Design and Development of Seed Sowing Robot using Shrimp Mechanism

A project report

Submitted in partial fulfillment of the requirements for the award of degree of

Bachelor of Technology in Mechatronics Engineering (Robotics and Mechatronics)

Submitted to
Patel C. H.

LOVELY PROFESSIONAL UNIVERSITY, PHAGWARA, PUNJAB

From 02/12/22 to 04/23/22

SUBMITTED BY

Name of students	**Name of Supervisor**
Sankeerth Pradeep	Patel C.H.
Registration Number	**UID of Supervisor**
11806060	15755

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Registration Number 11806060	**UID of Supervisor** 15755
Patel.C.H	
Signature of student	**Signature of Supervisor**

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Declaration by the supervisor

To whom so ever it may concern

This is to certify that **Sankeerth Pradeep, 11806060** from Lovely Professional University, Phagwara, Punjab, has worked on **“Design and Development of Seed Sowing Robot using Shrimp Mechanism”** under my supervision. It is further stated that the work carried out by the student is a record of original work tothe best of my knowledge for the partial fulfilment of the requirements for the award of the degree, **Bachelor of technology (Mechatronics Engineering).**

Name of Supervisor: Patel C.H.

UID of Supervisor: 15755

Patel.C.H

Signature of Supervisor

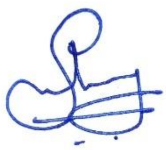
Dated: 25/04/2022

Declaration by student

To whom so ever it may concern

I, **Sankeerth Pradeep, 11806060,** hereby declare that the work done by me on **“Design and Development of Seed Sowing Robot using Shrimp Mechanism”** under the supervision of, **Patel C. H., Assistant Professor,** Lovely professional University, Phagwara, Punjab, is a record of original work for the partial fulfillment of the requirements for the award of the degree, **Bachelor of technology (Mechatronics Engineering).**

Sankeerth Pradeep (11806060)



Signature of the student

Dated: 25/04/2022

Lovely Professional University
Phagwara, Punjab

CERTIFICATE

I hereby certify that the work which is being presented in the capstone entitled **"Design and Development of Seed Sowing Robot using Shrimp Mechanism"** in partial fulfilment of the requirement for the award of degree of **Bachelor of Technology** and submitted in Department of Mechanical Engineering, Lovely Professional University, Punjab is an authentic record of my own work carried out during period of Capstone under the supervision of **Patel C.H**, **Assistant Professor**, Department of Mechanical Engineering, Lovely Professional University, Punjab.

The matter presented in this capstone has not been submitted by me anywhere for the award of any other degree or to any other institute.

Date: 25/04/2022 **Sankeerth Pradeep**

This is to certify that the above statement made by the candidate is correct to best of my knowledge.

Date: 25/04/2022

Patel C.H
Supervisor

The B-Tech capstone examination has been held on _____________

Signature of Examiner

TOPIC APPROVAL PERFORMA

School of Mechanical Engineering (SME)

Program : P138-NN1::B.Tech. (ME - Mechatronics)

COURSE CODE : MEC410 **REGULAR/BACKLOG :** Regular **GROUP NUMBER :** MERGC0063

Supervisor Name : Patel C.H. **UID :** 15755 **Designation :** Assistant Professor

Qualification : M.Tech **Research Experience :** 6 Years

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SPECIALIZATION AREA : CAD/CAM & Mechatronics **Supervisor Signature:** Patel.C.H

PROPOSED TOPIC : Design and Development of Automated Seed Sowing Mobile Robot

Qualitative Assessment of Proposed Topic by PAC		
Sr.No.	**Parameter**	**Rating (out of 10)**
1	Project Novelty: Potential of the project to create new knowledge	7.16
2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	7.16
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	7.44
4	Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills.	8.44
5	Social Applicability: Project work intends to solve a practical problem.	7.44
6	Future Scope: Project has potential to become basis of future research work, publication or patent.	6.88

PAC Committee Members		
PAC Member (HOD/Chairperson) Name: Dr. Manpreet Singh	UID: 20360	Recommended (Y/N): Yes
PAC Member (Allied) Name: Dr. Manjeet Singh	UID: 21545	Recommended (Y/N): Yes
PAC Member 3 Name: Dr. Vishal Francis	UID: 24813	Recommended (Y/N): Yes

Final Topic Approved by PAC: **Design and Development of Automated Seed Sowing Mobile Robot**

Overall Remarks: Approved

PAC CHAIRPERSON Name: 24694::Dr. Vijay Kumar Singh **Approval Date:** 03 Mar 2022

Acknowledgement

I would like to express sincere gratitude to Patel C. H. for being a great mentor to me. He guided me through each phase of the project with proper support and resource backup. I am also thanking the University for giving such a great opportunity. I am grateful for accepting our topic and helping us carry our project work. The university took great care in conducting our capstone exam.

I would also like to thank each of my teammates for their contributions. It is because of our collective work and co-ordination that the project is successful.

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This project and paper publications is financially self-funded.

Date: 25/04/2022

Sankeerth Pradeep

Student, B.Tech, Lovely professional University

Abstract

Agriculture is the backbone of the national economy. Various scientific advancements are happening in this field including achievements like genetically modified seed for better production, uses of drones for surveillance and growth tracking and so on. This paper is on one such advancement where automated are used to perform various task. This decreases the need of human interventions required for any operation. Thus, saving human workforce for other tasks and it also helps to reduce labor wage to be paid. In this project a seed sowing robot is being designed, analyzed, and developed. The robot is designed and analyzed using Autodesk Fusion 360. The previous works in this field uses a simple four-wheel mechanism which struggle in rocky terrains or inclined planes. The robot uses shrimp mechanism, so that it is able to move on all types of terrains, which is one of the significances of the robot. It serves a huge purpose in hilly areas like in coffee plantations. The machine had a six-wheel set up. Four wheels were attached to a sub frame connected to the main chassis. An arm was extended from the main chassis at the front and rear end. A wheel each are connected to these arms. The front and the rear wheels also have a steering mechanism actuated by a servo at the end of each arm. The main chassis of the prototype was 3D printed. The links that are attached to this main chassis was made from aluminum frames. The parts were joined using nut and bolts. The analysis was done on to determine the stress levels, factor of safety and the level of deformations possible with a total of 4 kg. The analysis showed that the robot can withstand the load and work perfectly with heavier loads. Other parameters of the robot were also tested, including its battery life, the seeding process and its performance in various terrains. The robot was able to move on inclined planes with a slope up to 45^{o}. It was able to move on different terrains with different kind of obstacles. The robot was able to climb over obstacles with twice the size of its wheels. The seeding process is done using a servo motor which opens and closes a flap which drops a seed at a time. The servo opens and closes the flap in every 1.5 second. The seed falls at a gap of 10 cm from each other. The battery was tested to find the time a full charged battery could power the device. The test showed that a fully charged battery could power the model for a total duration of 46 minutes. The robot is efficient and can make the seeding process quicker. It requires low human intervention. The seed is planted at a particular distance so that the maximum space is utilized, and the seeds receive enough space, nutrients and water for their proper growth.

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List of Abbreviations

a. **Wi-Fi :** Wireless Fidelity
b. **CAD :** Computer Aided Designing
c. **FDM :** Fused Deposition Modeling
d. **PLA :** Polylactic acid
e. **DC :** Direct Current
f. **RPM :** Rotations per minute
g. **Rx:** Receiver pin
h. **Tx:** Transmitter pin
i. **IDE:** Integrated Development Environment
j. **PWM:** Pulse width modulation
k. **D:** Digital Pins
l. **CAM:** Computer Aided Manufacturing
m. **CAE:** Computer Aided Engineering
n. **Li-on:** Lithium ion
o. **N:** Newton
p. **mm:** Millimeter
q. **m:** Meter
r. **Kg:** Kilogram
s. **Nm:** Newton meter
t. **V:** Volt
u. **A:** Ampere
v. **mA:** Milliampere
w. **mAh:** Milliampere hour
x. **m/s:** meter per second

CHAPTER- 1

Introduction

Since human civilization, agriculture has been an essential part of humanity. It is one of the primary sources of food that humans eat. With time, the evolution of agriculture techniques and tool have happened due to the advancement in the technology fields. Nowadays, a lot of new technology and tool can be seen in the agriculture sector even though most farmer follows conventional techniques and tools such as the iron plough, crowbar, sickle, ox, etc., while farming. With the increase in human populations in recent years, the agriculture sector is blooming as food needs have also increased. So, with the help of modern technologies, the cultivation process can be increased and more accurate and efficient.

There are a set of steps that should always be followed while farming. The first and foremost step of farming is soil preparation or land preparation. The very next step is the seed sowing. It is the process of planting the seed into the soil; depending upon the type of seed, soil, or land, there are various seed sowing methods, namely broadcasting, dibbling, drilling, seed dropping behind the plow, transplanting of seedlings, hill placement and check row planting[1]. The seed sowing also comprises sowing the seed with constant inter seed distance and appropriate depth of soil, which also depends on seed to seed. The factors such as the rise in labor cost and the recent development in robotics have played a vital role in the rising demand for agricultural equipment that requires less human effort and time[2- 4]. Automation is a requirement in industries since it aims to improve the quality of life for humans at home, at work, and in every aspect. Still, it also allows for the speedier distribution of high-quality products and services while reducing downtime and human error[5, 6].

The conventional seed sowing method can be divided into three types: 1) Manual broadcasting, 2) Digging long, narrow trenches using a country plough and then manually planting the seeds, and 3) Seeds are dropped in the furrow through a metal/bamboo funnel connected to the country plough. The well-experienced farmers are well versed with multiple row traditional seeding tools. It also has manual metering of seeds. Nevertheless, the seeds are still not uniformly distributed while performing manual seeding. Due to this, the inter-row and intra-row of seeds result in bunching and gaps in the field. Hence, the following limitations are found in the traditional sowing methods:

- Seed sowing is not uniformly while dropping on the field
- Irregular distributions of seeds result in gaps and bunching of seeds.
- Poor control over depth of seed placement.

In the agriculture sector, even though humans will still be responsible for managing a farm, more straightforward tasks can be automated, saving time to a large extent and saving the labor cost[7]. This issue can be resolve by a simple mobile robot with a seed sowing mechanism attached which can be easily controlled using a smartphone via Bluetooth or Wi-Fi, which will help the farmers automate the farming process to some extent. A swarm of such robots can plant seeds on any large farm[8]. Using swarm robots will save time to a great extent. Moreover, the typical mobile rovers fail to traverse up a steep inclination and an extremely rough terrain. The typical mobile robot cannot move efficiently on rough terrain without any shock absorber or suspension system to neglect the external vibrations. This is where an alternative mechanism needs to be implemented in rovers used in agriculture. One such rover mechanism is the shrimp rover mechanism. Figure 1.1 a) shows the standard mobile rover used for seed sowing. b) shows the construction of the shrimp rover mechanism[9,10]

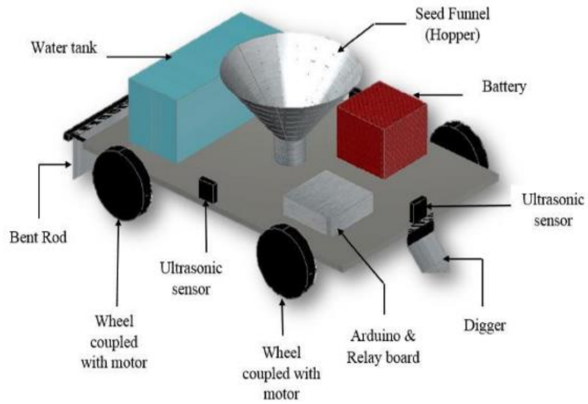


Figure 1.1 (a)

Figure 1.1 (b)

Figure 1.1 (a) Typical seed sowing mobile robot, (b) Shrimp Rover Mechanism

The Agribot must be robust and reliable, quick, easy to do maintenance, and have the flexibility to allow future expansions and connection of new equipment. More and more autonomous applications in the agriculture sector will be utilized in upcoming years. It provides an idea that applying robotics technology in agriculture may be technically tricky than industrial robots. The current world's population is to grow to more than 9.15 billion by 2050. Therefore, the challenge for the next decades will be to supply and fulfil the needs of the expanding world population by creating a well structure, effective and efficient agriculture system while not destroying the environment and preserving the quality of mother nature.

The shrimp rover, a wheeled mobile robot, is used in this study. In terms of motion, the shrimp rover robot is akin to the marine species "shrimp." Two bogies are built on the right and left sides of the robot's body, respectively, using the rhombus design[11]. There are two wheels on each bogie. The front wheel and the rear wheel, respectively, are located in the front and rear of the rover robot. The front wheel is spring suspended to ensure that all wheels are in contact with the ground surface[12]. This unique shrimp rover is a six-wheeled robot with six motors driving it. It features one front four-bar that allows it to climb over obstacles of a particular height without losing stability[13]. The parallelogram bogies on the middle four wheels balance the wheel response forces when climbing. To boost the climbing abilities, the single rear wheel is attached directly to the main body and is also powered by a motor[14]. Currently, intense research been carried out on mobile robots in the field of agriculture[15]. Pankaj Kumar, along with G. Ashok, designed and fabricated a seed sowing rover that completely automates the seed sowing process[16]. Hussain Nor Azmi et.al was able to achieve an increase in the crop seeding efficiency of over 35% using a mobile robot[17]. A. Nageswara Rao et. al created a robot that calculates the distance traveled using input from wheel encoders. This information is utilized to activate the seed mechanism, which keeps the crops inter seeding distance constant with uniform time intervals[18]. Dr. Chanda V Reddy et.al; built a seed-sowing robot that can move around the field and sow the seeds. It is also capable of traveling on a 45-degree slant and identifying obstacles in front and behind, making the planting efficient and accurate[19]. Saurabh Umarkar and Anil Karwankar developed a robot capable of Sowing seeds and digging holes. It can also move along different ground contours and execute tasks such as digging, planting seeds, and closing the ground[20].

CHAPTER- 2

Literature Review

With the increase in the global population, the food supply and need also increases. To go hand in hand with the population rise, the agriculture should be catalyst. The conventional or traditional farming are slower in process due to primarily human effort and manually work. Recently lots of research are carried on the AMR or AMM (automatic mobile manipulator robot) in field of agriculture. These robots provide various feature which can results in efficient and faster farming process. The study is based on the research between the year 2020 to 2022 and the summaries are provided.

- Harry Rogers,Charles Fox[21] (2020): In this study , they have enabled wider experimental uptake and built interest in autonomous precision agriculture, developed a low cost open-source hardware and software platform with automated precision seed planting, which was used by the other researchers and practical Agri hackers. The planting rate of the robot while seeding was 1.1 seeds per second. The minimum distance between seeds was on average of 399mm apart from each other. The average speed of the robotics system was traveling at 0.39m/s. A swarm of similar robots can be used to have a faster seeding rate than it.
- Kruthika Ramesh, K.T. Prajwal,C. Roopini,Monish Gowda M.H., V.V.S.N Sitaram Gupta[22] (2020): They have developed a robot for the automation of the seeding process. This robotic system provided uniform depths for the seed placement and uniform distance between the two successive seeds were obtained.
- Thenmozhi Devaraj,Sakthiya Ram Shankar Raja, Madhumitha Janarthanan[23] (2020): In this study ,they developed an agribot which is capable of sowing, spreading, and ploughing task can be done with the help of this robot. Base on the data given it can be noticed that the robot was able to sow the seeds at equal distances. It was also able to maintain an approximate distance that was being instructed or preprogrammed.
- Pankaj Kumar, G Ashok[24] (2020): The article aims to present the design, development, and fabrication of smart robots which significantly reduced the human efforts and time of seed sowing activities by the farmers. They designed

a robot with an end effector which picks up and drops the seed uniformly in a lane. This smart and automated sowing of seeds used a robot which reduced the labor requirement and also reduced human ergonomics.

- Bhise Sanket Sunil, D. B. Kadam, Kore Vinit Vikas, Kolekar Arun Anand[25] (2020): The development of a seed sowing robot based on Bluetooth technology was designed. They used software compatible with an android system with Bluetooth inbuilt connectivity for the control of the robot. In this robot solar panel was used for power supply purposes by the connecting the battery. After that, a mobile application will be connected to the robot through Bluetooth connectivity. With the help of this robot, farming can be managed more efficiently the other feature provided by this particular robot is the per cycle two seed drop mechanism in soil.
- A Nageswara Rao, Dr S Pichi Reddy, N Raju[26] (2020): Implementation of the robotic assisted agriculture activities (i.e., navigation when the robot arm is engaged with the ground). The contribution of this research work was to design a seeding mechanism, with efficient manner. Which results in minimum required force from the mobile robot, while the seeding performance was efficient. The system that was developed was fully automatic, except for the tele operation where the user gives the command to the robot to start the programmed tasks. The fact that sharp sensors for navigating through the rough terrains encourages its applicability in the actual greenhouse environment, along with white line tracer. If the line is missed or stained, information from the sharp sensor can be used to navigate independently.
- Sandesh N G, Bhumika D, Bhavana K, Mohammed Ausim, Vinay K.[27] (2020): Designed and developed a Bluetooth controlled agribot to sow seed in a straight lane field. The Agribot can be remotely controlled using Bluetooth. The robot can measure the moisture content of the soil as the appropriate moisture is needed for a good harvest. The robot also has a ploughing and a separate sowing mechanism for the particular task.
- Dr. R. C. Karpagalakshmi, K. Gobinathan, C. Siva[28] (2020): A Agribot that can plough, sow seed, rotate and irrigate the land. The agribot uses photo interpreted speed sensor LM393 to calculate the distance covered. It plants the seed at a distance of 15cm at the inter crop or seed distance. An Ultrasonic sensor was

used to detect obstacles and the protocol to overcome these obstacles were initiated, when the obstacles are detected. The Agribot has also got the irrigation system which will be automatically turned on after the sowing process.

- Sai Prasanth, Sathish Kumar, Sattanathan Periyasamy, Shaolin Mathew[29] (2020): The developed agribot uses solar energy to power the agribot which sows seed. The robot was a solar powered robot. The process was completely automated thus it ensures proper utilization of seed. The drilling mechanism was attached to the robot to drill holes for sowing the seed.
- Hussain Nor Azmi, Sami Salama Hussen Hajjaj, Kisheen Rao Gsangaya, Mohamed Thariq Hameed Sultan, Mohd Fazy Mail, Lee Seng Hua[30] (2021): The research work aims to develop a low-cost agricultural robot for crop seeding in agriculture fields. The driving force behind this work was to reduce human interference, labor requirements, and the overall operating costs in the field of agriculture. In order to keep the costs to minimum, the robot seeder prototype was assembled using simple, cost-effective, and off-the-shelf components. The tests were conducted on the agricultural robot prototype showed that it could perform as required under real-world usage scenarios The crop seeding test showed that the robot was able to sow 138 seedlings in 5 min, with an accuracy of 92%, compared to 102 seedlings by human workers. This results in an increase in the crop seeding efficiency of over 35%.
- Dr. Chanda V Reddy, Anudheep R, H M Vishal, Harshitha S, Sai Spoorthi N[31] (2021): Developed a robot which can detect obstacles, sow seed. It can detect if any obstacles were present and if no obstacles were present, it will move further by sowing the seeds. In this particular system the robot will sow the seed on the field until it finds an obstacle. If any obstacle was found it stops and before sowing the seed on the field it usually turns right thus moving forward. The servo motor was used to enable the moisture sensor into the ground to check the moisture content level of the soil and thereby helps in sowing the seeds into the ground.
- Renuka Dhawale, Shweta Kalshetty, Bhushan Patil, Prachi Choudhari, Ajay Pal Singh.[32] (2021): In this paper, that have designed and built a Automated seed sowing Agribot. The robot was automated thus requires only monitoring not the controlling part. The robot was equipped with ultrasonic sensor to detect any

obstacles on its path. Moreover, the robot has moisture sensor to check the water content in the soil.

- Anirban Kumar, Heshalini Rajagopal[33] (2022): Developed an automated system for seeding as well as irrigation process in the agriculture which reduced the labor cost. The agriculture robot was programmed to drop the seeds at an interval of 6 s and 7 cm of inter seed distance. This method provided better precision. The system has a lifting mechanism which lifts the chassis when an object is detected in front.

2.1 Problem Formulation:

The term "formulating a research problem" refers to stating a problem in a fashion that can be researched. It refers to the process of shaping a study topic so that it is ready for scientific examination. The research topic is simply referred to as a research problem. A researcher must refine the issue and specify explicitly what will be investigated about it. This is referred to as the formulation of the research problem, and it entails narrowing down a larger study field into a single research topic and setting goals. Once the research challenge is defined, the topic is ready for scientific investigation, or research.

Considering the problems in our agriculture sector while the seed sowing process, the increase of the labor cost and human error possibilities. The seed sowing is one of the main factors which decides the quality of the yield later. In this work our prime focus is on designing and developing a seed sowing robot. With the help the literature review, we came to know about different features that can be provided to the agrobot which results in effective task in the field.

2.2 Research Gap:

The current AMR robots used in the agriculture sector are still in developing stage. The further improvement can be made with enhancement in the automation part of the robotics system and the cost of the robot. Most the mobile robot at the present scenario doesn’t provide the suspension systems as these robot works on field which can be uneven, irregular and rough surface. Which can lead to many problems in the real-life conditions. Further work on the easier or non-sophisticated suspension system can be work on to ease the mobility without any hindrance during real life situation.

CHAPTER- 3

Methodology

This paper's methodology explains the processes and methods used to find, acquire, and analyze information that aids in the research. To allow for a more thorough discussion of the research, this part has been broken into seven sub-sections. The first section explains the study's purpose, the second section explains the research methods or steps, the third section explains the shrimp rover mechanism, the fourth section explains the seeding mechanism, the fifth section explains the robot's motor and battery calculations, the sixth section explains the hardware configuration, seventh section tells about the application used for controlling the robot, eight section depicts the circuit diagram and the ninth section shows the Arduino programming.

3.1 Objectives of the Study

As the world's population grows at an exponential rate, agriculture has become the most significant sector. It is also the backbone of emerging countries' economies. Agriculture is concerned with the production of crops, fruits, poultry, and dairy products, among other things. This field necessitates a large amount of manpower, which is exacerbated by bright sunlight. As a result, it is critical to protect farmers' health while still increasing production rates. As a result, a lot of studies are being conducted in the sector of agriculture to introduce more automation in order to enhance production rates while reducing personnel work. Thus, the focus of this research is on the creation of a seed sowing mobile robot that uses a shrimp rover mechanism and can be employed in hard terrains, namely in hilly locations, to aid farmers in saving time, increasing production, and reducing workload.

The following are the goals of the proposed project:

- Create a robot that moves through uneven terrain utilizing a shrimp mechanism.
- To develop a seed-dropping mechanism for the shrimp robot that assures that only one seed is dropped at a time.
- The robot should be able to climb a 40-degree incline, making it adaptable to hilly environments.
- From full charge to 20% charge, the robot should work for 30 minutes.

3.2 Research Methodology

The flow-chart below depicts the research methodology adopted for the research:

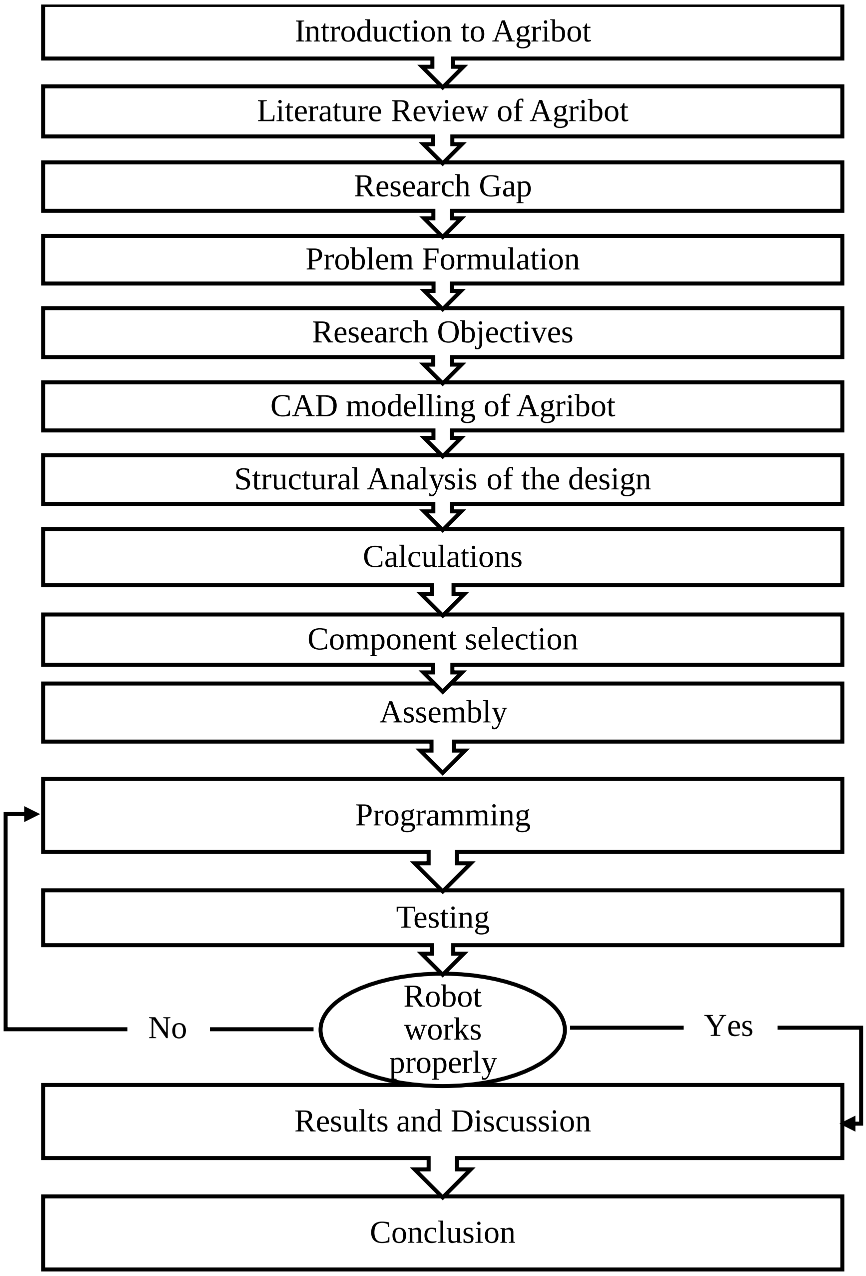


Figure 3.1. Flow Chart for Research Methodology

3.3 Shrimp Rover Mechanism

For high terrain applications, certain types of rovers have been invented by the researchers. One of the mechanisms that has been invented is rocker-bogie mechanism[34]. Rocker-bogie is basically a mars rover which consists of a rocker and a bogie that can travels through uneven, rough terrains[35]. Another research led to a creation of a new mechanism known as crab rover mechanism[36]. But due to less ground clearance it is not much effective in high terrain movement. During the time, one of the research projects led to the rise of shrimp rover mechanism[37]. From these mechanisms, rocker-bogie mechanism is already used in agriculture for seed sowing[38]. But shrimp mechanism is not yet introduced for the purpose of seed sowing. As the main aim of this work is to develop a seed sowing robot for hilly terrain, shrimp mechanism was inspired in this work, because of its special capabilities to be able to adapt in high terrains.

The shrimp rover is a unique climbing robot with six motorized wheels arranged in a special arrangement. Its unusual wheel arrangement aids the robot in traversing difficult terrain and allowing it to climb obstacles. The rover's wheel layout is 1+2+2+1. Two wheels are positioned on a bogie on each side and one in the front and one in the back[36]. This arrangement of wheels provides maximum range of movement for the rover.

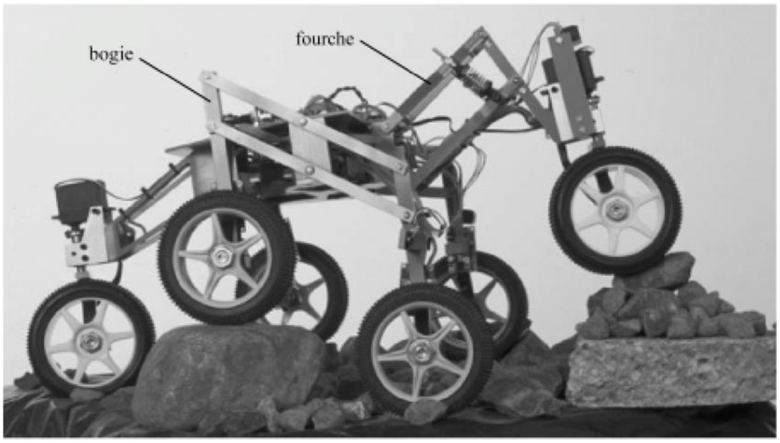


Figure 3.2. Shrimp Mechanism[35]

One suspension spring as shown in Figure 3.3, is inserted between two horizontal links on the front and rear forks. This aids in the energy storage and return process while climbing an obstacle, as well as avoiding both horizontal connections from colliding each other while the robot descends a steep slope ensuring proper ground contact of wheels. All the links of the rover are made of aluminum as it is light weight and has high strength.

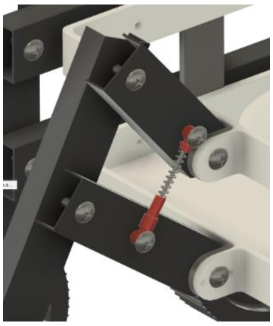


Figure.3.3. Spring Arrangement

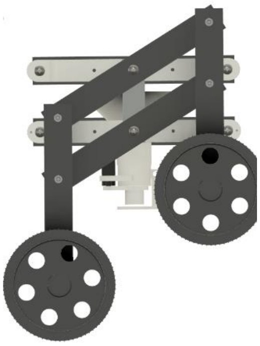


Figure 3.4.Central Pivoted Side Bogie

On both the sides, two wheels are attached to links which are arranged in a parallelogram arrangement. The single revolute joint which attaches the bogie to the robot body rotates about a central pivot allowing free movement for the bogie as shown in Figure.3.4. The side bogie can rotate about the central pivot at an angle up to 45°.

3.4 Seeding Mechanism

In seed sowing robots, different types of seeding mechanisms have been introduced by the researchers. One such mechanism includes a rotating wheel having grooves which allows only one seed to occupy into it. This wheel rotates in an opening of seed storage where it picks up one seed and drops it to the funnel where it will be dispersed to ground[39]. Another mechanism invented was a two-lane seed sowing robot in which a rotating wheel with and extrusion at its end picks up the seed and drops into two seed passages[40]. In this study, we presented a novel mode of seeding mechanism which is truly accurate and efficient. This seeding mechanism makes sure that only one seed drops on the ground at a time and at a distance of 10cm-12cm at equal intervals of time.

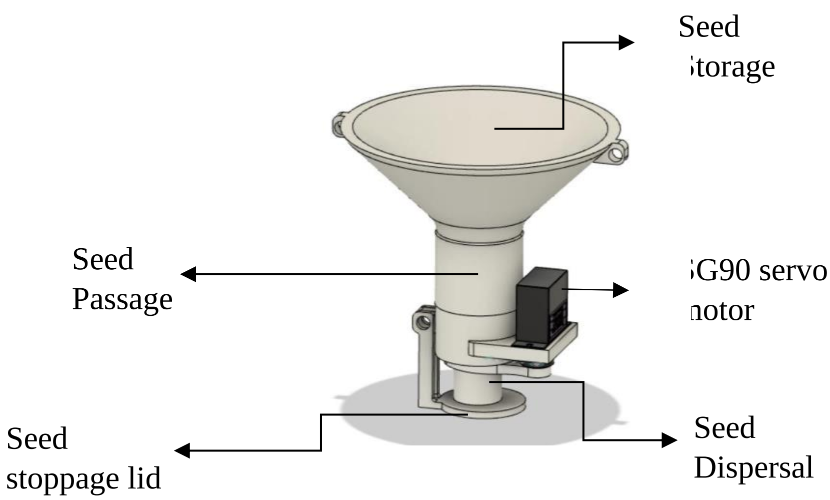


Figure 3.5. Seeding Mechanism

The seeding mechanism consists of a seed storage unit, seed passage, seed dispersal unit and seed stoppage cover. The seeds are stored in the seed storage which is designed of a funnel shape and printed using FDM printer using PLA plastic. The seed storage is attached to a seed passage which is made in such a way that seeds will pass through it one by one. The seed passage leads seeds to seed dispersal unit. The seed dispersal unit is designed as of a cam, in which separate space is provided which allows only one seed to stand. One SG90 servo motor moves the seed dispersal unit. When the hole in the seed dispersal unit comes in align with the hole of the seed passage, one seed occupies the space in the seed dispersal unit. The seed stoppage cover prevents the seed from falling at this point of time. Then the servo motor rotates the seed dispersal unit and thus it allows the seed to fall down. During this time, the cam design of the unit closes the seed passage hole thus preventing the seed from falling down. By this process, it ensures that only one seed falls at a time.

Figure 3.6. Seed Dispersal Unit

3.5 Calculations

3.5.1 Motor Calculation

Selection of motor is very important, and this depends on the entire weight of the robot and the surface it shouldclimb. So, the motor calculation for the 6 DC motors is given below[41]:

- Let's assume the weight of the robot, M_R = 2.5 kg.
- Total load which could be carried by robot, M_L = 1.5 kg.
- RPM chosen for the motor is, N= 30rpm.
- Wheel diameter, D_W = 100mm = 0.1m

The rover should climb 40° on an inclined surface. So, let's say the maximum slope incline percentage is 84%. So, the angle of incline= arctan (0.84) = 40°.

Calculation of nominal velocity (linear velocity):

Nominal velocity,

$$Vn = \frac{\pi \ \times Dw \times N}{60}$$

$$= \frac{3.14 \times 0.1 \times 30}{60}$$

$$= 0.157 \text{ m/s}$$

Calculating motor power/ torque:

If we omit friction, the motor torque needed to climb on 40° inclined slope can be found out. The thrust forces needed to overcome gravity on the slope is,

$$F_T = g \times k \times (M_R + M_L)$$

where g is the acceleration due to gravity and k is the slope.

$$F_T = 9.81 \times 0.84 \times 4$$

$$= 32.69 \text{ N}$$

The mechanical power needed to move the robot uphill is,

$$P_U = F_T \times V_n$$

$$= 32.96 \times 0.157$$

$$= 5.1742 \text{ W}$$

The above power is for the entire robot. So, we have 0.86 W per one motor.

The corresponding torque for one wheel is,

$$T = \frac{1}{6} \times \frac{D_W}{2} \times F_T$$

$$T = \frac{1}{6} \times \frac{0.1}{2} \times 32.96$$

$$= 0.275 \text{ Nm}$$

$$= 2.8 \text{ Kg-cm}$$

3.5.2 Battery Calculation

The battery calculation for the robot is given below[42]:

1. Arduino

   Current= 200 mA

   Voltage= 5V

   Power= 200*5 = 1000 milliwatts

2. DC Motor

   Current= 300 mA

   Voltage= 12V

   Power= 300*12 = 3600 milliwatts

3. Servo Motor MG996r

   Current= 900mA

Voltage = 6V

Power= 5400 milliwatts

4. SG90 servo motor

   Current= 250mA

   Voltage= 6V

   Power= 1500 milliwatts

5. L298N motor module

   Current= 2A

   Voltage= 5V

   Power= 10 Watts

There are 2 motor modules, therefore $10 \times 2 = 20$ Watts

So, the total power of the whole circuit is 49.5 Watts.

Let the robot run for 30 minutes. So, if we want to run 49.5 Watts for half an hour, then we need a (49.5*0.5) Watt- hour battery. The battery will drain completely after 30 minutes. But this can damage the battery. So, let's assume that the battery should run for 30 minutes from full charge to 20%, so that the battery won't get drained completely.

Therefore, change in state of Charge×Capacity = 49.5×0.5 Watt-hours

$$\Delta SOC * Capacity = 24.75\, Wh$$

$$Capacity = 24.75 \times (1.00 - 0.2)$$

$$= 24.75 \times 0.8$$

$$= 30.94\, Wh$$

Converting Watt-hours to milliampere hour,

$$mAh = \frac{1000 \times Wh}{Voltage}$$

$$mAh = \frac{1000 \times 30.94}{11.1}$$

$$= 2787\, mAh$$

3.6 Hardware Configuration

For this project, one Arduino UNO, one HC-05 Bluetooth Module, two L298N motor drivers, one MG996r servo motor, one SG90 servo motor, 6 DC motors of 5V, 5Kg-cm, 30 RPM and three 3.7V 2600mAh Li-ion batteries connected in series are used.

3.6.1 Arduino UNO

Arduino UNO is a microcontroller board based on the ATmega328P, which is a single chip microcontroller. It has a 5V operating voltage. It also has 6 analog input pins and 14 digital input/output pins out of which 6 provide PWM output. It has a flash memory of 32KB and 16MHz clock speed[43].

Figure 3.7. Arduino UNO

3.6.2 HC-05 Bluetooth Module

For connectivity, HC-05 Bluetooth module is used which is has a range of less than 100m. The operating voltage of the module is 5V. This module is normally used in short range applications. It uses a Serial Port Protocol (SPP). It is very easy to connect the Bluetooth module. The module needs to be powered with 5V supply, the Rx pin of Bluetooth should be connected to the Tx pin of Arduino and Tx pin of Bluetooth needs to be connected to Rx pin of Arduino[44].

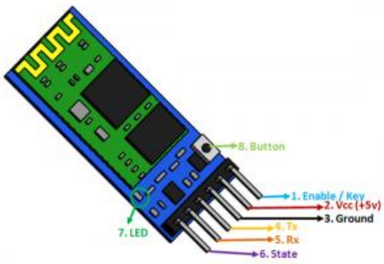


Figure 3.8. HC-05 Bluetooth Module

3.6.3 L298N Motor Driver

The L298N motor driver is powered by 5-35V DC supply. It can control two motors at a time. Drive current of the component is 2A with a max power of 25Watts. In this project, the motor driver is powered by 11.1V DC supply[45].

3.6.4 DC Motors

Six 12V, 5Kg-cm torque, 30rpm motors are used to give motion to all the six wheels. It has a shaft diameter of 6mm, torque range of 5 Kg-cm, 6V-12V voltage. The motor gives 30RPM at 12V. But it also runs smoothly from 4V to 12V giving wide range of RPM. Along with the motors 100mm diameter 20mm thickness wheels are also used[46].

Figure 3.9. DC Motors

3.6.5 MG996r Servo

MG996r is a high torque DC servo motor. It has a stall torque of 9.4 kgf-cm at 4.8V and 11kgf-cm at 6V. Its operating voltage ranges from 4.8V to 7.2V. This motor is used for steering mechanism for front and back wheel in this project as a high torque motor is required to steer the robot[47].

Figure 3.10. MG996r

Table 3.1. Component Specifications[48-53]

DC motor	Voltage: 6V to 12V Current: 300mA Shaft Diameter: 6 mm Torque Range: 5 Kg-cm Speed: 30 RPM at 12V Weight: 200 g
Wheel	Diameter: 100mm Thickness: 20mm
MG996r Servo Motor	Weight: 55g Dimension: 40.7×19.7×42.9mm Stall torque: 9.4kg/cm (4.8v); 11kg/cm (6.0v) Operating speed: 0.19sec/60degree (4.8v); 0.15sec/60degree (6.0v) Operating voltage: 4.8 ~ 6.6V Gear Type: Metal gear Dead band width: 1us Wire length: 32cm
L298N motor module	Motor driver: L298N Motor channels: 2 Maximum operating voltage: 46 V Peak output current per channel: 2 A Minimum logic voltage: 4.5 V Maximum logic voltage: 7 V Weight: 26 g
Bluetooth Module	Bluetooth protocal: Bluetooth Specification v2.0+EDR Frequency: 2.4GHz ISM band Modulation: GFSK (Gaussian Frequency Shift Keying) Emission power: ≤4dBm, Class 2 Sensitivity: ≤-84dBm at 0.1% BER Security: Authentication and encryption Profiles: Bluetooth serial port Power supply: +3.3VDC 50mA Working temperature: -20 ~ +75Centigrade Dimension: 26.9mm x 13mm x 2.2 mm

SG90 Servo	Torque: 2.0kg/cm (4.8V), 2.2kg/cm(6V) Speed: 0.09s/60° (4.8V), 0.08s/60°(6V) Rotate angle: 180° Operating voltage: 4.8 ~ 6V. Gear: plastic. Dead band: 7us. Weight: 10.5g.

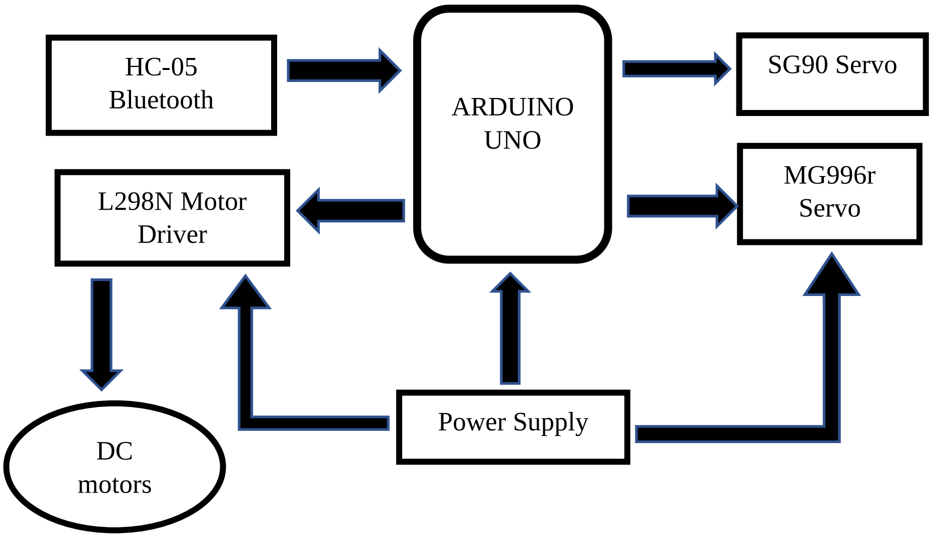


Figure 3.11. Block Diagram

Figure.3.11 depicts the block diagram of the seed sowing robot. The robot uses six DC motors to six wheels of the robot. DC geared motors are used as they have low speed and high torque which is very important for our application. High torque is needed for the motor to easily climb the obstacles. The DC motors are connected to L298N motor drivers. These L298N motor drivers gives the output to the DC motors. HC-05 Bluetooth module, SG90 servo motor and MG996r servo motor are connected to Arduino. Power supply is given to Arduino using power bank, while the power supply to motor drivers and MG996r is given by the 11.1V batteries.

The wheel ends of the links are connected to the geared D.C. motors. After that, the motors are attached to the wheels. Two L298N motor drivers control the power to the wheels. The Arduino Uno microcontroller provides input to the motor drivers. The microcontroller receives and processes user input through the usage of a Bluetooth module. To move and guide the robot, it transmits control signals to the motor driver and servo motors. Using the Arduino IDE, the microcontroller is programmed to accomplish the foresaid operation. The robot may be controlled to move forward, backward, left, and right in manual mode. The robot travels forward in the Automated mode, dispersing seed at regular intervals.

3.7 Application Used for controlling Robot

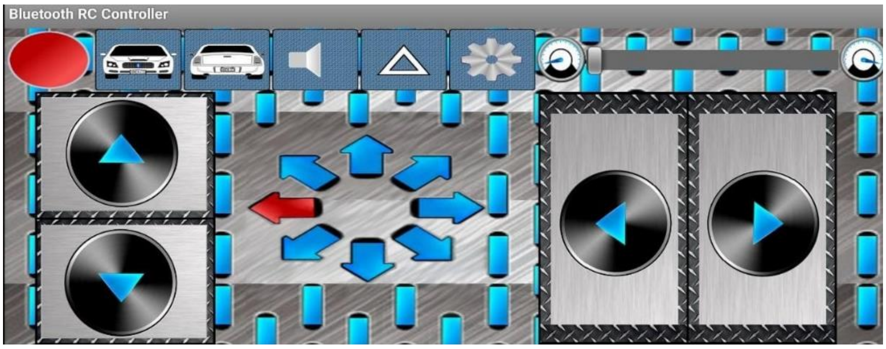


Figure 3.12. Application Interface

Bluetooth RC controller android application is used for controlling the robot. Bluetooth is connected to this application and is controlled by operating the switches. The forward and reverse direction arrows move the robot forward and backward respectively. Left and right direction arrows is used to turn the direction of the robot by activating the steering mechanism and also by rotating left and right motors in the opposite direction. Horn switch is used to make the robot semi-automatic. When the horn switch is activated, the robot moves straight and disperses the seeds in equal intervals of time.

3.8 Circuit Diagram

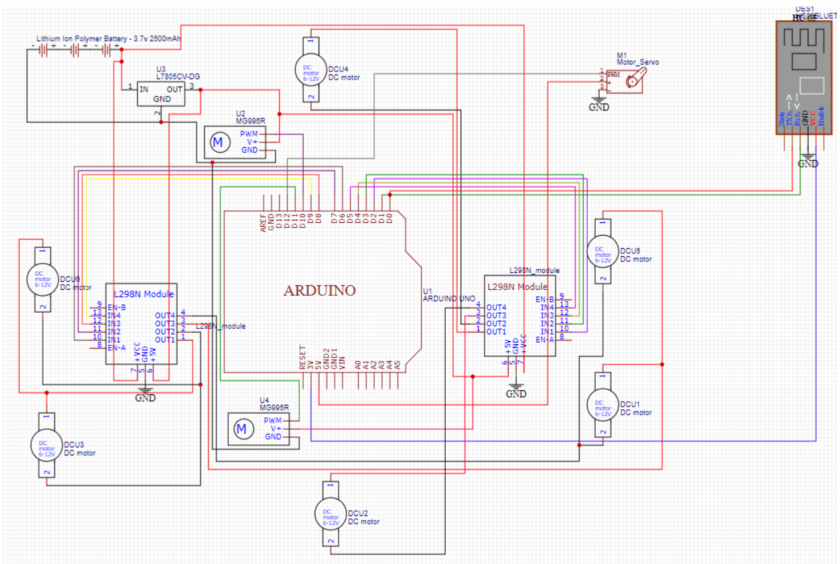


Figure 3.13 Circuit

Figure 3.13 presents the circuit diagram for the robot. Two DC motors on one side of the bogie are connected in parallel and connected to one of the output ports of the motor driver. The other two motors on the other side bogie are connected as same and connected to second output port of the motor driver. The input to this motor drivers is connected to D6, D7, D8, D9 pins of Arduino. The front and rear wheel DC motors are connected to second L298N motor driver on first and second output ports respectively. The inputs of the motor drivers are connected to Arduino UNO. 11.1V power supply is also given to the motor driver and an extra 5V supply is given to +5V pin of motor driver converting the 11.1V to 5V using L7805 voltage regulator. Bluetooth's Rx and Tx is connected to D1 and D0 respectively. The power supply to Bluetooth module is provided by Arduino. PWM pin or MG996r is connected to D10 which is a PWM pin in Arduino. The PWM pin of SG90 servo motor is connected to D12 of Arduino. The 5V to this motor is connected with 5V in the Arduino. All the negative terminals are grounds in breadboard.

3.9 Arduino Program

```
#include <SoftwareSerial.h>
#include<Servo.h>
Servo frnt;
Servo bck;
Servo seed;
#define motor_left 8
#define motor_right 6
#define motor_right_dir 7
#define motor_left_dir 9
#define motor_front 2
#define motor_front_dir 3
#define motor_back 4
#define motor_back_dir 5
SoftwareSerial MyBlue(0, 1); // RX | TX
char flag = 'f';
int pos=0;
void setup()
{
 frnt.attach(10);
 bck.attach(11);
 seed.attach(12);
 pinMode(9,OUTPUT);
 pinMode(8,OUTPUT);
 pinMode(7,OUTPUT);
 pinMode(6,OUTPUT);
 pinMode(5,OUTPUT);
 pinMode(4,OUTPUT);
 pinMode(2,OUTPUT);
 pinMode(3,OUTPUT);
 Serial.begin(9600);
 MyBlue.begin(9600);
 Serial.println("Ready to connect\nDefualt password is 1234 or 000");
  frnt.write(60);
  bck.write(60);
}
void loop()
{
 if (MyBlue.available())
   flag = MyBlue.read();
 if(flag =='F'){          // action to be performed if input is 'f'
         frnt.write(45);
         bck.write(45);
         digitalWrite(motor_front_dir,HIGH);
         digitalWrite(motor_front,LOW);
         digitalWrite(motor_left_dir,HIGH);
         digitalWrite(motor_right_dir,HIGH);
         digitalWrite(motor_left,LOW);
```

```
  digitalWrite(motor_right,LOW);
  digitalWrite(motor_back_dir,HIGH);
  digitalWrite(motor_back,LOW);
 }
 else if(flag == 'B'){ // action to be performed if input is 'b'
  frnt.write(45);
  bck.write(45);
  digitalWrite(motor_front_dir,LOW);
  digitalWrite(motor_front,HIGH);
  digitalWrite(motor_left_dir,LOW);
  digitalWrite(motor_right_dir,LOW);
  digitalWrite(motor_left,HIGH);
  digitalWrite(motor_right,HIGH);
  digitalWrite(motor_back_dir,LOW);
  digitalWrite(motor_back,HIGH);
 }
 else if(flag == 'L'){        // action to be performed if input is 'l'
  frnt.write(0);
  bck.write(0);
  digitalWrite(motor_front_dir,HIGH);
  digitalWrite(motor_front,LOW);
  digitalWrite(motor_left_dir,HIGH);
  digitalWrite(motor_right_dir,LOW);
  digitalWrite(motor_left,LOW);
  digitalWrite(motor_right,HIGH);
  digitalWrite(motor_back_dir,HIGH);
  digitalWrite(motor_back,LOW);
 }
 else if(flag == 'R'){      // action to be performed if input is 'r'
  frnt.write(90);
  bck.write(90);
  digitalWrite(motor_front_dir,HIGH);
  digitalWrite(motor_front,LOW);
  digitalWrite(motor_left_dir,LOW);
  digitalWrite(motor_right_dir,HIGH);
  digitalWrite(motor_left,HIGH);
  digitalWrite(motor_right,LOW);
  digitalWrite(motor_back_dir,HIGH);
  digitalWrite(motor_back,LOW);
  }
 else if(flag =='S'){  // action to be performed if input is 's'
  digitalWrite(motor_front_dir,LOW);
  digitalWrite(motor_front,LOW);
  digitalWrite(motor_left_dir,LOW);
  digitalWrite(motor_right_dir,LOW);
  digitalWrite(motor_left,LOW);
  digitalWrite(motor_right,LOW);
  digitalWrite(motor_back_dir,LOW);
  digitalWrite(motor_back,LOW);
  Serial.println("stop");
 }
 else if(flag=='V')
 {
    while(flag!='G')
    {
      frnt.write(45);
      bck.write(45);
  digitalWrite(motor_front_dir,HIGH);
  digitalWrite(motor_front,LOW);
  digitalWrite(motor_left_dir,HIGH);
  digitalWrite(motor_right_dir,HIGH);
  digitalWrite(motor_left,LOW);
  digitalWrite(motor_right,LOW);
  digitalWrite(motor_back_dir,HIGH);
  digitalWrite(motor_back,LOW);
  Serial.println("front");
  delay(1500);
  digitalWrite(motor_front_dir,LOW);
  digitalWrite(motor_front,LOW);
  digitalWrite(motor_left_dir,LOW);
  digitalWrite(motor_right_dir,LOW);
  digitalWrite(motor_left,LOW);
  digitalWrite(motor_right,LOW);
  digitalWrite(motor_back_dir,LOW);
  digitalWrite(motor_back,LOW);
  Serial.println("stop");
  seed.write(60);
  delay(500);
  seed.write(0);
  delay(500);
  if (MyBlue.available())
  {
  flag = MyBlue.read();
  }
   }
 }
}
```

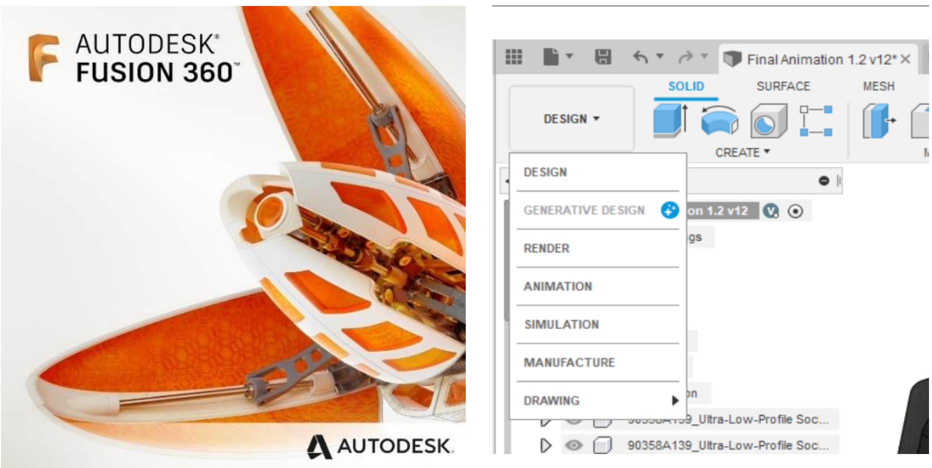
Figure 3.14. Arduino Code

CHAPTER-4

CAD Modelling

4.1 Design Software

CAD Modelling abbreviated for Computer Aided Design modelling allows designers to bring concepts into reality through different CAD Software. It has features to refine, modify, and test different designs before ready for production. One such CAD software is Autodesk Fusion 360 Figure 4.1 (a). It enables users to create 3D models, engineer, simulate, and manufacture all in one product development software. Although Autodesk Fusion 360 is a much newer 3D program, it is quickly gaining popularity among professionals and hobbyists alike. It integrates CAD, CAM, and CAE software (Figure 4.1 (b)). It takes a more contemporary approach to design and offers a lot of design, simulation, and production capabilities. For engineering tasks, mechanical parts, and product design, Fusion 360 will be a good choice. Fusion 360 is also cloud-based, which makes working in groups much easier.



(a) (b)

Figure 4.1. (a) Fusion 360 (b) Features available in Fusion 360

Since Fusion 360 is a cloud-based software, it allows users to use the software in multiple devices at a time. It has a unique feature where a team can work on the same design on cloud. This is one of the main reasons to opt Fusion 360 to design the model for the project. It enables the users to see the progress and can give feedbacks regarding the design that has been developed by the other teammates.

4.2 Conceptual Design of Shrimp Rover

Shrimp is a revolutionary long-range rover architecture with six motorized wheels. The rover has a steering wheel in both the front and rear, as well as two wheels on a bogie on each side, in a rhombus layout. Figure 4.2 shows the architecture of a simple shrimp rover. The front wheel is spring suspended to ensure that all wheels always have excellent ground contact. The rover's steering is accomplished by synchronizing the front and rear wheel steering as well as the speed difference between the bogie wheels. This enables high-precision maneuvers and even on-the-fly rotation with minimal slip.

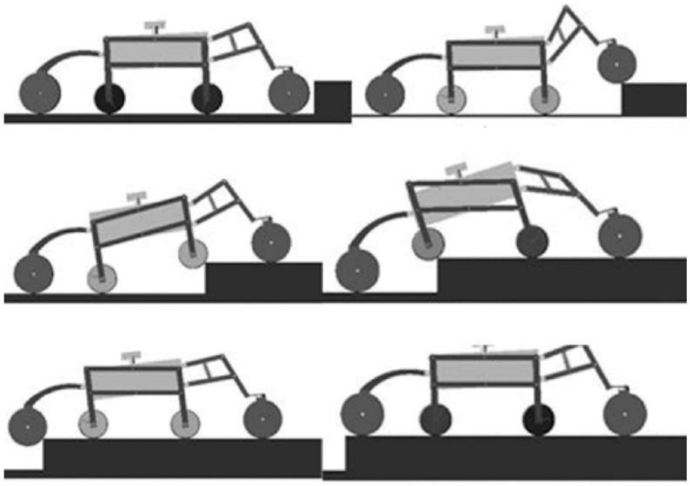


Figure 4.2 Schema of a Shrimp Rover[54]

Because of its passive mechanical design, the "Shrimp" construction is substantially simpler. The bogies and fork have a parallel design that allows for a high ground clearance while always maintaining all six powered wheels in contact with the ground. This ensures exceptional climbing abilities over obstacles, as well as great terrain adaption.

The use of parallel articulations for the front wheel and bogies allows for the creation of a virtual center of rotation at the wheel axis while maintaining a high ground clearance. Even with low friction coefficients between the wheel and the ground, this ensures optimal stability and climbing skills. This rover can traverse unstructured obstacles up to two times its wheel diameter passively. This architecture is ideal for long-range planetary missions because of its tremendous mobility

4.3 Design of Robot Locomotion

This shrimp rover, shown in Figure 4.3, is a robot with six wheels, each driven by six motors. It features one front four-bar that allows it to climb over obstacles of a particular height without losing stability. The parallelogram bogies on the middle four wheels balance the wheel response forces when climbing. To boost climbing capacity, the single rear wheel is attached directly to the main body and is also powered by a motor.

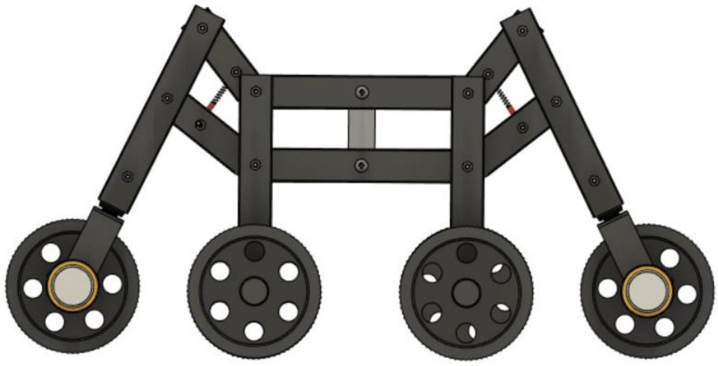


Figure 4.3 Design of Shrimp Rover

The parallel architecture of the bogies and the fork, as illustrated in Figure 4.4, allows for a configuration for the six powered wheels while maintaining a high ground clearance. This provides optimal stability, adaptability, and climbing skills. On a convex surface, the robot is designed to keep all six motorized wheels in touch with the ground.

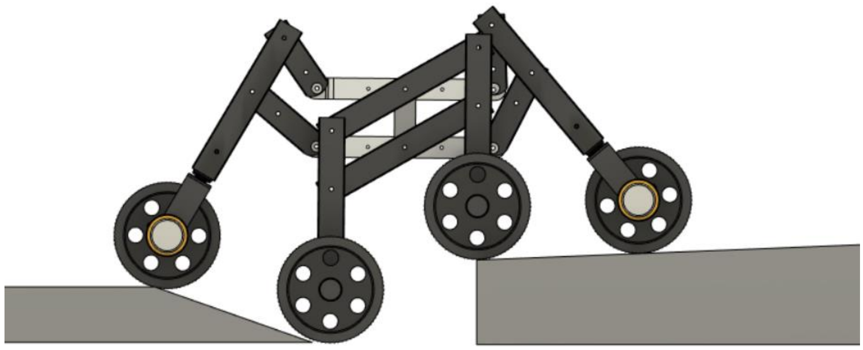


Figure 4.4 Rover on Uneven Terrain

The bogies are the rover's most crucial component. Even when travelling over tough terrain, they provide lateral stability. To ensure good adaptability of the bogie, the pivot should be placed as low as feasible while maintaining maximum ground clearance. As shown in Figure 4.5, parallel bogies have a higher ground clearance than traditional bogies, allowing the robot to traverse over higher obstacles[55]. The larger pivot aids the bogie to be stable on highly uneven terrain.

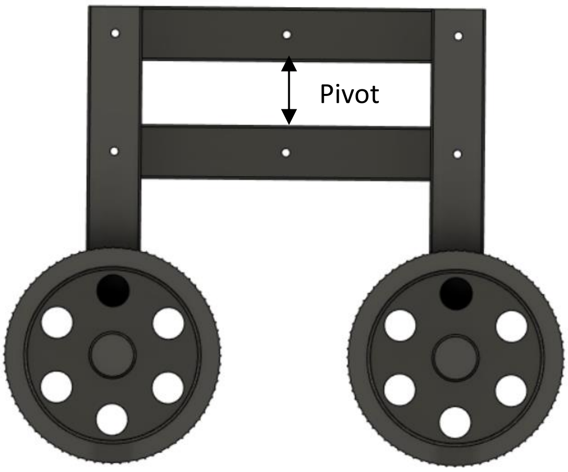


Figure 4.5 The Rover Bogies

The fork in Figure 4.6 serves mainly three purposes. Because of the energy stored in the shock absorber spring, it can be ensured that the front wheel will always be in contact with the ground. When the robot comes into contact with an obstruction, the horizontal force acting on the front wheel produces a torque around the front wheel's instantaneous rotational center. The front wheel's four-bar system reveals that the immediate center is positioned under the horizontal line, causing the wheel to move up appropriately.

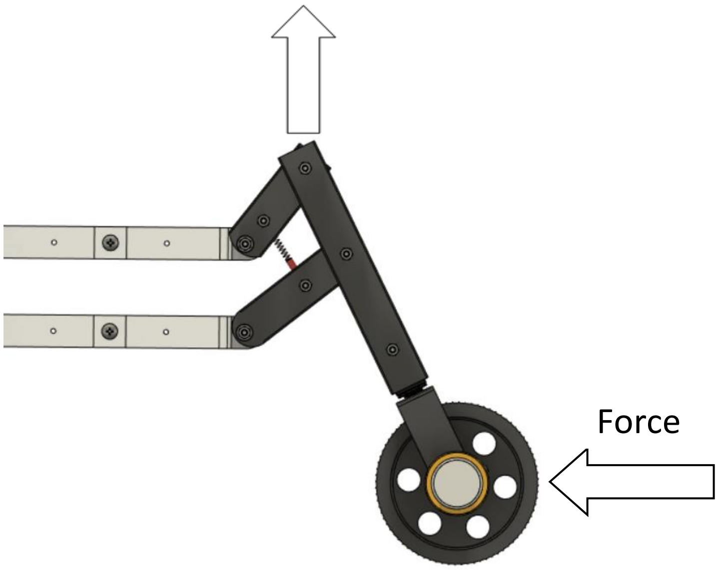


Figure 4.6 Front Fork while encountering an obstacle

The fork will be pulled up when the front wheel rises. The energy will be stored in the suspension spring. Even if other wheels aren't in good shape and don't entirely touch the ground while rising, the stored energy in the spring assures that the wheels are in contact with the ground at all times.

The major propulsion for robots travelling long distances and climbing over barriers is friction between wheels and the ground. Because of their small contact area with the ground, general wheels have less friction. However, large-diameter (here 100 mm) and width (here 20 mm) wheels can help.

4.4 Design of Robot Components

The Front fork consists of a small link and a longer one which is connected to the master link which accommodates the steering motor and its mechanism. The former two links are used to connect the master link to the rover chassis. And these are interconnected using a suspension spring. When the force is applied the energy is stored in the spring as the links move upwards as depicted in the Figure 4.6. All the three links are of aluminum used in fabrications. Figure 4.7 – Figure 4.9 are the detailed CAD drawings of the front fork components. (All units in mm for all the CAD Drawings, first angle Projection is used.).

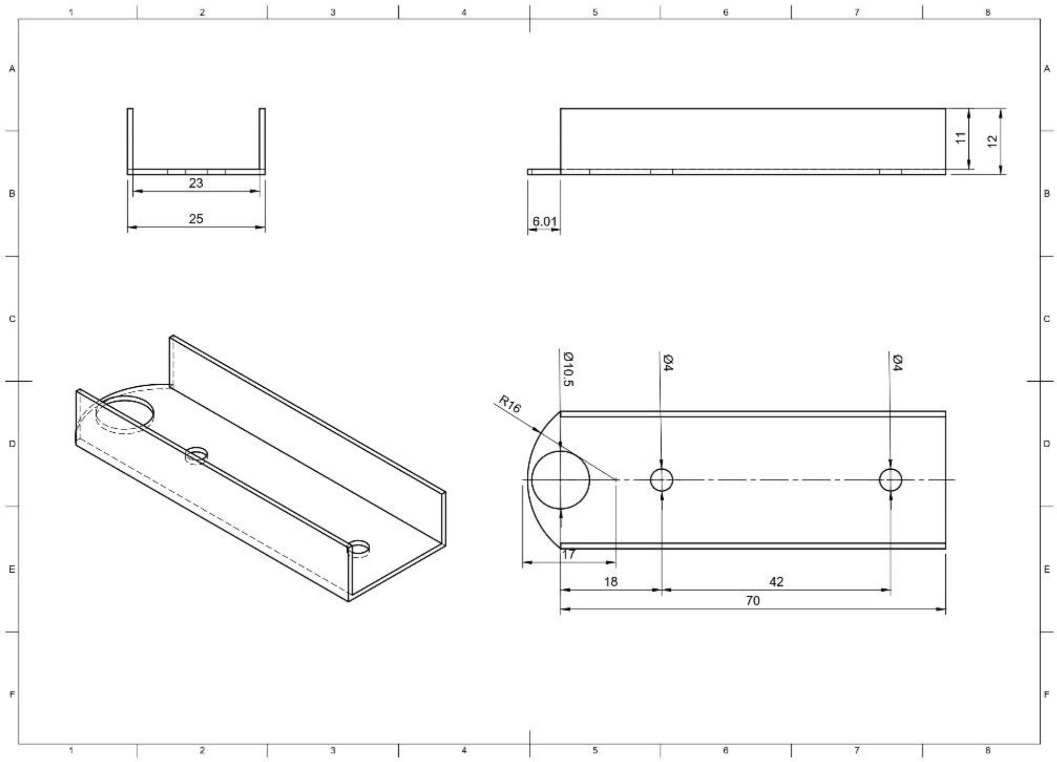


Figure 4.7 Front Fork Short Link

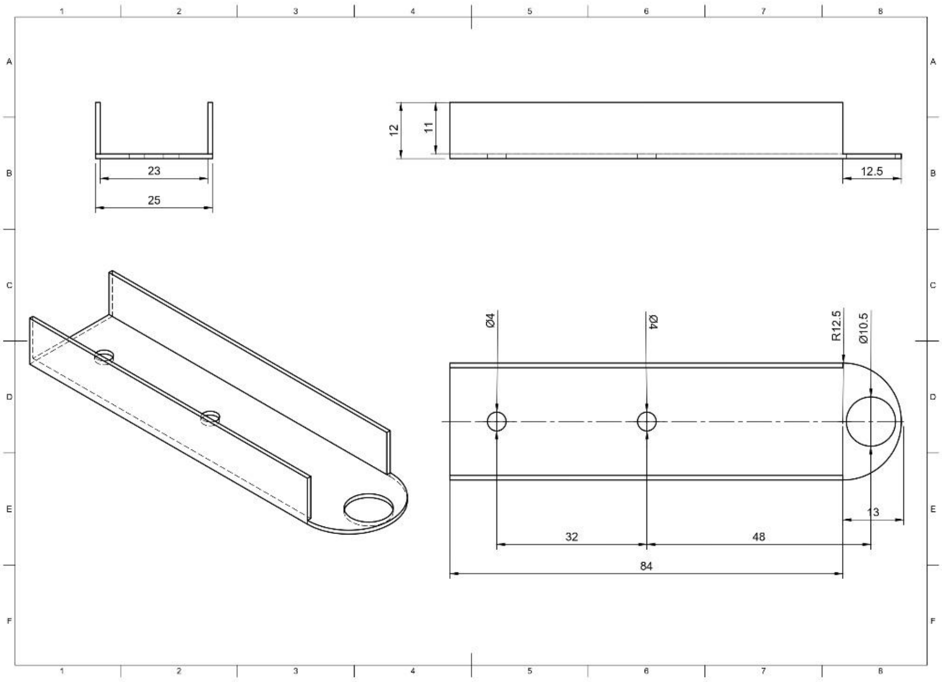


Figure 4.8 Front Fork Long Link

The above two links also accommodate the suspension spring. This spring will be fixed to the links and when the front fork lifts up this spring compresses. This ensures that the links does not coincide and also ensures that the energy stored in the spring will be able to revert the energy to the links to keep the wheel in contact with the ground at all times.

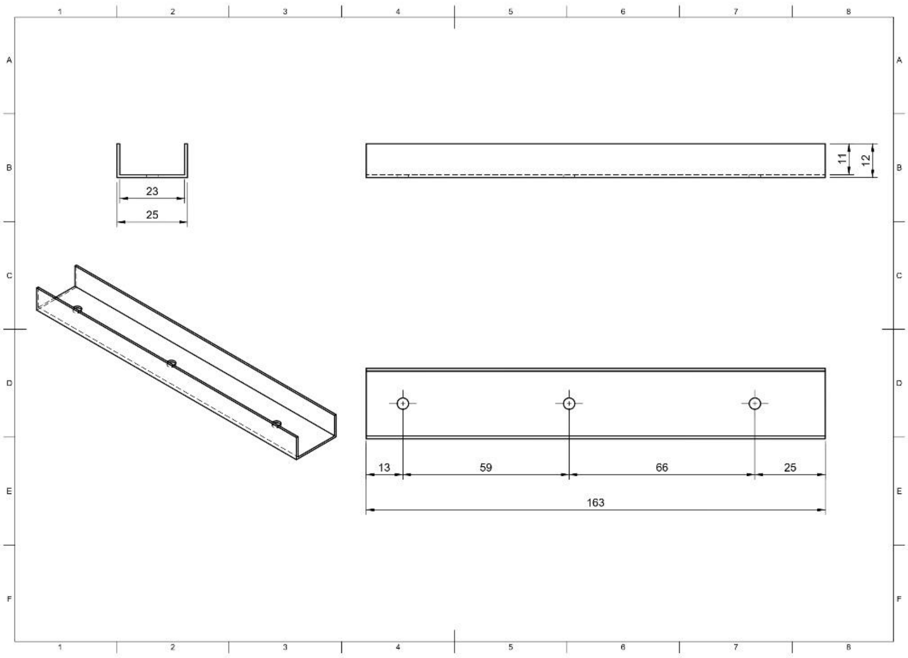


Figure 4.9 Front Fork Master Link

At the end of the master link, there is a support attached for the MG996R Servo motor. This motor is used for the steering mechanism. This support has intricated details and is difficult to manufacture from Aluminum extrusions. Therefore, these are 3D printed using an FDM Printer. Figure 4.10 depicts the detailed drawing of the Servo Holder.

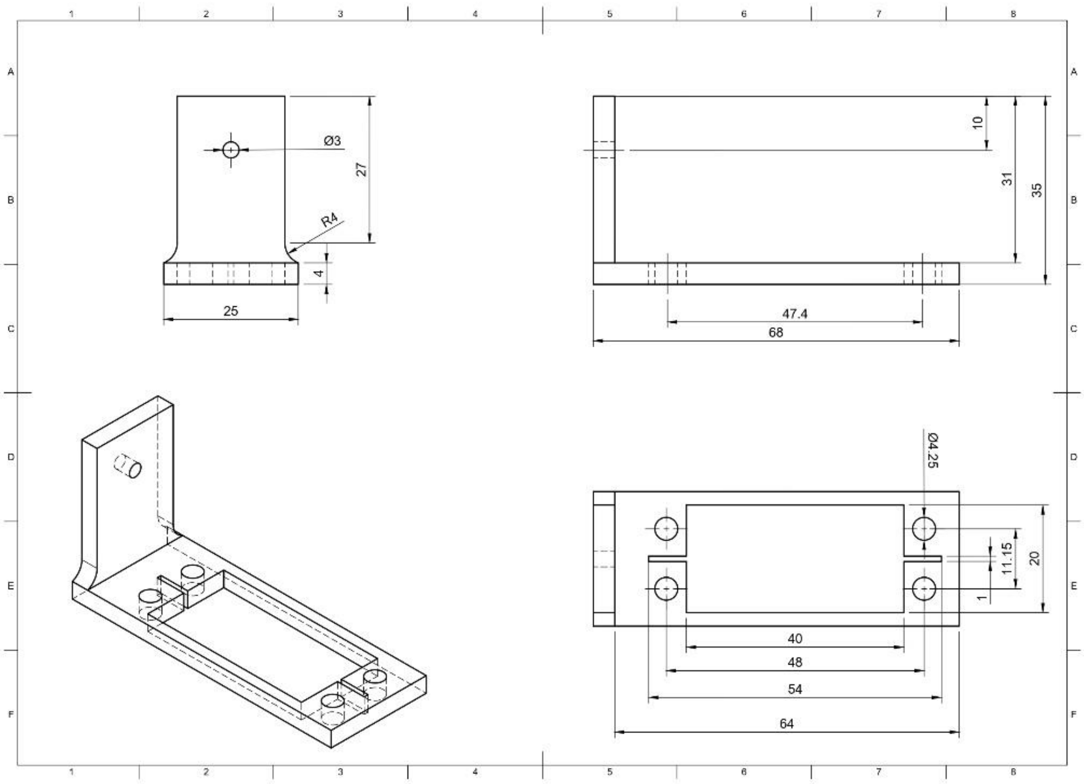


Figure 4.10 MG996R servo holder

The servo motor is then connected to the wheels and the DC Motor that drives these wheels using a L Clamp. It is fabricated from Aluminum extrusion. This L Clamp also houses both the DC motor and the wheels. And the position of this link is controlled using the servo motor. This is the steering mechanism for the rover.

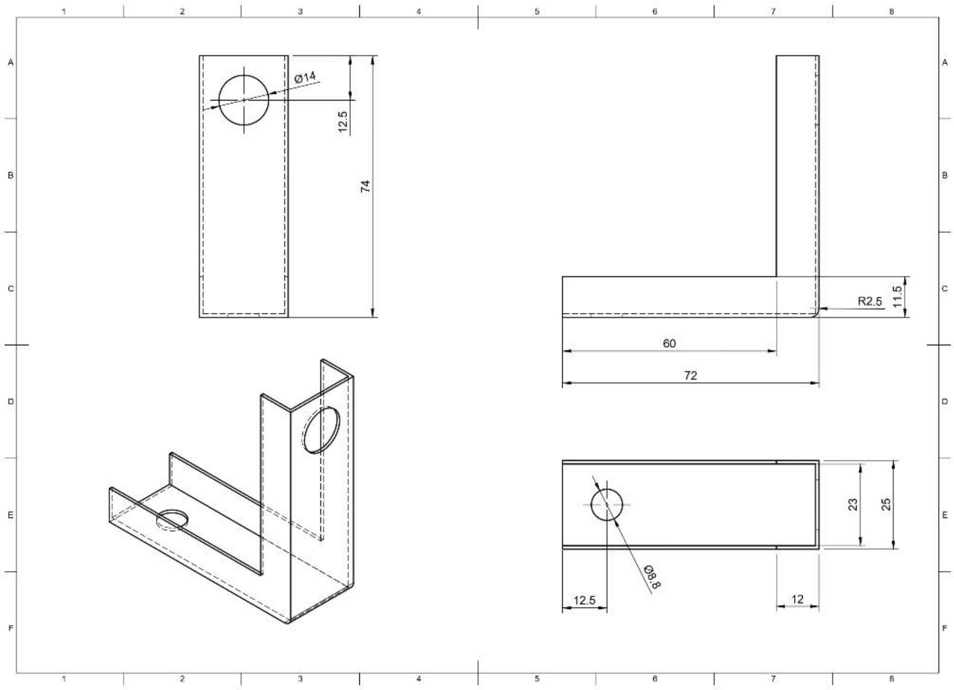


Figure 4.11 L Clamp for Steering Mechanism

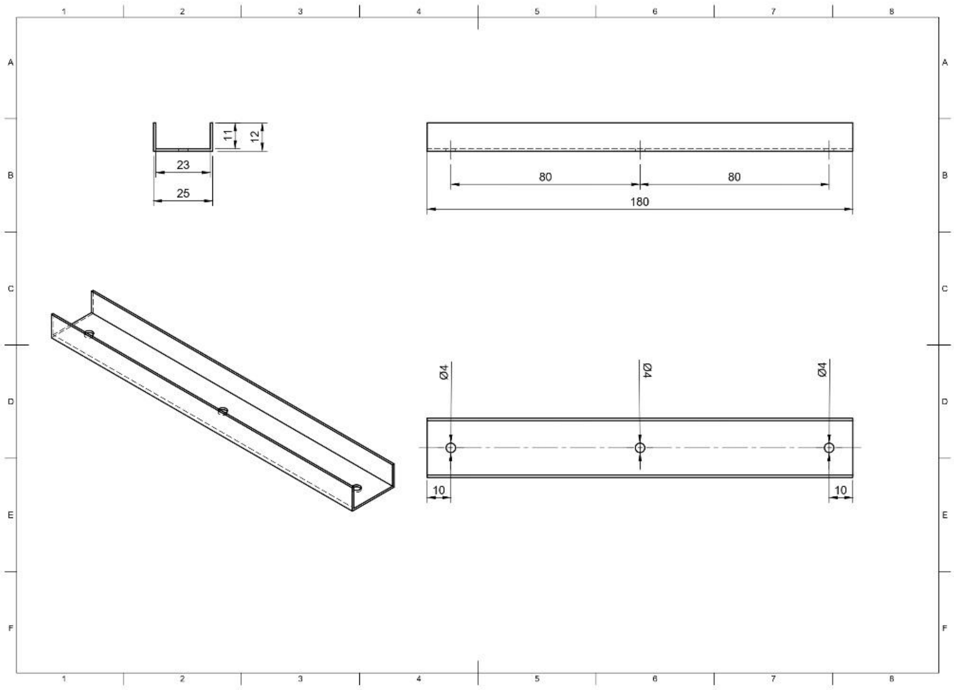


Figure 4.12 Bogie Horizontal Link

The bogie consists of four links. They are Horizontal Links (2 Nos) and Vertical Links (2 Nos). All the four links are of Aluminum. These are chosen as they provide better rigidity for the links. This will assure that the rover is stable while traversing on highly uneven terrains with heavier payloads.

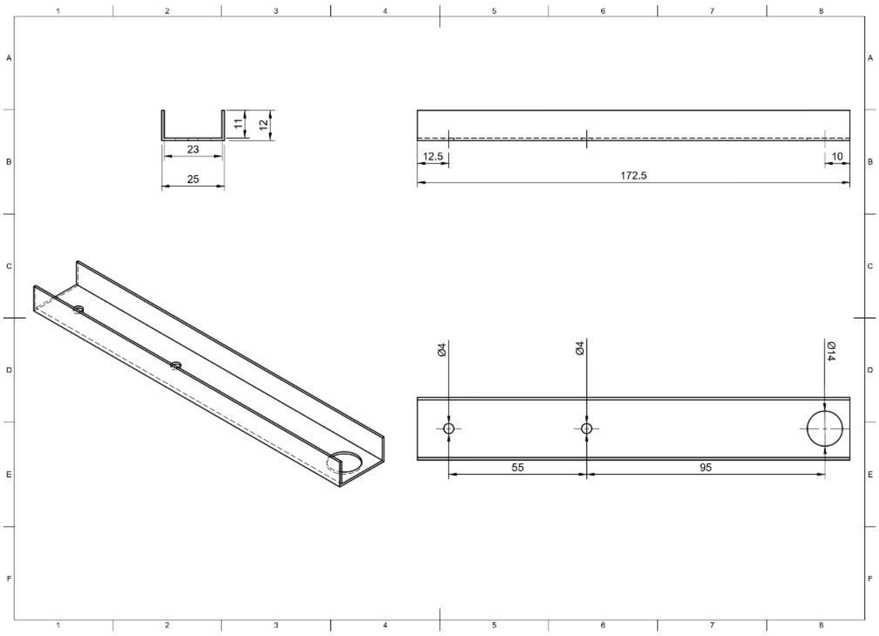


Figure 4.13 Bogie Vertical Link

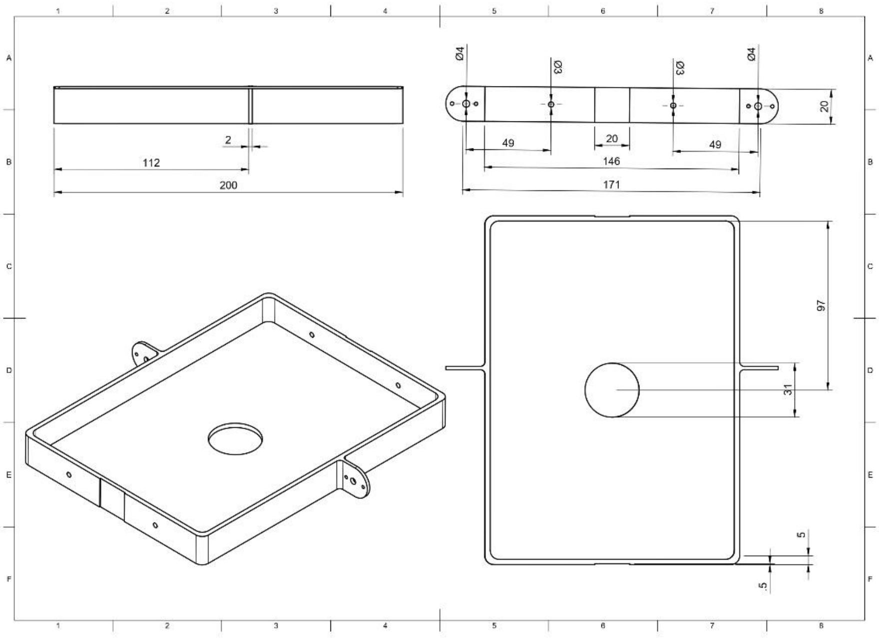


Figure 4.14 Base Body Chassis

The body base chassis (Figure 4.14) has been designed in such a way that it can accommodate all the electronic components and as well as the seeding mechanism with the seed storage funnel compartment. It is entirely 3D printed using an FDM Printer. An upper body frame has also been designed and manufactured by means of 3D printing. This frame is used to connect all the links and to provide support to the links.

It has the same dimensions as of the body base chassis. But is just a frame with inside being hollow.

A novel seeding mechanism has been developed for this rover; it consists of a funnel shaped compartment (Figure 4.15) where the seeds are stored in. This is fixed to the base frame. The funnel has an extrusion at one end, which supports SG90 servo motor. This servo motor controls the seed flow to the single seed compartment (Figure 4.16). A closing lid (Figure 4.17) that is fixed at the bottom breaks the flow of the seed passing through the seed dispenser unit.

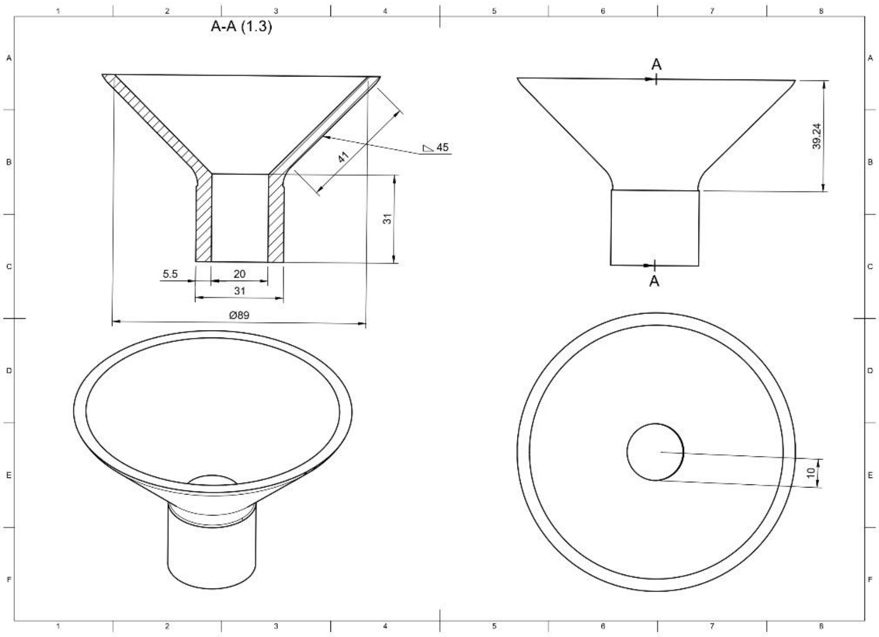


Figure 4.15 Seed Storage

The seed storage is in the shape of a funnel, and it stores all the seeds. It has a narrow passage that lets the seeds pass through it. The entre seed storage and the seeding mechanism are 3D printed using an FDM Printer.

4.5 Material Selection

The entire rover was initially manufactured using 3D printed materials. The bogie , front fork and the body chassis were all fabricated using 3D printed parts. The PLA material was used for the manufacturing of these parts. It was later analyzed, and the results were not satisfactory. The links those were manufactured from PLA by 3D printing were not stable and high bending moment was noticed when traversing through irregular terrains. This led to the selection of an alternative material for the fabrication of these links. Aluminum extrusions used in fabrication works was used as this alternative. It was noticed that the high rigidity of aluminum materials was able to withstand the payload and the rover was stable over uneven surfaces. Therefore, the bogie, front and rear fork were all fabricated using this material. The body base chassis and the upper body frame were still made of PLA 3D printed materials as less stress is induced to these parts. The Screws and Nuts used for joining all the links were of Steel. The properties of these materials used in the fabrication of the rover is mentioned in the Table 4.1.

Table 4.1 Material Properties (Autodesk Fusion 360)

Properties	**Aluminum**	**Steel**	**PLA Plastic**
Density	2.7E-06 kg / mm^3	7.85E-06 kg / mm^3	1.14E-06 kg / mm^3
Young's Modulus	68900 MPa	210000 MPa	2100 MPa
Poisson's Ratio	0.33	0.3	0.36
Yield Strength	275 MPa	207 MPa	2.94 MPa
Ultimate Tensile Strength	310 MPa	345 MPa	28.1 MPa
Thermal Conductivity	0.23 W / (mm C)	0.056 W / (mm C)	1.6E-04 W / (mm C)
Thermal Expansion Coefficient	2.36E-05 / C	1.2E-05 / C	8.57E-05 / C
Specific Heat	897 J / (kg C)	480 J / (kg C)	1800 J / (kg C)

CHAPTER-5

Analysis

Mechanical simulation software has evolved into an important component of any engineering design process. These tools, often known as computer-aided engineering (CAE), allow designers and engineers to digitally forecast a part's performance before any physical prototyping or production. These days, applications that combine design (CAD), manufacturing (CAM), and simulation tools (CAE) together in one software package are becoming more widespread. Fusion 360 from Autodesk accomplishes this: Aside from 3D modelling, it also includes CAM and CAE tools as standard features.

Figure 5.1 Different simulations tools in Fusion 360

In general, there are various types of engineering simulations that can be performed. Fusion 360 concentrates on the following simulation types:

Deformation and stress analysis for a given set of structural loads and constraints, including both linear and non-linear material qualities, is known as linear and non-linear static stress. The findings reveal common failure conditions as well as stress levels[56].

To assess how parts respond to heat inputs and stress distributions from thermal and structural loads, thermal distribution and thermal stress are utilized. Temperature distribution, heat flux, and stress distribution are all shown in the results.
The natural frequencies in vibration for the provided parts are determined by modal frequencies analysis, which must be avoided. Vibration mode forms, modal frequencies, and mass involvement parameters are among the findings[56].

To understand how parts respond to motion, impacts, and cyclical stresses, event simulation is employed. It also allows the user to look at multi-body interactions like those seen in assemblies. All affected parts will experience displacements, stresses, and strains, which will be detailed in the results.

Fusion 360 also has topology optimization (also known as Shape Optimization) and generative design. Even though such tools mainly rely on simulations, they are more akin to design-aid tools that supply geometrical solutions rather than numerical findings for performance analysis[56].

5.1 Static Structural Analysis

The maximum load applied for the analysis study is 40 N. A load of 4 Kg has been considered. Which is approximately 40 N. All the six wheels of the rover are fixed. The load is applied normal to the base chassis of the rover. These are the boundary conditions that has been used for the static structural study of the rover.

Initially the Factor of Safety of the rover is computed. The most typical way to represent a safety factor is as a ratio between a measure of the maximum load that will not cause the specified type of failure and a matching measure of the maximum load that will be applied. Constructions should be able to withstand loads and disturbances that are greater than those anticipated. Using explicitly chosen, numerical safety factors is a typical technique to obtain such safety reserves. As a result, if a safety factor of two is used when building a bridge, the bridge is calculated to withstand twice the maximum load to which it will be exposed in practice[57]. Figure 5.2 represents the safety factor of the rover. The proposed design of the agribot was able to achieve a minimum safety factor of 4.45. This ensures that therover can handle the provided payload without any failure moreover it can withstand much larger load about 4.45 times the specified load.

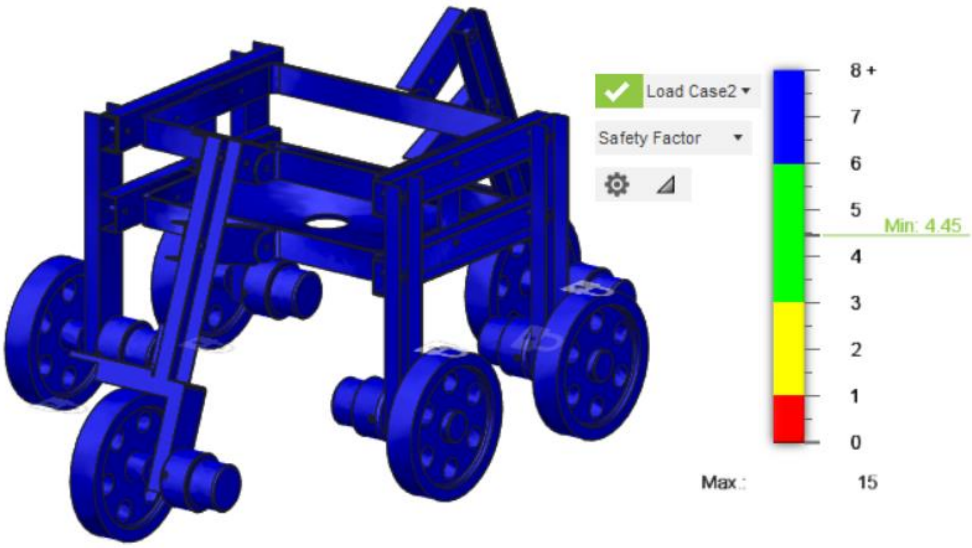


Figure 5.2 Factor of Safety of the Rover

The next parameter calculated was the Von Mises stress. The Von Mises stress is a measurement that can be used to evaluate if a material will yield or fracture. It's most commonly used on ductile materials like metals. The von Mises yield criterion asserts that a material will yield if its von Mises stress under load is equal to or greater than the yield limit of the same material under simple tension. The material is predicted to yield if the von Mises stress is greater than the simple tension yield limit stress. The von Mises stress isn't really a stress at all. It is a theoretical value that permits the general tridimensional stress yield limit to be compared to the uniaxial stress yield limit[58]. Figure 5.3 depicts the results of Von Mises stress study carried out on the rover with given boundary conditions. The wheel is fixed and an overall payload of 40N acts on the chassis of the rover. The design analysis shows a safe value of stress. Maximum Von Missesstress was found out to be 33.85 MPa.

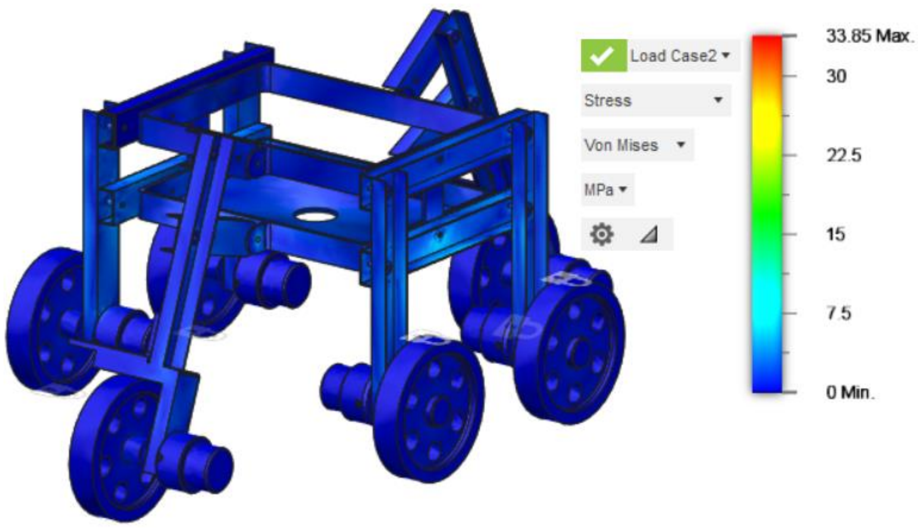


Figure 5.3 Von Mises Stress of Rover

Next parameter to study is the deformation or the displacement of the rover body due the applied forces. Deformation is the alteration of an object's shape or size as a result of applied external forces. Strain is the ratio between the deformation and the original length, while deformation is the measure of how much an object is stretched[59]. The deformation (Figure5.4) due to the applied load was also studied for the model. The deformation is negligible for the given boundary conditions and is safe. It has a maximum deformation of 0.5097 mm. This also means than it is safe with heavier payloads.

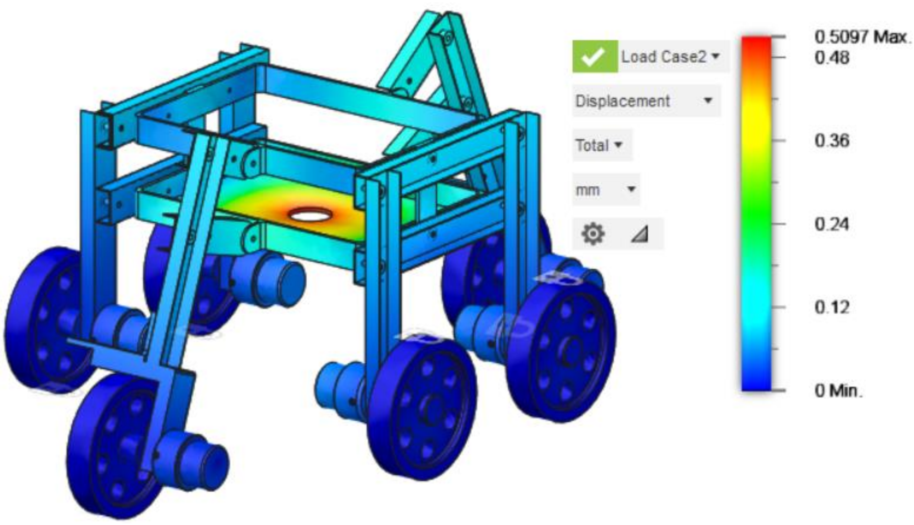


Figure 5.4 Deformation in the body of the rover

CHAPTER- 6

Manufacture and Fabrication

After the CAD model is designed in Autodesk Fusion 360 software, the base plate, the frame of the chassis of robot, motor holder and the seeding mechanism was kept for 3D print. The printer used was WOL3D Ender 3.

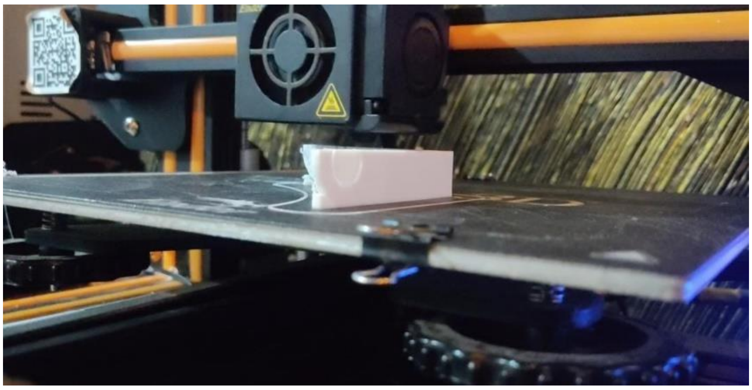


Figure 6.1. 3D Printing

It took several days to complete the manufacturing of 3D printed parts. By this time, aluminum frame was bought from aluminum fabrication shop for all the links of the robot. The frames were measured using a scale as the designed dimensions and was cut with a hacksaw. Holes of 3mm was made on the aluminum at specific locations using a driller wherever nut and bolt is used. Inorder to fix the DC motor to the frame a hole of 10mm is made on every links where motors are attached. 2cm long 3mm diameter nuts, bolts and washers are used for joining the links and to get rotary motion. Likewise all the links are sliced, drilled and joined together. Then after,the bogies are connected to body made of PLA using the same nuts and bolts.After assembling all the links, spring is arranged on each front and rear forks. Later motors and wheels are fixed to the links. Then the 3D printed seeding mechanism is joined and attached to the base of robot using fevikwik glue. The picture of robot after complete assembly of every component is shown in Figure 6.3.

Figure 6.2. Nut, Bolt and Washer

Figure 6.3. Robot After Complete Assembly

CHAPTER- 7

Results and Discussion

7.1 Structural Analysis

Structural analysis was done on the agribot model using Autodesk Fusion 360. The analysis was done to determine and understand the stress and various forces acting on the model when subjected to load. The analysis was critical to determine the structural integrity of the model and to choose the suitable material. The analysis is carried on the crucial parts like chassis and links. This helps to understand how the parts behave when subjected to load. Thus, helps to determine if the model sustains the load it is meant to undergo. The analysis can be done to determine the support reactions, bending moment, rotation, stress, strain shear force and various other factors.

The model was designed with a PLA basic chassis. The chassis holds the microcontroller, Bluetooth module, motor drivers, batteries and has the seed container attached to its centre. The chassis also acts as the centre hub to which the links are attached to. In this model the analysis was performed to determine the extent of deformations and various stresses acting on the model. Thus, displacements and stresses are mainly investigated along with some of the common failures seen in similar robots.

The vertical ground reaction force for the analysis was calculated using the formula W=mg, where W represents the vertical ground reaction force, m is the mass of the vehicle and g is the acceleration due to gravity. The mass of the chassis with the motors, other electronic components is 2.5 Kg. The mass with full load it is approximated as 4 kg. The acceleration due to gravity is approximated as $10m/s^2$. The Vertical ground reaction force is thus calculated to be 40 N.

The Von Mises yield stress method is used in this analysis. This analysis is applied on ductile materials likes metals to find if they yield or fracture under the applied load. As per the method, if the Von Mises stress is greater than or equal to the yield limit of the material model will yield. In this study the test for stress, safety of factor and displacement is done.

The result of the stress Analysis is shown in Figure 5.3. The analysis was done with assumption that the wheels are fixed and the maximum payload that will act on the chassis is 40N. As per the result the maximum Von Misses stress was found to be 33.85 MPa. The analysis shows a safe value of stress as evident in the figure.

The Figure 5.2. shows the factor of safety analysis. The figure shows that the model exists at a safe region. The factor of safety was determined to be 15. This ensures the rigidity of the model. It also depicts that the robot can carry load larger than 4 Kg, even though the present application is limited to a total load value of 4 Kg.

The Deformation analysis shows a result as in Figure 5.4. The maximum deformation for the given conditions were recorded to be 0.5097mm. This result shows negligible deformation. Similar to the previous analysis, this analysis also shows possibility of working with heavier load without any failure. The maximum reaction force at wheels was seen to be 1.65N and the maximum contact pressure was 16.59 MPa.

These analysis shows that, the robot is solid and stress acting on the robot is below the yield strength of the materials. The deformation from the above load condition is very low and is negligible. Thus, it is evident that the robot can undergo greater stresses which means it can work under larger load conditions.

7.2 Inclined Surface Test

The main objective of using the shrimp mechanism for the robot was to ensure that the robot could travel on uneven surfaces filled with obstacles and on inclined planes. The mechanism attached the side wheels to a main frame using a separate frame. As a result, the main frame always remained parallel to the surface irrespective of the angle in which the wheels or side frames were. An extra wheel with two link arm is attached at the front and rear end each. This helps the robot to rover over large obstacles. To check if the robot was able to travel on such uneven or inclined planes, it was tested under different circumstances.

Theoretically, the shrimp mechanism can overcome obstacles up to two times the circumference of the wheel, if given proper suspension setup in the wheels. As per this design the wheel is able move over obstacles more than the size of the wheels. This was tested by moving the rover through an uneven surface with obstacles. The robot was able to move over obstacles of height more than the diameter of its wheels. Figure 7.1 shows the rover moving over obstacles.

The robot was also tested on inclined plane. In Ideal case the rover should be able to climb surface with slope over 45°. The robot's performance on inclined surface was tested over an inclined surface with slope approximately equal to 45°. The robot moved on the surface with ease. This shows that the robot is efficient to when used on inclined surfaces. This test is shown in Figure7.2.

The test shows that the agribot is able to hover across all the harsh surfaces it was intended to move on. The suspension used in the present case is average and if switched with a better suspension setup would improve the ability of the rover to perform in extreme terrains.

Figure 7.1. Rover on Obstacles

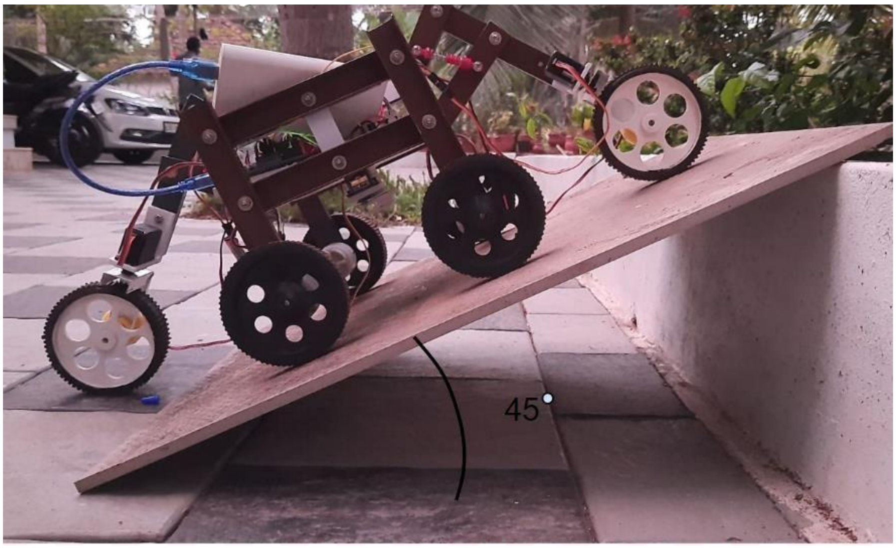


Figure 7.2. Rover climbing a 45° inclined

7.3 Seeding Test

The primary task the agribot was designed to do is seed sowing. The seed has to be planted at proper distance as per the size of the pant and the amount of nutrients required for each plant. This process makes certain that each plant receives the proper amount of nutrients. It also ensures the optimal usage of the field to fill the maximum number of plants that the field can accommodate. It is important that the seeding procedure of the rover is put to test. This prototype is made to plant coffee seeds. The ideal spacing for coffee seeds is calculated as 10-12 cm from each other.

In this test the agribot is put on automated mode, where it travels in a straight line and drops seed at constant intervals. The robot is tested on an open ground as shown in Figure 7.3. Once the robot is put on automated mode it travels in a straight line and drops seed every 1.5 sec. The speed of the rover is about 0.1m/s. Thus, the robot drops the seed every 10 to 12 cm as mentioned above. This is shown in the Figure 7.4. Once the robot finishes this process in a lane, the robot is switched back to manual mode. The robot is then manually controlled to move to the next lane. It is then again put to automatic mode and starts to disperse seed in the next lane at constant interval

Figure 7.3. Agribot at initial position

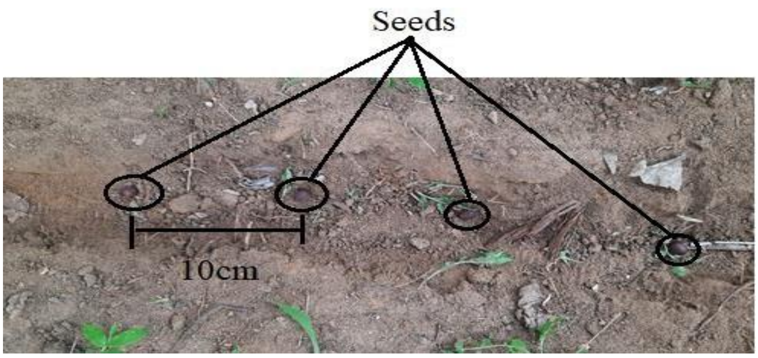


Figure 7.4. Distance between seeds after sowing

7.4 Battery Life Test

It is important to know the battery capacity of the robot to estimate the amount of work it can do in a single charge. The batteries were initially charged to 100%. The rover was then continuously used till the batteries completely drain. In this case 6 V is the minimum voltage at which the motors work, thus the batteries are considered to be completely drained once the motors stop working. The calculated value of battery life from 100% to 20% charge was 30 minutes.

The robot was moved on different surfaces of different inclinations and different level of obstacles. The mode of usage was also switched between manual and automatic repeatedly. The robot worked continuously for 46 minutes before it stopped working.

CHAPTER-8

Conclusion and Scope of Future Work

8.1 Conclusion

Automation being the most rapid change happening in the world, it is vital that an industry like agriculture, which acts as the backbone of many economies, should also attain it. The project designs, analyses and develops an agribot that can be controlled via Bluetooth and is used to disperse seed at constant interval or spacing. The robot can be manually controlled to move around. It can move forward, backward, left and right. The robot also has a automate mode where it travels in straight line and disperse seed in constant intervals. The robot is designed to be used in multi terrain field and hilly areas, example in coffee plantations.

The design and analysis were done using Autodesk Fusion 360. Shrimp mechanism was used as the roving mechanism. This mechanism was chosen as it exhibits exceptional ability to climb on inclined surface and hover over large obstacles. The mechanism can climb steep slopes up to 40^o inclination. It is also able to move over obstacles up to twice the size of wheels. It uses a simple seeding system where a servo operates a flap that opens and closes to disperse seeds one by one. The analysis proved that the robot could sustain load heavier than 5 Kg. The model was then constructed. The main frame was 3D printed and made of PLA. The other links in the model was made from aluminium frame.

The constructed prototype was tested under various conditions to study various parameters of the prototype. It was tested in various terrains and the rover mechanism turns out to be efficient on all type of surfaces. The seeding mechanism was also tested. It worked perfectly dispersing seed at a constant gap of 10-12 cm. The battery life was also tested from 100% to 0%. The battery life of the robot was calculated to be 46 minutes.

8.2 Scope of Future Work

The field of automation has infinite possibility, so is the future scope of projects in this field. The rover can undergo various upgrades that have been limited in this study due to restriction in cost and time. These changes can improve the durability and efficiency of the robot.

The working range of Bluetooth technology is around 5 m. This may not always fulfil the needs the robot has to work in. Thus, it is important to have a better range of control. This can be achieved using radio frequency technology. A simple rf receiver can be installed in the robot and it can be controlled using the paired rf transmitter. The range of rf technology is over 100m.

The agribot doesn’t use any kind of sensors in this project. A variety of sensors like proximity and moisture sensor can be included in the design to increase the autonomy of the robot and collect more data. The proximity sensors can be used to detect obstacles and thus robot can increase the power supply to wheels only when necessary. This improves the battery life of the robot. The moisture sensor and soil composition sensor can be used to gather details of the soil. This information can be used to discharge deficient minerals to the soil. This can be done by further attachments in the robot or can be done separately.

Cameras and more powerful micro controllers can be introduced such that the robot can be made fully automated. The robot can gather visual data from the cameras. This can be passed to the micro controller and passed to advanced algorithms such that the robot can determine the possible movements it has to undergo.

The suspension system used in the present project serves its purpose in this project. But a better suspension setup can be used such that the front and rear wheels have better contact with ground while travelling on uneven surfaces. This also ensures that the suspensions also absorb most of the shock from the ground.

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Status of the Research Paper	Submitted for review

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Abstract

Agriculture is the backbone of the national economy. Various scientific advancements are happening in this field including achievements like genetically modified seed for better production, uses of drones for surveillance and growth tracking and so on. In this project a seed sowing robot is being designed, analyzed, and developed. The robot is designed and analyzed using Autodesk Fusion 360. The previous works in this field uses a simple four-wheel mechanism which struggle in rocky terrains or inclined planes. The robot uses shrimp mechanism, so that it is able to move on all types of terrains, which is one of the significances of the robot. It serves a huge purpose in hilly areas like in coffee plantations. The machine had a six-wheel set up. Four wheels were attached to a sub frame connected to the main chassis. An arm was extended from the main chassis at the front and rear end. A wheel each are connected to these arms. The front and the rear wheels also have a steering mechanism actuated by a servo at the end of each arms. The main chassis of the prototype was 3D printed. The links that are attached to this main chassis was made from aluminum frames. The parts were joined using nut and bolts. The analysis was done on to determine the stress levels, factor of safety and the level of deformations possible with a total of 4 kg. The analysis showed that the robot can withstand the load and work perfectly with heavier loads. Other parameters of the robot were also tested, including its battery life, the seeding process and its performance in various terrains. The robot was able to move on inclined planes with a slope up to 45°. It was able to move on different terrains with different kind of obstacles. The robot was able to climb over obstacles with twice the size of its wheels. The seeding process is done using a servo motor which opens and closes a flap which drops a seed at a time. The servo opens and closes the flap in every 1.5 second. The seed falls at a gap of 10 cm from each other. The battery was tested to find the time a full charged battery could power the device. The test showed that a fully charged battery could power the model for a total duration of 46 minutes.The robot is efficient and can make the seeding process quicker. It requires low human intervention. The seed is planted at a particular distance so that the maximum space is utilized, and the seeds receive enough space, nutrients and water for their proper growth.

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