



DESIGN AND DEVELOPMENT OF AN AUTONOMOUS SOLAR POWERED LAWN MOWER

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Abstract The cost implications and the stress involved in keeping our public and private residence clean at all times is becoming too high that even the rich, government and non-governmental organization finds it difficult to achieve. As a result of these, our environments are becoming largely unkept, this therefore encourages dangerous reptiles to cohabit with man because of the bushy nature. Again, the availability and the reliability of the existing Lawn mower is not guaranteed due to the high cost of maintenance, inadequate skilled man power, and lack of spare parts for repairs. This work is therefore aimed at designing and developing a Lawn mower that is capable of carrying out clearing task, avoid obstacles during operations and powered by sunlight. An easy to operate lawn mower, low maintenance cost with little or near zero man machine interface was conceived, designed and developed. For the purpose of this work, materials were sought locally in line with the requirements of the task of clearing a fairly overgrown grasses. Design calculations were carried out to aid material selections in line with engineering best practices. Finally, an autonomous lawn mower capable of cutting grasses using energy from the sun was designed, developed and tested. Our result showed that this machine so developed, cuts grasses effectively and efficiently with ease, sense and avoid obstacles close to it during operations and operate with little or no human supervision. It is therefore our view for government to scale up the manufacture of this machine so that our environment will be clean again, thus avoiding the huge effects of untidy, unclean and disease infested surrounding that will negatively affect our economic and health status as a nation.

Key words: mower, autonomous, environment, solar, man

Introduction

The elderly, the disabled and the abled body young men do not feel comfortable mowing grass manually using a lawn mower despite the need for them to mow them, because of the stress involved. Therefore, for this reason lawn mowers were developed. Initially, these mowers were designed for manual operations, but with the increase in the technological advancement of electromechanical power control and automation that, autonomous lawn mower were created. It eliminates the element of man power interaction in cutting grass.

Autonomous lawn mower are intelligent machines capable of performing tasks in the world by themselves, without full involvement of human control and it includes the knowledge of Mechanical, Electronics, Electrical and Computer Science Engineering. The lawn mowing technology employs a blade that rotates to cut the grasses on the lawn at an even height (Daniyan et al., 2019). The problem associated with manually cutting of grass are as follows: longer time span for mowing large lawn, limited flexibility of the mower operation due to

external power source and frequent high maintenance cost and wear and tear of mechanical parts (Chouhan et al, 2017) and as a result of this, there is a call for automation in the mowing of lawn in the society today. The background of this project lies in the discomfort that manual lawn mower brings to elderly and young people. The stress caused by these act leads to frustration as moving the lawn mower with a standard motor is stressful, and the operator does not take pleasure in it. Some mowers with heavy engines create pollution due to the combustion in the engine. Motor powered engines require periodic and other maintenance activities such as changing the engine oils, greasing and many more (Varsha et al. 2018). Technologies have brought about available chips on system and this could make the mower automated by reducing size, and cost of DC motors by making the system independent of fossil fuels to be able to make use of renewable energy. While ultrasonic sensor, PIR sensor and light dependent robot could make the autonomous lawn mower recognize its surroundings (Fernandez and Vijayakumar, 2018). The purpose of this device is to maintain fast mowing process by eliminating time delay that usually accompanies

manual lawn mowing process. The design and construction of the solar powered autonomous lawn mower would solve the problem of manual labor and danger likely to be encountered in manually mowing the lawn and decrease air pollutions to the environment as an innovation of existing technology. Optimizing the use of gasoline powered lawn mower and replace it with solar powered autonomous lawn mower is a justifiable need for the event of mowing. The solar powered autonomous lawn mower, automatically mow grass in a lawn to an even height using revolving blades. It equally navigates within the space of the lawn without colliding with obstacles on its way. To understand what autonomous lawn mower is we need to know what autonomy means first. According to the Merriam-Webster dictionary, autonomy means: the state of existing or acting separately from others; the power or right to govern itself. This implies that an autonomous lawn mower also needs to have intelligence, i.e. the ability to act separately on its own. In this sense autonomous is similar with self-driving. So we can refer Autonomous lawn mower as self-operating mower on a lawn. A lawn is an area full of grasses while a mower is a person or machine that cuts high grasses on the lawn. Autonomous devices can detect their surroundings using radar, Lidar, GPS, odometer, and camera-enabled computer vision. This section illustrates the existing related system with orderly literature review of various related work that have been done in the past as so many related researches has been done in lieu to this research project, a very relevant ones are discussed below:

As in (Patel et al. 2016) a portable, durable and easy to operate mower was designed. The researcher in his work studied different paths before coming up with a plan so the mower can work with minimum time and energy in the various paths that was studied before coming up with the design. The paths considered in this work includes a square path and a spiral path which was now preprogrammed in an Arduino Uno R3 microprocessor which controls the operation of the mower. Finally, the researcher made the mower in such a way that it could operate on three-way path by combining the square path and spiral path to make it the third path but this research is limited in a way that only a bump sensor was utilized to sense an obstacle on its path rather an ultrasonic sensor which should have been taking into consideration to also avoid stationery obstacles.

Furthermore (Neha, 2018) designed and constructed an automated grass cutter robot based on internet of things specifically for agricultural purpose to aid farmers that uses hand help devices and grass cutter that uses petrol engine for cutting grass in the farm.

The researcher used an Arduino Uno microcontroller and other embedded system with a linear blade for cutting grass combined with a motor drive for the wheels of the robot. The major drawback of this work was that it needed a separate person to operate the robot which makes it not fully automated.

(Nimkar et al. 2017) In his research first of all reviewed different technological developments for making efficient and cost effective lawn mowers. After which effort was made to modify the old mower by improving its usability. As a way of improvement to old mower the researcher made the overall geometry smaller and lighter. Adjustable cutting motor height was introduced in this work for better mowing of grass at intricate locations.

(Ojo and Oluniyi, 2018) Designed and constructed an autonomous lawn mower from locally sourced materials. In their work the lawn mower body was first designed with Autodesk Inventor to give an idea of how the robot will look like. The electronic parts were later taken into consideration. First, the researcher thought of how to power the lawn mower and came up with the idea of charging its battery from the sun even while it is at work and can also be charged directly from the electrical power source. Either ways, the battery required to power the whole system must be charged. This research work has some limitations which include the humidity sensor being unable to differentiate between the humidity of grass and the floor in cases where the floor is wet and also the PIR's range of sensing is really high, as this might make the mower not work with any living thing on the lawn.

(Tanaji et al. 2018) proposed an automated mower robot for the purpose of reducing the manpower and usage of electricity. The system control for this work was done by the Schmitt trigger circuit. The grass cutter and vehicle motors were interfaced to a Schmitt trigger circuit that controls the working of all the motor.

(Mathias et al, 2017) In his work, discussed a prototype autonomous lawn mower with camera-based non-contact obstacle avoidance. Their work consisted color cameras and an ARM-based processing board, which can be incorporated to an autonomous lawn mower with little effort.

(Abhishek et al. 2014) Constructed an autonomous vehicle for cleaning purpose using microcontroller and also an obstacle sensor in form of IR sensor in order to avoid obstacle in its path. More than two infrared sensor was used in the construction of this work, by placing at the four corners of the robots to detect obstacle. When an obstacle is detected the microcontroller controls the wheels of the robot by a motor driver to avoid a jam. In this research they went ahead to introduce a vacuum cleaner on the robot for

cleaning process. Their work was powered by a 12V rechargeable battery.

(Okafor et al. 2016) Designed and developed domestic solar powered lawn mower of 0.13 m²/s field capacity for operational convenience. In this research work a twin solar panel of 75A/130W capacity each, which charges the battery of the mower was utilized. The mower was designed in such a way that the solar panels were connected in series to an improvised charge controller incorporated to prevent complete discharge or overcharge of the battery. The lawn mower has its cutting blade attached to a 2.1kW, 24V DC electric motor, driven by two 12 volts, 75AH lead accumulators connected in series. The findings from this research showed that the mower was able to carry out the mowing process neatly.

(Wilko et al, 2018) reviewed and provided an overview of recent trends and challenges in the area of intelligent and autonomous vehicles. They focused on planning, and decision-making for autonomous vehicles by improving its functional capabilities, with several prototypes already driving on our roads and streets. The planning methods considered in this work provides safe and system compliant performance in complex, cluttered environments while modeling the uncertain interaction with other traffic participants are required.

Going further (Rickel, 2019) designed a robotic lawn mower that was self-guided without a need for human directional control. This autonomous lawn mower was constructed using a standard self-propelled lawn mower as its base with the design taking into consideration the ability of the mower to mow a 20 by 20 feet of within a time frame a human can achieve such task. The limitation of this work is that a user interface which makes it not completely autonomous was factored into their design to manually start the machine and a remote to switch it off.

In (Krasniqi, 2016) teamed up with another researcher to examine the market and technical trends of autonomous vehicles starting from the early used car to those that are fully autonomous, the importance of internet of things in driving this autonomous car. In this work the researcher went further to examine the key issues and challenges faced by the industry where autonomous vehicles are being produced. The demerit of this work was that the researcher only analyzed and looked at the internet of things technology as a driver for Autonomous vehicles with the focus on market trends of this technology and the trends of Autonomous Vehicles ecosystem without implementation. They only pointed out that the potential of this ecosystem is huge and that it will transform the automotive industry immensely. From the researcher's perspective of this ecosystem, 2020 is

seen as the target timeframe by which autonomous cars will be seen on roads.

Finally, (Ibe, 2017) Designed a hand-held grass mowing machine which is a petrol powered machine with rotary blades for cutting grass on lawn by using locally available materials when designing the machine. The researcher considered strength, durability, ease of assembly and disassembling when designing the machine. This machine saves both energy and time, which is not so with the manual and push able mowing methods, thereby providing greater and flexible mobility.

Based on findings from previous and related research done in the past, it was observed that most of them were limited in one area or the other. But this research project is a huge modification of (Ojo Damilare, 2018) work as the material to be used are going to be locally sourced for but will make use of both the bumper sensor and ultrasonic sensor so the mower do not only detect bump on its way but also detect and avoid obstacles aside bumps. This project made use of light weight metal as a medium of chassis and the power source will be compensated with an on board solar panel so that the autonomous lawn mower will have steady and constant power supply for effective operation and the blade that will be used on the cutting deck shall be improved to make it time efficient compared to previous research.

Materials and methods

The hardware of this system includes a programmable robot which is programmed to navigate the cutter automatically with embedded control systems by moving the mower in specified directions. The system is low cost & low power consuming so that anybody can afford it. The DC motor is connected to the power source which will turn on the blade to rotate. It can be utilized in an open space (lawn). The system is designed in such a way that the autonomous lawn mower does not need human intervention to successfully mow the grass therefore it can be operated by even an unskilled laborer, what is required of the laborer is to put on the machine. The 3D diagrams are shown in figures 1 to figures 6 below.

Design calculations

Selection of electric cutting motor

DC motor

Speed = 900 rpm

Voltage = 6 volt

Power = 180 w

$$T = \frac{P * 60}{2 * \pi * N}$$

$$T = \frac{180 * 60}{2 * \pi * 900}$$

Hence Torque produced by cutting motor is 1.90986 Nm.

Transmission system

Transmission system includes four drive namely gear drive, belt drive, chain drive and rope drive. Both gear and belt transmit rotational motion from one shaft to another. However, there are major difference in their uses and motion transmitting efficiency. But for this project a simple belt is used to transmit motion because the shafts are parallel and placed at distance from each other and the efficiency of simple belt drive are more because they are made from lower density materials but gear are made of dense materials.

Simple belt: The belt is selected depending on the power to be transmitted

Motor power= 180w

Motor Speed N1= 900 rpm

Cutting speed N2: 340 rpm

$$\text{Speed Ratio} = \frac{N1}{N2} = \frac{900}{340} = 2.6471$$

Stress strain (constructive relations)

Generalized hooks law

In Case of 1D

$$\epsilon_x = \frac{1}{E} \times \sigma_x$$

ϵ_x = Strain at the x axis

E= modulus of elasticity

σ_x = stress along the x axis

In case of 2D and 3D the following equation are required

$$\epsilon_x = \frac{1}{E} (\sigma_x - \nu(\sigma_y + \sigma_z))$$

$$\epsilon_y = \frac{1}{E} (\sigma_y - \nu(\sigma_x + \sigma_z))$$

$$\epsilon_z = \frac{1}{E} (\sigma_z - \nu(\sigma_x + \sigma_y))$$

$$\sigma = \frac{F}{A}$$

$$w = mg = 0.0225kg$$

$$\text{Area} = A = \pi r^2 = 3.142 \times 0.01143^2 = 4.104 \times 10^{-4} m^2$$

$$\sigma = \frac{F}{A} = \frac{0.0225 \times 9.81}{4.104 \times 10^{-4} m^2} = 537.83 N/m^2$$

Design calculation for Ultrasonic sensor

Frequency of oscilation = 20Mhz

$$\text{Cycle} = \frac{4}{20} = 0.2 \mu s$$

$$\text{timer count} = 0.2 \times 8 = 1.6 \mu s \text{ (prescaler} = 8)$$

at 20°C sound speed = 34000 cm/sec

within 1.6μs distance

$$= 1.6 \times 0.000001 \times 34000 \\ = 0.0544 \text{ cm per count}$$

But sound distance is twice (to come and come back) so relationship becomes

$$\frac{0.0544}{2} = 0.0272 \text{ cm per count}$$

Hence, to begin the measurement, the device requires a pulse of 10μs in the trigger input, after which it sends itself a burst of 8 periods of 40Khz, then echo output signal goes to 1 status and return to 0 status when echo is back. Timer1 measure this duration to avoid hearing the receiver when the emitter sends the burst value of 40khz.

Timer1 start again to begin count after 10 +200 = 210μs.

so minimum distance (theoretical) is

$$210 \times 0.0272 \text{ (because of the only one way)} = 5.712 \text{ cm .}$$

Using the Calculation above, the Ultrasonic sensor can be used to measure an obstacle within 30cm. Hence, the ultrasonic sensor limit for this project will be set at 30cm since the minimum distance it can measure is 5.712cm.

Design calculation for the resistor

The Red LED has the following specification

Voltage = 2V

Current = 15mA

The Green LED has the following Specification

Voltage = 2.1V

Current = 20mA

The formula to calculate the values of the Resistors to attach to the LEDs is given below

$$\frac{\text{Source Voltage} - \text{Forward Voltage}}{\text{Current}} = \text{Resistance}$$

For the green LED

Source voltage = 5V

$$\frac{5 - 2.1}{25 \times 10^{-3}} = \frac{2.9}{0.025} = 116\Omega$$

For the Red LED

$$\frac{5 - 2}{15 \times 10^{-3}} = \frac{3}{0.015} = 200\Omega$$

The values gotten for the green and red LEDs respectively are the lowest value of resistor to use with the LEDs in order not to damage the LEDs. These values of resistor would result into the LED been in its

brightest stage, so in order to reduce the brightness a $1K\Omega$ was used.

Source coding

The source code of the microcontroller is done using the Arduino IDE software by using C language and the sketch gotten is uploaded into the microcontroller. The main mode of operation of the lawn mower is autonomous mode. A sketch was made for the autonomous mode of the lawn mower and it was uploaded into the microcontroller for controlling the mower.

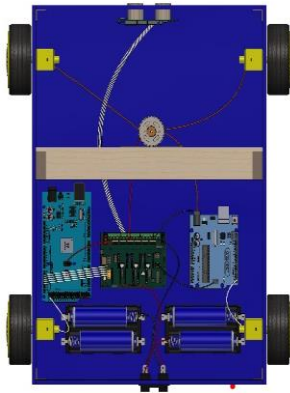


Figure 1: Inside view of the 3D modelling



Figure 3: Back view of the 3D modelling

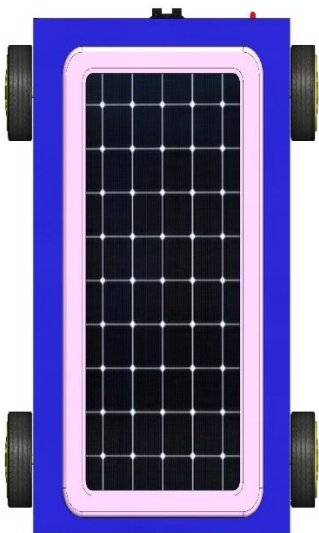
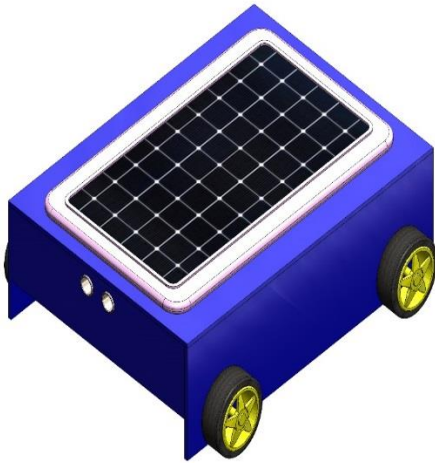


Figure 4: Side view of the 3D modelling



The mechanical body of the mower consists of four driving wheel which transmits force, and transform torque into tractive force from the tires of the lawn,

causing the autonomous lawn mower to move. A four-wheel design was taken into consideration for stability of the mower.

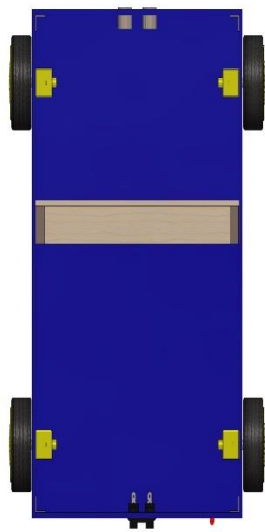


Figure 5: Bottom view of the 3D modelling

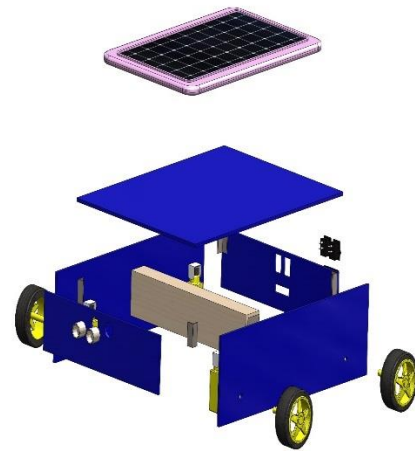


Figure 6: Exploded 3D diagram of the Lawn Mower

Principle of operation

This project is all about an autonomous lawn mower and it is powered by solar panels. The solar panel is placed at the top of the robot, which receives direct sunlight and charges the battery while mowing the lawn. The System consists of the Hardware and software. The Hardware is divided into three sections:

The Robot, the cutting mechanism and the power supply while the software includes the program which is written to control the robot and an Autodesk inventor was used to design the mechanical body of the mower. The code was written in such a way that it embeds the High and Low sensitivity of the sensor and other components embedded in the robot all other functional or peripheral elements in the robots are tied

to the microcontroller for prompt interpretation. When the device is turned on the robot performs the sensing function, movement of the base which is the cutting mechanism as it mows the grasses it senses a signal and sends an appropriate signal in return.

System components and description

Results and Discussion

The work deals with assembling, soldering, interconnections and other latent mechanical activities. The materials used for the cutting mechanism were locally sourced. Once they were gotten, the materials were then assembled and the control circuit was soldered on a Vero board according

to the specifications of the circuit design. After assembling, the testing took place then the figure 7 below shows the result of the experiment carried out on different grasses using the autonomous lawn mower. After making use of our autonomous lawnmower in trimming and cutting the lawn, the following result as seen in figure 7 was obtained. It was observed that the robot is more effective when working on a lawn with few or no obstacles. This allows the robot the freedom to reach and cover almost every part of the field at equal area parameters. The equal area parameters for the lawn with few or no obstacles were greater than the equal area parameters with many or scattered obstacles, meaning the percentage of area mowed for the first condition was greater compared to the other one.



Figure 7: The effect of autonomous lawn mower on overgrown grasses

Digital multimeter

The digital multimeter is a measuring tool used by engineers and technicians in measuring voltage, resistance, continuity, current, frequency,

temperature, and transistor. The multimeter is essential in the implementation and testing process of the Autonomous lawn mower, parameters like voltage, resistance value and also continuity were carried out with the aid of the multimeter on the hardware.



Figure 8: Digital multimeter

Work schedule

The research study on the design and construction of an autonomous lawn mower was not achieved in a day; it was broken down into different tasks with each having a respective period for startup and completion. The research project had various tasks that were carried out from commencement to completion. A

Gantt chart was developed to keep track of project progress as project tasks were listed based on their estimated start and completion times to accurately complete the project within the estimated time. The Gantt chart used is shown in the Table 2 below;

Table 2:: Gantt chat showing work progress

TASKS	WEEKS																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	█																								
2		█	█	█	█																				
3						█																			
4							█	█																	
5									█	█															
6											█														
7												█													
8													█	█	█										
9																█	█	█	█						
10																				█	█				
11																						█			
12																								█	█
13																									█

Task 1 – Proposal submission

Task 2 – Gathering of journals for the research and extensive literature review

Task 3 – Introduction section

Task 4 – Literature Review section

Task 5 – Scheduled meeting with Supervisor

Task 6 – Methodology section.

Task 7– Design consideration of model.

The breakdown in the chat above describe the sequential activities carried out to the achievement of this research. The span for the project was approximated Twenty-five weeks, the structure did not follow each other in a successive manner but each allotted time took into consideration. All factors required in executing the task including the likely problems to occur and subsequent measures to solve those problems when they arise in the course of carrying out the research study.

Critical evaluation

In the construction of the autonomous lawn mower, I worked on gathering related works to the subject matter at hand and this was not an easy task because I had to read through all the related works for better understanding before embarking on the task as I had to come up with the entire project myself. The hardware development was a successful one and what was left was to deploy it to integrate it into the university lawn

Task 8 – Implementation of model on a hardware prototype

Task 9 – Programming the microcontroller

Task 10 – simulating the controller circuit

Task 11 – Conclusion and recommendation section

Task 12 – Proof reading and correction by supervisor

Task 13 – Printing and binding of the report

mowing system. The development of this autonomous lawn mower will help in keeping the lawn neat and reduce cost of manual laborers employed to do the mowing. The development of this system has also taught me the importance of certain techniques that could be used in further engineering constructions.

Risk management

The risk associated with this project is that of connecting the control circuits which involves checking the power connection with a multimeter to avoid destruction of the circuit. This risk was effectively mitigated in the design of this project by first simulating it on a Proteus simulator software and also by ensuring tight connections when connecting the components on the Vero board, each terminal was adequately labeled to ensure proper connections.

Ethical issues

The size of cables used in the design of this project conformed to the required standard to prevent cable damage due to heating in the device. This design does not infringe on any existing knowledge as it is a unique design built on an existing knowledge but with better functionalities.

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