Agricultural Robots: Future Trends for Autonomous Farming

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ABSTRACT

From the era of stone-age, humans have managed to hunt and gather the food for their survival. Since historic times, humans have been using their brains to fulfill the necessity of food. From that time to 21st century human beings have been using their intelligence for their survival. Over the period of time methodologies of cultivating food have improved to such extent that nowadays robots are being used for farming purposes. Robots have simplified the job of farmers to a great extent. They have helped farmers in undertaking smart farming. Due to globalization the import and export of food have reached to a pinnacle where farmers are getting a good price returns on their crops. Due to this factor there has been increase in competition in agriculture sector. Farmers are shifting their gears towards robotic farming from the traditional farming. These things have resulted in advances in computer technology, advances in forecasting, automatic watering system etc. There has been rapid decrease in cost of new technology due to which robotic farming is becoming cheaper and effective day by day. Agro-bots (Agriculture robots) can be equipped with latest technologies such as computer-based sensors and actuators such as global positioning systems, machine vision and laser-based sensors. These technologies can be progressively incorporated into mobile robots with the aim of configuring autonomous farming. This paper will discuss about the introduction of robotics into agriculture field, its history, current trends, future trends and their impacts on society.

Keywords— Agro-bots (Agriculture robots), GPS (Global Positioning System), Machine vision, Autonomous farming, LASER sensors, mobile robots

ARTICLE INFO

I. INTRODUCTION

Food is the basic necessity of the mankind. There has been a tremendous increase in population over a past decade around the globe. This notifies that due to increase in population there has been a problem of food shortage in developing as well as developed countries. Researchers have been finding ways to increase food production without compromising our plant's natural resources and ecosystems. Therefore to combat the food shortages and to give best results in farming, we need a robot which would perform all the tasks which a farmer would do. Robots are non-tiring, non-emotional objects which are high in precision and accuracy and are known for repeatability Robots may be staffed in place of workers in farms for future commercial farms. These robots will identify, sprinkle and pick individual pieces of produce from plants, even when their targets are producing rice and wheat in the agriculture fields. Researcherssay that autonomous agriculture robots would protect human workers from the harmful effects of handling chemicals by hand [6]. And through a highly selective system of spraying, robots could reduce a farm's use of pesticides by up to 80 percent. Many driverless tractors have been developed in past by the engineers. But these tractors have failed to have an ability to embrace the complexity of the real world. Scientists in past had assumed agriculture farming robots as industrial robots such that, everything was known before hand where machines would work in predefined ways- such that robots which work on production line. But now new approaches and trends are to be studied which would not only upgrade the existing agriculture robots but would also help in complete autonomous farming. These smart machines would now be intelligent enough to work in an unmodified or semi natural environment. Technologies such as GPS (Global Positioning System), Laser Scanners, CCD (Charge Couple Camera), Gyroscopes, Spatial information etc can be fitted in the existing Agro-bots. Real-time kinematics, inertial devices, actuators (hydraulic cylinders, linear and rotational electrical motors), electronic equipment (embedded computers, industrial PC, and PLC) have enabled the integration of many autonomous tractors [3]. These tractors provide accurate positioning, variable spraying of fertilizers, mechanical intra-row weed control, and seed planters. Apart from these many farmers are encouraging fleets of robots for unified operation in less time[9, 10]. This has become a step forward in agriculture. Using fleets of robots for farming has its own set of advantages. By using a fleet a we can achieve a well defined objective in less amount of time. The implementation of complex and expensive systems will

be attractive for high-value crops for which smart machines can be replace extensive and expensive repetitive labors. It is important that the fleet deployed in a farm should be flexible, reliable, and maintainable. The system architecture involving sensors, actuators, computers performing algorithms should be simple, robust and modular. The system architecture can be handled by latest methodologies such as COTS, LIDAR's and other auxiliary systems. An autonomous tractor is shown in Fig. 1where its main systems, sensors and actuations systems are segregated and shown.

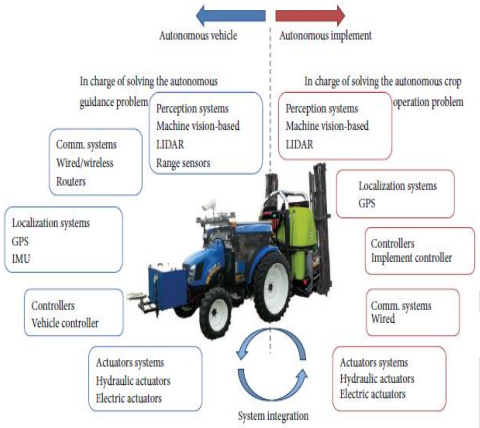


Fig. 1 Main systems of Agro-bot [3]

This research paper will deal with need of agro-bots, history of agro-bots and recent trends and technologies which can be incorporated into the agro-robots to improve its working and performance efficiency.

II. NEED AND HISTORY OF AGRO-BOTS:

Traditional farming involves tremendous labor filled with menial and tiresome tasks. Farming consists of mostly physical work. It requires pick and place of materials from one place to another. It requires placing of seed, watering, spraying and cutting operations which have been done manually since agriculture has been known. Agriculture industry is one of the last industries to use robotics and intelligent machines in place of labors [4]. There are various reasons behind this lack of automation in agriculture- the most primitive reason is insufficient funds for investment. Farming has been never been a large money making venture. There has been various times when there were insufficient funds to invest in mechanization. Due to this robotics is still not that common in agriculture industry. Other reasons which have limited the use of robotics in farming are- lack of knowledge of advancements in technology to farmers, seasonal yields, employment generator and etc. Introducing robotics in any industry is costly. Farmers owning a piece of land find it difficult to invest in purchasing an autonomous robot to perform farming. Therefore while incorporating newer technologies into agro-bots we need to take care of price of the robot. The price of robot should be such that it is affordable for a medium class farmer. Apart from the difficulties which a farmer has to face while buying a robot, many farmers are keen on purchasing agro-bot so as to make their work easier. In early history, manpower replaced the manual power to animal power. Oxen were used to carry out farming operations in fields. Later, animal power was replaced by machine power. Machines come into picture in 1800's. Various machines were discovered during that period. Machines such as motors, hydraulic pumps, diesel engines etc were introduced. The basic function of machine was to simplify the work. Machines were to be said as mini agro-bots. Those were semi-automatic machines which required human input and vigilance. Those semi automatic machines undoubtedly reduced the human effort. After the discovery of machines, interdisciplinary engineering was introduced. The main motive behind combining engineering was to manufacture a product which is self sufficient and autonomous. Computer technology, information technology, mechanical engineering, electronics, PLC, electrical energy and various other disciplines of engineering were used to manufacture an autonomous machine. In 1950's scientists started working on making machines autonomous. Autonomous machines (Robots) were introduced in mid 90's in various manufacturing and mining industries. These not only simplified the tasks in an industry but also helped in generating good returns. After the advancements in robots in almost every sector, research on robots which can be used in agriculture industry began in 2000. Companies like John Deere, ISO group, AGCO Fendt, Amazone-Bosch and etc are working on various autonomous agriculture robotics projects. Sample agro-bots are introduced in the markets and are used in developed countries for performing operations on large piece of lands. But still there is plenty of research to be made in the field of Agro-bots so as to make them technology sufficient, robust, flexible, cost-effective and efficient.

III. FUTURE OF AGRO-BOTS:

Early developments of robotic agriculture can be traced back to mid-1980s, when research on fruit harvesting robots flared up in Japan, Europe and USA. Since then, there has been continuous improvement and advances made in methods and technologies for robots used in farming. These robots are responsible for sensing and perception, navigation, actuation and manipulation, cognition, communication and cooperation among robots and with humans [2]. To perform the above operation future robots need to be technological advanced and equipped with latest detection and controlling system. There are various auxiliaries that can be attached to a Agro-bot which are shown in FIG.2.

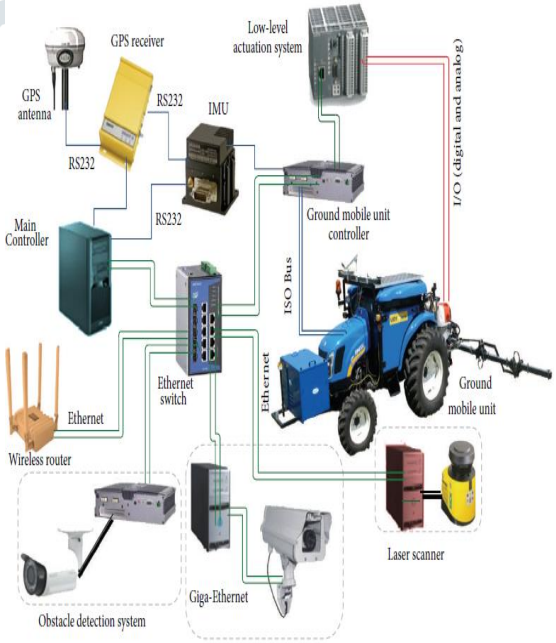
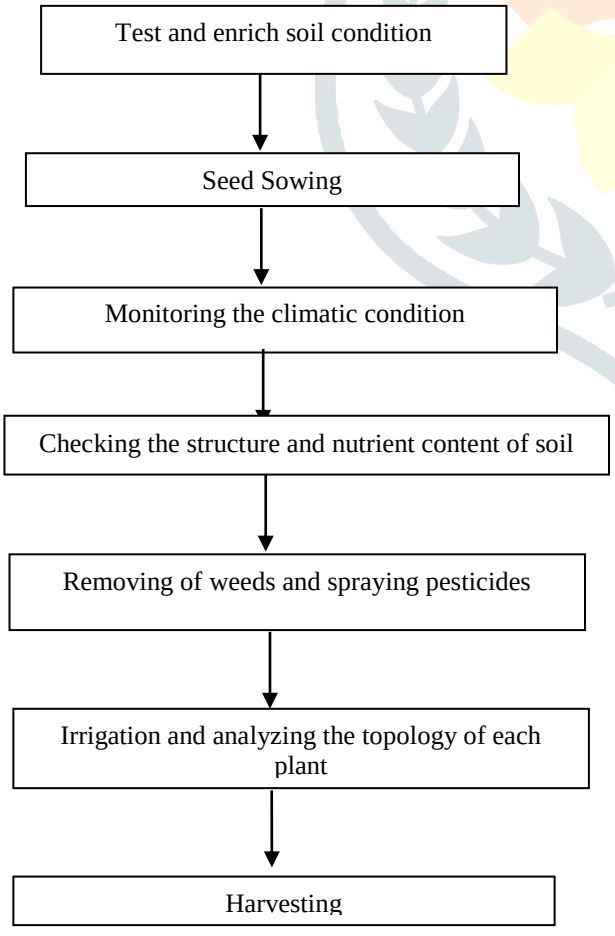


Fig. 2 Hardware architecture for Agro-bot [3]

Basically an Agro-bot consists of five systems-

i. Obstacle detection system
ii. Actuation system
iii. Laser scanner
iv. Main controller
v. GPS

These systems are needed to be upgraded so as to carryout corrective and effective robotic farming. Apart from above operations Agro-bots are also used in Fruit picking. Driverless tractor and sheep shearing robots are designed to replace human labor. In most cases, a lot of factors have to be considered (e.g., the size and color of the fruit to be picked) before the commencement of a task. Robots can be used for other horticultural tasks such as pruning, weeding, spraying and monitoring. Robots can also be used in livestock applications (livestock robotics) such as automatic milking, washing and castrating. Robots like these have many benefits for the agricultural industry, including a higher quality of fresh produce, lower production costs, and a smaller need for manual labor. They can also be used to automate manual tasks, such as weed or bracken spraying, where the use of tractors and other manned vehicles is too dangerous for the operators.Algorithm for an Agro-bot to carry out autonomous farming begins with testing of soil and ends with harvesting of crops. In mean time various sensors, detectors and appliances are used to automate the tractor. Feedback signals are sent throughout the loop and system is operated. To understand the latest devices and functions used in an Agro-bot we will follow the algorithm shown in flow chart 1:



Flow chart 1: Basic procedure for Agriculture

Future systems in Agro-bots

1. Electric agro-bots

Electronic robots should be manufactured which are chargeable and requires no conventional sources of energy. These electronic robots would lessen the chances of pollution created by a diesel robot. Pollution is directly proportional to the plant growth; therefore electronic robot vehicles can be introduced and known as green tractors. Up till now no company has taken any initiative to manufacture electrically chargeable tractors which can be used for multiple operations. This electronic model would control forward, backward, neutral, steering, speed and emergency stop operations. This robot can be used for real-time automatic data acquisition and crops monitoring with a help of computer based system in the agro-bot.

2. Navigation sensors

So as to perform automatic navigation of agro-bots, tractors should be equipped with latest navigation sensors. A method called as sensor fusion can be used to determine predetermined paths. Predetermined path also called as map can be navigated to perform an autonomous navigation of the robot tractors. We can use a method called see made by obtaining two-points in UTM (universal transverse Mercator) coordinates. These two-points can be used as the reference points to create navigation map using the developed software [1]. The sensors which can be used are RTK-GPS (real-time kinematic global positioning system) and IMU (inertial measurement unit). The RTK-GPS can be used to obtain the vehicle position with respect to UTM coordinates and IMU can be used to obtain the vehicle posture (roll, pitch, and yaw angles). These navigation sensors can be used to follow the predetermined points in the navigation map. The RTK-GPS has an accuracy of ±2 cm while the IMU has an accuracy of 0.5deg/hr. Other types of sensor which can be used instead of IMU are GPS compass. These sensors give absolute heading angle and position of the tractor. The position accuracy for the compass sensors is 60cm and heading angle accuracy is 0.3 deg. Another inexpensive sensor which can be used for navigation is AGI-3 GPS compass this type of sensor includes- internal sensors, memory storage, satellite receiver antenna for complex path planning and control algorithms. Among UTM, IMU and AGI-3 compass; AGI-3 compass provides better results for navigation sensors. This sensor is based on multi-GNSS (global navigation satellite system) which enables to provide correct and error free navigation for the autonomous machine using the GPS compass made by TOPCON. However more advancement is to be made in the field of navigation to make it accident free and efficient. Actions which are operated by using navigation sensor are to trace the path to a correct source so as

to take it to its determined destination. In grape vineries, automatic robots can be used to reach to the ripe grapes so as to harvest them. So as to reach the destination, GPS can be fed with latitudes and longitudes and as well as conditions in programming should be changed to if else loops. This will help the automatic robot to perform robotic tasks by accurately tracing the timeline of its operations and destination.

3. Safety system

Safety of the farmer and field worker is most important concern when it comes to autonomous robots. During the operation of tractor, safety measures such as laser scan, UV scan and other methods are to be used so as to scan the work envelop and make sure that there is no foreign entity in proximity of agro-bot. Laser sensor of 2-D can be used to obtain distance and angle of objects in front of it with respect to scanning range of that sensor. Usually laser sensor is mounted on the front bumper of the tractor. These sensors can be mounted on the sides of the agro-bot as well as at the back of robot so as to ensure 360 degrees of detection and warning. The laser scanner angle can be set into 100deg, 180deg, whereas as the distance can be set into 8m, 16m, 32m and 80m modes. Apart from laser scanner we can also use an ultraviolet sensor manufactured by Bosch and Sensing technology.

4. Real-time robot managing system

It includes a real-time monitoring system based upon the operations which are performed by the robot. A farmer can give instructions on his phone or PC just by monitoring live streaming of actions performed by the robot. This function also helps the robot to stop its actions and ask the farmer to proceed or not in case of a doubt. When the robot is intervened by any object in its navigation path, this information can be provided to the manager who can set commands on his phone to proceed, wait, stop or tackle. This type of real time robot managing system helps to reduce the accidents as well as helps in efficient error free farming. In real time managing system the agro-bot receives a command from the control center and as well as can send information or feedback using wireless LAN and packet communication. This also helps the farmer to analyze the data and send the necessary information to the farmers, retailers and producer's cooperative societies. The software which can be used for monitoring and keeping a track of real time status of agro-bots is called as GeoMationFarm which is a hitachi made software. This software is integrated with GIS map for accurate positioning and tracking of the multiple autonomous machines on the field at the same time. Apart from this in navigation map details about bots number of paths, three point hitch positions, vehicle speed and PTO rotation can be provided for better understanding and ease of operation for the farmer.

5. Agro-bot control through speech recognition and use of android phone

Speech recognition is the process of automatically recognizing the spoken words of person based on information in speech signal. Recognition technique makes it possible to the speaker's voice to be used in verifying their identity and control access to services. In the case of agrobots speech control can be effectively used to operate the robot by sitting at home. The most popular spectral based parameter which can be used in voice control approach is the Mel Frequency Cepstral Coefficients called MFCC [7]**.** Fig. 3 shows the block diagram of functioning of speech control and android maneuvering of the general robot assembly. Android smart-phones can also be coupled to the agro-bots so as to operate and control its action. Wi-Fi, Bluetooth, NFC, Infra-red and other technologies can be used to connect the smart-phone with the agro-bot. The control commands are dispatched from Bluetooth of the smart-phone to the agro-bots. The controlling device of the whole system is a microcontroller, Bluetooth module and a pair of DC motors that are interfaced to the microcontroller. The data collected by this Bluetooth module from the Android smart-phone is fed as input to the microcontroller. The Microcontroller acts accordingly on the DC motors of the agro-bot. The robot assembly in this venture can be made to maneuver in all four directions using the android smart-phone.

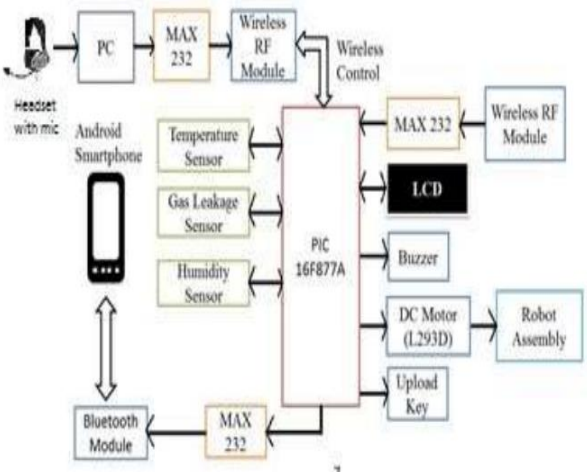


Fig. 3 Block Diagram for speech and android control

6. Vision-based guidance system by using novel molecular method

This method is used to track the direction and lateral offset of the crop rows by estimating the dominant parallel planar texture in a simulated overhead view. This method assumes that crops are planted in straight rows and flat grounds. This method does not perform any binary operations, or does it requires row spacing, color, lighting or

periodicity to trace the crop fields. The agro-bots operate in local coordinate frame aligned with crop rows for proper tracking. This type of vision based guidance can be utilized in critical farming, where error in movements of agrobots in an undefined direction or track can cause a loss of crops. This type of vision based guidance system is used for farming of strawberries, rice, sugarcane etc.

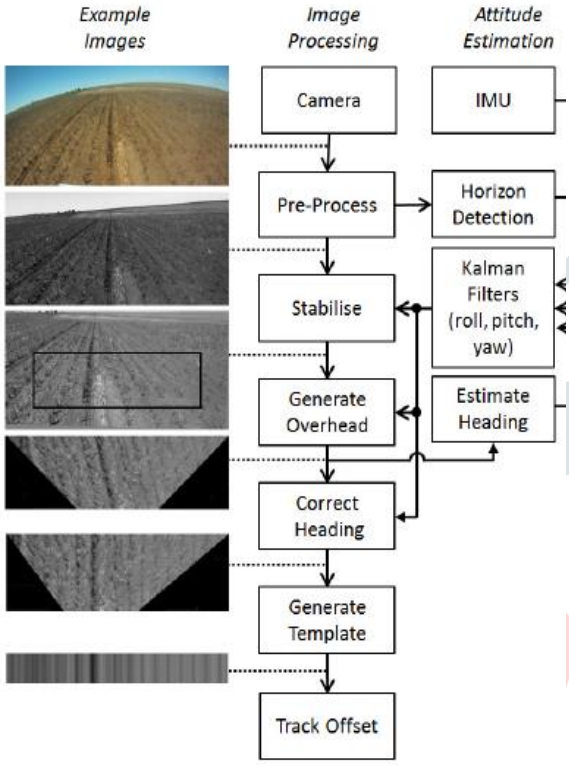


Fig. 4 Vision based guidance system [8]

Novel based system integrates the overhead image in the direction of crop rows to give an example of crop template**.** Fig. 4 explains the algorithm for tracking of row using the novel based model. The overhead image is skewed using an affine transform, summing of columns and then by calculating the variance of resulting vector [8]**.** This type of skewing and summing can be done in OpenCV and MATLAB; which helps in detecting the rows and columns separately. And thus tracking of crops can be done. This is a useful technology which should be upgraded in the agro-bots so as to simplify the track detection and ease the functional movement of bots for spraying, fertilizing and inspecting of crops.

IV. Challenges, Impacts and Implications of Agro-bots on Society

Agro-bots have been already introduced in markets. Many companies have introduced their agriculture robots by various other names. Agro-bots have been a great help to large –scale producing farmers. But still agro-bots have not been that used for farming. Very few percentages of farmers rely on autonomous robots for the farming. It has imposed a great impact on society. Agriculture was the last industry to come up with robots. This is due to most of the farmers are reliable on workers and existing machines. As well as farmers aren't rich and cannot afford to buy huge multiple task doer machines. Agro-bots have also imposed its implications on society through various ways. Agro-bots have eliminated animals used for agriculture as well it is eliminating conventional machines used since 1850's. Agro-bots have also eaten up jobs of daily workers on farms. These daily wage workers are solely dependent on the farming for fulfilling their basic needs. Due to agro-bots the farming can be done autonomously. Very few workers are needed on farm to operate agro-bot virtually and to inspect and rectify the errors of agro-bots. Agro-bots has been a boon for farmers as well as a con. The reasons behind not so success of agro-bots are-

1. Economic Feasibility
   Cost is an important factor when it comes to robotics. Agro-bots are bit expensive for the farmers to buy. Agro-bots are equipped with navigations system, vision based cameras, various end effectors, actuators etc. Inclusion of all the above components makes the autonomous tractor expensive. It is expensive for a farmer to buy an agro-bot. The cost of the agrobot depends upon the robot and various tasks which it can perform.
2. Need
   Agro-bot is suitable for large-scale farming. A farmer having a share of 10acres of land cannot afford to buy to an agro-bot. It will be simply waste of funds. Whereas, large-scale farming needs multiple agro-bots so as to manage the various operations on field- from sowing to milking the cows.
3. Lack of awareness among farmers
   Farmers are mostly illiterate and not that technology savvy. There is lack of awareness among farmers about autonomous tractors or robots. They liketo do the farming with traditional methods and are not educated about how farming can be done autonomously. This is one of the reasons why the agro-bots have not been that successful.

V. Conclusion

Traditional farming done by the farmers has remained unchanged for the centuries. Farmers think that it is still man's task to raise crops, harvest and sell them. Crops production requires preparing the land, sowing the seed, nurturing the crops with fertilizers, spraying pesticides, harvesting and processing it. All of this task can be easily done by using agro-bots. Therefore it is necessary to create awareness among farmers regarding the use of these autonomous robots to simplify their tasks. In this paper we studied about the need of agro-bots, history of farming, history of autonomous robots, their current functioning and future trends that will make the agro-bot more functional, effective, efficient, robust and cost efficient. Apart from this we need to find ways to reduce the cost of agro-bots by nstalling cheaper but efficient technologies. Cost has been a hindrance for the farmers to buy their own agro-bot and implement autonomous farming. Reducing the cost would certainly increase agro-bots sale and autonomous farming would become a common thing in couple of years.

VI. REFRENCES

1. Noguchi, Noboru, and Oscar Barawid. "Robot Farming System Using Multiple Robot Tractors in Japan Agriculture." *The International Federation of Automatic Control*(2011): 633-37. Web.
2. "Advances in Robotic Agriculture for Crops." *Robotic Agriculture Editorial* (2016): 1-2. Web. <www.elsevier.com/locate/issn/15375110>.
3. Emmi, Luis, Marino Soto, Gonzalo Pajares, and Pablo Santos. "New Trends in Robotics for Agriculture: Integration and Assessment of a Real Fleet of Robots." *The Scientific World Journal* 59th ser. 40.40 (2014): 1-21. Print.
4. Sistler, Fred. "Robotics and Intelligent Machines in Agriculture." *Journal of Robotics and Automation* 3.1 (1987): 3-6. Web.
6. Mohan, S., Praveen Kumar, and B. Paulchamy. "Certain Investigation of Precision Agriculture Robot Using Lab View." *International Conference on Current Trends in Engineering and Technology* 3rd ser. 3.210 (2013): 319-22. Web.
7. Chauhan, Gaurav, and Prasad Chaudhri. "Robotic Control and Using Speech Recognition and Android." *International Journal for Research and General Science* 3.1 (2015): n. pag. Web.
8. English, Andrew, Patrick Ross, and David Ball. "Vision Based Guidance for Robot Navigation in Agriculture." *International Conference on Robotic and Automation*14th ser. 1.4 (2014): 1693-698. Web.
9. A. Bautin, O. Simmonin, and F. Charpillet,"Towards a communication free coordination of multi-robot exploration," in *Proceedings of 6th National Conference on Control Architectures of Robots*, Nancy, France, May 2012.
10. N. Bouraqadi, L. Fabresse, and A. Doniec, "On fleet size optimization for multi-robot frontier-based exploration," in *Proceedings of the 7th National Conference on Control Architecturesof Robots*, Nancy, France, May 2012.