PRODUCT DEVELOPMENT COMPETITION

[Develop a model of an Electric Lawn Mower that can be used for grass cutting specifically in IIT Kharagpur]

TITLE

(ELECTRIC LAWN MOWER)

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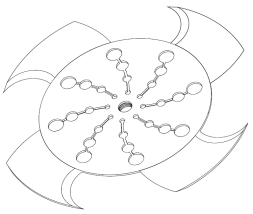
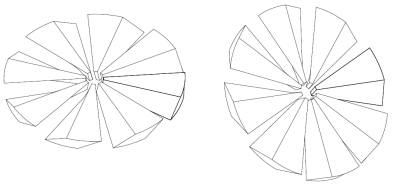
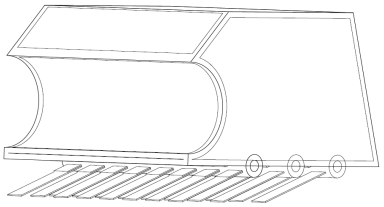
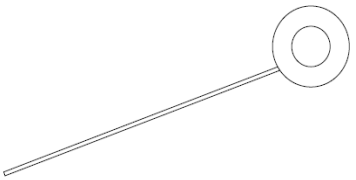
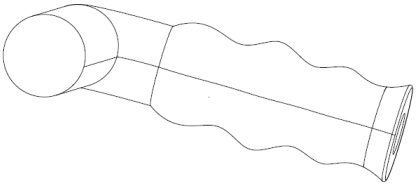
ABSTRACT : A lawn mower is a machine used to mow grass or plants. This machine is commonly used to tidy up the garden and also to clear the fields from grass or other types of grass. The commonly used lawn mowers are made of thin, hard and very sharp iron plates, so they can easily mow the grass. In the process of making the design of this lawn mower product, we first use the technique of brainstorming to determine the characteristics of the product to be made, then draw conclusions from the brainstorming that has been collected. The technique is then carried out by sampling by distribution an open and closed questionnaire to determine the type of product. After the open and closed questionnaires were finished, the conducted survey was marketed using technique sampling, and determined the validity and reliability test of the main product with competitor product I, competitor II and competitor III. The step problem to the sub problem is determined to classify the objectives to be made on the design of the lawn mower products. The step sub-problem to the sub solution is performed to determine the quality function development of the product.

INDEX

PROPOSED SOLUTION :

Serial No.	Components	Diagram
1	Blades	
2	Fan Blades	
3	Grass Box	
4	Grass Collector	
5	Handle	

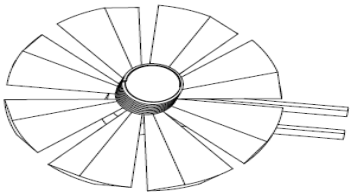
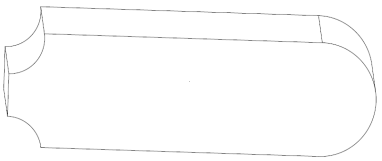
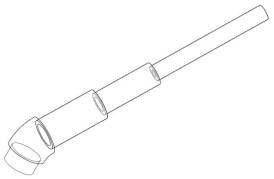
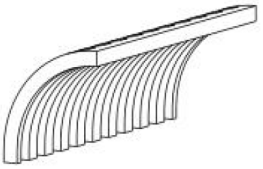
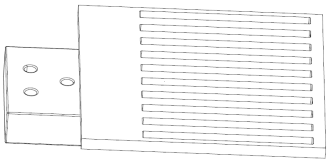
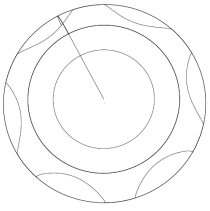
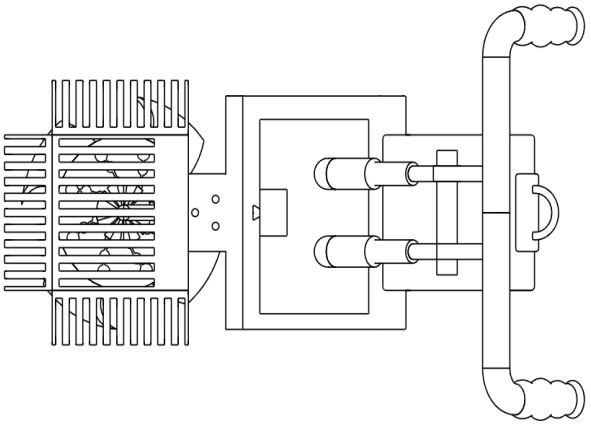
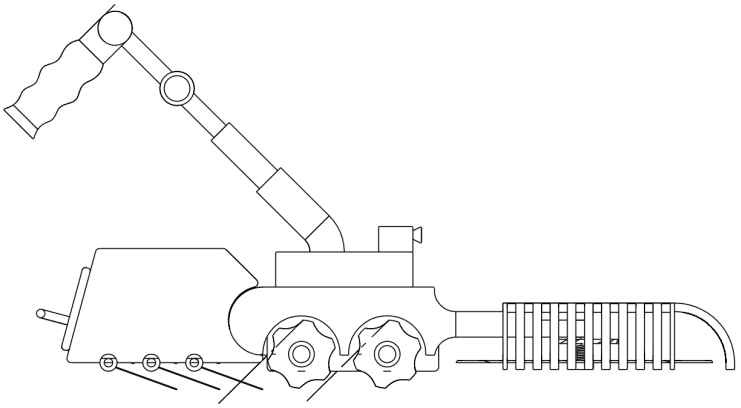
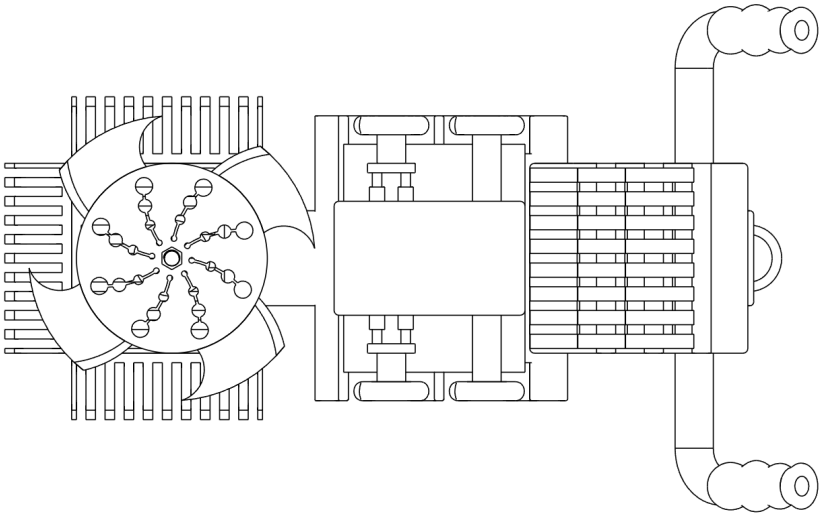
6	**Motor Mount**	
7	**Motor Box**	
8	**Protruder**	
9	**Nut Bolts**	
10	**Slide Cover**	
11	**Threading Screw**	
12	**Upper Cover**	
14	**Wheel**	

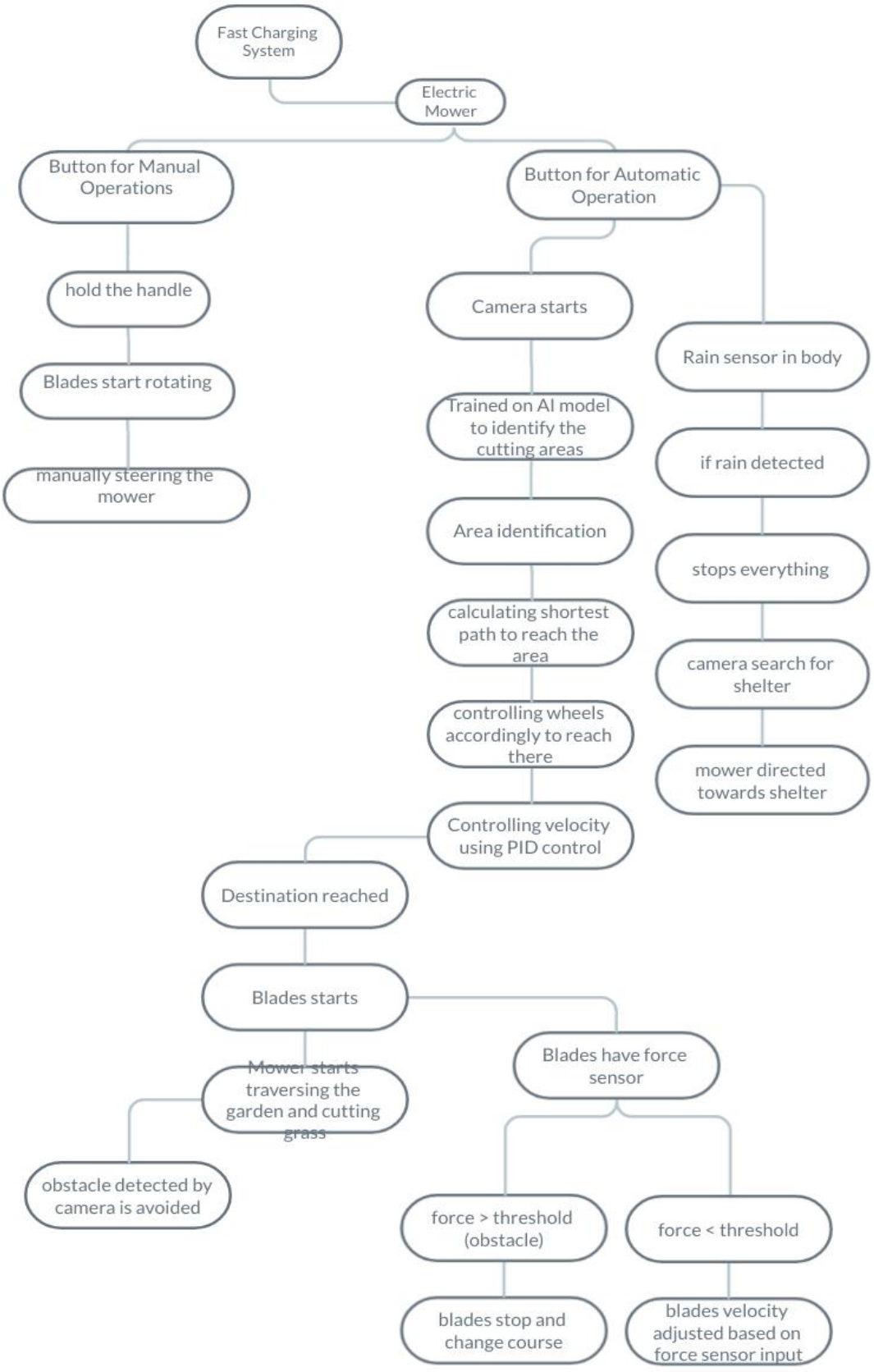
DIAGRAM OF THE FINAL PRODUCT







WORK-FLOW :

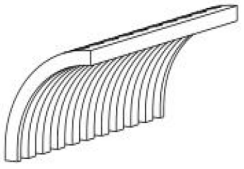

Fast Charging System
Electric Mower
Button for Manual Operations
Button for Automatic Operation
hold the handle
Blades start rotating
manually steering the mower
Camera starts
Trained on AI model to identify the cutting areas
Area identification
calculating shortest path to reach the area
controlling wheels accordingly to reach there
Controlling velocity using PID control
Rain sensor in body
if rain detected
stops everything
camera search for shelter
mower directed towards shelter
Destination reached
Blades starts
Mower starts traversing the garden and cutting grass
obstacle detected by camera is avoided
Blades have force sensor
force > threshold (obstacle)
force < threshold
blades stop and change course
blades velocity adjusted based on force sensor input

COST BREAKDOWN :

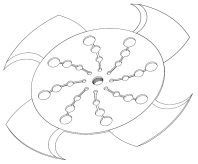
Material	Cost (₹)
Electric motor (250 W 24V 2650 RPM DC motor)	5100
Blade (2)	1450
Battery (24 V 10000 mAh)	1300
H-bridge Motor Driver	500
Electrical Components(wires, switches etc)	400
Touch Sensor (2)	320
Arduino(2)	900
Ultrasonic Distance Sensor	60
Rain Sensor	140
Handels+grass box	400
Wheels	1500
Single Board Computer (Amlogic S912, 1.5GHz, 8, 3.23" x 2.28" x 0.45" (82mm x 58mm x 11.5mm),40-Pin GPIO Header,2GBeMMC V5.1)	7950
Personal Computer and Peripheral Devices (CSL Narrow Box Ultra HD Compact v4)	18050
Camera (Procus Iris Car Dash Camera, FHD 1080P, 2" LCD Screen Video Recorder, 120° Wide Angle Lens, G-Sensor, Motion Detector, Loop Recorder, Expandable Upto 32GB)	2869
Total	40899

COMPARATIVE ANALYSIS :

1. **Blades (Comb-Knife theory)** : One circular blade at the bottom of the car. With this, we are adding another three comb like structured blades. It will help with cutting relatively large grasses, weeds or just collecting any plastic bags or chips packet. This blade will serve as a protector like if very thin plastic directly comes with our main rotating blades, it can be patched up and damage the machinery of the blades. The combination of the circular (ever thought why a barber cuts your hair with a knife and a comb) the front part of the mower has this comb loke design making grass cutting extremely efficient.

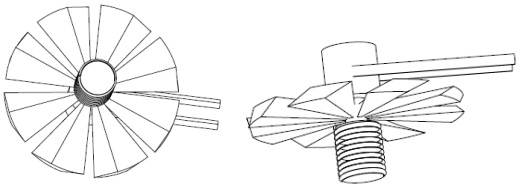


Comb like structure

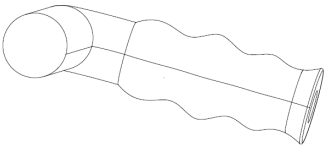


Knife structure

2. **Unique Motor Mount structure with the effect of ventilation** : The fan like object in this picture is a part of the motor it draws in air to allow proper ventilation and keeps the motor cool to some extent and enhances propelling out cut grasses.

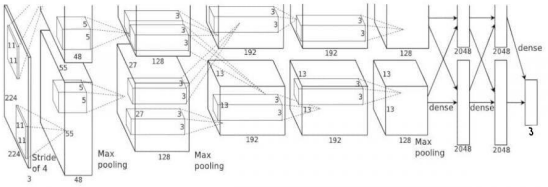


3. **Ergonomic design of handle :** The handle has a ergonomic design meaning it is very easy for gripping by hand moreover the height of handle is adjustable thus catering to different persons of different height (if you see the slanted rods in the pic you will observe that the rods slide into one another (much the same way as you see a selfie stick expand) Thus the mower has a compact design with amazing expandability. The handle can also be adjustable while the automatic movement.



4. **Deep Learning optimisation :** An AI-based approach is adopted for solving the estimation problem. The reason for this is that a combination of different types of sensor data should be handled, and the definition of long or short lawn grass is determined by the height of the lawn grass cutter from the ground. Moreover, a human operator estimates the length of a lawn grass based on sounds made by the lawn grass cutter while cutting grasses. Estimation using an AI-based approach is expected to be more efficient and accurate than estimation based on human judgement.For automatically detect its own path, it should not cover an already cut area several times. That will save time as well as our fuel. The blade of the lawn mower also has adjustable height meaning you can simply push in or out the screw according to the length of the trimmed grass you need (much the same way you adjust the blade in your hair trimmer while cutting your beard).The main deep learning algorithms ALEXNET is adopted considering the execution speed in real-world applications.

   ALEXNET : AlexNet is the name of a convolutional neural network which has had a large impact on the field of machine learning, specifically in the application of deep learning to machine vision.The network had a very similar architecture as LeNet by Yann LeCun et al but was deeper, with more filters per layer, and with stacked convolutional layers. It consisted of 11×11, 5×5,3×3, convolutions, max pooling, dropout, data augmentation, ReLU activations, SGD with momentum. It attached ReLU activations after every convolutional and fully-connected layer. AlexNet was trained for 6 days simultaneously on two Nvidia Geforce GTX 580 GPUs which is the reason for why their network is split into two pipelines.



   AlexNet takes 90 epochs which were trained for 6 days simultaneously on two Nvidia Geforce GTX 580 GPUs which is the reason for why their network is split into two

pipelines. SGD with learning rate 0.01, momentum 0.9 and weight decay 0.0005 is used. Learning rate is divided by 10 once the accuracy plateaus. The learning rate is decreased 3 times during the training process.

$$\nu_{i+1} := 0.9 * \nu_i - 0.0005 * \alpha * \omega_i - \alpha * \left[\frac{\partial L}{\partial \omega}\right]_{\omega i}$$

$$\omega_{i+1} := \omega_i + \nu_{i+1}$$

The update rule for *w* was where *i* is the iteration index, *v* is the momentum variable and *epsilon* is the learning rate. Equal learning rate for all layers, which was adjusted manually throughout training. The heuristic which was followed was to divide the learning rate by 10 when the validation error rate stopped improving with the current learning rate.

Experiments on ALEXNET Algorithm :

- **Measurement of Data** : The data measured by the sensors are obtained by driving the grass-mower on a field with long lawn grasses and short lawn grasses as well as without lawn grasses. The remote-control system through Bluetooth communication is incorporated in the robo-mower by mounting a mini-PC and running an ROS on it. The mini-PC can also handle the collected sensor data.Similarly, several ground conditions without lawn grasses are adopted which are asphalt, gravel, and stone pavement.

- **Featuring for classifying the data** : Statistical features of input data {xi}(i=1,2,⋯,q)for classification are calculated, including (i) maximum value, (ii) minimum value, (iii) average value, (iv) median value, (v) standard deviation value and (vi) skewness value. The values of six feature types are normalised into the interval [-1,1]. These features are used in configuring the ALEXNET model, and they are calculated for each time frame obtained approximately in every 2 s. Initially we are going to train our model using a lot of data collected from Imagenet. Total dataset is classified into Train and test sub dataset.

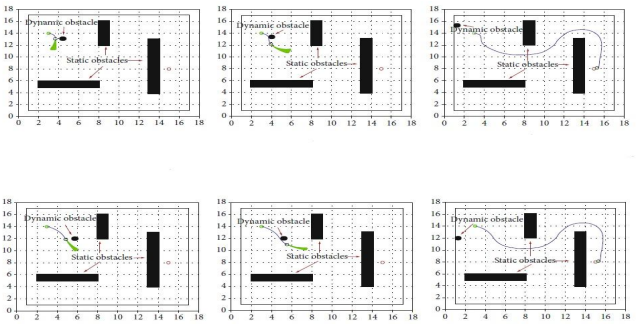
Groups	Training sample	Testing Sample
Long Lawn Grasses	13406	3207
Short Lawn Grasses	17034	4251
Not lawn Grasses	10560	2640
Total	41000	10098

- **Evaluation Result** : Seven combinations of sensor data used are shown in Table 4. These combinations cover all possible cases. Using the measurement data from C1 to C7, the best combination of sensor data is determined based on the above-mentioned evaluation criteria.Particularly, C6 and C7, excluding the built-in-horizontal or vertical angle sensor, have higher accuracy. It seems reasonable that the battery status and motor rotation conditions contribute to higher performance because the rotation of the motor becomes high when it encounters long lawn grasses. On the other hand, the load on both the grass cutting motor and travelling motor is reduced when the robo-mower travels on a ground without lawn grasses. From the evaluation results, C6 is desirable among seven cases. The reason is that the accuracy is high, with a difference of only 0.1 points from maximum 92.28%. The recall ratio of Short Lawn Grasses, 87.08%, is the highest.

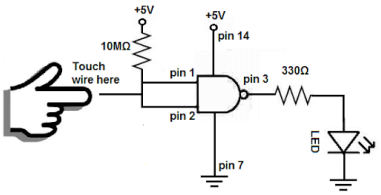
Combinations of sensor data		C1	C2	C3	C4	C5	C6	C7
Accuracy		75.84	77.52	86.32	90.92	91.58	92.18	92.28
Long Lawn Grasses	Precision	77.06	70.70	92.68	92.60	91.46	92.66	91.04
	Recall	73.02	67.70	93.46	93.60	93.64	93.44	93.56
	F-measure	74.99	69.17	93.07	93.10	92.54	93.05	92.28
Short Lawn Grasses	Precision	72.66	73.84	87.30	90.48	92.12	89.40	92.04
	Recall	60.88	68.28	70.06	82.00	83.26	87.08	85.58
	F-measure	66.25	70.95	77.73	86.03	87.47	88.22	88.69
Not Lawn Grasses	Precision	77.06	86.34	80.24	89.70	91.34	94.40	93.72
	Recall	93.60	96.60	95.46	97.20	97.90	96.08	97.70
	F-measure	84.53	91.18	87.19	93.30	94.51	95.23	95.67
Average of Precision, Recalls, and F-measures		75.56	77.20	86.35	90.89	91.58	92.17	92.25

5. **Obstacles detection and traversal in shortest path** : When using the Dijkstra algorithm to plan the shortest path, it is usually necessary to specify the starting position of the car, then introduce two sets S and U. Set S is used to record the vertices of which the shortest path has not been found, and the distance from the vertex to the starting point.
    - Initially, the starting point in the map is regarded as the set S, that is, the set S contains only the starting point. The set U contains vertices other than the starting point.
    - According to the specified starting point, find the distance d[i] from other points to the initial point.If the point is adjacent to the starting point, d[i] is the edge weight (that is, the length between the two points); if the point is not adjacent to the starting point, d[i] is ∞ .Select the smallest d½i from the set U (that is, the vertex with the shortest distance from the starting point), and add this vertex to the set S of vertices that have found the shortest path; at the same time, the vertex is removed from the set U of points that have never found the shortest path
    - Update the distance from each vertex in the set U to the starting point.Repeat steps (3) and (4) continuously until all vertices are searched; then, d½i corresponding to the targetpoint is the shortest path length.

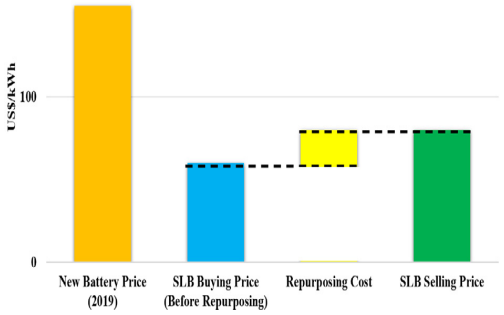
    We will be using infrared or IR sensors (our tv remotes use IR sensors that's why blocking the front part of the remote causes the remote not to operate the channels, volume....) this happens because IR is blocked by solid obstacles. Some more alternatives to IR sensors are thermal sensors (used by army and in airport security)ultrasonic sensors (like SONAR).



6. **Touch Sensing for automation of Blades and for safety purposes** : There might be a possibility that the Dijkstra Algorithm will be throwing some glitch or take a bit of time to operate optimally in the presence of sudden obstacles or mainly living beings. Lawn Mower accidents cause thousands of foot injuries.The U.S. Consumer Products Safety Commission estimates more than 37,000 Americans suffer a power mower-related injury each year. The blades will stop in contact with the Obstacle and it will automatically increase or decrease its speed according to how densely the grasses are in there. When there is contact with the surface of the touch sensor, the circuit is closed inside the sensor and there is a flow of current.

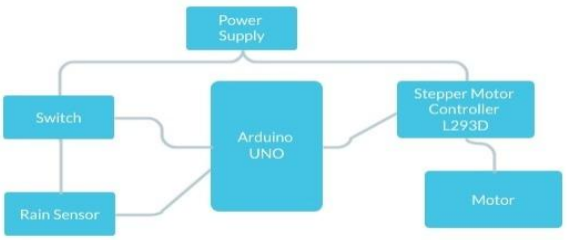


7. **Battery** : It is estimated that by the year 2030, the cumulative number of Electric Vehicles (EVs) will reach 85 million. Once EV batteries degrade to 70–80% of their initial capacity, EV owners will have to replace the EV's batteries as the residual capacity becomes insufficient for automotive use. As a result, more batteries will be discarded from EVs. These batteries could be re-purposed in other applications, where they are known as the



EV Second Life Batteries (SLB). We will be using a second life battery that will cut down our cost . Grass mowing is not too power consuming work (1.2-1.3 kW) .

8. **Rain Sensor for automatic shielding** : Basically we are adding a rain sensor with the help of Arduino. When it is raining, rain droplets will automatically activate the sensors which results in an umbrella that will cover the whole body. So, the electronic body might not be affected by the water-droplets. Present work proposes an automated rain sensing umbrella which opens up automatically when the rain starts and gets closed when the rain stops. The designed model will not require any human intervention for controlling the overall system. Whenever the rain falls, the rain sensor detects the intensity of the rainfall and sends the information to Arduino. The information collected by the rain sensor is processed by the Arduino and sends the processed information to the servo motor to take the desired action. The rain sensor consists of digital analog output pins from where the intensity of the rain is calculated. The information which is sent to the microcontroller is responsible for controlling which leads to folding and unfolding of the umbrella and based on the intensity of the rainfall. The LCD will show the intensity of the rainfall. The Arduino coding is used to set the threshold values and the amount of the power required to open the umbrella. Formulating the basic idea of a model can help to further the design of the model and the components which will be ultimately required for the fabrication of the system at very minimal cost with better efficiency.



9. **Fast Charging system :** Using gallium-nitride power switches from GaN Systems ; efficiency increases upto 97 %. EVs that incorporate our motive latest automotive-qualified gallium nitride (GaN) power-management technology will be able to charge faster and drive farther than automotive systems based on traditional silicon-based charging technology. Enabling automobile manufacturers to remove these barriers to widespread adoption of EVs is a major step toward lowering emissions that affect air quality and climate worldwide.For EV, TI GaN gives manufacturers advantages over traditional silicon or newer silicon-carbide (SiC) technologies, which generate significant heat during the charging process and bleed off energy while increasing charging time. The industry's fastest integrated gate driver enables twice the power output, doubling the power density compared to silicon MOSFETs and enabling automotive designers to optimise the design of their on-board charging architecture.

10. **Sound Cancellation :** Noise damping is a way of preventing vibrations on vehicle bodies and materials by converting the vibrations into heat. It works by reducing energy stored in an oscillation. The goal is to slow down an oscillatory system as fast as possible by adding noise damping materials into the system. Reduction of the duration and size of vibration a vehicle experiences will result in a reduction in noise.A popular product EV manufacturers have taken advantage of due to its great ability to dampen sound has been noise-damping mats & patch, sometimes also referred to as butyl foil mats.Sound damping mats are lightweight, typically made with butyl rubber & aluminium foil, and conforms well to sheet metal and other hard substrates. The butyl rubber has excellent vibration-damping characteristics and is complimented with the use of an aluminium backing. Using a thicker aluminium foil, they're able to achieve improved vibration damping and better heat control, as aluminium is excellent at dissipating heat .

LINK FOR THE CODING STUFF:

Code for Microcontroller:
https://docs.google.com/document/d/1ekElppgBSdEh-ig4Cl6qYxhAD35G5TE4cliCFhIZV-Y/edit?usp=sharing

Code for Deep Learning Implementation and Dijkstra Algorithm:
https://drive.google.com/drive/folders/1buHefLowUBIcs0h3TFrpUoBf0v81eid1?usp=sharing

LINK FOR THE CAD MODEL:
https://drive.google.com/drive/folders/13MJPl_MXs8nSVZRfzfV9t7sh5yK7SN9u?usp=sharing

LINK FOR THE VIDEO OF 3D MODEL:
https://drive.google.com/file/d/1s6KhHvSufDASOMAuI-jF78A63o7GEYhc/view?usp=sharing

MARKET ANALYSIS :

Market competitive analysis :

Key players operating in the global electric lawn mower market include Husqvarna Group, The Toro Company, Deere & Company, Briggs & Stratton Corporation, MTD Products Inc., Ariens Company, Robert Bosch GmbH, Honda Motor Co., Ltd., Hayter Limited, Mean Green Products, Unison Engg Industries, and D&D Motor Systems, Inc.

The growth of the market :
Rising awareness about the benefits of green roofs, such as better stormwater management by reducing runoff, energy conservation, and carbon sequestration, has encouraged their adoption since the past few years. Moreover, green roofs provide space for urban agriculture and offer a healthy and aesthetically pleasing environment. These factors are also likely to propel their

usage, thereby supporting market development. An emerging trend of covering roofs with small and medium-sized plants and vegetation is further expected to spur the demand for electric lawn mowers, thereby driving the overall market.

CONCLUSION :

The lawn mower has almost no limitations when it comes to manual handling, but making it fully automotive is still a very challenging task. Despite implementation of advanced features such as AI implementation, optimal battery storage using power electronics, fast charging, Arduino sensing, there is still a lot of work and research that needs to be done to make a fully autonomous working real model. The model is cost effective as it reduces labour costs and requires minimal maintenance. In all of the steps of the new product development process, the most important focus is on creating a superior customer value and the perfect motive to use it in the campus itself.

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ANNEXURE :

- **https://www.jetir.org/papers/JETIREA06023.pdf**
- **https://www.ijtsrd.com/papers/ijtsrd15824.pdf**
- **https://drive.google.com/file/d/1usw28AxAMkKwlq94Ob9kDD2NOv-xcBkD/view?usp=sharing**
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- **https://www.ijresm.com/Vol.3_2020/Vol3_Iss2_February20/IJRESM_V3_I2_60.pdf**
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