INTER IIT TECH MEET '21

AgroBot Design Innovation Challenge

Introduction to Solutions

Literature review and survey

The North-Eastern regions of India have several comparative features like fertile land, abundant water resources, high and dependable rainfall (annual rainfall about 2000 mm), and an agriculture-friendly climate. Yet, it has failed to convert its strengths optimally into growth opportunities in agricultural productivity (Barah, 2006).

We conducted an online survey and telephonic interview to understand the hill conditions, resources available, and people's socio-cultural setting. The analysis of responses from 28 respondents about farm activities that require mechanization is as follows:

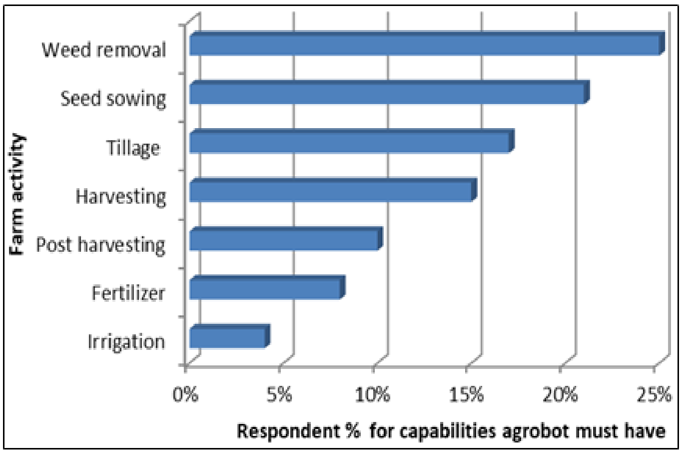

Fig.1: *Survey on AgroBot capabilities*

We realized that a major portion of the land in this region has a slope of more than 15°, undulating topography, inaccessible terrain, fragility in moisture stress, and also poor soil conditions. Moreover, socio-economic constraints exist, such as small holdings, poor productivity, production management, labour shortages, poor marketing, and lack of entrepreneurship. The objective was to design a cost-effective, eco-friendly, easily operable AgroBot to convert non-viable subsistence farming into viable farming through harnessing appropriate niche potentials of marginal mountain land.

Mechanized farming in hilly terrain

Rationale for mechanism

Hilly farming terrains in the North-Eastern regions of India have slope gradients ranging from 2° to 27° (Prokop & Poreba, 2012). The accuracy of position calculated through odometry is affected by slippage between the ground and the wheel or track. When travelling on a loose slope, the localization accuracy of the odometry decreases remarkably due to slippage. To improve its accuracy in such environments, terra-mechanics focuses on estimating the interaction between a vehicle and the ground with visual odometry.

Manoeuvring and alignment on these slopes

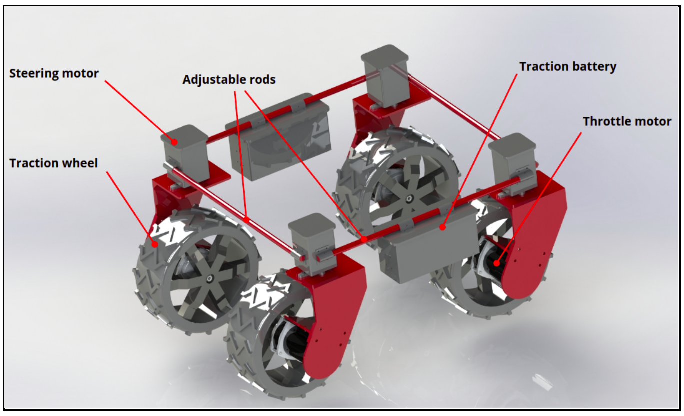

Fig.2: *Chassis & locomotion mechanism assembly*

Along with introducing a slip model to the kinematics (control), we also have mechanically modified wheels. A differential turning mechanism is not a preferred way for steering in these environments of low wheel traction. For manoeuvring and alignment on these slopes, the 4-wheel drive design of our robot coupled with each wheel's independent steering ability serves the purpose. With these capabilities, the vehicle wheels can be aligned in a staggered fashion (see Fig.2) to reduce slippage drastically. The low centre of gravity was aimed to get a stable design that includes mounting battery pods (high-density components) as low as possible.

A metering mechanism for irregular seeds

Rationale for mechanism

Delays in planting due to labour shortages and rain cause the rotting of rhizomes. Mechanized planting can help overcome labour shortages, improve operational timeliness, and reduce cost, drudgery, and yield losses. The seed rhizome's shape is irregular and could not be correlated to any standard shape. However, the variability in shape is expressed as 'Shape Index' (I_s). The shape index of the seed rhizome is calculated by the following expression (ISO, 1983):

$$I_s = [L^2 / (W \cdot T)] \cdot 100$$

where L, W, and T (all in mm) are the length, width, and thickness of the seed respectively. Metering mechanisms with three interchangeable disks with cell sizes of diameter 80mm, 30mm, and 10 mm are provided to accommodate different seed sizes. To get the dimension of the seed metering mechanism, the mean length, width, thickness, weight, and shape of seed rhizome along with the standard deviation and coefficient of variation were measured for over 30 rhizome seeds with three replications.

Working of seed metering mechanism

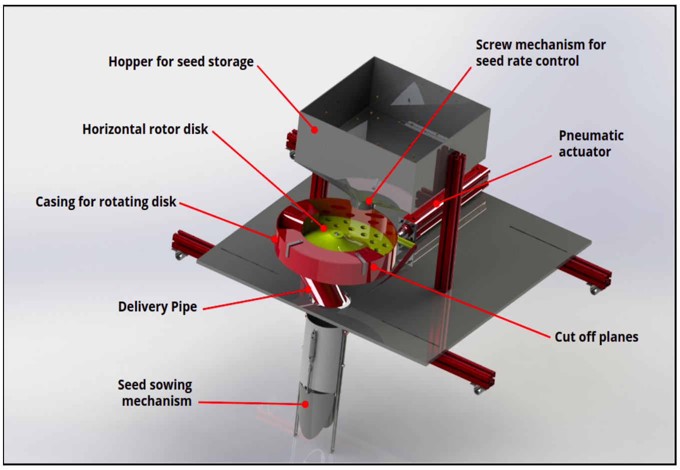

Fig.3: *Seed metering mechanism assembly*

Seeds are dumped in the hopper from the top. At the bottom of the hopper, a screw adjustment mechanism controls seed rate falling on the horizontal disk rotor. Cut-off plates over the disk ensure that a specified seed amount fills each cell. As each cell approaches the bottom chute in the casing, the seed rhizomes drop in the delivery tube. Calibration of the seed metering mechanism (rpm of the horizontal disc) is calculated based on bot forward speed, seedling spacing, no. of cells, and disc radius. The rotor disk rotation speed ensures seed dropping at the correct spacing between plant to plant. The delivery tube drops seeds in pits created by flap-type planters at required soil penetration. Two flappers at the back of the AgroBot cover the seed with soil and compact the soil around it to enhance germination and emergence. Horizontal disc cell type, the metering mechanism has high cell fill accuracy from past testing and is reliable.

Transplantation mechanism

Rationale for mechanism

Rhizomes seeds are stored in soil pits in a dry and shaded place between cropping seasons. In this method, around 25-30% of rhizomes rot in the pit itself, and about 10-15% of rhizomes sprout in the hole and are rendered useless for sowing. Transplantation can prevent these losses.

Working of Transplantation mechanism

The transplantation mechanism is inspired by flap-type planters. We have automated a flap-type planter using three pneumatic cylinders, a cylinder for pushing the flaps/blades into the ground, and another two cylinders to open and close the flaps.

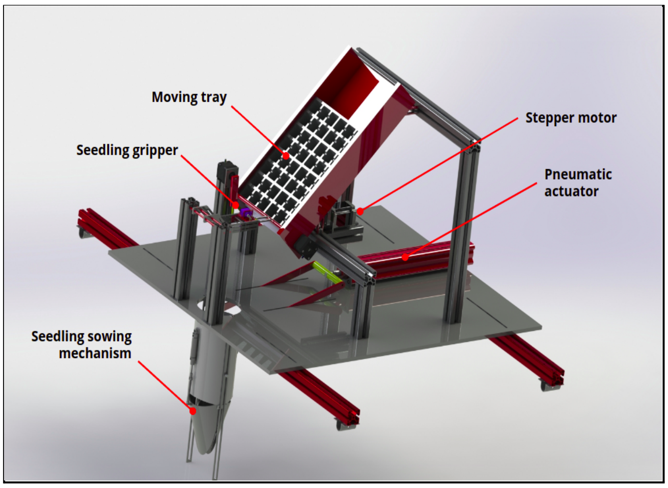

Fig.4: *Transplantation mechanism assembly*

The conveyor mechanism is implemented for the automatic supply of saplings to the planter. We have used a tray that will work like a conveyor belt and contain saplings for plantation. The tray will be mounted on a system with 2 DoFs, due to which the tray will be able to move in the azimuthal plane. A gripping / clipping mechanism is also added to drop saplings into the planter. Three motors are being used; 1 servo (for gripping mechanism) and 2 NEMA 23 motors for operating the conveyor tray.

Weed removal mechanism

Rationale for mechanism

There are two options available for weed removal: mechanical and chemical. We have opted for organic herbicides weed removal for the following reasons:

Mechanical weed removal requires the complete uprootal of weeds and their disposition away from the field. If this is not achieved, they will grow back in no time, making the process ineffective. The mechanical weed removal process can trigger soil erosion on steep slopes. Studies on steep slopes have indicated the soil loss of order 40.9 tonnes/ha.

Weeds grown within crop rows and closer to crop plants escape the mechanical remover and can also damage roots. Weeds grown within crop rows incur much higher losses. Furthermore, weed removal products with biological control agents (BCAs) act as sources of nutrition for the soil. They help provide agriculture with effective tools for abundant crop production while minimizing impacts on health and the environment.

Working with herbicide and powder application

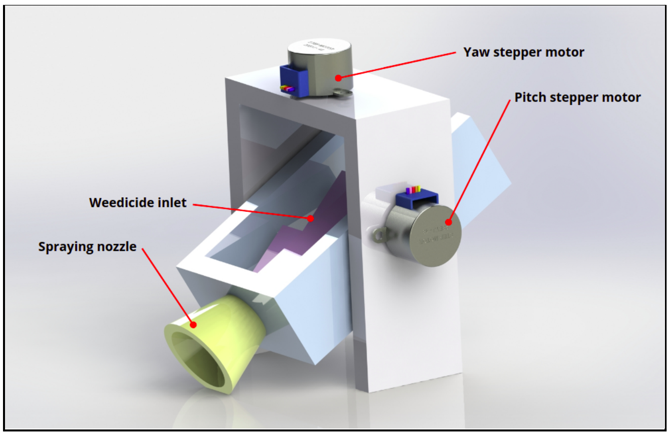

Fig.5: *Weed removal mechanism assembly*

Insect-pest control through ITK (Indigenous Technical Knowledge) involves the sprinkling of ash and powdered farmyard manure (FYM). The proposed mechanism can spray both liquid and powdered products. Both mechanisms are operated by spraying air at high pressure through a specially designed nozzle where the air mixes with liquid or powder and then exits via a nozzle. A 2-axis gimbal controls the direction of the nozzle. This allows us to control the region where the product is sprayed and increase the efficiency of spraying the organic product by reducing its wastage. The proposed mechanism can also be used for spraying fertilizers and other kinds of additives.

Model details

Mechanical assembly

The robot has a 4-wheel drive design which helps in generating greater torque for the movement. The wheels consist of rigid-rim, wire-mesh tires that are connected to their axles by spokes. Metal cleats are also mounted on the tire to ensure better traction in the loose soil. The seed metering mechanism, transplanting mechanism and weed removal mechanism have a rectangular platform. The platform is bolted to the base frame and the mechanism gets easily integrated. The base rod mounting points are changeable which gives the user freedom to vary the distances between wheels as per the crop/terrain requirement.

Electronics

IMU (Inertial Measurement Unit): This sensor can help with getting the acceleration and orientation of the AgroBot. The acceleration can be used to calculate velocity and distance travelled. Orientation can further be used to map the terrain and formulate better routes for later runs. The farmer may subsequently utilize this data to plan cropping patterns.
Smartphone Camera: It is used to identify weeds, monitor surroundings, help with navigation and provide visual feedback to the remote user.
Soil moisture & temperature sensor: It is used to measure the volumetric water content of the soil. This helps to plan the farming activities better with proper data collection for each event.
Sensor Positioning: The sensors are attached to the robot's frame with sturdy mounts, which helps avoid possible damages to the sensor. These mounts are modular, which enables the user to remove and incorporate a sensor into the robot.

Architecture

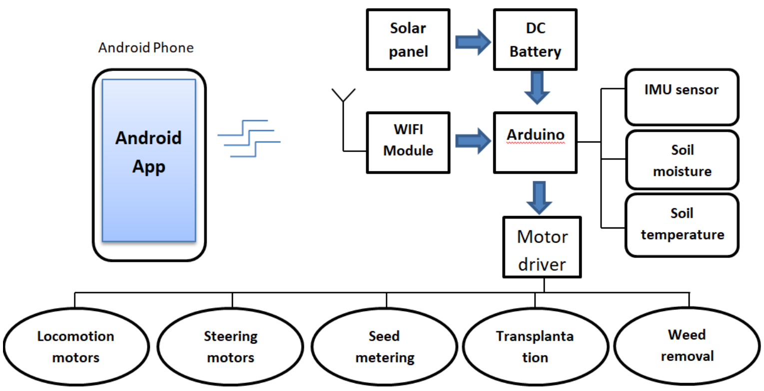

Fig.6: *Block diagram of Agrobot*

Hardware Components & Cost Analysis

Cost for mechanized farming in hilly terrain

Sr. no.	Main component	Sub-components	Cost/pc	Qty
1	Wire mesh tyres (with extrusions)	Rim	1200 Rs	4 pieces
2	Locomotion Motor (1000 Watts): Throttle*	Fitting and wiring	5000 Rs	4 pieces
3	Stepper Motor (NEMA34) 100 Watts, 42kg-cm: Steering (Link)*	Fitting and wiring	3000 Rs	4 pieces
4	Batteries (22000mAh; 22.2 V) - 1 hr endurance	LiPo type	11000 Rs	2 pieces
5	Solar Panel (200 W, 24 V) - optional	Controller	5000 Rs	1 piece

Cost for seed metering mechanism for uneven or irregular seed

Sr. no.	Main component	Sub-components	Cost/pc	Qty
1	Hopper	Support structure + exit pipe + screw mechanism	400 Rs	1 piece
2	Horizontal Rotor Disc	Disc with cells	300 Rs	3 pieces
3	Seed Cutoff Plates	Splitter (with 4 rubber slats)	400 Rs	1 piece
4	Casing	Cup with the delivery pipe	300 Rs	1 piece
5	Stepper Motor (NEMA23)*	Fitting and wiring	1200Rs	1 piece

Cost for transplantation mechanism

Sr. no.	Main component	Sub-components	Cost	Qty
1	300mm stroke pneumatic cylinder	Joining rods and mounts	1700 Rs	1 piece
2	50mm stroke pneumatic cylinder	mounts	250 Rs	2 piece
3	Planter mechanism	Blades and pipe	250 Rs	1 unit
4	Solenoid valves	connecting pipes and valves	500 Rs	3 piece
5	Air tank	Air tank, pressure valve	150 Rs	1 piece
6	Servo motor	Motor for gripping mechanism, gripper*	300 Rs	1 piece
7	Stepper motor	Motor for conveyor mechanism*	590 Rs	2 piece
8	Tray	Tray stand + seedling trays	250 Rs	1 unit

Cost for weed removal mechanism

Sr. no.	Main component	Sub-components	Cost/pc	Qty
1	Gimbal	Gimbal Structural parts	100 Rs	2 pieces
		Gimbal stepper motors*	850 Rs	2 pieces
		Customized Nozzle	100 Rs	3 pieces
2	Junction-cum-Atomizer	Main structure	100 Rs	1 piece
		Valve for liquid weedicide	200 Rs	1 piece
		Gate for solid weedicide	10 Rs	1 piece
		Solid weedicide gate servo motor*	200 Rs	1 piece
3	Agitator	DC motor*	100 Rs	1 piece
		Support	50 Rs	1 piece
		Semi-circular mass	50 Rs	1 piece
4	Tank	With flexible pipe	400 Rs	3 pieces

*-> CADs available on open-source platform

Total Agrobot cost ≈ Mechanical hardware cost (Rs. 11110) + Electronic hardware cost (Rs. 48700) = Rs. 59810

Maintenance

Transplantation mechanism

The planter mechanism has a low cost and is easy to repair. Connecting rods can be easily replaced with any metal rod (even cycle spokes temporarily). The only major components that need regular oiling and cleaning are the pneumatic cylinders and their solenoid valves. The solenoid valves may be covered with insulation to function in the rain (there are no other electrical parts).

Seed metering mechanism

The seed metering device is easily detachable. It must be cleaned and oiled regularly to ensure its durability. The gap between the disk rotor and casing must be checked for any particle stuck.

Mechanised farming in hilly terrain

The wheels and base are robust and only the motors need regular oiling. The ground clearance is ~ 20 cm which reduces chances of damage to the components.

Weed removal mechanism

The mechanism has very few moving parts and hence is durable. The gimbal that controls the nozzle requires maintenance but it is easily replaceable. The agitator attached to the powder carrying pipe is also replaceable by plugging although it is a moving part.

Extra features

Renewable source of power: Hilly regions have high solar irradiation and a 200W solar panel mounted on the roof of the robot is enough to charge two batteries.

Gyroscope ground level alert: Using the gyroscope of a smartphone integrated with a bot, the bot alerts farmers where water stagnation can occur.

Smartphone integration: Once a farmer connects his smartphone, the bot becomes aware of farm layout, crop type and farm activities to be carried from data in the smartphone. The ambient light sensor, gravity sensor, gyroscope, compass, camera, flash from a smartphone are available for bot to use.

3D printable parts: Several parts of the mechanism plastic made to prevent damage to seeds and saplings and can be modified as per required customisation.

Disease assessment on crops and light traps : The light trap mounted on the bot traps insects as it moves through the farm at night. The continuous surveillance using a smartphone camera and a computer vision algorithm keep track of yellowing and rolling of leaves and alert farmers with photos and crop location.

Manual steering option: A handlebar at the back of bot gives full steering control with motor locomotion.

Humidity and temperature sensors on bot: Regional databases of environmental conditions throughout a geographical location can be sampled by a group of bots.

Scalability and realisation

Co-operative ownership model and custom hiring to make it scalable for small landowners

The AgriBots will be hired from custom hiring centres and farmers integrate their smartphone with the bot. Employment is generated as bots in custom hiring centers will require maintenance and technological interventions. The significant trend witnessed by the northeastern states in recent times is the change in demographic patterns i.e increased male out migration. This has led to increasing farming-related workload for women. The mahila mandals, self-help groups (SHGs) in several hilly states have the potential for women in the development of these centres in hilly areas.

Value addition for small and marginalised farmers

In hilly areas, low use of agrochemicals indicates considerable potential for 'organic' agriculture and the AgroBot assists in the same to increase crop intensity. As drudgery reduces, farmers can devote time to microenterprise development like "farming for tourism". With the use of AgroBots as farmers get accustomed to use of technology they can access market information and move to lucrative high-value crops from local farm produce.

References

- Barah, B. C. (2006). *Agricultural Development in North-East India Challenges and Opportunities*.
- International Organisation for Standardization (ISO). (1983). Agricultural Machinery Handbook, No. 13, *ISO code No. 5691 (1981)*, pp. 387-389.
- Prokop, P., & Poręba, G. J. (2012). Soil erosion associated with an upland farming system under population pressure in Northeast India. *Land Degradation & Development, 23*(4), 310-321.