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Development and Fabrication of an Autonomous Seed Sowing Robot

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Abstract:
Automisation of agricultural processes provides the benefits of increased efficiency, productivity, healthy crops, efficient use of resources & material and labour cost savings. In this paper, an autonomous seed-sowing robot is designed to cope up the above goals. The robot divides the field into a grid with intersection points as places where the seeds are sown. The depth of the hole, the distance between points where the seeds are sown is calculated according to government data and is fed to the logic board of the robot. The robot goes to the starting points and makes a hole using a toothed wheel with teeth of increasing height. The delivery system makes sure that only one seed is dispensed per hole and the back plate mechanism fills the hole after sowing is done. Sensors are used for obstacle detection and robot changes its path accordingly. There are several robots available in the market and research has been done on many more, that perform the above functions separately but no one has integrated all the above functions in one system. The proposed robot does this and provides a better solution for low productivity nations.
Keywords: Agribot, Seed Sower, Multi-Function Robot

1. Introduction

An Agribot is a mechanical, artificial system and capable of performing various harvesting functions [1]. With the development of robot farming system, food production can be increased considerably and economically. Fruit picking robots, driverless tractor/sprayers, and weed removers are now designed to reduce human labour. This idea of using robots for various agricultural processes is not a new one [2]. Many people in the past have developed driverless tractors but none has been entirely successful, as they could not adapt to the complexities of today's era. Most of the ideas were inspired by industrial techniques and based on the production line where it was assumed that all the information regarding farming was known beforehand. The present day technology aims at developing smarter machines, which have the ability to sense and work in semi natural environments. These machines may not be as intelligent as humans are but they are expected to show sensible behaviour to external stimuli. In this respect, they must be well equipped and programmed such that they work sensibly for long hours in external environment unattended. By taking this approach, in which engineers design a system in terms of its actions, effects and interactions, we can develop a new machine that integrates these functions and solve the major agricultural problems of the country.

India is a country that thrives on agriculture as its major source of income. Agriculture and its allied activities cater to the needs of more than 70% of the country's population. Thus, in order to sustain, strive and diversify the potential of agricultural economy, it is necessary to look after both the human resource as well the new technologies that can be used. The agricultural aspect of robotics is the escalation of the use of mechatronics into the various bio-systems. It is acting as a replacement to the indigenous methods of agriculture and making the process economic as well as energy efficient [8]. In recent years, there has been a rapid increase in the interest in development of autonomous vehicles. Many researchers started developing more adaptable vehicles for agricultural operations. Such systems may reduce the excess utilisation of pesticides and energy inputs by the control [3]. There are many field operations that can be executed by autonomous vehicles, giving an upper hand over the conventional machines. Most of the researchers are working for autonomous vehicle design for precision agricultural mobile robots.

Different countries like the USA, European Unions, Denmark, Australia, Finland, India etc. are designing mobile robots for various agronomic purposes [6]. Research groups have developed different specialized navigation techniques like an odometer, vision based, sensor based, inertial, active beacon, GPS, map-based, landmark navigation techniques to operate robots under unified control space for farming. The above mentioned techniques are used for various applications like seed-bed preparation, seed mapping, seed placement, reseeding, crop scouting, weed mapping, robotic weeding control, micro-spraying, robotics gantry, robotic irrigation, etc.[5] However, the development of these platforms[4] presents two challenges:

- To develop a physical structure suitable for the agricultural environment.
- To develop an electronic architecture to integrate the various electronic devices.

An electronic architecture must be robust and reliable, provide quick, ease maintenance, and have modularity and flexibility to allow future expansions and connection of new equipment [7]. As more autonomous applications for agriculture will be operating in upcoming years, it gives an idea applying robotics in agriculture may be technically difficult compared to industrial robots. The projected world's population is to grow to more than 9.15 billion by 2050. Therefore, the challenge for the next decades will be to supply the needs of the expanding world population by developing a highly productive agriculture management, while at the same time preserving the quality of the environment.

Most of the literature in the above review showed us the use of various robots used worldwide for performing specific functions. However considering the Indian economy and the agricultural scenario in India, it is highly infeasible to use multiple robots in the field as it would be expensive as well tough to manage. The literature also failed to throw light on the integrated functions performed on a single robot, thus avoiding the use of multiple robots in the same field.

2. Working Methodology

In traditional farming, there are many different procedures like digging holes, seed sowing and covering holes with soil, which take much time, but with the help of the proposed Agribot these tasks can be complete in a single round. Thus, Agribot saves time in farming and increases productivity.
The Agribot performs its function through the interplay of the following mechanisms:

1. Hole Digging System
2. Seed Dispensing System
3. Hole Filling System
4. Drip Irrigation System
5. Control System and Sensors
6. Drive System

Dimensions:

- Chassis Dimensions: 30cm×20cm
- Wheel Dimensions: 12.5 cm(diameter)×6cm(width)
- Digging Wheel Dimensions:
  (i) No. of Teeth: 10 (ii) Feed Per Tooth: 0.5cm (iii) Minimum Teeth Size: 1.5cm
- Hole Filling Plate: 10cm×10cm
- Hole Dispensing System: 6cm (diameter) and 10cm (height)
- Approx. Weight of the Components: 3000 gram

2.1. Hole Digging System

Initially the operator places the Agribot at the starting position of the field. It creates its workspace by giving optimum spacing between the field boundaries and the lanes in which the seeds are sown indicated in figure 1. The spacing between two consecutive seeds is such that the plant growth can be most efficient. The values for the spacing are as per the data provided by the government. The Agribot's hole digging system is initiated by the arduino mega. This system consists of a toothed wheel driven by a motor. The teeth on the wheel are ten in number and have a pitch per tooth of 0.5 cm. The first tooth has a height of 1.5cm and the last has a height of 6.5cm. As per the government data 6.5 cm is the optimum hole depth for seed sowing. The wheel rotates at 60 rpm and the teeth are given appropriate relief and cutting edge angles to minimize power consumption and hindrance to chip flow.

After the hole is made, the seed delivery system is initiated. In this seed delivery mechanism, we have two plates. A motor is connected to the top plate, which is powered through a battery. The bottom plate is stationary inside the conical flask. The two plates consist of one hole each. While rotating when the hole of the top plate coincides with the hole of the top plate, the seed comes out through the hole, fulfilling its purpose. The seed delivery system is connected to the bottom of the storage tank. The storage tank has a load cell to ensure that the tank is not empty. The motor connected to the upper plate is controlled by the arduino mega.

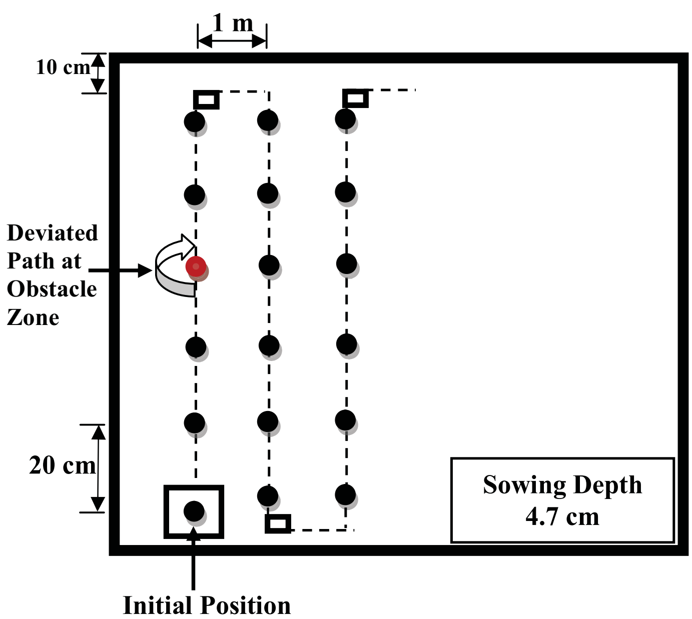


Figure1. Workspace of the Agribot

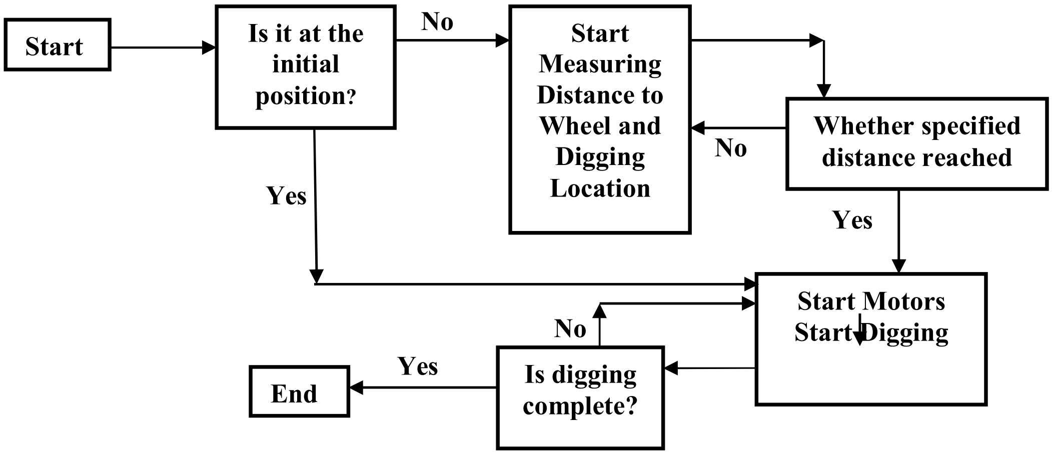


Figure 2. Flowchart of the Digging System

As seen from the flow chart (figure 2), the robot first goes to the initial position, if it is at the initial position it starts the motors and digging starts. The process continues until the digging completes. If it is not at the initial position, it starts measuring the distance until it reaches the next digging spot.

2.2 Seed Dispensing System

As per the flow chart (figure 3), the robot starts by measuring the seed quantity in the storage tank. If the tank is nonempty, it starts the servomotor to dispatch a single seed. If the tank is empty, it generates an alarm as an indication to fill the tank.

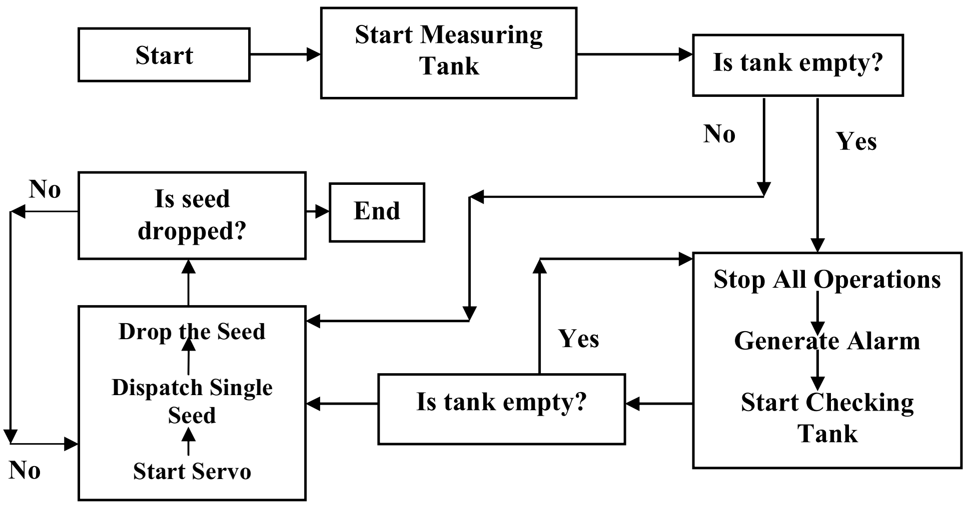
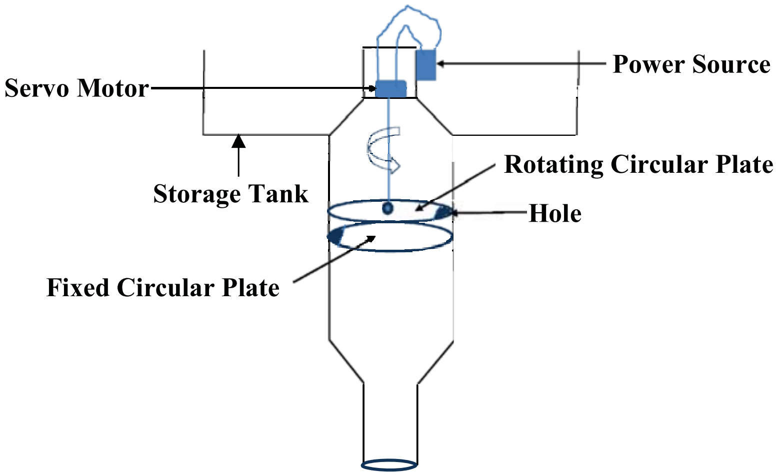


Figure3. Flowchart of the Seed Delivery System



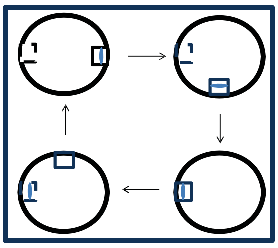


Figure 4. Schematic Diagram of the Seed Delivery System

After the hole is made, the seed delivery system is initiated. In this seed delivery mechanism, we have two plates. A motor is connected to the top plate, which is powered through a battery. The bottom plate is stationary inside the conical flask. The two plates consist of one hole each. While rotating when the hole of the top plate coincides with the hole of the top plate, the seed comes out through the hole, fulfilling its purpose. The seed delivery system is connected to the bottom of the storage tank as shown in figure 4. The storage tank has a load cell to ensure that the tank is not empty. The motor connected to the upper plate is controlled by the Arduino mega.

2.3. Hole Filling System

The next step is to fill the hole with soil. This is accomplished by a grass fibre sheet attached to the back of the Agribot as shown in figure 5. This sheet is flexibly connected using spring suspension system to ensure that the mechanism can overcome hindrances in its path.

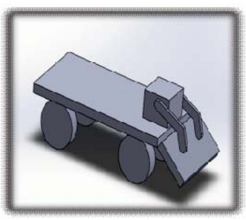


Figure 5. Back Plate of the Hole Filling System

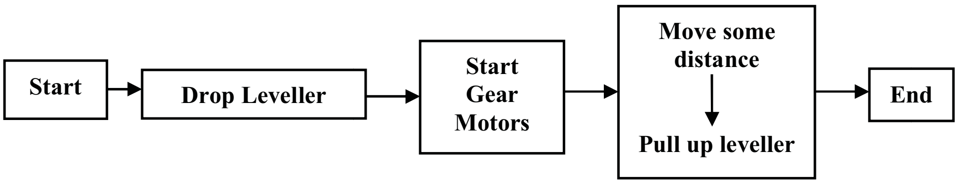


Figure 6. Flowchart of the Hole Filling System

As per the flow chart (figure 6), the robot starts by dropping the leveller operated by gear motors, it then moves up to a certain distance and then the leveller is pulled up.

2.4. Drip Irrigation System

To start the process, the moisture sensor shall be inserted to the soil for inspecting the moisture content. If the moisture is above the threshold value, all the processes are turned off, if it is below the threshold valve, it checks the moisture content percentage and accordingly pours the amount of water required for the particular space provided between the seedas given in flowchart (figure 7).

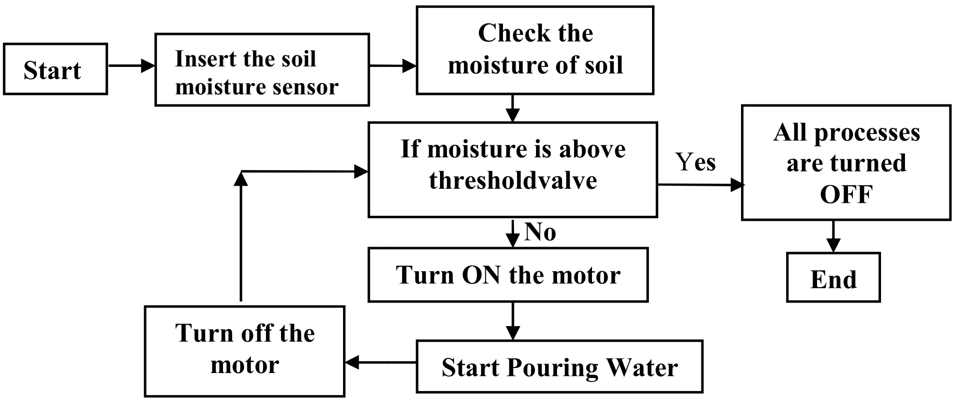


Figure 7. Flowchart of the drip irrigation system

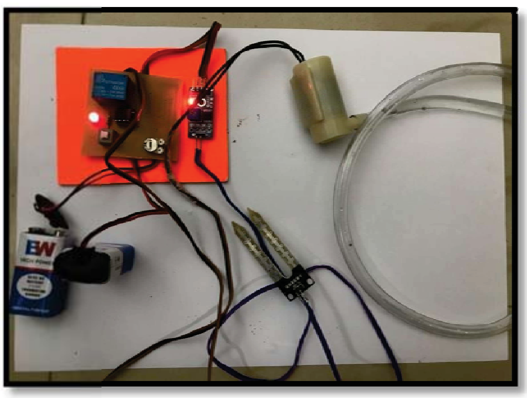


Figure 8. Schematic of drip irrigation system

After the hole is filled with soil the drip irrigation system is initiated. The drip irrigation system consists of a soil moisture sensor that measures the humidity content of the soil are shown in figure 8. The soil moisture sensor measures the conductivity of the soil. In this project an automation of farm irrigation and soil moisture control by 555 IC using, soil moisture sensor module. When the soil goes dry pump will start .The soil moisture sensor module has a comparator on it. The output of comparator is only when soil is dry. When the moisture in the soil is above the threshold, the microcontroller will turn off the motor. As per the requirement, we can vary the threshold value of the comparator.

3. Case Study

To realize the developed methodology an example has been considered and the time taken for a given size of land for seed showing method was highlighted. The same has been compared with the manual labour required for the particular work to show the efficacy of the proposed methodology. Usually the chickpea seeds having average diameter of 0.75cm, the depth of hole is taken as 5-6 times the seed diameter (according to standard data). Thus, in this case the hole depth is 6 times the average seed diameter= 6×0.75=4.5cm
Assuming, the field to be 10m×10m Then, the number of rows = 10
The number of seeds in a row = 50
Rounds to be turned by the digging wheel= (required hole depth-minimum tooth size)/ (feed per tooth×number of teeth)
Thus, rounds to be turned in this case= (4.5-1.5)/ (0.5×10) =0.6 rounds Speed of the digging wheel = 10 rpm
Then time taken to dig hole = 0.6/10 = 0.06 minutes = 3.6 seconds Seed dispensing time = 0.5 seconds (assumed)
Circumference of driving wheel = 39.25 cm Distance between two holes = 20cm
Speed of the wheel= 25rpm
Time taken to move between two hole positions = (distance to be moved/distance moved in one rotation)/ (RPM of the wheel) = (20/39.25)/25 =.02 minutes =1.2 seconds
Time taken to complete row = (3.6+0.5+1.2) × 49 = 260.7 seconds = 4.4 minutes Time taken to move from row to row = 6 seconds
Thus total time taken = 10×4.4 + 9×0.1 =44.9 minutes
Time taken to complete these tasks manually is 3 hours approximately by a skilled worker (According to Standard Data).

4. Executive Summary and Discussion

India has a population that is increasing at an alarming rate and this population demands resources. These resources though vital part of human existence are scarce. Thus, we need to use these resources efficiently and sustainably. Through our Agribot we wish to save water and use the finite agricultural land available to us in the most efficient manner. The Agribot performs all the tasks of seed sowing as well as integrates the task of drip irrigation. Labour cost is increasing with time and working in agricultural land is both tedious and harmful to health. Agribot is an autonomous robot that eliminates this labour requirement in both seed sowing and irrigation process. Robots can easily work in harsh and harmful environments. Thus,Agribot proves to be both economical and efficient. The robot also performs its tasks following all the government data for efficient and effective seed sowing and irrigation so that the farmer gets maximum productivity from the finite agricultural land available to him. The Agribot is durable, easy to repair and has high reliability due to the rigid components used the well thought out design and the microcontroller logic that can easily be changed to fit personal needs. By this project we tend to perform the four basic functions of agriculture namely digging, seed dispensing, water dripping and hole filling through a single robot thus reducing the use of multiple robots in agriculture. This would result in increase in crop production in the least time possible.

5. Conclusion

The purpose of this project was to look beyond the engineering community and to change the long standing pattern of self-initiated and out-dated methods of agriculture. To make this possible, we needed an independent analysis of the situation and the advice of experienced, creative and research professionals. The use of different sensing technology is finding widespread use in agriculture .The major constraints to agriculture is the increase in population and the significant decrease in cultivable land. Various technology like machine vision, image processing, and mechatronics can be assembled in an agricultural operation. The conventional large size machines available in the market are very capital intensive; moreover, they find their use in only large size agricultural fields as turning, transport and positioning are all non-productive activities. A small size robot would therefore solve these problems, would prove to be a game changer in the field of robotics, and would perform the multiple functions more efficiently and effectively. From the above calculations it is clear that tremendous time saving is done through automation in agriculture field, standards can be easily met and efficient and effective farming can be done with increased productivity.

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