Project Report
CS 684
Embedded Systems

Nutrient Feeding Robot

Group Number 1

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I. Introduction

This project focuses on automating the task of feeding specified amount of nutrients to plants in an even manner. The project is kept general enough so that it can be incorporated as a subsystem in any Automated greenhouse implementation. By keeping the work efficient, this project helps in reducing the manpower as well as ensuring minimal energy consumption. Feeding of nutrients is a critical aspect in the sustenance of plants and care has to be taken so that the nutrients are indeed fed as close to the roots as possible rather than dumping on top of the plants.

II. Definitions, Acronyms and Abbreviations

ZigBee: ZigBee is a specification for wireless personal area networks (WPANs) operating at 868 MHz, 902-928 MHz, and 2.4 GHz. A WPAN is a personal area network (a network for interconnecting an individual's devices) in which the device connections are wireless. Using ZigBee, devices in a WPAN can communicate at speeds of up to 250 Kbps while physically separated by distances of up to 50 meters in typical circumstances and greater distances in an ideal environment.[1]

Rack & Pinion Mechanism: The rack and pinion is used to convert between rotary and linear motion. The rack is the flat, toothed part, the pinion is the gear. Rack and pinion can convert from rotary to linear of from linear to rotary.

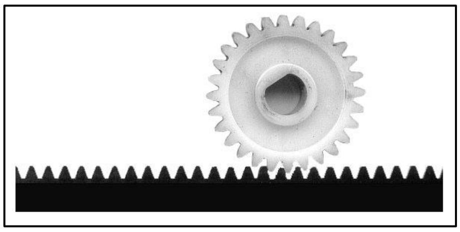


Figure 1. Rack and Pinion gear mechanism

III. Problem Statement

Given a trough number in the greenhouse, move to the trough and sprinkle nutrients evenly for every plant present in the trough. The bot has to detect each and every plant and then use some sort of mechanism to feed the loaded nutrients reach out to the roots of the plants. The bot should be able to maintain a fairly good accuracy of feeding within a particular threshold.

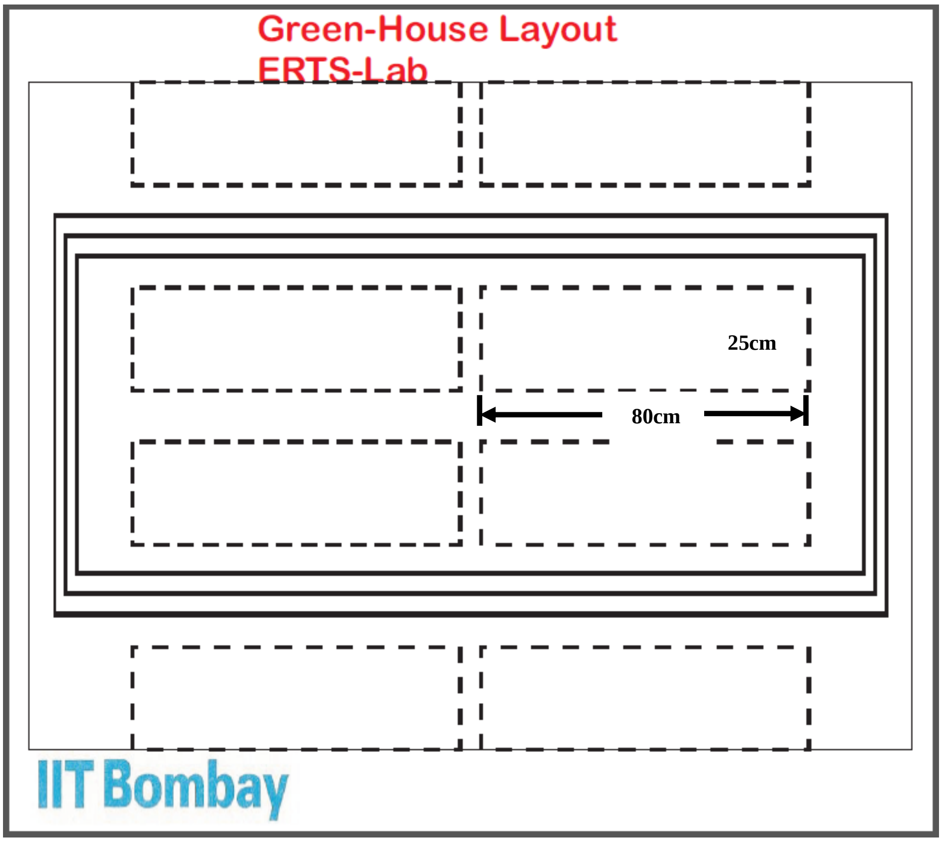


Figure 2 Greenhouse Layout used for the Project

IV. Requirements

Functional Requirements

1. User interface which takes the trough co - ordinates from the greenhouse server via Zigbee module, to initiate the feeding task.
2. Identifying the trough number, deciding which route to follow and move to the trough's starting point using white line follower module.
3. Take sufficient amount of nutrients on a Robotic arm equipped on the Firebird bot.
4. Detecting the stem of the plants using sensors and aligning the bot in a position which facilitates the feeding of the nutrients.
5. Sprinkling the nutrients evenly using a mechanism in the arm to reach out to the roots of the plants.

Non - Functional Requirements

1. Accuracy in the shaft encoder values of the additional motor required for the robotic arm.
2. Stem size for testing should have some minimum width so that detection is facilitated using the Infrared sensors.
3. Zigbee communication with the greenhouse server should have low delay.
4. Accuracy in white line sensors since the available greenhouse layout has a very thin white line for guidance in movement of the bot.
5. Accuracy of the wheels' shaft encoders since the bot is subjected to scenarios where taking turns accurately is vital.

Hardware Requirements

1. Additional DC motor with shaft encoders
2. Zigbee module
3. Vibrator mechanism
4. Infrared sensors
5. Sieve

V. Implementation

Overall System Description

- Detection of stem of the plants using Infrared Sensors
- C-shaped sieve/mesh to carry & feed nutrients
- Slider using a custom-made gear and track mechanism to move the sieve back and forth
- Vibrator attached to the sieve to sprinkle nutrients
- Interface with the Greenhouse server via Zigbee module installed on the bot

Working of the System

The bot is first placed in some fixed point in the greenhouse arena. Sufficient amount of nutrient to cover the intended area has to be placed on the bot's C-shaped sieve mechanism. The bot then waits for reception of an initiation signal from the greenhouse server to start the process. Once it receives this signal, it moves to the trough where it has to feed the plants. The movement of the bot within the arena is by means of a white line present in the greenhouse layout.

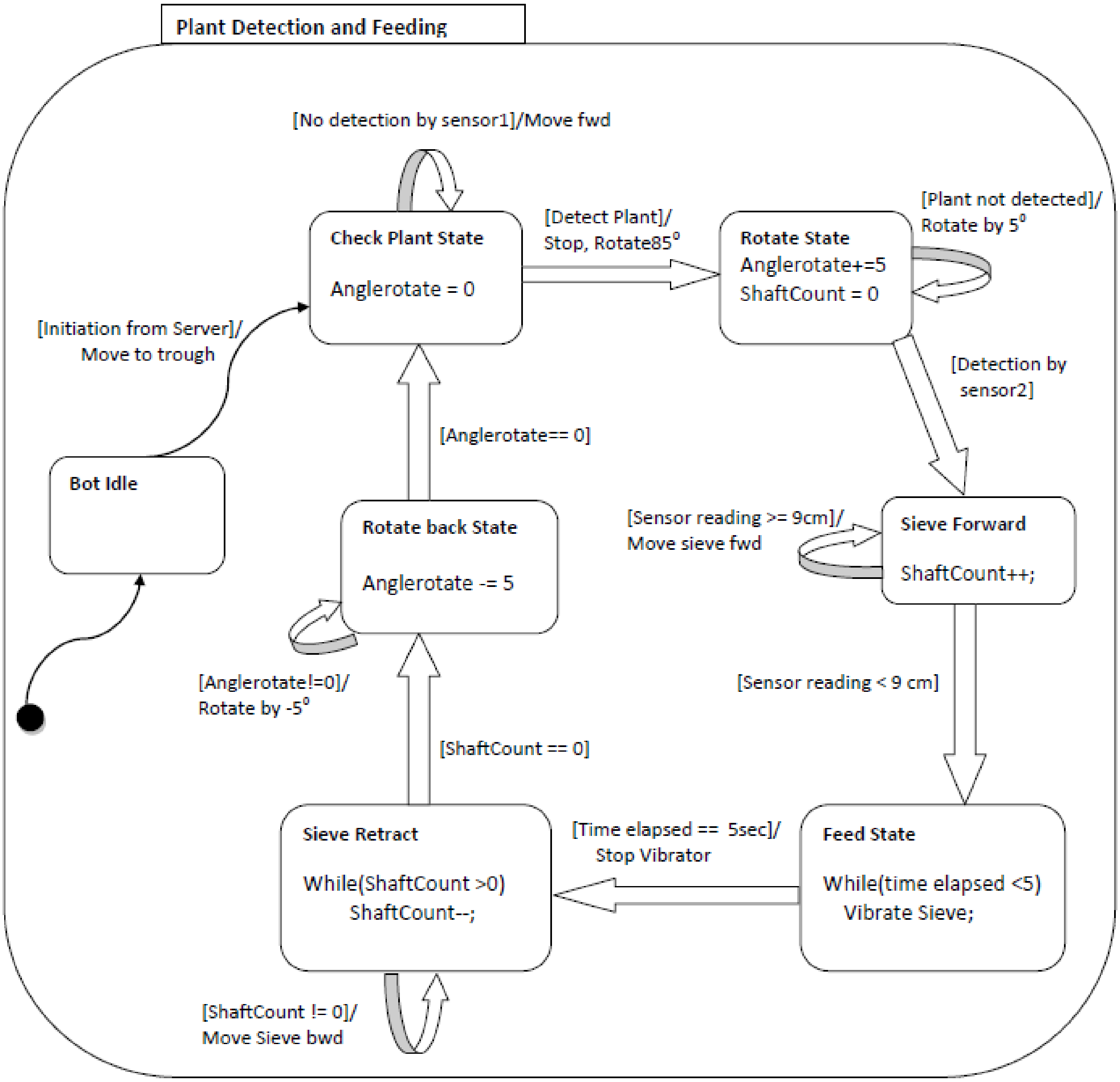
The bot has two infrared sensors attached to it. While it is moving forward one sensor on its right side will detect any stems that are present in the trough. Once a stem has been detected, the bot stops and then takes a right turn at an angle that is some degrees less than 90. One more sensor that is attached to the sieve mechanism indicates whether a stem is in front of the bot. The bot has been programmed in such a manner that it then takes short right turn in steps of 5 degrees until this sensor detects the stem.

Once the same stem has been detected by the second sensor, the bot stops. At this instant, the sieve mechanism and the stem of the plant would fall in a straight line. The objective of designing such a C shaped sieve is to catch the stem perfectly in the hollow space of the sieve. The sensor has been placed right above the sieve's hollow space to achieve this goal. A slider mechanism has been designed using a rack and pinion design powered by a fixed DC motor. The forward and backward rotation of the DC motor would then make the whole mechanism move forward and backward.

The slider mechanism enables the sieve to move forward and backward and the distance of this movement is controllable by use of the DC motor's shaft encoder. The sieve is slowly moved forward until the sensor attached to it reaches a safe distance with the stem. The motor then stops and then a vibrator attached to it is turned on for a short span of time. This vibration causes the nutrients present in the sieve to fall perfectly in the vicinity of the plant's roots. The time of vibration can be tweaked to control the amount of nutrients that needs to be fed to the plant.

Once the feeding is over, the shaft encoder of the slider mechanism's motor is used to take back the sieve to its initial position. Then the bot takes a left turn and comes back to the initial position where it detected the stem. It then moves forward and the remaining plants in the trough are also fed in the same manner.

State Chart Diagram



VI. Testing Strategy and Data

Testing Scenarios

1. The bot taking the inputs from the Greenhouse server properly.

2. The robot making use of the white line to move to a specified point in the room.

3. Ensuring that the sieve mechanism does not spill the nutrients during the forward movement of the bot.

4. Accuracy in sprinkling the nutrient evenly as required by the plant.

5. Energy estimation to determine how much battery power is required for each sub task and then based on this data, determining how many plants could be fed using a fully charged battery.

Sub Task	Energy = V * I * t (KWh)
Forward Movement(10cm)	5.614×10^{-6}
Bot – Angular movement (85^0)	9.1×10^{-6}
Bot – Remaining angular movement till stem	1.3×10^{-5}
Slider Forward movement	1.36×10^{-5}
Vibration	1.43×10^{-5}
Slider Backward movement	2.24×10^{-5}
Bot – Angular movement till initial position	1.21×10^{-5}
Full Trip for 1 stem	9.011×10^{-5} KWh
For 1 trough (Assuming 7plants in 1 trough each kept 10cm apart)	6.3077×10^{-4} KWh

The Firebird-V has a Nickel Metal Hydride(NiMH) battery pack which operates at

9.6V and 2100 mAh. [2]

Total energy that can be obtained from a fully charged battery = 2.016×10^{-2} KWh

No. of troughs that can be serviced using a fully charged battery = $\dfrac{2.016 \times 10 -2 \text{ KWh}}{6.3077 \times 10^{-4} \text{ KWh}}$

= 31.96

~ 32 Troughs

VII. Discussion of the System

Problems Faced	Solution identified
The initial design of the sieve was such that it did not feed the nutrients to an area close to the plant. Instead the nutrients were dumped on top of the plant. This design only works when the plants are very small and hence was impractical.	The shape of the sieve was modified to a C-shaped design. Thought was given as to how the sieve could be moved close to the plant to feed the plants. This led us to the idea of using a slider mechanism based on a gear and track setup.
Infrared Sensors give some random values which are erroneous and this affected the code that was written for detection of the stem. This happens because for detection of some object a conditional statement is written which checks if the value obtained from the sensor falls in a particular range. If an erroneous value comes within this range the bot will behave unpredictably.	Whenever a value within the specified range is obtained from the sensor, a counter is incremented. Only when this counter reaches some threshold value say 4 or 5, the object is assumed to be detected. Care has to be taken that if the threshold is set to a very high value, the object detection may have issues if the bot is moving fast.
Once the stem was detected by the bot we had initially written code to make the bot turn a full 90^0 and then do the rest of the process. This turned out to be a bad idea since the accuracy of the position encoders of the bot's wheels was not that predictable and certain turns caused the bot to turn the bot more than 90^0 resulting in failure in the detection of the plant.	Instead of taking a complete 90^0, the bot was coded to take an angle of 80^0 and then take small steps of 5^0 until the sensor could detect the plant.
Initially we used a DC motor without position encoder for the slider mechanism and the problem we faced was in bringing the slider back to its initial position after feeding the plant. The idea wholly depended on the use of delays as well as the readings from the infrared sensor which resulted in inaccurate values as well as unpredictable behaviour.	The problem was handled by using a DC motor with position encoder and noting down the shaft count while moving forward and moving backward until the same shaft count was reached.
Initially the DC motor to control the slider mechanism was connected to the C1 slot in the	Switched the DC motor to the C2 motor slot.

Firebird bot. Although the velocity of this motor could be configured, the interrupts from this slot is by default turned off in the bot. This means that the position encoders of C1 motor cannot be used.	
C2 motor slot's port configuration for velocity control is not stated in the software or hardware manual.	We could not resolve this issue and had to code in such a manner that we gave lots of delays to control its velocity.

VIII. Future Scope

1. For feeding a plant after detection the current implementation depends upon the bot to take a 90^0 turn and then do its function. Instead as a power efficient alternative, the slider mechanism itself could be rotated by 90^0 left or right instead.
2. Current implementation focuses on the sprinkling aspect rather than on the fetching of the nutrients. The fetching of nutrients can also be automated. One proposed solution is to use one more robot which controls the opening of a container filled with nutrients using a servo motor. The feeding bot can move underneath this container and communicate with the other bot wirelessly and control opening or closing of the container.

IX. Conclusions

The project is kept general enough so that it can be incorporated as a subsystem in any Automated greenhouse implementation. By keeping the work efficient, this project helps in reducing the manpower as well as ensuring minimal energy consumption. Feeding of nutrients is a critical aspect in the sustenance of plants and care has to be taken so that the nutrients are indeed fed as close to the roots as possible rather than dumping on top of the plants.

From the results obtained in the energy analysis, the robot is capable of feeding approximately 32 troughs containing 7 plants on a fully charged battery. This implies that the project could be used for practical applications in a real greenhouse.

References

[1] http://searchmobilecomputing.techtarget.com/definition/ZigBee

[2] Fire Bird V ATMEGA2560 Hardware Manual

[3] Fire Bird V ATMEGA2560 Software Manual

[4] WinAVR User Manual – 20100110, http://dybkowski.net/download/winavr-usermanual.html