Agricultural Robots for a Sustainable Green Environment : A Review

BASKARAN S.[1]*, RAMESH KUMAR T.[2], VENKATASA PRABU D.[3], MEENAKSHI PRIYA B.[4]
[1]Research Scholar, Mechanical Engineering, Bannari Amman Institute of Technology, Tamil Nadu, INDIA
[2]Associate Professor, Mechanical Engineering, Bannari Amman Institute of Technology, Tamil Nadu, INDIA
[3]Research Scholar, Mechatronics Engineering, Kongu Engineering College, Tamil Nadu, INDIA
[4]Professor, Mechatronics Engineering, Kongu Engineering College, Tamil Nadu, INDIA
E-mail:baskaran@bitsathy.ac.in

Abstract:- The emergence of robots in agriculture exorbitantly boosted the productivity and output of agriculture in so many countries. It will reduce the dependency on fossil fuels, which in turn decrease the large levels of pollution caused by farm machineries. In addition, the usage of robots in agriculture decreased the cost of operation and preparation time of agricultural activities that will provide a solution to persisting problems faced by agricultural communities around the world like labor scarcity, Non-uniformity in yield, low rate of production and deficiency in throughput etc. Agriculture is a strategic industry that serves as the foundation for social stability and economic development. However, the global economic and social development is severely jeopardized by environmental deterioration, rapid population growth and shortage of resources. Agricultural Robotics is the impregnation of automation technology into bio environment such as agriculture, forestry, green house and horticulture etc. The intentions of this review paper is to validate the latest developments in the field of agriculture, Possible power sources and various sensors like global positioning systems (GPS), machine vision, dead-reckoning sensors, laser-based sensors, Accelerometers, inertial sensors and geomagnetic direction sensors. Lots of field work such as digging, harvesting, sowing, weeding and spraying operations have been performed by agriculture robots or agbots further, its performances are also enhanced in conjunction with technology.

Key-Words: - Agbots ; Global Positioning Systems; Power Sources; Field work

1 Introduction

Modern research and developments in robotics for agricultural field applications and the underlying methodologies, principles, limitations and gaps are reviewed. Impressive advances have been made in methods and technologies for robot sensing, perception, navigation, actuation, manipulation, cognition, communication and cooperation with humans. The feasibility of Robot based cultivation has been studied as well as implemented by many researchers. Robotic systems for crop production are even more sophisticated since they must operate under unstructured agricultural environments without reducing productivity and work quality relative to concurrent methods [1]. Modular agricultural robot was equipped with a precision-spraying end-effector and configured for this application. A disease-sensing system on the basis of multispectral imaging and relevant detection algorithm was integrated with real-time manipulator control [2].A multi-robot tractor system was proposed in this article. The system can extend the operation width and reduce total work time. Each robot tractor can individually track its desired lands, and the robot tractors can also maintain a spatial pattern during the work process [3].The main contribution of this research lies in the design of an image processing architecture to detect crop rows and weeds in maize fields. It consists of two modules the first is in charge of crop row detection, obtaining high quality images, its segmentation to obtain binary images where plants appear as white pixels and the remainder in black and to estimate the crop rows as accurately as possible. The second module uses the crop rows detected to calculate weeds density and to obtain the information to control the tractor guidance and the overlapping [4].This work demonstrates that it is possible to combine current agricultural machines, which use internal combustion Engines for power, with new technologies that are based on clean energy sources to obtain significant reductions in the emission of atmospheric. The use of Electrical energy systems allows small electrical actuators to be used, which are able to apply the treatments in small areas consuming very little power [5].

This paper presents an up to date review on IoT applications for agro-industrial and environmental fields. Selected studies came from five continents, and Asian countries during this study, it was discovered that most of the research still focuses on monitoring applications (62%); however there is a growing interest in closing the loop by doing control (25solutions in logistics and prediction (13environmental applications using IoT [6].This review paper gives an abbreviated assessment on machineries in farming finished in past 24 years. Though the research expansions are ample, but still there are many shortcomings (e.g. ability to adjust in all directions and insufficiency of multifunction ability) that are suspending the expansions needed for commercialization of the system. It shows oneself that cultivation might be done correctly and cheaper with a group of small machines than with a few large ones [7].This paper provides a comprehensive review of the research on technologies in agricultural vehicles for the last two decades. Although the research developments are abundant, there are some shortcomings (e.g., low robustness of versatility and dependability of technologies) that are delaying the improvements required for commercialization of the guidance systems [8].This paper is mainly based on minimizing man power and cost of the equipment, which can be affordable to all farmers. Most of the present successful agrobot models represent use of powerful fuel based IC engines and heavy machineries, which require skilled technician and causes unnecessary environmental pollution and also reduction in fossil fuel. In order to solve this problem, the use of automation unmanned agrobot is implemented by this work [9].

Nomenclature

RTK	Real Time Kinematics
IR	Infra-Red
LIDAR	Light detection and ranging
GPS	Global Positioning System
CCD	Charge Coupled Device
LDR	Light Dependent Resister.

2 Need for Robots in Agriculture

Farmers are increasingly under pressure to feed more people as the world's population is expected to reach 9.6 billion people by the year 2050. The world population today is 7.4 billion, world needs a 70% increase in food production by 2050, in order to achieve this, With the limited land, water and labour resources, it is estimated that the efficiency of agricultural productivity must increase at least by 25% to meet that global demand for food grains, in order to achieve this farming equipment need to evolve. The increasing opportunities in other sectors is day-by-day reducing the man power availability in farming. As mentioned by IEEE Robotics and Automation Society, Robotics and automation can play a significant role in society for meeting 2050 thus technology is pervading all sectors, agriculture will be no exception.

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3 Taxonomy of Robot Based Agricultural Operations

Agricultural robots can be categorized into various groups on the basics of operations it perform such as harvesting, seeding, weeding, pest control, etc. Many industries have the goal of creating robot farms where all of the work will be done by machines. The barrier to this kind of robot farm is that farms are a part of nature and nature lacks uniformity unlike the robots that work in factories. Factories are shaped around the task at hand, whereas, farms are not. Robots on farms have to operate by complementing with nature. Industrial Robots need not to deal with irregular terrains or dynamic conditions. Researchers are working to overcome these problems. To some extent Robots are exploited in Agriculture for the undermentioned operations, it is getting smarter and smaller with an aid of recent technologies.

3.1 Fungicides

Robots can tackle plant diseases that cause a lot of damage to crops. Fungi is often the most common disease that causes huge crop loss around the world. Encountering a fungal disease is only possible with a help of fungicide, it's a kind of pesticide. Fungal diseases deter the growth and development of a crop. It attacks the leaves which are essential for photosynthesis and reduce the fertility of the plants and cause blot on the crops eventually making them worth less on the market. Post-harvest fungi can even grow and spoil the fruits, vegetables, or seeds. Robots can treat plants that have been infected or destroy them if necessary. Robots could be able to treat only the plants that need it, rather than covering the entire crop field with fungicide.

3.2 Herbicide

Robots can be used to remove weeds. Robots can accomplish this task in two ways it can pull weeds from around the plants or just cut the tops off. Robots are imparted with a capacity to collect the removed weeds, collected weeds can be brought to a composting site restricting the need for herbicides, harmful chemicals that destroy or restrain the growth of plants. Robots would spray Herbicides that are meant to kill weeds but there is a chance to damage the crops.

3.3 Pesticide

Pesticides are used to have a check on insects which are harmful to crops. It is very effective but not without side effects to the environment. Insects eventually develops an ability to adapt for the toxin in a pesticide.

3.4 Seed Distribution Mapping

Seed mapping concept involves recording the geospatial position of each seed that goes into the ground. It is extremely simple in practice using RTK GPS is fitted to the seeder and infrared sensors mounted below the seed chute. Whenever the seed falls, it cuts the infrared beam that in turn triggers a data logger to enable recording the position and orientation of the seeder. A simple kinematic model is enough to calculate the actual seed position.

3.5 Weed mapping

Weed mapping process records the position, density (biomass) and ideally sort out different weeds using machine vision technique. For automatic weed detection, numerous studies were performed by applying variety of classification and discrimination techniques. Weed mapping technique helps farmers to decide with local variable treatment procedures such as variable rate herbicide application. Farmers can either practice conventional farming with spraying or choose to conduct organic farming with mechanical weeding. In this context, the reliable alternative to autonomous weed mapping is manual weed mapping, in which the farmer has to register and map the weeds in the field manually with a hand-held GPS. There are numerous methods that can impound needless plants without using toxic chemicals. A simple example would be to promote the drooping of the weeds by breaking the soil and root interface by ploughing the soil within the root region.

3.6 Harvesting

Robots are mainly used in agriculture for selective harvesting of the fruits and crops. The robots will be able to detect the fruit, sense its ripeness, then move to grasp and softly detach only the ripe fruit. Harvest robots are small and safe, have the ability to see obstacles and navigate accordingly. Harvest robots are designed to collect, track and communicate information so that owners can effectively record and plan work. Apart from fruit plucking, robots are also most ideal for harvesting cereal crops like paddy, Millets, Maize & wheat etc by chopping the sections of plants stalk.

4 Widely Used Sensors and Controllers in Agriculture Robots

Sensors and controllers play a vital role in agricultural automation as it can be used for wide variety of tasks such as mapping, localization, navigation, guidance, path planning, plant detection, recognition and measurement of environmental parameters like temperature, humidity, soil moisture and light intensity by means of these functionalities it support decision-making, execution of the task, and evaluation of the robot's performance.

4.1 Self-Localization and Navigation

Sensor division may also be based on its position or the information it is measuring, i.e., internal and external sensors. Internal sensors measure the state of numerous different parts of the system, e.g., encoders reporting joint or wheel angles, accelerometers measuring linear accelerations or inertia, with respect to body frame coordinates and gyroscopes measuring rotational accelerations essentially, rate of change of orientation. These sensors are generally used for dead reckoning. Inertial sensors are used in a number of vehicle applications as an alternative to odometers for dead reckoning for avoiding the difficulty of modelling odometer error and gyroscopes measuring rotational accelerations. The external sensors used in agricultural robots or automated systems that collect ambient information regarding the state of the system relative to the position of the robot using GPS, IR, machine vision, laser radar (LIDAR), ultra- sonic waves. Among these external sensors, machine vision and GPS sensors have achieved the greatest commercial success.

GPS sensors, which provide absolute positioning of the system, are used for navigation and guidance. The advanced and high-accuracy GPS systems, i.e., real-time kinematic (RTK) GPS and differential GPS (DGPS), enable accurate real-time measurements. RTKGPS receivers give very accurate results during open field operation it justifies their use as the primary sensor in agricultural vehicle navigation systems for steering control. However, in covered areas or controlled environments the GPS is not as accurate as in open fields. Some greenhouse environment might generate positioning errors since its structure sent back the GPS signal in multiple directions. Since the errors of GPS and dead-reckoning sensors are complementary in nature the integration of a GPS with internal sensors for navigation reduces the errors accumulated by each, and acts as a reference.

4.2 Plant Detection and Path Planning

Machine vision is a highly versatile technology, often used for plant or object detection and plant characteristic measurements associated with specific agricultural tasks. The sensor consists of a camera and a CCD (Charge Coupled Device) or a CMOS (complementary metal oxide semiconductor), usually operating in the IR, NIR or visible spectrums to extract both colour and depth information. It is a relatively inexpensive and powerful sensing tool. However, it must be combined with other sensors within the proper framework for use in desired agricultural activity. Multiple camera positions and viewing angles are taken simultaneously (i.e., stereo vision) or in time series due to the complex structure of the environment and the crop based on requirement. LIDAR(Light Detection and Ranging) is used for distance measurements, mapping and obstacle detection and avoidance. Due to its ability to accurately measure a relative vectorial position (distance and direction), it is a promising tool for agricultural robot-guidance applications. Path planning is considered a sub-task of navigation, which in turn is one of the most common and required supporting tasks of agricultural robots.

The basic path-planning problem involves finding a good-quality path from a source point to a destination point that avoids collision with obstacles. In other-words Path-planning is an important primitive for autonomous mobile robots that lets robots find the shortest path between two points. Otherwise optimal paths could be paths that minimize the amount of turning, the amount of braking or whatever a specific application requires. Path planning was originally studied extensively in robotics application, but has gained more relevance in other areas, such as computer graphics, simulations, geographic information systems, very-large-scale integration (VLSI) design, and computer games. Path planning is one of the core problems for the development of autonomous vehicles and auxiliary systems in modern robotics applications.

5 Measurement of Environmental Parameters

5.1 Temperature Sensor (LM35)

LM35 is a basic temperature sensor that can be used for experimental purpose. It give the readings in centigrade since its output voltage is linearly proportional to temperature. The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in °C).

5.2 Humidity Sensor (HIH4000)

Humidity is defined as the amount of water present in the ambient air. Humidity sensors aids in determining the total amount of water vapour present in atmospheric air. Humidity sensors depends on this principle consists of a hygroscopic dielectric material sandwiched between a pair of electrodes forming a small capacitor. Most capacitive sensors use a plastics as the dielectric material, with a dielectric constant ranging from 2 to 15.

5.3 Light Sensor (LDR)

LDR is a light dependent resistor. Resistance of the LDR relies on the wave lengh of the light. When the light on the LDR is varied, resistance of LDR changes appropriately. Resistance of the LDR varies from 1k ohm to 500 k ohm. In full light resistance of the LDR is very low below then 1 k ohm and in the absence of resistance of the LDR is raises to peak value above i.e 500k ohm.

5.4 Controllers

Selection of controllers used in Agricultural Automation depends on the complexity, Cost, space and speed. There is no single controllers which serves the desired purpose completely. Some of the commonly used controllers include raspberry pi, Arduino, PLC, Atmel AT mega, PIC microcontrollers etc. Controllers needs to be programmed for actuating the devices and drives to perform control action based on the inputs from sensors. Every controllers has its own specific software's which can be operated from PC in addition there is also a variation in programming languages between aforementioned controllers. Selection of controller is also influenced by ease of programming and cost of manufacturing.

Factual Statistics Associated with Agricultural Robots

Agricultural robot market size is at $817 million in 2013 are anticipated to reach $16.3 billion by 2021, a hefty growth for a nascent market. Wintergreen Research foundation has released some of Agro Automation companies based on extensive survey. It has enlisted plenty of companies around the world as the market leaders in Agricultural Automation. The competition among major players is expected to speed up in the fore coming years.

Table 1 List of active companies involved in Agricultural Automation

ABB Robotics	Harvard Robobee	Shibuya Kogyo
Agile Planet	Harvest Automation	Ossian Agro Automation / Nano Ganesh
AgRA: RAS Agricultural Robotics and Automation	IBM	Precise Path Robotics
Agrobot	Jaybridge Robotics	Robotic Harvesting
Australian Centre for Field Robotics	KumoTek	Sicily Tractor Harvesting
Blue River Technology	National Agriculture and Food Research Organization	Shibuya Seiki
Fanuc	Millennial Net	Universidad Politcnica de Madrid
Georgia Tech Agricultura	iRobot	Agricultural Robotic

l Robots		Research Labs
Google / Boston Dynamics	Kyoto University	Yaskawa / Motoman

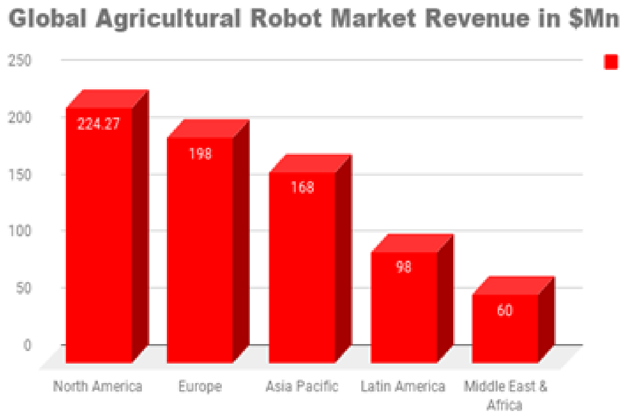
Source: Wintergreen research

A Survey Conducted by daily mail magazine in 2016 gives the following results for top 10 farming technologies around the world.

Table 2 Farming Technologies

Application	Percentage of Votes Polled
GPS Steering system	36%
Robot milking	19%
Smartphones	13%
Combine yield	5%
Cow heat	5%
Driverless	2%
Aerial Drones	2%
Electronic ear	2%
Farm	2%
Robot	2%

According to the market research survey done by Transparency Market Research (TMR), the estimated value of global agriculture robots market is $1.01 bn at the end of 2016, in terms of revenue. Market revenue is high in North America followed by Europe, Asia pacific, Latin America and Middle East Africa. Application wise Robots are more frequently used in diary management and less frequently used in crop and soil management.



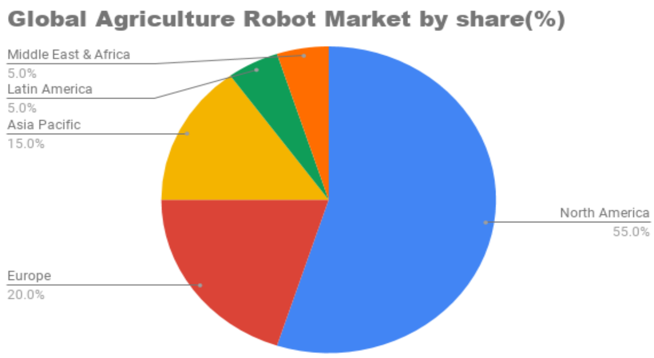


Figure 1. Global Agricultural Robot Market Revenue. Source: TMR Analysis

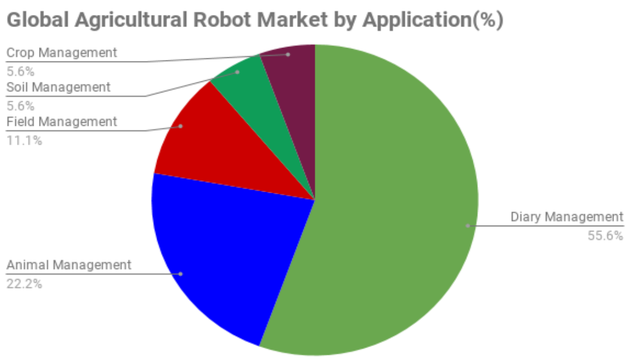


Figure 2 Global Agriculture Robots market by share (%) Source: Research Nester

Figure. 3 Agricultural Robots market by Application(%)
Source: Grandview research

Table 3 Summary of Agricultural Automation based papers in Scopus

Category	Type	Number of Papers
CROP	Apple Tomato Pepper Cucumber Strawberry Watermelon Other Vegetables and flowers	363 176 73 51 46 374
AGRICULTURAL TASK	Transplanting and seeding Plant protection and weed control Harvesting	255 326 302

Source: Bio systems Engineering Journal

Conclusion

This study investigated the feasibility of disruptive technologies in Agriculture that will substitute the traditional way of doing Agriculture. Though the research expansions are ample, but still there are many shortcomings that are suspending the expansions needed for commercialization of the modern Agricultural systems. Due to the shrinkage of workers, resources and agricultural lands, world is setting up for an enormous challenge for human survival use of modern agricultural machineries could be a viable solution to face the threat. Focus is also given to application areas and factual data's with reference to Automation in Agriculture.

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