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AUTOMATED FARMING USING GANTRY ROBOT

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ABSTRACT: *In today's world of chemical farming and use of silicone sprays, colored dye and injections to make vegetables fresh, access to organic and healthy vegetables is very limited. The alternative to buying vegetables can be to growing them at home, but long work hours and busy schedules make it difficult for people to do so.Our project seeks to solve this problem by automating home gardening. The project consists of making a gantry type robot which will perform two operations – seed sowing and irrigation. A number of different plants can be planted based on the weather conditions in that time period. These seed are sown automatically by the end effector, and based on the soil moisture which is measured using soil moisture sensor the plants are irrigated. Since different plants have different water requirements, irrigation using end effector allows better control of water and provides optimal growing conditions to the plants. End effector irrigation also prevents wastage of water. To provide more control on growing conditions, soil moisture sensors will determine the frequency and amount of water to be given to each plant. The robot has raised beds (1.5m x 1m) for growing plants. The gantry is made with aluminum extrusions (2020 and 2040). It is powered using NEMA17 stepper motors which provide accurate control and high torque for operation. To provide movement, timing belts (6mm width) and timing pulleys are used. A4988 motor driver and Arduino Mega microcontroller is used for programming and control of the project. The irrigation system uses solenoid valve and vacuum pump is used for seed dispensing.*

I. INTRODUCTION

The modernization of the agricultural sector has led to increasing in the harmful effects on the environment. Pesticides and insecticides are used on cultivation lands to protect humans and the crops from various diseases. However, misinformation on the required number of pesticides is causing a large negative impact on health of the consumers. The side effects of pesticides also include health hazards and negative environmental effects. Large number of pesticide residues has been found in fruits and vegetables. The fact that vegetables and fruits have a very small shelf life is an incentive for farmers to use food processing pesticides to improve their shelf life. Also, the long-mismanaged supply chain from farmers to the retailers causes partial decay of the vegetables; to counter this many vegetable vendors and farmers use chemical injections to ripen raw vegetables overnight. Customers place huge emphasis on aesthetic value of the vegetables too, and hence the vendors use chemical dyes and silicon sprays to maintain the appearance of fresh and healthy vegetables. All these practices have a large negative impact on human health as these harmful chemicals easily enter human body through consumption and cannot be easily washed away. Vegetables are rich in vitamins, minerals and fibers and are an important part of a healthy diet. Hence it is important to ensure that healthy and fresh vegetables are readily available to everyone. One way to get organically grown vegetables free from pesticides and other chemicals is growing them in house using home/kitchen gardens.

1.1 DESCRIPTION OF THE PROJECT

1.1.1 EXISTING SYSTEM:

There have been efforts in automating the gardening process however most of the tools until now focus on monitoring the process or are focused on only a part of the gardening process. Some projects have extensive climate control with measuring soil content using soil moisture sensor, regulating ambient air with carbon dioxide sensors and exhaust fans, and controlling illumination using LED lights. However, in these projects seed sowing has to be done manually. Projects focused on seed sowing only have also been done, but as the name suggests their main aim is only sowing seeds. These seed sowing devices are based on mobile robots, they are only suitable for large scale irrigation and not for small scale kitchen gardening. Also, these automated seed sowing devices can only sow limited kind of seeds at a time provided by the farmer. For small scale kitchen gardens, diversity of plants is required which cannot be fulfilled by automated seed sowing robots.

1.1.2 NEED FOR THE PROJECT:

Based on recent trends in automated farming technologies, we found out that there is tremendous scope in automated farming robots. As stated earlier in 1.2 Challenges with Current Systems, a lot of projects are focused on a part of the farming process and not on automating the entire process. There has been huge growth in the number of people willing to obtain organically grown vegetables. A large number of these people reside in urban areas and are capable of investing money in kitchen gardens. However due to increasing workloads and work time of people in urban areas, it is becoming difficult for people to dedicate time for gardening. Automated farming robot offers a niche solution for the urban dwellers that would like to enjoy home grown food but are unable to do so because of their other commitments. Therefore, the need for this project exists from both the technological and economic prospective. As there have not been any previous projects done, this project has a unique approach to the problem, and also the project can be sold as a product in the future.

1.1.3 OBJECTIVE:

The project seeks to solve the problem by automating home gardening. The project consists of making a gantry type robot which will perform two operations – seed sowing and irrigation. These seed are sown automatically by the end effector, and based on the soil moisture which is measured using soil moisture sensor the plants are irrigated. To provide more control on growing conditions, soil moisture sensors will determine the frequency and amount of water to be given to each plant. The irrigation system uses solenoid valve and vacuum pump is used for seed dispensing.

1.1.4 APPLICATIONS:

Automated farming robot automates the entire gardening process, right from sowing seeds to monitoring environmental conditions, and irrigating the crops. As a standalone product, the project would find application among urban households as a source of fresh organic vegetables. The gantry system allows different crops to be grown in a small space. This is essential in urban kitchen gardens as space is always a constraint. The end effector selects the seeds required based on user specification and plants them in the predefined grids in the soil. Since irrigation also takes place with the help of an end effector, crops are irrigated based on their water requirement. This prevents any unnecessary wastage of water. A soil moisture sensor ensures that soil conditions are optimum for plant growth. The robot is attached on top of raised beds, which allows better control of the soil. The raised beds also provide better drainage and prevents run off of nutrients from the soil. The robot works without any human intervention and can operate every day until the crops grow. Thus, very low effort and time is required to be invested to grow organic vegetables using the automated farming robot. Therefore, the main application and objective of the robot is to grow different types of crops without any human intervention and provide optimum growing conditions for them.

II. PROPOSED SYSTEM

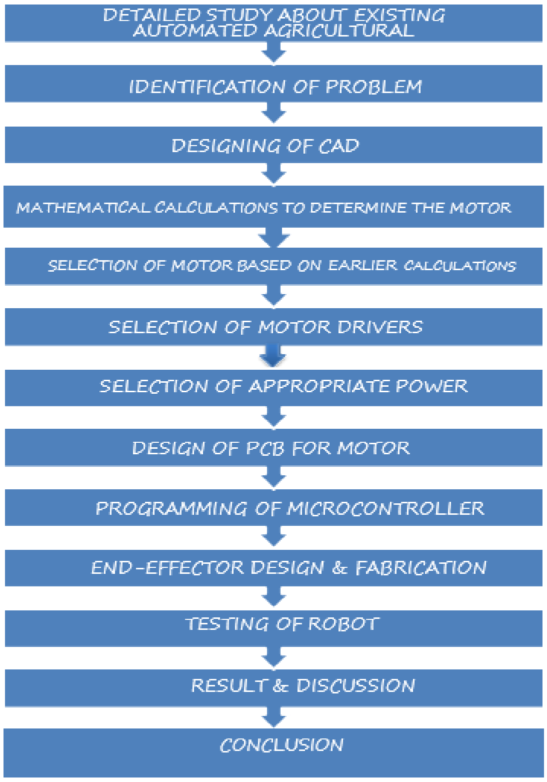


Figure 1.1: Methodology of the project

2.1 MECHANICAL STRUCTURE:

The model consists of Raised bed which is of the length-1.5m, breadth-1m and height-0.75m. We have selected pinewood material to construct the raised bed, it being cost effective and easy to install. The pathway of the gantry system is made up of aluminum extrusion as they are uniform and linear for the wheels to roll over it. Movement of the x-axis is provided using 2 stepper motors on each side of the gantry to achieve smooth movement, similarly y-axis movement is provided with single stepper motor and movement of z-axis is provided with stepper motor and lead screw.

figure 1.2: CAD MODELOF THE ROBOT

2.2 FABRICATION OF THE MODEL:

After the stress analysis of the structure was over, some parts were purchased and other parts were custom made as per the requirements. The base is made up of pine wood which is used to hold the soil. After this 2040 aluminum extrusion are placed along the length of the base with supporting plates to get perfect straight guide way, then the V-wheels are attached to the gantry wheel plate and placed on the x- axis, now the x-axis is fitted with belt and tied at both ends with the help of belt clips on the extrusions. The y-axis is made with the V-wheels mounted on the cross plate which is responsible for the movement of y-axis, it is also belt driven and fitted at both the ends. Z-axis is the end effector of the system which is lead screw driven, connected with 2020 aluminum extrusion. This aluminum extrusion movement is facilitated by V- wheels for smooth movement, and mounted on cross plate of Y-axis. Control panel is placed on the left side of the X-axis arm, which consists of all the connections for wire and water pipes are channeled through flexible pipes. The main power supply (SMPS) of the system is mounted on the side of the wooden base.

2.3 COMPONENTS

2.3.1 MECHANICAL COMPONENTS:

Serial no.	Component	Specification
1	Lead screw	Material: stainless steel Length: 600mm Diameter: 8mm lead screw Pitch: 2mm
2	Aluminum extrusion	Type: 2040 • Length 0.75m- 2nos • Length 0.75m-2nos • Length 1m- 1nos Type: 2020 • Length 0.75m-1nos
3	wheels	Material: nylon Type of bearing: rubber sealed Outer diameter: 26mm Inner diameter :21.8mm Thickness: 6.8mm
4	Supporting plates	Material: steel Thickness: 6mm
5	Allen bolt with T-nut	Material: mild steel Length: 10mm,15mm Diameter: 4mm,5mm
6	GT-2 pulley & belt	Material: Aluminum Teeth: 20 Inner diameter: 5mm Outer diameter: 15mm Pitch: 2mm belt width: 6mm
7	Shaft coupling	Material: Aluminum Length: 25mm Inner diameter:5mm and 8mm Outer diameter: 18mm
8	Belt clip	M5 x 10mm screw and T-nut Quantity: 6
9	Cable carrier support	Material: mild steel Type: L clamp Quantity: 5
10	Motor mounts	Material: 6061 aluminum Quantity:3

figure 1.3: **LIST OF MECHANICAL COMPONENTS**

2.3.2 ELECTRICAL COMPONENTS:

Serial no.	Component	Specification
1	Switch mode power supply	Voltage: 12v Max current: 10A
2	Solenoid valve	Voltage:12-24v Current: 3A
3	Vacuum pump	Voltage:12v Max current: 6A
4	Stepper motor	Voltage: 12v Max current: 1.6A Max torque: 4.2 kg N-cm No. of leads: 4 Motor type: single shaft Weight: 300gm Rotor inertia: 54 gm-cm^2 Step angle: 1.8 deg Quantity: 4
5	Arduino mega	Voltage: 5v Max current: 600mA
6	A4988 motor driver	Supply voltage: 8v-35v Max Current:2A
7	Cooling Fan	Voltage: 12v Current: 2A
8	Dual channel relay module	Trigger voltage: 3.3v-5v Max current: 10A
9	Limit switch	Operating temp: -45°C - 75°C Rated volt: AC 125V-250V Per weight: 2 grams Current rating: 5 Amp
10	Boost converter	Input: 12v Output: 24v Max current: 3A

Figure 1.4: **LIST OF ELECTRICAL COMPONENTS**

Component	Specification
Soil sensor	Input voltage: 3.3-5v Output voltage: 0-4.2v Input current: 35mA Output signal: Both analog and digital

Figure 1.4: **LIST OF ELECTRICAL COMPONENTS**

III. METHODOLOGY & IMPLEMENTATION

3.1 METHODOLOGY:

Objectives were defined for the project and based on these objectives a CAD model was designed. Most of the projects till date focus on only monitoring the environment or controlling a small part of the farming process. The objective behind making the automated farming robot was to limit human intervention to the minimum and automating the entire farming process while making it more efficient. Objectives were defined for the project and based on these objectives a CAD model was designed. The primary constraint was work volume, based on which other parameters were fixed. Once the design was ready, structural analysis was performed to check robustness of the design. To provide actuation stepper motors were selected after calculation of static loads on the joints. Based on the torque calculations NEMA17 motor was selected. And for fabrication for guide rails, aluminum extrusions were used as explained in the previous chapters. With the designs ready, fabrication of the robot began. Raised bed was the first part to be made, on which the x axis guiderails with aluminum extrusion were laid. The fabrication process went on for a month. At the end the mechanical structure was ready with the timing belts and motor mounts in place. For the electrical part, motor wiring was done from a 12V 10A SMPS to the respective motors, and then the additional wiring for controller connections was done. Initially the motor was tested without limit switches and after satisfactory performance, limit switches were added to set a home position. This required additional wiring too.

After the gantry system was completed, work began on the end effector. End effector was fabricated with aluminum plates and necessary mounts were added for soil sensor, vacuum pump and irrigation system. The vacuum pump collects the seeds from a dispenser placed at the home position, keeps the suction on until the gantry reaches the desired grid position and deposits the seed in the ground. Irrigation system is controlled through a solenoid valve and relay. Switching on the relay opens the valve and water reaches the end effector to irrigate plants at the required position. The water pressure is through the input supply pressure, usually a tap connection, but in our case a bucket of water kept at a height higher than that of the robot was able to created necessary water pressure. The soil moisture sensor was then calibrated to give correct soil moisture readings. Soil moisture is measured in gm/cc (weight by volume). Soil moisture sensor readings determine the required times for watering the plants which might change based on the weather conditions.

3.2 ALGORITHM:

The program for automated farming robot was written for Arduino Mega Microcontroller. The program was written on Arduino's native IDE. The Arduino programming language is heavily based on C/C++ language.

3.2.1 MAIN LOOP:

1) Go to home position on start up using homepos_x(), homepos_y() & homepos_z(). Move z axix 5000 steps up.

2) Perform seeding operation using seeder().

3) Perform irrigation using gowater() function twice each day.

4) Check soil moisture using check soil() and water plants whenever required, twice each day.

5) End.

3.2.2 HOME POSITION FUNCTIONS:

Homepos_x()/y()/z() perform the same function which is going back to the predefined home position, x,y & z denote three different axis.

1) Check if limit switch is pressed (HIGH).
2) If it is HIGH go out of loop as the axis is already at home position.
3) If it is LOW perform steps 4 & 5 until limit switch is HIGH, then exit.
4) Move back by 1 step
5) Check limit switch condition.
6) End.

3.2.3 SEEDER() FUNCTION:

This function picks up seeds from a container at initial positions and places them at the required grid locations. Seed sequencing operations take place here. It is one of the most important functions and it is required to run only once during each operational cycle.

1) Repeat steps 2 to 8 three times, then jump to step.

2) Go to the required grid on y axis, repeat steps 3 to 8 four times, and then jump to step 1.

3) Go to home position on x axis.
4) Start vacuum pump to pick up seed.

5) Move z axis 5000 steps down, wait for 2 seconds and then come back up.

6) Go to grid on x axis while y is constant.

7) Stop vacuum pump to drop the seed.

8) Start solenoid valve to water the plants. Wait for 5 seconds and stop the valve.

9) End.

3.2.4 CHECK SOIL FUNCTION:

Checksoil() is used to measure the soil moisture content. If the soil moisture is greater than 30% weight by volume the soil cannot hold any more water and there is no point in further irrigation. While on the other hand if the soil moisture is below 5%, plants undergo permanent wilting and hence it is important to ensure this doesn't happen.

1) Go to all grid locations.

2) Collect input from soil sensor.

3) Check if the soil sensor value is more than 576 (5% soil moisture value).

4) Start solenoid valve at those locations (watering).

5) Wait for 5 seconds and close solenoid valve.

6) End.

IV) SOIL SELECTION

4.1 SOIL SELECTION:

Red soil is a type of soil that develops in a warm, temperate, humid climate under deciduous, having thin organic and mineral layer overlying a yellowish-brown leached layer resting on an alluvium red layer. It is generally derived from crystalline rock.it contain low in nutrients, humus and difficult to cultivate because of its low water holding capacity. Red soil is rich in iron content but it lacks of phosphorus, nitrogen and lime contents. It is mainly found in Tamil Nadu, southern Karnataka, Andhra Pradesh and some parts of Madhya Pradesh etc.

4.1.1 CHARACTERISTICS:

- Texture of red soil varies from sandy to clayey.
- It includes porous and friable structure, absence of lime, kantar and free carbonates and small quantity of soluble salts.
- In general, it is found to be shallow and its pH value ranges from 6.0 – 8.0.
- This soil contains some amount of the acidic nature and the moisture of the soil contains.

V) RESULTS & ANALYSIS

5.1 STRESS ANALYSIS OF THE GANTRY:

Stress analysis test is done to find out the maximum load of the gantry can handle at the time of operation. With the help of a software, stress analysis test was done.

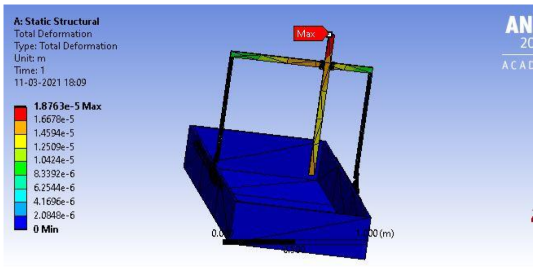
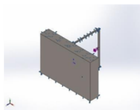


Figure 1.5: stress analysis of the gantry system

As shown in the above figure, A maximum force of 40KN was applied on the y axis of the gantry for which the displacement of the extrusion takes place. By this test it was confirmed that it can handle more weight than the actual weight it has to handle.

Fixture name	Fixture Image	Fixture Details
Fixed-1		Entities: 2 face(s) Type: Fixed Geometry

Resultant Forces

Components	X	Y	Z
Reaction force(N)	8.00674	-4.99725	-26.99601
Reaction Moment(N.m)	0	0	0

Figure 1.6: force acting on the gantry

5.2 SOIL SENSOR TESTING:

Red loam soil has a water holding capacity of 35% after which the soil starts to lose water. Thus, knowing the soil capacity we wanted to calibrate the soil sensor by adding specific amount of water to soil and measure the value. In the table 5% water means 5% weight of the soil sample taken for soil calibration. Weight of the soil is kept constant for all successive test is done.

Specimen	sensor value
soil without water	1023
soil with 5% water	963
soil with 10% water	576
soil with 15% water	512
soil with 20% water	409
soil with 25% water	187
soil with 30% water	132
soil with 35% water	121

Figure 1.7: soil sensor calibration

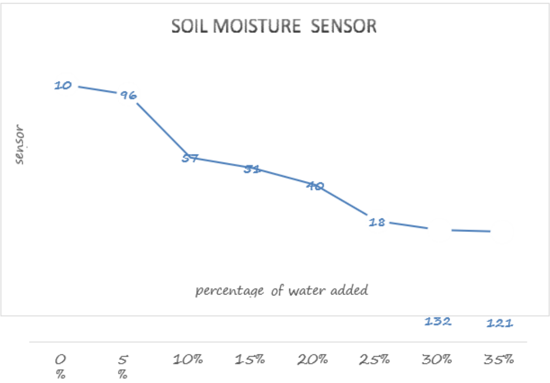


Figure1.8: Percentage water vs sensor value

5.3 LIMITATIONS:

- The robot has to go to the home position to pick up the seed every time after successfully placing one seed at a given co-ordinate.
- The robot cannot control the C02 content and sunlight inside the workspace.
- Due to the fixed height of our robot, it can grow crops which grows to a maximum height of 750mm.
- The robot cannot remove the unwanted plants growing with the crops, a human intervention is required to remove it.
- Before starting the sowing process, a human is required to plough the work area to loosen it, so that the end effector can easily insert the seed into the soil.

VI) CONCLUSION & FUTURE SCOPE

6.1 CONCLUSION:

The project was completed in stipulated time and met all the objectives. As part of the final trials, we have started growing the first batch of crops with the automated farming robot. The first column has spinach, second has radish and the last column has tomatoes. The robot has planted these plants autonomously without any human intervention and it will continue to water then for the next few weeks

6.2 FUTURE SCOPE:

The project has three main objectives: sowing, irrigating and maintaining adequate soil moisture levels. This automates the typical farming process where a person would sow the seeds manually, water them once or twice a day and check soil moisture through visual inspection. However, this process can be further improved to create the optimum growing conditions for plants. Here's a list of updates which can be further added on to the automated farming robot.

- Carbon Dioxide Control- Carbon Dioxide is one of the most important requirements for healthy plant growth. Carbon Dioxide levels can be controlled by placing the robot in a greenhouse. CO2 levels can be measured by a sensor and they can be controlled by keeping an exhaust fan which regulates the flow of air inside the greenhouse.

- Sunlight- like CO2, sunlight is also extremely important. Inside a greenhouse, artificial lighting could be provided to imitate sunlight. The advantage of this would be the fact that this lighting could be regulated to better suit the plant growth.

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