Turftech: A smart solar powered lawn mower with IoT based remote control

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Abstract: The Internet of Things presents a promising avenue for meeting the demand for highly automated systems with superior efficiency. The study focuses on the lawn mower design and fabrication and evaluates its performance in real-time. The smart lawn mower is designed to maintain the land by clearing unwanted vegetation such as shrubs, grasses, bushes, and more. The machine is equipped with a range of advanced components, including a solar panel, solar charge controller, rechargeable batteries, node MCU, DC motors, motor drivers, servo motors, and an ESP32 camera. The lawn mower is powered by DC motors with solar-powered rechargeable batteries, making it environmentally friendly as it does not emit pollution or noise. To enable remote access and control of the machine, an IoT-based Android app was developed. The control mechanism comprises a movement control in all directions, an on-off mechanism, and a stop function. The camera connected to the model head displays the field view to the user, providing real-time feedback on the machine's performance. The results indicate that the machine is highly effective in clearing unwanted vegetation and maintaining lawns. Overall, the smart lawn mower presents a promising avenue for the development of automated machines for various applications.

Keywords: Android application, grass cutting, IoT, Lawn Mower, Solar Powered.

1. Introduction

People are passionate about being surrounded by natural beauty and often visit places with lush greenery. To create a serene environment, many individuals choose to grow plants and gardens around their homes. Lawn mowers are essential tools for maintaining the greenery around these areas, facilitating the upkeep of a clean and pleasant environment. Previously, grass cutters were manually operated with blades that provided an even cut to the grass. The rotation of the blades produced kinetic energy, allowing for efficient grass cutting. However, nylon strings have replaced blades due to their flexibility and low cost (Nkakini & Yabefa, 2014). Machines are generally powered by either fuel or electrical energy, but to reduce costs, hand-held grass cutters have been fabricated and powered by rechargeable batteries (Sivagurunathan, Sivagurunathan & Chia Jun Hao, 2017). Solar-powered lawn mowers have also been developed, utilizing renewable energy sources that have minimal environmental impacts. A study on the simulation of solar-powered grass cutters considered parameters such as latitude, solar panel specifications, battery size, location, and DC motor, and concluded that these machines can be modelled using PVSYST software (Behera et al., 2022).

The extended use of handheld grass cutters may elevate the hand-arm vibration syndrome risk, which is caused by a prolonged hand operation combined with high forces and uncomfortable positioning, worsened by vibration. To reduce the handle vibration, grass cutters have been designed with tuned vibration absorbers (Tint et al., 2012; Hao & Ripin, 2013; Lowndes, Heald & Hallbeck, 2015). A vibrational behaviour analysis of the lawn mowers was conducted through experimental modal analysis compared with FE modal analysis, demonstrating the importance of a proper selection of parameters such as nylon string length, engine speed, and material selection for the handle to obtain the optimum hand-arm vibration (Bertini et al., 2018; Mallick, 2010). Within the advancement in agricultural machinery, the semi-automated multipurpose machines powered by solar energy was developed with a Bluetooth interface that allows the user to select the preferred

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function to perform various tasks such as grass cutting, seed sowing, fertilizing, pesticide and water spraying, among others (Chadalvada et al., 2021). However, the traditional grass cutting methods such as the cutlass method are inefficient and time-consuming, necessitating the development of the fully automated grass cutting machines. To address this issue, modern energy sources and IoT techniques have been incorporated into the grass cutting tools, resulting in advanced designs that are more efficient and require only minimal human intervention (Chander et al., 2021).

In recent years, IoT-based solar-powered grass cutters have been developed to cut shear grass, controlled via Bluetooth modules, and designed to reduce human labor costs. The use of the solar panel power supplies, Arduino UNO, DC motors, rechargeable batteries, and motor drivers have made the manufacturing costs of these machines more affordable (Balakrishna & Rajesh, 2022). Additionally, the self-governing grass cutting machines have been developed with infrared and ultrasonic sensors, enabling them to detect and avoid obstacles in the lawn. The functional requirements for the automatic lawn mowers include a degree of automation, sensor precision, cameras, and a GPS (Okafor, 2013; Daniyan et al., 2020; Mahadevaswamy et al., 2021; Mori & Swaminarayan, 2021). Characteristics such as portability, durability, ease of handling and maintenance, zero emissions, and continuous working are also crucial for an effective lawn mower design (Nagarajan, Sivakumar & Saravanan, 2017; Sayed et al., 2019).

The smart lawn mowers have various functions, including grass trimming, distance measuring, obstacle evasion, and infrared motion body detection (Babangida, Brahmaiah & Sharm, 2020). The modern lawn mowers also support edge trimming and side cutting, and can be operated in either full autonomous mode or semi-autonomous mode, reducing the level of human involvement (Mhamukar et al., 2019; Olawale & Olajide, 2021). The research on the smart lawn mowers has highlighted the necessity of installing boundary wires around the lawn's perimeter to confine the machine within the designated area and path for grass cutting (Bhutada & Shinde, 2017).

In recent years, several studies have explored the smart and automated lawn mower systems using IoT, renewable energy, and automation technologies. However, most of these implementations either focus on partial automation, lack real-time control, or do not integrate modular features such as camera feedback and solar energy. The system proposed in this paper offers a unique combination of:

- Wi-Fi-based Android control (Uzhavan app) for remote, real-time operation,
- Camera feedback using ESP32-CAM for field monitoring,
- Hybrid energy system (solar + petrol engine) for extended runtime and sustainability,
- High-torque BTS7960-controlled DC motors suited for outdoor conditions.

At the outset, the proposed system overcomes key limitations of existing mowers by offering real-time control, modular features, and hybrid energy, ensuring greater efficiency and scalability.

2. Methodology

The lawn mower is powered by two DC motors that are driven by a solar-powered 24V rechargeable battery which is linked to the solar power panel over a solar panel controller to prevent overcharging during the day and discharging overnight, which could result in battery drain. The voltage is stepped down from 24V DC to 5V DC using a voltage regulator, which is then supplied to the ESP32cam and ESP8266 Wi-Fi modules. These modules are connected to an Android phone using an IP address. The gear motor is responsible for the movements, such as forward, reverse, left, and right, and is controlled by the ESP8266 module. The high-power BTS7960 (motor driver) operates the gear motor. Lawn mower's operation is controlled by a customized Android application. The control panel utilizes direction buttons to manage the lawn mower's movements. The camera module is connected to a servo pan tilt, which is attached to a servo motor for a complete 360-degree rotation. A relay is connected to the petrol engine, which powers up the self-motor. The Android application controls the on-off status of the engine. Figure 1 shows the schematic of the intended lawn mower design.

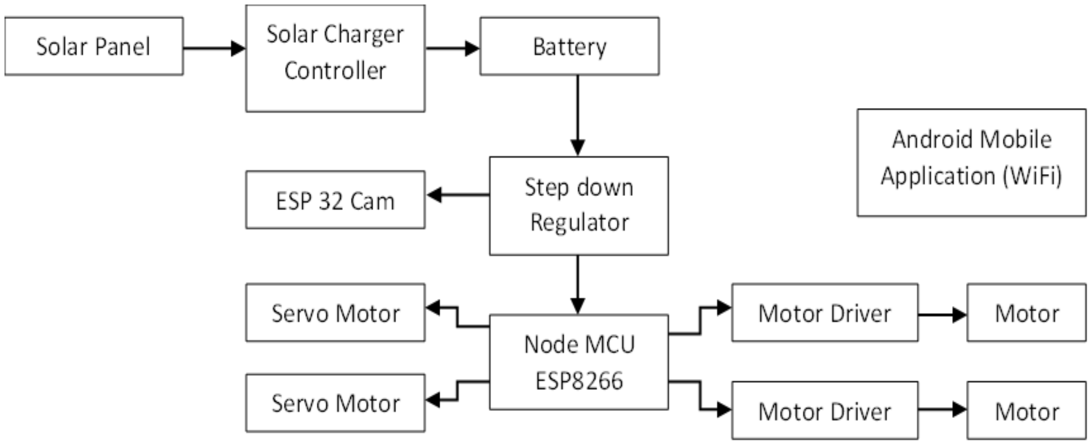

Figure 1. Lawn Mower Block Diagram (*Source: Own Research)*

The projected lawn mower design is environmentally friendly with its use of solar power and rechargeable batteries, reducing carbon emissions and operating costs. The Android application provides a user-friendly interface for controlling the lawn mower's movements and engine, making it an accessible option for the general public. Overall, this design offers a maintainable and resourceful product for lawn maintenance (Behera et al., 2022).

3. Component description

A well-designed lawn mower should be easy to manoeuvre and operate, while also being durable and reliable. The used components work together to create a powerful and efficient lawn mowing machine that can handle even the toughest grass-cutting tasks. The components are:

The sunlight is converted into electrical energy by the **Solar panel**, which powers the system. The solar panel specifications include a power output of 75 watts, with a 22-volt open-circuit voltage (Voc) and a 4.94-ampere short-circuit current (Isc). This setup not only promotes the environmental sustainability, but also ensures the field autonomy and portability. It outperforms lead-acid battery setups in energy density and recharging efficiency.

The solar charge controller manages the charge flow from the panel array to the battery thereby preventing overcharging of both the battery and the panel. The solar charge controller is configured to operate with a specification of 12 volts and 10 amperes.

Node MCU ESP8266 is a micro-controller board equipped with a Wi-Fi module, used in the project for applications related with the internet of everything. It consists of a Wi-Fi module chip, a 3.3V regulator, a logic level converter circuit, a USB to serial chip, and a 4 MB flash memory which offers sufficient storage for program code and data, while the USB to serial chip allows easy programming and debugging of the board. The logic level converter circuit ensures the compatibility with different types of sensors and actuators. The Wi-Fi module chip enables the board to connect wirelessly with other devices, allowing it to function as either a server or a client. It serves as a perfect fit for battery-powered IoT projects. ESP8266 was chosen over Arduino Uno and Raspberry Pi because it **is** cost-effective**,** compact, and power-efficient**,** and it eliminates the need for an external Wi-Fi module—making it ideal for lightweight embedded IoT applications. (Mahadevaswamy et al., 2021). **ESP32CAM** is a compact camera module with a footprint of 40x27mm, specifically designed for IoT applications. Its high-reliability connection with IoT hardware terminals makes it a popular choice for developers working on IoT projects that require a camera module. The ESP32CAM features an ESP32 chip and a 2-megapixel camera, enabling it to capture high-resolution images and videos. It is well-suited for a wide range of IoT implementations including security systems, smart homes, and remote monitoring. ESP32-CAM offers an integrated solution with both processing and connectivity**,** keeping the design simple and low-cost while delivering higher resolution imaging.

The **Motor driver BTS7960** plays a critical role as an interface between the motors and the Node MCU. It enables the Node MCU to regulate the lawn mower's speed and direction. The BTS7960 is a dual H-bridge driver capable of handling a maximum current of 43 amperes per channel, making it an ideal choice for driving heavy-duty motors. Its high current capacity and efficient design ensure reliable and smooth operation of the lawn mower. The BTS7960 is an essential component for achieving precise and accurate control over the lawn mower's movement, providing a safer and more efficient mowing experience. While modules like the L298N are more commonly used and affordable, they can only handle up to 2A and are prone to overheating under heavy loads. BTS7960 ensures reliable performance under load**,** making it better suited for the torque requirements of lawn mowing.

The **Servo motors** are integral to controlling the lawn mower's movement. The servo motors have a small and compact design, with dimensions of 21.5 x 11.8 x 22.7 mm. The operating voltage of the servo motors is between 4.8 V and 6 V, which is compatible with the power supply of the Node MCU. The servo motors' precise and accurate movement enables the lawn mower to traverse intricate pathways and contours, ensuring a clean and efficient cut. The small size of the servo motors also makes them easy to mount and integrate into the lawn mower's design (Mallick, 2010).

The 24V 3000 RPM speed **DC motor** is utilized to power a grass cutting machine. The motor is powered by solar energy and is responsible for driving the wheels to rotate at the specified speed and in the intended direction. Its ability to convert electrical energy into mechanical energy makes it a suitable component for this application. The motor's speed is adjustable by varying the current strength in field windings or by adjusting the supply voltage. With a gear ratio of 1:10 and a stall torque of 2 kg-cm at 12V, this motor offers the necessary power and control required for efficient grass cutting.

The **Frame** of the grass cutting machine plays a vital role in providing stability and support to the components mounted on it. In this project, the frame is designed with the dimensions of 1220x610x750 mm using mild steel as the material of choice. The rectangular rod used in the fabrication process features dimensions of 40 x 20 x 1.6mm. To construct the frame, the rectangular cross-section rod is welded onto a base made of mild steel plate. This provides a sturdy and durable foundation for the grass cutting machine, ensuring that it can withstand the harsh outdoor conditions it is likely to encounter.

The **Chain drive** transmits the power from the motor to the conveyor chain drive. The chain drive consists of a driving gear and a driven gear, with the driving gear being powered by a one horsepower motor. The chain is used to transmit the power, which in turn powers the conveyor chain drive. This setup ensures smooth and efficient power transmission, allowing the grass cutting machine to operate with optimal performance. The use of a chain drive also provides several advantages over other forms of power transmission, including low maintenance requirements and high efficiency.

The **Bearing house** is responsible for supporting and enabling the smooth rotation of the shafts. In this project, two bearings are press-fitted onto a hollow shaft, while a solid shaft is placed inside the bearing to transmit power without any vibration. The solid shaft is turned in a lathe to meet the precise dimensions of the inner diameter of the bearing, ensuring a secure fit and smooth rotation. The bearing housing is then welded onto the frame using the arc welding, providing a sturdy and reliable support structure for the bearings and shafts.

The **Conveyor chain drive** is responsible for driving the conveyor belt and facilitating the movement of the cut grass. It consists of a chain and five gears, including two bull gears and three sprockets. The gears are connected with a long chain, with only one bull gear acting as the driving gear while the other four gears are idle gears. The driving bull gear is welded onto the bearing house and is powered by the motor, while the idle bull gear is welded onto the idle bearing house. The three sprockets are welded onto the frame and rotate freely on a shaft. Together, these components ensure the smooth and efficient driving of the conveyor belt, facilitating the collection and disposal of the cut grass.

The **Two-stroke petrol engine** is utilized to power the grass cutting machine, providing the necessary energy required for an efficient operation. The Two-stroke engines are well-suited to this application, completing one power cycle in a single revolution of the crankshaft. This plan allows for a compact and lightweight engine, making it ideal for being used in the portable grass cutting machines.

The **Drive shaft** transmitting mechanical power, torque, and rotation to the connected drivetrain components is designed to connect the components that cannot be connected directly, enabling the efficient transfer of the power between them. The drive shaft is typically made of high-strength materials such as steel or aluminium, ensuring that it can withstand the stresses and strains of the operation without failure. It is also designed to provide a smooth and efficient power transmission, reducing the friction and wear on the connected components. Due to its importance in the overall operation of the grass cutting machine, the drive shaft is carefully engineered and manufactured to precise specifications, ensuring an optimal performance and reliability.

The **Cutting head** is the business end of the grass cutting machine, responsible for cutting the grass efficiently and effectively. In this project, the cutting head consists of a nylon string, which is well-suited to this application due to its durability, flexibility, and cutting ability. The nylon string is designed to rotate at high speeds, striking and cutting the grass with precision and speed. This design allows for a clean and even cut, ensuring that the grass is trimmed to the desired height and appearance. Additionally, the use of a nylon string as the cutting element offers several advantages over other cutting methods, including reduced noise, vibration, and environmental impact (Tint et al., 2012).

4. Working

The proposed lawn mower design offers a unique and innovative approach to grass cutting, using advanced technologies to automate the process and provide greater control and convenience to the user. The system operates by utilizing a 12V battery supply, which is powered by solar energy, to drive the various components of the grass cutting machine. This includes the ESP8266 and ESP32cam modules, which are responsible for connecting the machine to an android phone via Wi-Fi. Once the connection is established, the user can control the lawn mower drive and view the field through the android application. The control panel of the application provides a range of options, including on-off buttons and movement buttons, allowing the user to operate the grass cutting machine from anywhere with ease. The working of the proposed design is shown as flowchart in Figure 2. This design offers several advantages over the traditional grass cutting methods, including greater convenience, efficiency, and control (Olawale & Sunkanmi, 2021). Furthermore, the use of the solar energy as the primary power source makes this lawn mower design environmentally friendly and sustainable, reducing the reliance on non-renewable sources of energy (Balakrishna & Rajesh, 2022). The Wi-Fi connectivity and android application control integration also showcases the potential for innovation in the field of the grass cutting machines, offering new opportunities for automation and efficiency. Overall, this proposed lawn mower design marks a major breakthrough in the field of grass cutting, leveraging cutting-edge technologies to provide a more effective and convenient solution for maintaining lawns and fields.

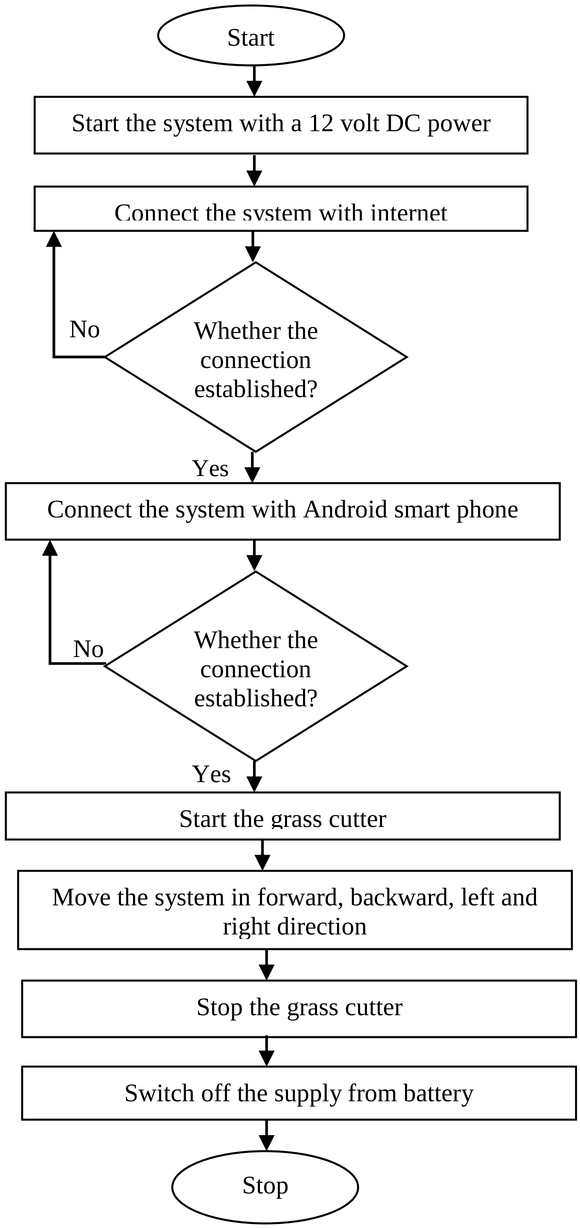

Figure 2. Lawn Mower Working Flowchart (*Source: Own Research)*

5. Design calculation

This calculation is for the design of a lawn mower's transmission system, specifically for the chain and spur gear components. The calculation begins by determining the power to be transmitted (24 W), the driver gear speed (1200 RPM), the driven gear speed (500 RPM), and the centre distance between the two gears (800 mm).

For the chain calculation as shown in Table 1, the transmission ratio (i) the gear ratio is determined by dividing the driver gear speed by driven gear speed, resulting in a value of 2.4. Using this ratio in the driver too, the gear has 27 teeth, and the driven gear is calculated to have 65. The centre distance is then determined based on the maximum and minimum values, and a pitch is selected based on the centre distance. The chain is selected based on the pitch and total load, which is calculated as the sum of the tangential force, the centrifugal tension, and the tension due to sagging. The design load is determined based on the total load and a factor of safety, which is found to be well above the recommended minimum value.

Table 1. Design of Chain calculation

DESIGN CALCULATION Power transmitted N = 24 w Driver gear speed, n_1 = 1200 Rpm Driven gear, n_2 = 500 Rpm Center distance = 800 mm **CHAIN CALCULATION:** **Transmission ratio** $i = n_1/n_2 = 1200/500 = 2.4$ Number of teeth is driving sprocket $Z_2 = i \times Z_1 = 2.4 \times 27$ $Z_2 = 64.8 = 65$ **Center distance** $P_{max} = a/30 = 800/30 = 26.6 = 27$mm $P_{min} = a/50 = 800/50 = 16$mm **Pitch Selection** Selection of the pitch = 25.40 **Chain selection** Selection of chain= 16mm **Total load** $P_T = P_t + P_c + P_s$ $P_T = (1020 \times N)/V$ $V = (Z_1 \times P \times n) / (60 \times 1000)$ $= (27 \times 25.40 \times 1200)/ (60 \times 1000)$ $V = 13.716$ $P_t = (1020 \times 24) / (13.716)$ $P_t = 1784.7$ N	**Centrifugal tension** $P_c = W/g \times V^2 = 7.85 \times 13.71^2$ $P_c = 1475.5$ N **Sagging Tension** $P_s = k \times W_a = 6 \times 77.0085 \times 0.8$ $P_s = 369.64$ N $P_T = P_T + P_c + P_s$ $= 1784.7 + 1475.51 + 369.64$ $P_T = 3629.85$ N Design Load = $P_T \times K_s$ $K_s = K_1 \times K_2 \times K_3 \times K_4 \times K_5 \times K_6$ $K_1 = 1.25$ $K_1=1.25$ $K_2 = K_3 = K_4 = K_5 = K_6 = 1$ Design load = 3629.82 x 1= 3629.85 **Factor of Safety** n = Breaking load/design load n = 195000/ 3629.85 n = 53.72 Recommended minimum factor of safety is 11.77 Calculated factor of safety is 53.72 : Design is safe **Calculation of bearing Stress:** $\sigma = (P_t \times K_s)/ A$ A= 6.3 cm^2= 6.3 x 10^2 mm^2 $\sigma = (1784.7 \times 1)/ (6.3 \times 10^2)$ $\sigma_a = 2.83$ N/mm^2	For n_1 = 1200 mm σ = 2.1 Kgf/ mm^2 = 21 N/ mm^2 Induced shear stress is less then allowable design is safe **Chain Length** l = lp x p $lp = 2ap + ((Z_1 + Z_2)/2) + (((Z_1 - Z_2)/2\pi)^2/ ap)$ $ap = a_0/ p = 800/25.40 = 31.49$ $l_p = (2 \times 31.49) + ((27 + 65)/2) + (((65 - 27)/2\pi)^2/31.49)$ $l_p = 110.14$ $l = l_p \times p = 110.14 \times 25.4 = 2797.59 = 2798$ mm **Centre distance** $a = (e + \sqrt{e^2 - 8m P})/ 4$ $e = lp - ((Z_1 - Z_2)/ 2) = 110.14 - 46 = 64.14$ $m = ((Z_1 - Z_2)/2\pi)^2 = ((65 - 27)/2\pi)^2 = 36.57$ a = 799.82 = 800 mm **Diameter of sprocket** $d_1 = (p/(\sin (180/Z_1)) = (25.4/(\sin(180/27)) = 218.7 = 219$ mm $d_2 = (p/(\sin (180/Z_2)) = 25.4/(\sin(180/65)) = 525.73 = 526$ mm

For the spur gear calculation as shown in Table 2. The material is selected (steel C45), the driver gear teeth number is determined, and it is calculated using the transmission ratio. The initial tangential force is then calculated based on the power to be transmitted, the gear speed, and a factor of safety. The bending stress and the surface stress are then calculated for the gear, and compared to the allowable stress values to determine if the gear is safe to use. Overall, these calculations are important for ensuring that the transmission system of the lawn mower is designed to withstand the forces and loads it will experience during operation, and that all the components are safe to use.

Table 2. Design of Spur Gear calculation

SPUR GEAR: **Material selection:** Pinion = steel C45 Gear = steel C45 (Same Material Used for Both) **I. Number of teeth:** Z1 = 18 Z2 = i x Z1 i= n1/ n2 = 1200/500 = 2.4 Z2 = 2.4 x 18 = 43.2 ≈ 44 **II. Calculation of initial tangential force:** F_t = P/v x ko Assume ko = 1.5 v = πd1n1/ 60 x1000 v = π x 18m x 1200 / 60 x 1000 v = 1.10309m F_t = (24/ 1.1309) x 1.5 = 31.833 x 103/ m N/ mm^2 **III. Initial dynamic load:** F_d = Ft x C_v C_v = (5.5 + (22)1/2) / 5.5 C_v = 1.852 F_d = (58.95 x 103)/m **IV. Calculation of beam strength:** Fs = πmb [σb] y_1 b = 10 mm σb = 135 N/mm^2	y1 = 0.154 – (0.912/Z_1) = 0.154 – (0.912/ 18) = 0.1033 Fs = π x10m x m x 135 x 1033 = 438.11 m^2 **V. Calculation of module** F_s = F_d M^3 = 58.9547/438.11 m = 5.124 Standard module m = 6mm **VI. Calculation of accurate dynamic load:** F_s = F_t + 21V_1 + (C_b + F_t)/ (21V_1 + √C_b + Ft) V1 = π x 18 x 6 x 1200/ (60 x 1000) Ft = (31.833 x10^3) = 5305.5 C = 8150 x e C = 8150 x 0.030 C = 244.5 b = 10 x 6 = 60 F_d = (5305.5 + 21(6.785) (244.5 x 60 + 5305.5))/(21 x (6.785) √(244.5 x 60 + 5305.5) F_d = 141.598 F_s > F_d : design safe F_w = d1 QKb Q = (2 x 2.4)/ 2.4+1 Q = 1.411	Σ_c = 140 N/ mm^2 k = [140]^2 x sin 20 x ((1/2.15 x10^5) + (1/2.15 x10^5))/1.4 k = 0.04454 F_w = 407.26 F_w > F_d design safe Basic dimensions of pinion and gear m = 6mm Centre distance a = m (Z_1 + Z_2)/2 = 6 ((18+44)/2) a = 186 mm Height factor f_o = 1 Bottom clearance C = 0.25 = 0.25 x 6 = 1.5 mm Tooth depth h = 2.25 m = 2.25 x 6 h = 13.5 = 14 mm Pitch diameter d = mz1 = 6 x 18 = 108 = mz2 = 6 x 44= 264 Tip diameter da = (z1 + 2 fo 1 m) da = (18 + 2) 6 = 120mm da = (44+2)6 = 46 x 6 = 276 mm

6. Software programming and integration

The grass cutting machine is operated using the Uzhavan app, an Android application that communicates with the Wi-Fi module present in the ESP8266 (Node MCU). The control unit is developed using the open platform language and programmed using an Integrated Development Environment (IDE). This programming approach enables the Lawn Mower to perform various functions and interact with the user interface seamlessly. Additionally, the interfacing of the app with the control unit ensures that the user can efficiently operate the Lawn Mower with ease. The integration of the software programming ensures that the machine for grass cutting is an efficient tool for maintaining lawns (Mori & Swaminarayan, 2021).

Moreover, the software programming and integration enable the Lawn Mower to perform complex operations, which enhances the safety of the user and the machine. The programming language used in the control unit is flexible, allowing for modifications and upgrades to be implemented effortlessly. The open-platform nature of the language also ensures that the Lawn Mower can be integrated with other devices and platforms easily. The Wi-Fi module present in the ESP8266 (Node MCU) enables the Lawn Mower to be controlled remotely, providing convenience to the user. In essence, the software programming integration ensures that it is not only efficient and safe but also user-friendly and versatile.

7. Fabrication results

The Lawn Mower prototype is a complex system that comprises various electronic and mechanical components such as a Node MCU, a DC motor, a motor driver, a petrol engine, rechargeable batteries, a blade, a solar panel conveyor chain drive, and wheels, among others. These components work together to ensure that the Lawn Mower operates efficiently. The ESP8266, which is one of the critical components of the Lawn Mower, is programmed using Integrated Development Environment software to manage and interface with the designated network. Additionally, the Uzhavan App, which is developed for the android mobile, is used to manage the system.

The wheels of the Lawn Mower are controlled through the movement of the DC motor, which is controlled by the processor. The blade, which is essential for cutting the grass, is powered by the petrol engine. The rechargeable batteries provide power to the ESP8266 and other electronic components, while the solar panel conveyor chain drive ensures that the batteries are charged efficiently. The integration of these components ensures that the Lawn Mower prototype is efficient and can perform various functions such as obstacle detection, avoidance, and user-friendly interface. The use of modern technology in the design of the Lawn Mower prototype ensures that it is easy to maintain, cost-effective, and environmentally friendly (Sivagurunathan, Sivagurunathan, & Chia Jun Hao, 2017).

Figure 3 showcases the top view of the fabricated prototype of the Lawn Mower. This view provides a detailed representation of how the various components are arranged and integrated to form a functional Lawn Mower. The positioning of the electronic and mechanical components is essential in ensuring that the Lawn Mower operates efficiently. The integration of the DC motor, motor driver, petrol engine, rechargeable batteries, blade, solar panel conveyor chain drive, and wheels, among others, ensures that the Lawn Mower prototype is an efficient tool for lawn maintenance.

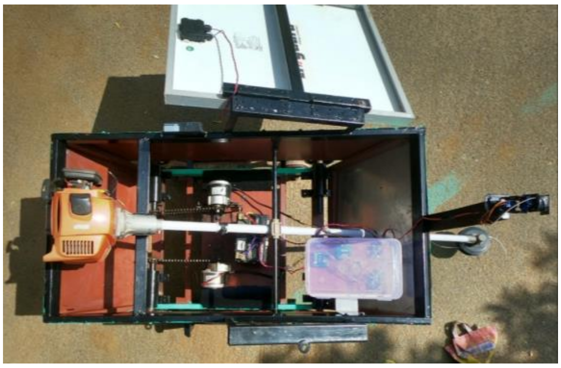

Figure 3. Top View of the fabricated prototype of Lawn Mower *(Source: Own Fabricated Model)*

The Lawn Mower prototype is represented in Figure 4 and Figure 5, which showcase the side view and front view of the fabricated model. These views illustrate how the various components are arranged and integrated to form a functional Lawn Mower. Additionally, Figure 6 displays the view of the field in the developed android application with the control panel, which enables the user to operate efficiently.

Figure 4. Side View of the fabricated prototype of Lawn Mower *(Source: Own Fabricated Model)*

Figure 5. Front View of the fabricated prototype of Lawn Mower *(Source: Own Fabricated Model)*

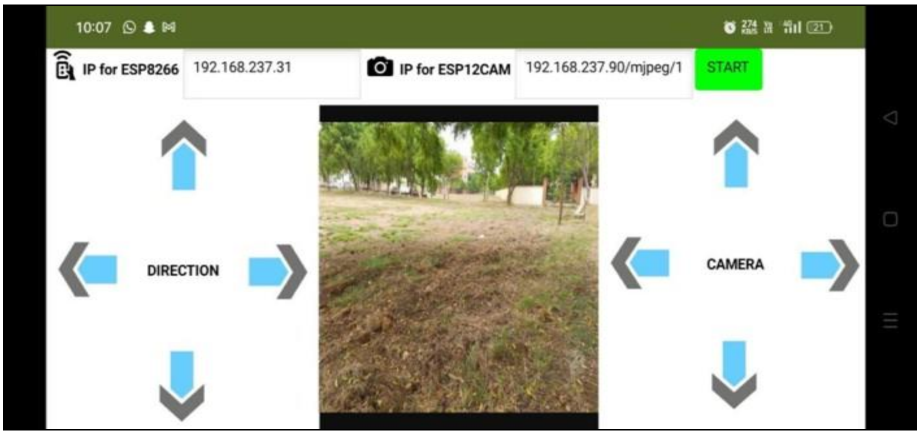

Figure 6. Control Panel of Uzhavan App with camera view *(Source: Own design App Result)*

The fabricated model of the machine prototype is a testament to the effectiveness of the design and the integration of its various components. The views provide a clear understanding of how the system operates and how the user can interact with it. The developed android application with the control panel ensures that the user can effectively control the Lawn Mower, making it an efficient tool for lawn maintenance. This design approach ensures that the Lawn Mower prototype is not only efficient but also easy to use and maintain.

8. Conclusions

The design and fabrication of the mobile app-controlled Lawn Mower prototype have been successfully executed. The integration of the IoT technology, the DC motors, solar-powered rechargeable batteries, and the Uzhavan app has enabled the Lawn Mower to perform various functions efficiently. Usage of the solar energy has made the turfinator eco-friendly and reduced pollution. The designed Lawn Mower prototype is an essential tool for maintaining agricultural land and gardens, and its user-friendly interface ensures that it can be operated efficiently from anywhere with no human observation in the field. The use of electronic and mechanical enhancements has made the machine highly efficient and reliable.

In future, the project can be enhanced by incorporating more advanced features such as GPS tracking and mapping, remote diagnostics, and predictive maintenance. Such enhancements will improve the functionality and reliability of the lawn mower, making it an even more indispensable tool for lawn maintenance. Additionally, the integration of the AI technology can enable the Lawn Mower to learn and adapt to various terrains and grass types, further improving its efficiency and performance. The future scope of the project is vast, and with continued research and development, the Lawn Mower prototype can be improved to meet the evolving needs of the industry.

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