# REVOLUTIONIZING FARMING USING SWARM ROBOTICS

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***Abstract*— Swarm robotics is a diligence of swarm intelligence, it deals with natural and artificial systems in an environment composed of many individuals that co-ordinate using decentralized control to perform a certain task or work towards a common goal in the presence of a co-ordinator. This highly adaptable and self-organized system of robots is a new approach to co-ordination of multi robot systems.**

**Incorporating this system of robots revolutionizing the process of farming is one of the major breakthroughs in this generation of robotics. This synopsis mainly deals with application of this completely autonomous system in scouting, ploughing, providing water, harvesting etc., also constantly monitoring the crops during its growth period and keeping the farmer informed about the crops year round. This system is implemented by reducing the constraints of cost and power consumption, hence diluting the amount of hardware required for its implementation without compromising the quality of service. It also proposes a simple operation mechanism for high efficiency of the system and simple communication protocol to ensure fast intermediate data exchange. Lastly, throws light on the future challenges faced and its application of the same structure in various fields.**

***Keywords*— Swarm Intelligence, Decentralized, Farming, Self-organized, multi-robot, Autonomous.**

## I. Introduction

Swarm robotics [9] is an advent in the coordination and multitasking of multi-robot systems which consist of large numbers of mostly simple physical robots. This collective behaviour emerges from the communication and interactions between the robots, interactions of robots with the environment and humans[3][5]. The artificial swarm intelligence has been inspired by biological studies of behaviour of ants, bees, wasps and termites [16][17]. This behaviour and flawless co-ordination has been the spark for changing the perspective on how robots were understood, and gives a new trend to their functionality; such as solving problems through large population.

Due to ever growing prices of groceries and staple crops, we plan to introduce a simple autonomous system where swarm robots will reduce the cost, eliminate the major problem of unavailability of work-force, reduce waste of land drastically, increase productivity, constantly monitor the crops throughout its growth period. This system will be able to achieve a very high efficiency at a low cost. It also drastically increases the productivity of the farmer and yields him high profits, with very less investment. The highly autonomous nature of this system adds to its user friendliness. It has practically zero maintenance issues. Hence, reducing cost of all the basic goods in the market which directly affects the economy of the nation. This system aims in providing faster, cheaper, real time cost effective solutions.

### A. *Swarm Robotics in Farming*

Agriculture plays a major role in the economy of a country. With the advancements in every field of our day-to-day life, people are advancing towards new trends in the market. However there are a few setbacks; one such field which has observed a major setback is farming. The increased immigration of people to cities, increased labour wages, lack of man power, increased cost of production, and have made farming a bane to the farmers. The result of which is increased prices of food and other consumable products. In order to solve the problem of labour force and the labour wages burden on a farmer, we are proposing a model based on swarm robots or simply called as robotic farmers. Swarm robots are basically a group of robots which operates in coordination to achieve a specific task, which is farming in our scenario. We mainly concentrate on 4 important processes in farming viz., ploughing, seeding, irrigation and harvesting. The unique selling proposition of our project is its efficiency in overcoming the power consumption barrier; since most of the farming is performed during day time, solar panels can be mounted on top of swarm robots and solar energy can be harnessed for farming processes. All the mechanical actions of bots are governed by Newton's Laws of motion and the directions are determined by Fleming's rules, which make the system operation more reliable. The main hardware comprises of MSP430, L293DNE, Zigbee Modules, power supply circuitry and the softwares used are CodeComposerStudio and Termite.

## II. Dynamic Structure

The Robots which are used to achieve this functionality consists of The Texas Instruments MSP430 family of ultra-low-power microcontrollers mounted on the top forms the heart of the robot system, consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency, hence solving the major problem faced in adaptability as complicated algorithms can be interfaced easily. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 1 µs, thus having very high response time.

MSP430G2253 series are very low cost ultra-low-power (1.8 V to 3.6 V) mixed signal microcontrollers with built-in 16-bit timers, up to 24 I/O pins, a versatile analog comparator, and built-in communication capability using the universal serial communication interface with enhanced UART supporting auto baud-rate detection, which plays a major role in interacting between the user and robot.

The motors for the movement of the robot have been implemented using L293DNE quadruple high current H-Driver used to control 2 bidirectional motors. The power is drawn from a simple 6F22 9V battery.

For the wireless communication of data ZigBee has been employed. ZigBee is a low-cost, low-power, wireless mesh network standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications. Operating with a very small voltage (5V) drastically reduces the power-usage; therefore smaller batteries can easily satisfy the power requirements of the module also increasing the battery life. Incorporation of mesh networking not only provides high reliability also enhances the range within which the system can be controlled in a diverse environment. In our work, we have used the ZigBee router to transfer the information from the computer to the robot. We transmit the data to ZigBee connected to computer through software by name TERMITE. This software accomplishes our need for establishing communication. Then the ZigBee (connected to the robot) receives the information and passes the information to the microcontroller to perform the task specified by the programmer.

Termite is an easy to use and easy to configure RS232 terminal. A conventional easy to use interface consists of a program interface line, capable of representing the transmitted and received data. Other advantages include easily configurable baud rate, flow control, external plug-in interface and local echo. Highlights of the utility are the ease of installation (possibly with pre-configured settings) using a heuristic search for the appropriate COM port and, as was mentioned, its user-friendliness.

The L293DNE is a quadruple high-current half-H driver. The L293 is designed to provide bidirectional drive currents of up to 1 A at voltages from 4.5 V to 36 V. The L293D is designed to provide bidirectional drive currents of up to 600-mA at voltages from 4.5 V to 36 V. Both devices are designed to drive inductive loads such as relays, solenoids, dc and bipolar stepping motors, as well as other high-current/high-voltage loads in positive-supply applications. All inputs are TTL compatible. Each output is a complete totem-pole drive circuit, with a Darlington transistor sink and a pseudo-Darlington source. Drivers are enabled in pairs, with drivers 1 and 2 enabled by 1,2EN and drivers 3 and 4 enabled by 3,4EN. When an enable input is high, the associated drivers are enabled, and their outputs are active and in phase with their inputs. When the enable input is low, those drivers are disabled, and their outputs are off and in the high-impedance state. With the proper data inputs, each pair of drivers forms a full-H (or bridge) reversible drive suitable for solenoid or motor applications

## III. Why Farming

The lack of technology involved in farming methods has resulted in extreme dip in productivity, and the efficiency of the traditional methods which are still followed by major Indian farmer population has to be replaced by new effective methods of farming. Its implementation has been the major issue as most of the farmers are illiterate and have no hands on experience with technology. Scarcity of capital has driven most of these farmers out of business. Lack of storage space, adverse transportation facilities, ineffective and improper post-harvest management, water availability, depletion of soil, unavailability of cheap labour and lack of crop insurance crop monitoring marketing are other side concerns which have been provoking farmers to jump to other professions hence this situation has resulted in dwindling number of farmers.

Depletion in production quality overuse of fertilizers and pesticides have also has adverse effects on the environment.

## IV. Effects on Society

Farmers being the economic backbone of our country, any slightest glitch in the production of raw materials or food crops adversely affect the consumer and the stock market of the country. This results in increase in prices of basic needs, sky rocketing groceries and vegetable prices. The government has its hands crossed in the subject of dwindling number of farmers due to lack of basic needs for farming. Increase in farmer suicide rates have become a major concern for the Indian farmer’s society. Urbanization and industrialization of farm lands has left us nothing but to import staple crops and raw materials from foreign countries at high prices, which in turn has led to decrease in self sufficiency of the nation and lack of Nutritious appetite. Lastly profitless investments have driven the farmers to bankruptcy and losing lands to various multinational companies (MNC’s).

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## V. Existing Technologies

IOWA inventor David Dorhout is working on a swarm of robots that could revolutionize agriculture. The prototype "Prospero" is a swarm of autonomous microplanters. The next phase in the project will be robots that tend, robots that harvest, and finally robots that can do it all. Obviously the project has a while to go before it could be an affordable farming method.

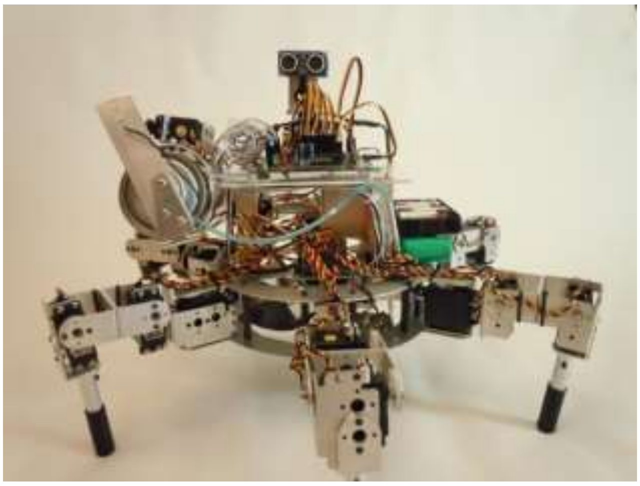

Fig. 1 Prospero Swarm Bot

Operating as one organism to plant a field, they determine where and how to plant each seed to maximize the productivity of each acre, farming inch by inch. First they check the ground below to see if the seed has already been planted and if proper seed spacing has been achieved. If not they will plant a seed at the optimal depth. Then they mark the seed's location and apply any necessary fertilizers, herbicides and insecticides. It communicates wirelessly with the rest of the swarm to optimize the swarm's planting efficiency, letting nearby robots know if it needs help planting in that area. Prospero does all this now.

## VI. Preliminary Design

The design of the bot and the placing of the various elements and the three layered structure is as shown in the figure. The bottom layer is designed to accommodate the harvesting tool as well as the battery source for the operation of the bot and the plough tool setup. The middle layer consists of two square containers containing seeds and the water. Finally the hardware required for the operation is mounted on the top most layers of the bot.

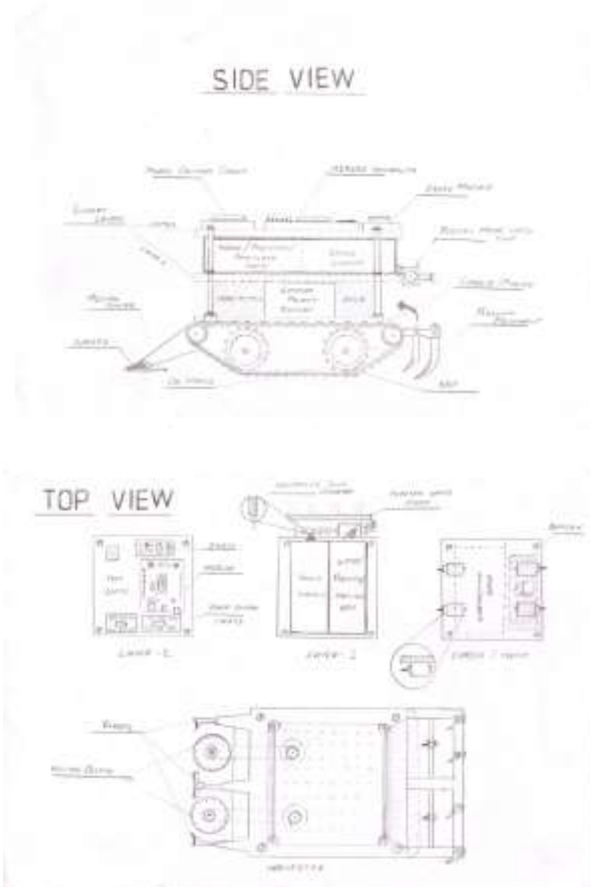


Fig. 2 AutoCAD Design

## VII. Implementation

Our major priority has been to apply this immense potential of distributed, co-ordinated systems to revolutionize farming. We believe in the distant future farming will be completely overtaken by robotic systems [12]. The first batch of swarm robots will scout the area, then a few robots will then automatically plough the field based on the scouting data obtained. The next batch of robots will then sow the seeds in the required area. Soon after these fertilizers, insecticides, pesticides are sprayed

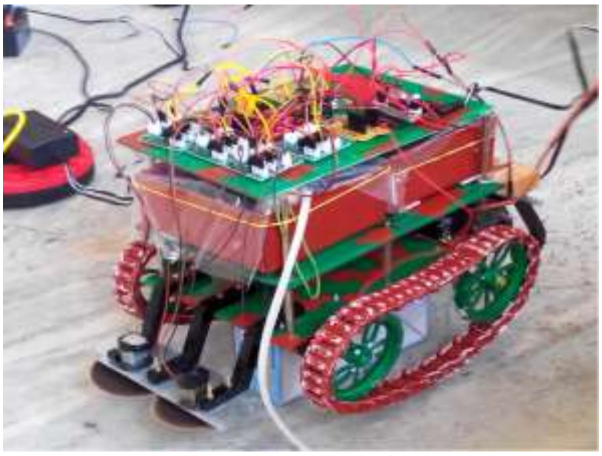

Fig .3 Final Structure

using the next batch of bots. The last batch of robots will then water the entire cropping area. In the later stages the yield from the crop is automatically processed and the products are segregated by these robots.

### *A. Block Diagram*

The Robots which are used to achieve this functionality consists of The Texas Instruments MSP430 family of ultra-low-power microcontrollers mounted on the top forms the heart of the robot system, consists of several devices featuring different sets of peripherals targeted for various applications. The architecture, combined with five low-power modes, is optimized to achieve extended battery life in portable measurement applications. The device features a powerful 16-bit RISC CPU, 16-bit registers, and constant generators that contribute to maximum code efficiency, hence solving the major problem faced in adaptability as complicated algorithms can be interfaced easily. The digitally controlled oscillator (DCO) allows wake-up from low-power modes to active mode in less than 1 µs, thus having very high response time.

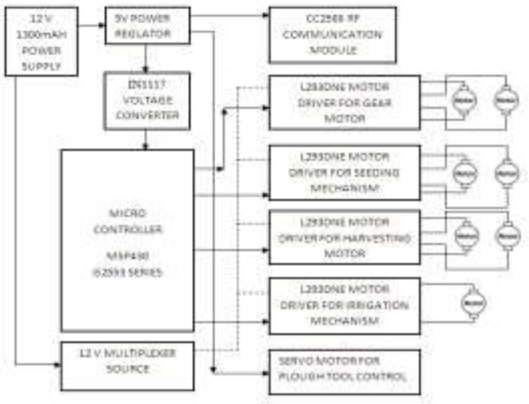


Fig. 4 Block Diagram of the Module

MSP430G2253 series are very low cost ultra-low-power (1.8 V to 3.6 V) mixed signal microcontrollers with built-in 16-bit

### *B. Algorithm*

**Step1**: Swarm robots to be activated are powered ON.
**Step2**: They are positioned in respective areas.
**Step3**: command is given to the robots through zigbee transmitter.
**Step4**: On reception, ploughing mechanism is first enabled. Here the soil is loosened and tracks are formed with the specially designed plough tool.
**Step5**: After the completion ploughing the tool is inclined to an angle of 60degree from the ground level.
**Step6**: Seeding mechanism is enabled. The plough tool is reconfigurable hence the same tool is used seeding where the seeds present in the seed container flows out through this plough tool which is provided with a channel for the seeds to flow uniformly. The seeds are dropped as and when the bot moves over entire field.
**Step7**: Seeding mechanism is disabled.
**Step8**: Irrigation mechanism is enabled. The water is sprayed to the entire field with the flow control achieved with the help of water pump immersed in water. Meanwhile the plough tool is shifted such that it covers the soil over the seed sowed.
**Step9**: Irrigation mechanism is disabled and the plough tool is lifted from the ground level such that it does not disturb the further mechanisms.
**Step10**: Harvesting mechanism is enabled. The harvesting tool is controlled using DC motor of 1200RPM, Which rotates the harvesting tool such that it cuts the crops as the bot moves over the entire area of the field till the harvesting is completed.
**Step11**: Harvesting mechanism is terminated.
**Step12**: All the mechanisms are completed successfully.
**Step13**: Swarm robots are powered OFF.

### *C.* Flowchart

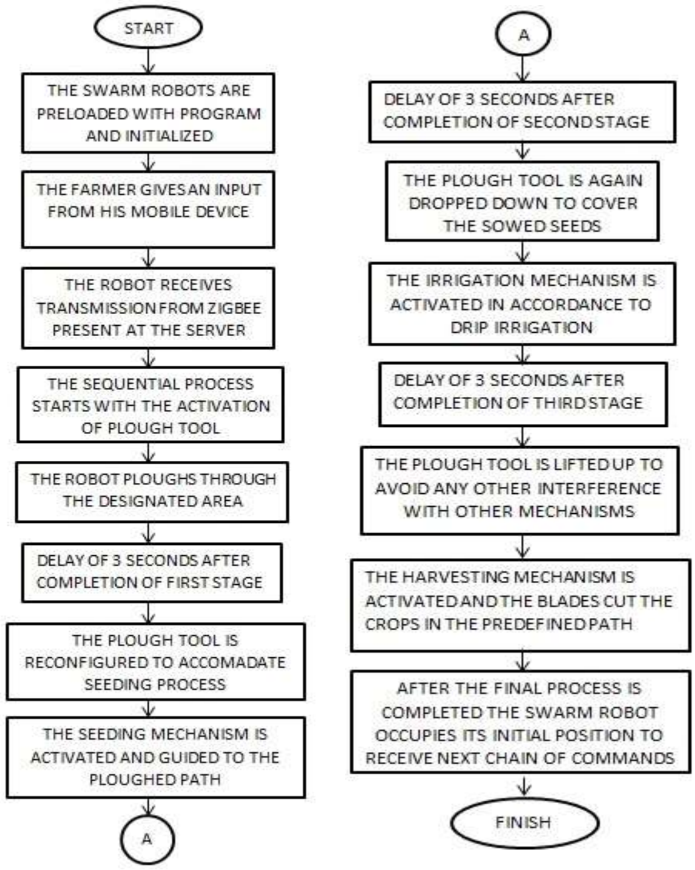


Fig. 5 Flow Chart of Mechanisms

The flowchart clearly represents the various processes that have been inculcated in the present swarm bots.

## VIII. MECHANISM

### *A. Ploughing*

The first and foremost step in the farming is ploughing. This process is done in order to loosen the soil and create a path or tracks on the farm land in order to sow the seeds uniformly [14]. The structure and the design of the plough tool depends on the various constraints such as the type of soil to be ploughed and the depth required based on the type of crop that has to be grown and so on. There are many types of ploughing mechanisms that has been adopted which can be broadly classified into two categories; one is the manually driven ploughing tool and the other being machine driven. We have designed the plough tool using Catia software.

The design and dimensions of the plough tool are in accordance with the size of the bots. The angle of inclination and length of the tool are calibrated by considering the depth required for ploughing the soil and it varies with the type of crops and soil. The tool is operated by using a 12V dc servo motor. The initial and final positions of the plough tool are controlled by coding it in a required manner using CodeComposerStudio.

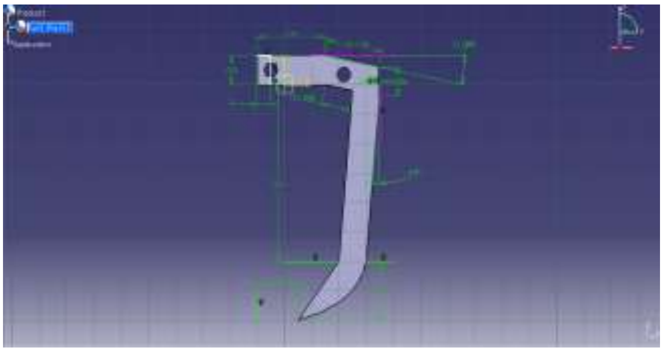

Fig. 6 Plough Tool

*B. Seeding*

The next major step in the process of farming is seeding. Seeding usually depends on the type of crops being grown and the type of seeding varies over a variety of crops. In case of robots, utmost care has to be taken to ensure uniform spacing and controlled flow of the seeds from the bot; where in the seeds required for sowing is stored in a container and is mounted on the bot at the suitable position. The typical structure used for the seeding is as shown in the figure.

Fig. 7 Seeding Provision

Seeding is controlled using the following mechanism as shown in the figure below. Pulses form MSP430 board is based on the frequency by which the seeds have to be sent. This is usually dependent on the speed if the Swarm bot or the nature of the seeds that has to be dispatched.

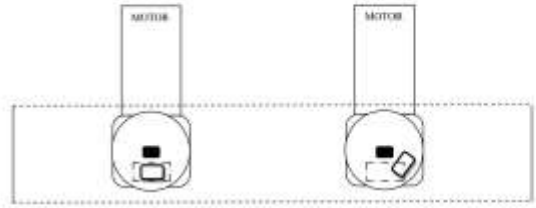


Fig. 8 Seeding Mechanism

*C. Irrigation/ Fertilizer*

Based on the amount of water required for that particular crop suitable irrigation methods are adopted. Our bot inculcate the drip irrigation for the irrigation process. The water required for the irrigation is stored in a container and is mounted onto the bot. The frequency of drop of the water is controlled using water pump. The water from the container flows to the field through the structure provided for irrigation uniformly. The same irrigation tool can be used for fertilizing by replacing the water with fertilizer.

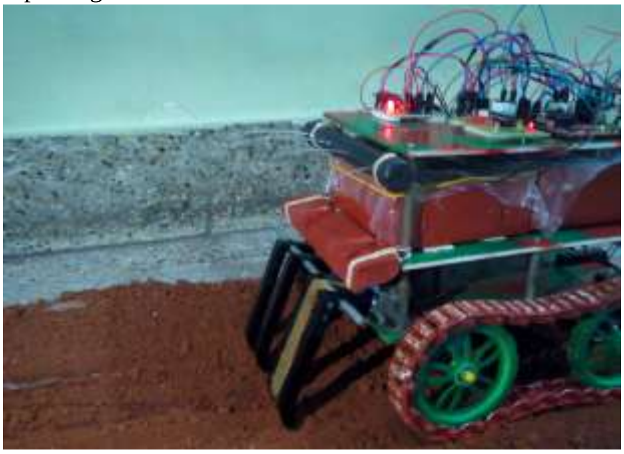

Fig. 9 Irrigation/ Fertilization Implementation

*D. Harvesting*

The final process under farming is harvesting where in the crops are cut down or chopped using the designed harvesting

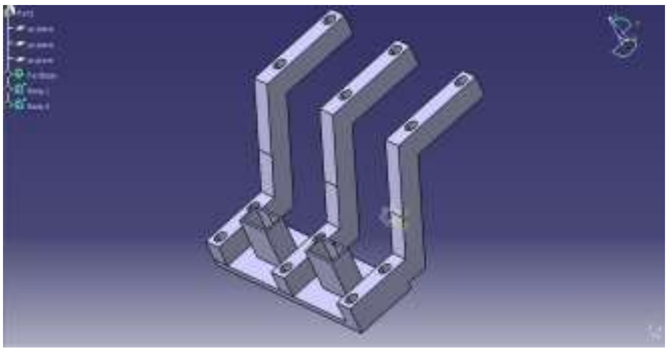

Fig. 10 Harvesting Support

tool. The harvesting tool is driven by the dc motor which rotates the harvesting tool at a rate of 1500rpm which is sufficient enough to cut down the crops in order to separate the grains from the crop. The present bot only performs the crop chopping action and doesn't involve any process regarding the grain separation from the crop.

### *E. Connectivity*

In this environment we have hosted a SQL server from our laptop which is connected to an android mobile device. This connection can be established in from of Wi-Fi, Bluetooth, or a simple data network connection over the network or service provider [10]. The diagram below represents the connection of the system program of TERMITE to the Code Composer Studio.


Fig. 11 Wireless control of swarm robots using mobile phone

## IX. RESULTS

The experiments were conducted on a piece of land replicating the farm field. The area of the farm land was scaled down to $1m^2$ for the purpose of obtaining the experimental results in the controlled environment. All the environmental factors such as uneven ground, presence of stones, etc., were employed in the test area.

In this setup the swarm robots were deployed to perform all the four mechanisms sequentially on the dry and wet soil. After many test runs, the readings were tabulated.

| FUNCTION | RECORDINGS (Dry) | RECORDINGS(Wet) |
|---|---|---|
| Ploughing | Asymmetric ploughing at distance of 2cm -2.5cm | Asymmetric ploughing at distance of 2cm -2.2cm |
| Depth achieved | 1.5 cm – 1.7cm | 1.0 cm – 1.2cm |
| Torque of Helical Gear motor | 5 Kg/cm (10Kg/cm for 2 motors) @ 150RPM | 4.7 Kg/cm (9 Kg/cm for 2 motors) @ 150 RPM |
| Torque of Side Shaft motor | 1 Kg/cm @ 75 RPM | 1 Kg/cm @ 75 RPM |
| Power Drawn from the battery Source | 5.8185 W | 5.9852 W |
| Average operation time for 1300mAh Lead- Acid Baterry | 6-8 hours | 5-6 hours |
| Distance between batch of seeds | 0.1cm – 0.2 cm | 0.1cm – 0.2 cm |
| Average time of mechanism to be completed | 40 seconds | 45 seconds |
| Average time required for entire process | 3 Minutes 50 Seconds | 4 Minutes 10 Seconds |
| Average growth time of Ragi seeds planted | 6 Days (~144 hours) | 5 Days (~120 hours) |
| Average time required to empty water tank | 50 minutes | 50 minutes |
| Average time required to empty seed storage | 7 hours | 7 hours |

## X. ADVANTAGES

The three major criteria that drive our system are (1) *Speed*, (2) *Accuracy*, (3) *Flexibility and* (4) *Low Cost*. The systems mentioned above are either product specific or can handle equipment in only. Diversity in delivery systems has yet to be achieved and the system proposed in this paper completely satisfies all required multitasking capabilities and bridges the gap between the warehouse and the industrial activities.

It drastically reduces the manpower thereby eliminating human error, thereby achieving maximum efficiency. Each robotic unit in the proposed system costs around $100 to $120. Therefore a complete system can be easily incorporated in a few thousands of dollars. It uses simple control software to control hundreds of autonomous mobile robots; this robotic fulfilment system enables extremely fast cycle times, from receiving to picking to shipping. The system is completely modular, which means you can start with a small system, and add more gear as your business grows. The size of the robots isn't one of the constraints as it should posses enough mechanical power for heavy lifting. The result is a building that is quick and low-cost to set up, inexpensive to operate and easy to change anywhere in the world. Offers complete industrial delivery solution.

## XI. TECHNICAL CHALLENGES

One of the major challenges faced by any robotic system is obstacle avoidance [11]. Here in this work, robots itself can be a major obstacle while tracking the assigned path, due to the presence of other bots which are assigned similar work. This can be overcome using a simple process even in the absence of inter-bot communication.

When request from two or more users for the same or different materials coincide, there is a high possibility that path for both the bots are similar and they themselves might be an obstacle to each other [13]. This will result in complete breakdown of the system. In order to overcome this drastic problem, the robots are assigned different time slots, based on the priority of the request sent from the user. Therefore each robot is given a priority number; the bot with higher priority will be given the clearance and assigned the path to the specific location in the warehouse. The instructions for the next robots with the next higher priority number are withheld for a certain amount of time. After which the path is assigned to complete the requested task.

The next challenge is to overcome the range of data transmission between two or more robots. Infrared systems which were used traditionally had many drawbacks such as line of sight communication, loss of data in the presence of heat signatures etc., this can be overcome by using ZigBee modules which have high communication range with larger bandwidth to handle a lot of data. The module implemented in this design has indoor communication range of 30-40 meters and outdoor communication range of 70-100 meters. Also the proposed communication protocol enhances data transfer, and the system doesn't misbehave when data is lost. Thus, eliminating the problem of connection loss or information leak.

## XII. Other Applications And Future Challenges

In security- Military and police organizations use robots to assist in dangerous situations, such as detect landmines.

In restaurants- Robots can serve as waiters and cooks.

In household activities- This technology implemented in industries can also be applied for domestic uses such as fetching food from the refrigerator or from any other part of the house. It can also keep the premises clean and tidy by employing robots with vacuum pumps. It has the ability to guide elderly people to move around the house, also guide them while walking on the streets.

In order to cope up with the ever-changing technology, the future of this system can be enhanced by employing vision-guided model which moves through manufacturing, warehousing, and distribution operations utilizing stereo cameras to build 3D map of environment. It then uses map and its own reasoning ability to navigate predetermined path to complete assigned transport task. Using GPS sensors to track the exact area with pin point precision; along with other altimeter, so as to cover different floors of the area.

The robotics industry, while in development for half a century, is still relatively in its infancy and faces a number of challenges in the years ahead. Besides the technological and cultural hurdles to overcome, questions remain unanswered regarding their economic and environmental impacts as well as the ethical issues of human and robot interaction. What is obvious is that robots, whatever form they take, will increasingly play a role in societies around the world and that the ecosystem of services and capabilities will offer increasing opportunities for designers in the years to come [15].

Swarm robots can also be presented as self-healing mini robots for search and rescue operations. The self- healing robots will be able to dock with each other, share energy, and co-operate to maximise their abilities to achieve different tasks [1]. A swarm could be released into a collapsed building following an earthquake. They could form themselves into teams searching for survivors or to lift rubble off stranded people. Researchers from 10 universities such as RICE, California Institute of Technology, University of Texas etc., are associated with the project. Future applications include space exploration, environmental services and medicine.

## XIII. Conclusion

Thus swarm robotics has been one of the cutting edge technologies of the present and has the potential to replace all the existing robotic systems or those systems which still require a lot of manpower; hence change the course of the future. Even though our paper stresses on application of the prototype in a controlled environment, it can be easily extended to larger operating environments. Its simplicity and cost effectiveness have been its major weapons. Limited hardware use makes it easy to handle and maintenance free. A simple communication protocol enables the system to function without any technical problems and also provides real time solutions. In a broader sense Swarm system intelligence and architecture can be configured and programmed to suit any modern day system environment. However, there is an increased need for research and development of Swarm Intelligence based systems which alter the course of how robots are understood by the common man.

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