DIC's Terrace Farming Robot for Hilly Areas

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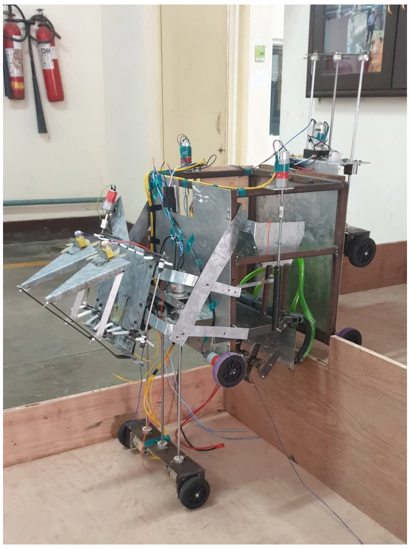
INDIAN INSTITUTE OF TECHNOLOGY, KANPUR



Technical Report

December 2019

1 Problem Statement

The problem statement tells us to build an autonomous robot which will be able to work on terrace farms present in hilly areas. This necessitates the bot to have some features specific to the terrace farms. A terrace farming robot should be able to *climb steps*, *follow the wall* of the steps and *detect the end of a step.* Alongwith the previous features, the bot also has to perform basic functions required in farming such as - *ploughing*, *seeding*, *harvesting*, and *irrigation.*

2 Approach

PARAS performs the following sub-tasks:

- Ploughing
- Seeding
- Stair-Climbing
- Watering
- Harvesting

We have taken a modular approach to solve this problem which increases the dexterity of the robot and also keeps it lightweight. The various agricultural tasks are divided into different units. Each of these units can be attached to the bot and be replaced by another module as and when needed, or can be attached simultaneously when the intended work is done. By making the modules detachable and replaceable, we aim to reduce the bot's weight as only the particular modules in use is attached to the bot at a time.

3 Mechanical Design Overview

The design consists of an integrated assembly consisting of a main chassis to climb terrace and attachments for agricultural processes.
One module takes care of the work of ploughing and seeding. These two processes are combined into a single module as the seeds can be dropped directly into the furrows made by the plough, and hence, both the procedures are executed together.
Another module takes care of the harvesting part. This attachment takes care of cutting the stalk and stacking the crops separately at the side. The third module deals specifically with watering.

Attachment of Modules to the main chassis: For doing any particular task, the appropriate module is attached to the main chassis, using the *connector* present in the main body. The *connector* lead screw can adjust the positioning of the attachment as per requirement. Using the angular lead screw (along with a stepper motor) reduces the chances of the attachment getting dislocated due to jerks from the ground.
Keeping in mind various constraints a terrace farming bot would face, different climbing mechanisms were analysed, and the one best suited was chosen. In our design, the essential task of climbing is done using electric linear actuators that lift the whole bot to a higher or a lower level, thereby allowing the bot to climb.

3.1 Stair Climbing Module

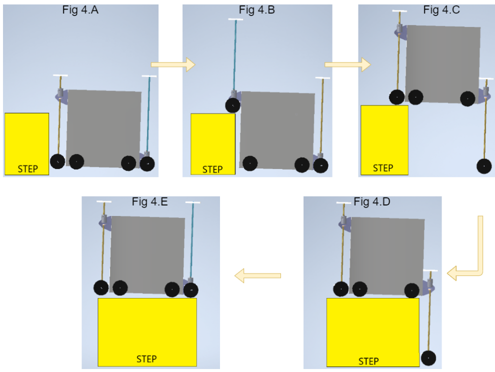
There are 6 DC geared motors in the bot, out of which four are for the wheels mounted on the main chassis for the motion of the body. The motion of each linear screw is achieved by a DC geared motor attached to it through a gear train mechanism, which, in turn, is connected to a platform with 2 guiding wheels.
The linear screw is attached to the body through a linear bearing so that when the linear screw is actuated, the bot can lift up or down with it. The motor used for lead screw movement is connected to the DC input voltage in a specific fashion to limit the linear movement of the lead screw after a particular point.

3.1.1 Mechanical movements while climbing up

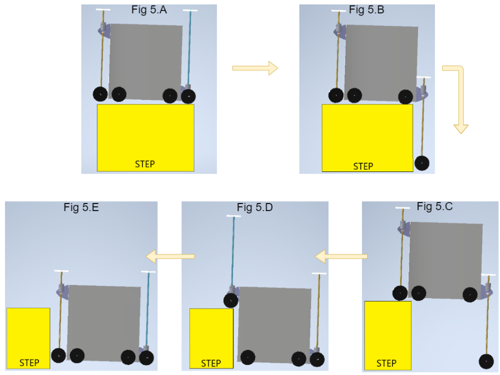
1. The bot primarily needs to be aligned parallel to the step edge.
2. The front lead screw then moves upward by step height after which the bot moves a small distance.

3. To then move the main chassis up by the same amount, a reverse motion of both the front and back lead screws is programmed to ensure upward relative movement of the main body with respect to the lead screws. This will hold the main part of the bot in mid-air.
4. The bot can now move a fair amount of distance which will land the main chassis onto the upper step.
5. Finally, the back lead screw is moved upward with respect to the main chassis to level the actuators.

The robot climbs down similarly in the reverse order.



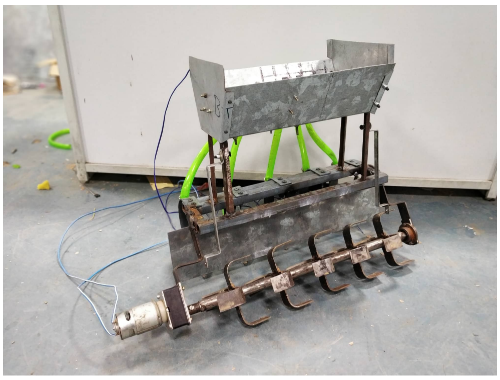
(a) Bot climbing up the step



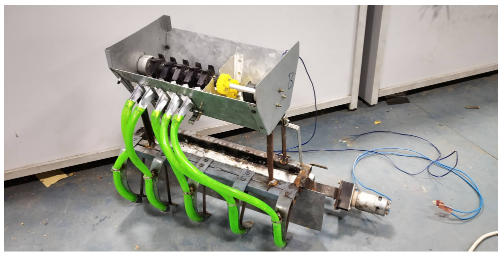
(b) Bot climbing down the step

Figure 1: Mechanical Movements - Stair Climbing Module

3.2 Ploughing and Seeding Module



(a) Front View



(b) Back View

Figure 2: Ploughing and Seeding Module

3.2.1 Ploughing

PARAS uses a rotary tiller or rotavator (derived from rotary cultivator). Rotary tiller, or rotavator, is a tillage machine designed for preparing the land by breaking the soil with the help of rotating blades suitable for sowing seeds (without overturning of the soil). It prepares the topsoil rather than turning the entire soil to prevent erosion and nutrient loss in terraces. The rotavator is engineered using two sets of blades or tines that are attached to a motorized horizontal shaft. The tiller spins the tines, digging them down into the topsoil to a predetermined depth. The rotor usually rotates in the same direction as the chassis wheels.
The blades are bent at an angle of 90 degrees so that it comes to contact with the soil at an optimal angle of 45 degrees. The bent part of the blade carries and turns the soil.
Rotavator motor :- 1 DC geared motor, 100RPM, 37KgCm stall torque, 24V

3.2.2 Seeding

This module has been designed for the purpose of seeding. The seeds are transported from the hopper via tubes. One tube is associated with a single seeding claw. The seeding claw ensures that the seed is sown at the required depth. The height of the ploughing module can be adjusted by the linear actuators by which it is connected to the main chassis. This allows for ploughing and seeding at variable depths. The seed flow from the hopper is regulated through specially designed wheels attached to a rotating shaft, inside the hopper. It has extrusions on its outer circumference, which pick up the seeds at regular intervals and drop them down into the seed tube. This creates a time(t) gap between dropping of 2 seeds through the tube, while the robot moves ahead ($v * t = d$), creating a desirable gap(d) between the two seeds in a straight line. By controlling the speed of the robot and angular velocity of the shaft, we can have the desired distance required between the two seeds. The seeding claws are placed horizontally at sufficient gaps to ensure that the gap between two seeds is optimum for them to sprout and grow.
Seed hopper :- 1 DC geared motor , 300RPM, 2KgCm stall torque, 12V

3.3 Irrigation Module

The irrigation system consists of a pump, and five nozzles. Water gets pumped from the reservoir provided. The five nozzles provided ensure that the watering is done directly on seeds or at the roots of the plants. This helps in water conservation.
Water Pump :- 1 Mini Pump KPM36A, 12V

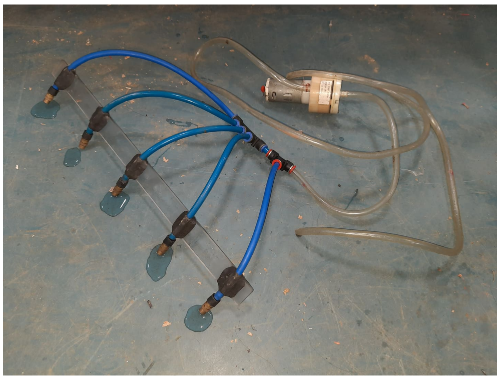


Figure 3: Irrigation Module

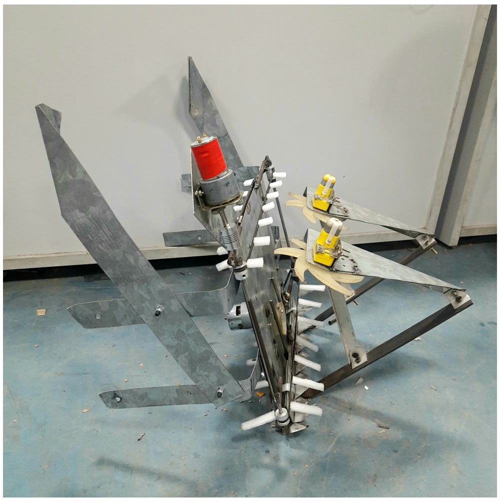


Figure 4: Harvesting Module

3.4 Harvesting Module

This attachment takes care of cutting the stalk and stacking the crops separately at the side. This specialized harvesting equipment utilizes conveyor belts to mimic gentle gripping and automated transport replaces the manual task of removing each seedling by hand. The star-shaped structures stack the crop in bundles. The star-shaped parts are driven by controlled DC motors for proper gripping of plants. The cutting mechanism of the harvester is present at the bottom, which cuts the crop after it is properly gripped. The mechanism has two blades overlapping each other such that the bottom plate is stationary while the top plate moves parallel to it (similar to the mechanism used in hair trimmers) to cut plants with the help of shear forces. The crop is then collected in a belt that has specially designed spikes on it. The belt is driven by a geared DC motor. The belt carries the harvested crops and places it on one side of the robot on the terrace neatly. This ensures very less damage to the crops.
Star blades :- 2 DC geared motor, 100 RPM, 12V
Conveyor belt :- 1 DC geared motor,300 RPM, 20KgCm stall torque, 12v
Cutting blade :- 1 DC geared motor RS775,1000 RPM, 12V

4 Electrical Design Overview

4.1 Control System

PARAS uses HC-SR04-Ultrasonic sensors and MPU 9250 for localisation.

4.1.1 Positioning of sensors:

1. 4 Ultrasonic sensors: 2 each on the opposite faces of the robot parallel to the step wall as the robot traverses the step.
2. 2 ultrasonic sensors: 1 each on the lead screw bases used in the climb up and climb down mechanisms. These will be facing downwards.
3. 1 ultrasonic sensor: on lead screw face used to measure the distance from the wall while climbing up.
4. 1 IMU and 1 Magnetometer placed horizontally on the base of the robot. IMU is placed on the base of the robot.

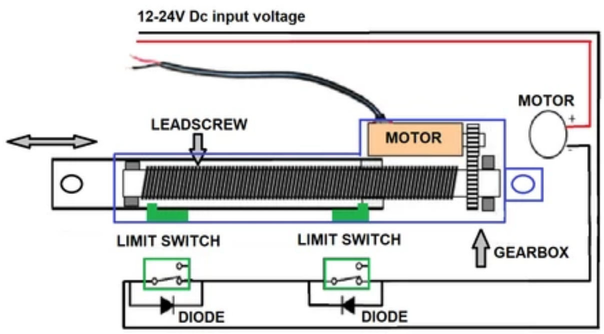


Figure 5: Lead Screw Circuit Design

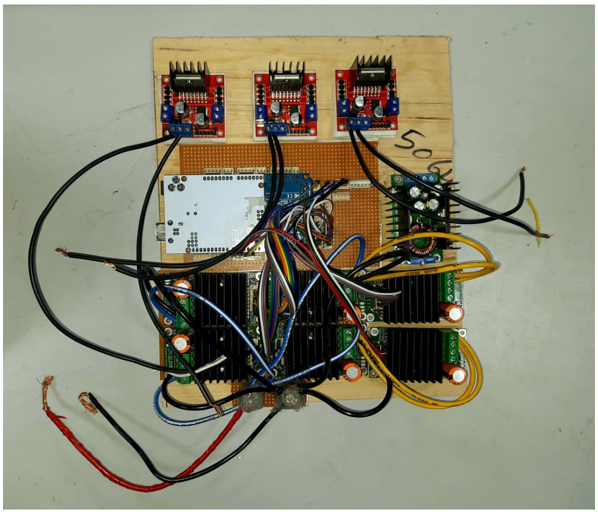


Figure 6: Motor Driver Circuit

4.1.2 Circuit Design

Working of Linear Actuator Circuit: There are two modes of operation in the climbing module: one being "step up", and the other being "step down". As per the circuit diagram due to presence of diodes, when the left limit switch is open and the right one is closed, the current can only flow in an anti-clockwise sense while in the complementary case, the current can only flow in a clockwise sense ensuring upward or downward movement of lead screws with respect to main body.

Working of Seed Rate Controller: Shaft of seed flow rate mechanism is powered by a controlled DC geared motor with a motor driver. The user can vary the seed flow rate using a physical knob present on the bot while the ploughing is easily executable with a regular DC motor.

4.1.3 Mapping & Localization

To move around the desired field autonomously, the bot has to map its environment according to a suitable algorithm so as to cover maximum part of the terrace field without human assistance and maximum efficiency. Once the bot enters into an unfamiliar space, it begins mapping its surroundings, this task does not need to be performed again on that space. This mapping needs to be carried out using multiple distance sensors attached at various directions, **PARAS** uses ultrasonic for the said purpose while the industrial model would be equipped with a 1D - LIDAR for better precision and wide range.

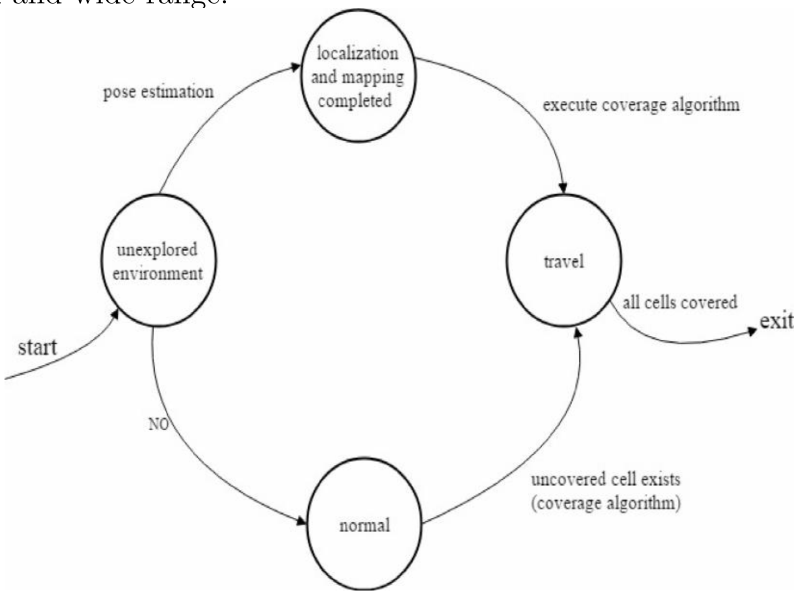


Figure 7: Flowchart - Mapping Algorithm

Now we need to administer an area coverage spanning algorithm on the acquired map to execute the farming related tasks. Wall-following needs to be carried out for major part of locomotion of the bot. With the map generated, firstly the bot has to plan a path to migrate around the field. Following flow-chart demonstrates a suitable algorithm to traverse the desired field.

4.1.4 Locomotion

We aim to perform the given tasks traversing at a particular parallel distance from the wall of the next step, so in a way, we have to follow the wall for guiding the locomotion of the bot.
The 2 ultrasonic sensors placed on the lead screw bases detect the 40cm depth of the lower step. While stepping down, once the input measured by the ultrasonic sensor facing downwards exceeds a certain limit i.e. goes 40 from 0 (when the lead-screw wheel loses contact from ground); the climb down mechanism will initiate.
IMU is used to measure the angle of the robot with respect to the step (yaw of the IMU). This angle is used to ensure that the robot is aligned with the step.
The ultrasonic sensor measures the distance $d1$ which is perpendicular to the wall (obstacle) and not the distance $d2$ perpendicular to the robot.
In our algorithm we would be working with the following parameters -

1. Value $d1$ - calculated using the ultrasonic sensor
2. Angle imposed at the wall (a) - calculated using IMU yaw calculation.

Using the above-mentioned parameters and their previous values (those from the previous iteration) of angles and distance, an algorithm can be created to give an optimised performance. The root idea being, if too close, initiate the climb up mechanism, if too far (step size), initiate the climb down mechanism.
PARAS uses two PID controllers; one for the distance, and one for the angle. This ensures that the bot follows a straight line instead of a sinusoid-like curve (in case of a single PID controller).
PARAS also uses a filter to reduce the sensor noise so that it does not affect the motion of the bot.

4.1.5 Dual PID Controller:

PARAS uses two PID controllers; one for the distance, and one for the angle. This ensures that the bot follows a straight line instead of a sinusoid-like curve (in case of a single PID controller).

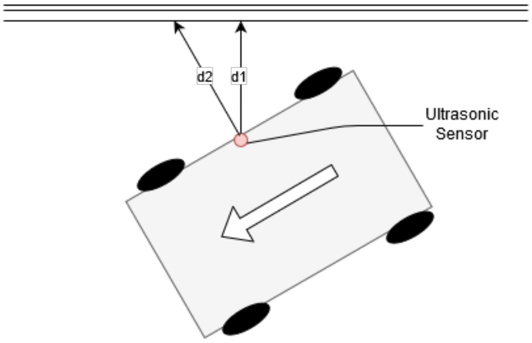
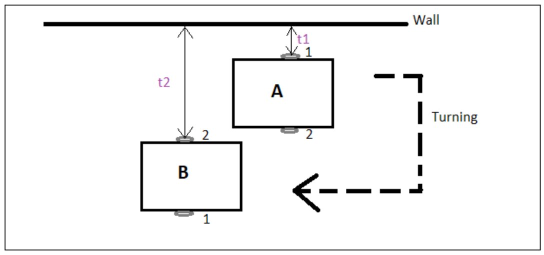


Figure 8: Distance Sensing



In position A, ultrasonic sensor 1 measures the perpendicular distance from wall(t1).
After turning, in position B, ultrasonic sensor 2 measures the perpendicular distance(t2).

Figure 9: Turning

We are also using a filter to reduce the sensor noise so that it does not affect the motion of the bot.

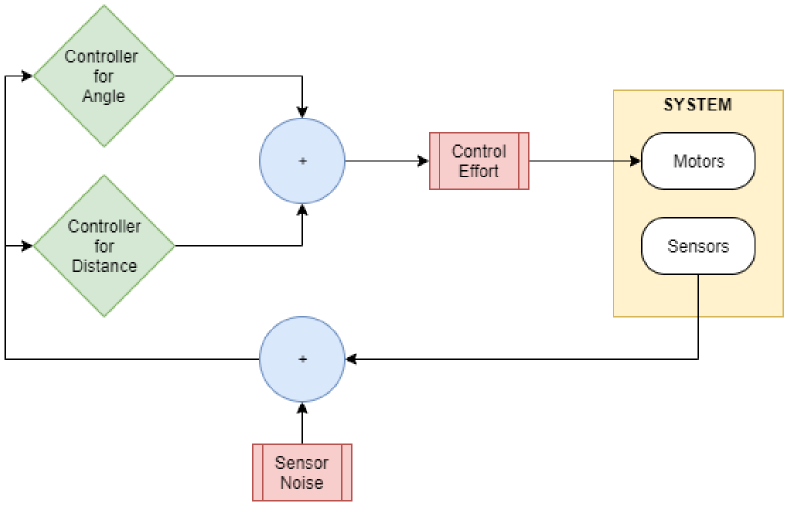


Figure 10: Dual PID Loop

4.2 Power Management System

A primary source of rechargeable 24V, 16000mAh Li-Po battery is used to power the bot. Three voltage levels are needed to function different components - 24V, 12V, 5V. A buck converter is used to obtain 12V from 24V while 5V is obtained from motor driver terminals. A Solar Panel System can also be incorporated to recharge the batteries while operating, these panels can be efficiently utilized as the bot spends a lot of time under clear and sunny skies. This reduces the need for recharging frequently. Mobile generators can also be used as an alternate source of power as it is not necessary that we may have proper supply to electricity in the terrains. The bot can be powered for a minimum of 2 hours while operating with battery.At maximum only 8 motors are utilized at an instant and average current of 0.75 Amps is sucked by a motor (using 1 Amps for calculation) juices the bot for 2 hours from 16000mAh battery. A spare battery [supplied to the farmer] can also be used to power the bot in case the original one depletes.

4.3 Testing and Experimentation:

We manufactured a test-bot to test our controller system for wall following, step detection, and basic locomotion. The test-bot had a miniaturised version of our actual electrical circuit to help us debug any faults in the circuit itself. We tested our sensor circuit in both lab environment as well as outdoor environment, to find out any possible loss in information due to interference from outside sources. Each of the individual farming modules was tested in actual farmland conditions for their specific functions The climbing module was also tested on an arena simulating a step in a terrace farm.

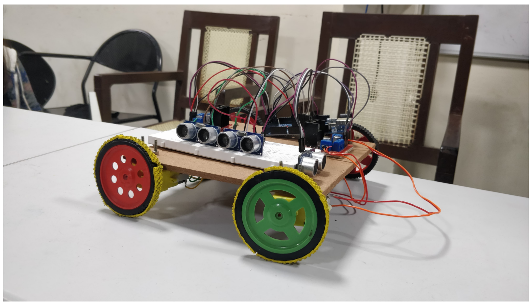


Figure 11: Test-bot for elecrical circuit testing

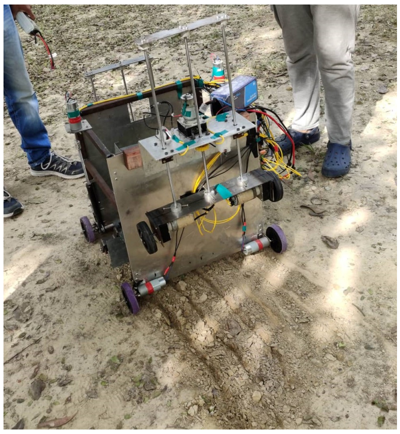


Figure 12: Field testing of plough

5 Innovations

5.1 Modularity

Modular Structure which can be easily attached and detached will allow farmers to use different processes according to need of the crop. The modular structure will make our robot robust allowing farmers to switch attachments easily.

5.2 Climbing Mechanism

- **Stability:** The steps in terrace farms are usually quite high. This will need the bot to have high stability during stepping up and down. So,Center of gravity of our bot is low hence decreasing chances of toppling. All the time, COG of the bot lies within the stable gait. This is done by keeping at least four or more wheels on the ground at all times.

- **Variable Step Height:** There is no uniformity in step height so, to tackle this problem, our bot has a distance sensor on the linear actuator which will detect the step height through the upper edge of the step, and extend accordingly.

5.3 Localisation and Motion Planning

Most of the terrace farms have uneven terrace pattern. To perform various agriculture tasks on the field, we have mapped each step using 8 ultrasonic sensors. For energy efficiency, we have generated minimum needed rectangular patterns which a bot can cover in a single run. The bot travels through each rectangle and this way it will cover the entire area of a step.

5.4 Universality

- **Attachment Lift Mechanism:** Different crops are trimmed at different heights to ensure productivity. Our harvester design includes lifting mechanism which will allow farmers to trim crop at different height. Similarly, ploughing depth depends on soil moisture and crop, so a linear actuator motion is converted to circular motion which will lift plough and will allow the bot to plough at different depth.

- **Seeding Mechanism:** Research data claims that for good yield, seeds should be inserted in ridges after every certain distance, specific to the seed. To achieve this, we have used a PWM controlled motor for scooping the seed and sending them to be sown. By controlling the angular velocity of the motor and the linear velocity of the robot, we can define the distance between two consecutive seeds.

5.5 Robust Modules

- **Irrigation:** In terrace areas farmers either rely on rainfall or sprinkle water all around the field inconsistently. The irrigation module will sprinkle water around ridges which will ensure targeted absorption of water.

- **Harvesting:** Our design allows us to grip the trimmed crop and sweep it sideways which can be collected in a hopper. This will reduce labour to pick crops, after harvesting.

6 Learning-Based User Interface

Our robot can work for different crops by changing subfactors - Plough Depth, seed rate, water level, harvesting height.

These inputs depend on the crop, climatic condition, moisture content in soil, humidity and temperature of surroundings. The robot can also decide the crop to be sown according to the climatic and soil conditions.

”Latest concept of agro-climatic zoning or agroecological zoning may be implemented to decide the suitable crops. The concept agroecological regions and subregions include : bioclimate as a function of rainfall, temperature , vegetation and potential evapotranspiration ; length of growing period as a function of rainfall, potential evapotranspiration and soil storage and soil scape as a function of soils and physiography.” So the robot contain temperature sensor, soil sensors, humidity sensor to predict soil and climatic conditions. Implementing learning models on sensors data which includes coupling with crop specific suitability criteria for soil and crop will further let us develop the whole concept of decision support on type of crops suitable or not in a given soil and climate.

The interface will allow farmers to choose which module to be used at what time, he can manually control each parameter or let the bot decides them on the basis of sensors data and crop chosen. The interface will also suggest farmer, most productive crop according to the sensors data and predictive model. The predictive model may be corrected each time by considering its own prediction.

7 Integration

The bot then moves with the attachment, while the module performs its specific task, and the chassis moves along the wall using a feedback system of ultrasonic sensors and IMU. The bot then detects the end of a step with the help of another ultrasonic sensor and turns accordingly. After completing the specified task for the present step, the bot climbs up/down to the next step to perform the same set of tasks.

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[5] Pape

CONTENTS

IMPACT OF OUR PRODUCT[1]

Current Scenario

- As of now, farming in rural India is done by the whole family and they are **not able to focus on their jobs** and move out as they are not able to hire labour in such low profits.
- With the rising population food demand is also rising in parallel, it is projected that by **2050 we would require 70% more food** than what is consumed today. To counter this we need an agricultural revolution, and **automation might just be the ticket**.
- Higher output and increased productivity are the two of the biggest reasons in justifying the use of automation.
- **Worker Safety** is also an important aspect which we cover by bringing automation.
- Despite the claims of high quality from good workmanship by humans, automated systems typically perform the manufacturing process with less variability than human workers, resulting in greater control and consistency of product quality.

Potential Improvements in Terrace Farming

- ➔ Higher production rates
- ➔ Increased productivity
- ➔ More efficient use of materials
- ➔ Better product quality
- ➔ Improved safety
- ➔ Shorter workweeks for labour
- ➔ Reduced factory lead times.

Agriculture and GDP

- It is estimated that India's agriculture sector accounts for only around **14 percent of the country's economy** but for **42 percent of total employment**.[6]
- As around 55 percent of India's arable land depends on precipitation, the amount of rainfall during the monsoon season is very important for economic activity.[6]
- India ranks first in the world with highest net cropped area followed by US and China.[7]
- **Terrace farming is done in many states and consists of a good section of total agriculture done in INDIA.**

Social Impact

Our product aims at reducing drudgery of labour- Terrace farming is labour intensive. The labour in terrace farming include many women, children as well as elderly people who are affected in a negative manner to a large extent by the methods currently used in terrace farming. Our model is designed such that it will reduce the toil of people involved in terrace farming. We will familiarize rural people with new and improved technology.

STAKEHOLDER ANALYSIS

Current Findings[1]

- **Terrace farming has been practised for centuries.**
- **Major source of livelihoods** - Large number of hillside farmers across the globe practise this method.

- **One of the most predominant forms of agriculture** - Asia and the Pacific (China, India, Nepal, Bhutan, Japan, and the Philippines), South America (Peru, Ecuador, Bolivia), Central America (Mexico, Honduras, Guatemala), Europe (Italy), Middle East (Yemen), and East Africa (Ethiopia, Tanzania, Rwanda)
- **One of the oldest and most successful techniques** - for conserving soil and water during cultivation on steep slopes.
- **No reliable quantitative data** -
  -China- terraced land is reported to be approximately 13.2 million ha
  -Peru - terraced land is reported to be approximately 2 million ha
- **Nepal and India** - Animate power is predominantly used.
- Only a subset of terrace farms have shifted from ancient to modern techniques.
- **Majority of terrace farms are managed traditionally** -
  -using simple tools
  -limited animal draft power
  -relatively abundant household labor
- Furthermore, majority of terrace farms are under rainfed conditions and lack irrigation. As a result, many terraces are not as productive as farms that have appropriate mechanization and irrigation.

Target Customers (for India)[2]

1. **Demographic Profile**[3] - The customers being targeted are mainly from rural areas of India, especially those in hilly areas. Approximately 500,000 villages and over 1.2 billion people, India has agriculture as the basic occupation. The villages of India are connected through a variety of essential linkages with other villages and with urban areas. Most villages are characterized by a multiplicity of economic, caste, similarity, occupation as well as religion. Factionalism is a typical feature of villages$_{11}$.

2. **Geographic Profile**[4] - Terrace farming in India is practised in the hilly areas of Kerala, Himalayan slopes of Uttaranchal, Himachal Pradesh and Arunachal Pradesh.

3. **Psychographic Profile**[5] - As hilly rural areas are characterized by poor road connectivity as well as poor internet connectivity, the people living in these areas immigrate to nearby cities in search of better jobs giving up terrace farming. Television and public gatherings remain as the major recreational activities in these areas.

State-wise Analysis
(for Himachal Pradesh)[8]

- Demographic Profile of Himachal Pradesh

	Himachal Pradesh	All India
Population (million) (census 2011)	6.8	1121
Decennial Growth Rate (%)	12.94	17.64
Population Density per Sq. Km	123	382
Sex Ratio (female per 1000 males)	972	943
Rural Population	89.96	68.84
Literacy Rate	82.8	73
Life Expectancy (2006-10)	70	66.1
Male	67.7	64.6
Female	72.4	67.7
Forest area as a % of total area	66.5	21

- Out of the total geographical area of 55.67 lakh hectare the area of operational holdings is about 9.55 lakh hectares and is operated by 9.61 lakh farmers.
- The **average holding size is about 1.00 hectare**.
- Distribution of land holdings according to Agricultural Census shows that 87.95 percent of the total holdings are of Small and Marginal.
- About 11.71 percent of holdings are owned by Semi Medium and Medium farmers and only 0.34 percent by large farmers.
- Land Utilization Pattern:

Parameter	**Himachal Pradesh**	**INDIA's Average**
Land available for cultivation out of total land holdings	75.3% of total area	85.9% of total area
Net area sown	11.9% of total culturable area	45.8% of total culturable area
Irrigation Facilities	20% of net cropped area	45% of net cropped area

- There are several government run schemes for the promotion of agricultural in the state and government has provided subsidies also, some of them are:
    - Government has introduced Mukhya Mantri Khet Sanrakshan Yojna vide which 60 percent assistance for fencing the farm will be provided. The fence will be energized with the help of solar power or electricity.

- Different camps will be organized to educate farmers about the soil health of their farm to improve productivity. The State Government will also provide useful advice on farmers mobile phones to improve the farm production.
- To promote organic farming in the State , Govt. is providing 50 percent assistance to the farmers for setting up Vermi Compost Units.
- Government has introduced Rajiv Gandhi Micro Irrigation Scheme which is targeting 8,500 hectare area to be brought under Drip/ Sprinkler irrigation system and benefiting 14,000 farmers.
- An incentive of 50 percent subsidy has been provided for construction of Lift Irrigation Scheme/installation of Bore Wells by individual or group of farmers for irrigation.

ON-FIELD SURVEY AND ANALYSIS

Field Trip Details

A **field trip** to a village of Himachal Pradesh in district UNA - Village LOHARA, Tehsil AMB was undertaken.

Current Scenario

MSP_9 of wheat in HP = INR 1,840
Average production of wheat in hilly areas = 20 Quintals/Hectare
Average production of wheat as of now[10] = 32 Quintals/Hectare
(for the crop of wheat in Una district of Himachal Pradesh)

Activity	**Cost (INR/ha)**
Cost of seeds	80kg / ha * 25 =2,000
Cultivation Cost (use of tractors on rent)	900*3 hours= 2,700
Manures & Fertilizers (Cow-dung from home)	0
Gross Returns	36,800
Net Returns	**32,100**

With our Robot **PARAS**

For 1 hectare land
Traverse lengths = 100m
Speed = 6m/min
Total lengths = 200
Power required per second = 12*23.5 = 282 Watts (data taken from electrical report)

Time taken to traverse = (100/6)*200 = 3334 mins = 56 hours
Time taken to climb stair = 30s
*On avg. a particular field is of 15 marlas
1 hectare = 400 marlas
Need to plough 27 strips of land
Total stair climbings = 27
Time to climb stair = 13.5mins
Total turns = 199
Time taken for a turning = 30s*199 = 99.5 mins
Miscellaneous Time = 5 hours for complete ploughing
Total time = 64 hours for ploughing
Total power required for one function = 64*282 = 18048 watt-hour
Total power required for complete cultivation = 54144 watt- hour =54.2 units

(for the crop of wheat in Una district of Himachal Pradesh for a single season)

Activity	**Cost (INR/ha)**
Cost of seeds	75kg / ha × 25 =1875
Cost of cultivation	1.92*unit$_9$*54.2 = 105
Gross Returns	32*1840 = 58,880
Net Returns	**56,900**

- Increase in Profit = 24800/ season
- Increment of Profit from now in a year = 45000(approx.)

Considering that a farmer generates 40k a year, our product will turn out to be free of cost within a span of maximum 2.5 years including all the maintenance costs.
Maximum Establishment Cost incurred by the farmer- Selling Price of one bot (INR 50,000 approx) + Transportation + Miscellaneous = INR 60,000 approx.
Running Cost over a harvest period incurred by the farmer- Maintenance cost + Electricity Cost + Miscellaneous = INR 3,000 per month

COST ANALYSIS

Development Cost Analysis

Materials used-

Part Name	Module	Quantity	Weight (gram)	Total Weight (gra	Material
Frame	Main Chassis	1	2400	2400	Mild Steel Square I
Chassis Sheet	Main Chassis	2	300	600	Aluminium
Lifting Mechanisn Lead Screw	Main Chassis	2	100	200	Stainless Steel
Shaft	Rotavator Plough	1	300	300	Mild Steel Pipes
Blades	Rotavator Plough	5	140	700	Mild Steel Flats
Bearings with Housing	Rotavator Plough	1	150	150	Mild Steel
Sheet	Hopper	1	300	300	Galvanized Iron (different thicknes
Base Support	Hopper	4	70	280	Mild Steel Flats an Pipes
Plastic Gears	Hopper	2	20	40	Plastic
Seed feeder	Hopper	5	40	200	PLA
Flexible Pipes (transporting see	Hopper	5	10	50	Plastic
Shaft	Hopper	1	20	20	Aluminium
Bearings - MS	Hopper	2	50	100	Mild Steel
Housing - Alumir	Hopper	2	20	40	Aluminium
Pipe Holder	Seeding	5	25	125	Mild Steel
Seed Dropper	Seeding	5	5	25	Mild Steel
Frame rods	Plowing + Seeding	4	350	1400	Mild Steel
Housing for Bear on Plough	Plowing + Seeding	2	100	200	Mild Steel
Blades of Plough	Plowing + Seeding	5	300	1500	Mild Steel
MS Pipe	Plowing + Seeding	1	500	500	Mild Steel

Seed Collector	Plowing + Seeding	5	30	150	3D printed PLA
Shaft	Plowing + Seeding	1	200	200	Aluminium
Tray	Plowing + Seeding	5	20	100	Galvanized Iron
Sheet Metal Case	Plowing + Seeding	1	500	500	Galvanized Iron
Housing for beari on Seeder	Plowing + Seeding	2	20	20	Aluminium
Plough Support R	Plowing + Seeding	5	15	75	Mild Steel
Square MS Pipes	Plowing + Seeding	3	400	1200	Mild Steel

Total Materials Used-

Material	**Quantity(kg.)**	**Cost/kg (Rs.)**	**Total Cost**
Aluminium	2	300	600
Mild Steel	10	50	500
Galvanized Iron	3	55	165
PLA	0.2	1200	240
Total			**1,505**

Items bought from Market-

Part Name	**Module**	**Quantity**	**Cost/item (Rs)**	**Total Cost (Rs)**
Bearing on plow	Plowing + Seeding	2	180	360
DC Motor for PLA Assembly	Plowing + Seeding	1	2500	2500
Plastic Gears	Plowing + Seeding	2	30	60
Anti Rust Paint	Plowing + Seeding	-	150	150
Bearing on Seeder	Plowing + Seeding	2	200	400
Long Lead screw	Main Chassis/ Assem	2	560	1120
Short Lead screw	Main Chassis/ Assem	1	320	320

Ultrasonic Sensor	Electrical Componen	8	75	600
IMU	Electrical Componen	1	150	150
Arduino Mega	Electrical Componen	2	790	1580
High Torque Motors	Assembly	2	2500	5000
Medium Torque Mot	Assembly	4	1500	6000
Low RPM Motor	Seeder	1	100	100
L-shaped low-torque motors	Test-bot	4	75	300
L Shaped Motor	Harvester	2	75	150
Motor driver	Test-bot	2	700	1400
Arduino Mega	Test-bot	1	790	790
Ultrasonic Sensors	Test-bot	3	75	225
Breadboard	Test-bot	1	65	65
Wooden base	Test-bot	1	20	20
Plastic Wheels	Test-bot	4	20	80
Nylon Wheels	Main-bot	8	55	440
Nuts and Bolts	Miscellaneous		3500	3500
Total				**25,310**

Machining Processes-

Machining Process	**Time (Hrs)**	**Cost/ Hour (Rs.)**	**Total Cost**
Water Jet Cutting	2.5	2000	5000
Welding	5	500	2500
Shear Cutting	2	300	600
Folding	2	300	600
Riveting	1	150	150
Grinding	3	300	900

Drilling	5	300	1500
Lathe	12	300	3600
Total			**14,850**

Human Resources-

Human Resource	Days	Cost/ Hour (Rs.)	Total Cost (Rs.)
Skilled Labour	6	Rs. 1400/ Day (8 Hrs) 2 people	8400
Unskilled Labour	6	Rs. 1800/Day (8 Hrs) 4 people	10800
Total			**19,200**

Total Development Cost-

Resource	**Cost (Rs.)**
Materials Used	1505
Items bought from Market	25310
Machining Processes	14850
Human Resources	19200
Practice Arena	12000
Miscellaneous	3000
Total Development Cost	**96,045**

Manufacturing Cost Analysis
(estimated for 50 bots to be manufactured)

Resource	**Cost for 1 bot (Rs.)**
Materials Used (metal and other raw materials)	1045
Items (Motors, Pulleys, etc)	16000
Machining Processes (Water Jet, Lathe, etc.)	11615

Human Resources (expertise supervision)	13000
Miscellaneous	1500
Total Manufacturing Cost	**43,160 ~ 45,000 (approx)**

Testing and Trials Cost Analysis

Activity/ Item	Cost incurred per bot (Rs.)
Motor Testing	20
Lifting Mechanism Testing	30
Electrical Components Testing	10
Material Testing	10
Miscellaneous	30
Total Testing and Trials Cost	**100**

WHY WOULD A FARMER SWITCH?

Overview

Farmers in the hilly areas are rural and land per unit housing is also lowest in hilly areas, every season of the crop is of great value for a farmer, directly relying on our machine would be very tough for him. Switching to a new model of agriculture is always a slow and tough process. For this, we need their trust, which in turn, needs that our model is completely economically viable.

To Make This Happen

Trust: Our efforts to transform the lives of our farmers is fueled by the constant trust that our product will garner by the farmers of our country and their families.
Economically feasible: The average monthly income of an agricultural family in India is around Rs 6500/-. Considering how low this figure is, we know that to make those farmers invest their hard-earned money in our product, we need to make it as cost-efficient as it can practically get.

- Subsidies- We will contact government authorities to cope up with us as we have the same interest. Most of the state governments of hilly states have floated in several subsidies, as we listed above some main found in Himachal Pradesh. Even the Central Government is also promoting the boost of agriculture.
- EMI Model
- Co-operative Establishment Model - As farmers may not be able to afford this much cost, they can follow this model to achieve the goal.

Awareness: Illiteracy of farmers acts as a huge barrier to new and useful information. Therefore, before bringing our product to them we need to think of ways to make them aware of its existence. We need to make them aware of our product and the endless possibilities that it is going to bring in their lives.

MARKETING STRATEGY

Strategies

Based on the research done on customer profile and considering the main constraints like communication barriers with people speaking distinctive languages, unawareness about modern technology, we have devised the following marketing strategy to spread awareness about PARAS.

- **BLOCK LEVEL CAMPS** - Live presentation of the working of all the modules of PARAS by local representatives. This would familiarize farmers with the new technology and its application. Presentation by local representatives would establish the trust of the rural people in our product.
  By the government grant-in-aid is also being provided to the Panchayat Samitis under the head Social Education and General Education for developmental activities in the social educational fields. We can consult different Panchayat Samitis also to cut the costs of our camps and help us out in organizing successful camps.

- **ADVERTISEMENTS** - Through Newspapers, Radios, Televisions we will channelize our publicity.

- **AGRICULTURE MELAS** - We will participate in several agricultural melas and make our product reach out to the public. Several State Governments organize these annually in some major cities of the State.
  Example- **Farm** Technology Awareness-cum-Demonstration **Mela**

- **Marketing By establishing Distribution Chains.**

Marketing Cost Analysis

Strategy	**Cost (Rs.)**
Block level Camps	8-12k / camp
Advertising	15k /month
Exhibiting in Agriculture mela	15k annually

Marketing through Distribution Chains	20k/month (approx)

Targeting the sale of at least 50 models of PARAS in the **first month**, by conducting around 5 block-level camps, total Marketing Cost for one robot in the **first month** is estimated as-

Strategy	**Approximate Marketing Cost for 1 bo sold (Rs.)**
Block level Camps	1250
Advertising	300
Exhibiting in Agriculture mela	25
Marketing through Distribution Chains	400
Total Marketing Cost per robot	**2000 (approx)**

FINAL COST PRICE

Activity	**Cost Incurred per bot (Rs.)**
Development Cost to be Recovered	2000 (approx)
Manufacturing Cost	45000
Testing and Trials Cost	100
Marketing and Sales Cost	2000
Miscellaneous	5000
Final Cost Price of one Terrace Farming Robot	**54100**

CONCLUSION

After performing a meticulous analysis of the market conditions, we strongly believe that there will be a strong symbiosis between the Terrace Farming Robot developed by the team- PARAS and the Indian Terrace Farming Community. PARAS is designed for Indian farmers first and is economically viable for them. As its name symbolizes, it truly has the potential to produce “gold” from the Indian Terrace Farming Industry by reducing drudgery involved in the Terrace Farming along with increasing overall efficiency and productivity.

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