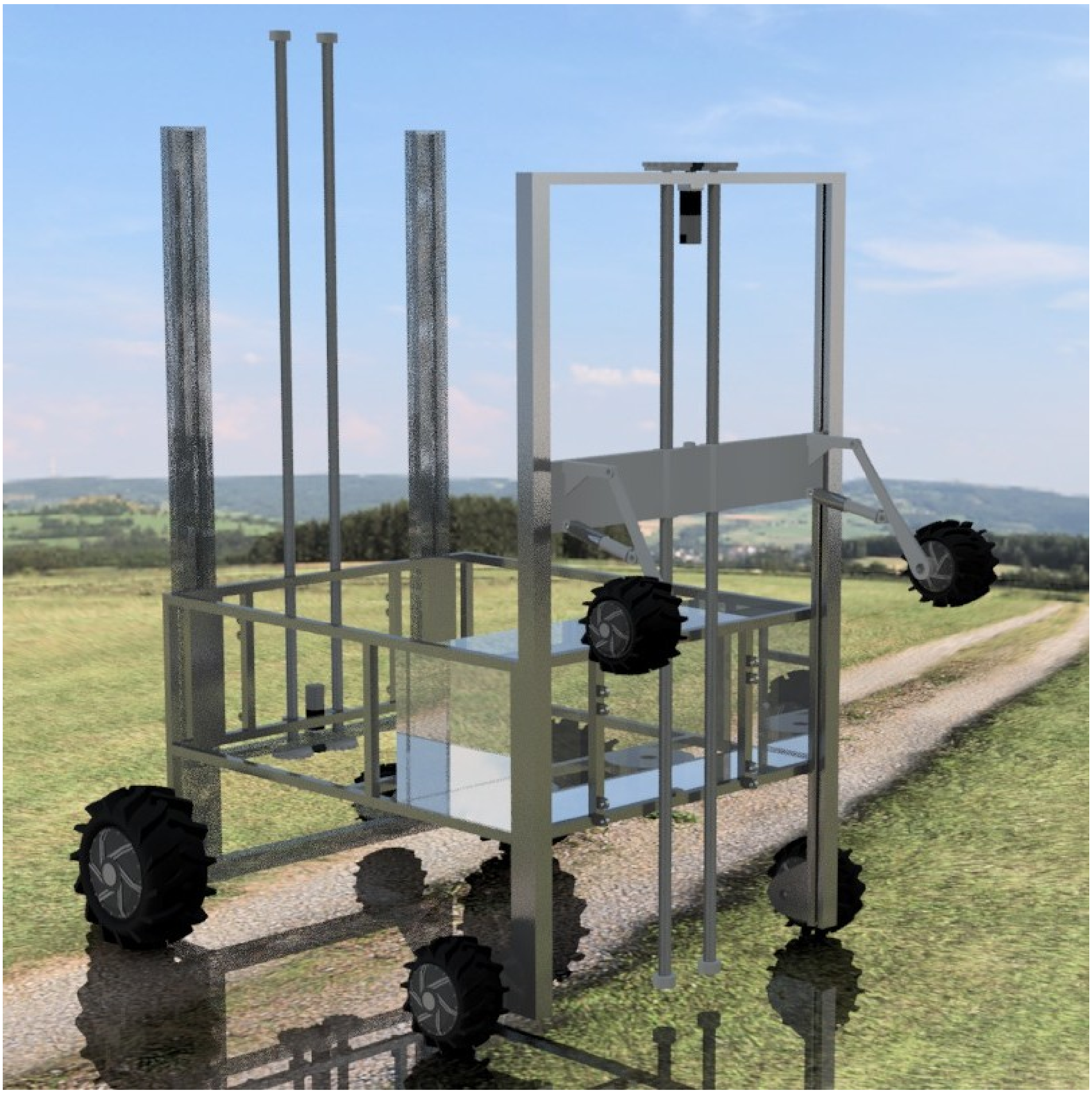

FarmBot

Agrobot Design Innovation Challenge
Design Report

Inter IIT Tech Meet 9.0

March 2021

1 Problem Statement and Approach

1.1 Problem Statement

To design an agricultural robot which can provide a solution to the following challenges:

1. Mechanized farming in hilly terrain
2. Seed metering mechanism for uneven or irregular seeds (crops like ginger and turmeric).
3. Automation of transplantation method of farming.
4. Automated weed removal in farms.

1.2 Approach

Our robot is designed to perform the following tasks to address the challenges above:

1. Ploughing
2. Seed (sowing)
3. Weed removal (chemical and mechanical)
4. Transplantation
5. Navigation through hilly terrain
6. Climbing up and down terrace-farming steps

We achieve these tasks by adopting a modular approach. Our robot features 3 detachable modules- the **seed-metering module, the transplantation module, and the weed-removal module.** Each of these modules can be attached to the bot and be replaced according to the function required to carry out a specific agricultural process. In addition to these, our robot also features a detachable mechanism which enables it to climb up and down distances up to 2.5 meters and traverse inclines up to 40 degrees.

2 Mechanical Design overview

The design consists of an integrated assembly consisting of main chassis to climb terrace and attachments for agricultural processes.
One module takes care of the work of the **seed-metering module**. We have used a **vacuum-needle seeder** through which we pick the seeds and put them into a funnel which is further dropped into the soil.
Another module takes care of **transplantation** of saplings to increase its productivity. In this module we have used a transplantation mechanism used to transplant saplings in the field.
And the last module deals with weed removal mechanism. We have used two **delta robotic arms(based on 3D printer mechanism)** which will extirpate weeds or spray weedicide over it through a nozzle attached to the claw of the arm.

3 Hardware Specifications and Cost Analysis

Module Name	Materials Used	Major Dimensions*(in cm)*	Total cost (*in Rs.*)
Main bot	Al , S.S.	(270, 155, 360)	2,55,000
Weeding module	Al	(70, 70, 72)	18,200
Ploughing and Seeding module	Al , Plastic , S.S.	(128, 180, 77)	51,000
Transplantation module	Al , rubber	(128, 180, 77)	9,500
		Total	**3,33,700**

A more detailed cost analysis and hardware specifications can be found here.

4 Modules

4.1 Step climbing Mechanism

We have employed 6 motors for enabling movement of the bot. 4 of the 6 motors are used to drive the main chassis, and 2 motors are used for vertical movement of the robot. These 2 motors are used to actuate the lead screws. The motion of each lead screw is achieved by a DC geared attached to it via a gear train mechanism, which is in turn, connected to a platform with two guiding wheels. Further, the assembly of the linear screw, platform and guiding wheels is connected to the chassis via a hinge mechanism; which allows it to vary the angle of the lead screw with respect to the chassis. This hinging mechanism also allows the bot to remain level when it is climbing an incline.
The lead screw is attached to the body through a linear bearing so that when it is actuated, the robot can move up or down with it. The motor used to actuate the lead screw is connected in a fashion designed to contain its movement within geometrically permissible limits.

Figure 1: Main Chassis

4.2 Seed-metering mechanism

This module has been designed for the purpose of sowing almost all kinds of seeds. Needle seeders use a vacuum and thin needle to pick up seeds from a vibrating tray, and pass them inside the hopper which travels through a pipe into mud. The vibration keeps the seed spread evenly in the tray and picks up one seed each. The needles are lifted up to a row of hoppers and released into tubes and further into mud, and then the process is repeated.
Needle seeders have a variety of adjustments, including needle size, vibration speed, suction pressure, ejection pressure. This increases the speed of operation, because in a vacuum seed feeder we can place 7 seeds in 7 different hoppers.

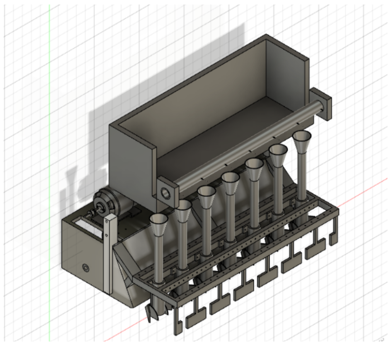

Figure 2: Plough+Seeder

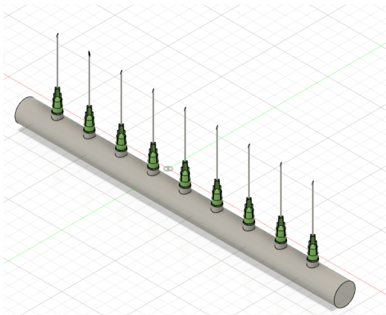

Figure 3: Vaccum Needle

4.3 Transplantation:

The transplanter is a specialised machine used to transplant seedlings in the field. The transplanter comprises of a seedling honeycomb configuration, a 3D printer-like seeding mechanism for the tray. transplanter helps in traversing the sapling row and uses the forks to pull seedlings from the tray and push these to the ground. The transplanter fits around 264 plant saplings and can be planted at 2”, 4” or 6” spacing. Each cell is 1.25” deep.

Loading and transplanting mechanism: We are using paper pot trays for growing saplings. One seed is added to each of these paper pots by our seed loader system. The seed loader mechanism uses vacuum to pick seeds one by one. Seeds are then germinated into saplings in the tray itself. When transplanting these trays are placed on our transplantation module. Farmer has to take an end of this paper pot chain and bury it in the ground. Now as our bot moves forward plough attached to the transplantation module creates trenches in the ground to and saplings are then unloaded in the ground. The rear part of our module fills these holes back.

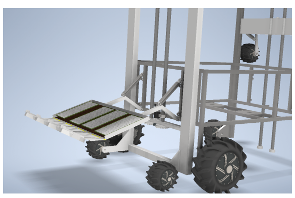

Figure 4: Bot with Transplanter

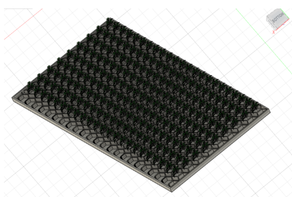

Figure 5: Saplings tray

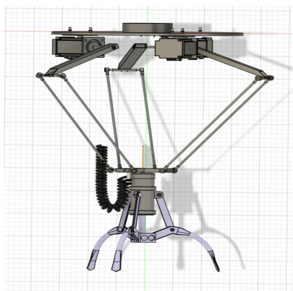

Figure 6: Delta Robot

4.4 Weed-Removal Mechanism:

The weed removal mechanism in our robot features a camera, and two delta-robotic arms. All of these components are placed on the underside of the chassis. While sowing the seeds, we ensure that the crop is planted uniformly in rows. This gives us good access to the majority of weeds which prop up between the rows. The camera is used to continuously obtain images of the ground under the robot. These images are processed using an algorithm to detect the weed plants falling within the field of view of the camera. The delta arm nearest to the weed is commanded to move towards the plant. The end-effector of the delta arm features a gripper-claw and a sprayer. After navigating to the plant, depending on the distance from useful plants, the robot either uses the gripper-claw to entirely uproot the weed, or spray a small, precise dose of herbicide to exterminate it.

4.4.1 Mechanism of the Delta Robot:

A standard delta-robot, commonly seen in 3D printers has been used.

4.5 Algorithm Used for Weed Detection:

To differentiate between weeds and the crop, we detect the crop plants, by using two features.

1. The plants belonging to the crop look similar, so we can visually identify them
2. They are grown manually so their location is not random: there is a pattern. Using the location of nearby plants, we can predict if there should be a plant at a given location.

Using the combination of these 2 systems we can be certain in identifying of a certain plant is weed or crop. The algorithm can be described as:

(a) Using a Visible Range Camera, we identify a plant.
(b) Using a Convolutional Neural Networks, we try to identify whether the plant is crop or weed, it generates a value between 0 and 1 about the probability of the plant being a weed
(c) We threshold these values to identify whether the plant is a crop or a plant
(d) We find the cartesian coordinates of plants in the vicinity of the plant in question and feed that data to another computational module which returns another number indicating the probability of the plant being a weed or a crop.
(e) We threshold the product of these values to finally determine whether the plant is a crop or a weed

5 Electrical Design Overview

5.1 Battery Management System (BMS)

With any high voltage rechargeable battery packs, one of the most important concerns is safety and optimization. We have a required maximum voltage of 72V and a maximum current of 250 Ampere. So, BMS is very sensitive in our case.
The parameters, which we have to control through this system are:

- Cell Voltage
- Current
- Temperature

Performance Optimization: Every battery works best at its minimum and maximum rated charge limits. Therefore, we calculate the State of Charge (SoC) of the battery using the Coulomb Counting Method, and use individual cell balancing to maintain all cells in a pack at their max capacity with equal voltage.
State of Health (SoH): BMS uses the collected data points with temperature, voltage, current to estimate the State of Health(SoH) of the battery. These real-time parameter values are compared with initial values using an anomaly detection algorithm to find the percentage value of SoH. Therefore, voltage sensing, current sensing, temperature sensing modules are used for this.

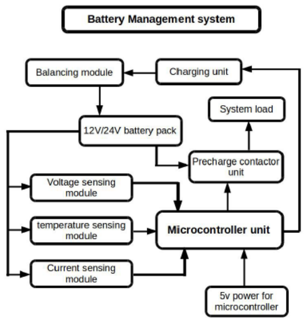

Figure 7: Block Diagram

5.2 Controls:

The control of the robot is quite simple via remote control. There are three joysticks, one to control the movement of the main chassis wheel motors, one for climbing up and down the steps, and the third one for lead screw wheels. This provides total movement of the bot. To fulfill other different operations, there is a range of potentiometer dials that can be adjusted by the farmer. Features like Extended arm actuator, control of seed rate, Transplanter lift mechanism, and Delta claw's grabbing mechanism can be controlled by these dials. There are start-stop buttons for autonomous movement of delta for plucking and herbicide spray on weeds, and for Plougher and Seeder. This provides a farmer with simple control over all the operations of the robot, labeled explicitly.

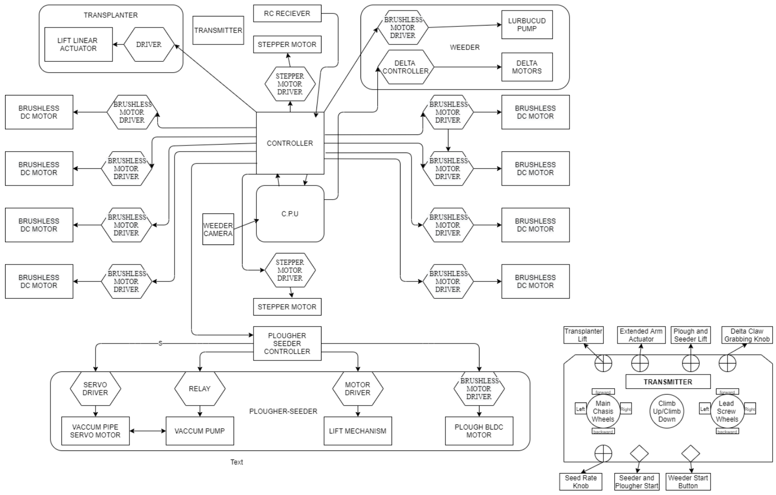

Figure 8: Circuit Diagram

6 Simulation:

We simulated different sub-parts and the final assembly to test them in a virtual environment, focusing on the specifications of the electrical and mechanical parts.
1. Even at the slope of 40 degrees, motors require a power of 800W. Considering, the safety and efficiency of the robot, we have chosen a motor of 3000 + 4000W
2. From the simulation of the climbing mechanism, we calculated the torque of the motor used in the lead screw.
3. For the wheel design,we performed stress simulation using **Ansys** to test the wheel's rib design for plastic deformation.
4. We did analysis by applying the axial+bearing force iteratively on the diameter of the lead screw to check the diameter for which it will not buckle up.

6.1 Dynamic Analysis

Tyre Design: Performed traction and torque analysis on Ansys to decide upon the type of tire tread that provides excellent stability in the hilly terrain.
R1 tyre is also chosen for its Radial construction that reduces soil compaction, self cleaning ability, and angular lug design for optimum performance in varying field conditions.

COM Positioning: a. Placed battery at the bottom of frame so that the center of mass of the bot remains closer to the ground, which provides stability.
b. The rear wheels of the bot are bigger than the front wheels because the heavy rear wheels provide a proper weight distribution as the battery is located near to front wheels.
The two smaller wheels at the front have a much better steering radius which means it's easier to turn sharp corners. It enables the bot to cover the maximum area of the field while carrying out different jobs.
The videos of simulation can be found here.

7 Innovations and Uniqueness

7.1 Modularity

Our robot features multiple modules which can be detached or attached easily and quickly, This enables the robot to perform a versatile palette of tasks. This also makes the robot easy to maintain; and enables easy replacement of parts in the event of a malfunction.

7.2 Climbing Mechanism

7.2.1 Stability

Steps in step-farming procedures are generally very high: upto 2.5 meters. Hence, stability is a major point of concern while designing a robot which is expected to climb up and down steps like these. Our robot achieves stability during its climbing motion by employing a design which ensures that at any given time, at least 4 wheels remain on the ground;

minimizing the chances of toppling. Further, the hinge-mechanism employed on the lead-screw assembly allows the robot to climb steps with non-sharp edges as well.

7.2.2 Climbing on inclines

Farming in hilly areas and on highly uneven and irregular surfaces provides another unique challenge: our robot should be able to navigate steep inclines without toppling or rolling backwards; all while remaining level if need be. This is achieved by our novel lead-screw mechanism; which ensures that the robot always remains level, and can also provide an extra set of wheels for increased stability.

7.3 Autonomous Weed Removal Mechanism:

The weed removal mechanism employed is fully autonomous. This saves the user from the discomfort of weeding their crop manually.

7.4 Accommodation of Various Crops for seeding mechanism

Seeds of different crops vary immensely from one another. Hence, it is often very tough to design a mechanism involving seeds which can accommodate a broad range of shapes and sizes. We have achieved this by using swappable needles for different seeds.

7.5 Industrial Size

Our robot is an industrial solution for multiple farming challenges. It is a powerful, large robot which can handle massive fields on its own, and is much quicker than an average human farmer.

7.6 Highly Reduced Usage of Herbicides

Our solution will reduce the amount of herbicide used in a field drastically: by 90 percent. The weed removal mechanism features the use of a precision delta robotic arm sprays a precise amount of herbicide just over the weed, instead of spraying the entire field. This will lower costs associated with herbicide use for farming and help preserve the quality of the soil of the field.

8 Compatibility and Ease of Operation in Small Agricultural Lands

We believe that our robot is a good solution to the needs of the owner of a small agricultural land, because it is a one-time investment which will keep on paying back for many many years.

- Reduced Manual Labour
- Time-efficient
- Easy and simple operation
- Almost fully autonomous
- Modules can be attached to existing tractors easily

For these reasons, we believe our solution is easily operable, and highly compatible with small agricultural lands.

9 Value Added for Small and Marginalized Farmers

Farmers owning less than 5 acres and 2.5 acres are called small and marginalized farmers respectively. We believe that there are multiple methods by which our robot can be made accessible to these groups. Some of these are:

- Incorporating an EMI model: EMI models are popular methods of making large investments feasible pool in towards a common investment to acquire the product.
- Subsidies: State and National Level governments can incentivize sales of this product by providing support in forms of subsidies.

10 References

1. Delta Robot
2. Transplanter