

Development of a Solar-Powered Robotic Lawn Mower

ABSTRACT

Lawn keeping has been a major issue in campus environment due to rising cost of diesel fuel and lack of man power to operate both tractor-mounted and motorized lawn mowers. An automated solar-powered robotic lawn mower was developed in this research work to solve this problem. The components of the mower include a frame, three caster wheels, two gear motors which provide the forward motion, a 12v DC cutter motor which rotates the cutting blade, 2202mAH limpo battery for power supply, a 16W solar panel for charging the battery, a charge controller, a Raspberry Pi 3 B+ microcontroller which controls the motors, and a VNC mobile app for setting inputs for control. The mover was locally fabricated at the Agricultural Engineering workshop of The Federal Polytechnic, Ado-Ekiti, and it was tested in an open field. The effective field capacity and field efficiency of the machine were found to be 0.13 m²/s and 88% respectively. The total cost of producing the mower was 185,800 naira. The mower is recommended for large scale production and for usage on campuses.

Keywords: Solar, Mower, Motor, Mowing, Control, Program

1. INTRODUCTION

Lawn maintenance and landscaping play a crucial role in maintaining clean and attractive gardens and yards. As humans strive to adapt to their environment, they create habitats that are suitable for their survival. The natural environment that humans inhabit is often covered with vegetation, including trees or grasslands (Allie, 2021). As human intellect has evolved, significant efforts have been and will continue to be made to enhance the condition of habitats for various purposes, such as security and aesthetic value.

A lawn mower is a mechanical device designed for cutting grass and maintaining the neat appearance of a lawn or yard. It typically consists of a motor or engine that powers one or more rotating cutting blades. When the mower is pushed or driven across the grass, the blades spin rapidly, effectively trimming the grass to a desired height (Siregar et al, 2018; Bagaihing et al.,2022). These blades could be powered by hand, by pushing the mower forward to operate the mechanical blades, or by an electric motor, solar power, or a small internal combustion engine. Some mowers also incorporate additional functions such as mulching or collecting the grass clippings. There are various types of blades used in lawn mowers. Rotary mowers have a single blade rotating around a vertical axis, while cylinder or reel mowers have multiple blades rotating around a horizontal axis.

There are different types of lawn mowers available to cater for various needs and lawn sizes. Push mowers are manually operated, requiring the user to push them forward to cut the

grass. They are suitable for smaller lawns and offer a cost-effective option. Self-propelled mowers, on the other hand, feature a drive system that propels the mower forward, reducing the effort required by the user. They are ideal for larger lawns or areas with uneven terrain. There are also reel mowers and rotary mowers (Bhaskar, 2015). The most recent innovation is the rotary mower, which research has shown to be more effective than reel mowers due to its cleaner cutting and the option to collect grass clippings. The cutting blade is a critical component of rotary mowers, which typically have openings on the side of the housing for expelling cut grass. Some models are equipped with a grass collector at the exit point. Although the blade is not usually sharp enough to provide a clean cut and may result in brown tips, it is easy to remove, sharpen, or replace. Apart from sharpness of the cutting blade, other factors identified as affecting the performance of a mower include cutting height, frequency of mowing, mowing patterns, clipping and mulching.

Other types of mowers include riding mowers and robotic mowers. Riding mowers are driven like a small vehicle, allowing the operator to sit on them and cover large areas more quickly. There is recent transition from manual or ride-on mowers to automatic electric or solar-powered mowers and emergence of robotic lawn mowers (Vidyalakshmi et al., 2022). A robotic lawn mower is designed to operate either entirely on its own or less commonly by an operator by remote control. Additionally, the inclusion of ultrasonic sensors and light-dependent resistors in a compact and affordable package makes the mower more responsive to its surroundings. With the reduced costs and increased availability of Raspberry Pi and Arduino microcontrollers which provide automation for the mower, traditional lawn mower designs have been monitored and improved upon (Takami and Tajiri, 2018; Pirchio et al., 2018)

Lawn mowers could be powered by electricity or gas. Electric mowers can be corded or cordless, utilizing electricity from an outlet or rechargeable batteries respectively. They are generally quieter and produce zero emissions, making them environmentally friendly options. Gas-powered mowers, on the other hand, run on gasoline or petrol, offering more power and mobility. However, they require regular fueling and maintenance. Solar-powered lawn mowers are superior to those powered by internal combustion engines because they eliminate the emissions associated with internal combustion mowers, which contribute to environmental pollution and the greenhouse gas effect responsible for exacerbating global warming (Tint et al. 2015; Agressianto and Anshory, 2023).

Solar energy is a green and renewable energy source that does not require gasoline refills or the periodic replacement of spark plugs. Solar lawn mowers could be utilised in rural areas where electricity is not readily available. Nigeria, located in a tropical region with abundant sunshine, is an ideal area for the utilisation of solar energy. Therefore, a solar powered robotic lawn mower was designed and developed in this research in order to remove drudgery involved in manual mowing and eliminate environmental pollution caused by the use of gasoline powered mowers.

2. MATERIAL AND METHODS

2.1 Materials

The materials used in the construction of the solar powered mower include the following:

- i. Gear motors: Two gear motors were used to provide forward speed as shown in Fig 1a. The gear motors are supplied with current from the battery. They are actuated by a motor driver which is controlled by the programming code loaded on the Raspberry pi 3 board.

ii. DC motor was used in powering the cutting blade of the lawn mower (Fig 1b). It can operate at a range of 12v to 24v. It has high torque for cutting and resisting obstacles during cutting. The DC motor is powered by direct current from the battery and is also programmatically controlled by the motor driver through the Raspberry Pi board.

iii. Raspberry Pi 3: The Raspberry Pi 3 is a microcontroller that controls the operation of the mower. The DC motor, gear motor, motor driver, battery and switch are all connected to the Raspberry pi 3 board. The Raspberry shown in Fig. 1c is programmed using the Python programming language.

iv. Motor Driver: this is a module that controls the working speed and direction of the gear two motors simultaneously as well as that of the DC motor. This driver is of model L293D and is a 16 pin motor driver IC (Fig. 1d). It provides bi-directional drive currents at voltages from 5v to 36v (Danny, 2019).

v. Battery: A limpo battery model 5500 of 2202mAH capacity was used as the power source for the mower (Fig. 1e)

vi. Frame: This forms the chassis of the mower, in which other component is directly or indirectly attached to. It was constructed by cutting the angle iron into a length of 300mm, 200mm, 206mm, and breadth of 300 mm and height of 200mm. The angle iron were bolted together in order to make the mower portable. The frame is shown in Fig. 1f.

vii. Cutting Blade: A mild steel bar was used for the cutting blade and it was bolted to the DC motor which rotates the blade at a speed of 1000rpm. The cutting blade is shown in Fig. 1g.

viii. Solar Panel: the solar panel provides charging source for the battery in order to ensure continuous power supply to the mower. The solar panel has capacity of 16W and is shown in Fig. 1h.

ix. Charge Controller: A charge controller was used to limit the rate at which electric current is added to or drawn from the battery. It prevents overcharging and also protects against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk.

2.2Method

2.2.1 Design Consideration

The following factors were considered in the design of the solar-powered autonomous mower:

i. Rate of Operation: The rate of operation should be adequate to cover enough area per unit time.

ii. Weight: The weight of the mower should be light in order to reduce the power requirement for forward motion.

iii. Stability: It should be stable and not vibrate during operation

iv. Speed: The speed is limited to 0.5m/s in order for effective operation and control

v. Power: The mower is powered by a rechargeable battery in order to ensure continuous operation for a long time.

2.2.2 Design Calculation

In order to determine the capacity of the battery and solar panel used, the total weight of the machine, the torque required for cutting, torque required for forward motion and the total

power requirement for the lawn mower were calculated to be 67.5N, 6.75Nm, 1.58Nm and 0.27kW respectively.

2.2.3 Power and Control System Design

The power system of the mower consists of a solar panel, charge controller, cooling fan, battery and switch. The raspberry pi, motor driver, and cooling fan are powered by a 5V, 12V and 7V supplied by the battery respectively. Fig. 2 shows the layout of the power system. The solar panel charges the battery through the charge controller. Both the raspberry pi and the motor driver are powered by the battery. The motor driver controls the flow of current to the motors for the control of the forward, reverse, left and right motion. The programming code written in Python loaded on the Raspberry Pi controls the motor driver which in turn controls the motors. A mobile VNC (Virtual Network Computing) server was used as the mobile interface for the mower as it supports Python programming language. The mobile VNC was connected to the Raspberry Pi through WiFi.

2.2.4 Programming Code

The programming code used to control the motors was written in Python Programming Language and is loaded on a memory card inserted into the Raspberry Pi. The Raspberry Pi has 40 GPIO (General Purpose Input and Output) pins. Three of the pins were connected to the motor driver using jumper cables. Each of the pin corresponds to each of two gear and one DC motor on the mower. The Raspberry Pi is connected to an Android Phone through WiFi and a VNC mobile server was used as the graphical interface for controlling the mower remotely. When the mower is started and the Raspberry Pi is switched on, the program for starting and controlling the mower is started on the Android phone and the motors start working to move the mower forward and to rotate the cutting blade. The mower can also be stopped and the direction changed through the phone. The Python code for controlling the mower is shown in Program Listing 1.

Program Listing 1

```
import RPi.GPIO as GPIO
import time

# GPIO pin numbers for controlling the motors
motor_pins = {
    'motor1': {
        'enable_pin': 17,
        'forward_pin': 18,
        'reverse_pin': 27
    },
    'motor2': {
        'enable_pin': 22,
        'forward_pin': 23,
        'reverse_pin': 24
    },
    'gear_motor': {
        'enable_pin': 5,
        'forward_pin': 6,
        'reverse_pin': 13
    }
}

# Setup GPIO pins
GPIO.setmode(GPIO.BCM)
```

```

for motor in motor_pins.values():
    GPIO.setup(motor['enable_pin'], GPIO.OUT)
    GPIO.setup(motor['forward_pin'], GPIO.OUT)
    GPIO.setup(motor['reverse_pin'], GPIO.OUT)

# Function to control the motors
def control_motors(motor1_direction, motor2_direction, gear_motor_direction):
    GPIO.output(motor_pins['motor1']['forward_pin'], motor1_direction == 'forward')
    GPIO.output(motor_pins['motor1']['reverse_pin'], motor1_direction == 'reverse')
    GPIO.output(motor_pins['motor2']['forward_pin'], motor2_direction == 'forward')
    GPIO.output(motor_pins['motor2']['reverse_pin'], motor2_direction == 'reverse')
    GPIO.output(motor_pins['gear_motor']['forward_pin'], gear_motor_direction == 'forward')
    GPIO.output(motor_pins['gear_motor']['reverse_pin'], gear_motor_direction == 'reverse')

# Example usage
try:
    while True:
        # Forward motion
        control_motors('forward', 'forward', 'forward')
        time.sleep(1)

        # Reverse motion
        control_motors('reverse', 'reverse', 'reverse')
        time.sleep(1)

        # Turn left
        control_motors('reverse', 'forward', 'forward')
        time.sleep(1)

        # Turn right
        control_motors('forward', 'reverse', 'reverse')
        time.sleep(1)

        # Rotate gear motor clockwise
        control_motors('stop', 'stop', 'forward')
        time.sleep(1)

        # Rotate gear motor counter-clockwise
        control_motors('stop', 'stop', 'reverse')
        time.sleep(1)

except KeyboardInterrupt:
    # Stop motors and cleanup GPIO
    control_motors('stop', 'stop', 'stop')
    GPIO.cleanup()

```

2.2.4 Operation and Testing of the Mower

The mower components were assembled and the final assembly is shown in Fig. 3. The testing operation and testing of the mower was carried out in an open field. An area of 10m by 1m was marked for the test operation. The mower was programmed and operated to mow an area of 1m by 1m and the operation was done in 10 trials. The time spent in mowing for each of the trials was recorded. The effective field capacity and field efficiency was calculated for each of the trials.

3. RESULTS AND DISCUSSION

The test result is shown in Table 1. It was observed that there was a little vibration of the mower during the test because of unevenness of the land. Some grasses were not properly cut because the blade was not sharp enough. The result obtained from the test carried out shows that the mower was able to carry out the cutting operation of a 1m² lawn area for an average of 7.58s. It was able to cut the total area of 10m² for 75.8s. The effective field capacity and average field efficiency of the mower obtained from the test operation were calculated to be 0.132m²/s and 88.01% respectively.

4. CONCLUSION

A solar powered robotic lawn mower has been designed, fabricated and tested. The machine is easy to operate and maintain and its efficiency of the mower was found to be satisfactory. The total cost of production is N185,800.00. It can then be concluded that the solar powered robotic lawn mower give the user the ability to cut their grass with minimal effort.

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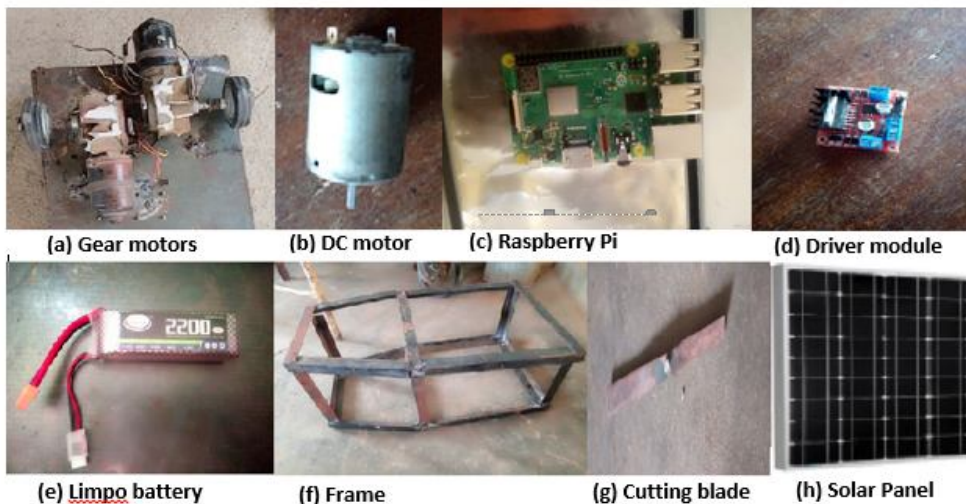


Fig. 1: Mower Components

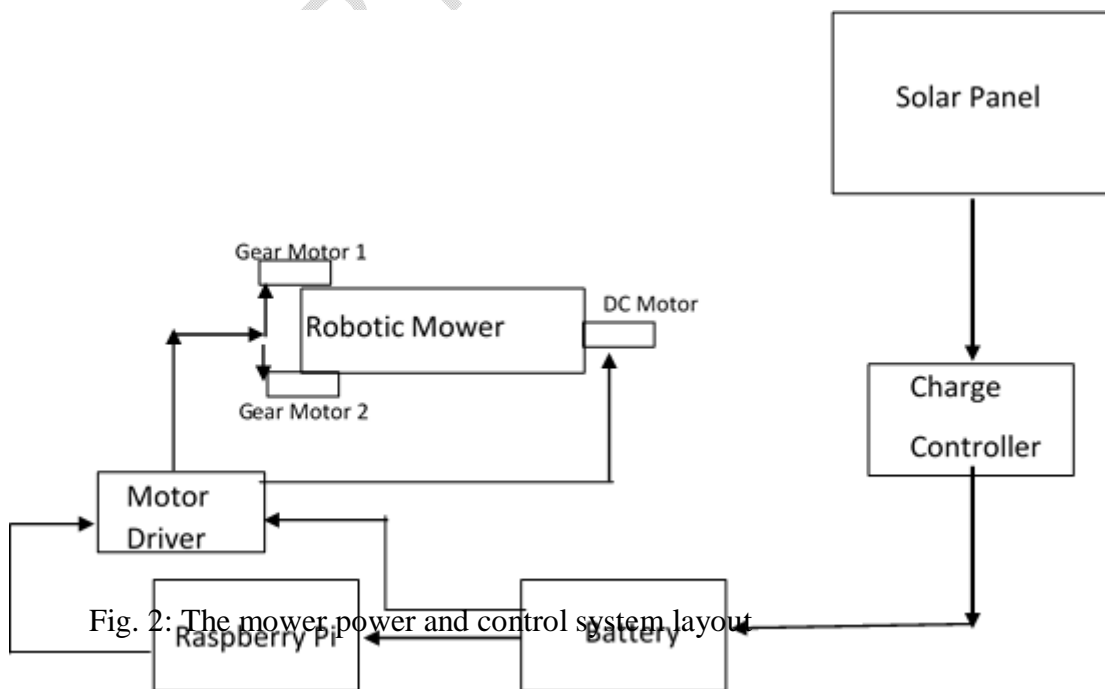


Fig. 2: The mower power and control system layout



Fig. 3: The constructed mower

Table 1: Cumulative result of mowing

| Mowing Trial | Area (m ²) | Time Mowing (s) | Effective Field Capacity (m ² /s) | Theoretical Field Capacity (m ² /s) | Field Efficiency (%) |
|----------------|------------------------|-----------------|--|--|----------------------|
| 1 | 1 | 7.20 | 0.1389 | 0.15 | 92.60 |
| 2 | 1 | 7.80 | 0.1282 | 0.15 | 85.47 |
| 3 | 1 | 8.00 | 0.1250 | 0.15 | 83.33 |
| 4 | 1 | 7.60 | 0.1316 | 0.15 | 87.73 |
| 5 | 1 | 7.50 | 0.1333 | 0.15 | 88.87 |
| 6 | 1 | 7.60 | 0.1316 | 0.15 | 87.73 |
| 7 | 1 | 7.60 | 0.1316 | 0.15 | 87.73 |
| 8 | 1 | 7.60 | 0.1316 | 0.15 | 87.73 |
| 9 | 1 | 7.40 | 0.1351 | 0.15 | 90.07 |
| 10 | 1 | 7.50 | 0.1333 | 0.15 | 88.87 |
| Average | | 7.58 | 0.1320 | 0.15 | 88.01 |