ROBOTICS: THE FUTURE FOR FARM MECHANIZATION

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ABSTRACT

Farming in the near future has to produce more food and fibre to feed a growing population with a smaller rural labor force and contribute to overall development of countries. Robotics in agriculture, the sustainable food production method has the potential to improve competitiveness and increase crop productivity compared to the current methods, thus becoming an increasingly active area of research. In this paper, robotics and its application in agricultural fields are discussed, that helped to increase the accuracy and precision in agriculture.

Key words – robots, agriculture, application, drawbacks

1. INTRODUCTION

World's population increases, so do the demand for food and to congregate the mounting population, farmers must adopt advanced technology at the production of all crops. One such technology is robotics where, robots must be utilized to accomplish most tasks efficiently in intensive agriculture. The word "robot", made its way into English from Czech in the 1920s, means slave or forced labor and it was pioneered by Karel Capek through a play, *Rossum's Universal Robots* (*R.U.R.*), which anglicized "robot" as a man-like machine. A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialized devices through variable programmed motions for the performance of a variety of tasks (Gupta and Arora, 2009)

The idea of robotic agriculture, involves industrial style of farming where everything was known before hand and the machines could work entirely in predefined ways. The robots, an autonomous machine must exhibit sensible behavior in recognized contexts and should have enough intelligence embedded within them to behave sensibly for long periods of time, unattended, in a semi-natural environment, whilst carrying out a useful task (Blackmore *et al.,* 2004).

The robotics, study of robots, in real time is spreading very fast all over the world in every day to cover further domains, as the opportunity of replacing a robot in place of human as an operator provides effective solutions with return of our own investment in less time. Conventional techniques in agriculture depend on human power for lifting, pushing, dragging, weeding, fruit picking. Further, humans are prone to work in dangerous and hazards environment when they are spraying chemicals and pesticides it may create a problems to farmers. Consequently, robotics comes in use, when the duties, that need to be performed, are potentially harmful for the safety or the health of the workers, or when more dangerous issues are granted. In the case of automated agriculture, above said problems are exemplified and robots can work restlessly in all environments (Kamalesh *et al*., 2014).

1.1 Laws of robotics

Machine ethics should be followed while construct of robots as given by Asimov, 1984. Ethics involves three laws of robotics in a way, how intelligent machines, rather than human beings, should behave.

- **Law 1**: A robot may not injure a human being, or, through inaction, allow a human being to come to harm.
- **Law 2**: A robot must obey the orders given it by human beings except where such orders would conflict with the First Law.
- **Law 3**: A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

1.2 History of Agricultural robotics

The ancient people used simple tools such as spears, nets and various other traps to catch their prey during the Stone Age period (2,000,000-3500 BCE). Subsequently, in the period between 2500 BCE to 1750 AD, the use of animals had been prominent in agriculture. Archeologists believed that dogs were the first animals to be domesticated. Dogs helped early people by hunting and also kept rats and other rodents from eating the crops. The use of animals in farming and the continued use of tools allowed farmers to cultivate more land and also increased the size of many farms. Further, the caschrom, a long pick with a cross-handle and projecting foot-piece used for digging stony ground, helped farmers to tear up the soil and flip the dirt to either side. Then, the Agricultural Revolution lasted from about 1750-1900 A.D., when America changed the world drastically. The main cause of the Agricultural Revolution was the introduction of machines. A well-known machine introduced during this time was cotton gin, one of the first machines used in agriculture. This machine was able to quickly separate cotton seed from cotton fibers, creating up to fifty pounds of cleaned cotton a day, the equivalent of hundreds of man-hours. This led the way to our modern agricultural machines. Another major change that occurred during the Agricultural Revolution was the creation of the United States Department of Agriculture, or the USDA. The research done by the USDA today helped to create robots and other technological improvements for American farms. During this time period of nineteenth and twentieth century's, some of the modern agricultural machines, such as the lawnmower and the tractor were invented and used worldwide. The first Deere, Tate & Gould factory were built, involved in making tractors during this era and these machines grown to become the presently known modern agricultural robots.

1.3 Timeline exploring the history of machinery into the field

Agricultural robots are part of an overall automated process for every type of human endeavor. Robots are being used more widely than expected in a variety of sectors, and the trend is likely to continue with robotics becoming as ubiquitous as computer technology over the next 15 years. It is also believed that the robots, esp. in agriculture facilitate to perform tasks that require low cost with greater accuracy and reliability. However, implementation of robotic technology took a protracted way in field of agriculture (Table 1).

Table 1: Chronological development of robots and automated machines in field of agriculture

S. No.	Period	Significance
1.	1842	The first grain elevator is used in New York
2.	1845 - 70	Transition from use of horses to tractors and reduction in labour cost
3.	1850 – 75	Transition from hand power to mechanization esp. for threshing
4.	1854	The self governed windmill was developed
5.	1892	The first gas tractor was created
6.	1926	The cotton stripper was created for easy harvesting
7.	1945 – 55	The use of pesticides and herbicides increased
8.	1959	The tomato harvester was evolved
9.	1990s	The use of IT and precision technique became prevalent in agricultural field
10.	1994	Satellite technology began to allow the farmers to track and plan their practices
11.	2002	Yamahas industrial autonomous helicopter, the unmanned crop spraying in Japan was done
12.	2011	Introduction of R-gators, the unmanned ground vehicle
13.	2012	Automation in harvest with the help of agricultural robots
14.	2013	Association of unmanned vehicle system international (AUVSI) released the economic impact of unmanned aircraft system used in agricultural precision system

1.4 Classification of robots

Robots are broadly classified based on its locomotion and the way it is controlled. Robots, based on locomotion are further classified as stationary and mobile robots.

Stationary robots: Robots cannot move from one place to another and remain stable. It works with intelligence from the place, where it is installed. Eg: e-nose, e-tongue, grain elevators etc.

Mobile robots: Robots that can move from one place to another with the predefined pathway. These robots are further divided based on the way and the environment it is designed to work. They are categorized as following

a. **Land based robots**: The robots that are designed to work on land

   1. **Wheeled robots**: Movement of robots on wheels. Different types of wheels *viz*., standard, orientable, ball and omni are utilized for constructing robots. Standard wheels allow the robot to move in the forward direction while an orientable wheel helps the robot to move in both

forward and backward directions. Robots with ball wheels stirs and en-routes multidirectional movements. The strength of omni wheel is the enhanced maneuverability in congested environment.

2. **Legged robots**: Locomotion of robots depends upon the orientation of legs.
3. **Tracked robots**: Tracks facilitate robots motion on terrains, hard and uneven surfaces.

b. Aquatic robots: The robots that are designed to work in water Eg: autonomous underwater vehicle

c. Flying robots: The robots that are designed even to work in air Eg: drones

d. Hybrid/Wheel-legged Robots: Wheel-legged robots are irregular robots with multiple functions. Wheels can make your robot move faster, are easier to design and build. Legged robots on the other hand are excellent on uneven surfaces and rough terrain. E.g. jumping or hoping robots.

The key and main components of robots are given in table 2, which mainly helps for the functioning of autonomous vehicle.

Table 2: Key components and its function of robots

S. No.	Components	Functions
1.	**Mechanical linkage**	Different type of mechanical assembly which contains gears, wheels, arms, etc. is known as mechanical linkage
2.	**Sensors**	The sensors are the transducers which convert one form of energy into another form ex. light sensors, touch sensors, US sensors, IR sensors, etc.
3.	**Actuators**	The devices which help to produce connectivity between electronics circuits and mechanical assembly are known as actuators
4.	**Transmissions**	A conductor for transmitting optical or electrical signals or electric power
5.	**Stepper Motors**	Stepper motors are used to obtain either rotational motion or step motion to the mechanical assembly of the robot
6.	**Power conversion unit**	This is the power supply of the robot either mains supply or batteries
7.	**User interface and software**	This is the controlling software section of the robotic anatomy that controls the overall working of robot to carry out a particular task

2. APPLICATION OF ROBOTICS IN AGRICULTURE

The robotic approach may not be economically justifiable in many broad acre crops but will certainly be more attractive in high value crops where a smart machine can replace expensive repetitive labour. The application of this technology in crop production could reduce the production cycle to three stages: seeding, plant care and (selective) harvesting and thus the potentiality of applying autonomous robotic vehicles compared to conventional systems are discussed below.

2.1 Ploughing: Ploughing is one of the most important primary cultivation processes and had been carried out since the start of civilization. It is effectively the inversion or mixing of topsoil to prepare a suitable seed bed. It also has the ability to bury surface crop residues and control weeds. Earlier, ploughing was performed with the help of a man and pair of bullocks, subsequently, replaced by manned tractors which reduced the man power. Further, to improve the accuracy man less tractors came into existence that failed to embrace the complexity of real world. To overcome this difficulty, automated compact robot can be made to obtain specific results. Dattatraya *et al*., 2014 and Zanwar and Kokate, 2012 assembled an autonomous system for cultivating ploughed land that required less power. The developed robotic system was an electromechanical and artificial agent steered by DC motor that had four wheels. The infrared sensor used detected the obstacles in the path and also sensed turning position of vehicle at end of land. The machine was controlled remotely and solar panel was used to charge DC battery. It was reported that the farm was successfully cultivated by the machine, depending on the crop considering particular rows & specific columns. A meticulous study was done on different types of robots by Kamalesh *et al*., 2014 to increase the efficiency and precision in agriculture fields. They expressed that cultivators were interested and satisfied to use tested robots in agricultural fields for ploughing, cultivating and leveling to increase the productivity rate.

2.2 Planting: Planting method includes broadcasting, seed drilling, row planting etc., selection of these methods should be based on planting equipment, time and labor availability, seeding costs, planting date opportunity, weather, crop usage and yield goals, and stand establishment risks associated with each method. In addition, calibration of planting equipment is critical to get the correct number of seeds in the soil. Robotics, now, had paved a way to overcome the said risks. Chavan *et al*., 2015 designed enhanced robotic system for seeds sowing in pre defined row spacing ploughed lands and observed that this system effectively reduced the labour costs and also placed the seeds in a uniform manner. Shiva Prasad *et al*., 2014 also designed system for seeding, fertilizing and soil ph, temperature, moisture, humidity checking. The designed system involves robot navigation to the destination successfully, performed operation with no hurdles, thus, was reported very useful for the farmers who were intended to do agriculture activity.

2.3 Grafting: Despite the labor intensive nature, manual grafting has been used as the predominant method worldwide. Grafting speed and success rate are strongly affected by plant species, grafting methods and operators. Recently, automated grafting or grafting robots gained importance against labor management issues during period of seasonal demands. Chang *et al*., 2012 compared the hand and robotic tube grafting in sweet pepper and indicated that the survival percentage of both the methods were on par with each other. In addition, they observed that the enhanced grafting speed recorded with robotic tube grafting. Nishiura et al., 1995 constructed a grafting robot to perform the "plug-in method" on the basis of the seedling characteristics and the structure and physical properties inside the stem. It had been demonstrated that the proposed technique of cutting vegetative materials using an ultrasonic level vibrating blade can reduce the damage to the vegetative tissue.

2.4 Irrigation and watering: Irrigation of land is a paramount in farming and it needs continuous monitoring to avoid under irrigation and over irrigation. Automation in agriculture envisages monitoring and controlling the irrigation, that directly or indirectly affect the growth of crops. Chauhan *et al*., 2014 introduced the technology that would monitor the soil moisture and decides the duration of irrigation for maintaining the moisture at an optimum level to harvest maximum crop output. A completely autonomous system for watering potted plants was presented and evaluated by plotting a graph between the number of plants watered and the time required by the mobile robot. The evaluation indicated that the system was highly cost-effective and efficient in terms of time, to perform the watering operation (Hema *et al*., 2012).

2.5 Crop scouting: Unmanned aerial vehicles (UAVS), also known as **drones**, are aircraft either controlled by 'pilots' from the ground or increasingly, autonomously following a pre-programmed mission. Zhang *et al*. (2014) examined the feasibility of applying unmanned aerial vehicle acquired images for monitoring crop conditions based on the actual requests from producers. The results suggested that it is plausible to obtain images and process them in a timely fashion for precision agriculture applications. However, due to current costs and operational logistics the application is still in its infancy stage.

2.6 Weeding: Weeds have a controversial nature. But to the agriculturist, they are plants that need to be controlled, in an economical and practical way, in order to produce food, feed, and fiber for humans and animals. Removal of weeds also involves many energy-intensive methods. But now smarter and more environmentally friendly approaches are available for eradicating weeds. One such approach is utilization of robots in weeding. Robots performs the elementary functions of farming involves harvesting, spraying, seeding, weeding, grading etc. and gradually appears advantageous to increase productivity, improve application accuracy and enhance handling safety (Sani, 2012). The autonomous assembly was developed for weed control system in ploughed land with no intervention of man power. The assembly consisted of two different mechanisms that detected weeds and obstacles present in path of the vehicle by color and infrared sensor respectively. The high speed of the weed removal operation ensured the scope for further expansion (Kulkarni and Deshmukh, 2013).

2.7 Spraying: The inhalation of chemical spraying could be fatal or cause permanent damage to the human health. Thus, use of an autonomous pesticide spraying device would help in avoidance of human exposure to hazardous chemicals and ensures the application of optimal calculated amount of spray to all plants evenly, minimizing waste due to increased accuracy and precision. An autonomous mobile robot was designed for use in pest control and disease prevention applications in commercial greenhouses. The effectiveness of this robotic system is to navigate successfully down the rows of a greenhouse, while the pesticide spraying system efficiently covers the plants evenly with spray in the set dosages (Sammons, 2005)

2.8 Data collection: The scientific world demands qualified workers equipped with related expertise and skillful hands for recording observations and other skilled works to be performed in field and lab conditions. An unmanned agricultural robotics system (UARS) was designed, constructed, and operated with multiple sensors, including crop height sensor, crop canopy analyzer, normalized difference vegetative index (NDVI) sensor, multispectral camera, and hyper spectral radiometer by Wang *et al*., 2014 to measure various morphological data of crop. They reported that UARS, a ground-based automatic crop condition measuring system helped scientific community and also farmers to maximize the economic and environmental benefits through precision agriculture.

2.9 Harvesting: Robots in harvesting operation were started with the tomato fruit harvesting robot since 30 years ago. The robot consisted of manipulator, a harvesting end-effector, a color TV camera which was used for stereo vision, and a battery car for traveling in the pre-defined pathway. The robotic technologies were further applied to cherry tomato, strawberry, cucumber, eggplant, cabbage, mushrooms, orange, apple, grape, watermelon, asparagus etc. Although some of the developed robots can automatically perform fruit harvesting operations with a 60-70 % success rate, the robots are still slow and the costs are expensive. The three types of harvesting robot were developed by Hayashi *et al*. (2005). They reported that prototype strawberry harvesting robot could judge maturity and make basic harvesting movements, eggplant-harvesting robot achieved a harvesting rate of 29.1%, averaging 43.2 seconds per fruit and stereoscopic vision system of tomato-harvesting robot could detect individual fruit and harvest the ripened tomato with an accuracy of 85%.

2.10 Post harvest technology: Quality maintenance of horticultural produce after harvest involves many difficult tasks. Consequently, during many post harvest handling operation, all the main movements including package rotation are now carried out by robots, where, few conventional technology and mechanical components are required, resulting in a very reliable system. Crate loaders are also available for pre-pack picking and placing systems that load bags, clamshell and other small package units into the crates or cases at a processing rate of more than one unit per second.

It is also known that quality of agricultural products immediately affects the market value. Therefore, quality maps should also be obtained as well as yield map. Qiao *et al*., 2005 created a database of spatial yield and quality information for sweet pepper by using the mobile fruit grading robot. Then a real-time mapping method was developed from the database. Three hundred and seventy-two sweet pepper fruits harvested from 300 plants were utilized for the experiment in laboratory. Information such as plant location, harvesting time, fruit index (number of fruits from a plant), fruit size, colour, shape, defects and grade also mass was obtained. Based on these information sources, a database was established to create both a yield map and a quality map. Results indicated that the database was adequate to represent the spatial variability of yield and quality in a field as yield and quality maps, the developed mapping program is effective and practical, and that the system can be applied in real time.

3. DRAWBACKS IN ROBOTICS

Initial cost of robots is very high despite of the many positive application known. Also, robotics in certain situation lacks capability to respond in emergencies, which cause inappropriate and wrong responses, lack of decision-making power, loss of power, damage to the robot and other devices. Furthermore, it is reported that robots even injures human beings.

4. CONCLUSION

The exploitation of robots in agriculture will rally round in near future and guarantees the increased food production. Robotics and automation can, in many situation, increase productivity, safety, efficiency, quality, consistency of products as well works continuously even in an unfavorable conditions without any humanity needs and illnesses. It is also evident from the research that there is a significant potential for applying these autonomous systems in various agricultural operations when it is possible to impose adequate control and safety regulations systems at reasonable cost. However, certain modification in plant morphological characters like, easy harvest of produce, uniform fruit shape and maturity, training methods etc., will also ensure successful implementation of robotic technology to accelerate plant production.

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