Robotics in Agriculture : Then and Now

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Abstract— The world's growing population demands increased food production, placing pressure on farmers to optimize cultivation practices. Agricultural robots, or "agribots," offer a promising solution by automating tasks and improving efficiency. This paper explores the current state of agricultural robotics, focusing on its role in digital farming.

We review recent advancements in robots designed for various tasks, including weed control, field scouting, and harvesting. The paper highlights key challenges in this field, such as object identification, task planning algorithms, and sensor optimization. Additionally, we discuss the emerging trend of utilizing swarms of collaborative robots to enhance data collection and resource management. Finally, the paper explores the potential of simpler robotic manipulators for efficient harvesting within the digital farming framework.

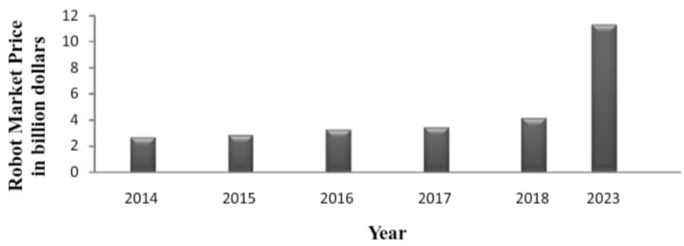
Keywords— Agribots,Cultivation Practice,Field Scouting, Sensor Optimization, Planning Algorithm, Digital farming frameworkcational-project; education; record-keeping; Blockchain;

I. INTRODUCTION

Agriculture, the backbone of human civilization, faces significant challenges in the 21st century. A growing global population demands increased food production, while factors like labor shortages, climate change, and resource scarcity threaten agricultural sustainability. In this context, robotics has emerged as a transformative technology with the potential to revolutionize the agricultural sector.

This research paper explores the burgeoning field of agricultural robotics. We begin by highlighting the pressing challenges facing agriculture and outlining how robotics can address these issues. We then provide an overview of the different types of robots being developed for agricultural applications, including ground-based robots, aerial vehicles (drones), and robotic arms. We will discuss the specific tasks that these robots can perform, such as planting, weeding, harvesting, and monitoring crop health.

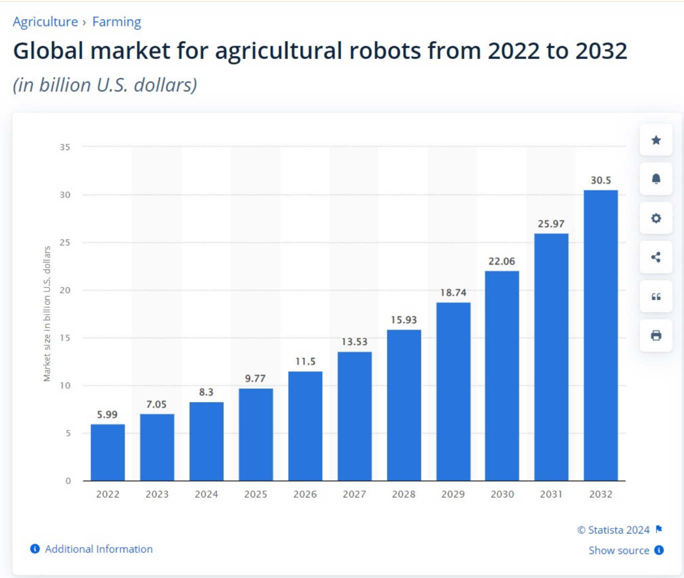
Furthermore, this paper will explore the potential benefits of adopting agricultural robots. These benefits include increased efficiency, improved productivity, reduced labor costs, and more precise application of resources like water and pesticides. Additionally, we will examine the challenges associated with the integration of robotics into agriculture, such as the high initial investment costs, technical complexity, and potential job displacement.



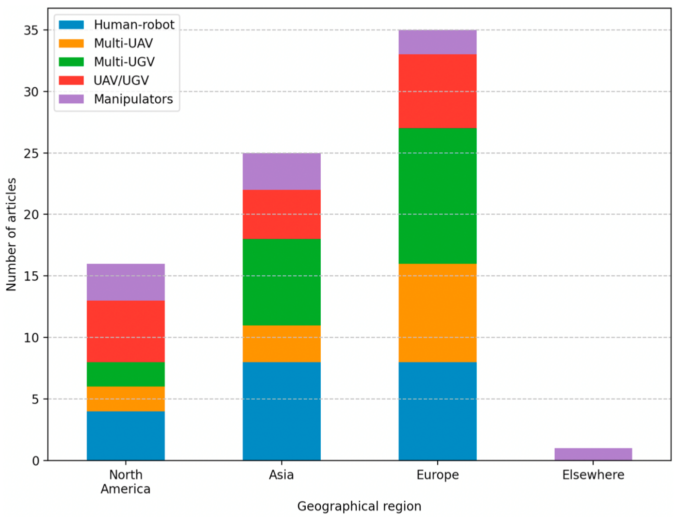
Source: https://www.mordorintelligence.com/

Figure 1 Valueof agricultural robot market in the world

Finally, we will discuss the future outlook for agricultural robotics. We will explore emerging trends and advancements in the field, and analyze the potential impact of robotics on the future of agriculture. This research paper aims to provide a comprehensive understanding of the role that robotics can play in ensuring a sustainable and productive agricultural sector for generations to come.



"A management strategy that uses electronic information and other technologies to gather, process, and analyze spatial and temporal data for the purpose of guiding targeted actions that improve efficiency, productivity, and sustainability of agricultural operations" [1] is the definition of precision agriculture, or PA as it is commonly known. According to this definition, the use of robots in agricultural jobs can further PA by utilizing advanced machinery for precise operations, administration, and measurements. As a result, [2] provided an examination of the implications of the adoption of agricultural robots in the workforce. Comprehensive reviews that encompass a wide range of agricultural robot research may be found in [3-5].



These studies demonstrate the variety of agricultural applications that can be realized by substituting autonomous equipment for human labor. The primary goals of implementing robots in agriculture are (a) increasing productivity and efficiency, (b) addressing the labor shortage of seasonal laborers, and (c) carrying out difficult and potentially hazardous activities. The following interpretation of those agricultural advancements can be made in a broader, industrial framework.

II. RESEARCH METHODOLOGY

A number of elements are coming together to propel the rapidly advancing area of robotics in agriculture, including:

a.Growing food demand: As the world's population rises, there is increasing need to boost agricultural production.

Operations	Conventional farming	Precision agriculture
Selecting an Optimal Site	Manually	Using drones and GPS
Soil Preparation	Adding chemicals based on previous experience	Using sensors like temperature sensor, Humidity Sensor, Volatile matter sensor etc
Field preparation (Ploughing and planking)	Using tractors and bullocks	Agricultural robot for automatic ploughing
Seeding and planting	Manually using hand tools	Precision drills, Broadcast seeders, Seed drills, Air seeders
Watering	Drip Irrigation	Drip Irrigation using Internet of Things
Fertilizer and Pesticide application	Hand spray and manually	UAVs and UGVs, Sprayers, GPS, Smartphone Applications, and Remote sensing
Weed removal	Using hand tools	Blue River Technology and Naio Technologies Weeding Robot Oz

b.Labor shortages: As the workforce in agriculture ages and becomes smaller, automation becomes a more appealing option.

c.Technological developments: Robots with greater sophistication are now possible thanks to advancements in fields like artificial intelligence, machine vision, and sensor technology.

Robots are being developed by researchers for a variety of purposes, such as planting, weeding, spraying, harvesting, and managing animals. Autonomy and navigation:Making robots capable of functioning well in unpredictable and unstructured agricultural contexts is a major challenge. This calls for research in areas such as obstacle avoidance, path planning, and simultaneous localization and mapping (SLAM).Identifying and manipulating objects: Robots must be able to recognize and engage with interesting objects, such as weeds, cattle, and crops. This calls for developments in sensor technology, grasping strategies, and computer vision.

Source: Sweeper EU H2020 project consortium – www.sweeper-robot.eu.

Figure 1 SWEEPER robot in action: The world first fully automated sweet pepper harvesting platform

Cooperative human-robot: Although complete automation is a long-term objective, human-robot collaboration is expected in the near future. To guarantee a secure and efficient connection between people and agricultural robots, research is still being done.

a. TrimBot [142] trimbot2020.org
b. Wall-Ye vinyard robot wall-ye.com
c. Lady bird[144] Univ. of Sydney
j. MARS[146,147] echord.eu/mars
e. SMP S4 smprobotics.com
f. VineRobot vinerobot.eu
g. HV-100 Nursery Bot harvestai.com
h. VinBot[5 9,148] vinbot.eu/
i. Mantis [52] Univ. of Sydney
d. GRAPE grape-project.eu

Figure 4 Examples of general purpose robots for field scouting and data collection

The following are important fields of research and development:

a. Multi-functional robots: creating robots that can carry out a greater variety of jobs, hence decreasing the demand for specialist machines.

b. AI and machine learning: Combining AI and machine learning can allow robots to learn from experience, make decisions, and adjust to changing environments.

a. A prototype surveillance field robot[138], AdaptiveAgroTech.com
b. OSCAR field survey robot, Inspectorbots.com
c. Husky UGV for field scouting and 3D mapping, Clearpathrobotics.com
d. Point cloud and detected maize plants[69], and 3D point clouds of vineyard created by VinBotRobotnik Automation (www.robotnik.eu)[140]

Figure 3 Examples of a prototype and professional field robots for scanning and 3D reconstruction of plants and environment

c. Big data and analytics: Making the most of agricultural data to improve robot performance and guide management choices.

One of the main components of contemporary, sustainable agriculture is precision spraying, which greatly depends on precise and timely field data. In order to provide targeted spraying applications with eyes and ears, field scouting and data collection robots are utilized.

A. Customized Field Scouting

Field scouting has traditionally involved farmers or other qualified individuals performing manual inspections. There are drawbacks to this strategy:

a. Time-consuming and labor-intensive: Scouting vast fields can require a lot of labor.

b. b. Subjectivity: Human observation, which is subjective and error-prone, is the foundation of data collection.

c. Limited frequency: Because of personnel expenses and time limits, frequent scouting is frequently impracticable.

The Field Scouting Robot is a potential solution. It works by:

A. Automated data collection: These robots, outfitted with AI algorithms and sensors (such as cameras and multispectral scanners), autonomously traverse fields to gather data on:

a. Crop health: Look for indications of illness, pest infestation, or malnutrition.

b.Weed pressure: Map and identify weed populations to enable focused weed management.

c.Levels of nutrients and soil moisture: These factors influence fertilization and irrigation choices.

B.Greater frequency: Robots are able to survey fields more often, giving a more comprehensive view of crop health and possible problems.

C. Data objectivity: When compared to human observation, sensor data provides a more unbiased and quantitative evaluation.

Benefits of Robotic Weed Control and Targeted Spraying:

A.Reduced herbicide use: Significantly lower overall herbicide application, leading to:

a. Lower costs for farmers

b. Reduced environmental impact

c. Slower development of herbicide resistance in weeds

B.Improved crop yields: By effectively controlling weeds without harming crops, robots can help to maximize crop yields.

C.Sustainability:** Robotic weed control promotes a more sustainable approach to agriculture by minimizing chemical use and protecting the environment.

Challenges and Research Areas:

A.Accurate weed identification: Developing robust computer vision algorithms that can accurately distinguish weeds from crops in various lighting and weather conditions.

B.Real-time decision making: Enabling robots to analyze data from sensors and cameras and make real-time decisions about where and how much herbicide to apply.

C.Weed control methods: Researching and developing a variety of weed control methods suitable for robotic application, including mechanical weeding techniques and targeted herbicide delivery systems.

IV. RESULTS

Research on robotics in agriculture has gained significant attention in recent years due to the potential for improving efficiency, reducing labor costs, and addressing challenges such as labor shortages and sustainability. Here's a brief summary of some key findings and trends in this field:

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Table 1
Summary of Irrigation Automation Using Various Artificial Intelligence Technologies.

No.	Algorithms	Method of evapotranspiration / desired calculation	Other Technologies	Advantages/Results	References
1.	PLSR and other regression Algorithms	Evapotranspiration model	Sensors for data collection, IOT Hardware Implementation	Increased efficiency and economic feasibility	Choudhary et al. (2019)
2.	Artificial Neural Network based control system	Evapotranspiration model	Sensors for measurement of soil,temperature,wind speed, etc.	Automation	Umair and Usman (2010)
3.	Fuzzy Logic	FAO Penman-Monteith method	–	Optimization	Kia et al. (2009)
4.	ANN (multilayer neural model), Levenberg Marquardt, Backpropagation	Penman–Monteith method	–	Evaporation decreased due to schedule and savings observed in water and electrical energy	Karasekreter et al. (2013)
5.	Fuzzy Logic	–	WSN, Zigbee	Experimental results verification. Can be applied to home gardens and grass	Al-Ali et al. (2015)
6.	ANN Feed Forward, Backpropogation	–	–	Optimization of water resources in a smart farm.	Dela Cruz et al. (2017)
7.	Fuzzy Logic Controller	Penman–Monteith method	Wireless sensors	Drip irrigation prevents wastage of water and evaporation	Anand et al. (2015)
8.	Machine Learning algorithm	–	Sensors, Zigbee, Arduino microcontroller	Prediction and tackles drought situations	Arvind et al. (2017)

1. Autonomous Vehicles: One prominent area of research involves the development of autonomous vehicles for various agricultural tasks such as planting, weeding, spraying pesticides, and harvesting. These vehicles are equipped with sensors, cameras, and AI algorithms to navigate fields, identify crops and weeds, and perform tasks with minimal human intervention.
2. Soft Robotics: Soft robotics is another area of interest, particularly for tasks that require delicate handling such as fruit picking. Soft robotic grippers and manipulators are designed to mimic the dexterity and sensitivity of human hands, enabling them to harvest fruits without damaging them.
3. Drones and UAVs: Unmanned aerial vehicles (UAVs) or drones are being used for aerial surveillance, crop monitoring, and spraying fertilizers or pesticides. Advanced imaging techniques such as multispectral and hyperspectral imaging allow drones to capture detailed information about crop health and growth patterns.

Benefits of Field Scouting and Data Collection Robots:

A.Improved efficiency: Automating data collection saves time and labor costs.
B.Enhanced decision making: Data-driven decisions lead to more targeted spraying and improved resource management.
C.Increased productivity: Early detection of crop issues allows for timely intervention and potentially higher yields.
D.Reduced environmental impact:Targeted spraying minimizes unnecessary chemical use and protects beneficial insects and pollinators.

Challenges and Research Areas:

A.Navigation and autonomy: Developing robust navigation systems for robots to operate effectively in diverse field conditions.
B.Sensor fusion and data analysis:Integrating data from multiple sensors and applying AI algorithms for accurate and actionable insights.
C.Data communication and integration:Enabling seamless data transfer between robots, spraying equipment, and farm management platforms.

V. CONCLUSION

The future of agriculture is increasingly intertwined with robotics and digital technologies. This section explores the synergy between agricultural robotics and digital farming, highlighting how they work together to revolutionize the agricultural sector.

Agricultural Robotics: The Muscle
Agricultural robots are the physical embodiment of automation in farming. They are designed to perform various tasks, including:
a.Planting and Seeding: Robots with precise actuators can efficiently plant seeds at optimal depths and spacings.
b.Weed Control: As discussed earlier, robots equipped with computer vision and targeted application tools can manage weeds with minimal herbicide use.
c.Field Scouting and Data Collection:** Robots equipped with sensors autonomously navigate fields, collecting valuable data on crop health, soil conditions, and pest presence.
d.Harvesting: Robots are being developed to automate the delicate harvesting of fruits and vegetables, reducing labor needs and potential crop

damage.
e.Livestock Management: Robots can automate tasks like milking, feeding, and monitoring animal health in livestock operations.

Digital Farming: The Brains

Source: www.AdaptiveAgroTech.com
Figure 6 A conceptual illustration of digital faming and virtual orchards with emphasize on the role of agricultural robotics

Digital farming encompasses the use of various digital technologies to collect, analyze, and manage data for informed decision-making in agriculture. Key components include:
a.Sensors: A network of sensors embedded in fields, robots, and agricultural machinery collects real-time data on various parameters like soil moisture, air temperature, and crop health.
b.Big Data and Analytics:The vast amount of data collected is stored and analyzed using big data tools and artificial intelligence (AI) to identify patterns and trends.
c.Farm Management PlatformsThese platforms integrate data from various sources, providing farmers with a holistic view of their operations and facilitating data-driven decision-making.

The Symbiotic Relationship

Agricultural robotics and digital farming work together in a powerful feedback loop:

a.Robots Generate Data: Robots equipped with sensors continuously collect field data, providing a more comprehensive and real-time picture of crop health and environmental conditions.
b.Digital Farming Analyzes Data:Data collected by robots is fed into farm management platforms and analyzed using AI. This analysis helps farmers identify areas needing attention, optimize resource allocation, and make informed decisions about spraying, irrigation, and fertilization.
c.Data Informs Robotic Actions:Insights gleaned from data analysis can be used to program robots for more targeted actions. For example, robots applying herbicides can adjust application rates based on real-time data on weed pressure.

Benefits of the Synergy

1.Improved Efficiency: Automation and data-driven decision-making lead to increased efficiency in resource use, labor savings, and overall farm productivity.
2.Enhanced Sustainability:Precision spraying and targeted resource allocation minimize environmental impact and promote sustainable agricultural practices.
3.Optimized Yields:Early detection of crop issues and data-driven interventions lead to improved crop health and potentially higher yields.
4.Improved Farm Management:Digital farming empowers farmers with real-time data and insights for better decision-making and risk management.

Challenges and Future Directions

a.Interoperability:Ensuring seamless data exchange between robots, sensors, and farm management platforms from different manufacturers is crucial.
b.Data Security and Privacy:Robust data security measures are needed to protect sensitive farm data.
c.Accessibility and Affordability:Making these technologies accessible and affordable for smaller farms is essential for widespread adoption.Benefits of Field Scouting and Data Collection Robots:
d.Navigation and autonomy: Developing robust navigation systems for robots to operate effectively in diverse field conditions.
e.Sensor fusion and data analysis:Integrating data from multiple sensors and applying AI algorithms for accurate and actionable insights.
f.Data communication and integration:Enabling seamless data transfer between robots, spraying equipment, and farm management platforms.

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