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 to be 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. 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, and 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.

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 basic needs, sky rocketing groceries and vegetable prices. This colossal wastage can be avoided by developing scientific ware-housing facilities. The government has taken several steps to provide storage facilities.

E. Storage of food grains:

Storage of food grains is a big problem. Nearly 10 per cent of our harvest goes waste every year in the absence of proper storage facilities. This colossal wastage can be avoided by developing scientific ware-housing facilities. The government has taken several steps to provide storage facilities.

F. Farm Implements:

Although some mechanisation of farming has taken place in some parts of the country, most of the farmers are poor and do not have enough resources to purchase modern farm implements and tools. This hampers the development of agriculture.

Technological advancements help provide farmers with tools and resources to make farming more sustainable. New technologies have given rise to innovations like conservation tillage, a farming process which helps prevent land loss to erosion, water pollution and enhances carbon sequestration.

IV. 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

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.

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.

An increasing number of "FARMBOTS" are being developed that are capable of finicky and complex tasks that have not been possible with the large-scale agricultural machinery of the past. For instance, the bots are under development to remotely check crops for their growth, moisture and signs of disease.

It is not just on the ground that technology promises to transform farming. Unmanned air vehicles, or drones, are also coming into play on farms. In South America, with its vast ranches, drones are being used for the surveillance of widely dispersed herds and crop monitoring, and in Japan smaller models are programmed to spray pesticide on crops. In the US, there are experiments under way to use drones for surveillance and perhaps even herding.

The use of unmanned robots is rather more futuristic but people are working on it. As well as field operations, there is potential in fruit harvesting and even livestock management. It is certainly an exciting time to be involved in farming. But there is also scepticism over how likely it is that new robot technology will take off. The potential use of robots on farms has been discussed for years, but we haven't yet seen anything practical close to reaching the market.

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.

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 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.
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 seedling where the seeds present in the seed container flows out through the 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.

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

C. Functional Block Diagram

The MSP430 has one active mode and five software selectable low-power modes of operation. An interrupt event can wake up the device from any of the low-power modes, service the request, and restore back to the low-power mode on return from the interrupt program.

It is extremely easy to put the device into a low-power mode. No special instruction is needed: The mode is controlled by bits in the status register. The MSP430 is awakened by an interrupt and returns automatically to its low-power mode on return from the interrupt program.

A wide range of peripherals is available, many of which can run autonomously without the CPU for most of the time. They classed as application-specific standard products.
(ASSPs) and contain specialized analog hardware for various types of measurement.

C. Communication

There are separate shift registers for transmitting and receiving, in contrast with the single register in a loop used in the USI and the conceptual model of SPI. Moreover, these registers are double-buffered and the user has no direct access to the shift registers themselves. This means that a byte is moved from the receive shift register to RXBUF as soon as reception is complete, which leaves the shift register ready to accept the next transfer. Similarly, a byte written to TXBUF remains in its buffer until the previous byte has been transmitted, at which point it is moved to the transmit shift register. This relaxes considerably the constraints on handling interrupts in the USI, where the shift register must be read and updated rapidly between transfers. Although there are separate registers, reception and transmission are not independent because of the nature of SPI. A byte must be sent in order to receive a byte, even if there is nothing connected to the output pin.

D. Power Regulator

Since most of the sensitive components like the ZigBee, servo motor which is used in the following robots needed a controlled non-fluctuating voltage to operate, we specifically designed a step down regulator from 12V to 5V. The 5V sources is used by 3 different peripherals such as LM117 for microcontroller, servo motor and lastly the ZigBee module.

Apart from its usage in the sensitive systems it is also used to regulate the 12V coming from the battery, which is in-turn sent to the L293DNE motor drivers which are connected to various motors across the system. The power regulator is as shown in the diagram.

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.
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.

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.

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.

D. Harvesting

The final process under farming is harvesting where in the crops are cut down or chopped using the designed harvesting 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 does not involve any process regarding the grain separation from the crop.
Fig. 14. Wireless control of swarm robots using mobile phone

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.

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 1m² 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.

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 $600 to $720. 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 fulfillment 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 is not one of the constraints as it should possess 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.

In modern agricultural systems farmers believe they have much more central roles and are eager to apply technology and information to control most components of the system, a very different view from that of traditional farmers.

<table>
<thead>
<tr>
<th>No.</th>
<th>FUNCTION</th>
<th>RECORDINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ploughing</td>
<td>Asymmetric ploughing at distance of 2cm - 2.5cm.</td>
</tr>
<tr>
<td>2.</td>
<td>Depth achieved</td>
<td>1.5 cm – 1.7cm</td>
</tr>
<tr>
<td>3.</td>
<td>Torque of Helical Gear motor</td>
<td>5 Kg/cm (10 Kg/cm for 2 motors) @ 150 RPM</td>
</tr>
<tr>
<td>4.</td>
<td>Torque of Side Shaft motor</td>
<td>1 Kg/cm @ 75 RPM</td>
</tr>
<tr>
<td>5.</td>
<td>Power Drawn from the battery</td>
<td>5.8185 W</td>
</tr>
<tr>
<td>6.</td>
<td>Average operation time for 1300mAh Lead-Acid Battery</td>
<td>6-8 hours</td>
</tr>
<tr>
<td>7.</td>
<td>Distance between batch of seeds</td>
<td>0.1cm – 0.2 cm</td>
</tr>
<tr>
<td>8.</td>
<td>Average time of mechanism to be completed</td>
<td>40 seconds</td>
</tr>
<tr>
<td>9.</td>
<td>Average time required for entire process</td>
<td>3 Minutes 50 Seconds</td>
</tr>
<tr>
<td>10.</td>
<td>Average growth time of Ragi seeds planted</td>
<td>6 Days (~144 hours)</td>
</tr>
<tr>
<td>11.</td>
<td>Average time required to empty water tank</td>
<td>50 minutes</td>
</tr>
<tr>
<td>12.</td>
<td>Average time required to empty seed storage</td>
<td>7 hours</td>
</tr>
</tbody>
</table>

**TABLE I. EXPERIMENTAL RESULTS (DRY SOIL)**

<table>
<thead>
<tr>
<th>No.</th>
<th>FUNCTION</th>
<th>RECORDINGS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ploughing</td>
<td>Asymmetric ploughing at distance of 2cm - 2.2cm.</td>
</tr>
<tr>
<td>2.</td>
<td>Depth achieved</td>
<td>1.0 cm – 1.2cm</td>
</tr>
<tr>
<td>3.</td>
<td>Torque of Helical Gear motor</td>
<td>4.7 Kg/cm (9 Kg/cm for 2 motors) @ 150 RPM</td>
</tr>
<tr>
<td>4.</td>
<td>Torque of Side Shaft motor</td>
<td>1 Kg/cm @ 75 RPM</td>
</tr>
<tr>
<td>5.</td>
<td>Power Drawn from the battery Source</td>
<td>5.9852 W</td>
</tr>
<tr>
<td>6.</td>
<td>Average operation time for 1300mAh Lead-Acid Battery</td>
<td>5-6 hours</td>
</tr>
<tr>
<td>7.</td>
<td>Distance between batch of seeds</td>
<td>0.1cm – 0.2 cm</td>
</tr>
<tr>
<td>8.</td>
<td>Average time of mechanism to be completed</td>
<td>45 seconds</td>
</tr>
<tr>
<td>9.</td>
<td>Average time required for entire process</td>
<td>4 Minutes 10 Seconds</td>
</tr>
<tr>
<td>10.</td>
<td>Average growth time of Ragi seeds planted</td>
<td>5 Days (~120 hours)</td>
</tr>
<tr>
<td>11.</td>
<td>Average time required to empty water tank</td>
<td>50 minutes</td>
</tr>
<tr>
<td>12.</td>
<td>Average time required to empty seed storage</td>
<td>7 hours</td>
</tr>
</tbody>
</table>

**TABLE II. EXPERIMENTAL RESULTS (WET SOIL)**

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contrast to the isolation inherent in traditional arrangements, modern agriculture tends to see its success as dependent on linkages access to resources, technology, management, investment, markets and supportive government policies.

As a result, much of the success of modern systems depends on the development and maintenance of soil fertility through the specific provision of nutrients when they are depleted; of machine power and technology to create soil conditions necessary to promote plant growth with minimal disturbance and minimal soil loss; of the use of improved genetics for crops and livestock to enhance yields, quality and reliability; and, on modern genetic and other techniques to protect plants and livestock from losses to competing plants, diseases, drought insects and other threats.

This success also depends on access to efficient, effective irrigation to supplement rainfall in many climates; on advanced harvesting, handling and storage equipment and techniques to prevent losses and to market commodities efficiently. It depends, in turn, on both public and private investment to provide access to technology, equipment, information and physical facilities throughout the production marketing system. And, it depends on well supported commercial and financial systems and broad public policies that support effective commercial markets at all levels that generate economic returns throughout the system.

Our system provides the following major advantages:

A. Completely autonomous

It only has a start and stop button which can be easily accessed by any user irrespective of the age group. It does every mechanism and functions on its own without the indulging the user at any stage.

B. Eliminates the need of labour

As said earlier, there is a great dependency on labor in the productivity of any farmland. This system eliminates that need without compromise inefficiency and productivity of the system. Apart from the this it also keeps up the schedule of the crops and gives year round maintenance and monitoring.

C. Cost Effective

Since the robots are one-time investment, there is no reinvestment on human resource every year. Instead of investing on labour this can be re-invested only in the purchase of raw materials. In case of crop failure there is tragic loss in farming not only in terms of money but also genuine work and hardship. But this system even during crop failure can be just restarted in a moment’s notice.

D. Minimum hardware and Low power consumption

This system runs on a limited number of hardware components, during failure all the blocks can be easily tracked, debugged or replaced immediately by a minimum trained official. Apart from which the microcontroller requires just 3.3V to operate and the entire system power consumption is less than 6W. This may vary during real time operation but the constraints itself being very small at this stage will be a major advantage while actually implementing the prototype.

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.