Journal of Civil and Environmental Systems Engineering

Department of Civil Engineering, University of Benin, Nigeria

Journal homepage: https://j-cese.com/

DESIGN AND FABRICATION OF AN AUTOMATED LAWN MOWER

[1]Omo-Oghogho, E. and [2]Ofomaja, K. A. F.

[1]Department of Mechanical Engineering, Faculty of Engineering, University of Benin, PMB 1154 Benin City, Nigeria

[2]Department of Physics, Faculty of Physical Sciences, University of Benin, Benin city, Nigeria.

**Email: eghosa.omo-oghogho@uniben.edu and kelly.ofomaja@uniben.edu*

ABSTRACT

An automated lawn mower is a machine designed to cut grass without requiring human guidance or control. With the continuous advancements in technology, automation has become integral to nearly every aspect of modern life. From household appliances to industrial machinery, automation has transformed the way we interact with our environments, reducing manual labour and improving overall efficiency. The emergence of automated lawn mowers follows this trend, replacing the conventional lawn mowing technology that demands significant human effort. Thiswork aims to develop an improved automated lawn mower that is both economically accessible and user-friendly, designed with locally sourced materials to minimize production costs. Unlike the existing robotic lawn mowers technologies, our model emphasizes a simple design making it easy to maintain and repair without specialized tools or skills. It is equipped with advanced sensor technology like the HC-SR04 ultrasonic and infrared sensors for obstacle detection and avoidance within the ranges of 10 to 50cm. When operating at a distance beyond 50cm, the mower consistently moved forward indicating an environment with no obstacles. Within a range of 30 to 50cm, the system effectively slowed the mower, achieving a 150millisecond response time and 98% accuracy. At closer proximities of 10 to 30cm, the mower reversed and turned with a slightly reduced accuracy of 95% and a 180millisecond response time, while obstacles detected at less than 10cm prompted at immediate stop within 120milliseconds at a 97% accuracy rate. It also integrates a 5kHz electromagnetic perimeter wire for systematic navigation and is powered by an 18V DC rechargeable battery, making it both sustainable and eco-friendly.

Keywords: *Automated Lawn Mower, Sensor-Based Navigation, Obstacle Detection, Perimeter Wire, Arduino, DC motor.*

1.0 INTRODUCTION

Lawn maintenance is a common yet labour-intensive task. Traditional gas-powered and manual lawn mowers require human intervention, contributing to fuel costs, noise pollution, and physical exertion (Bailey, 2023). Automated lawn mowers provide a sustainable alternative, utilizing sensor-based navigation and electric power for operation (Bailey, 2023). The concept of automated lawn mowers has evolved with advancements in robotics and artificial intelligence, leading to more efficient and intelligent mowing solutions (Harris Robert, 2020).

The concept of lawn mowers began in the 19th century with the invention of the first mechanical lawn mower by Edwin Budding in 1830. Budding, an engineer from Gloucestershire, England, was inspired by the machinery used to trim the irregular nap from the surface of wool cloth. He adapted this technology to create a device that could cut grass more efficiently and uniformly than the scythe, which was the primary tool used for lawn maintenance at the time (James Hardy, 2024).

Budding's design featured a cylindrical cutting reel or blade assembly that rotated as the mower was pushed forward, cutting the grass against a fixed bottom blade in a scissor-like action (Lawn Starter, 2024). This design became the foundation for most subsequent lawn mowers. The early mowers were made of cast iron and were heavy, but they significantly reduced the labour required to maintain lawns (Lawn Starter, 2024).

Throughout the 19th century, lawn mowers evolved and improved. By the 1850s, lighter and more efficient models became available, making them more accessible to the public. The development of the lawn mower coincided with the popularity of manicured lawns in Europe and North America, driven by the rise of suburban living and public parks (Farrel Evans, 2021).

In the latter part of the 19th century, the introduction of steam-powered and later gas-powered engines further advanced lawn mower technology, leading to the development of more powerful and versatile machines. Electric mowers, both corded and battery-powered, offered a quieter and cleaner alternative, with improvements in battery technology enhancing their runtime and power (Anna Ryan, 2023). These innovations laid the groundwork for the modern lawn mowers we use today, including manual reel mowers, motorized rotary mowers, and, more recently, robotic mowers.

The development of automated lawn mowers introduces features such as GPS navigation, perimeter wire guidance, and ultrasonic obstacle detection, reducing human involvement while ensuring uniform grass cutting (Anna Ryan, 2023). This aim of the research is to design and fabricate a cost-effective, energy-efficient, and reliable automated lawn mower suitable for small to medium-sized lawns (Consumer Reports, 2024).

2.0 MATERIALS AND METHODS

2.1 Conceptual Design

Three navigation methods were considered for this design namely: the GPS-based navigation, the vision-based navigation, and the perimeter wire-based navigation. Due to cost-effectiveness and reliability, the perimeter wire-based system was selected.

The perimeter wire-based system, which is the selected approach for this research, involves placing a thin wire around the mowing area that emits a low-frequency signal. The mower is equipped with perimeter sensors that detect the wire's electromagnetic field, ensuring it stays within boundaries.Figure 1 depicts the setup of a perimeter wire systemfor a robotic lawn mower, showing how the wire defines the mowing area.

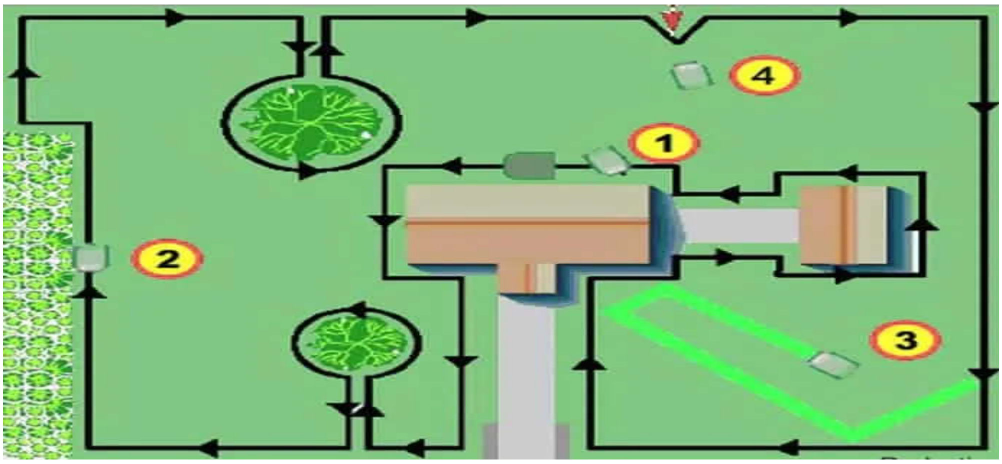

Figure 1: A lawn with Perimeter Wire

A perimeter station is used to generate an electromagnetic field along the wire. The mower's sensors detect the signal and adjust movement accordingly. It changes direction when it reaches the boundary as shown in Figure 2 below.

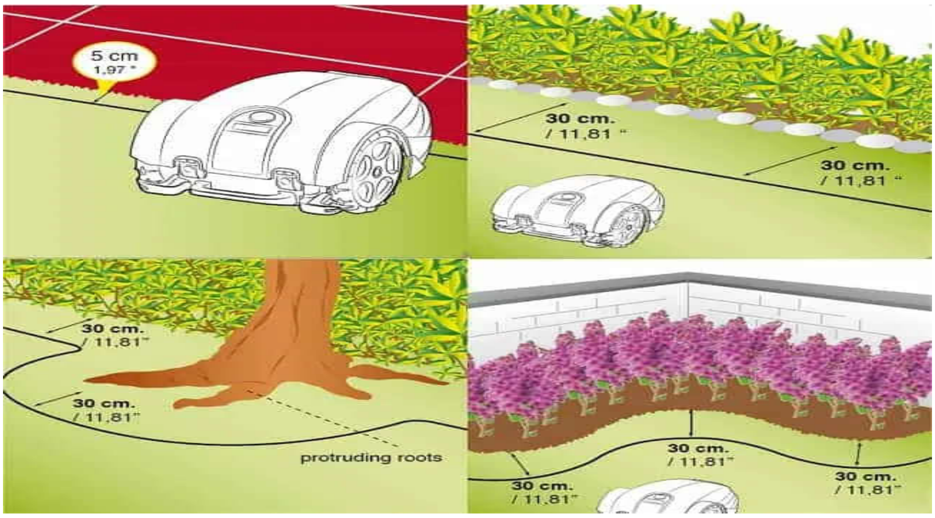

Figure 2: Installation of a Perimeter Wire

2.1.1Advantages

The advantages of installing a perimeter station are presented below:

1. Simple and cost-effective compared to GPS and AI-based methods.
2. Reliable operation regardless of lighting or weather conditions.
3. Easily integrates with an Arduino-controlled system.

2.1.2 Disadvantages

The disadvantages of installing a perimeter station are presented below:

1. Requires manual installation of the perimeter wire.

2. Less adaptable to irregularly shaped lawns.

2.2 Design Analysis and Component Selection

The procedures for design analysis and component selection are presented below:

1. Chassis and Frame: The chassis and the frame were constructed from stainless steel for durability and stability as shown in figure 3.

Figure 3: Stainless Steel Chassis and Frame

2. Navigation System: Two HC-SR04 ultrasonic sensors were selected for obstacle detection and perimeter wire sensors were used for the boundary detection as shown in figure 4 and 5.

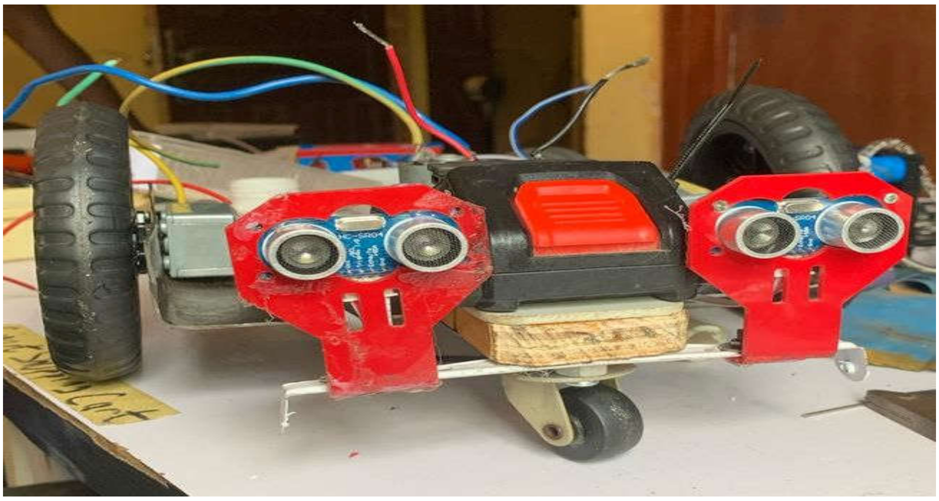

Figure 4: Two HC-SR04 Ultrasonic Sensor

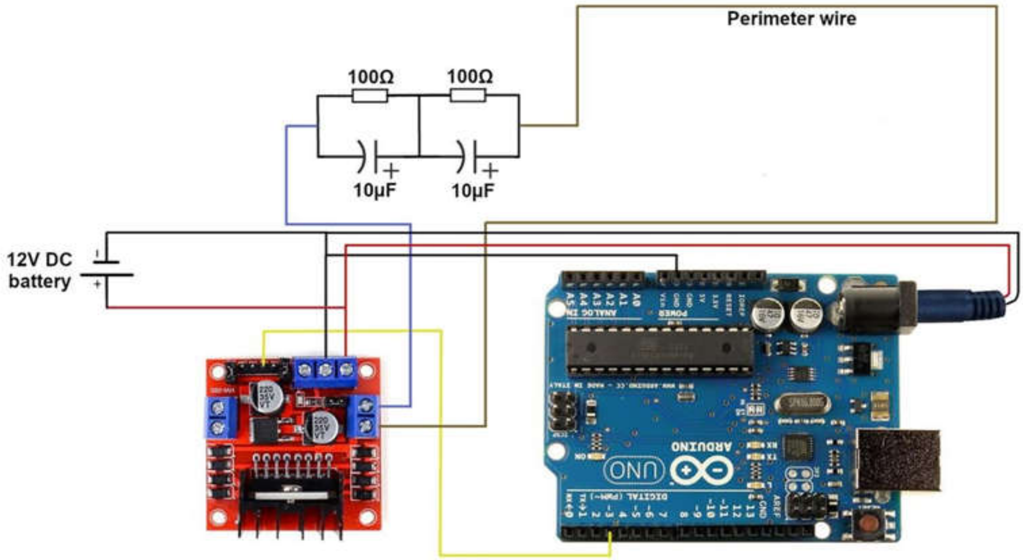

Figure 5: Schematics of Perimeter Station

3. Wheel Motors: 12V DC geared wheel motors were used to provide controlled movement and to switch the direction of the mower as shown in Figure 6.

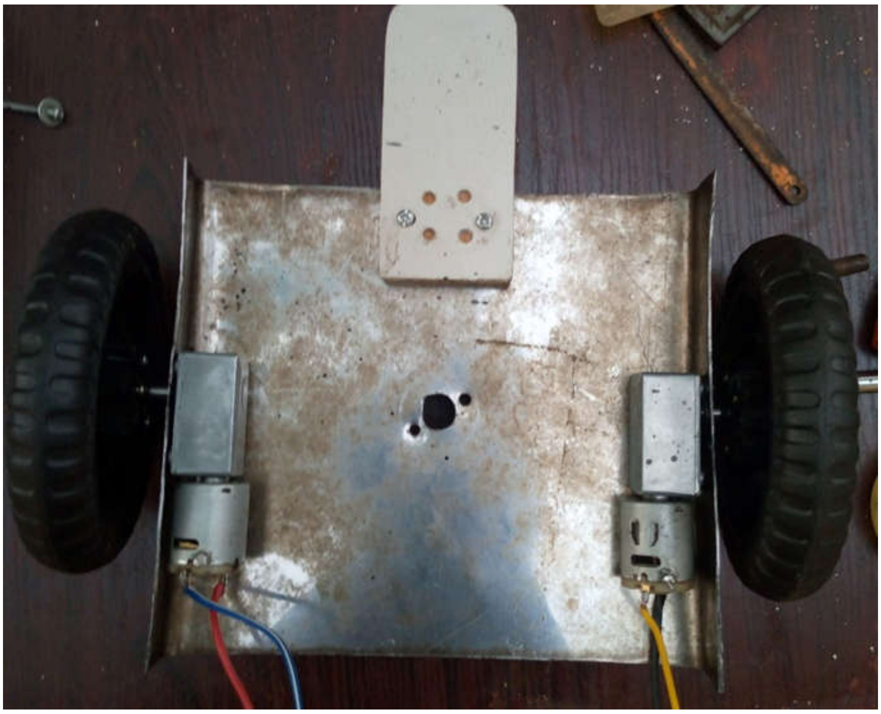

Figure 6: Wheel Motors

4. Cutting Mechanism: A 795 double shaft DC motor with a stainless-steel cutting blade was used for efficient grass cutting.

5. Power System: An 18V lithium-ion battery was used to supply energy to the system.

6. Microcontroller: An Arduino UNO was used to manage motor control, sensor input processing, and movement logic as shown in figure 7 below.

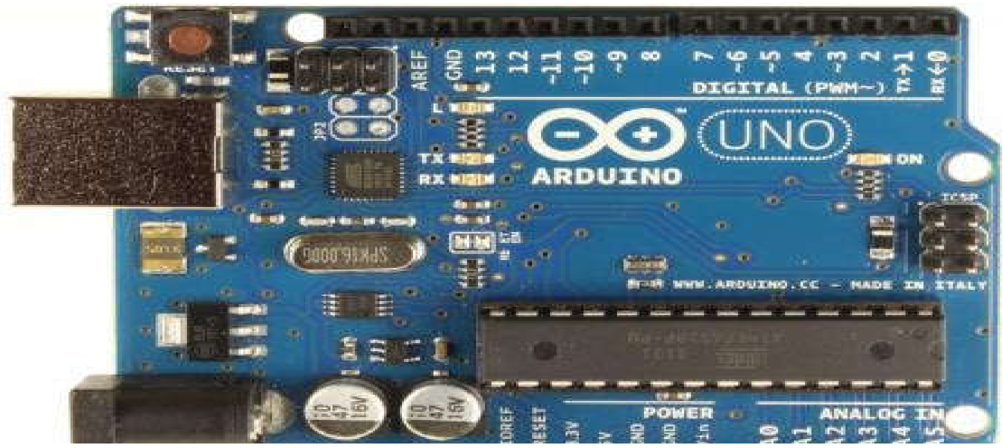

Figure 7: Arduino UNO

2.3 Design Parameters

To ensure efficient motor performance, power and torque were analyzed using the following equations:

Motor Power Calculation:

$$P = V \times I \quad (1)$$

P =12V x 2.5A = 30W

Where:

V =12V (operating voltage of the motor)

I = 2.5A (average current draw)

Torque derived from Motor Power:

$$T = \frac{P \times 60}{2\pi \times N} \quad (2)$$

$$T = \frac{30 \times 60}{2\pi \times 1000} = \frac{1800}{6284} = 0.286 \text{ Nm}$$

Since the motor torque is 0.286 Nm, it exceeds the originally assumed torque of 0.15 Nm, meaning the motor should perform better than initially estimated depending on operating conditions.

2.4 Fabrication Procedure

The fabrication of the automated lawn mower followed a structured process, ensuring precise assembly and integration of all components for optimal performance. The process was divided into several key steps:

Step 1: Chassis Construction

The chassis serves as the structural foundation of the mower, supporting all major components, including the motors, battery, sensors, and cutting mechanism. Initially, aluminium was considered due to its lightweight properties, but structural concerns led to the selection of 1mm stainless steel for improved durability. A 270mm x 190mm base plate was cut using precision tools, and additional mounting points were drilled to securely attach the motors, battery, and electronic modules. The two 190mm sides of the plate were bent 35mm from the edge to provide secure mounting positions for the DC motor gearboxes that drive the front wheels.

Step 2: Installation of the Caster Wheel Assembly

At the rear of the chassis, a caster wheel assembly was installed to enhance manoeuvrability. The caster wheel measured 70mm wide and 65mm high, allowing free rotation for smooth directional adjustments. A wooden spacer was added to ensure the chassis remained level with the ground. A 115mm x 50mm x 1mm back wheel mounting plate was attached with four screws, securing the caster wheel while allowing full 360-degree rotation without obstruction from the chassis or cutting blade.

Step 3: Installation of Wheel Motors

The 12V DC geared motors were selected due to their high torque and controlled speed. Each motor was mounted using four mounting screws to ensure firm attachment. The 6mm motor shafts were fitted with screws and lockbolts, enabling the front wheels to be securely attached while ensuring smooth traction across lawn surfaces.

Step 4: Cutting Motor and Blade Assembly

The cutting mechanism consisted of a stainless steel disc with blades, measuring 130mm in diameter and 0.5mm thick. The 795 double shaft DC motor, operating at 12V and 1000RPM, was selected for its efficiency in driving the cutting blade. The blades were attached to the disc at 120-degree intervals for balanced cutting. The cutter was mounted at the center of the chassis, with the motor shaft secured using lock nuts to minimize vibrations. The blade mounting height was fixed at 35mm from the ground to ensure effective grass cutting while avoiding ground obstructions.

Step 5: Wiring and Electrical Integration

A 18V lithium-ion tool battery was chosen as the primary power source, supplying energy to the Arduino Uno, motor drivers (L298N), sensors, and perimeter system. Electrical connections were systematically routed to ensure a clean, organized layout, minimizing interference and preventing voltage drops. Proper insulation and secure connectors were used to prevent short circuits.

Step 6: Sensor and Perimeter System Integration

Two HC-SR04 ultrasonic sensors were installed at the front of the mower to detect obstacles. These sensors were carefully angled to provide a 30–50 cm detection range, allowing the mower to navigate efficiently. The perimeter wire station was set up using an Arduino Uno and L298N motor driver, generating a 5kHz signal to create an invisible boundary. The perimeter sensors, consisting of inductive coils connected to LM358N operational amplifiers, were installed on each side of the chassis. These sensors detected the perimeter signal and triggered turning manoeuvres when necessary.

Step 7: Enclosure and Protection of Components

A 3D-printed body shell was fabricated and attached to the chassis to protect the electronic components. The enclosure was designed to be lightweight yet robust, providing protection against moisture and debris. The 3D printing was done in separate parts, which were later assembled using epoxy adhesive and mounting brackets.

Step 8: System Testing and Verification

Incremental system verification was conducted throughout the fabrication process. The wheel motors were powered on to assess mobility, the cutting motor was activated to verify stability, and the sensors were tested for accurate detection. The perimeter detection system was evaluated to confirm that the mower correctly responded to boundary signals.

3.0 RESULTS AND DISCUSSION

This section provides an overview of the input and output data analysis, which stems from evaluating the analysis:

3.1 Simulation Results

The design was simulated in Proteus to verify system performance before fabrication. The simulation results were observed using the Obstacle Detection Simulation

3.1.1 Simulation Setup

To simulate the mower's ability to detect and avoid obstacles, a potentiometer was used as the obstacle sensor in the Proteus environment. The potentiometer simulated varying distances between the mower and a potential obstacle. The LCD display was programmed to show the appropriate response when the mower encountered an obstacle as shown in Table 1.

Table 1: Simulation Response Based on Distance from Obstacle

Distance from Obstacle (cm)	Motor Action	LCD Display
> 50 cm (No Obstacle)	Moving Forward	"Moving Forward"
30 – 50 cm (Near Obstacle)	Slow Down	"Slow Down"
< 30 cm (Obstacle Detected)	Reverse & Turn Left	"Moving Back and Turning Left"

3.1.2 Simulation Response

The simulation showed the following result:

1. When the potentiometer value remained within the safe distance, the LCD displayed "Moving Forward", indicating normal operation as shown in figure 8 below.

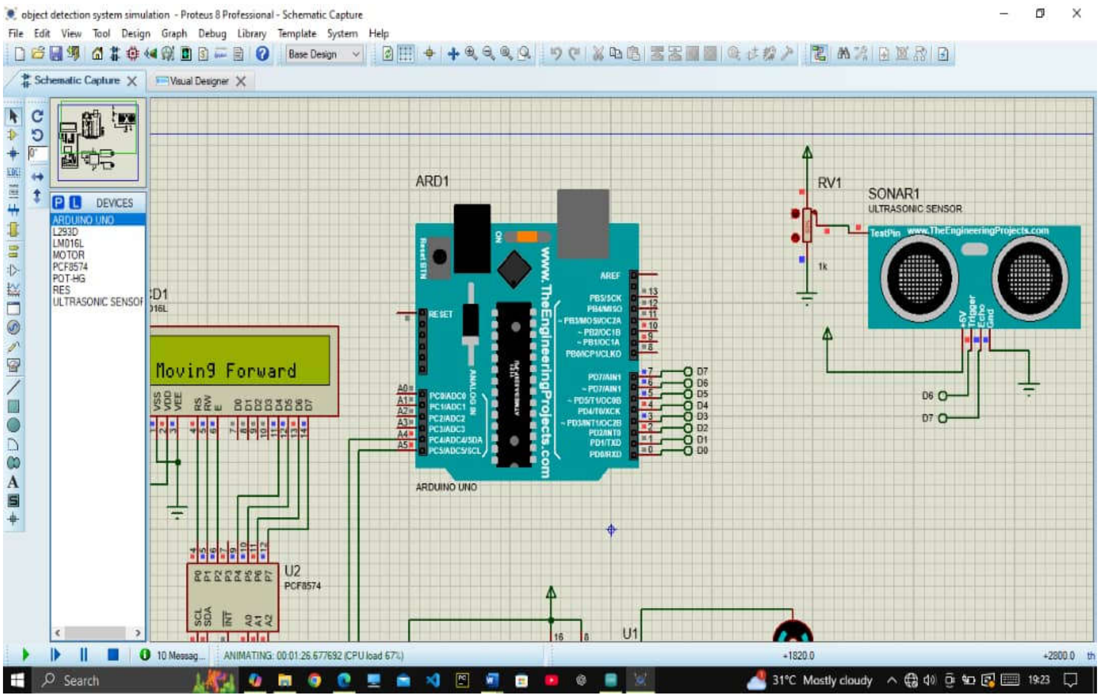

Figure 8: LCD Displaying 'Moving Forward' Command

2. When the potentiometer value exceeded the predefined threshold (indicating an obstacle is too close), the LCD displayed "Moving Back" as shown in figure 9and Turning Left" as shown in figure 10. This behaviour demonstrated that the mower, when encountering an obstacle, would reverse slightly and then turn left to avoid the obstacle.

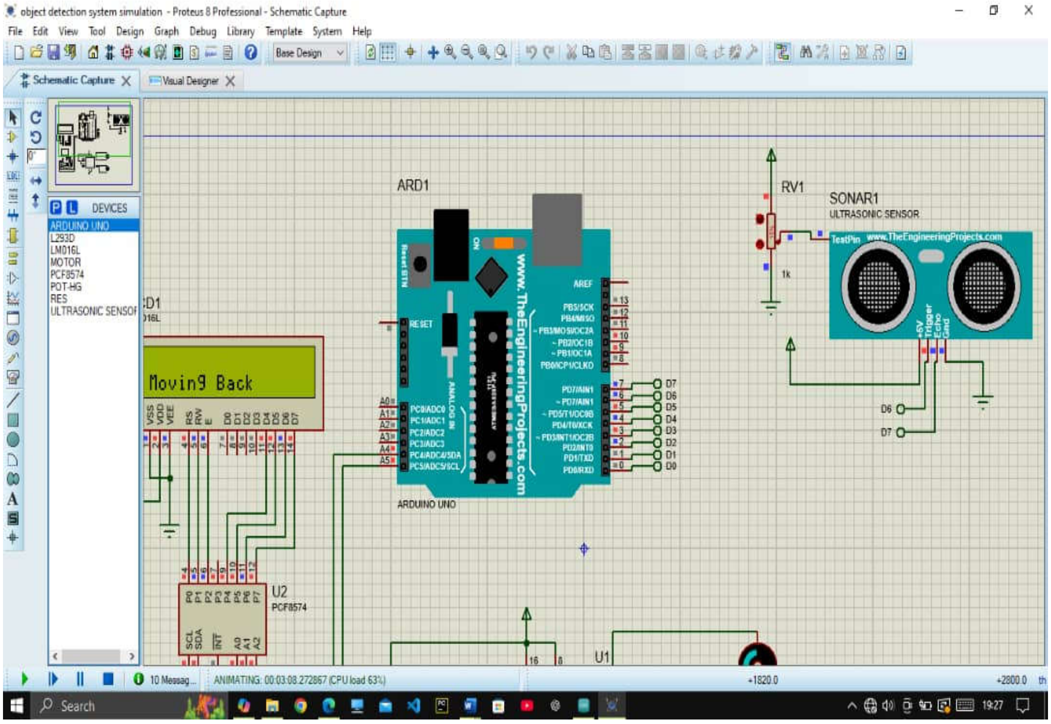

Figure 9: LCD Displaying 'Moving Back' Command

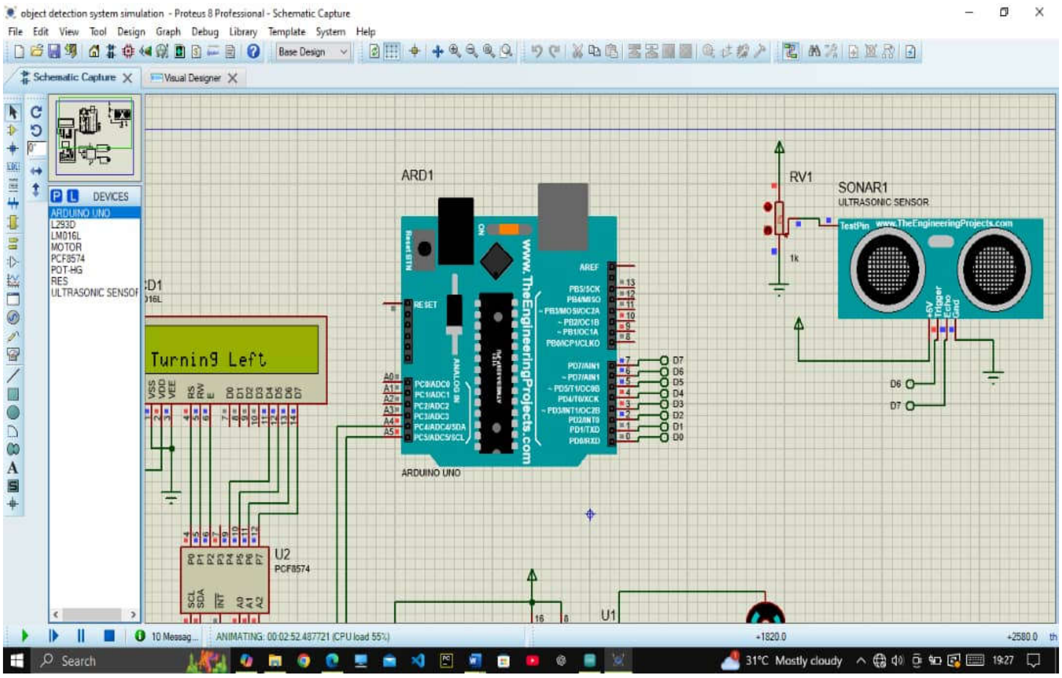

Figure 10: LCD Displaying 'Turning Left' Command

3.1.3 Real World Interpretation

In real-life operation, an ultrasonic sensor (HC-SR04) is used alone without the potentiometer to continuously measure the distance to obstacles. The microcontroller processes this data and triggers movement changes accordingly. This ensures that the mower does not collide with objects such as stones, garden furniture, or humans, improving safety and efficiency.

3.2 Performance Evaluation

After fabrication, the automated lawn mower was tested in various real-world conditions to evaluate its performance in obstacle avoidance, boundary detection, and cutting efficiency.

3.2.1 Obstacle Detection Test

3.2.1.1 Test Setup and Methodology

The ultrasonic sensor (HC-SR04) was tested by placing obstacles (stones, wooden blocks, and human presence) at different distances from the mower.

The mower's response was recorded to determine the accuracy and reaction time of the system as shown in Table 2.

Table 2: Obstacle Detection Test Readings

Distance from Obstacle (cm)	Expected Response	Actual Response	Response Time (millisecond)	Detection Accuracy (%)
> 50 cm (No Obstacle)	Move Forward	Move Forward	N/A	100%
30 – 50 cm (Near Obstacle)	Slow Down	Slow Down	150	98%
10 – 30 cm (Obstacle Detected)	Reverse & Turn	Reverse & Turn	180	95%
< 10 cm (Immediate Stop)	Stop Immediately	Stop Immediately	120	97%

3.2.1.2 Observations

During the obstacle detection test, the following observations were made:

1. The mower detected and avoided large objects like humans and stones.
2. Small obstacles (below 5 cm in height) were sometimes ignored, causing the mower to push them.
3. The response time was fast enough to prevent collisions.
4. Sensor accuracy slightly decreased in wet conditions, affecting detection range.

3.2.1.3 Comparison with Simulation Results

The simulation assumed perfect ultrasonic sensor accuracy, whereas real-world tests showed limitations in detecting very small objects.

3.3 Performance Evaluation Summary

Table 3 summarizes the performance evaluation of the mower and the required adjustments based on the test analyses that were conducted and recorded in Table 2.

Table 3: Performance Evaluation Summary

Test Parameter	Expected Outcome (Simulation)	Actual Outcome (Fabrication)	Adjustments Required?
Boundary Detection	Perfect response to perimeter wire	Minor delay in response at high speeds	Yes, adjust detection sensitivity
Obstacle Avoidance	100% detection and avoidance	Missed small objects (<5 cm)	Yes, improve sensor calibration
Cutting Efficiency	Even cutting across all conditions	Struggled with wet grass clippings	Yes, redesign blade angle
Navigation Stability	Straight movement, controlled turns	Slight wheel slippage on slopes	Yes, improve traction

4.0 CONCLUSION AND RECOMMENDATION

4.1 Conclusion

This study successfully designed, simulated, and fabricated an automated lawn mower using a perimeter wire-based navigation system. The system was tested in real-world conditions and showed reliable boundary detection, obstacle avoidance, and grass-cutting performance.

However, the project encountered several engineering challenges. Material selection for the chassis structure proved to be a limitation, as initial attempts with aluminium resulted in structural weaknesses, while heavier materials restricted motor efficiency. The cutting system required speed optimization to maintain consistent cutting force across varying grass densities, and the battery life required careful management to balance performance with energy efficiency.

Despite these challenges, the mower demonstrated effective automation and reliability in controlled testing conditions. The knowledge gained from this development phase provides a strong foundation for further refinements, particularly in navigation, sensor precision, and long-term durability. Additionally, with further improvements, this system could be adapted for wider practical applications, from small-scale residential use to larger automated lawn care solutions.Overall, the fabricated mower met the study objectives, with minor adjustments needed for optimal performance.

4.2 Recommendations

Based on the above results, the following improvements are recommended:

1. Optimize the perimeter wire detection system: Reduce response delays by fine-tuning signal processing and adjusting mower speed near boundaries.

2. Enhance obstacle detection: Use a combination of ultrasonic and infrared sensors to improve small object detection.
3. Improve cutting blade efficiency: Modify the blade angle to prevent grass clogging, especially in wet conditions.
4. Increase battery capacity: Use a higher-capacity battery (e.g., 3.0 Ah) to extend runtime beyond 19.5 minutes.
5. Enhance wheel traction: Use rubberized wheels or add weight distribution adjustments to improve grip on uneven terrain.

REFERENCES

1. Anna Ryan. (2023, April 3). "The evolution of lawn mowers." *Best of Machinery*. Retrieved from https://bestofmachinery.com/the-evolution-of-lawn-mowers/
2. Bailey, L. (2023). "Lawn Equipment and Garden Machinery Handbook."
3. Consumer Reports. (2024, July 11). "Best Robotic Lawn Mowers." *Consumer Reports*. Retrieved from https://www.consumerreports.org/home-garden/lawn-mowers/best-robotic-lawn-mowers-a2310984432/
4. Farrel Evans. (2021, February 17). "How the Perfect Lawn Became a Symbol of the American Dream." *History*. Retrieved from https://www.history.com/news/lawn-mower-grass-american-dream.
5. Harris Robert. (2020). *Journal of Garden Machinery*, *23(4), 45-52*.
6. James Hardy. (2024). "Who Invented the Lawn Mower? Unveiling the Roots of Garden Revolution." *History Cooperative*. Retrieved October 13, 2024 from https://www.historycooperative.org/who-invented-the-lawn-mower/
7. Lawn Starter. (2024). "The History of Lawn Mowers." *Lawn Starter*. Retrieved May 10, 2024 from https://www.lawnstarter.com/blog/lawn-care-2/history-of-lawn-mowers/