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Design and Fabrication of Autonomous Lawn Mower with Water Sprinkler

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ABSTRACT

Internet of things (IOT) is the new technology which is used to drive automated grass cutting machine. It is a conventional approach for cutting the grass of the lawn using remote operated device so as to avoid the hazards of horny grasses which can harm humans and provide scratches on exposed body parts and even some times cloth gets stuck in these. The lawn Mowers which are available at present in market are bulky, costly and most of them are powered by gas engine and Internal combustion engine which is surely a threat for the environment ,and another issue rises up when we water the garden, it is very time consuming and also laborious. There is a fundamental need to develop such environmental friendly lawn mower that can cut the grass in an efficient way and also water the lawn at the same time. This paper presents the study of various parameters such as blade cutting speed, turf quality, battery life span along with the design analysis of lawn mower. Here an approach of an autonomous lawn mower is proposed which can minimize the physical effort in cutting the lawn by eliminating the need to follow behind the mower and also helps us to make the environment pollution free and safe. The results show that the cutting speed action of blade has an important impact when it strikes the grass. The speed of the high torque DC motor is 7000 rpm and the blade tip sped is 4398m/min.

Keywords: Arduino UNO, Design Analysis, Rely Module, Bluetooth Module, Water Sprinkler.

INTRODUCTION

A Lawn Mower is a device which can cut or trim the grass to a desired level by adjusting the height of the cutter blade. It is mandatory to maintain and keep up lawns in garden, school, sports tracks, field, colleges, Industries etc, but mowing along with a lawn cutter and at the same time watering the garden can be very tedious and time consuming especially when the area of the yard is very vast. Most of the houses still using manual method of cutting which leads to inaccuracy of cutting level of grass and moreover the mowers which are available in the market are very costly and operated by traditional endothermic engines which lead to the depletion of fuel resources and carbon ratings along with the excessive amount of hazardous emissions. Hence, to mitigate pollution and abate local emissions and noise, unconventional approaches have been developed recently, including lawn mower conversion, i.e., Conversion of manual lawn mower to autonomous lawn mower.

Hunt [1] invented a hybrid lawn mower in which internal combustion engine is used for mowing structures and electric motor is used for driving the wheel of lawn mower. An alternator is connected to a battery pack which provides electrical power; controller is used for controlling the speed of the wheel. Baloch and Kae [2] proposed a model which incorporated PIC16F877 micro-controller, sensing device, analyzer and actuator. The major intension is to develop a lawn mower with minimum cost and which would be able to help the user to cut the

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grass of a particular region of smooth ground by avoiding any hindrance along the path. Some limitations are there like the speed of gear motor is slow. Hence, balancing sensors are needed to accommodate the change in ground surface. Medina [3] has invented a mower which can operate with remote control device using a hand held transmitter and a remote control lawn mower unit, which is helpful to elderly people who maintain their lawns or to those with disabilities where physical labour is not recommended. Levratti et al. [4] developed localization algorithm-based lawn mower which has been equipped with Kalman Filter which accommodates an expert navigation technique and also enhances the quality action of the lawn mower. Yang et al. [5] proposed an algorithm for a self-directed mower utilizing the technique of vision-based localization and mapping. Ground speed sensor and an omni-directional vision sensor along with an IMU are used in this design. In this paper the task has been separated into two parts, one is instruction and other one is cutting. In instruction part, the system discernment the 3D locations of prominence and defines a periphery in the territory by a discernment of its own trajectory. During the cutting part, the system's site is discernment with the help of prominence and periphery plan obtained from the instruction part. Ouyang [6] build a robotic lawn mower which consists of ultrasonic sensor and RF devices and it is also called network sensor. In this device a user can monitor or modify the setting of the boundary stand to define the mowing area and also can track the position, control and monitor the mowing routes with the help of computer or cell-phone through a wireless network, a WIFI, or an internet. Guo and Sun [7] designed a model that comprises a camera which can obtain a real time image and also help to avoid the obstacles. It also includes Jetson tk1 and Arduino system, in which initially an image is converted into black and white picture and resized to 640*480 pixels and finally, it is divided into 40*40 patches. However eature compression is there with principle component analysis and linear discriminant analysis. Wang and Huang [8] proposed a mower which is dependent on computer vision and various trajectory making algorithms. The mower has been deliberate to run twice in order to fulfill the given job.

On the basis of mentioned review, it is concluded that an autonomous lawn mower indeed has a great effectiveness for upcoming use. A comprehensive study is performed to decide on diverse material, method and designing of different lawn mower that offer features such as solar panel lawn mower, hybrid lawn mower, obstacle avoidance lawn mower etc. Conceptual task has been performed on the provision of autonomous lawn mower and numerical terminology introduced, based on best assumptions. Planned technique figured out novel reasons for designing an efficient lawn mower. Reasons under consideration are blade cutting speed, turf quality, battery life span and the design analysis. Knowledge with respect to the factors governing for an autonomous lawn mower is beneficial for the society and based on which appropriate suggestions are applied into the designed model. Their effects on the lawn and effectiveness are compared for the given design.

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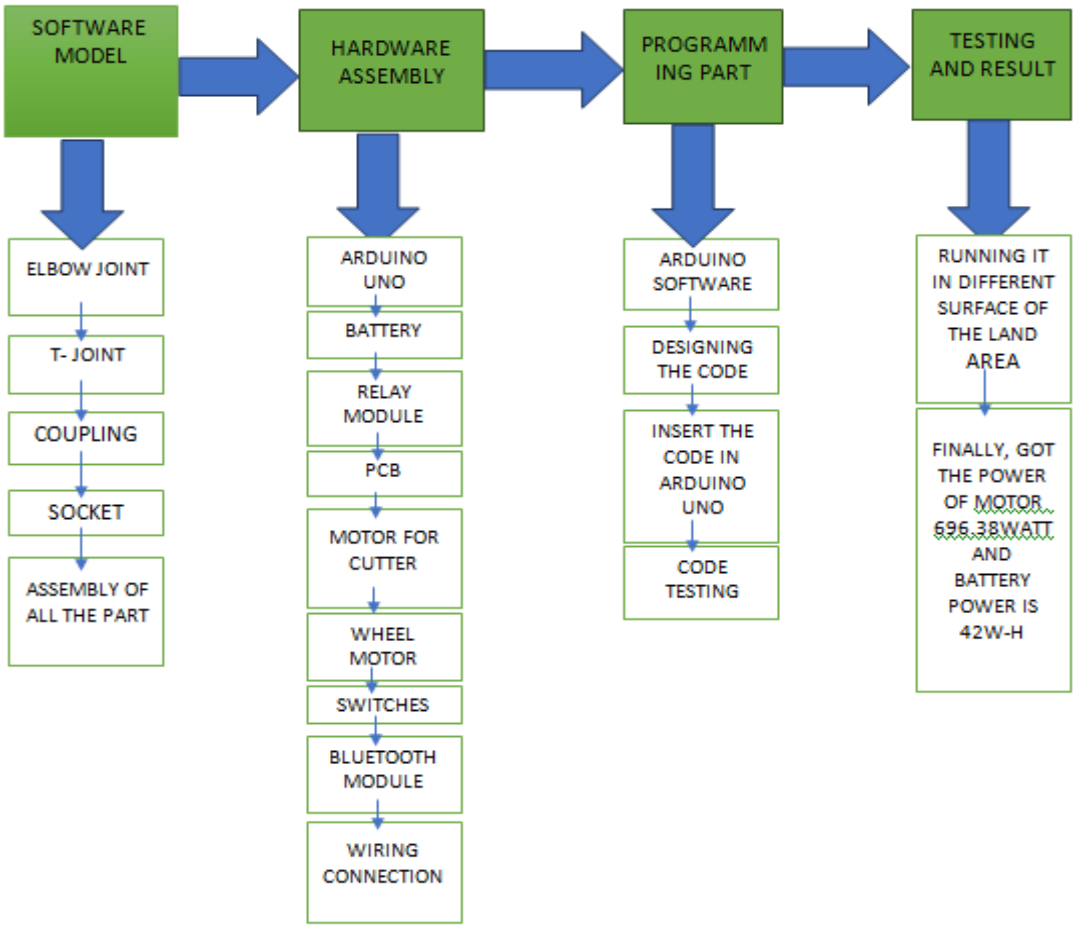

Figure (a): Block diagram of Autonomous lawn mower

In this work, the frame of an autonomous lawn mower is designed in CREO Parametric modeling software. The body formation of lawn mower incorporated with T-joints, Elbow and couplings. After building the model of lawn mower in software we have elected different hardware parts like PVC pipe for frame, rubber castor wheel, hexa-brass coupling wheel, Arduino Uno, wooden pieces, blade cutter, motor, battery etc. The mower is designed in a way that it can carry the load of battery, water tank and other apparatus.

DESIGNING THE AUTONOMOUS LAWN MOWER

The autonomous lawn mower embedded with a water sprinkler that spray the garden and water is flowing through the pipe from water tank to sprinkle with the help of pump. The cutter blade provides a cutting action in the lawn by the help of high torque DC motor. The voltage of 12V is applied at high torque DC motor for cutting operation, Rely Module, 12V rechargeable battery, cutter blade, water sprinkler and Arduino UNO which is the brain of robotic lawn mower. The Bluetooth module is used to control speed and direction of lawn mower.

Factors under consideration in the designing and analysis of lawn mower are given below:

- Since the practical mowing system suffers from environment pollution and inaccuracy of cutting level of grass, these issues are considered in the analysis during the cutting action of grass cutter.
- Motor speed is considered for the cutting quality of the turf surfaces.

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- Blade tip speed has been considered.

In this experiment the sharing force of the grass cutter to be considered as 9.5N. The blade radius has taken as 10 cm. The formula of the torque is given:

$$T = F*R$$

Where, F = sharing force

T = Shaft torque

R= Radius of blade

$$T = 9.5*10$$

$$T = 0.95Nm$$

Shaft power is calculated as

$$P = 2\Pi Nt/60$$

Shaft speed is considered 7000rpm for this experiment.

Where, P = Power developed by shaft

T = required torque

N =shaft speed

$$P = 2*\pi*7000*0.95/60$$

$$P = 696.38 \text{ watt.}$$

Blade Tip Speed:

Blade Tip Speed can be defined as in a certain amount of time how far a point on the outer most edge of the extended blade travels. The circumference of a circle $C = \pi D$

The blade diameter of the lawn mower measured as 20cm. For the convenience of the calculation we consider motor speed is 6000rpm and the value of pi = 3.1416 for one complete revolution.

$$\text{Tip Speed} = \Pi \times D \times N$$

Where, T is noted for tip speed (rpm) of blade

D is blade diameter which is 20cm

N is speed of motor = 7000rpm

$$T = \pi*D*N$$

$$T = 3.1416*.2*6000$$

$$T = 3769.92\text{m/min [Neglecting the frictional losses]}$$

Battery Power calculation:

In this project the voltage of high torque dc motor has taken as 84Watt and 12V.

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So, maximum current drawn from motor = 84/12 = 7A

We want to cut the grass and water a certain land for a minimum amount of time assuming that that the surface of the land is flat. Therefore, we have been considering a running time of 30minutes a mower can travel without any obstacle.

Battery required for run time is = 7A*.5h = 3.5A-h

We used lithium ion battery so total power of battery = 12V*3.5A-h = 42W-h

Energy calculation:

For a given time consider 1hour energy consumed by motor= power*time = 78*1 = 78W-h (Assuming motor power is 78watt)

We have calculated battery run time which is 3.5A-h. So, we can calculate energy stored in battery = capacity*Voltage = 3.5W-h*12V = 42W-h.

Mechanical Design:

The literature survey which has demonstrated above is an attempt that has been made to design the frame of a low-cost autonomous mowing machine. For progression of the grass mowers existing in the market hardware parts and material should be set by considering less expenditure and uplift ease issue. The design of autonomous grass cutter prepared through drafting and modeling software is given in figure (b).

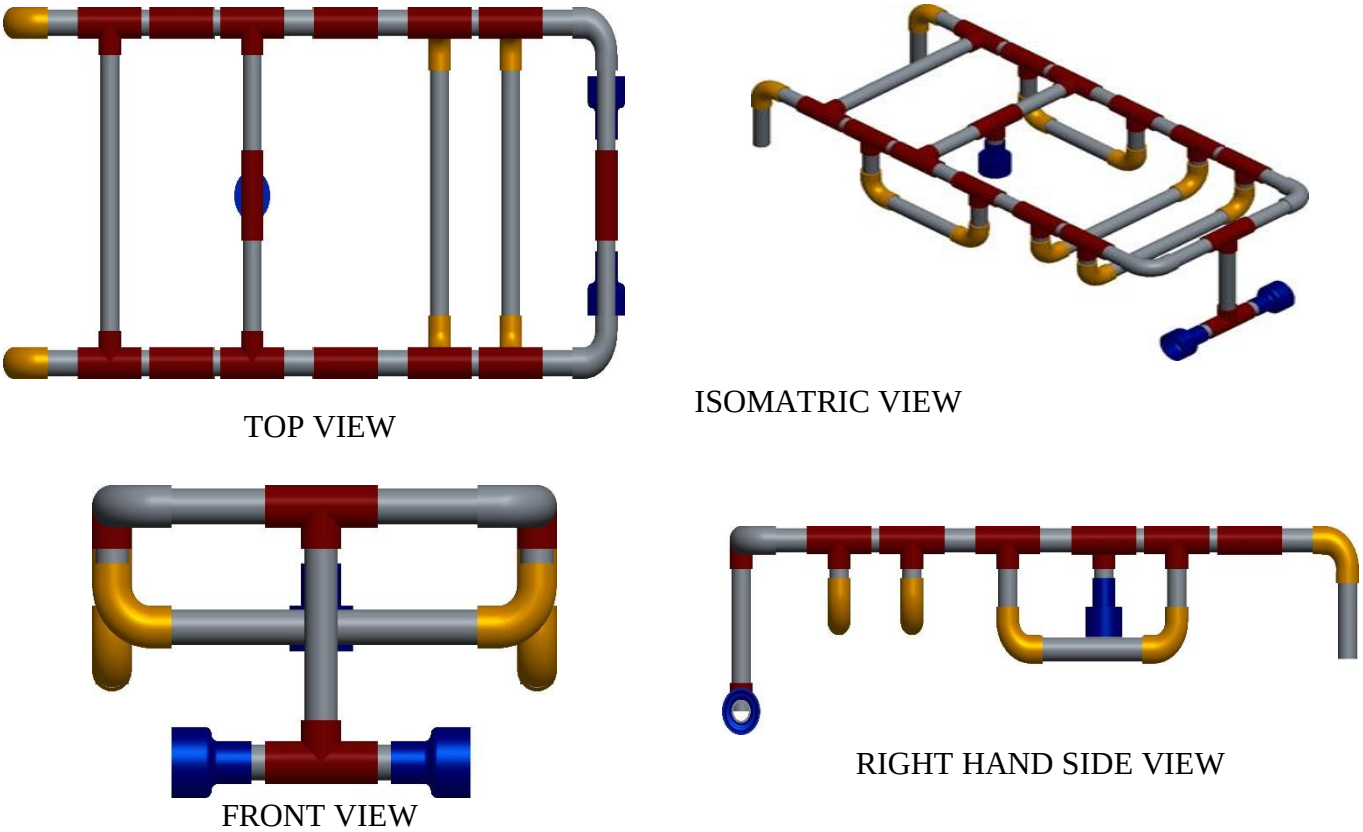

Figure (b): CAD Model of Proposed Lawn Mower

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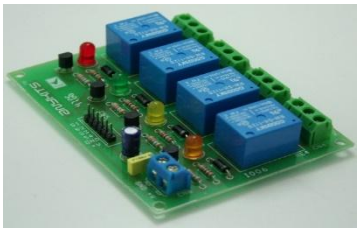
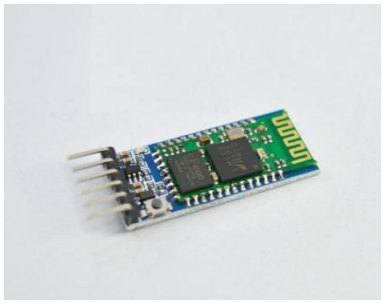
The above drawing has shown the different view of lawn mower. The dimension of this body is 34*64 mm and height 25mm. The body has been made with PVC pipe (Length 9 feet, 25mm) which is portable and easy to carry at any place. The design contains 10 pieces elbow (90^{o}-25mm-1$^{''}$), 15 pieces T-joint (25mm-1$^{''}$), PVC coupling (1$^{''}$ to 1$^{''}$ 2 pieces, 1$^{''}$ to 1/2$^{''}$ 2 pieces) and a socket which can help to carry the load of battery, wheel and motor. A special socket is equipped in the middle of the lawn mower which can hold the high torque DC motor for cutting purpose. Assembling all elements together, we can design our robotic lawn mower.

EXPERIMENTAL SETUP AND PROCEDURE

Experiments have been performed using an Arduino UNO, blade cutter, a Rely Module (4-Channel), Bluetooth Module and a Water sprinkler. The detail and specification of components of this project is given in a tabular form:

Components Name	Components Image	Specifications
Arduino UNO		It has 14 digital pins (6 analog pins, 6 are used for PWM outputs) 16 MHz ceramic resonator It accepts voltages between 7 and 20 volts It can be connected by a USB cable which is used for power supply or 9V external battery can be used.
Relay Module		4-Channel Relay interface board, and each one needs 15-20mA Driver Current. Equipped with high-current relay, AC250V 10A; DC30V 10A. Standard interface that can be controlled directly by microcontroller (Arduino uno, 8051, AVR, PIC, DSP, ARM, ARM, MSP430, TTL logic active low). Both have to control by 12V and 5V input Voltage.
Bluetooth Module		3 to 5V, Low power operation Supported baud rates are 9600,19200,38400,57600,115200,230400 and 460800. Frequency: 2.45 GHz UART interface with programmable baud rate

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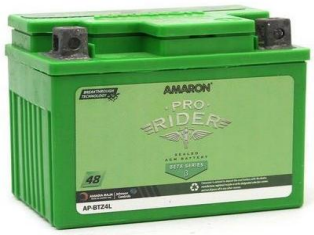
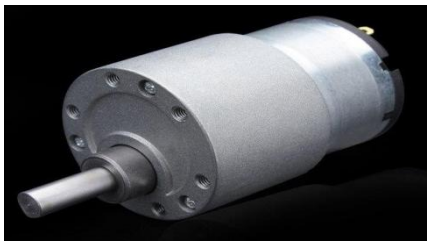
Water Sprinkler Nozzle		Material Used: PVC pipe Color: White Size:21*12mm/0.8*0.5inch Spraying diameter: 0.9-1.1 m
Lithium Ion battery		Usable Capacity: 100 Amp-hours Voltage: 12 Volts Continuous Output: 100 Amps Maximum Output: 200 Amps for 30 seconds Lifetime Capacity:300,000 Amp-hours Lifetime Cycles: 3000- 5000 Cycles Dimensions:(LxWxH):12.75"x 6.875" x 9.0" Weight: 29 pounds Cell Type: LiFeP04
High torque DC motor		3500-9000RPM, 12V-36V, 775 Motor DC Large Torque, High-power Length of Shaft: 17mm Ball bearing, with cooling fan
Rubber Castor Wheel		Diameter: 8" x 2-1/4". Upper Limit of Weight: 300lb ea. Complete Height: 10". Measure of Top Base: 4-1/2 x 4". Spacing between Bolts: 3-5/8" x 2-5/8".
DC Metal Gear Motor		Type: DC Metal Gear Motor Voltage: 12V Rpm: 300

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Hexa-Bruss Coupling Wheel		Use: Movement of Robot Diameter: 10cm Width:2cm
Pump		USE: water sprinkling Voltage:2.5v to 6V Lift: 0.4- 1.1m
Elbow Joint		Type: Elbow-Joint NO of Pieces: 10 Dimension: 90^{o}-25mm-1''
Tee-Joint		Type: Tee-Joint No of pieces: 15 Dimension: 25mm-1''
Water Tank		Maximum capacity: Two liter.

The proposed lawn mower could keep turf physical condition and lawn quality as well as water the garden automatically by performing entire and equivalent exposure of abundant region. The block diagram of proposed mower is given in Fig (c).

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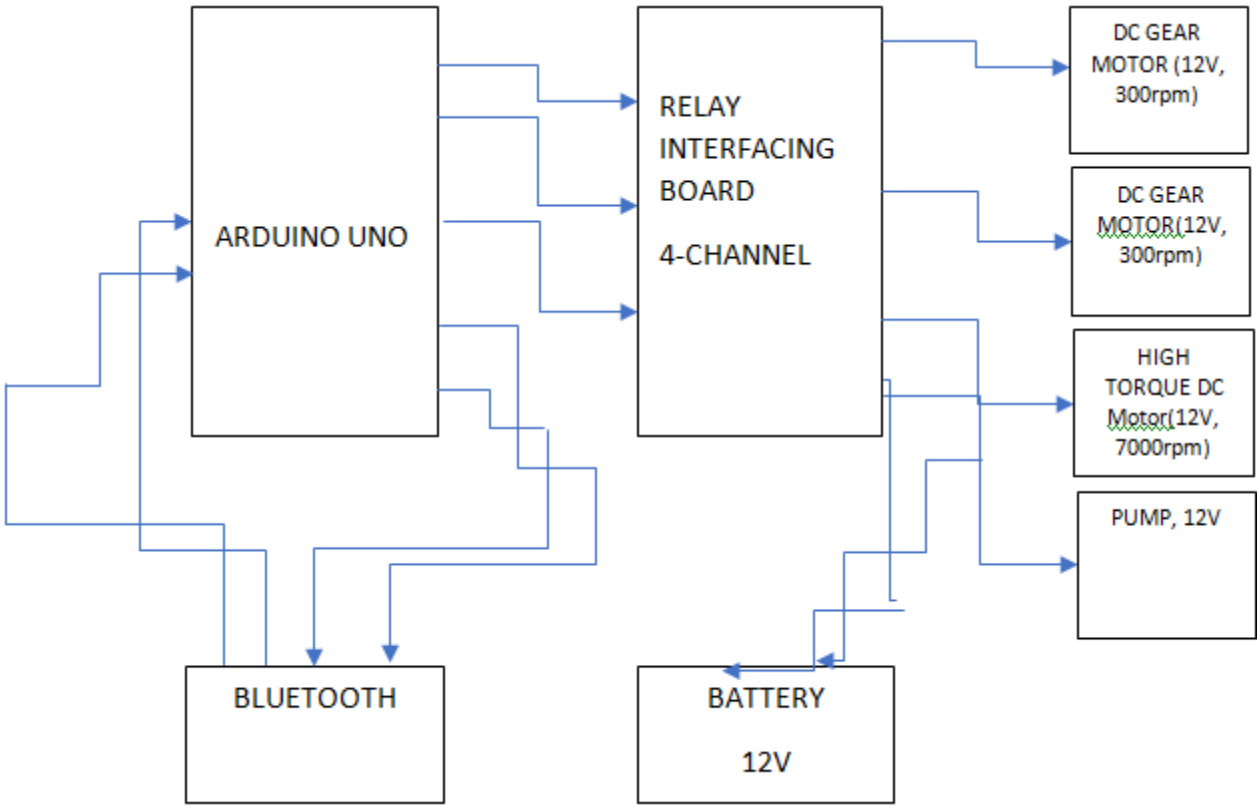

Figure (c): Circuit diagram of robotic lawn mower

The figure(c) shows the block diagram of "Robotic Lawn Mower". This design consists of an Arduino Uno which is the heart of the lawn cutter, a Relay module, a water pump, a set of linear blades used for cutting operation and a Bluetooth sensor device. The goal of this project is to cut the grass of a yard evenly along with watering the garden without creating any hazardous condition. When the switch is closed, the Arduino sends a signal to the relay to switch on the motors wheel and the motors start rotating in the forward direction. It also sends the signal to the relay connected motor and pump where blades attached with motor and water sprinkler connected with pump. The rotating blades continuously cut the grass at a high speed as the mower impelled forward. And also water the garden with the help of water sprinkler.

The entire machine can be handled by using smart phones. Here we have used Bluetooth sensor (HC05) which is used as a transmitter and receiver signal and four channel relay module. Channel 1 is connected with front wheel 1, similarly channel 2, 3, & 4 are connected with front wheel 2, cutter blades & pump respectively. For operating the lawn mower with smart phone we can install Bluetooth transmitter HC05 from Android Application. Then we can connect mobile phone with robotic lawn mower Bluetooth device. The software interface designed in a way according to our programming, in software interface when we press 1 both wheel will move forward direction. For cutting and pumping operation press 6. After that for turning left and right direction 4 and 5 is used accordingly.

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FACTOR CONSIDERATION DURING THE DESIGN OF AUTONOMOUS LAWN MOWER

Quality of Cutting

The quality of grass cutting depends on the blade material and blade tip speed. In this project high torque dc motor has been used for cutting operation, it provide around a speed of 7000rpm which is sufficient to cut the grass evenly of a flat garden.

Good Efficiency

In the past, internal combustion engine has been used to cut the grass of the garden. It was not that much efficient because of its low efficiency (40%) whereas DC motor equipped in lawn mower is more efficient than IC engine in power utilization which is more than 90%. The motors are powerful for use in all type of field surfaces and conditions.

Eco-Friendly

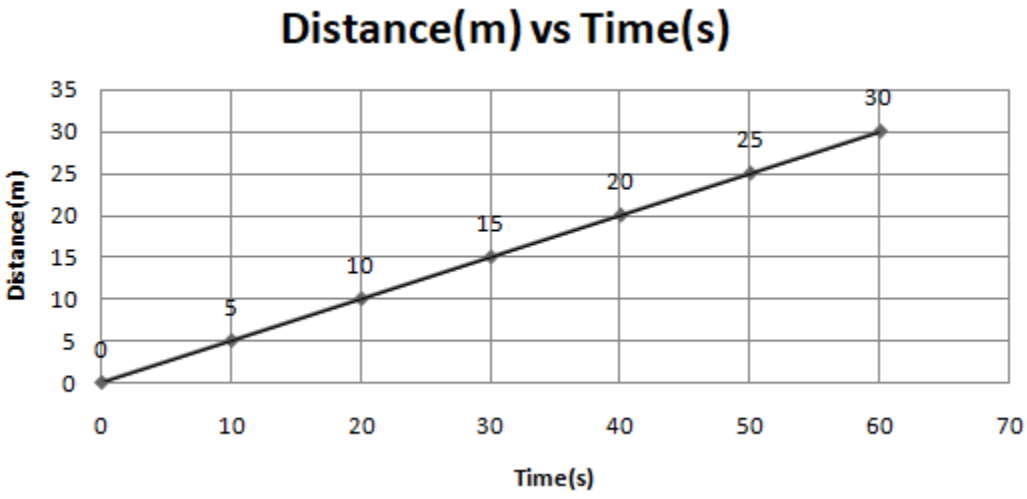
The electric battery is derived from non-conventional sources, so electric mowers are very eco-friendly.

Lithium Ion Battery

Lithium ion batteries are light in weight more powerful and durable. Rate of self-discharge is much lower than that of other rechargeable batteries. If you have to cover the large area of lawn you can choose autonomous lawn mower vehicles with a removable set of batteries.

RESULT AND DISCUSSION

The system of autonomous lawn mower considers the time and distance cover by the lawn mower in a flat playground. Three factors are considered when it moves in forward, backward and turns the direction. Figure (d) shows the distance cover by a mower in given time:



Figure(d): Distance vary with time

The graph fairly demonstrates that when the time is increasing the area distance covered by the lawn mower is also increased. That means when the mower is passing through a particular area it will cut the grass along with water the garden in a given time.

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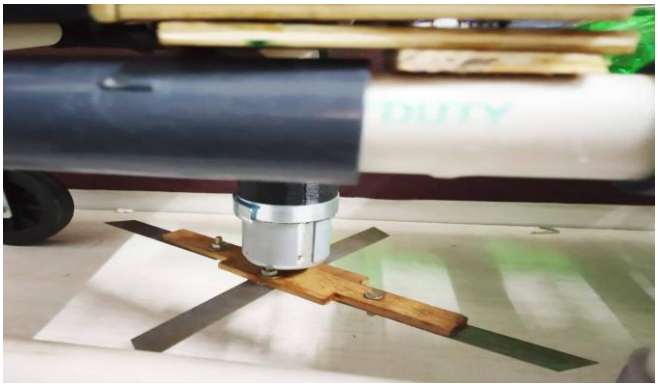
During the process of implementation of this robot, several difficulties and factors associated with the plan, various equipments and their application were faced. In this section, accomplishment of the proposed mowing robot is apprises in the form of direction control of robot with mobile phone, level of mowing and water sprinkle accuracy. The proposed lawn mower is given below:

Figure(e): Robotic Lawn Mower with Water Sprinkler

The robot has been arrayed with three motors: two DC metal gear motors for the wheels and one for cutter blade high torque DC motor for cutting purpose, an Arduino Uno and a battery. The battery terminals are connected with power circuit board. The output of the power circuit board is given to Arduino with a voltage of 12V to 9V. So the Arduino receives a power of 9V. The relay module 1, 2, 2, 4 are connected to the pins 10, 11, 12, 13 of Arduino respectively. The motors 1, 2, 3 are connected in parallel with 1, 2, 3 of relay pins and pin 4 is connected with pump. The Arduino Uno has been programmed with Arduino software programming language. The actions and path control by android application has been performed effectively.



Figure(f): Blade Cutter

The cutter is rotating at a very high speed of 7000rpm. Whenever we need to cut the grass of the yard we just have to turn on the switch of lawn mower which is attached with the mower itself and connect the Bluetooth device with it. One can control it and move it any direction with the help of mobile phone.

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Figure(g): Circuit Arrangement

Water sprinkler is attached at the back side of the mower which is further connected with pump. And the pump is attached with a water tank, where water has been stored. When the switch of the pump is ON water will be going through the pipe to water sprinkler.

COST ANALYSIS

S. No.	Components Name	No. of Components	Price Per Piece	Total
1	Arduino UNO	1	400	400
2	Rubber castor wheel	2	140	280
3	Hexa-Bruss coupling wheel	2	150	300
4	PVC Pipe	2	100	200
5	Relay Module	1	260	260
6	Lithium Ion Battery	1	1000	1000
7	9V battery for Arduino	4	20	80
8	Elbow-joint	12	15	180
9	Tee-joints	14	22	308
10	Bluetooth Module HC-05	1	380	380
11	Linear blade	4	20	80
12	Card Board	1	300	300
13	Socket	1	450	450
14	Water Sprinkler	1	20	20
15	Pump	1	180	180

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16	Water Tank	1	30	30
17	High Torque DC motor	1	500	500
18	Metal gear motor	2	375	750
19	Wire	1	50	50
20	Screw Driver	1	180	180
21	Fevi-stick	1	150	150
Total Cost = 6068(INR)				

CONCLUSION

The developed automated mechanism proved to be advantageous in terms of four considered attributes, mainly blade cutting speed, turf quality, battery life span and the design analysis of lawn mower. The model could be carried commercially a minimal amount of operating cost and production. Thus, the lawn of the very vast field can be mown easily without human effort. It is much portable and can be directed with smart phone so, one can easily operate it with their hand set. The gist of this job is, it can cut the grass of a specific area of flat land and also water the garden along the way. If we want only cutting action, we must have to turn off the switch of pump, in that case cutter blade switch should be on. This project is environmentally safe because it has been operated by an electric battery and an electric motor and also easy to carry at any place. In future more research would be possible to control the lawn mower with voice command. Depends on the atmospheric situation of soil and grass the lawn mower mobilized with temperature and humidity sensor to get the rate of the humidity and temperature of a desired territory.

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