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Potential aspects of robotics in Indian agriculture : Scope and future

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ABSTRACT : Robotics can play a very important role in Indian agriculture as far as the constantly decreasing size of farming fields is concerned. In comparison to foreign countries where the size of farm is large and heavy machinery can be used advantageously, this is not the case with Indian farms. In the process streamlining limited economic resources at farmer, robotics can reduce the burden by cutting cost on purchase in terms of quantity. Robotics uses small sized equipments to do the same operation which is very suitable for small sized farms. Precise use of costly pesticide and fertilizer can also be done by the automated robots. These brained machines can effectively perform repetitive agricultural operations with no or little error. The robots can also alleviate problems of traditional farming like soil compaction, use of renewable energy resources, drudgery etc. Many researchers have developed different agricultural robots in India and foreign countries. This paper deals with different robotic systems used in various agricultural operations in India as well as other countries. These are classified into several task groups such as planting, weeding, pest control, harvesting or picking, etc.

KEY WORDS : Robotics, Agriculture, Drones, Autonomous vehicles, Precision farming

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Robots are autonomous or semi-autonomous physical machines that have some sort of artificial intelligence that interact with the surroundings and perform specified tasks. Robots resemble human beings in certain aspects. They have brain or stored instructions set, sense the environment (Kang *et al.*, 2012), take decision and complete the job accordingly. These machines are better than humans in performing repetitive tasks with greater accuracy in almost all working conditions. The science of robots dealing with the mechanical design, production, operation and application of robots as well as their intelligence systems for their control, sensory feedback and information processing is considered as robotics.

In India, there are large numbers of smaller farms. Small and cost effective robots can be best match for them. In comparison to foreign countries, where the size of farm is large and heavy machinery can be used advantageously, this is not the case with Indian farms. In India, the farmer has limited economic resources to spend on farm inputs. In the process of streamlining these resources, robotics can reduce the burden by cutting cost on purchase in terms of quantity. Robotics uses small sized equipments to do the same operation which is very suitable for small sized farms. Tractors can be replaced by various small efficient autonomous machines (Naik and Thakur, 2017). Precise use of costly pesticide and fertilizer can also be done by the automated robots.

These brained machines can effectively perform repetitive agricultural operations with no or little error.

The robots can also better tackle problems of Indian traditional farming like human drudgery, compaction of soil due to repeated use of heavy machinery, etc. The robots, mostly run on electric batteries, can make best use of solar power cells, where solar irradiation is abundantly available at farm. This also complement the farming in far-flung areas where solar energy is only choice. The flexible and interconnected robotic and autonomous systems can work seamlessly alongside their human coworkers and thus will increase their productivity gradually. Although robotics, today, involve high initial cost but their production at large scale and indigenization of the technology will surely bring their affordability in the range of the large farmer population. Many researchers have developed different agricultural robots in India and foreign countries. This paper deals with different robotic systems used in various agricultural operations in India as well as other countries. These are classified into several task groups such as planting, planting, weeding, pest control, harvesting or picking, etc.

Robots in Indian agriculture operations:

Seeding and transplanting:

Seeding and transplanting is on rising need for automation. Handling of nursery process and seedlings is a cumbersome task for labour. These small repetitive tasks which require good control and accuracy can be better handled by robots. Nurseries have good uniformity in sizes and other physical properties, therefore, it is easy to automate operations related to this system. In greenhouses, seeds and seedling are also costly affair. Robotic machines can handle these operations easily with greater accuracy.

In automation process, the plantations of seeds are automatically done by robotic seed drills. The robot drill consists of a DC motor to drive the system and a micro-controller to maintain seed to seed spacing and other functions. Different seeds at different distances can be placed by varying the settings of micro-controller. When the robot reaches the end of the field we can change the direction either automatically or with the help of remote switches. The whole process is controlled by micro-controller (Anonymous, 2018).

Kang *et al*. (2012) and Astrand and Baerveldt (2004) developed a vegetable transplanting (Fig. 1). The robot consists of the transplanting part, nursery tray moving part, plant pot moving part, main frame and controller. The transplanting capacity of the developed robot was 2800 pots per hour and has 99 per cent rate of success. An automated pneumatic nursery tray seeder was tested for sowing seeds by Naik and Thakur (2017) and Blackmore *et al*. (2004). It saved Rs. 20.23 per 1000 seeds sown amounting to 66.08 per cent of the manual sowing cost. A automatic rice transplanter was tested in Japan (Nagasaka *et al*., 2004) which was sufficiently precise for the rice transplanting. It used real-time kinematic global positioning system for precise positioning and gyroscopic sensors to measure direction. Leemans and Destain (2007) developed a mechanism which positioned the seed drill tynes in relation to previous lines by a machine vision system.

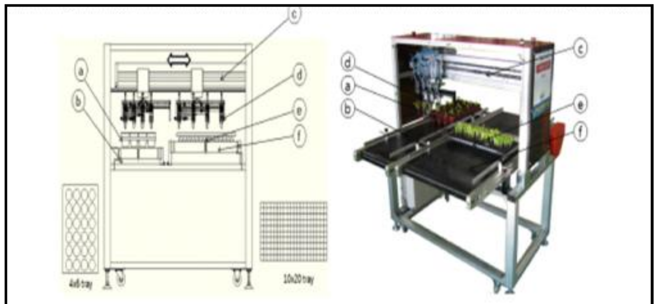

Fig. 1 : Vegetable transplanting robot (a), Planting pot (b), Pot moving conveyor (c), Transplanting device (d), Transplanting finger (e), Cell tray (f) and Tray moving conveyor

Autonomous precision seeding combines robotics with geo-mapping. A map is generated which shows the soil properties (quality, density, etc) at every point in the field. The tractor, with robotic seeding attachment, then

Fig. 2 : Soil moisture content monitoring spherical robot (Hernandez *et al.*, 2013)

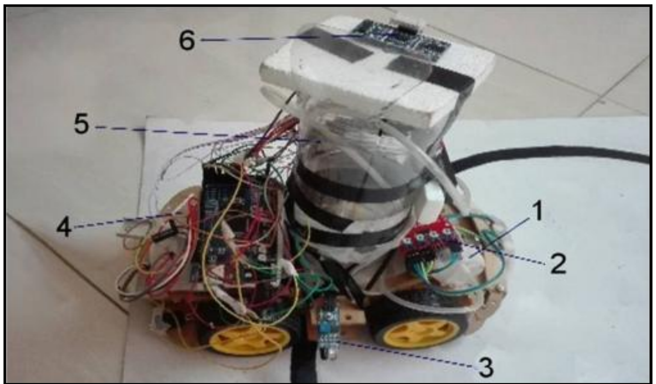

Fig. 3 : Garden robot for irrigation - parts: (1), DC pump (2), Signal conditioning circuit (3), IR sensor (4), Arduino AT meaga 2560 (5) and Water tank (6) Ultrasonic sensor (Rafi *et al.*, 2016)

places the seeds at precise locations and depths so that each has the best chance of growing.

Irrigation:

In India, irrigating and fertilizing crops in traditionally methods used a lot of water which is quite inefficient. The traditional process sometimes consumes additional water or sometimes the water reaches delayed due to which the crops get dehydrated. Due to unplanned use of water the ground water level is also decreasing day by day. Uncertainty of rains and scarcity of land water also worsen the problem. Robot-assisted precision irrigation techniques can reduce wasted water by targeting only specific plants.

Ground robots autonomously navigate between rows of crop and pour water directly at the base of each plant. Robots also have an advantage as they are able to access areas where other machines cannot. For example, corn growers face a problem that the plants grow too quickly to reliably fertilize them. Robot aims to solve this problem as it easily drives between the rows of corn and targets nitrogen fertilizer directly at the base of each plant. Several researchers focused on autonomous irrigation with sensors in agricultural systems. Irrigation management is also one of the important activities in precision agriculture (Keshtgary and Deljoo, 2012 and Zhang, 2004). A low-cost spherical robot was developed to detect moisture content of soil (Hernandez *et al.*, 2013) (Fig.2). As per the slogan -more crops per drop, growers are also exploring to develop irrigation techniques by using less fresh water (Balendonck *et al.*, 2008; Kim *et al.*, 2008; Coates, 2006 and Ngaira, 2007). One of them is making agriculture in a manner of sense, which uses a different type of sensors (Lopez *et al.*, 2009 and Benghaem, 2010). Rafi *et al.* (2016) developed a gardening robot (Fig. 3) which can irrigate the plants placed in a predefined path autonomously without any human intervention. It was capable of comparing movable objects and stationary plants through its ultrasonic sensor to minimize water loss. Khattab *et al.* (2018) developed process for automation in drip irrigation for the greenhouses. A wireless sensor network was also studied to control the irrigation automatically (Hussain *et al.*, 2013).

Crop monitoring and analysis:

The manual inspection of farms is still popular in India. These traditional methods are time-consuming and subject to observer's skills. The same field conditions are interpreted differently by different observers. So optimum amount of input resources can not be applied. Also, perpetual monitoring of field is impossible by human. Robots can do the same effectively and precisely (Mulla, 2013). Ground robots and drones provide a way to collect this data autonomously. The farmer can then move the drone to the field, initiate the software via a tablet or smart phone and view the collected crop data in real time. Ground based robots provide even more detailed monitoring as they are able to get closer to the crops like AGROB V14 (Santos *et al.*, 2015), e-AGROBOT (Pilli *et al.*, 2015), AGRowBot (Hemsworth, 2017), Terra Sentia (Holland, 2018), etc. Some can also be used for other tasks like weeding and fertilizing.

Wireless Sensor networks can be used for monitoring in diverse types of climates and conditions, spatio-temporal changes in climate, hydrology, pressure, motion, soil moisture, plant eco-physiology, pests and reporting best options to the agriculturist. Having such information at regularly would be a big boon for the farmers. In the adverse conditions which challenge the agriculturists, automation system can be used to control irrigation, fertigation and pest control.

Valente *et al.* (2011) developed a wireless sensor network and an aerial quadrotor robot to assit farmers in monitoring variables from fragmented crop fields. The e-AGROBOT robot was used to detect diseases in early age by image processing. It also applied pesticides to the diseased plant. The robotic sensors can detect Microplitis Croceipes, a tiny parasitoid wasp which damages cotton crop, at early stages (Joshi and Kanade, 2017). These attacks can be effectively controlled by selective use of specific pesticide.

AGROB V14 is small and a cost effective outdoor robot for application on mountain vineyard monitoring tasks.

Crop weeding and spraying:

Weeds and pests on the farms are controlled in many ways like hoeing, spraying of weedicides, etc. Spraying of weedcides has become a common tool now-a-days due to the less cost involved per unit area and less labour requirement. But applying pesticides uniformly to all fields is not only wasteful but also severely damages the environment. The crop plants also get damaged or their growth is inhibited to some extent is many cases. Robots can enhance the efficacy of these pesticide applications.

The micro-spraying by robots can significantly reduce the quantity of herbicide used in weeding control. These robots use image detection techniques to identify weeds and then apply a specified amount of weedicide on them. Lee *et al.* (1999) designed a real-time intelligent robotic weed control system for tomato crop for selective application of the herbicide. It reduced the cost of the operation by 54 per cent in comparision to conventional weeding. Lamm *et al.* (2002) also developed a selective chemical spraying real-time robotic weed control system for cotton. Lettuce bot developed by Blue River Technology (Anonymous, 2018) is a tractor hitched robot which selectively kills the weeds plants with 98 per cent accuracy. A machine-vision robotic machine was also developed to remove weeds in organic sugar beet farm (Bakker *et al.*, 2005).

Some robots hoe the weed plants instead of chemical application. This operations is very helpful in case of organic farming where use of chemicals is prohibited. Astrand and Baerveldt (2004) developed an autonomous robotic weed control system with a selective rotary hoe for sugar beets. A robotic vehicle was also developed to operate in 0.25 and 0.5 m row crops and equipped with cameras for row guidance and weed detection (Bak and Jakobsen, 2004).

Maruyama and Naruse (2014) developed a robotic weeding system for a rice field with specially designed wheels that mix up the soil and water to avoid germination of weed seeds. A similar intra-row mechanical weeder used real-time kinematics global positioning system (GPS) to locate plant positions (Perez-Ruiz *et al.*, 2012).

Fig. 4 : Ag bot II (Image: Queensland University of Technology)

Advanced robots uses mechanical ways or laser (Griepentrog *et al.*, 2010), pulsed high voltage (Mizuno *et al.*, 1990 and Blasco *et al.*, 2002) to destroy weeds if the weed is identified as resistant to herbicide. AgBoT II (Anonymous, 2018) is such an advanced agriculture robots that has a robotic hoe arm along with chemical spraying unit (Fig. 4). It also reduces operational costs of weeding. This robot runs on solar power so, also result in reduction in fossil fuel caused pollution and can be advantageously used in sub-tropical countries like India.

Autonomous tractors:

In way of exploring the new ideas for the crop production in agriculture, it is necessary to establish the operational requirements of an autonomous tractor. Blackmore *et al.* (2004) retrofitted a small grounds tractor with steering, throttle and continuously variable transmission actuators controlled by a proprietary automatic steering system (Fig. 5). The three point linkage

Fig. 5 : A deterministic autonomous tractor (Blackmore *et al.*, 2004)

and power take off, could also be controlled. The resulting system followed predefined instructions in a deterministic way by itself with reasonable accuracy but it was not able to react to unknown obstacles and situations. Khot *et al.* (2005) also developed an autonomous tractor for mechanical weed control in row crops. An initial stage solar powered multipurpose agriculture tractor robot was also prototyped (Mahendheran *et al.*, 2017). It was capable of tilling, plough, harvesting, spraying and cutting with special implements.

Autonomous tractors are yet to be fully automatic, but show scope for development. A number of prototype guidance systems (Kayacan *et al.*, 2015; Ming *et al.*, 2009 and Torii, 2000) have been developed but waiting for commercialization.

Picking and harvesting:

Harvesting of cereal crops like corn, wheat, paddy, etc. is quite simple and can be done with today's combine harvesters. But in case of horticulture crops, it is difficult, laborious, time consuming and require manual dexterity. Hence, the use of robots is beneficial in harvesting of these crops. Harvesting robots have been used for apple, cherry, tomato, petty-tomato, cucumber, grape, etc. since long time. Henten *et al.* (2002) and Tang *et al.* (2008) developed the autonomous robots for harvesting of cucumbers. A robotic device consisting of a manipulator, end-effector and image-based vision servo control system was developed for harvesting apple (Zhao *et al.*, 2011). It has a success rate of 77 per cent and the average harvesting time as 15s per apple. Kondo *et al.* (1996) devised a cherry tomato harvesting robot with a success rate of 70 per cent. Delicate fruits like cherry, grape are also tested to be picked by robots. Tanigaki *et al.* (2008) developed cherry harvester robot with 3-D vision sensor. The European Union is also funded the project- cRops (Clever Robots for Crops) focused on creating robots to harvest high value crops.

Although these robots have 60-70 per cent success rate and slower speeds (Kondo *et al.*, 2006 and Zhao *et al.*, 2011), still they offer better solutions considering the human labour and drudgery involved in harvesting.

Conclusion:

Although adoption of autonomous vehicles is yet to be achieved in India, still these machines promise a bright future. These robots tend to alleviate current problems faced by Indian farmers in some way. Indigenization of these machines and increased production of these machines will definitely bring their cost down, a barrier in their adoption, and ensure better penetration in agriculture.

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