Revolutionizing Agriculture: Harnessing the Power of Robotics

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1 author:

Aradhana Bordoloi
Assam Agricultural University

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Aradhana Bordoloi

Department of Horticulture, Assam Agricultural University, Jorhat
Corresponding author email id: aradhanabordoloi14@gmail.com

Abstract

This book chapter explores the dynamic and innovative field of robotics in agriculture, delving into its historical evolution, diverse applications, and the associated issues and challenges. The historical context highlights the gradual progression of agricultural automation, from early mechanization to the modern integration of robotics. Subsequently, a comprehensive analysis of the current examples of robotic applications in agriculture is presented, covering precision planting, automated harvesting, intelligent monitoring, and data-driven decision-making. Despite the remarkable advancements, the chapter also addresses the pertinent issues and challenges facing the widespread adoption of agricultural robotics. Additionally, the integration of robotics into existing agricultural systems requires standardized protocols and interfaces, demanding a collaborative approach among researchers, industry stakeholders, and policymakers. The chapter emphasizes the transformative potential of robotics in agriculture, from increasing productivity and resource utilization to promoting sustainable farming practices. It emphasizes the significance of overcoming existing challenges through collective efforts to maximize the benefits of these cutting-edge technologies. By embracing robotics in agriculture, the industry can usher in an era of smart farming, contributing to a more efficient, ecologically conscious, and food-secure future.

Keywords: Agriculture, Intelligent monitoring, Revolutionizing, Robotics, Sensor

Introduction

Agriculture, as the backbone of human civilization, faces significant challenges in the modern world, including population growth, climate change, and the scarcity of resources. To overcome these obstacles and ensure sustainable food production, the agricultural industry has turned to innovative technologies, such as agricultural robotics. This chapter explores the application of robotics in agriculture, examining the history, types of robots, sensor technologies, artificial intelligence, benefits, challenges, real-world applications, and future trends in this rapidly evolving field.

Agricultural robotics, often referred to as agri-robotics, is a specialized field that encompasses the design, development, and deployment of robotic systems to revolutionize various aspects of agriculture. It involves the integration of cutting-edge technologies, such as artificial intelligence, machine learning, sensors, and automation, into agricultural processes to enhance productivity, sustainability, and resource efficiency. The scope of robotics in agriculture is broad and encompasses multiple domains, including precision farming, crop monitoring and management, automated harvesting, selective spraying, pest control, and soil analysis. These robotic solutions offer precise and data-driven decision-making, reducing human intervention, optimizing resource usage, and minimizing environmental impacts. By addressing labor shortages, conserving resources, and increasing yields, robotics in agriculture holds the potential to transform traditional farming practices and pave the way for a more efficient and resilient agriculture sector in the face of global challenges.

Historical Evolution of Agricultural Robotics

Agriculture had significant growth during the nineteenth and twentieth centuries. During this time, some of the modern agricultural tools, such as the lawnmower and the tractor were invented and adopted globally. Research to include autonomous vehicle navigation in agriculture started to take shape in the 1920s, which marked the first development of robots in agriculture (Yaghoubi *et al.*, 2013). This led to the advancements of autonomous agricultural vehicles between the 1950s and 60s (Yaghoubi *et al.*, 2013). The vehicles still required a cable system to direct their direction, so the concept was not entirely successful. As technology in other fields started to advance, agricultural robot development proceeded. Machine vision guiding did not become feasible until the 1980s, following the invention of the computer. Other advancements throughout the years include the use of robots to pick oranges in France and the US (Roy,1987).

Field Specific Agricultural Robots

Robotic agriculture is mostly used because of the increased demand for food. Robotics has a strong connection to the numerous pre- and post-production processes in agriculture and other related sectors. Picking and harvesting are the two main agricultural tasks where robots are used. Along with speed, it provides greater accuracy. The vision systems in agricultural robots are capable of locating a product regardless of the environment, including dust, temperature, and wind movement (Reddy *et al*., 2016). Robotic applications in agriculture are increasingly being used for picking and harvesting, but there are other fields in which they can be used that ultimately aid in the growth of the agricultural economy. Agricultural robots are useful in many works, but only a small number of them are shown below:

1. **Seeding robots:** A robotic system was developed by Keerthana *et al*. (2018) at Excel College of Technology, Tamil Nadu for seeding of four crops—cotton, maize, soybeans, and wheat. For each of these four crops, the system models the necessary row and column distances. Agrobot is an agricultural robot designed by BIT Hyderabad students for carrying out different agricultural operations including seeding. The robot's motor is controlled by a relay, and its primary design is based on image processing (Gollakota and Srinivas, 2011). Raj *et al*. created and tested a seeding and microdose fertilization robot in 2019. The robot's ability to plant various seeds was anticipated, and the trial's results showed excellent prototype performance (Bhimanpallewar and Narasingarao, 2020).

2. **Weeding robots:** Over the past ten years, as a consequence of interdisciplinary collaboration efforts between several worldwide research groups and enterprises, several promising technologies for weed control robots have been introduced and deployed (Shamshiri *et al*., 2018). Developed by interdisciplinary teams, BoniRob is an integrated multipurpose farming robotic platform for controlling weeds in row crops and can also provide detailed field maps (Ruckelshausen *et al*., 2009). It stomps out two weeds every second with a Bosch drill that is one cm wide when it roams around fields looking for weeds (Murugesan *et al*., 2021). An autonomous, solar-powered, compact robot called Tertill was created by Franklin Robotics to cut weeds (Shamshiri *et al*., 2018). Hortibot is another robot designed by the University of Aarhus Faculty of Agricultural Sciences for transportation and attaches a range of weed identification and control tools, such as cameras, herbicides, and spraying booms (Jorgensen *et al*., 2007). According to the report of Perez *et al*. (2000), a technique for capturing and analysing near-ground images to identify broad-leaved weeds in cereal crops under real-world field situations has been developed.

3. **Micro spraying robots:** The idea of a spray boom is reduced to the centimetre level with micro spraying. By carefully choosing when to turn the jets on and off, it applies highly focused chemicals and can treat small areas. It is a component of a bigger system that can identify specific weed plants and find their leaves for treatment. It is important to take extreme caution in the vicinity of a crop to prevent either crop damage or soil disturbance. Using a micro spray, which distributes extremely tiny

amounts straight into the weed leaf, is one way to eradicate weeds that are growing close to agricultural plants. An individual weed plant can be located using machine vision, and it can then be targeted with an herbicide using a group of nozzles put closely together. Tests have demonstrated that using a gel as a carrier rather than water can prevent splashing (Reddy *et al*., 2016).

4. **Irrigating robots:** To water indoor gardens, a robotic irrigation system was developed by Lamsen *et al*. (2022). When a moisture sensor detects dry soil, an Arduino microcontroller increases the water flow.

5. **Crop protection robots:** Spraying harmful pesticides manually is a traditional method of crop protection, which is bad for farmers' health. An intelligent robotic system was created to automatically spray pesticides based on a control algorithm for navigation and a high-efficiency trajectory calculation algorithm to reduce exposure to pesticides (Chang *et al*., 2023). An autonomous spraying robot with two components, a vehicle, and a spraying control system, was created by Cantelli *et al*. (2019). Then, experiments were done to show that the two components working together could produce a spraying operation that was safer and more precise. A semi-autonomous robot created by Bhat *et al*. (2019) can climb Areca Nut trees and then spray pesticides with servo-controlled nozzles. This will result in greater quality and productivity. One well-known piece of equipment is the Japanese-made Yamaha R-MAX, a prominent platform for aerial pesticide spraying (Cheng *et al*., 2006). Using sensitive ultrasonic sensors, Tewari *et al*. (2020) created a robotic selective sprayer. Based on ultrasonic detection technology, the nozzles only spray in the direction of the tree canopy, reducing the amount of pesticides used in orchards by 26%.

6. **Field scouting and data collection robots:** Collecting timely and accurate information is one of the key aspects of good management. Field information collecting robots have been developed to efficiently complete this task. (a) Trimbot2020 is a remarkable outdoor robot built on a Bosch Indigo lawn mower platform integrated with a Kinova robotic arm. It is designed for automatic bush trimming and precise rose pruning, making it an invaluable asset for maintaining garden aesthetics and plant health. (Strisciuglio *et al*., 2018) (b) Another noteworthy creation is Wall-Ye, a pioneering vineyard robot specifically designed to address the challenges faced in viticulture. It can effortlessly map vineyards, carry out efficient pruning, and potentially even assist in harvesting grapes, significantly enhancing vineyard management practices. (Diago & Tardaguila, 2015) (c) Furthermore, the agricultural domain has seen the advent of Ladybird, an autonomous and versatile farm robot catering to a wide range of tasks (Bergerman *et al*., 2016). Equipped with advanced surveillance and mapping capabilities, Ladybird can efficiently classify and detect different vegetables, leading to improved crop monitoring and streamlined farming operations.

These groundbreaking robotic innovations are reshaping the landscape of modern agriculture, bringing greater efficiency, precision, and productivity to the industry.

7. **Harvesting and fruit picking robots:** Rice cutter machines have been widely available for a significant period, and over the years, numerous algorithms have been devised to automate their operation using the established mechanical framework (Qi *et al.*, 2020). Geng *et al.* (2022) introduced an innovative automatic corn harvester system that successfully met trial requirements with an impressive 95.4% deviation rate at typical harvester speeds. This notable achievement sets a benchmark for enhancing the automatic row alignment process. Later, Pooranam developed an enhanced PSO algorithm and utilized it to create a robotic swarm harvester, designed to assist farmers in efficiently carrying out large-scale tasks such as reaping, threshing, and cleaning (Pooranam and Vignesh, 2021).

Issues and Suggestions

Although agricultural robots are becoming more popular and have diverse natures and characteristics, there are some worries and problems that may be resolved by taking the right actions, like:

1. There is still a need for more research and development because some fruits and products are not ideal for agricultural robots.
2. As it requires a variety of equipment and procedures, farmers need to receive sufficient training on these tools. Thus, workshops might be organised to train the cultivators and agro industry experts in this field.
3. Agricultural robots are expensive, both in terms of initial investment and ongoing maintenance. Therefore, appropriate help from the concerned nations, divisions, agricultural companies, NGOs, Charitable Trust, etc. is required.
4. Agricultural robots require regular maintenance for their successful applications and higher production.
5. For agricultural robots to be developed, upgraded, and maintained, it is necessary to have a sufficient number of properly educated workers.
6. Robots require power to operate, however in India, the percentage of power cuts in farming areas is more than 65%, this problem needs to be solved.

Conclusion

In conclusion, robotics in agriculture offers transformative benefits and enhances productivity and sustainability. While challenges remain, cooperative efforts are essential to realize its potential and build a wealthy and food-secure future. Embracing these technologies can revolutionize farming practices and lead to a more effective and environmentally conscious agricultural sector. The agricultural robotics industry is an emerging field with enormous employment potential. Robots will also undoubtedly be useful in attracting the young generation to agriculture and boosting production.

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