A Project Report On

Multipurpose Autonomous Agricultural Robot

Submitted in partial fulfillment of the requirement for the 8^{th} semester

Bachelor of Engineering

in

Computer Science and Engineering

DAYANANDA SAGAR COLLEGE OF ENGINEERING

(An Autonomous Institute affiliated to VTU, Belagavi, Approved by AICTE & ISO 9001:2008 Certified)

Accredited by National Assessment & Accreditation Council (NAAC) with ‘A’ grade

Shavige Malleshwara Hills, Kumaraswamy Layout, Bengaluru-560078

Submitted By

Nihar Raviprakash 1DS18CS078

Siddhant Sharma 1DS15CS106

Vedansh Khandelwal 1DS19CS186

Yadu Krishna 1DS19CS194

Under the guidance of

Ms. Nidhishree M S

Asst. Professor, CSE ,

DSCE

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Department of Computer Science and Engineering

DAYANANDA SAGAR COLLEGE OF ENGINEERING

Bangalore - 560078

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Department of Computer Science & Engineering

CERTIFICATE

This is to certify that the project entitled **Multipurpose autonomous agricultural robot** is a bonafide work carried out by **Nihar Raviprakash [1DS18CS078], Siddhant Sharma [1DS18CS106], Vedansh Khandelwal [1DS19CS186]** and **Yadukrishna [1DS19CS194]** in partial fulfillment of 8th semester, Bachelor of Engineering in Computer Science and Engineering under Visvesvaraya Technological University, Belgaum during the year 2020-21.

Ms. Nidhishree MS	**Dr. Ramesh Babu D R**	**Dr. B G Prasad**
(Internal Guide)	Vice Principal & HOD	Principal
Asst. Prof. CSE, DSCE	CSE, DSCE	DSCE
Signature:...........	Signature:...........	Signature:...........

Name of the Examiners:	Signature with date:
1..........................	....
2............................	....

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We are pleased to have successfully completed the project **Multipurpose Autonomous Agricultural Robot**. We thoroughly enjoyed the process of working on this project and gained a lot of knowledge doing so.

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Nihar Raviprakash 1DS18CS078

Siddhant Sharma 1DS15CS106

Vedansh Khandelwal 1DS19CS186

Yadukrishna 1DS19CS194

Abstract

In recent years, there has been growing interest in the development of autonomous agricultural robots for tasks such as planting, weeding, watering, and harvesting crops. These robots have the potential to improve the productivity and sustainability of agricultural operations by reducing the need for manual labor and enabling precision farming techniques.

In this study, we present the design and implementation of an autonomous agricultural robot that is capable of performing a range of tasks in various crop environments. Our robot is equipped with sensors and algorithms for navigation, object detection, and task execution, and is capable of operating in both indoor and outdoor settings.

We conducted a series of experiments to evaluate the performance of our robot in real-world conditions. Our results show that the robot is able to accurately and efficiently complete a variety of tasks, such as planting seeds, removing weeds, and applying water or pesticides to crops. We also demonstrate that the robot can adapt to changes in the environment and adjust its behavior accordingly.

Overall, our findings suggest that autonomous agricultural robots have the potential to significantly improve the efficiency and sustainability of agricultural operations. However, further research is needed to address challenges such as the integration of these robots into existing farming systems and the potential impact on employment in the agriculture sector.

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LIST OF ABBREVATIONS

GPS-Global Positioning System.

UGV-Unmanned Ground Vehicle.

IDE-Integrated Development Environment.

PCB-Printed Circuit Board.

SRS-System requirements specification

AR- Augmented Reality.

CHAPTER 1

INTRODUCTION

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1.1 BACKGROUND

As agriculture grows in size, together with the size of the equipment used on them, there is a need for ways to automate processes, previously performed by the farmer himself, such as sowing, fertilizer spraying, controlling the fields for pests etc. These tasks are perfectly suited for autonomous robots, as they often require numerous repetitions over a period of time and over a large area. The use of robots is a rather new development as most of the existing solutions for automatic supervision, is designed for standard farm equipment, such as tractors, combine harvester and pesticide sprayers. When activities like crop monitoring and mapping of fields or precision spraying of pesticides, a smaller robot is ideal, as it is gentler on the crops and to the ground. This is due to the lower weight compared to a tractor, causing much lesser soil compaction. The degree of soil compaction is important to consider, especially when dealing with monitoring and mapping as this is often performed multiple times throughout the year, as soil compaction can cause a number of problems, such as reduced crop growth and denitrification. (Ray *et al.,* 2015)

A Multipurpose Autonomous Farming Vehicle is an electric agricultural vehicle designed to carry various agricultural process like seed sowing, irrigation, crop growth monitoring and fertilizing. The vehicle is designed to carry out these operations with least intervention of a human being. First the agriculture land is mapped and distance between each plant is set. Then the vehicle is made to run in predefined path with the help of GPS. After sowing is done the vehicle is made to run in field at regular intervals to monitor the crop from seed to a fully-grown plant. Each plant is individually fertilized whenever necessary, thus preventing the excessive usage of fertilizers as well as wastage of fertilizers. (Charansingh *et al.,* 2016)

Currently, there are many challenges faced by the farming, not least of which are a reduction in the available workforce, and a more systematic style of farming. Such factors demand an increase in farming efficiency and productivity. In this work, the autonomous farm is seen as a complex system, where there is necessarily a seamless integration of requirements, bringing together the areas of robotics for autonomous farming, and Precision Agriculture, which deals with issues of agronomy. There is urgent need to mechanize the agricultural operations so that wastage of labor force is avoided and farming is made convenient and efficient. Agricultural implements and

machinery is a crucial input for efficient and timely agricultural operations, facilitating multiple cropping and thereby increasing production.
This robot achieves this with its smart system to map the land, sow seeds, and monitor it to some extent. All this is done autonomously with very little human intervention.

1.2 OBJECTIVE

The main objective of the machine is to make agriculture much easier, efficient and profitable. But these objectives can be achieved when all the small basic objectives are met. These include:

- Design and simulate electric vehicle, that is capable of independently carrying out various farming activities systematically.
- Perform stress analysis of designed vehicle.
- Calculating seed sowing with optimum row and plant spacing.
- The vehicle is designed to carry out various agricultural activities with least intervention from a human being.
- The vehicle is designed for farmers who have medium and large size agricultural land and spend lot of money on manual labors for planting and maintaining the crops.
- The autonomous farming vehicles includes increased productivity, increased application accuracy, and enhanced operational safety.

1.3 OPERATIONAL REQUIREMENTS

A number of requirements for the operational performance of the VEHICLE, has been set by previous groups. The relevant requirements for use in this project are:
1. When a fault occurs, the robot is allowed to deviate from its course, for instance driving on top of the rows, for a maximum of 30 seconds.
2. The robot must be able to continue operation with at least one sensor/actuator fault.
3. Operating under both normal and faulty operation the robot must not be potentially dangerous to its environment.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1 PAPER

- The paper titled "Multifunctional Robotic Vehicle for Agriculture Application" by Charansingh A. Patil and Sunil U. Nyati, presented at the International Conference on Global Trends in Engineering, Technology, and Management (ICGTETM-2016), has been instrumental in enhancing your understanding of the requirements for a versatile farming vehicle. It has also influenced your approach to designing and integrating various equipment onboard the vehicle.
- The research paper titled "Architecture of an Automated Agricultural Tractor: Hardware, Software, and Control Systems" authored by Ray Eaton, Jayantha Katupitiya, Anthony Cole, and Craig Meyer, was presented at the 16th Triennial World Congress in Prague, Czech Republic in 2015. This paper offers comprehensive details regarding the control architecture of an automated farming tractor, encompassing key components such as the steering control system, traction control system, and automation software.
- The scholarly article titled "Development of an Adaptive Strategy for Precision Agriculture Monitoring Using Drone and Satellite Data" by Deepak Murugan, Akanksha Garg, and Dharmendra Singh was published in the IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, Volume 10, in 2017. This publication elucidates the utilization of unmanned aerial vehicles (UAVs), commonly known as drones, alongside a range of sensors to facilitate accurate monitoring of agricultural activities. Additionally, it explores the integration of cloud-based computing for efficient processing and analysis of the data captured by the drones, enabling precise assessment and interpretation of crucial agricultural information.
- The scholarly article titled "Optimizing Sensor Planning for a Collaborative UAV and UGV System in Precision Agriculture" authored by Pratap Tokekar, Joshua Vander Hook, David Mulla, and Volkan Isler, was published in the IEEE Transactions on Robotics, Volume 32, in 2016. This publication delves into the effective deployment of unmanned ground vehicles (UGVs) within the agricultural domain.This paper focuses on the integration of unmanned aerial vehicles (UAVs) and unmanned ground vehicles (UGVs) to optimize land mapping and path learning for precision agriculture applications, offering valuable insights into the efficient utilization of these collaborative systems in the field of agriculture.

2.2 BOOK

- The publication titled "Package of Practices for Agriculture" issued by the University of Agricultural Sciences, Bangalore in 2016, provides comprehensive information regarding diverse agricultural practices tailored for various crops.

2.3 PATENT

- The United States Patent Application Publication with the title "Seed Metering Device for Agricultural Seeder" by Bruce Peterson and Brent W. Nelson in June 2010 has played a pivotal role in assisting the design of the seed sowing mechanism for our agricultural vehicle. It provides valuable insights into the precise collection and controlled individual dropping of seeds, ensuring a consistent distance between each seed during the sowing process.

CHAPTER 3

MARKET ANALYSIS

CHAPTER 3

MARKET ANALYSIS

- India is the world largest market for farm equipment (30% of world's production).
- India has also been shifting towards farm mechanization due to scarcity of labors, increase in daily wages for labor in agricultural land and favorable credit terms.

MONTH WISE TRACTOR SALES												
FY	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March
2014-15	49668	54625	66172	40345	32953	68353	77983	36219	27945	33964	29416	33820
2015-16	40244	44716	57550	35315	26074	45089	65098	46885	27898	34128	32096	38671
2016-17	46031	51566	65938	38248	30319	67361	93907	40763	30038	36021	34492	48160

Table 3.1: Month wise tractor sales (*Source: tractor and mechanization association of India*)

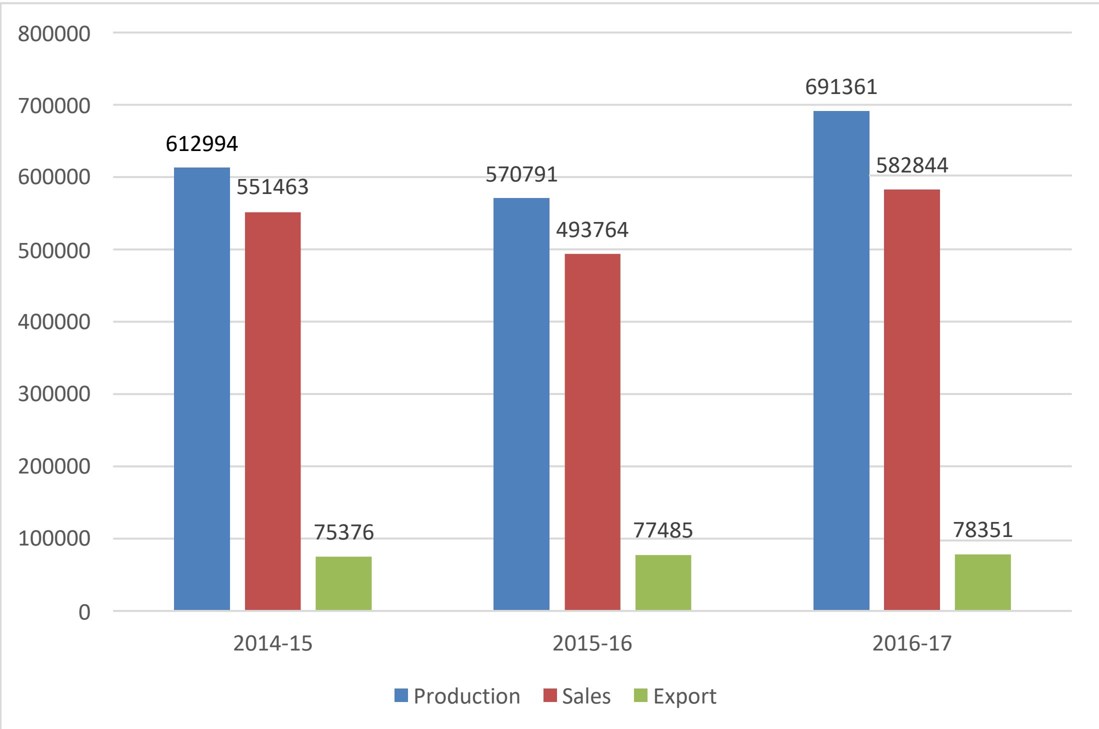

Fig 3.1: Annual Tractor production sales and export

3.1 MARKET PLAYERS

- The existing farm equipment companies have manufactured various tractors and other equipment's and are successful in their business.
- Few companies have launched tractors with latest technologies and higher horse power with improved fuel efficiency.
- Last year Mahindra launched its driverless tractor and Escort launched its electric tractor, but both aren't yet available in the market.
- In the global market many companies have come up with the conceptual models of autonomous tractors.
- There are many companies in India that manufacture tractors and farm equipment of various sizes and capacity for different applications.
- Few major companies which are doing well in the market are
  - Mahindra & Mahindra
  - TAFE
  - ESCORT
  - John Deere
  - International Tractor Ltd.
  - New Holland

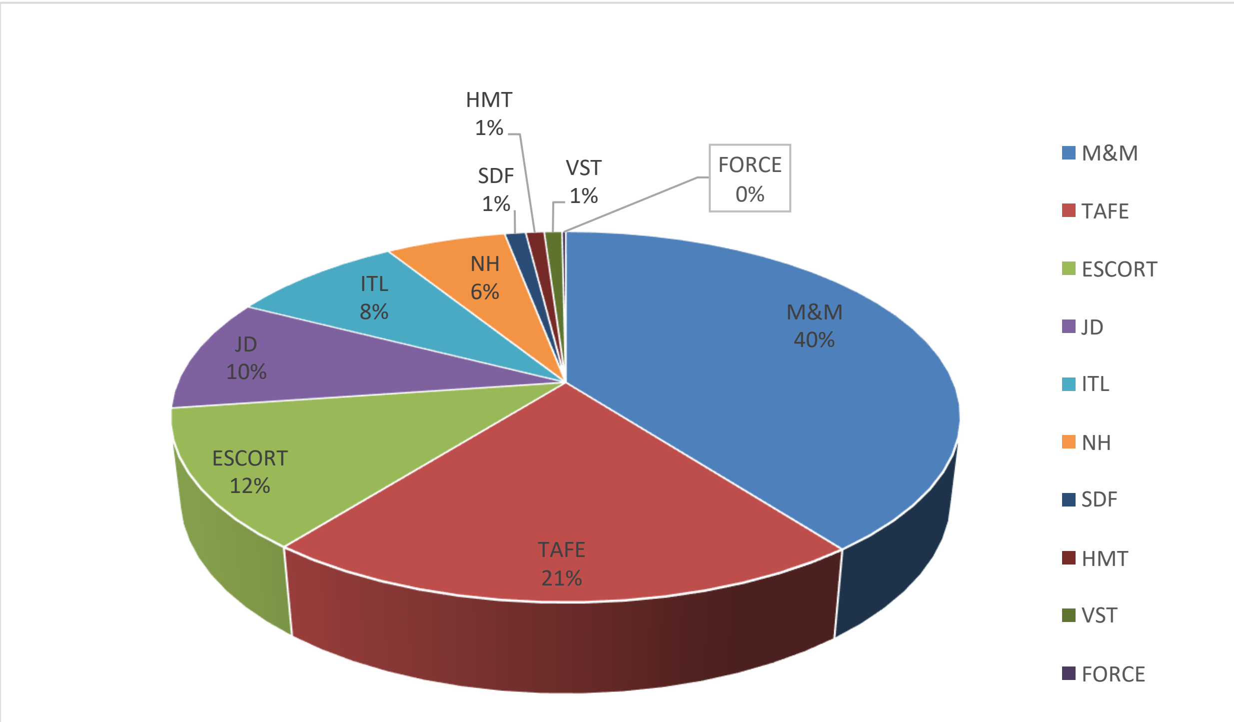

Fig 3.2: Tractor market share

CHAPTER 4
VEHICLE DESIGN

CHAPTER 4
VEHICLE DESIGN

The main aim of the project was to design an autonomous electrical vehicle capable of carrying out various agricultural activities. The vehicle had to be designed in such a way that it should be able to easily carry various equipment and components. To do so the frame of the vehicle is divided into 3 parts. Two side frames and one main frame. This enables proper weight distribution on the vehicle.

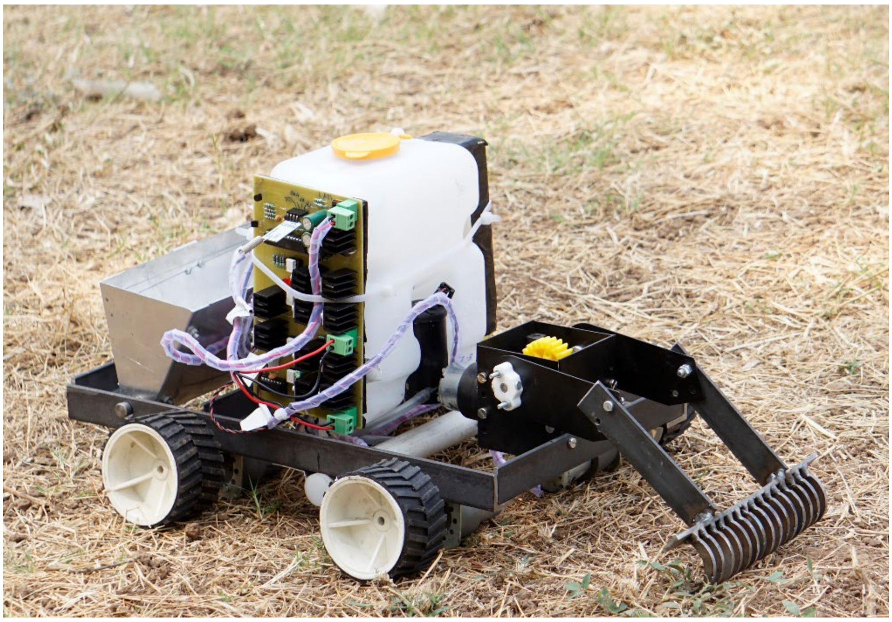

Fig 4.1: Three divisions of frame

Typical equipment and components on farming vehicle:

- Plough
- Seed sowing mechanism
- Seed carrier
- Pesticide carrier
- electrical motor
- Battery

4.1 SEED, PESTICIDE AND ELECTRICAL COMPONENTS CARRIER

The vehicle is designed to have separate seed carrier and pesticide carrier. The main frame of vehicle carries both seeds and pesticide. The frame is separated into 2 halves. The first half is for the seeds and second half is for the pesticides.

The necessary electrical and electronic components such as suction pump, microcontroller and PCBs etc. are placed on separately on front side of the main frame. Seclusion of electrical compartment from main body prevents dust and pesticide particles from entering into electrical components. Also, because of its position at the front of vehicle all electrical components can be easily accessed whenever necessary.

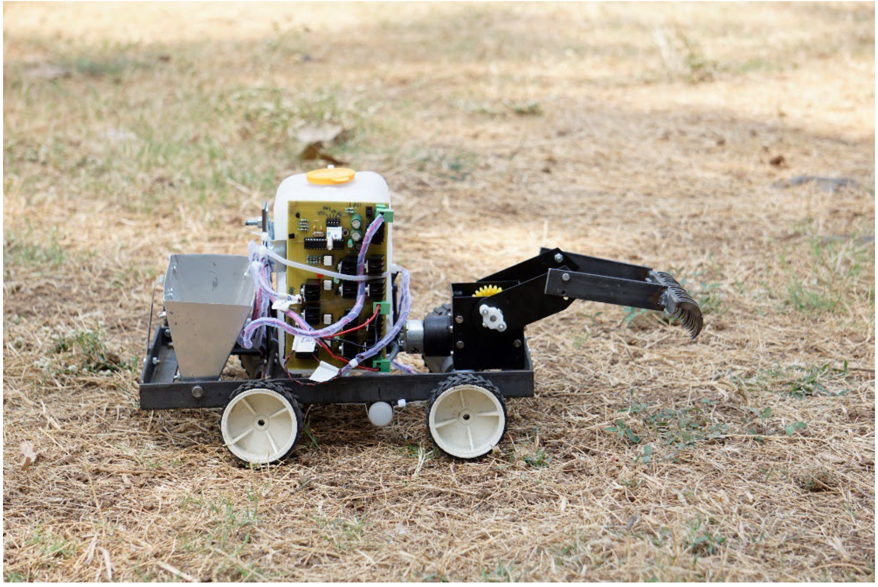

Fig 4.2: Seed, pesticide and electrical components carrier

4.2 EQUIPMENT HOLDER

The vehicle is designed in such a way that underside of the vehicle can carry all the necessary farming equipment such as plough and seed sowing mechanism. The length of space between the two side frames is 40 inches. This is enough for 3 seed Sower. The distance between each seed is 12 inches. The plough and seed sowing mechanism are fixed onto the circular bar of diameter of 1.5 inch and placed on the slider racks. The vehicle is designed such a way that it can carry different equipment at different height from the ground. This is because, pesticide sprayer and crop monitoring sensors should be placed at higher distance to prevent them from contacting the tall crops.

Fig 4.3: Cut section showing slider racks

4.3 BATTERY AND TOOLS COMPARTMENT

The battery required to run the vehicle is situated on sides of each side frames. The location of the battery compartment enables easy maintenance of the batteries. Battery of 152Ah 72 Volt battery is placed in battery compartment. To maintain uniform weight distribution the batteries are kept at both the sides.

Above the battery compartment, the space is provided for tools compartment. This area can also be used store other things based on requirements.

Fig 4.4: Battery and tools compartment in side frames

CHAPTER 5
ELECTRONICS

CHAPTER 5

ELECTRONICS

5.1 SYSTEM REQUIREMENTS SPECIFICATIONS

System requirements specification (SRS) is a text written to specify in detail the system components, both hardware and software, which are needed for the system implementation, along with functional and non-functional and operational requirements, as anticipated from the system. (Ashwin *et al.,* 2016)

5.1.1 Hardware Specification

This section gives details of the hardware components required for the system implementation and deployment. The vehicle requires the following hardware components:

- Arduino uno [ATmega328]
- Motor shield [L298 H-bridge]
- GPS shield [GP3906-TLP GPS Module], used for communication between the GPSreceiver and the available GPS satellites.
- Magnetometer [triple-axis], heading of the vehicle relative to magnetic north.
- Ultrasonic sensor, measures the distance to the nearest obstacle using the time of flight of emitted sound waves
- Servos [to drive throttle]
- Wi-Fi module [IEEE 802.11 connectivity], communication between the OBC and the API base station.

5.1.2 Software Specification

This section gives details of the software components required by the intended system under development. The vehicle requires the following software components

- Arduino IDE

  The Arduino Integrated Development Environment - or Arduino Software (IDE) - contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them.

5.2 CIRCUIT DIAGRAM

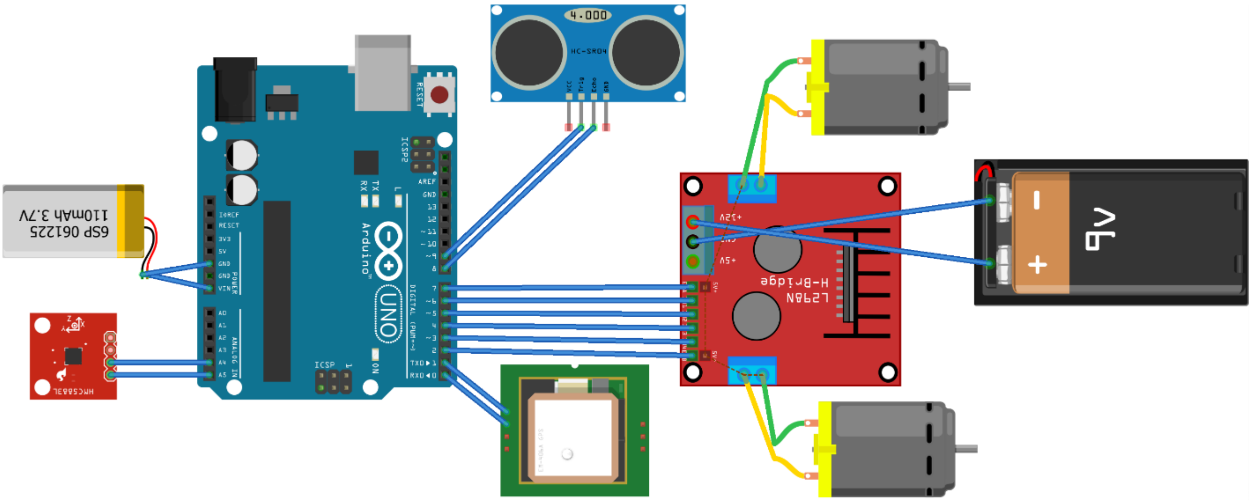

Fig 5.1: Circuit diagram of autonomous system

Above is the pictorial representation of the components used for the autonomous drive of the vehicle.

5.3 CODE

The program takes waypoints from the point that we provide on the map. The waypoints can be downloaded and then fed into the microcontroller using Wi-Fi module.

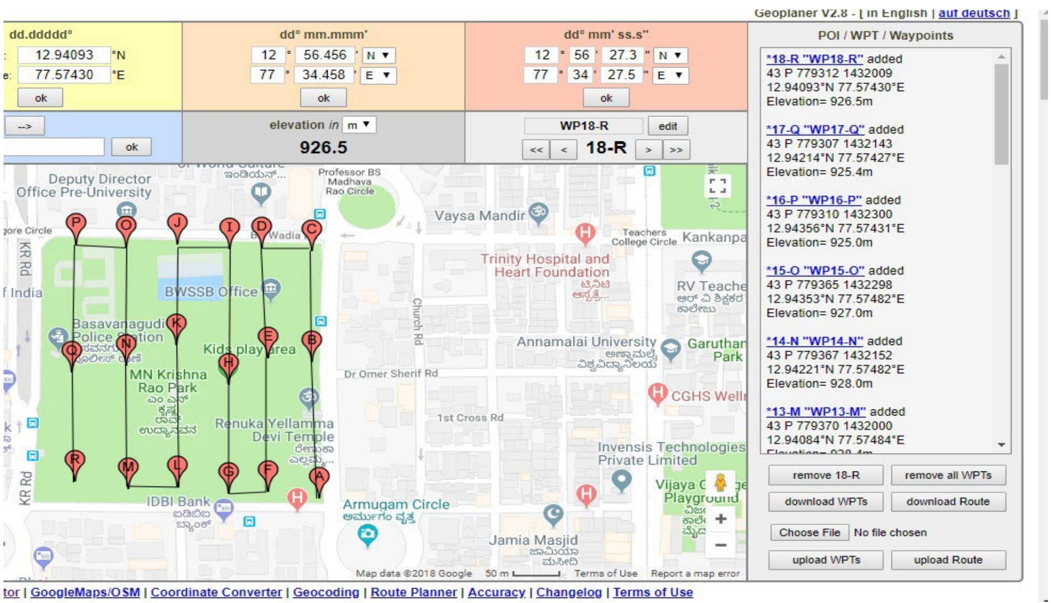

Fig 5.2: Waypoint from geoplanar

The Arduino is controlled through a C++ program uploaded using Arduino IDE. The main action happens in the Arduino sketch loop () function which runs repeatedly. The basic program controllogic is:

- Check to see if the kill switch was pressed (if enable in the configuration).
- Process any new GPS information and update the course and distance to the target. Move on to the next waypoint if we have reached the current destination.
- Read compass to get current bearing and decide the desired direction to turn the car and also maintain a fixed straight path in case of no turns.
- Move the vehicle and check for any obstacles we need to avoid.
- Update LCD display and the program

CHAPTER 6

VEHICLE CALCULATIONS

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VEHICLE CALCULATIONS

Total Force

F_i = m x g (at stand still)

=500 x 9.81

= 4905 N

Frictional force $F_f = C_r$ x W

Aerodynamic drag $F_d = C_d$ x A x ρ x $\frac{v^2}{2}$

Density of air ρ = 1.2 kg/m³

Coefficient of drag, C_d = 0.8

$$Fa = 0.8 \times 1.6 \times 1.2 \times \frac{(2.77)^2}{2}$$

= 5.89 N

Rolling Resistance

$F_R = C_R x W$

= C_R x m x g

= 0.06 x 500 x 9.81

= 294.3 N

Total force

$F = F_i + F_r + F_a$

= 4905 + 5.89 + 294.3

= 5205.19 N

Total torque required

T = F x r

= 5205.19 x 0.2286

= 1189.906 Nm

Each wheel = 594.95 Nm

Finding RPM

Wheel size = 18" (0.4572m)

i) V = 10 km/hr. = 2.77 m/s

V= 2π x r x ω

2.77 = 0.2286 x 2 x π ω

ω = 125 rpm

ii) V =15 km/hr. = 4.166 m/s

V= 2π x r x ω

4.166 = 0.2286 x 2 x π x ω

ω = 188 rpm

iii) V =20 km/hr. = 5.55 m/s

V= 2π x r x ω

5.55 = 0.2286 x 2 x π x ω

ω = 250 rpm

Suspension Calculation

Data:

Wire radius = 5 mm

Outer radius = 30 mm

Spring material : [ASTM-A228]

Ultimate strength = 1725 – 3790 MPa

Modulus of elasticity = 207 GPa

Modulus of rigidity = 79 GPa

Finding stiffness K

$$K = \frac{Gd^4}{8ND^3}$$

D_{mean} = 50 mm

$$c = \frac{\text{Dmean}}{d} = \frac{50}{10} = 5$$

wahl factor

$$k = \frac{4c-1}{4c-4} + \frac{0.615}{c}$$

$$= \frac{19}{16} + \frac{0.615}{5}$$

k = 1.311

$$Y = \frac{8 \times 200 \times 9.81 \times 50^3 \times 5}{10^4 \times 79 \times 10^3}$$

Y = 12.41 mm

$$\text{Stiffness } K = \frac{F}{Y}$$

$$= \frac{200 \times 9.81}{12.41}$$

= 158.09 N/mm

Battery and Hub Motor Calculation

Total distance for 1 acre is assumed to be 8127 m by considering the following factors

i) Row and plant spacing of maize.

ii) Field dimension as 64m x 64m

Total distance travelled by the vehicle for 1 acre is 11.5 km.

Speed = 15 km/hr.

=4.166 m/s

Torque = 500 Nm

Total force =5205.19 N

Power required = F_T x V

=5205.19 x 4.166

= 21684.82 W

= 21.6 kW

Power for each motor = 10.842 kw

Motor = 72 v power =10 kw Ampere =125 amps

The battery capacity is calculated by comparing the dimensions of the batteries that are presently available in the market.

72 v 40 Ah

Dimension

L = 401 mm

B = 193 mm H=252 mm

Total volume = 0.4 x 0.25 x 0.19

=0.019 m^3

Total volume for battery = 0.019 x 2

=0.038 m^3

340 mm x 168 mm x 175 mm

0.34 x 0.16 x .175

0.0099 = 0.01m^3

Volume to current

0.01 m^3 40Ah

0.038m^3 =152 Ah

Battery = 10.9 Kwhr

CHAPTER 7

SEED SOWING

CHAPTER 7

SEED SOWING

Traditionally the seeds are sown with the help of a seed drill that is operated using a tractor. Although the present methods have better efficiency but these mechanisms are not effective when it comes to increasing the productivity of the farm. This is due to incapability of the existing technology to meet the following agronomic principles –

i) Plant to proper depth
ii) Uniform plant depth
iii) Good soil to seed contact
iv) Proper population
v) Uniform soil pressure
vi) Good in row spacing

The above-mentioned agronomic principles vary from one crop to the other. In this report we have considered few crops which are grown across the globe.

7.1 CROPS

7.1.1 MAIZE

Soil type

Maize will grow on a wide range of soil types, providing they are well drained. A pH range of 5 - 8 can be tolerated but best growth is achieved in the range of pH 5.6 - 7.5.

Maize does not grow well in saline soils. Yield reductions of 10 - 20+ percent can be experienced if soil extracts contain 2.0 - 4.0 ds/m respectively. Yield decline is likely if irrigation water has a reading of more than 1.5 ds/m. Seedling and flower growth is most sensitive to salinity.

Soil temperature

Soil temperature at planting depth (5-7.5 cm) should be 12°C or higher and have been on an upward trend for three or more days.

While seed will germinate at 12°C, growth is often slow and foliage develops a purple color. Temperatures of 15°C + are safer and result in better growth.

Planting moisture requirement

Dryland maize should be planted on a full soil moisture profile. Irrigated crops should be irrigated pre-plant and then if using flood irrigation not watered until 6 weeks old. If conditions are hot and dry, a quick flush 2 - 3 weeks after emergence may be required.

Maize is not tolerant of waterlogging especially during seedling and flowering stages.

Desired plant population per hectare	**Number of seeds/kg**				**Average seed spacing, 90 cm rows**
	2500	**3000**	**3500**	**4000**	
	Seed Sowing Rate kg/ha				
15 000	7	6	5	4.5	63 cm
20 000	9	8	7	6	47 cm
25 000	12	10	8	7	37 cm
30 000	14	12	10	9	31 cm
50 000	24	20	17	15	19 cm
60 000	28	24	20	18	16 cm

Table 7.1 Maize seed sowing parameters

Calculation for seed population

Distance between the rows $= \frac{10000}{\text{planting rate}(\frac{kg}{ha})}$ x seeds/kg x row width

Planting rate $= \frac{\text{desired population}}{\frac{seeds}{kg} \text{x \% germination x \%emergence}}$

Row spacing

Row spacing may vary with machinery used, but 75 - 91cm is usually acceptable. The rows should match the harvester width.

Seed placement depth

50 to 75 mm into moisture. Plant deep enough to allow roots to develop in moist soil and grow down into subsoil moisture ahead of the drying front.

7.1.2 SOYBEAN

Plant population

In dryland crops aim for 200,000 plants/ha. On lighter granite soils 180,000 - 200,000 plants/ha is better.

In irrigated crops aim for 300,000 plants/ha or up to 400,000 plants/ha for high yielding situations, or for late plantings made in January. Some varieties of small or upright stature respond to higher planting rates.

Average seeding rate

Seed size can vary considerably so adjust the seeding rate accordingly. usually around 5000 to 7000 seeds/kg for most varieties. Assuming an average seed size of 5700 seeds/kg and 80% establishment.

Seeding rates

Target population	Seeding rate
200,000 plants/ha	42 kg/ha
300,000 plants/ha	63 kg/ha

Table7.2: Soybean seeding rate

Germination percentage

All seed offered for sale must clearly state the germination percentage of that seed line. Use the best seed quality available. It is not recommended to use seed lower than 80% viable.

Seed placement depth

The seed placement depth depends on the type of soil, for heavy soil it ranges from 2-3 cm and for lighter soil the depth varies from 3-4 cm.

Row Spacing

Row spacing and plant population are closely related.as the spacing increases, number of plants per hectare decreases. To get better yield an optimum spacing of 30-45 cm is maintained.

7.1.3 GROUND NUT

Soil Management

Groundnut crop does best on well drained, light textured loose and friable soil having reasonably high calcium, pH 5.5 to 7.0, and a moderate organic matter. Make good tilth of soil with 2 ploughing to obtain optimum germination. In terrace and flat land of high rainfall areas, raised beds of 10-15 cm height are to be prepared to avoid water- logging problems.

Manures & Fertilizers.

FYM = 5 - 10t/ha

N = 40 kg / ha

P_20_5 = 60 kg/ha

K_20 = 40 /ha

All these amounts of NPK should be placed in the furrows below the seed at sowing. Furrow application of lime at 2 t /ha as CaCo3 or CaSo4 every year is recommended. Gypsum at 500 kg/ha at the time of flowering should be applied to supply Ca + S to groundnut. Soil application of 10 kg Mg So4 corrects Mg deficiency.

Seed Rate & Spacing

Botanical types	Seasons	Spacing on (Row x Plant) in cm	Seed rate (kg/ha)
Bunch Type	Kharif	40 x 10	90 – 110
Semi spreading type	Kharif	45 x10	90 – 100
Spreading type	Kharif	60 x 10	90 – 100

Table 7.3: Seed rate and spacing for groundnut

7.2 CALCULATION FOR SEED SOWING MECHANISM

Velocity = 2.5 km/hr.

Distance = 30cm

Time =4.32 sec

Radius = 2”

S = r x ϴ

$$S = 5.08 \text{ cm} \times 45^o \times \frac{\pi}{180}$$

S = 5.08 x 0.785

S = 4 cm

V = 0.1 m/s

$$V = \frac{\pi \ x \ d \ x \ n}{60}$$

$$0.1 = \frac{\pi \ x \ 0.1016 \ x \ n}{60}$$

n = 18.8 rpm

CHAPTER 8
WORKING

CHAPTER 8
WORKING

8.1 EQUIPMENT LOADING AND UNLOADING

The equipment like plough and seed drop mechanism is placed on the equipment carrying stand. The equipment is locked in its place. The stand is placed on a flat surface. Each equipment is placed on its own stand. The attachment of equipment to the main body of vehicle is carried out autonomously.

First to load the plough, the vehicle aligns with equipment and moves in straight line towards the equipment and it is made to slide through the sliding rack provided on the inner wall of the vehicle. The locks keeping the equipment in place is removed. Once the equipment is slides inside the rack and reaches its position the linear actuator is actuated to lock the plough in its position. Then the vehicle carrying ploughs moves backward, away from the equipment stand and rotates 180°.

Next, to load the seed sowing mechanism the process is repeated. But here the vehicle moves towards the equipment in reverse direction towards the equipment stand. The seed sowing mechanism is slid into rack that is placed above the rack provided for plough. The vehicle is provided with two sliding racks placed at two different heights.

After finishing all the task of ploughing and seed sowing, the vehicle returns to the equipment stand area. First, to unload the plough the vehicle moves in straight line towards the equipment stand. Once the plough is in proper position the linear actuators are activated to open the lock. Opening of actuators allows the free sliding of equipment inside the rack. Next, the lock on the equipment stand is manually closed. After the lock is closed the vehicle moves backward. Thus, leaving the equipment on the equipment stand itself.

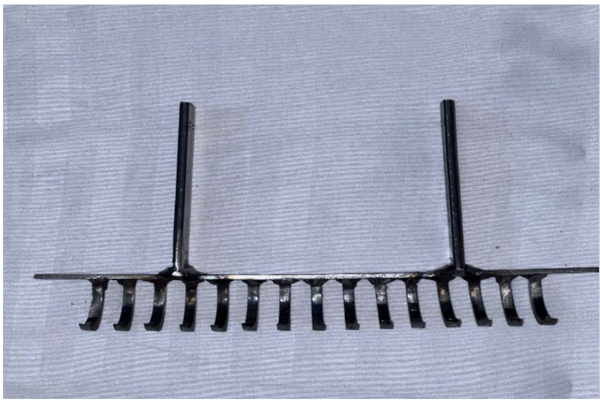

Fig 8.1: Equipment stand and plough

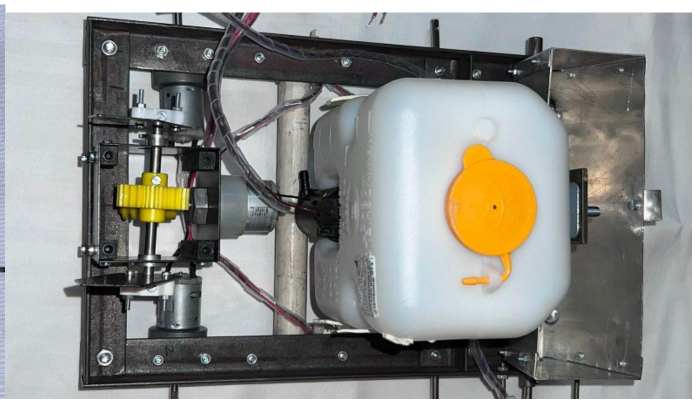

Fig 8.2: Slider racks for equipment

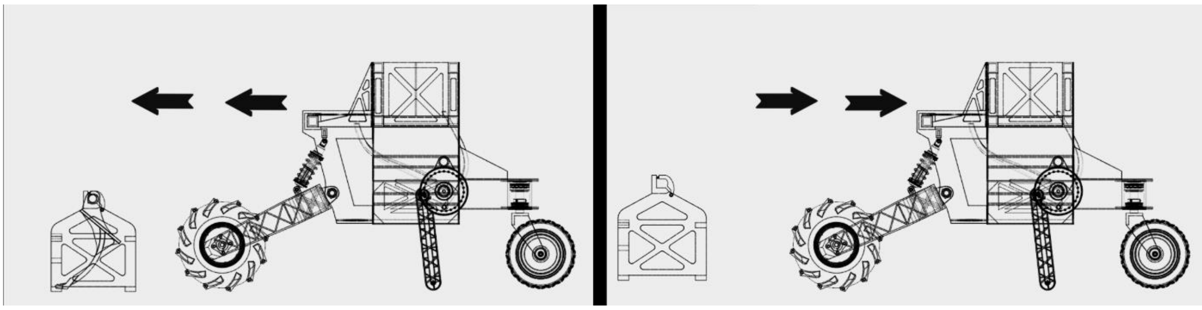

Fig 8.3: Movement of vehicle during loading of equipment

8.2 STEERING MECHANISM

The direction in which the vehicle steers is controlled by a simple process of regulating speeds of the hub motor powering the front wheels of the vehicle. The path that has to be traced by the vehicle is stored inside the microcontroller. At the end of each lane the vehicle has to steered right or left. In order to steer the vehicle to the right, power supply to right wheel is stopped and power is supplied only to the left wheel. This will steer the vehicle in right direction. Once the vehicle turns to required amount the power supply to the right wheel is resumed. The vehicle will continue to move in straight line until the end of lane. Next, the vehicle has to be steered to the left to move to the succeeding lane. This is done using same method, but the power supply to the left wheel is cut off and power is supplied only to right wheel. The rare wheels of the vehicle are not controlled by any means of electricals or electronics. Rare wheels are free to rotate in 360° and follow the direction of front wheels. The rare wheels are castor wheels mounted on combined thrust and radial ball bearing.

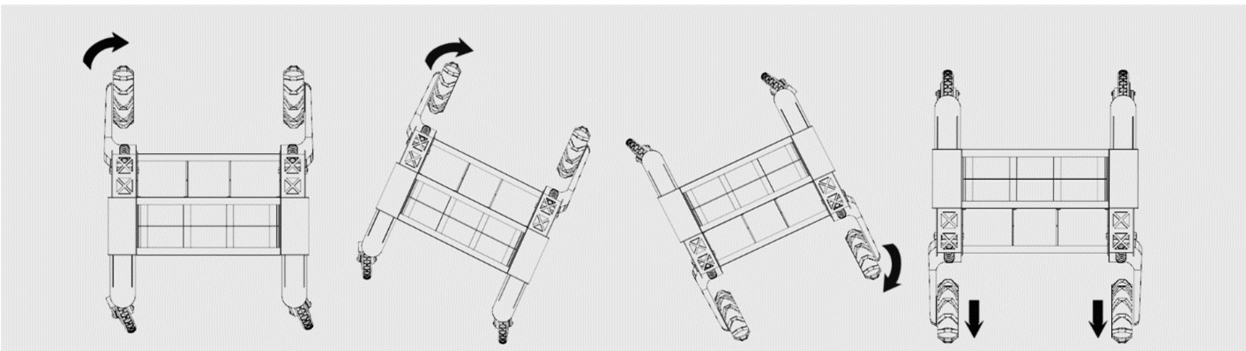

Fig 8.4: Motion of vehicle during right turn

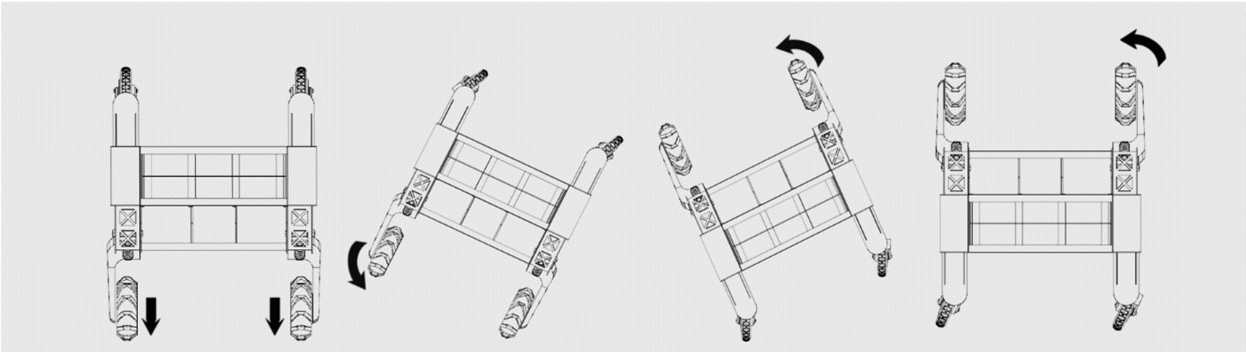

Fig 8.5: Motion of vehicle during left turn

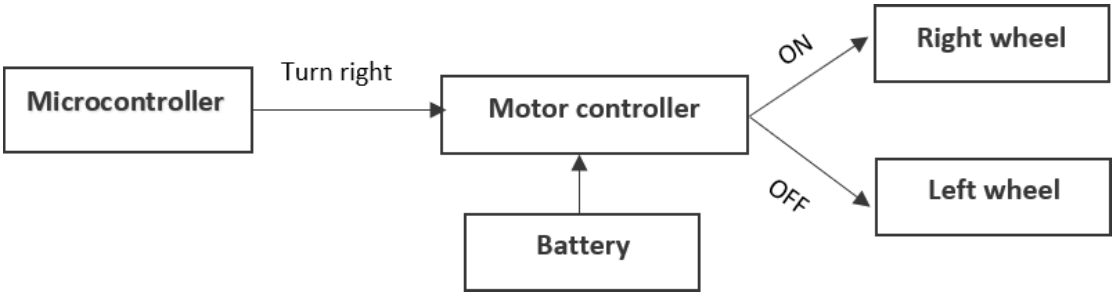

Fig 8.6: Flowchart of steering control

CHAPTER 9
SIMULATION AND ANALYSIS

CHAPTER 9

SIMULATION AND ANALYSIS

Here, CAD model of chassis is created in Fusion 360 and then imported to Autodesk Inventor software. The boundary conditions and load re applied to the chassis. Shear stress, deflection, strain etc. are evaluated to determine the physical characteristics of the chassis.

9.1 MATERIAL

The material used for the structure is steel AISI 4130 for its following properties

- Easily machined using conventional methods
- Good overall strength, toughness, low weight, weldability etc.
- Versatile alloy with good corrosion resistance

Name	Steel AISI 4130 366 QT	
General	Mass Density	7.85 g/cm^3
	Yield Strength	1357 MPa
	Ultimate Tensile Strength	1426 MPa
Stress	Young's Modulus	207 GPa
	Poisson's Ratio	0.33 ul
	Shear Modulus	77.8195 GPa

9.1.1 Physical properties

Mass	176.327 kg
Area	9500120 mm^2
Volume	22462000 mm^3

Center of Gravity	x=2.7508 mm y=-61.5521 mm z=507.978 mm

9.2 MESH

Meshing is the discretization of a model into small elements containing nodes that can be solved by the software using advanced matrix math and then merged together to show the correct result for the whole.

Avg. Element Size (fraction of model diameter)	0.5
Min. Element Size (fraction of avg. size)	0.2
Grading Factor	1.5
Max. Turn Angle	60 deg
Create Curved Mesh Elements	No

9.3 BOUNDRY CONDITION AND LOADS

9.3.1 Forces

Load Type	Seed + pesticide	Load Type	Battery
Magnitude	440.000 lbforce	Magnitude	158.715 lbforce
Vector X	0.000 lbforce	Vector X	0.000 lbforce
Vector Y	-440.000 lbforce	Vector Y	-158.715 lbforce
Vector Z	0.000 lbforce	Vector Z	0.000 lbforce

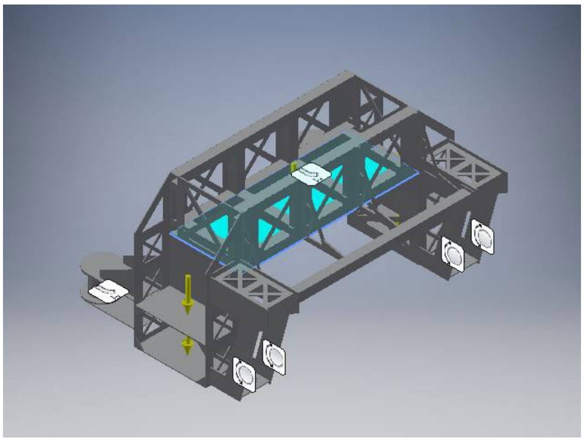

Fig 9.1: Load due to seeds and pesticide

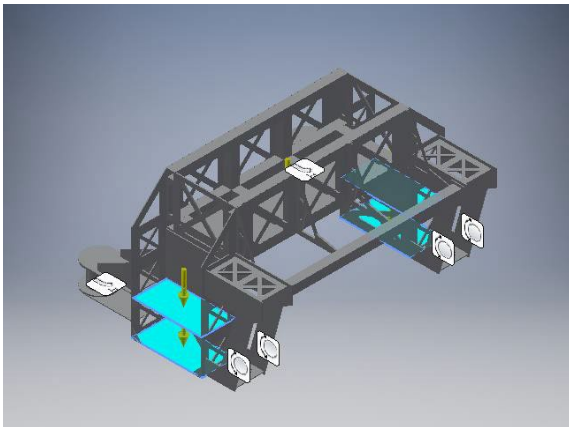

Fig 9.2: Load due to batteries

9.3.2 Constraints

Constraint Type	Fixed Constraint

Constraint Type	Pin Constraint
Fix Radial Direction	Yes
Fix Axial Direction	Yes
Fix Tangential Direction	No

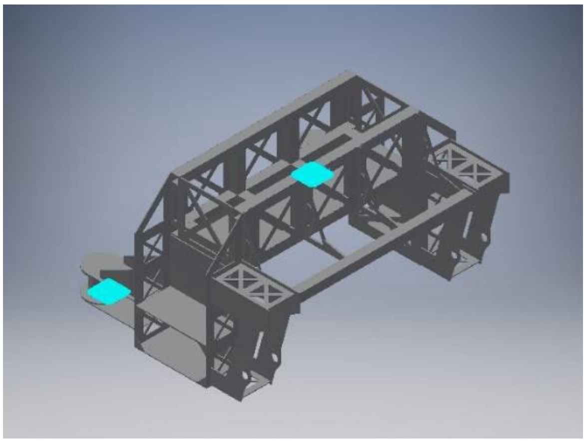

Fig 9.3: Fixed constraints

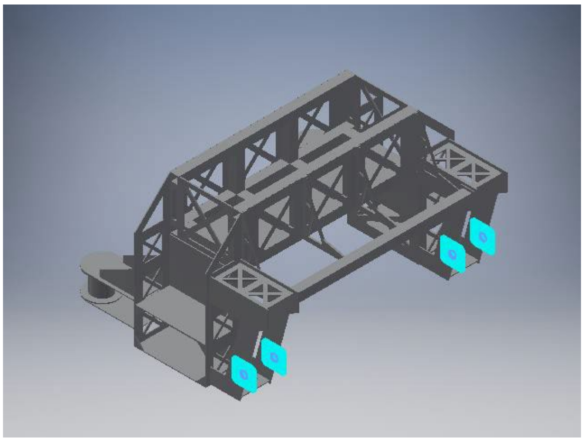

Fig 9.4: Pin constraint

9.3.3 Reaction Force and Moment on Constraints

Constraint Name	Reaction Force		Reaction Moment	
	Magnitude	Component (X, Y, Z)	Magnitude	Component (X, Y, Z)
Front wheel	1318.56 N	334.568 N	42.1143 N m	-8.88817 N m
		1275.38 N		-28.6626 N m
		-9.07191 N		29.5478 N m
Back wheel	1428.38 N	-334.778 N	42.7178 N m	26.2558 N m
		1388.57 N		33.6963 N m
		9.18882 N		0 N m

9.4 ANALYSIS

9.4.1 Von Mises Stress

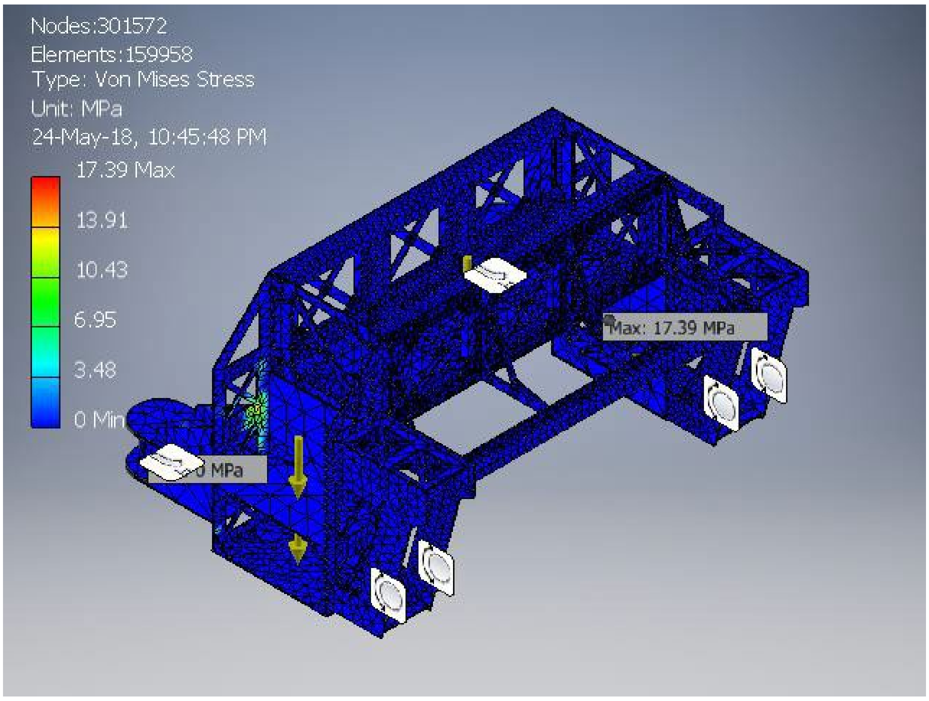

Fig 9.5: Stress analysis

9.4.2 Displacement

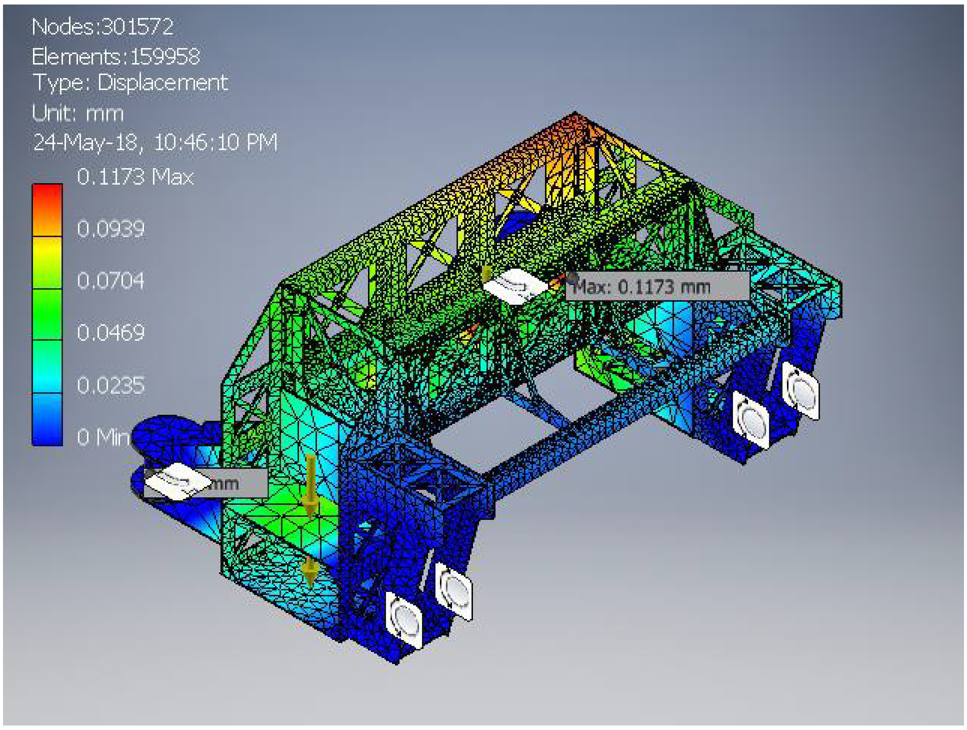

Fig 9.6: Displacement analysis

9.4.3 Safety Factor

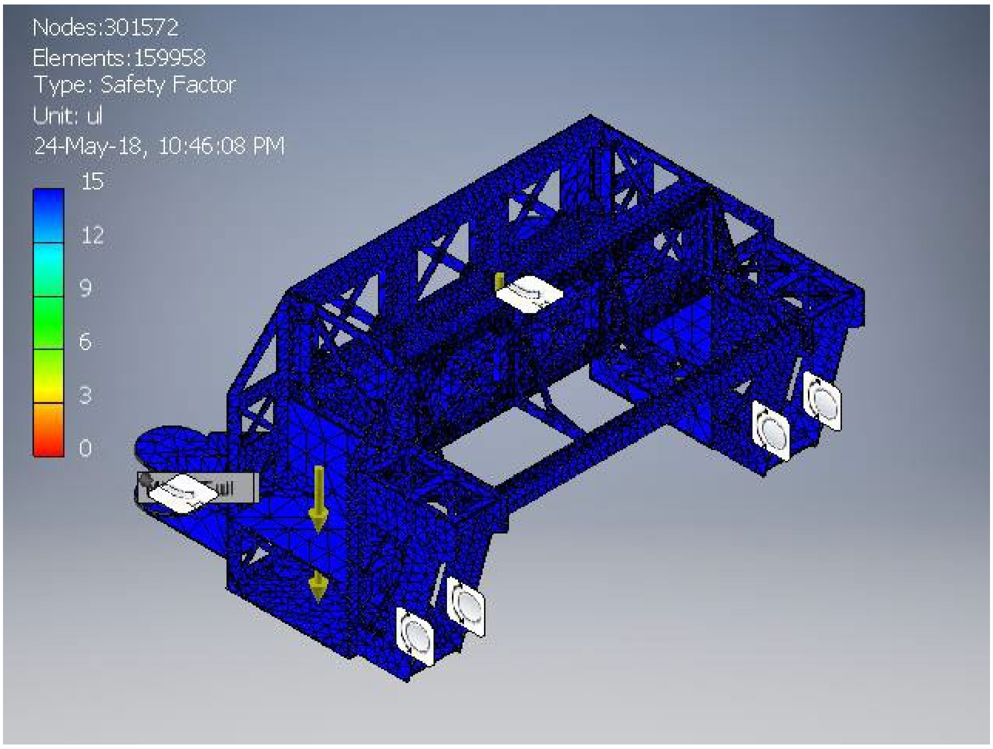

Fig 9.7: Factor of safety analysis

9.4.5 Equivalent Strain

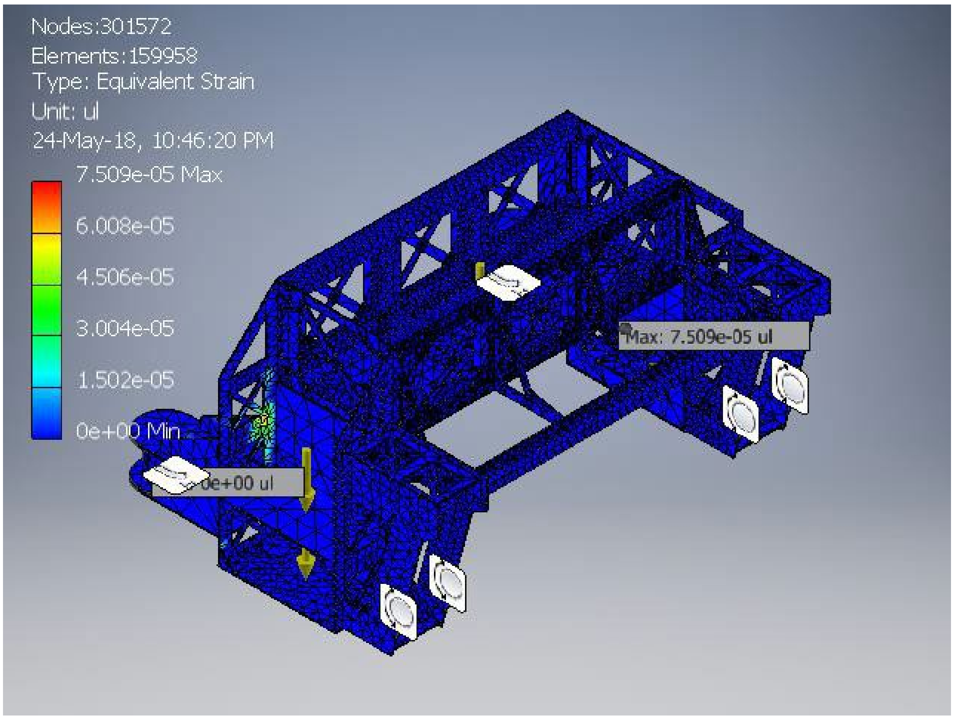

Fig 9.8: Strain analysis

9.4.6 Result Summary

Name	**Minimum**	**Maximum**
Volume	22462000 mm^3	
Mass	176.327 kg	
Von Mises Stress	0 MPa	17.3874 MPa
Displacement	0 mm	0.117324 mm
Safety Factor	15 ul	15 ul
Equivalent Strain	0 ul	0.0000750949 ul
Contact Pressure	0 MPa	184.625 MPa

9.5 SIMULATION

The vehicle simulation on uneven terrain is carried out on Autodesk INVENTOR. The 3D model of uneven terrain is designed using WEBOTS. Various forces acting on different points of vehicle is derived from the simulation and corresponding graphs are plotted.

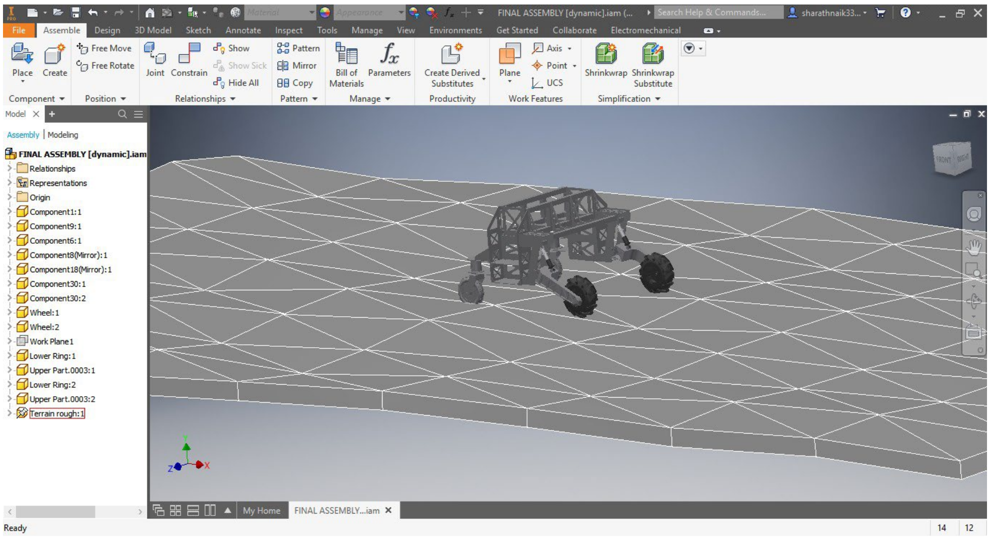

Fig 9.9: Simulation using Inventor 2019

Some of the results obtained from the simulation are as follows :

- Graph depicting all the forces acting on the wheels with average maximum force of 3000N on each wheel.

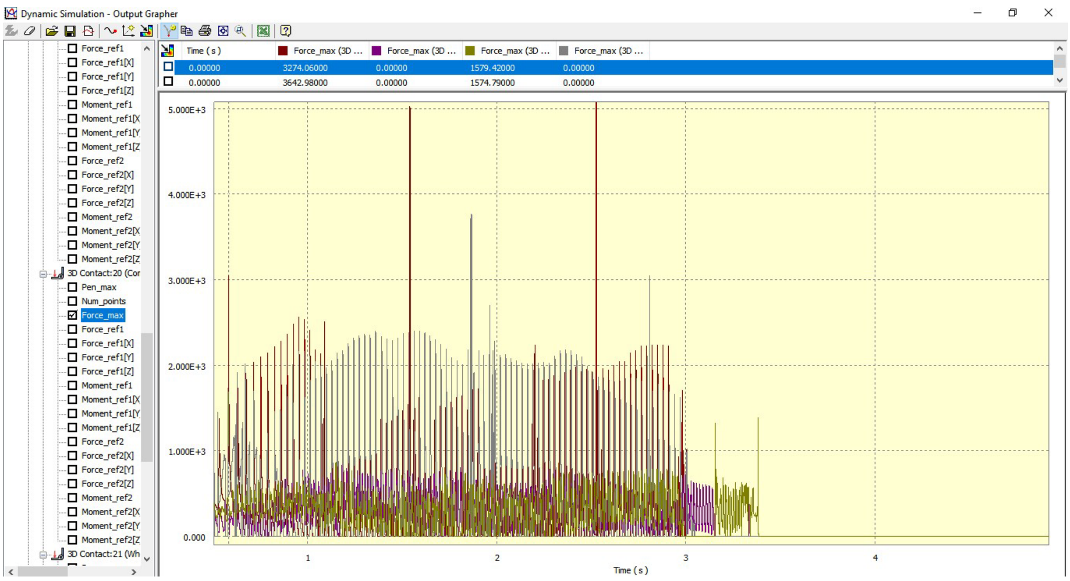

Fig 9.10: Combined forces on all wheel

- This graph shows force on both back and front wheels. We can see the force varying repeatedly as the vehicle moves along the uneven terrain.

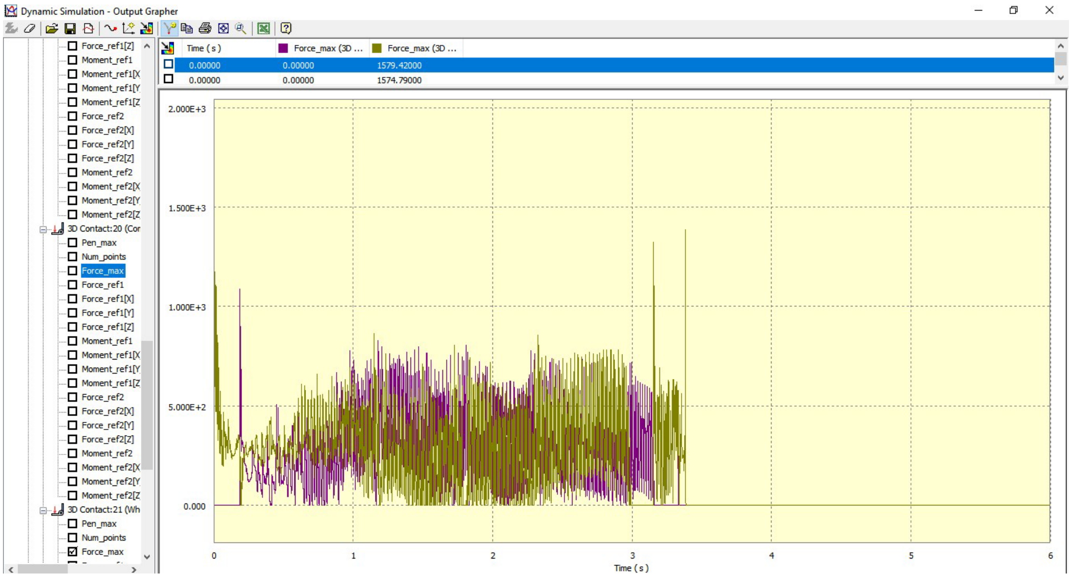

Fig 9.11: Forces on front wheel

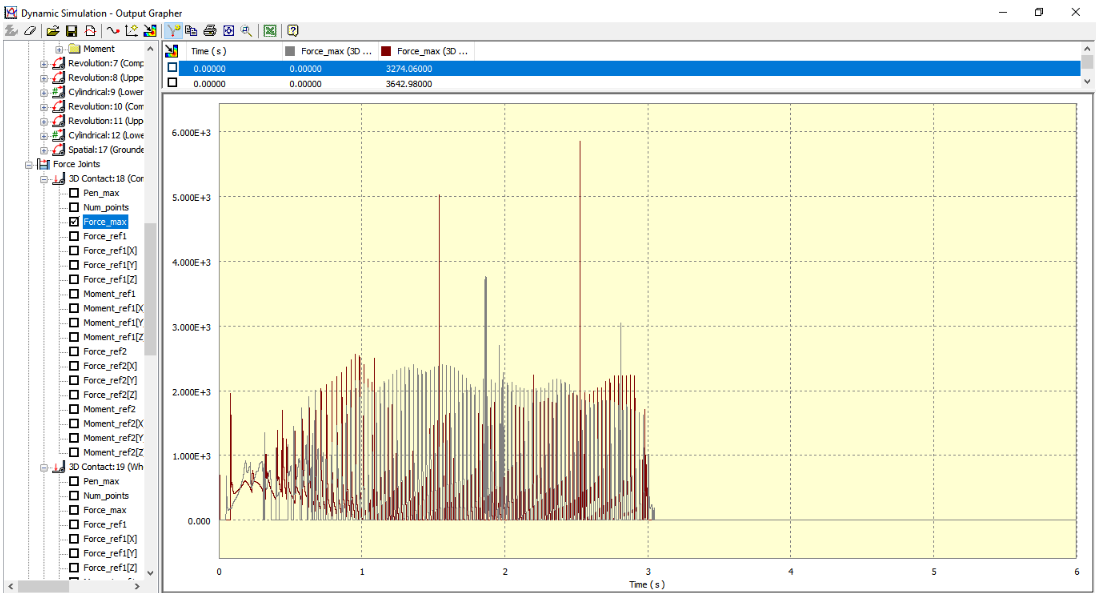

Fig 9.12: Forces on rear castor wheel

- We can also see the change in the length of the mono suspension on either wheels as it varies within the free length. It also shows that the spring does not compress higher than the full compressed length.

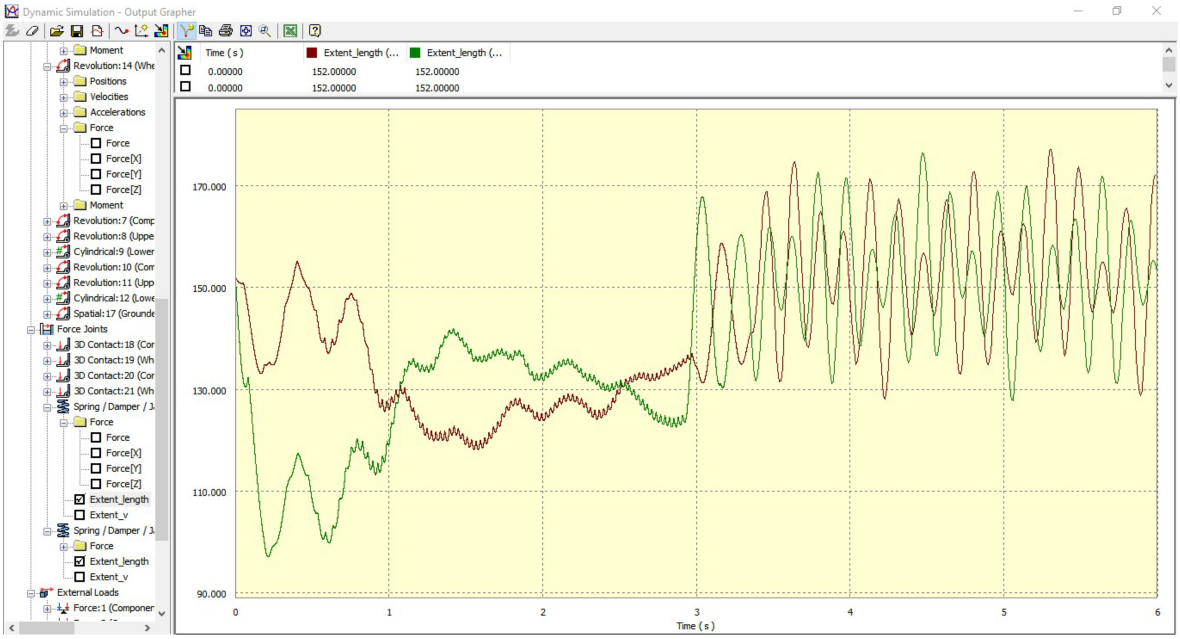

Fig 9.13: Variation in spring length

9.6 OUTCOMES

The chassis frame component has been modelled and analyzed. The various parameters such as displacement, stress distribution is completely analyzed and studied. The study shows that the area where the stress concentration is maximum due to applied load and the portions that has to be considered in the design of chassis frame in order to avoid frequent failures to improve its reliability. Although these areas oh high stress and deformation is very less thus does not need any changes. Factor of safety comes under safe level making it an optimal chassis for our frame.

Simulation shows that the vehicle works under forces that does not exceed the strength of the vehicle and shows us the dynamic movement of the vehicle in uneven terrain. This data can be used to make necessary changes to the vehicle.

CHAPTER 10
CONCLUSION

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CONCLUSION

Agriculture robots is going to affect the way of agriculture in India. We know that in today's world people are moving towards technological fields for working causing a shift in people's interest for agriculture. Due to this the labor force is decreasing. If this continues then there will be no one to produce food. This is where the robot helps in making sure agriculture is continued but with more profit and efficiency.

An initial outcome from this study indicates that most of these autonomous systems are more flexible than conventional systems and may reduce labor costs and restrictions on the number of daily working hours significantly. Moreover, it is possible to substitute the most trivial working routines with autonomous systems although some routines are nearly impossible to automate due to the required accuracy of the specific tasks. In addition, at this stage of development, the initial investments and annual costs for expensive GPS systems are still relatively high but it seems possible to design economic viable robotic systems for grass cutting, crop scouting and autonomous weeding. Findings show that there is a significant potential for applying these systems if it is possible to impose adequate control and safety regulations systems at reasonable costs.

The outcome of this project is to make farming more accurate and efficient Increase productivity by constant monitoring. Reduce time and decrease expenses and also the ability to maintain individual plants in novel ways. It even controls soil toxicity by checking pesticide concentration in each specific. This way we can modernize the way of farming

CHAPTER 11
FUTURE PERSPECTIVE

CHAPTER 11

FUTURE PERSPECTIVE

Most new machines brought to the market are bigger than the previous model. When discussing this issue with equipment manufacturers, this trend is likely to continue into the future. This is easily demonstrated if the cost of the operator is taken into account. As most operators are paid by the hour, a larger machine that can increase the work rate over a smaller one can have a significant economic advantage. Although many farms have removed field boundaries to take advantage of the larger machines, many smaller farms cannot follow suite due to environmental concerns and suffer economically because of it. As this equipment becomes larger, it also becomes very capital intensive with new tractors and combines becoming prohibitively expensive for the small and medium sized farm. Reliability also becomes an issue as all processes are carried out in series. If one part of the mechanization system breaks down then all field operations stop. An alternative approach would be to use available information technologies to automate these processes to the point where they do not need a human operator. By removing the person from the immediate control of the system, it offers new opportunities. This doesn’t include only lands but even unmanned aerial vehicles which can take the agriculture field into new field with 3d mapping and AR. Some of the future advances include:

- Availability of charging stations near field will help to increase operating hours of the vehicle.
- Implementation of artificial intelligence will greatly enhance the accuracy of farming activities like crop monitoring and weed detecting.
- Vehicle upgradation makes it more viable to add extra features that could support the farmer to use the vehicle for other purposes.

CHAPTER 12
REFERENCES

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REFERENCES

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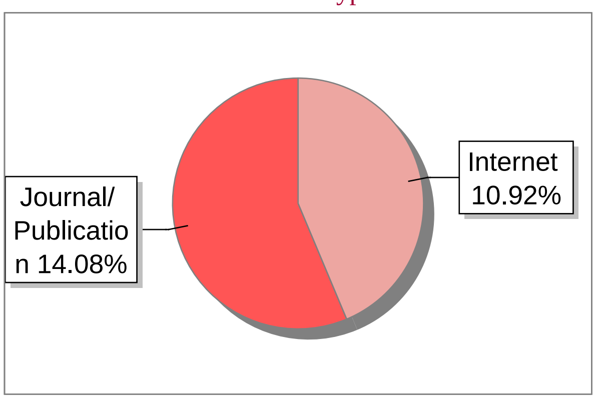

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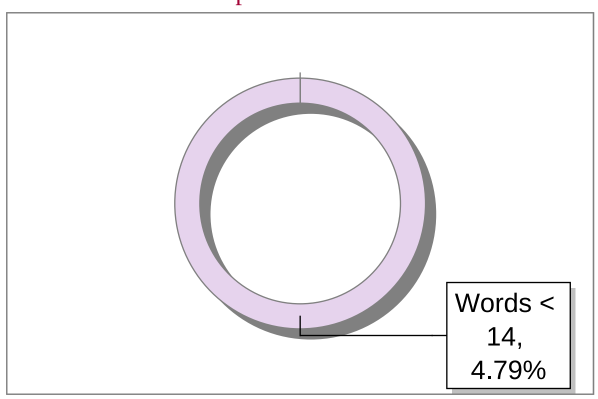

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Shavige Malleshwara Hills, Kumaraswamy Layout, Bengaluru-560078

Submitted By

Nihar Raviprakash 1DS18CS078

Siddhant Sharma 1DS15CS106

Vedansh Khandelwal 1DS19CS186

Yadu Krishna 1DS19CS194

Under the guidance of

Ms. Nidhishree M S

Asst. Professor, CSE ,

DSCE

2022 - 2023

Department of Computer Science and Engineering

DAYANANDA SAGAR COLLEGE OF ENGINEERING

Bangalore - 560078

Multipurpose Autonomous Farming Vehicle

1st Nihar Raviprakash
CSE dept,
Dayananda Sagar College of Engineering
Bengaluru, India
rprakash.nihar@gmail.com

2nd Siddhant Sharma
CSE dept,
Dayananda Sagar College of Engineering
Bengaluru, India
siddhant.ss1808@gmail.com

3rd Vedansh Khandelwal
CSE dept,
Dayananda Sagar College of Engineering
Bengaluru, India
vedansh.k05@gmail.com

4th Yadu Krishna
CSE dept,
Dayananda Sagar College of Engineering
Bengaluru, India
yadukrishnanok@gmail.com

5th Nidhishree M.S
CSE dept,
Dayananda Sagar College of Engineering
Bengaluru, India
nidhishree-cse@dayanandasagar.edu

***Abstract*—This In recent years, there has been growing interest in the development of autonomous agricultural robots for tasks such as planting, weeding, watering, and harvesting crops. These robots have the potential to improve the productivity and sustainability of agricultural operations by reducing the need for manual labor and enabling precision farming techniques.**

In this study, we present the design and implementation of an autonomous agricultural robot that is capable of performing a range of tasks in various crop environments. Our robot is equipped with sensors and algorithms for navigation, object detection, and task execution, and is capable of operating in both indoor and outdoor settings.

We conducted a series of experiments to evaluate the performance of our robot in real-world conditions. Our results show that the robot is able to accurately and efficiently complete a variety of tasks, such as planting seeds, removing weeds, and applying water or pesticides to crops. We also demonstrate that the robot can adapt to changes in the environment and adjust its behavior accordingly.

Overall, our findings suggest that autonomous agricultural robots have the potential to significantly improve the efficiency and sustainability of agricultural operations. However, further research is needed to address challenges such as the integration of these robots into existing farming systems and the potential impact on employment in the agriculture sector. (*Abstract*)

Keywords—component, formatting, style, styling, insert *(key words)*

I. Introduction

An autonomous agricultural robot is a type of robot that is designed specifically for use in agriculture. These robots are equipped with sensors and algorithms that enable them to navigate, perceive their surroundings, and carry out specific tasks such as planting, weeding, watering, and harvesting crops.

The development of autonomous agricultural robots has been driven by a number of factors, including the increasing demand for food and the need to improve the productivity and sustainability of agricultural operations. Traditional methods of farming often rely on manual labour, which can be time-consuming, labour-intensive, and prone to error. Autonomous agricultural robots, on the other hand, have the potential to perform tasks with high accuracy and efficiency, freeing up human workers to focus on other aspects of farming.

One of the key challenges in the development of autonomous agricultural robots is the need for robust navigation and perception algorithms. These algorithms must be able to operate in a variety of environments, including indoor and outdoor settings, and must be able to adapt to changes in the environment such as the growth and movement of crops. Additionally, the robots must be able to perform a range of tasks with high precision and accuracy, such as planting seeds at a specific depth and spacing, or applying water or pesticides to crops in a targeted manner.

Another challenge in the development of autonomous agricultural robots is the potential impact on employment in the agriculture sector. While these robots may reduce the need for manual labour in some cases, they may also create new opportunities for employment in the design and maintenance of the robots themselves. Additionally, the adoption of these robots may require significant investment in terms of time and resources, and may require farmers to adapt their existing farming practices and infrastructure.

Overall, the use of autonomous agricultural robots is an emerging and rapidly evolving field, and further research is needed to fully understand their potential benefits and limitations. These robots have the potential to improve the productivity and sustainability of agricultural operations, but their successful implementation will require careful consideration of the technical, economic, and social implications of this technology.

II. Specific Objectives

The main objective of the machine is to make agriculture much easier, efficient and profitable. But these can we achieved when all the small basic objectives are met. These include:

• Design and simulate electric vehicle, that is capable of independently carrying out various farming activities systematically.

• Perform stress analysis of designed vehicle.

• Calculating seed sowing with optimum row and plant spacing.

• The vehicle is designed to carry out various agricultural activities with least intervention from a human being.

• The vehicle is designed for farmers who have medium and large size agricultural land and spend lot of money on manual labours for planting and maintaining the crops.

• The autonomous farming vehicles includes increased productivity, increased application accuracy, and enhanc ed operational safety.

III. LITERATURE REVIEW

A. Paper

D Charansingh A. Patil, Sunil U. Nyati, 2016. “Multifunctional Robotic Vehicle for Agriculture Application”. International Conference on Global Trends in Engineering Technology and Management (ICGTETM-2016)

This paper helped us to understand the requirements of multipurpose farming vehicle. It also helped us to manage our approach towards designing the various equipment onboard.

Ray Eaton, Jayantha Katupitiya, Anthony Cole and Craig Meyer, 2015.” Architecture of an automated agricultural tractor: hardware, software and control systems”. 16th Triennial World Congress, Prague, Czech Republic 2015

This paper gives details about the control architecture of automated farming tractor, steering control system, traction control system and automation software.

Deepak Murugan, Akanksha Garg, and Dharmendra Singh, “Development of an Adaptive Approach for Precision Agriculture Monitoring with Drone and Satellite Data”, IEEE journal of selected topics in applied earth observations and remote sensing, vol.10, 2017.

This paper gives the information on use of drone and other sensors for precise agriculture monitoring. This also talks about the use of cloud-based computation to evaluate the data received from the drone.

Pratap Tokekar, Joshua Vander Hook, David Mulla and Volkan Isler, “Sensor Planning for a Symbiotic UAV and UGV System for Precision Agriculture”, IEEE transactions on robotics, vol.32, 2016.

This paper gives information about use of unmanned ground vehicle efficiently in agriculture. This also includes combining unmanned aerial vehicle and unmanned ground vehicles for land making and path learning.

M. P. Arakeri, V. K. B. P., S. Barsaiya, and S. H. V, "Computer Vision Based Robotic Weed Control System for Precision Agriculture," IEEE 7 International Conference on Advances in Computing, Communications and Informatics (ICACCI), 2017.

This paper helped us identify weed in onion crop and control its growth by spraying required amount of herbicide.

X. Gao et al., "Review of Wheeled Mobile Robots’ Navigation Problems and Application Prospects in Agriculture," IEEE Access, vol. 6, pp. 49248-49268, 2018.

This paper gave us a detailed explanation of mapping, localization, and path planning in navigation.

Sourav Saha, Siddhartha Paul, Sudip Halder, Kanishka Majumder, “Smart Agricultural System: Better Accuracy and Productivity”, Devices for Integrated Circuit (DevIC), 23- 24 March, 2017, Kalyani, India.

This paper gave us a better understanding and use of IOT with smart sensors to monitor soil moisture, light detection and electronic scarecrow.

B. Book

“Package of Practices for Agriculture”,2016 University of Agricultural Sciences, Bangalore.

This book gives the information about the different agricultural practices carried on for different crops.

C. Patent

Bruce Peterson, Brent W. Nelson, June 2010. “Seed Metering Device for Agricultural Seeder”. US 20100300342A1. United Stated Patent Application Publication.

This patent helped to design seed sowing mechanism for our vehicle. It gives brief idea of how the seeds have to be individually collected and dropped with constant distance between them.

IV. METHODOLY AND METHODS

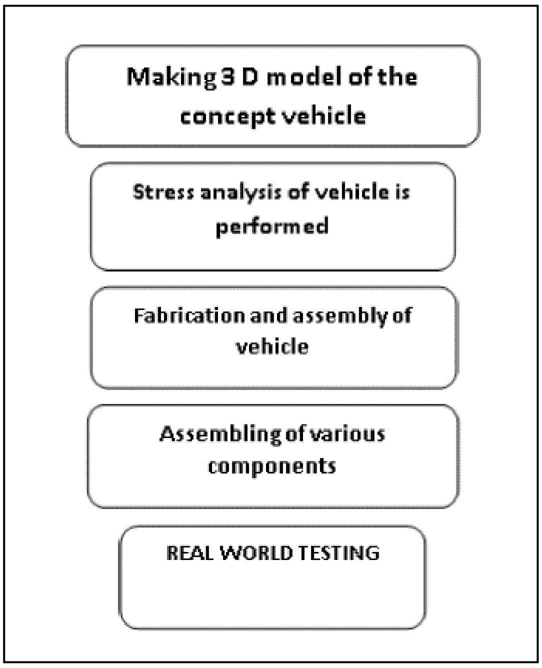
1) Define the research question and objectives: The first step in conducting a study on agricultural autonomous robots would be to clearly define the research question and objectives. This could include identifying the specific tasks or challenges that the study aims to address, and defining the metrics that will be used to evaluate the performance of the robot.

2) Develop a robot prototype: The next step would be to design and build a prototype of the agricultural autonomous robot. This could involve selecting the appropriate sensors and algorithms for navigation and task execution, and integrating these components into a physical robot platform.

3) Conduct experiments: Once the robot prototype has been developed, the next step would be to conduct experiments to evaluate its performance. This could involve testing the robot in a controlled environment, such as a laboratory or greenhouse, as well as in real-world agricultural settings. The experiments could include tasks such as planting, weeding, watering, and harvesting crops, and could be designed to assess the robot's accuracy, efficiency, and adaptability.

4) Analyse the results: After the experiments have been conducted, the next step would be to analyse the data collected from the experiments and evaluate the performance of the robot. This could involve comparing the robot's performance to that of human workers or other farming methods, and identifying any challenges or limitations of the robot.

5) Discuss the implications: Finally, the study could conclude with a discussion of the implications of the research findings. This could include a discussion of the potential benefits and challenges of using agricultural autonomous robots, as well as any recommendations for further research or development in this area.



V. EXPECTED OUTCOMES

Some potential outcomes of using this technology could include:

• Increased productivity and efficiency: By reducing the need for manual labor, autonomous agricultural robots have the potential to increase the productivity and efficiency of agricultural operations. This could enable farmers to produce more crops in a shorter amount of time, or to use fewer resources such as water and pesticides.

• Improved crop yields: The use of autonomous agricultural robots could enable precision farming techniques, such as targeted watering and pest control, which could improve the health and yield of crops. This could lead to higher profits for farmers and a more stable food supply for consumers.

• Reduced labor costs: By replacing some of the manual labor currently required in agriculture, autonomous agricultural robots could reduce labor costs for farmers. This could make farming more financially sustainable and could potentially lead to lower prices for consumers.

• Enhanced sustainability: By enabling more efficient and targeted use of resources such as water and pesticides, autonomous agricultural robots could help to reduce the environmental impact of agriculture. This could improve the sustainability of agricultural operations and could help to protect natural resources for future generations.

Overall, the expected outcome of using autonomous agricultural robots would depend on a variety of factors, including the specific tasks and environments in which they are used, and the broader economic, social, and environmental context in which they are implemented.

VI. PRODUCT COST

Part	Specification	Cost/item (Qty.)	Total cost
BLDC hub motor	48v, 1kw	15000(2)	30000
Lead acid battery	12v 24AH	3000(4)	12000
Motor controller	48v 50A	3000(2)	3000
Tire	90/90-12	1200(2)	2400
Monoshocks	320mm Air shocks	4000(2)	8000
Plexiglass	5' x 3'	1400(2)	2800
TOTAL			58200

ELECTRONICS			
Part	Specification	Cost/item (Qty.)	Total cost
Servo motors	MG995	460(2)	920
Arduino Uno		460(2)	920
Relays	4-channel	167(2)	334
Motor driver	12-channel	300(2)	600
GPS		800(1)	800
Magnetometer		365(1)	365
Ultrasonic sensor		71(10)	710
LCD		1700(1)	1700
pH sensor	Liquid type	1154(2)	2308
Moisture sensor		40(5)	200
DC Motor	100rpm	597(1)	597
Electric pump	12v 70psi	800(2)	1600
TOTAL			11054

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