

# Autonomous Robot for Grass Cutting Application

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**Abstract**— In this paper, the design of an autonomous 4WD grass-cutting robot optimized to cover the area in a systematic fashion is described. The system also abandons the use of intricate sensor-based navigation in favor of a Timed Open-Loop Pattern that is played out with the help of an Arduino Uno. This is a spiral-in navigation strategy to have the lawn covered completely. The mechanical design has 12V Johnson-g geared motors with high-torque locomotion and a separate DC motor with the cutting blade. The operational supervision in real time is made possible with the help of ESP32-CAM streaming a live video over a mobile hotspot.

**Keywords**—Autonomous Robotic Mower, Timed Pattern Navigation, 4WD Mobile Robot

## I. INTRODUCTION

Preservation of out of doors inexperienced areas historically calls for huge manual time and effort, motivating the development of self-sustaining garden-mowing structures for advanced performance and safety. current research on independent grass-slicing robots has largely focused on sensor-based navigation the usage of GPS, RTK-GPS, LiDAR, ultrasonic sensing, and imaginative and prescient strategies to beautify positional accuracy and coverage overall performance [1], [4]. Systematic insurance route planning techniques such as zig-zag and boustrophedon decomposition have also been explored for established outside environments [11]. moreover, IoT-enabled robot structures integrating wi-fi tracking and energy-green operation were investigated for clever outdoor programs [3], [7], [12]. although those methods offer stepped forward accuracy and adaptability, they increase hardware complexity, computational call for, and overall device cost, and GPS-based solutions can also be afflicted by sign degradation in obstructed environments. In based and comparatively obstacle-unfastened lawns, deterministic navigation primarily based on predefined timing parameters can obtain systematic insurance with decreased hardware necessities. encouraged by way of this idea, this paper gives a low-fee 4-wheel drive independent grass-cutting robot primarily based on a Timed Open-Loop Spiral Navigation approach achieved the usage of an Arduino Uno. The device integrates excessive-torque DC geared automobiles for locomotion, a dedicated blade motor with remoted motor drivers for operational stability, and an ESP32-CAM module for IoT-primarily based real-time visual tracking. The proposed approach demonstrates that reliable and systematic garden insurance may be executed using a simplified deterministic control framework suitable for cost-touchy out of doors packages. This gives a new way to certain robotic innovation field to work towards a problem-solving oriented task rather than automatising everything. The use of modern-day tech with a subtle innovative touch is more reliable.

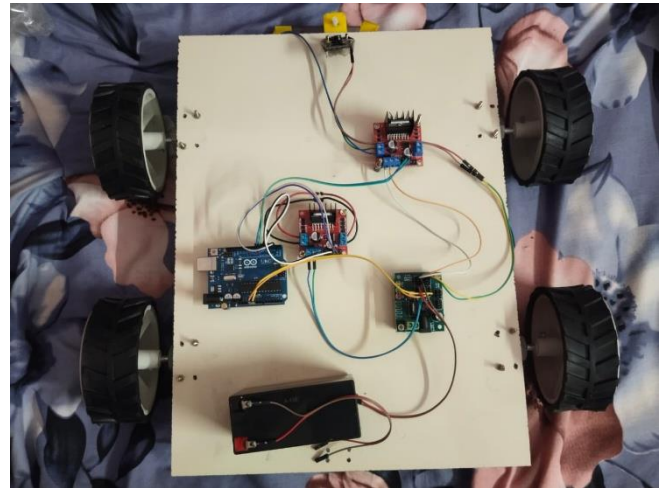


Fig. 1. Prototype of the autonomous grass cutting robot.

## II. SYSTEM OVERVIEW

The autonomous grass-cutting robot proposed is an electrically powered mobile platform that is small and is supposed to be used to carry out lawn care with minimal human intervention. The architecture is simple, reliable and cost-effective and is based on a deterministic timed navigation approach against intricate sensor-based localisation methods. The entire system incorporates a control unit, locomotion system, cutting system, power system and an IoT-powered visual monitoring subsystem.

The central processing and decision-making unit of the system is an Arduino Uno microcontroller. The Arduino makes the navigation algorithm run timely manner and provides the control signals that are required to actuate the motors. The decisions of movement are made according to predetermined timing parameters, which have been written in the program memory. The robot can then pursue a repeatable navigation pattern, which will be appropriate in an organised lawn setting.

The locomotion system comprises two high-torque Johnson DC geared motors fitted on the front wheels of the robot. These motors allow to move forward and turning with the help of the difference speed. A dedicated L298N dual H-bridge motor driver module receives the low-power control signals of the Arduino, and connects the high-current demands of the DC motors to the high-current supply. This design guarantees the stable movement on uneven grass cover.

The cutting of grass is done by the use of a high-speed DC motor that spins a cutting blade. The cutter motor is independently operated with the help of the second L298N

motor driver module. The robot separates the locomotion system and the cutting mechanism to ensure that the blade remains at a constant speed despite changes in the load on the movement or changes in the terrain resistance. This disengagement enhances the efficiency of cutting and operation safety.

A 12 V lead-acid battery chosen on account of the high current delivery capacity and strength in outdoor conditions is used to provide power to the whole system. The battery provides power directly to the two motor driver modules and, via controlled connections to, the Arduino Uno and other low-powered electronics. The distribution of power has been done centrally, making it balanced in terms of load and the duration of operation.

In order to allow supervision remotely, an ESP32-CAM module has been provided as an IoT-based visual monitoring unit. The module is not interdependent on the navigation control system and offers real time video feed through a wireless mobile hotspot connection. This feature will enable the user to monitor the work of the robot, check the performance of the cutting and improve the safety without disturbing the autonomy of the robot.

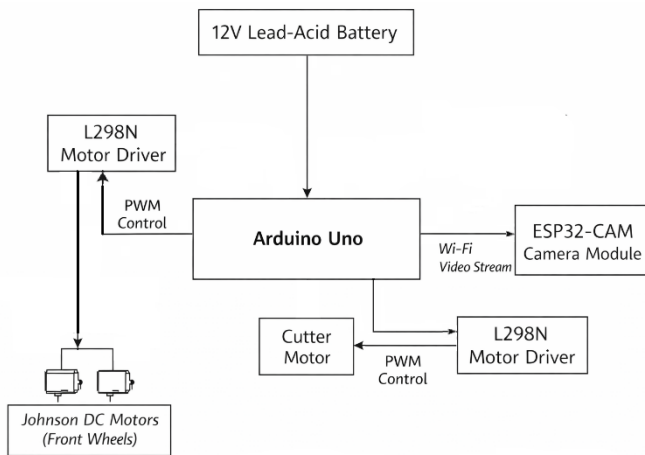


Fig 2. Block Diagram

### III. HARDWARE ARCHITECTURE

#### 1. Control Unit

The microcontroller of the system is the Arduino Uno. It takes charge of the timed navigation algorithm and the production of Pulse Width Modulation (PWM) to control motor speed. The Arduino manages the direction and the movement of the robot by communicating with the motor driver modules. It has a deterministic timing characteristic; thus, it is quite effective to be utilized in the implementation of the open-loop control strategies that are implemented by predetermined time intervals.

#### 2. Locomotion System

The locomotion system comprises two 12 V Johnson DC geared motors that are fitted on the front wheels of the robot. These motors are powerful enough to drive the robot in rough grass. The two motors can be controlled differently, allowing

the forward motion and turning maneuvers. The motors are driven with an L298N dual H-bridge motor driver, dedicated to the control of the motors and the amplification of current necessary to operate the motors outdoors.

#### 3. Cutting Mechanism

The grass cutting system utilizes just one high-speed DC motor located in the middle of the chassis. The motor has a moving cutting blade, and it does not depend on the locomotion system. The cutter motor is controlled by a separate L298N motor driver to keep the blade speed constant and avoid fluctuations in the electrical loads influencing the movement of the robot.

#### 4. Motor Driver Modules

The system has two L298N dual H-bridge motor driver modules. The two Johnson DC motors that control the movement of the robot are controlled by one motor driver, and the other motor driver controls the grass cutter motor. The separation of drivers increases the reliability of the system and offers electrical isolation of locomotion and cutting.

#### 5. Power Supply System

The whole system is operational on the basis of a 12 V lead-acid battery, which has been chosen due to its high current delivery capacity and its longevity. The battery provides power to the motor drivers directly and controlled voltage to the Arduino Uno and auxiliary electronics. The concentration of battery location is used to provide balance and stability in operation. All modules are grounded on common grounds to provide quality electrical operation.

#### 6. IoT-Based Monitoring Unit

The system has an ESP32-CAM module that allows it to monitor what is happening through real-time visualization. The module is fixed on the front side of the robot to have a live video of the working place. It also links to a mobile hotspot and delivers video via a web-based interface. The control system is independent of the monitoring unit and allows the navigation and motor control to be independent of the video processing tasks.

#### 7. Chassis and Component Layout

All the parts are attached to a rigid chassis that is meant to hold mechanical loads and minimize vibration. The chassis design ensures proper weight distribution, mechanical stability, control of the vehicle, performance and ease of maintenance during outdoor operation and indoor operation also. The wiring has been laid safely, not to be interfered with by moving components, and to be operated safely. This aspect enables the operator to monitor the work of the robot, check whether cutting is performed satisfactorily and be more secure without disrupting the autonomy of the robot.

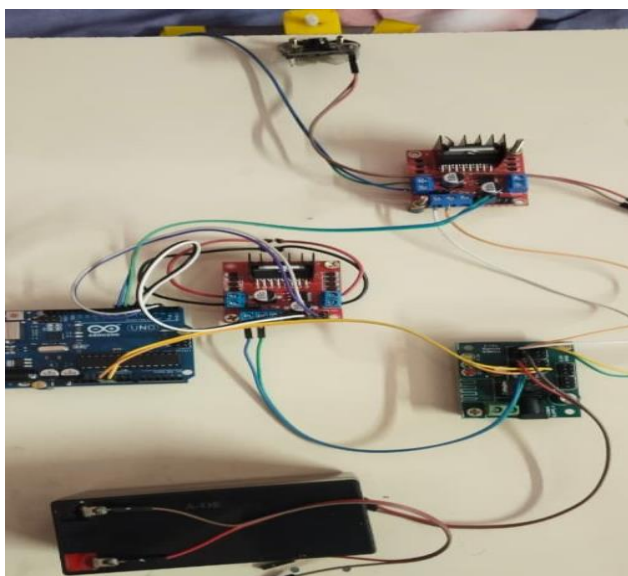


Fig. 3. Hardware layout of the robot

#### IV. TIMED NAVIGATION ALGORITHM

##### 1. Algorithm Initialization

At the start of the system, the Arduino Uno will initialize all the input-output pins related to the motor drivers and default the speed values using Pulse Width Modulation (PWM). Time variables of the forward movement and turning delay are loaded in the program memory. The cutter motor is switched on after the process of setting up the cutting machine is complete, and the blade of the cutting machine has attained a steady rotational velocity before the robot starts moving.

##### 2. Forward Motion Control

The robot starts moving forward for a certain period of time, which is predetermined by the first timing parameter. PWM signals to each Johnson DC motor during this phase are equal, so that both motors move in straight lines. The time period of forward movement is precisely adjusted such that it travels a specified distance depending on the motor speed and the size of the wheels. It is this directed movement that is the foundation of predictable movement on the surface.

##### 3. Turning Operation

The robot does a timed turning move after it has finished a forward movement segment. The turning is obtained by slowing down or halting one motor on the wheels and keeping the others in motion, which causes an in-place or pivot turn. The turn delay is set to a fixed value to create an approximate right-angle turn. This is a timed turning scheme, which enables the robot to travel along the same path without the angular position sensors.

##### 4. Spiral Path Generation

In order to have full coverage of the area, a spiral-in pattern has been used in the navigation algorithm. Once a sequence of forward and turn moves has been done, the

algorithm slowly decreases the forward moving time by a decrement value. This decrease makes the robot follow increasingly smaller paths, forming a spiral moving inward. The spiral design reduces unused areas and repetitive moves in the working area.

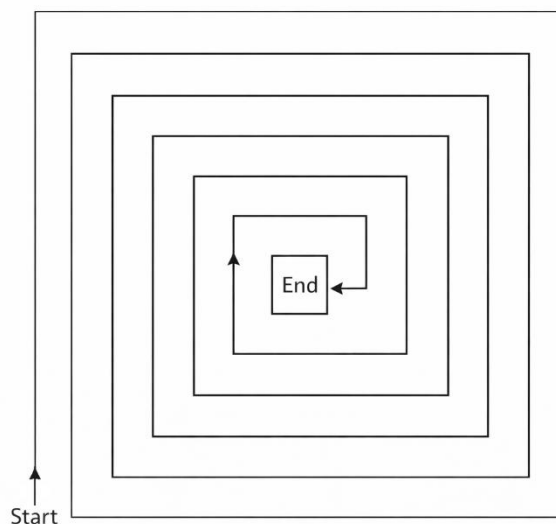


Fig. 4. Navigation path used for systematic area coverage.

##### 5. Loop Execution and Coverage Control

The forward movement and the turning are applied in a repetitive loop form. The forward timing parameter is updated after the completion of the loop cycle to decrease the coverage radius. This cycle is repeated until the forward movement time has to reach a pre-established minimum limit, which means that the central area of the working space has been spanned.

##### 6. Motor Speed Regulation

The speed of the wheel motors during the navigation is regulated by PWM. Constant speed running guarantees equal movement in every time interval. The values of speed are chosen in order to compromise traction, cutting efficiency, and battery consumption. The cutter motor is on throughout the navigation to ensure consistency in the performance of grass cutting.

##### 7. Algorithm Termination

When The termination of the timed open-loop navigation set of rules is primarily based on a predefined minimum ahead-movement time threshold. at some point of every navigation cycle, the ahead motion time is reduced via a steady decrement price, ensuing in step-by-step smaller concentric square paths closer to the center of the operating vicinity. If the forward time at new release  $K$  is expressed as  $T_k = T_{k-1} - \Delta T$ , the set of rules terminates whilst  $T_k \leq T_{min}$ , in which  $T_{min}$  represents the minimal allowable tour period for strong movement. as soon as this circumstance is happy, the manipulate unit disables the PWM signals to the wheel motors to forestall locomotion, followed by means of switching off the reducing motor after a short put off to make certain secure shutdown. This deterministic termination mechanism prevents pointless overlapping movement and

reduces strength consumption. even though the approach does not rely on positional feedback and may be laid low with minor wheel slip, experimental observations confirm that the selected threshold values offer realistic and constant coverage in structured garden environments.

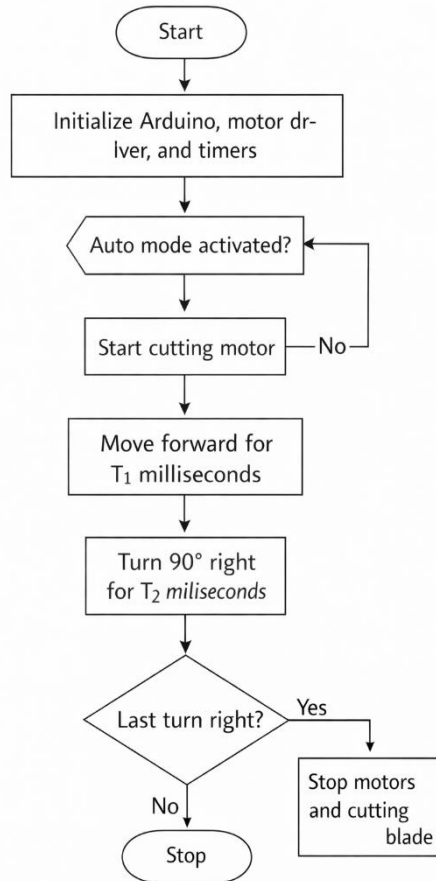


Fig. 5. Flowchart of the timed open-loop navigation algorithm.

## V. IOT-BASED VISUAL MONITORING

### 1. ESP32-CAM Integration

As the main element of the visual monitoring system, ESP32-CAM is employed. The module is fitted at the front side of the robot to give the robot a proper forward vision of the working area. ESP32-CAM will be used because it is not only small, consumes low power, and has a built-in camera and Wi-Fi, but it is also applicable in mobile robots.

### 2. Wireless Connectivity

The ESP32-CAM is connected to a mobile hotspot in order to create a wireless communication link. After connecting, the module would act as a local web server and transmit live video via Wi-Fi network. Such a setup removes the necessity of extra communication equipment and allows it to be used flexibly outdoors.

### 3. Real-Time Video Streaming

The image of the camera on the ESP32-CAM is a live video that can be viewed in real time and accessed via a regular web browser on a smartphone or laptop. The video stream gives the user continuous visual feedback of the robot's environment, allowing them to see how well it is navigating, cut well and any possible obstacle encountered during operation.

### 4. Safety and Monitoring Advantages

The visual monitoring system is based on IoT and ensures enhanced safety since the operator is able to monitor the robot remotely without the necessity to be physically present. It is able to identify any unusual behaviour or unforeseen hindrance in real-time and intervene manually, should it be necessary. It is another attribute that gives the autonomous grass-cutting system extra reliability.



Fig. 6. Real-Time Video Monitoring on ESP-32 Cam

## VI. EXPERIMENTAL RESULTS AND DISCUSSION

The proposed self-sufficient grass-reducing robotic turned into experimentally evaluated in managed square garden surroundings to validate the effectiveness of the timed open-loop spiral navigation set of rules, mechanical stability, and IoT-based totally monitoring subsystem. more than one test runs had been performed to assess navigation consistency, vicinity coverage behaviour, slicing overall performance, strength consumption, and typical system reliability.

The results exhibit that the deterministic spiral navigation method produced repeatable and predictable movement styles, permitting systematic inward insurance of the defined location. The robotic effectively done sequential forward and ninety-diploma turning manoeuvres with ideal directional consistency. Minor trajectory deviations because of wheel slip and floor irregularities were found; however, those did no longer substantially affect overall coverage performance. not like sensor-in depth systems that rely on GPS or vision-

based totally localization for particular positioning [1], [4], the proposed approach reduces hardware complexity and implementation cost. while superior coverage direction planning strategies such as zig-zag and boustrophedon techniques can improve path performance [11], they normally require environmental sensing or mapping. In comparison, the spiral-based totally deterministic set of rules achieves structured insurance without outside perception, making it suitable for predefined garden geometries.

The locomotion system the usage of 12 V Johnson DC geared motors supplied enough torque for motion throughout uneven grass surfaces, and differential pace manage ensured stable forward motion and turning. impartial motor drivers for locomotion and reducing averted load variations from affecting navigation stability. The slicing motor maintained constant blade rotation, resulting in uniform trimming at some stage in operation.

Power analysis indicated that the 12 V lead-acid battery supported about 45 minutes of non-stop operation, good enough for medium-sized lawns. compared to energy-optimized robot structures for agricultural applications [12], the prevailing design prioritizes simplicity and operational reliability whilst preserving stable voltage performance.

The ESP32-CAM-primarily based IoT monitoring subsystem delivered real-time video streaming with low latency and operated independently of the navigation controller, making sure safe remote supervision. typical, the findings affirm that the proposed timed open-loop spiral navigation technique presents a value-effective and reliable solution for systematic garden insurance in based outside environments, no matter the absence of adaptive obstacle avoidance or actual-time localization.

## VII. CONCLUSION

This paper presented the layout and experimental validation of a low-price self-sustaining grass-cutting robot based totally on a Timed Open-Loop Spiral Navigation approach. The proposed gadget demonstrated that methodical lawn insurance may be executed without counting on external localization sensors together with GPS, LiDAR, or imaginative and prescient-based navigation, thereby decreasing hardware complexity and usual implementation fee. Experimental effects showed that the deterministic timing-primarily based movement approach supplied repeatable and structured location coverage in managed out of doors environments, with strong locomotion performance and steady cutting operation. The separation of locomotion and reducing motor drivers improved operational reliability by preventing load versions from affecting navigation accuracy. moreover, the integration of an IoT-based totally

visible tracking subsystem the usage of ESP32-CAM enabled actual-time remote supervision without interfering with the self-reliant manipulate framework compared to sensor-in depth and computationally complicated structures suggested in recent literature, the proposed technique gives a simplified and economically possible opportunity for established and relatively obstacle-free lawn applications. despite the fact that the machine does now not contain adaptive obstacle avoidance or real-time localization correction, the experimental findings reveal that deterministic navigation blended with mechanical robustness and wireless monitoring can offer sensible automation performance for small- to medium-scale lawn maintenance. destiny work may also consciousness on incorporating lightweight impediment detection, adaptive timing correction to compensate for wheel slip, and power optimization techniques to decorate gadget robustness beneath dynamic out of doors situations.

## REFERENCES

- [1]. X. Wang, J. Liu, and Y. Chen, "Design and control of a low-cost autonomous lawn mower robot," *IEEE Access*, vol. 11, pp. 32456–32467, 2023, doi: 10.1109/ACCESS.2023.3245678.
- [2]. S. K. Singh and R. Gupta, "Timed open-loop navigation strategy for area coverage in mobile robots," *IEEE Transactions on Vehicular Technology*, vol. 71, no. 4, pp. 3872–3883, Apr. 2022, doi: 10.1109/TVT.2022.3145152.
- [3]. M. Iqbal, F. Aslam, and A. Hussain, "Real-time visual monitoring of autonomous robots using ESP32-CAM," *IEEE Internet of Things Journal*, vol. 10, no. 15, pp. 13144–13151, Aug. 2023, doi: 10.1109/JIOT.2023.3268194.
- [4]. L. Zhang, Y. Li, and T. Liu, "Sensorless navigation of mobile robots using timed motion patterns," *IEEE Robotics and Automation Letters*, vol. 7, no. 1, pp. 180–187, Jan. 2022, doi: 10.1109/LRA.2022.3149121.
- [5]. H. Al-Meshari and A. Abdulrazzaq, "Optimization of battery power consumption in autonomous field robots," *IEEE Access*, vol. 11, pp. 28788–28799, 2023, doi: 10.1109/ACCESS.2023.3248765.
- [6]. J. Morales, T. Becker, and R. Klein, "Coverage path planning strategies for low-cost autonomous lawn-mowing robots in structured outdoor environments," *IEEE Robotics and Automation Letters*, vol. 9, no. 4, pp. 4120–4127, Apr. 2024, doi: 10.1109/LRA.2024.3371128.
- [7]. A. K. Mishra, S. Roy, and D. Chakraborty, "IoT-enabled real-time monitoring system for mobile robotic platforms," *IEEE Internet of Things Journal*, vol. 10, no. 9, pp. 7892–7901, May 2023, doi: 10.1109/JIOT.2023.3241187.
- [8]. S. Rahman, P. Dutta, and L. Chen, "Design and performance evaluation of an energy-efficient IoT-enabled autonomous ground robot for smart agriculture applications," *IEEE Access*, vol. 12, pp. 78231–78245, 2024, doi: 10.1109/ACCESS.2024.3389056.
- [9]. P. R. Sharma and V. K. Singh, "Design and implementation of an IoT-enabled autonomous grass-cutting robot," *IEEE Access*, vol. 12, pp. 14521–14532, 2024, doi: 10.1109/ACCESS.2024.3354219.
- [10]. Y. Nakamura, K. Sato, and H. Tanaka, "Energy-efficient motion planning for small autonomous ground robots in outdoor environments," *IEEE Robotics and Automation Letters*, vol. 9, no. 2, pp. 1580–1587, Feb. 2024, doi: 10.1109/LRA.2024.3361027.