporating this function, both the safety of users and the dependability of the system are significantly improved. The need for renewable energy in everyday applications is increasing due to the rapid depletion of fossil fuels. Currently, nearly 80% of the world's electricity is generated from oil, coal, and natural gas, which are finite resources and major contributors to global warming. In contrast, solar energy is clean, abundant, and freely available. By utilizing solar power, this machine not only reduces operating costs but also contributes to environmental protection.

Compared to traditional grass cutters, the solar-powered model is quieter, requires less maintenance, and offers continuous operation without external charging. It is particularly useful in rural and semi-urban areas where electricity supply may be limited but sunlight is abundant. Moreover, the design can be scaled for larger fields or integrated with IoT technologies for remote monitoring and control in the future.

This project aims to provide an eco-friendly, safe, and efficient alternative to conventional grass-cutting methods. By combining solar technology with automation, the proposed system minimizes human effort, reduces energy costs, and enhances overall safety. In the long run, such innovations can play a crucial role in promoting sustainable agricultural practices and green energy adoption.

II. LITERATURE SURVEY

The idea of lawn maintenance and automation has been evolving for over a century. One of the earliest milestones was Passmore's lawn motor patent in 1869 [2], which laid the foundation for mechanized grass cutting. With the growth of technology, researchers began exploring energy-efficient and eco-friendly alternatives to traditional machines. For instance, hydrogen-powered lawn mowers were studied as early as the 1990s, showcasing clean energy possibilities [5].

Recent years have seen a significant shift towards solar-powered solutions. Bainganel et al. [3] designed and developed a solar grass cutter, demonstrating how renewable energy can reduce operational costs and environmental impact. Similarly, Langade et al. [4] reviewed automated solar grass cutters and highlighted improvements in automation and cutting efficiency. Later, Ulhe et al. [13] and Mohyuddin et al. [14] worked on upgrading solar grass cutting machines, showing practical enhancements in performance, reliability, and user-friendliness.

The application of electronics and control theory has also played a crucial role in such systems. Classic works like Boylestad and Nashelsky's *Electronic Devices and Circuit Theory* [6] and Horowitz's *The Art of Electronics* [9] provide fundamental principles for designing control circuits used in automated machines. Similarly, Theraja and Theraja [12] contributed valuable knowledge on electrical technologies essential for motor-driven applications. Contributions from Conaster et al. [7] and Conway & Jones [8] further addressed electrical applications and issues such as harmonic pollution, which are relevant to reliable robotic operation.

Research on grass-cutting robots is not limited to renewable energy; it also expands into automation and robotics for agriculture. Roy and Ghosh [15] reviewed various autonomous agricultural robots, emphasizing their role in reducing human effort and improving efficiency in field operations. Complementing this, Li et al. [16] designed a four-wheel drive lawn mower robot capable of working on steep slopes, solving one of the key challenges of stability and navigation in uneven terrains.

Apart from academic research, industrial resources such as Google's digital tools [1] and ITIC guidelines on performance curves [10] have provided valuable technical references for researchers. Historical perspectives like Ransome-Wallis's work on railway engineering [11] also offer insights into the evolution of mechanical systems that parallel advancements in automated machinery.

Overall, the literature indicates a clear trend toward combining renewable energy, automation, and control systems to create efficient and safe grass-cutting robots. These studies form the foundation for developing modern solutions that are not only environmentally sustainable but also capable of addressing real-world agricultural challenges.

III. MODULE DESCRIPTION

The proposed autonomous grass-cutting system is organized into several functional modules that work together to achieve efficient and reliable performance. The first essential part is the power supply module, which provides a stable DC voltage to all the electronic components in the system. This supply is typically obtained from rechargeable batteries and, in some designs, may be supplemented with a solar charging arrangement to enhance sustainability and reduce dependency on external power sources.

At the core of the robot lies the control module, usually implemented using a microcontroller such as an Arduino or ESP32. This unit acts as the brain of the system by receiving input signals from the sensors, executing programmed logic, and sending appropriate control commands to the actuators. It is responsible for decision-making and overall coordination of the different tasks.

The sensing unit is essential for providing environmental awareness to the system. It integrates ultrasonic and infrared sensors that actively monitor the robot's surroundings to identify obstacles or boundaries. By doing so, the module ensures safe grass-cutting operations, preventing collisions and protecting both the equipment and nearby property.

The actual grass cutting is performed by the cutting mechanism module, which generally consists of a DC motor connected to a rotating blade. The motor is chosen based on the required torque and speed to cut grass efficiently while maintaining low power consumption. This module is designed to operate reliably under varying field conditions and to maintain a consistent cutting height.

To enable movement across the lawn, the robot incorporates a navigation module. This includes geared DC motors, motor drivers, and the necessary wheel assembly. The navigation module interprets control signals from the microcontroller to move forward, reverse, or turn in specific directions. For more advanced versions, this module can be enhanced with GPS or vision-based systems to allow systematic coverage of larger areas. In some configurations, the system is further supported by a communication module. This optional unit uses wireless technologies such as Bluetooth, Wi-Fi, or IoT platforms to enable remote control, data logging, or real-time monitoring. Through this feature, the user can receive updates on battery status, coverage area, or maintenance alerts, and can also send commands without direct physical interaction with the robot.

All these modules are carefully integrated to form a cohesive and autonomous grass-cutting robot. Their coordinated operation ensures that the device can navigate, sense, decide, and cut with minimal human intervention, making it both cost-effective and convenient for routine lawn maintenance.

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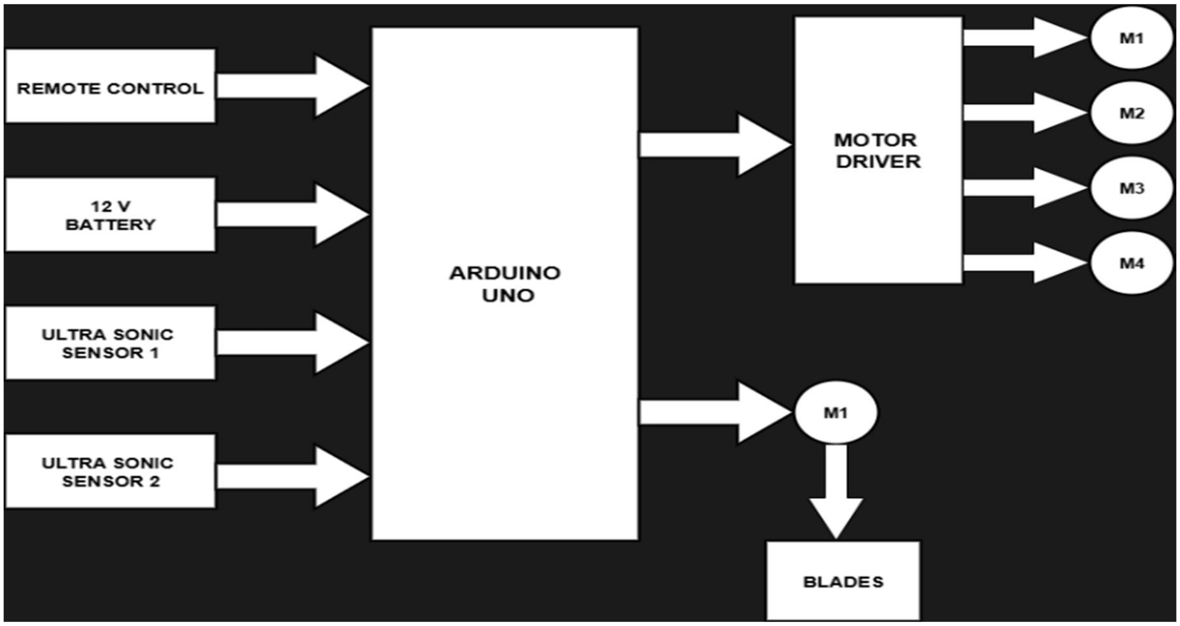
IV. BLOCK DIAGRAM



The block diagram represents an automated grass cutter system that uses an Arduino Uno microcontroller as the main control unit. The system is designed to perform grass cutting operations autonomously or through remote control. A 12V battery serves as the primary power source, supplying energy to the Arduino board, motor driver, blade motor, and all other electronic components. The system is equipped with a remote-control module, which allows the user to manually operate or override the robot's functions. Two ultrasonic sensors are connected to the Arduino to detect obstacles in the environment. These sensors continuously measure the distance to nearby objects and send this information to the Arduino, enabling the robot to avoid collisions while cutting grass.

The Arduino processes the sensor and control input and sends commands to a motor driver, which controls four motors (M1, M2, M3, and M4) that drive the wheels of the robot. This allows the grass cutter to move forward, backward, and turn in different directions depending on its surroundings and the user’s commands. In addition to the wheel motors, the Arduino also controls a separate blade motor (M1), which powers the cutting blades. This motor drives the blade mechanism that trims the grass as the robot moves. The blade motor is typically activated only when the robot is in motion and no obstacles are detected, ensuring safe and efficient cutting. In essence, this automated grass cutter robot is a smart system that combines mobility, obstacle detection, and a cutting mechanism to maintain lawns with minimal human intervention. It is especially useful for home gardens and small fields where regular grass maintenance is required. The integration of sensors, motor control, and blade activation in one Arduino-based platform makes it a cost-effective and intelligent lawn care solution.

V. EQUIPMENT REQUIRED

A. Arduino UNO

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Arduino is an open-source hardware and software platform that focuses on developing single-board microcontrollers and kits for building digital systems. It’s hardware is released under the CC-BY-SA license, while the accompanying software is distributed under the GNU Lesser General Public License (LGPL) or the GNU General Public License (GPL). These licensing terms allow anyone to manufacture Arduino-compatible boards and freely share the software.

Official Arduino boards are widely available through authorized websites and distributors. Depending on the model, the boards are built around different types of microcontrollers and processors. They are equipped with sets of digital and analog I/O pins, enabling easy interfacing with expansion shields, breadboards for prototyping, and other electronic circuits.

In addition, many Arduino boards support serial communication interfaces, including USB ports, which are also used to upload programs. Programming the microcontrollers is typically done in C or C++ through a simplified API, often referred to as the Arduino language. This programming environment is inspired by the Processing language and is supported by a customized version of the Processing IDE, making it beginner-friendly yet powerful for advanced projects.

B. DC Motor

The working of a DC motor is based on the principle that when a current-carrying conductor is placed in a magnetic field, it experiences a mechanical force. In a DC motor, the armature winding is supplied with direct current, which produces its own magnetic field. This field interacts with the magnetic field of the stator, which is either produced by permanent magnets or field windings, and as a result, a torque is developed on the armature conductors. According to Fleming’s Left-Hand Rule, the direction of this force is perpendicular to both the current and the magnetic field, which causes the armature to rotate.

To ensure continuous rotation, a commutator is used, which reverses the direction of current in the armature conductors whenever the armature passes through the neutral zone. This reversal keeps the torque always acting in the same direction, thus maintaining continuous motion. As the motor rotates, the armature conductors cut through magnetic lines of flux, which induces an electromotive force in the opposite direction of the applied voltage.

This is known as back EMF, and it plays a vital role in regulating the motor’s speed. At higher speeds, back EMF increases and reduces the effective armature current, preventing the motor from overspeeding, while at lower speeds, back EMF is small, allowing more current to flow and generate higher torque. Hence, the DC motor converts electrical energy into mechanical energy through the continuous interaction of magnetic fields, current, and torque production.

C. DC Battery

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A 12V DC battery is an electrochemical energy storage device that converts chemical energy into direct current (DC) electrical energy. It is composed of multiple electrochemical cells connected in series, where each cell typically produces around 2 volts. In the case of a 12V battery, six cells are connected in series to achieve the required voltage. The working principle of the battery is based on redox reactions that occur between the positive and negative electrodes when the battery is in use. During discharge, the chemical reaction at the negative electrode (anode) releases electrons, while the positive electrode (cathode) accepts them through an external circuit, thus providing a continuous flow of electric current to the connected load. The electrolyte present in the battery facilitates the movement of ions between the electrodes to balance the charge transfer.

When the battery is recharged, an external DC supply forces the current to flow in the opposite direction, thereby reversing the chemical reaction and restoring the original chemical composition of the electrodes. Thus, the 12V DC battery serves as a compact and reliable power source, providing steady direct current output for operating motors, sensors, and other electronic components in robotic applications.

D. Ultrasonic Module

The ultrasonic sensor module works on the principle of sound wave reflection, similar to the concept of sonar or echolocation used by bats and dolphins. It consists of two main components: a transmitter and a receiver. The transmitter emits ultrasonic waves, usually at a frequency of 40 kHz, which travel through the air until they encounter an obstacle. When these waves strike an object, they are reflected back as an echo and are detected by the receiver. The time interval between sending the ultrasonic pulse and receiving the echo is measured by the sensor's control circuitry.

This non-contact measurement technique allows the ultrasonic module to accurately determine the distance of an object within its sensing range. Because of its reliability, low cost, and immunity to lighting conditions, ultrasonic modules are widely used in robotics for obstacle detection, navigation, and collision avoidance.

E. Blade

The working principle of a grass-cutting blade is based on the concept of high-speed rotary motion, where mechanical energy from the motor is transferred to the blade, enabling it to cut through grass efficiently. When the blade is rotated at a high velocity by a DC or brushless DC motor, the sharpened edges of the blade strike the grass with sufficient kinetic energy to shear it cleanly.

The cutting process is similar to a scissor action but achieved by rapid rotational force. The aerodynamic shape of the blade not only assists in cutting but also generates an upward airflow, which helps to lift the grass into an upright position before it is cut, ensuring uniform trimming. Depending on the design, blades can either chop the grass into fine pieces (mulching) or simply cut and discharge it. Thus, the blade works by converting rotational mechanical energy into a cutting force, making it an effective tool for grass-cutting robots and lawnmowers.

VI. CONCLUSION AND FUTURE SCOPE

From the review of existing robotic lawn mower systems, a suitable design layout was prepared, and the necessary components were chosen according to performance requirements. Based on insights from various research studies, modifications were introduced to improve efficiency. A prototype was then developed using a metal sheet chassis, equipped with ultrasonic and infrared sensors for obstacle detection. The successful demonstration of these sensors confirmed the feasibility of the design.

With the growing demand for automated solutions in gardening and agriculture, such a system can save considerable human effort and time. The proposed grass-cutting bot proves to be both cost-effective and convenient, making it more of a necessity than a luxury.

Looking ahead, the system offers wide potential for advancement. Future enhancements may include the integration of solar power for energy sustainability, the use of AI and computer vision for advanced navigation, IoT-based monitoring and remote operation, and the adoption of lightweight mechanical designs for better mobility. By implementing these improvements, the system can evolve into a smart, autonomous agricultural assistant capable of performing multiple field operations with greater precision and reliability.

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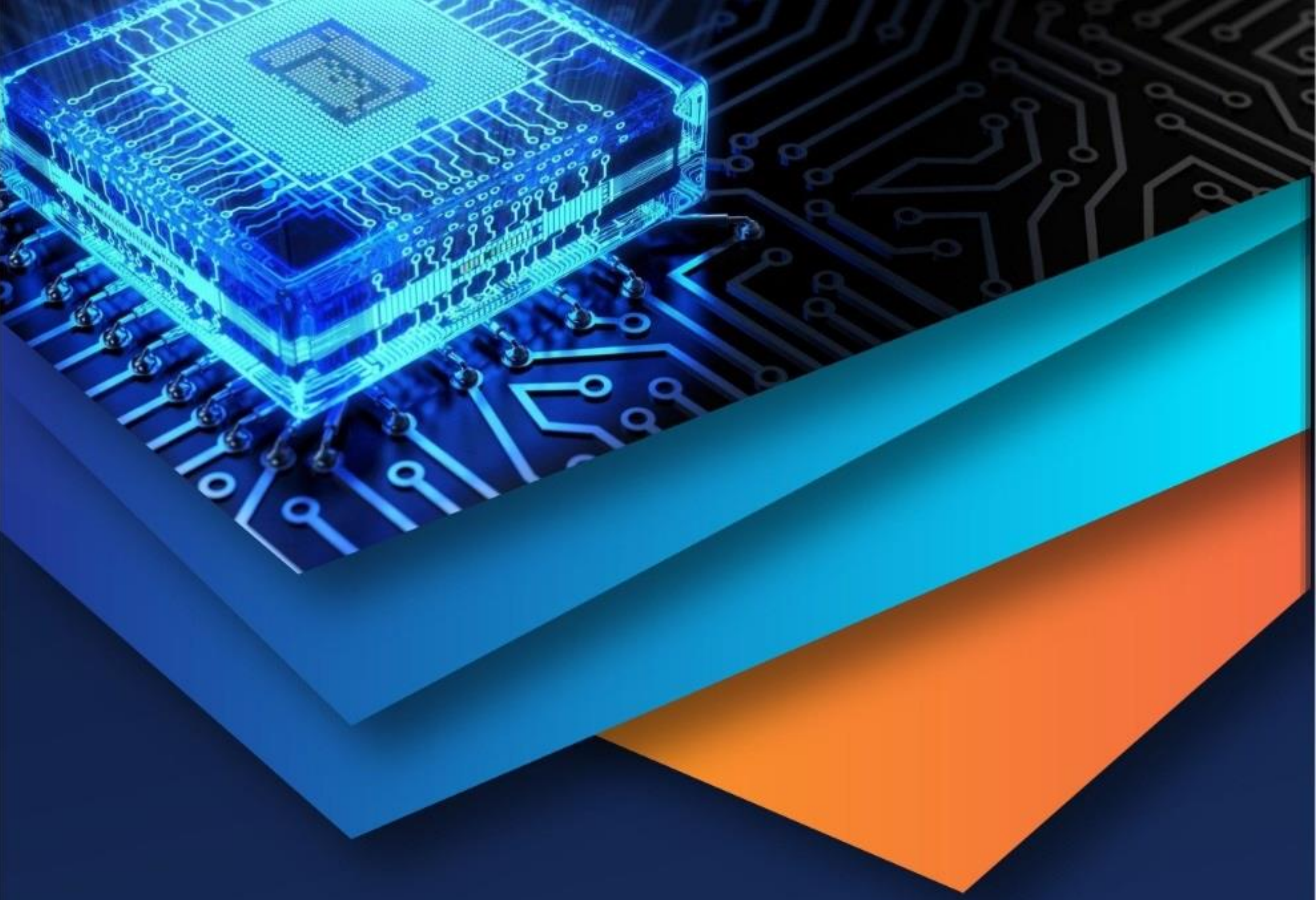

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