American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

A Wireless Semi-Humanoid Solar Powered Robomower

Victor O. Matthews[a], Etinosa Noma-Osaghae[b]*, Uzairue Stanley Idiake[c], Segun I. Popoola[d]

[a,b,c,d]*Department of Electrical and Information Engineering, Covenant University, Ota, Ogun State, Nigeria*

[a]*Email: victor.matthews@covenantuniversity.edu.ng*

[b]*Email: etinosa.noma-osaghae@covenantuniversity.edu.ng*

[c]*Email: stanley.uzairue@covenantuniversity.edu.ng*

[d]*Email: segun.popoola@covenantuniversity.edu.ng*

Abstract

Robotic lawn mowers have come to stay. The ease with which lawns and fields can be maintained without any human input is mind-blogging. As technology improves, the complexity and diversity of robotic lawn mowers keeps pushing into realms only imagined in the immediate time past. But in this age of interconnected things and interwoven thinking, there is a strong push for greater convenience, especially when distance becomes an impediment to getting domestic tasks done. This paper proposes a convenient way of maintaining lawns in absentia. It details the design and construction of a smart Robomower affixed with a wireless surveillance camera and enabled by the power of interconnected things. This represents a radical shift in lawn mowing. The novel wireless surveillance camera on the implemented smart Robomower makes it possible for owners of lawns to maintain them via the internet at all times, especially in absentia.

Keywords: Surveillance; Camera; Wireless; Green Energy; Gardener; Mower; Smart; Lawn, Grass; Motors; Internet of Things.

1. Introduction

Beauty has been said to be in the beholder’s judgment and a function of the amount of effort that have been directed toward achieving it. In residential, commercial and a host of other premises, trimming lawns to prevent grass and flower overgrowth is a norm. Before now, lawns were trimmed manually. This was a very laborious task [1,9].

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* Corresponding author.

But with the advent of simple machines like the Gear, mowing lawns became much easier. Advances in science and engineering later brought more efficient and powerful lawn mowers to the lawn care market. A great variety of tools exist in the market today for intensive lawn care and virtually everything that was done manually is now fully or partially automated.

Today, the world is moving with a break-neck speed towards a highly inter-connected world of things. The boundless nature of the internet is now being explored as a means to connect all devices anywhere in the world. This reality has a very far-reaching consequence. Automation would spike to a new all-time high as devices become remotely controlled and physical distance becomes less of an impediment. Convenience is taking a new dimension. With almost no effort, things that usually take so much energy and time to get done are being tackled and executed with finesse and dexterity by “convenience machines”[2,10]. One of those “convenience machines” that help users mow their lawns even when they are not at home is the subject of this work. Lawn care becomes possible regardless of the users’ distance from home.

This paper proposes the use of the power of interconnected things to create a smart Internet of Things (IOT) enabled Robomower with a virtual human control using wireless surveillance camera. The main objective was to use the internet as a means of sending information for the control of a solar powered, Robomower (lawn Mower). A surveillance camera was employed to give a real-time view of the lawn while remotely controlling the Robomower. Any user, from anywhere in the world can control the Robomower via a thumb joystick, a monitor and the internet [11].

To the best of our knowledge, there is no Robomower (Lawn Mower) that offers users the convenience of remote control via the internet and real-time views of the lawn with a wireless intelligent surveillance camera [12]. When users are away from home for an extended period of time, the lawn becomes overgrown with weeds. The inclusion of a wireless surveillance camera to give real-time views of the lawn to users who can remotely control the solar-powered Robomower, makes this work novel [13]. This paper improved on existing models of lawn mowers by giving users the benefit of “convenience” in lawn care while being miles away from their lawns. The designed and constructed prototype worked very well without any hitch [14].

2. Related Works

Sujendran and his colleagues, designed a path planning algorithm for a Smart Lawn Mower [3,15]. The plan considered the minimum in terms of energy and time to trim a given field area. The goal of the lawn mower design was to obtain a design plan that optimized energy and time simultaneously. The authors considered a variable, k, which is the number of turning operation to gauge the difficulty with which the designed lawn mower would trim grass. Mathematically, this was expressed as:

$$Difficulty = (B_w D_w - 1)d + \pi(D_w - 1)\frac{d}{2} + \left[\left(\frac{\pi}{2} - 1\right)k + \left(\frac{\pi}{4} - 1\right)(2D_w - 2k - 2)\right]d \qquad (1)$$

Where;

$d = 10800\pi R_{earth}$

$L_1 \rightarrow$ Length of working area

$L_w \rightarrow$Width of working area

$d \rightarrow$Straight navigation distance

$R_{earth} \rightarrow$Radiusof the earth

In getting the mowing power, the authors assumed that the power expended in mowing a given area is proportional to the distance the mower has to move and it was expressed as:

$$P = P_0\left[(B_w D_w - 1)d + \pi(D_w - 1)\frac{d}{2} - \left(2 - \frac{\pi}{2}\right)D_w d + \pi d + kd\right] \qquad (2)$$

Okafor and his colleagues gave a detailed design of a solar powered lawn mower that can be used effectively for domestic lawn mowing [4]. The designed lawn mower could cover an area of 552m^2 before the battery runs out. The authors declared that the strength of the grass determined the amount of power that would be expended by the lawn mower in trimming the grass. The authors specially designed the mower for tropical areas in Africa that have extended lengths of sunshine. The elimination of the need for gasoline was the main hallmark of the designed lawn mower.

In [5,16], a portable and automatic weed cutting device was designed. The objective of the authors was to design a weed cutting device that works without the need of a human controller. The authors made use of solar panels and batteries to power the designed weed cutter. The authors claimed that the designed portable weed cutter could cut weeds in agricultural settings with very little human input. The designed weed cutter uses an infra-red sensor to detect and avoid static and dynamic obstacles.

Vaikundaselvan and his colleagues designed an autonomous lawn mower that uses ultrasonic sensors to sense the presence of dynamic and static obstacles [7,17]. The designed mower was a robotic model that used an array of sensors to stay on the field or within the lawn. The prototype was specially created to be safe and efficient to use. The designed system uses a radio frequency module to achieve the remote control capabilities of the lawn mower. A set of relay triggers the appropriate control action sent by the remote controller.

A Solar Based Wireless Grass Cutter that is autonomous and remote controlled was designed in [8,18]. The authors made use of a keyboard with eight buttons to carry out the remote control function of the lawn mower. A radio frequency module provided the means to control the lawn mower remotely. An Ardruino board with an embedded microcontroller provided control functions for all aspects of the lawn mower’s operation [19].

3. Method and Materials

3.1. Main Features of the Implemented Smart Robomower

Table 1: Features of the Implemented Smart Robomower

Part	Feature
Motor	Squirrel cage induction motor
Motor Control	Pulse width modulation drive
Battery	12 Volts, Nickel Cadmium
Wireless Module	Ethernet enabled
Solar Panel	240 Watts, 13.5A
Wheels	Customized rubber wheels
Camera	Wide area wireless surveillance camera with obstacle sensors
Graphical User Interface	Web application
Power	36Volts, 5Volts
Blades	Rotary
Body Frame	Fabricated

3.2. The Block Diagram of the Implemented Smart Robomower

Collision with obstacles in the vicinity of the work area is very probable. This is due to the latency (time delay) between the remote control centre and the Robomower. To overcome this issue, the Robomower's wireless surveillance camera was equipped with an obstacle sensor (optical) that enables it to automatically avoid collisions with obstacles.

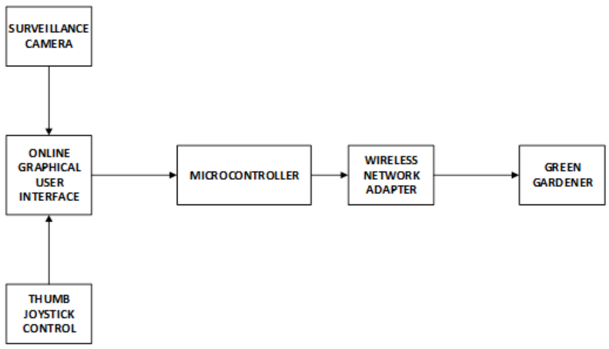

Figure 1: Block Diagram of the Implemented Robomower

3.3. Remote Control Command Side

Based on the labels on the circuit diagram, the parts are as follows:

- The main processor, an 8-bit microcontroller (PIC18F2620) coordinating the entire process.
- The controller side of the Robomower connects to the computer via a Bluetooth link. The computer remotely connects to the Robomower via the internet. The Wireless-Fidelity Module of the Robomower picks the control signal coming to it via the internet from the remote controller and executes the command received.
- A thumbwheel joystick which is basically two potentiometers placed in the X-Y direction.
- An Active-Low serial in parallel out LED driver

- LED indicators to show the pre-set speed level.
- A DC-DC converter to supply 5V power to the circuit.
- Push Buttons
- Adapter point for connection of in-circuit serial programmer.
- LED indicators to show the direction of the motors

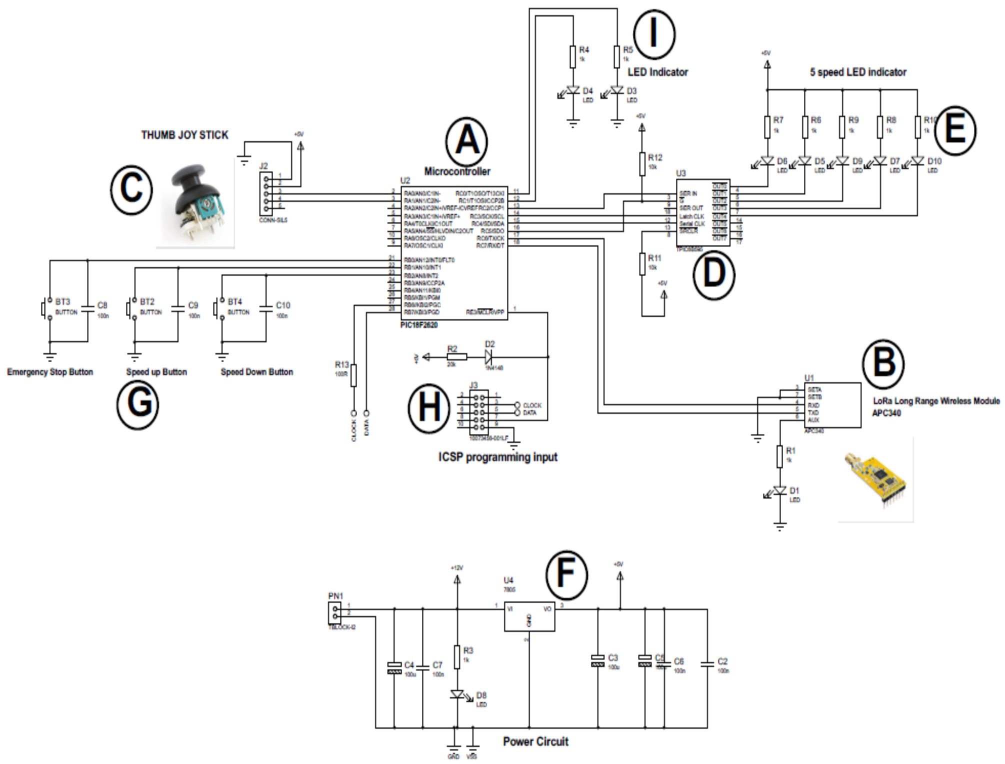

Figure 2: Circuit Diagram for Robomower's Controller

3.4. Working Principle

The thumb joystick is used to encode position. The thumb joystick is basically two potentiometers placed in the X-Y direction. These potentiometers slide with a resistance track range. Minimally, three points are available: the two extreme ends of the track range and the centre point (Joystick at rest). The two extreme track ends is used to encode and signify the movement and direction commands respectively (FWD, REV, LEFT, RIGHT) while the centre points is used to encode and signify the no movement commands (NULLMOV, NULLDIR). Based on the slide position on the resistance track, movement and direction command codes are sent to the robot controller serially by UART via the RF module. The encoding is done using Analogue-to-Digital conversion within the processor.

- FWD: move forward

- REV: move backward

- LEFT: turn left
- RIGHT: turn right
- NULLMOV: No movement either forward or backward
- NULLDIR: No movement either left or right

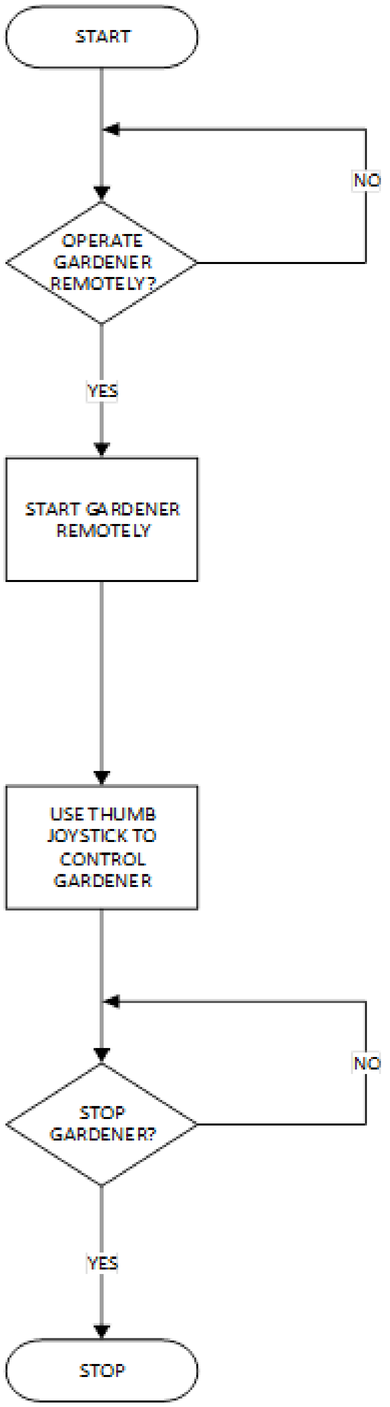

Figure 3: Flowchart of Semi-Humanoid Robomower

The pushbuttons G are used to activate the control commands. The keys pressed are detected and the proper serial command sent serially through the internet. The speed value is adjusted (increase or decrease) by push buttons. The LEDs indicate the speed level. There are 5 speed levels.

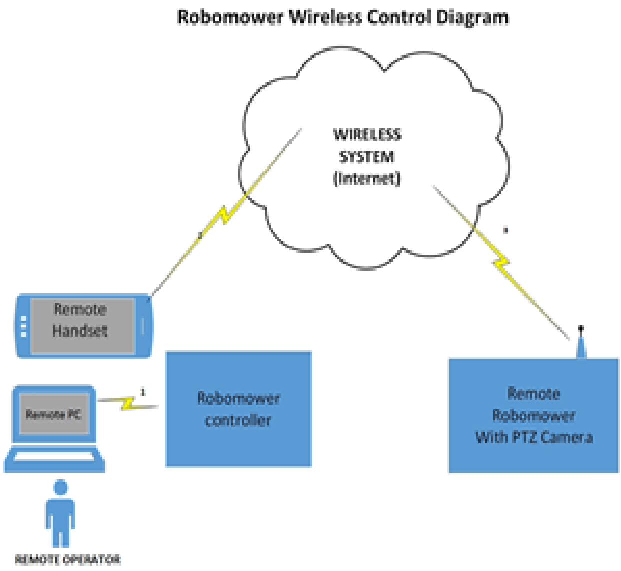

Figure 4: Robomower's Wireless Control Model

3.5. Algorithm for the Implemented Smart Robomower

STEP 1: Initialize online connection between remote control location and the Smart Robomower.

STEP 2: Initialize Graphical User Interface.

STEP 3: If the Robomower is to be operated remotely

GO TO STEP 4

ELSE STEP 1

STEP 4: Start the motor of the Robomower remotely

STEP 5: Use thumb joystick to control Robomower

STEP 6: Stop the Robomower

ELSE STEP 5

STEP 7: Stop

3.6. The Smart Robomower's Design Analysis

The Rotary Blades – Cutting force.

$$force = \frac{Shaft\ Torque}{Radius\ of\ Cutting\ Blade}$$

$$Shaft\ Torque = \frac{Power\ developed\ by\ shaft\ \times 60}{2 \times \pi \times Shaft\ Speed}$$

$$Blade's\ Radius = 0.312m$$

$$Shaft\ Speed = 50\ revolutions\ per\ minute$$

$$Supply\ Voltage = 36\ Volts$$

$$Power = 24\ Watts$$

$$Blade's\ Area = 0.52m \times 0.06m = 0.0312m^2$$

$$Blade's\ Volume = Thickness\ \times Blade's\ area$$

$$= 0.0312m^2 \times 0.006m = 1.872 \times 10^{-5}m^3$$

$$Steel's\ Density = 7922Kg/m^3$$

$$Blade's\ Mass = Steel's\ Density \times Blade's\ Volume$$

$$= 1.872 \times 10^{-5}m^3 \times 7922Kg/m^3 = 0.148Kg$$

$$Blade's\ Weight = Mass \times Acceleration\ due\ to\ gravity$$

$$= 0.148 \times 9.18 = 1.36N$$

$$Blade's\ Turning\ Torque = Blade's\ Weight\ \times Blade's\ Radius$$

$$= 1.36 \times 0.312 = 0.424Nm$$

The Robomower's Battery Size

$$Power = \frac{Voltage \times Current}{Power\ Factor}$$

$$Current = \frac{Power\ Factor\ \times Power}{Voltage}$$

$$= \frac{24 \times 0.8}{36} = 0.53Amps$$

The battery size taken was $75Ah$ at $36Volts$

The designed Robomower, control interface and web application are illustrated by Figures 5, 6, 7 and 8.

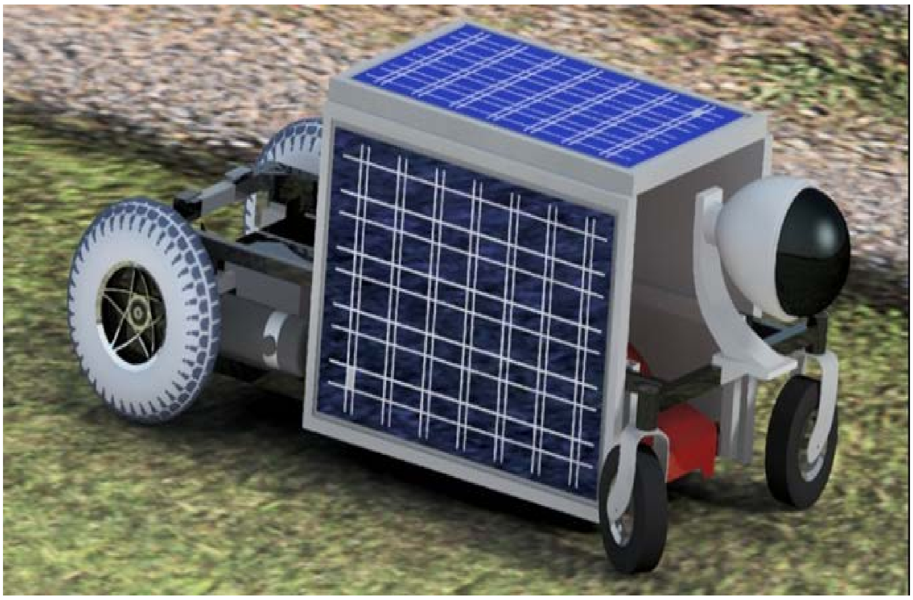

Figure 5: The Smart IOT Enabled Robomower with a Virtual Human Control using Wireless Surveillance Camera.

Figure 6: The controller of the Robomower

Figure 7: Side View of the Robomower's Control Panel

Figure 8: An Illustrative Portrayal of the Robomower's Camera View via the Internet

4. Design Evaluation

$Standard\ Coverage\ Area = 20m^2$

Table 2: The Robomower's Time and Battery Drop Relationship

Type of Grass	Time(s)	Battery Drop (V)
Guinea Grass	0.14	300
Carpet Grass	0.25	420
Annual Grass	0.56	515
Perennial Grass	0.71	575

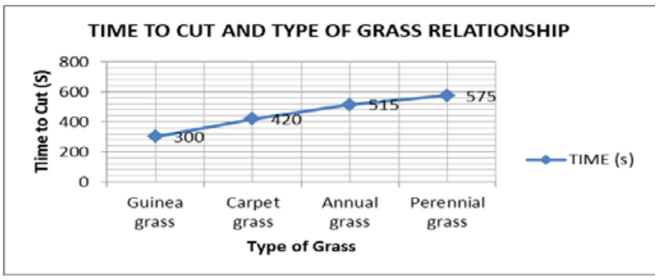

Figure 9: Time to Cut and Type of Grass Relationship

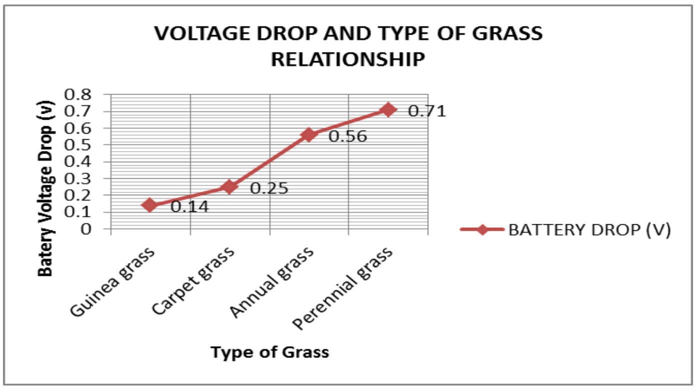

Figure 10: Voltage Drop and Type of Grass Relationship

The plot in Figure 9 shows that tougher weeds/grasses cause greater voltage drops across the battery terminals of the implemented smart Robomower. From the plot, perennial grasses being the toughest caused the highest voltage drop across the terminals of the smart gardener's battery. Perennial grasses also take a longer time to cut than all other grasses as shown in Figure 10.

5. Conclusion

The aim of designing and constructing a smart IOT Based Robomower that can be controlled remotely via the internet and with the aid of a wireless surveillance camera was achieved satisfactorily. The possibility of independent control the Robomower would be explored in later experimental designs.

Acknowledgements

This paper was sponsored in part by Covenant University, Ota, Ogun State, Nigeria.

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