Design and Development of an Agri-bot for Automatic Seeding and Watering Applications

Kruthika Ramesh, Prajwal K T*, Roopini C, Monish Gowda M H, V V S N Sitaram Gupta,
Department of Electrical Engineering, M S Ramaiah University of Applied Sciences, Bangalore, India
*Email: prajwal.ee.et@msruas.ac.in

***Abstract*— Agriculture is the backbone of rural India. Farmers face problems such as lack of timely availability of efficient workforce, as many have migrated from country side. Hence, to reduce the burden of farmers, automation in the field of farming is necessary. Automated robots are being developed over the past two decades to assist the agriculture activities like ploughing, sowing, weeding, pesticide spraying and fruit picking all over the world. This paper deals with building up an indigenous low-cost semi-automatic robot prototype that carries out a couple of farming processes. The robot developed in this work is semi-automatic and will be able to sow seeds based on seed spacing and depth while also regulating watering of plants. The applications of this can range from efficient and intensive commercial farming to using it for research and backyard gardening purposes. The developed robot prototype is tested for its functionality and performance in a restricted area. The robot is able to automatically seed and water according the path set by the user using the GUI that was developed. The amount of watering is based on the soil moisture sensor reading that is taken between the two plants The developed robot can be extended further by mounting it on a DC motor chassis which can be used to move the robot in the entire field.**

Keywords— Integrated Development Environment (IDE). Global Positioning System (GPS), Global System for Mobile Communication (GSM), Graphical User Interface (GUI), Indian National Rupee (INR), Revolutions per Minute (RPM), Parts per million (PPM).

I. INTRODUCTION

India is a land of agriculture. More than 70 % of the people in India carry out farming as their primary occupation, especially in rural areas. This caters to the food demand created by the ever-growing population. The economy of the country are greatly dependent on the income from it. Agriculture in India is still carried out using the old crude methods that are labour intensive. This results in low yields, food shortage and low profits. This will also directly affect the common people as food commodity prices increase rapidly as the demand does not match the supply. Hence, automation is required in the field of agriculture which reduces the manpower to a certain extent to carry out time-consuming and repetitve jobs.

The concept of automation in the field of agriculture is a couple of decades old. Several robots have been developed for autonomous ploughing, vegetable picking, tree climbing, farmbot, hortibot, beebot, riceplanting robot etc. that may or may not need human support. To bring complete automation without manual intervention in agricultre will take quite sometime. The aim of this research is to find out how well the concept works out in the Indian context. Based on the inputs from the end user the same robot can be rebuilt according the requirmental changes.

The robot built during the prototype phase is a semi-automated machine that sows a particular seed as per its depth and spacing specifications. It also monitors the soil moisture content and automatically waters the plants. This regulates water usage and reduces water wastage. Several other above-mentioned features can be added and make it more user friendly in future versions. The use case of this can be several ranging from cheaper but more intensive commercial farming, growing crops on a small-scale for research purposes and also small-scale backyard garden with plants of your choice. Several other functions like ploughing, weeding and pesticide spraying can be carried out by these bots as an extended function.

The overall objective is to build an indigenous low-cost semi-automatic robot prototype that carries out a couple of farming processes.

II. LITERATURE REVIEW

In [1], a review of the different types of agribots which are already available is discussed. An image processing algorithm is used to detect the obstacles in the path of the robot arm. Different techniques to send commands to the bot carry out functions especially the DTMF technique for long range is also discussed. The system that uses an image processing algorithm using IR sensors which may be difficult to work in real world scenario due to different external factors.Bluetooth is used to establish communication.

In [2], the authors have discussed about automatic ploughing, seeding, fertilizing and watering mechanisms. The automatic seeding and fertilizing is done using solenoid. Soil moisture sensor is used for automatic watering application using Rasbeery pi and internet. Auduino Atmega 328 is used for bot processes and Rasberry pi for communication with the bot. internet system is used by farmers to communicate with the bot to automatically carry out the processes; which reduces the burden of the farmers.

In [3], purpose is to develop a fully autonomous agribot for agricultural applications. GPS technology is used to locate robot in the field; Ultrasound sensor is used for obstacle avoidance: LPC arm controller and battery management system is used that drives the geared DC motors using Skid-steering mechanism; using encoders, sonar sensors and camera for navigation using image processing algorithms. Integration of drivers, actuators, control system, communication system, energy management system, task management system and sensors are mounted on a suitable platform according to required criteria; integrating with cloud services using TARBIL yet to be done. The built robot was tested in open fields but since environmental considerations are not met its design was changed during implementation.

In[4], developing an automatic drip irrigation system based on GSM was the main focus of this paper. The system uses several sensors to obtain the status of the field and the irrigation schedule is based on this data; Micro-controller and App/DTMF is used for control and communication respectively. The author developed a system which plans and schedules the watering process based on real time information of the field. Several problems in irrigation like physical work of farmer to control irrigation, wastage of water, wastage of time is solved.

In [5], the focus is to develop a robot for all agricultural tasks like ploughing, seed dispensing, fruit picking and pesticide spraying while also providing option for manual control. The system unit has developed using ATmega controller. Ultrasonic sensor is used for navigation in field; Outside, communication is through Bluetooth and GSM network; Camera and Image processing used for fruit picking and weeding The paper highlights the usage of image processing for weeding and fruit picking; Bluetooth and GSM used for communication for watering and significant potential to develop and use such systems. The author concludes that by investing initially a large amount of money, the agricultural tasks can be automated to a certain extent; beneficial in the long run.

III. SYSTEM ENGINEERING APPROACH FOR SYSTEM DEVELOPMENT

Systems Engineering (SE) approach is used to build the agri-bot as per specification so that a balanced system is developed. SE approach makes sure that the subsystems are properly selected as per requirement and no unnecessary wastage in cost and time is incurred. It helps in developing the best system with cost, schedule and performance optimization. It deals with identifying different subsystems available that constitutes concept exploration phase with divergent thinking for problem solving. The concept selection then involves convergent thinking to arrive at the best subsystem and hence, a balanced solution. The functional requirements are listed down along with hardware, software and mechanical requirements.

The functional requirements of the system is that it should perform three functions of automatic sowing, soil moisture testing and automatic watering. To carry out this process the hardware, software and mechanical requirements are jotted down in the following sections.

A. Hardware Requirements

The following subcomponents are required to carry out the required functions.

- Soil Moisture testing requires a soil moisture measuring unit with corresponding microcontroller
- Motor requirement for movement in X Y Z axis – Stepper/DC
- Motor driver for driving motors
- Mechanical Limit switch requirements to restrict motor movement
- Encoder requirement for more precision and closed loop
- Wireless data transmission through Bluetooth/Wi fi
- Bidirectional Level converter for 3.3V to 5V conversion
- Solenoid for seeding and submersible DC pump for Watering
- To switch on the DC motor and Solenoid, a MOSFET driver is used
- Voltage regulator for deriving required voltage for controller and driver supply from a 12V, 4A power supply (Adapter).
- Resistors and capacitors (for decoupling)
- Male to female, female to female, Male to Male bergs; Two pin power connectors for high and low current; Wires of different length.

B. Software Requirements

- To write embedded C logic to the microcontroller chosen Keil MDK ARM UV 5 or 4 is used
- To develop Graphical User Interface (GUI) to help users send commands to microcontroller for different applications Microsoft Visual Studio 2010 is used
- For designing the mechanical structure, CATIA V5 and Autodesk Inventor for mechanical designing are used. ADAMS is used for mechanical structure simulation

C. Mechanical Requirements

There are three mechanical design requirements for this bot. The main structure is to be conceptualized and designed

- For the seeder mechanism, a hopper/funnel with a slot to carry seeds and drop seeds when slot is opened
- A solenoid is used to open the slot
- For seeder requirements, a hopper/funnel with slot to carry seeds and drop seeds when slot is opened

- For watering, a DC motor Submersible Pump, Pipe, Sprinkler/Shower if required

IV. ELECTRONIC SYSTEM LEVEL BLOCK DIAGRAM

The electronic system level block diagram is given in figure 1. As seen in the figure, it is seen that the PC/UI is used to send data sets to the control logic embedded in the controller through the UART. Soil Moisture Sensor data can be interfaced to an ADC or GPIO pin configured as input. This is then sent to the control logic. The rotary encoder and limit switch readings are also obtained in the control logic. Based on all these readings, the motor drives are excited which in turn rotate the motors. This also sends power to the seeder and water solenoid valves to open accordingly and for a particular duration.

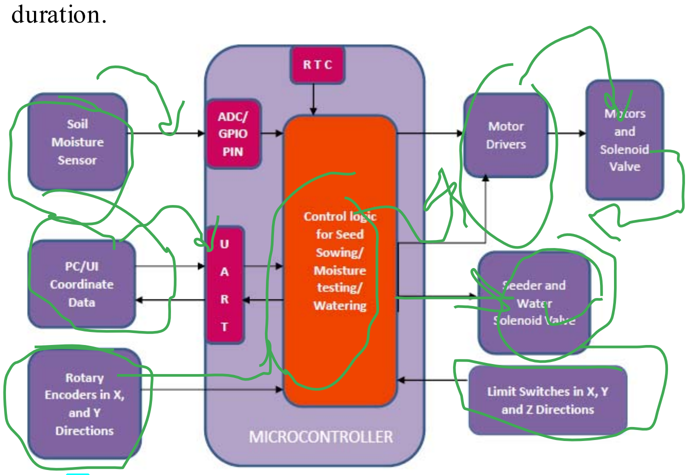

Figure 1: Electronic System Level Block Diagram

V. SOFTWARE DEVELOPMENT AND TESTING

The system involves three main algorithms to be developed. The first one is the main control algorithm that is used for complete autonomous working. This involves initializing all the peripherals and waiting for data sets from the PC through Bluetooth-UART. Based on the bytes received, the respective task is carried out as shown in Figure 2 and Figure 3. For each data set received the controller sends an Acknowledgement for successful transmission. The variables used in the flowchart are self-explanatory with key.

The second algorithm is the one written on the GUI side where the GUI based on the button clicked by the user performs a specific function. This is shown in figure 4. The form design of the GUI is shown in figure 5. The GUI also allows the user to select the COM port to send data through Bluetooth to the microcontroller. In this example, COM 21 is the Bluetooth Device Com port. The user has to first press on Reset Homing that sends a data set with command no=0 to the controller. The motors come to end positions and the end is detected using limit switches in each direction. The next command is 1 that is used for moving in X, Y and Z directions as per requirement (involves both Initialization and Start Task).

The X and Y motors during initialization move to the origin of the coordinate system simultaneously using interpolation as shown in an example in figure 6. While moving to the next coordinate set, it is required that either X or Y move simultaneously with Z using interpolation algorithm as shown in figure 7. This makes sure time is saved while moving to a particular coordinate system. The last button is to stop the send when the user clicks on the Stop button.

The control algorithm based on interpolation is discussed in figure 7. Several control algorithms for X Y plotter was looked into and interpolation technique seemed the best. Here, the difference between two sets of coordinates is found. Let's say it is dX, dY and dZ for X Y and Z direction respectively. Only two motors move simultaneously at one time. Suppose X and Y are moving together and number X steps is greater Y, then speed of X will more than speed of Y as shown in figure 7. X is termed as a dominant axis and Y the passive axis. Similarly, if Y steps is greater than X, speed of Y (Dominant) will be more than X (Passive). In the same way, X and Z or Y and Z movements are coordinated for simultaneous movement. This is continued until the last set of coordinates is reached.

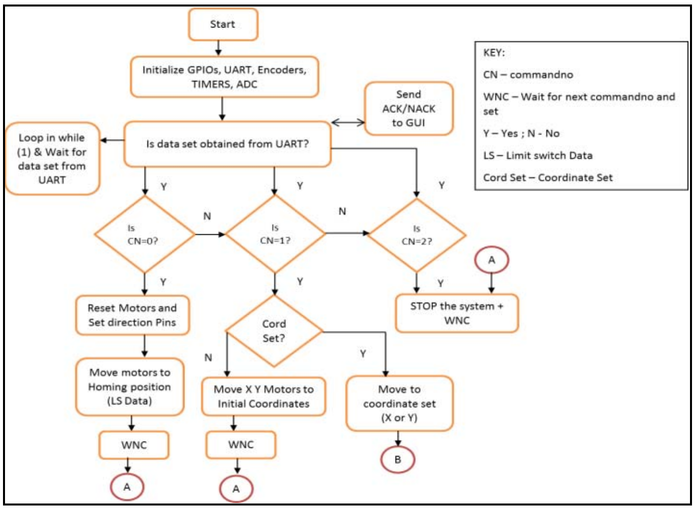

Figure 2: Main control algorithm flowchart

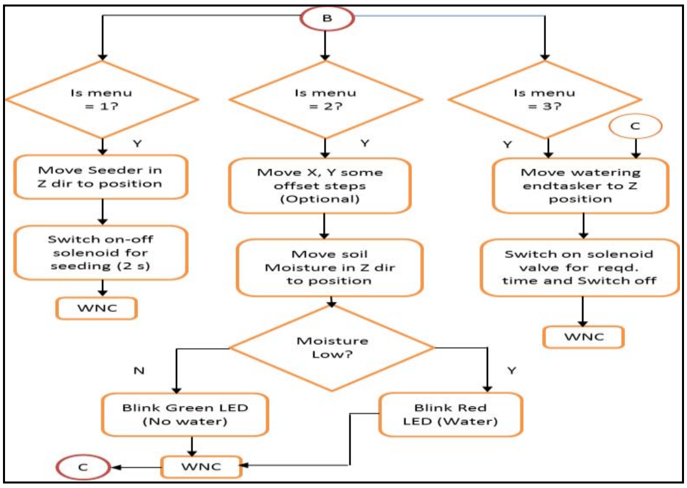

Figure 3: Main control algorithm flowchart (contd.)

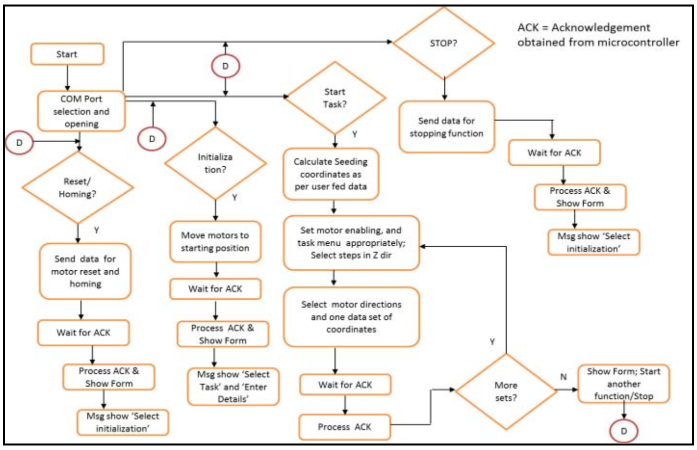

Figure 4: GUI side flowchart

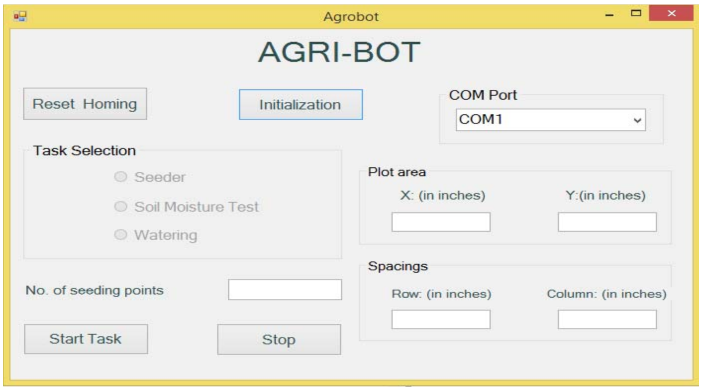

Figure 5: GUI Form

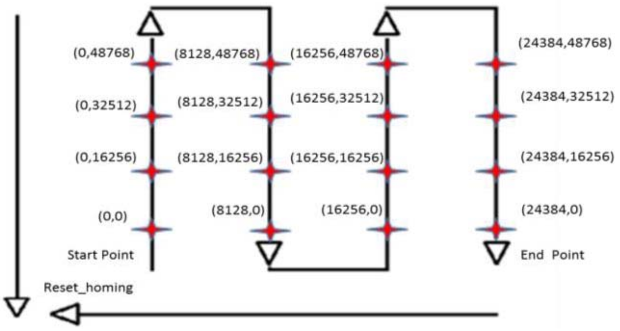

Figure 6: Path followed by the bot for seed sowing

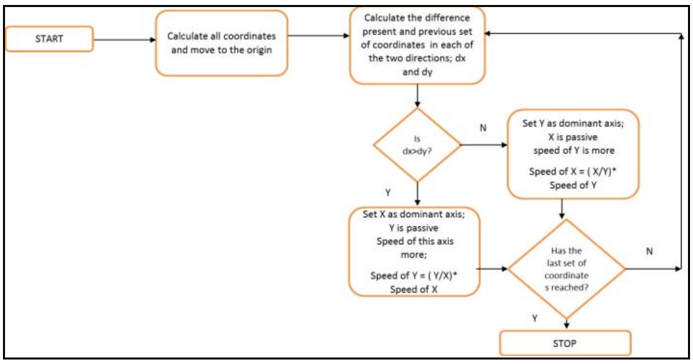

Figure 7: Interpolation based algorithm for bot movement

As an example, a plot area of 12 inches (X) X 21 inches (Y) is taken. The X dir row spacing = 2 inches and Y dir column spacing = 4 inches. The motor first resets (all move at once) and is detected by limit switch. Two inches offset on both X and Y is taken in order to calculate the coordinates as in figure 6. Once calculated, the system then moves to the starting position (2 inches offset in X and Y direction) based on interpolation technique discussed in Figure 7. This is termed as 0, 0. The algorithm makes sure that the system moves according to path shown in Figure 8. Once this is completed, reset/homing used again. Interpolation based control technique can be used for Y and Z axis and will be embedded in the code soon as this will save time. The pros of this interpolation algorithm are that it is easy to implement, consumes less data space and memory. The cons of the developed algorithm include less accuracy and frequent accumulation of the errors.

VI. MECHANICAL SUBSYSTEM CONCEPTUALIZATION

On the mechanical aspect, an X Y Z stepper motor bench was to be designed in order to test if the product concept works. The concept was designed with three motors as the controller selected could support only three motors. The design of concept in CATIA, and the structure of assembly is as shown in figure 8 and 9 respectively.

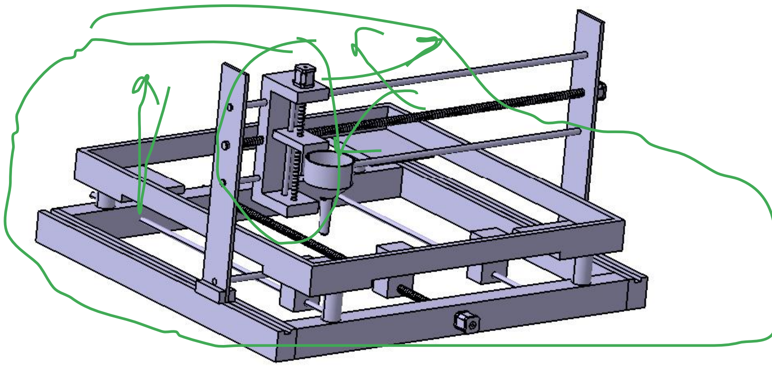

Figure 8: Perspective view of the designed structure in CATIA

Figure 9: Assembled Structure

A. Seeder Design

After literature review and ideation [8],[9],[10],[11],[12], it was decided that the seed dispenser should carry seeds and dispense it when it reaches a particular coordinate. To achieve the discussed functions, it has to have a hopper/ funnel like structure to store in the seeds and a small slot in the tube part of the funnel. The opening and closing of the slot is carried out using a thin plate attached to the solenoid that is mounted on the funnel. Weight balancing of the funnel/solenoid structure is very important. The weight will act on the structure that has been mounted on the Y- direction and may lead to overloading of the motor in the said direction. Hence careful design of the seeder design is an important task. When the required coordinate is reached, the Z-axis motor moves down to the required number of steps (in inches) and the pointed tip of the funnel is used to dig through the soil into which the seed is dropped when the solenoid is on (as the slot is opened). The duration of this process is a second after which the slot is closed as the solenoid goes off. Finally, The Z-axis motor brings the seeder back up by the amount of steps it took to go down. Figure 10 shows the drawing of the seeder design. A metal plate for soil covering attached to the Z axis assembly. When the movement takes place in Y or X direction, the seeds at the previous coordinate are covered with soil.

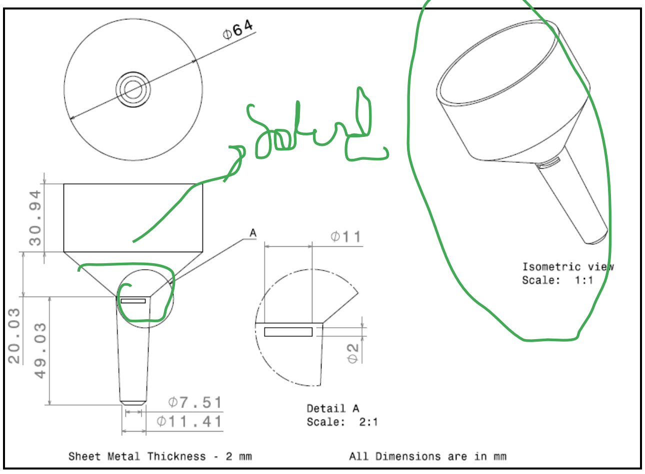

Figure 10: Seeder Design drawings

B. Soil Moisture sensor and Watering End-tasker Design

The soil moisture sensing breakout board and sensor is mounted on a Medium Density Fiberboard (MDF) board that gets fixed to the Z axis L clamp as of now. Two thick 12mm MDF boards are used to give the offset required between seeding points to measure soil moisture and pump water.cA submersible 8-24V DC motor pump is used for pumping water through a pipe with the pipe fixed in between the two MDF boards. Alternate arrangements can be made in future. Figure 11 shows the DC submersible pump used for pumping water. The motor is turned ON and OFF by the microcontroller through a MOSFET driver circuit.

Figure 11: 12-24V DC submersible pump for watering application

VII. CONCLUSIONS

The developed agri-robot sows seeds automatically by generating coordinates based on the data entered by the user. STM micro electronics 32-bit Cortex M4 ARM controller is used. STM32F4 microcontroller hold the control logic to use several peripherals interfaced to it like limit switches, encoders, soil moisture sensor, motor drivers etc. in order to make the system work. Watering is carried out using a submersible 8-24V DC motor water pump and a pipe. Several minute challenges were faced and were tried to rectify during software and hardware debug. Biggest challenge was due to misalignment in the mechanical structure fabrication and several measures were taken to rectify it.The total prototype system costing is approximately around Rs.25,000. But this will further recude once the final product has been designed after several iterations. The farmers'burden is greatly reduced if this sort of automation is adopted in agriculture. They don't have to depend much on labourers. It also saves their time as it is efficient, flexible and user-friendly. They can even rent such systems in case they cannot invest on it completely. In a nutshell, it is proved that system works as desired acocording to the functional requirements. The product specifications are matched to and are validated with complete system testing. Extension of this system to be adapted in field will definitely help combat the problems faced by the farmers in the field.

VIII. FUTURE SCOPE

1. Mechanical structure can be modified and rectified of present structure for more precise system testing
2. Mounting this/modified structure's concept on the chasis of a bot running using DC motors after slight modification.
3. Fully automate the end-tasker attachment from the present semi-automatic concept.
4. Carry out a proper Soil Moisture Unit Calibration

5. GUI can be made user friendly. Or a phone application can be developed for easy phone interface.
6. Encoders used can be of more resolution and precision so that they can be used to make the system more precise
7. One can interface the RTC and check for soil moisture content everyday at a particular time
8. Different extensions for the system can be made like ploughing, weeding, pesticide spraying etc.
9. Long range communication system can be used if bluetooth does not suffice in terms of range/distance.
10. In real time, the structure needs to be rigid and mounted on a vehicle for farming purposes which is quite challenging considering the indian irregular terrain of the land.

ACKNOWLEDGMENT

Authors would take this opportunity to thank all the members of the Ramaiah University of Applied Sciences, Bangalore for their endless support and guidance in providing enormous support to carry out this research successfully.

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