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Recent Advances and Future Prospects of Robotics in Agriculture

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***Abstract*: Agriculture is the primary occupation of our country. With the technological advancement in all spheres, agriculture has also witnessed developments with the introduction of robotics and automation. Agricultural robot or "Agribot" is a robot used for agricultural purposes. The advent of robots in agriculture drastically increased the productivity and output of agriculture in several countries. Further, the usage of robots in agriculture reduced the operating costs and lead time of agriculture. The current paper reviews the various applications of robotic agriculture in different areas of agriculture. The work also throws light on the future scope of robotic agriculture.**

***Keywords*: Robot, RIA, Mechanization, Weed Mapping, Seed Mapping.**

1. Introduction

Agriculture is just one step in the supply chain that leads to the table of the consumer. Just as automation has brought down the price of electrical goods by reducing the manpower involved, so is the price of agricultural production being reduced. Although electronic games are a luxury, food is a necessity that must be produced at all costs. We therefore need either more farmers or more ways to produce food with limited manpower. The robots are coming to the rescue. The goal of agricultural robotics is not only to apply robotics technologies on the field of agriculture but also to use the agricultural challenges to develop new techniques and systems [24].

The scope of agricultural robotics includes [23],

1. Most farming environments for produce, which presents large, semi structured open spaces
2. Farm facilities for a variety of animals, which could also present large semi structure open spaces (for example, cattle-grazing areas) or environments that are more built up, such as caged chicken farms
3. Forestry
4. Aquaculture.

India is an agricultural country. As the data presents, Indian agricultural sector accounts for about 18 percent of India's Gross Development Product, providing employment to fifty percent of country's workforce. However, with the increasing population, the demand for more and more production arises. In order to fulfil the requirement of food production, the process needs to be made faster. In order to achieve this, robotics plays a great role. Robotics and automation can play a significant role in enhancing agricultural process. With the help of robots, the various steps involved in agriculture can be optimized to a large extent [5].

Robots have been successfully used in several industrial applications like material handling, material transfer, processing, inspection & quality control. In the past twenty years, a similar trend has started to take place in agriculture, with GPS- and vision-based self-guided tractors and harvesters already being available commercially. The reasons for usage of robots in agriculture are to improve food quality and productivity, reduce labour costs and time. One more important reason for robotic agriculture is the unavailability of sufficient skilled man power in agricultural sector and it affects the growth of developing countries. The idea of mechanization (usage of automated equipment and robots) of agriculture was most obvious in recent years and there are many success stories of robotic agriculture. More recently, farmers have started to experiment with autonomous systems that automate or augment operations such as pruning, thinning, and harvesting, as well as mowing, spraying, and weed removal. In the fruit tree industry, for example, workers riding robotic platforms have shown to be twice as efficient as workers using ladders. Advances in sensors and control systems allow for optimal resource and integrated pest and disease management. Therefore, if the farmers are empowered with support of robots, the agricultural output of the nation can improve radically [2].

Advanced machine vision and machine learning are being incorporated into systems that integrate these technologies to produce new types of agricultural robots. Robots and automation technologies have the potential to dramatically improve crop quality and yields, reduce the amount of chemicals used, solve labor shortages, and provide hope for the economic sustainability of smaller farming operations. These factors are driving strong demand for robots throughout the farming process, including planting, pruning, weeding, pick-and-place, sorting, seeding, spraying, harvesting, and materials handling.

India being an agriculture based country, where about 80% people are dependent on agriculture, it becomes essential that this biggest industry in India is strengthened for its progress. A lot of work on field crops cultivation, harvesting, storage and handling are being done to enhance agricultural production. Use of tractors, combines, harvesters, tube well, irrigational implements and so many other implements have become

essential for agriculturists. Various sensors and tools are being used in this industry except a Robot - due to the lack of knowledge about it.

It is necessary to invent cost effective robots to make them available within the purchasing capacity of the Indian farmers, and to promote research, development, innovation, and standardization in robotics and automation to enable safe, efficient, and economical agricultural production. Academic and industrial researchers and engineers needed to advance the state-of-the-art in sensing, mobility, manipulation, and management technologies applied to production of grains, fruits, vegetables, nuts, and horticulture and nursery crops.

Planting, managing, and harvesting agricultural products require a lot of work. Unfortunately, farmers throughout the United States find it increasingly difficult to find enough workers for their fields. Regardless of why farmers can't keep up with the demand, tech companies say that they have an answer that requires very little from the workforce. Instead of relying on human employees, farms can turn to a new generation of agricultural robots that work autonomously and intelligently.

The most important current abilities of automatic agricultural vehicles can be grouped into four categories:

1. Guidance (i.e., the way the vehicle navigates within the agricultural environment)
2. Detection (the extraction of biological features from the environment)
3. Action (the execution of the task for which the vehicle was designed, e.g., radicchio harvesting [6])
4. Mapping (the construction of a map of the agricultural field with its most relevant features) [7].

However, those four cores are not independent. For safe and successful navigation, the vehicle has to know its position within the field and the elements from the surrounding environment (mapping); bad detection could lead to an incomplete or unreliable map. Furthermore, if the elements from the environment are not properly located within the map, an agricultural vehicle may not be able to execute its tasks successfully. In addition, an incomplete map should not be used for navigation purposes because of the risk of collision. As can be seen, the knowledge regarding the location of a vehicle within the environment and the location of the elements in an environment plays a crucial role in an automatic agricultural vehicle design.

2. Initial stage of agricultural robots

The idea of robotic agriculture (agricultural environments serviced by smart machines) is not a new one. Many engineers have developed driverless tractors in the past but they have not been successful as they did not have the ability to embrace the complexity of the real world. Most of them assumed an industrial style of farming where everything was known before hand and the machines could work entirely in predefined ways, much like a production line. On a global scale the need for more food is a serious issue. Usage of Agricultural Robots started slowly replacing the man power needed for agricultural purposes [3].

3. The new generation of agricultural machines

Several research groups in the world have been developing general-purpose agricultural robots succeeding in automating specific tasks that require intelligence, although they are still far away from fully autonomous systems. Some notable examples of agricultural robotic platforms can be found in [10]-[13], for strawberry, cabbage, and melon harvesting. All these systems rely on computer vision as a critical module to gain process automation. Visual methods have been also widely employed for visual servoing of agricultural machines [14]-[16], for fruit recognition on trees [17,18] or grade judgment [19], for weed control [20,21], as well as for poultry inspection and apple defects detection [22].

The advent of agricultural robots will herald a change in the way agricultural machinery is envisaged. Today, bigger is better because the productivity of the skilled driver/operator is improved. Mobile robots could change this by taking the driver out of the equation. Indeed, emerging mobile agricultural robots are likely to be slow, unmanned, light-weight and modular. Their slowness means that more attention is given to each plant, their lightness means no soil compaction, and their small size means potentially lower cost.

The latter point is critical if such mobile robots are ever to leave the drawing board because slower and small machines are inherently less productive therefore need to be lower cost. Today, most examples of such robots are only in the prototypes or early stage commercial trial phase but the direction of development is clear. The technological challenges will soon largely been solved and the industry will enter the phase of making and proving a commercial case, whether as an equipment or a service [9].

Modern agriculture has always relied on machines to make work easier and more efficient. Even the smallest farms use cultivators, plows, and harrows. The new generation of agricultural machines, however, have a higher level of sophistication that makes automation possible. Many of them do more than automate planting and harvesting. They also use artificial intelligence to make decisions that improve a farm's success.

4. Controlling weeds to improve crop yields

A company called Blue River Technology wants to control weeds with a robot it calls See & Spray. The robot patrols farmland and uses computer vision to detect weeds. When the robot encounters a weed, it can spray herbicides directly onto the invasive plant. The company estimates that its precision spraying technology can reduce the amount of herbicide used on farms by about 80%. Using sophisticated robots to spray specific plants would help prevent species from developing herbicide resistance. It would also improve environmental

conditions by keeping chemicals out of water systems. Currently, See & Spray only works with cotton producers, but it's easy to see how a few tweaks could make the technology useful for farms that grow other types.

5. Harvesting robots reduce the need for human workers

It's unlikely that more workers will flood the agriculture industry in upcoming years, so it makes sense for farmers to purchase harvesting robots that reduce the need for human workers.

When ripe fruits and vegetables sit in the field, weather conditions, insects, and time can make the produce unusable. Several companies have already developed harvesting robots designed to harvest produce at the right time, making yields larger and improving profits. Panasonic has a robot that uses image recognition to determine the ripeness of tomatoes. When it finds tomatoes ready to harvest, it collects them. Harvest CROO Robotics has a strawberry harvester that uses 16 individual robots to collect ripe fruits.

Picking is currently done using manual labour with machines at most playing the part of an aid that speeds up the manual work. Progress here has been hampered by the stringent technical requirements. The vision system needs to detect fruits inside a complex canopy whilst the robotic arms needs to rapidly, economically and gently pick the fruit. The lack of CAD models has also prevented rapid iterations in product development. The absence of universal applicability has also put off large investments as each harvester is likely to work on a narrow segment. This is however beginning to change, albeit slowly. A limited number of fresh strawberry harvesters are already being commercially trialled. Some versions require the farm layout to be changed and the strawberry to be trained to help the vision system identify a commercially-acceptable percentage of strawberries. At the same time, fresh apple robotic harvesting has also reached the level of late stage prototyping. Here, novel low-cost end-effectors are being developed together with low-cost good enough robotic arms that will work in parallel [9].

Intelligent Robots Can Improve Soil Quality and Crop Yields

Companies like Crop Diagnosis and PEAT build apps that help farmers diagnose and improve unhealthy soil conditions. The apps use imaging and GPS technology to diagnose problems and suggest useful solutions. The technology still needs human guidance, but it's only a matter of time before someone gives a robot similar software to do the job without much oversight.

6. Robotics is the future of agrochemicals

Agricultural robotics is also rapidly progressing on the ground. Vision-enabled robotic implements have been in commercial use for some years in organic farming. These implements follow the crop rows, identify the weeds, and aid with mechanical hoeing. The next generation of these advanced robotic implements is also in its early phase of commercial deployment. The end game however is to turn these implements into general-purpose autonomous weeding robots. This means that swarms of these small, light-weight robots will locate weeds and take site-specific precise action to eliminate them.

This has already starting to occur with numerous companies and groups developing and deploying a variety of weeding robots. Indeed, whilst most products are in prototype or semi-commercial trail phase, the first notable sales have also taken place aimed at small multi-crop vegetable farmers.

This has far reaching long-term consequences for the farming industry, particularly affecting suppliers of crop protection chemicals. This is because it changes the way we farm as farmers will no longer need to broadcast spray chemicals uniformly across the entire field. Instead, they will move even beyond variable-rate precision towards ultra-precision agriculture where the farm is managed on an individual plant basis and where each plant is given only the exact dose of chemicals that it requires.

When using an automated guidance device, spraying can be achieved more accurately, so that areas with too much fertilizer can be reduced. Pollution and the time needed to perform farming tasks are then both reduced. Furthermore, such automation can improve the farmer’s comfort, as the tracking task is performed by the vehicle itself [4].

7. Drones bring in increased data analytics into farming

Unmanned remote-controlled helicopters have already been spraying rice fields in Japan since early 1990s. The progress of drones is by no means limited to spraying. Their core function is to provide detailed aerial maps of farms, enabling farmers to take data-driven site-specific action. These light-weight low-cost drones are often loaded with small multi-spectral sensors, measuring key indicators about plant health, yields, water stress levels, nitrogen deficiency and so on.

This development will soon be entering into its growth years. This is because regulatory barriers for drone deployment are coming down and, more importantly, precision farming ecosystems is finally coming together meaning that farmers can act on what the data tells them. In time, the drone hardware will become commoditized and value will shift largely to data acquisition and analytics providers.

8. The future of agricultural robots

Today's agricultural practices cannot meet the dietary needs of the planet's growing population. By 2050, more than 9 billion people will need fruits, vegetables, meats, and dairy products. According to the United Nations, farmers will need to increase the world's food supply by about 28% to feed those people.

Agricultural robots will play a crucial role in meeting the future population's dietary needs. Innovations may include robots that pollinate plants, maximize the amount of milk taken from cows, and use intensive farming practices to shrink the amount of land needed to grow food.

9. Conclusion

The current review presented the necessity, advantages, applications and success stories of using Agribots in agriculture. The application of agricultural machinery in precision agriculture has experienced an increase in investment and research due to the use of robotics applications in the machinery design and task executions. Precision autonomous farming is the operation, guidance, and control of autonomous machines to carry out agricultural tasks. It motivates agricultural robotics. It is expected that, in the near future, autonomous vehicles will be at the heart of all precision agriculture applications. The goal of agricultural robotics is more than just the application of robotics technologies to agriculture. Currently, most of the automatic agricultural vehicles used for weed detection, agrochemical dispersal, terrain leveling, irrigation, etc. are manned. An autonomous performance of such vehicles will allow for the continuous supervision of the field, since information regarding the environment can be autonomously acquired, and the vehicle can then perform its task accordingly.

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