__Review Article__

TRANSFORMING AGRICULTURE: HARNESSING ROBOTICS AND DRONES FOR SUSTAINABLE FARMING SOLUTION – A REVIEW

ABSTRACT

The agricultural sector faces numerous challenges such as increased demand for food, environmental concerns, and labor shortages, exacerbated by a growing global population. To address these challenges sustainably, the concept of "smart farming" utilizing drones and robotics has emerged as a promising solution. This paper explores the transformative impact of robotics and drones in agriculture, focusing on their applications, benefits, challenges, and future prospects. It discusses the role of robotics in tasks such as tillage, seeding, crop protection, harvesting, and animal husbandry, highlighting their potential to enhance efficiency and productivity while reducing environmental impact. Additionally, it examines the various types of drones and their applications in precision agriculture, including monitoring, spraying, mapping, and surveillance. The paper concludes by emphasizing the need for careful consideration of challenges such as high costs, technological learning curves, and data security concerns, while acknowledging the significant potential of robotics and drones to revolutionize traditional farming practices and ensure a sustainable future for the agriculture industry.

KEYWORDS : Robotics, Drones, Smart Farming, Precision Agriculture, Sustainability

INTRODUCTION

Agriculture serves as the primary source of food globally Friha *et al*.(2021). However, it faces numerous challenges due to the growing demand for food, concerns regarding food safety and security, environmental preservation, water conservation, and sustainability Inone *et al*.(2020). With the global population projected to reach 9-11 billion by 2050, the agriculture sector is encountering obstacles stemming from increased population and food requirements Frona *et al*(2019). The concept of "smart farming" utilizing drones and robotics emerges as a promising solution to address these challenges sustainably. The escalating use of fertilizers and pesticides, coupled with intensive farming practices, poses potential environmental threats in the future. Additionally, factors such as limited arable land and a declining number of farmers worldwide compound these challenges, necessitating innovative and sustainable farming approaches Friha *et al*.(2021) Frona *et al*.(2019) Elijah *et al*.(2018).

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Smart farming, particularly focusing on drones and robotics, offers strategies to mitigate these issues by reducing reliance on human labor and optimizing agricultural processes Basso *et al*.(2020). Leveraging technologies such as Machine Learning and Deep Learning, AI applications in autonomous machinery like tractors, harvesters, and robotic weeders, as well as in drones and robotics, are revolutionizing conventional farming practices. This transformation enhances efficiency, minimizes errors, and provides more accurate yield predictions, leading to increased efficiency and cost savings for farmers Lakshmi *et al*.(2024). Furthermore, adopting techniques from Precision Agriculture Technologies in field operations can contribute to greenhouse gas emission reduction by managing inputs, enhancing fuel efficiency, and promoting carbon sequestration Balanfoutis *et al*.(2017). Encouraging the adoption of environmentally friendly practices and reducing chemical usage fosters a healthier ecosystem. Overall, these advancements in drones and robotics showcase their potential to ensure a sustainable future for the agriculture industry.

ROBOTS

Agricultural robots, also known as agribots, constitute a specialized category within the broader realm of robotics, designed specifically for farming purposes Reddy *et al*.(2016). These robots possess advanced capabilities in perception, decision-making, and execution, enabling them to operate effectively in challenging and hazardous agricultural environments. With the increasing demand for labor-saving techniques and efficient agricultural production, the development of agricultural robots has evolved continuously, catering to diverse application scenarios Kayacan *et al*.(2018). Depending on their intended tasks, agricultural robots encompass various types tailored for specific agricultural activities, such as handling fruits and vegetables and managing livestock.

2.1 Terrestrial Robots

Terrestrial robots are autonomous or semi-autonomous machines primarily operating on the ground, with some capable of aerial movement for tasks like crop spraying. These robots perform a range of functions including soil preparation, seed planting, crop care, data collection, and harvesting Lowenberg-DeBour *et al*.(2020).

- Tillage Robots: Advanced tillage robots aid in land preparation, reducing farmers' workload while enhancing cultivation quality and speed. Panarin developed software for tillage robots in 2021, ensuring seamless integration between robot hardware and software tools Panarin *et al*.(2021).

- Seeding Robots: Automated seeding robots optimize planting processes, contributing to cost savings and efficiency improvements. Kumar et al. developed an IoT-controlled seed-sowing robot, achieving complete seeding automation Kumar *et al*.(2021).

- Crop Protection Robots: Intelligent robotic systems for crop protection minimize human exposure to harmful pesticides. These robots employ high-efficiency trajectory algorithms for precise pesticide spraying, reducing environmental impact Meshram *et al*.(2022) Srivastava *et al*.(2014).

- Field Information Collection Robots: Robots equipped for field data collection assist farmers in decision-making by gathering essential agricultural insights. The University of Saskatchewan developed mobile robotic platforms for monitoring crop health, exemplified by their Canola plant phenotyping robot Qi *et al*.(2021).

- Harvesting Robots: Automated harvesting robots, such as rice cutters, streamline crop harvesting processes. Gang et al. developed an automatic corn harvester system with a high success rate, addressing the need for efficient harvesting solutions Chen *et al*.(2020).

2.2 Horticultural Robots

In response to labor shortages, horticultural robots enhance farming practices for fruits and vegetables. These robots encompass transplanting, patrolling, pesticide spraying, gardening, and picking functionalities.

- Transplanting Robots: Precision transplanting robots ensure accuracy and stability in crop transplantation, improving planting efficiency. Research by Jin et al. and Yang et al. focused on enhancing transplanting control and success rates Li *et al*.(2020).

- Patrol Robots: Independent patrolling robots collect vital information on crop maturity, pests, and environmental conditions, aiding farmers in decision-making processes Su *et al*.(2021).

- Pesticide Spraying Robots: Pesticide spraying robots employ various methods for precise and efficient pesticide application, reducing environmental impact Huang *et al*.(2021).

- Gardening Robots: Autonomous gardening robots face challenges in dynamically changing garden environments, with research focused on navigation and adaptability to seasonal changes Cheung *et al*.(2020).

- Picking Robots: Fruit and vegetable picking robots enable large-scale harvesting with selective or bulk picking capabilities, addressing labor shortages in agricultural settings Vascone *et al*.(2020).

2.3 Animal Husbandry Robots

Optimizing livestock production through smart automation is critical for addressing long-term challenges in animal husbandry. These robots include breeding, feed dispensing, milking, and egg collection functionalities.

- Breeding Robots: Disinfection robots and automated breeding systems enhance livestock productivity and hygiene, minimizing disease risks and improving production efficiency Gene-Mola *et al*.(2020).

- Feed Dispensing Robots: Automated feeding systems for livestock minimize feed waste and labor costs, improving production efficiency and animal welfare Feng *et al*.(2020).

- Milking Robots: Automatic milking systems revolutionize dairy farming by enabling continuous milking operations and data-driven farm management Feng *et al*.(2021).

- Egg Collection Robots: Mobile robots for egg collection streamline poultry house operations, improving efficiency and minimizing manual labor Peng *et al*.(2020).

Overall, the development and adoption of agricultural robots offer significant potential for optimizing farming practices, enhancing productivity, and mitigating labor challenges across diverse agricultural domains.

TYPES OF ROBOTS

1. Single-Rotor Drones: Known for their robustness and durability, single-rotor drones closely resemble actual helicopters in structure and design. These drones are among the most basic varieties available.

2. Multirotor Drones: Offering stability in flight, multirotor drones typically have a flight time of around half an hour. They are particularly well-suited for tasks such as aerial photography and surveillance.

3. Fixed-Wing Drones: Featuring a rigid wing similar to traditional aircraft, fixed-wing drones may be gas-powered. However, they lack the hovering capabilities of rotor-based drones.

4. Fixed-Wing Hybrid Drones: Hybrid VTOL (Vertical Takeoff and Landing) drones combine the benefits of fixed-wing and rotor-based designs. These drones feature propellers mounted on fixed wings, enabling both rotation and vertical landing.

5. Small Drones: Generally more affordable, small drones are not typically equipped for commercial applications.

6. Microdrones: Capturing the attention of consumers, microdrones are compact and agile. The Black Hornet, developed for the British military, is a prominent example of this category.

7. Tactical Drones: Sized for versatility, tactical drones are commonly deployed in large-scale missions and general combat scenarios, primarily for surveillance purposes.

8. Reconnaissance Drones: Widely utilized by military forces worldwide, reconnaissance drones such as the Heron, developed by Israeli Aerospace Industries, serve critical roles in intelligence-gathering missions for nations including the United States, Canada, Turkey, India, Morocco, and Australia.

9. Large Combat Drones: Boasting ranges exceeding 1,000 miles and endurance of up to 14 hours, large combat drones are synonymous with military operations and are designed for prolonged missions in hostile environments.

10. Non-Combat Large Drones: Primarily employed for reconnaissance and surveillance tasks, non-combat large drones offer enhanced capabilities compared to microdrones like the Black Hornet, catering to larger-scale reconnaissance missions.

11. Target and Decoy Drones: Versatile in function, these drones can mimic incoming missiles, serving as decoys or targets in military exercises and training scenarios.

12. GPS Drones: Leveraging GPS connectivity, these drones utilize satellite navigation for precise flight mapping and data collection, enhancing operational efficiency and accuracy.

13. Photography Drones: Equipped with autonomous flight modes and advanced stabilization systems, photography drones excel in capturing high-quality images over vast areas, meeting the demands of professional photographers and aerial imaging tasks.

14. Drone Racing: Emerging as a popular hobby, drone racing involves competitive events where participants race specially designed drones equipped with powerful engines, catering to both enthusiasts and skilled pilots seeking adrenaline-fueled competition.

DRONES

In 1951, Israel Abraham Karem introduced the world to the concept of drones. Nearly half a century later, in 2000, Yamaha, a prominent Japanese manufacturer, unveiled the inaugural agricultural drone, named the R-50. This groundbreaking creation was specifically engineered for tasks such as crop mapping and field analysis, heralding a new era in agricultural technology. Drones, also referred to as Unmanned Aerial Vehicles (UAVs), Unmanned Aircraft Systems (UAS), and remotely piloted aircraft, hold significant importance due to their multitude of advantages over traditional remote-sensing methods. For instance, drones excel in capturing high-resolution, top-quality images, even on overcast days Friha *et al*.(2021). Moreover, compared to manned aircraft, drones offer exceptional cost-efficiency and simplicity in setup and maintenance Inone *et al*.(2020). While initially developed for military purposes, drones have seamlessly transitioned into civilian domains, offering a plethora of benefits. They play pivotal roles in supply chain management, human-centric tasks Frona *et al*.(2019), surveying and mapping, smart agriculture practices, wildlife conservation efforts, disaster management initiatives, and cultural heritage documentation Panday *et al*.(2020).

USES OF DRONES

Drones, with their integration of computing capabilities, advanced technologies, and onboard sensors, have found myriad applications in agriculture. They provide valuable assistance in farming by swiftly delivering essential information for making decisions regarding irrigation, fertilization, and pest management Nunes *et al*.(2023). Precision spraying is a critical function drones excel in, effectively reducing chemical wastage and enhancing resource optimization Abbas *et al*.(2023) Kathod *et al*.(2023). Moreover, they are indispensable tools for mapping and surveying agricultural landscapes, facilitating informed crop planning and resource distribution Christiansen *et al*.(2017). Additionally, drones play a vital role in monitoring plant health, managing weed growth, and executing spraying tasks in agricultural settings. Their diverse applications span crop monitoring, soil and field analysis, and bird control, all contributing to the advancement of precision and sustainable agriculture practices. In sum, drones have the potential to revolutionize agriculture by significantly improving efficiency, productivity, and sustainability.

CONCLUSION

Robotics in agriculture is a burgeoning field aimed at enhancing the efficiency, productivity, and sustainability of farming and food production. With the capability to undertake tasks such as crop and soil monitoring, predictive analytics, supply chain management, and harvesting, robotics holds immense promise for revolutionizing agricultural practices. However, alongside its potential benefits, there exist several challenges and limitations that warrant attention.

High development and maintenance costs, coupled with the lack of standardization and regulation, pose significant hurdles to widespread adoption. Moreover, ethical and social implications, along with concerns regarding environmental impact, further complicate the integration of robotics in agriculture. To realize its full potential, careful design, evaluation, and implementation are essential to ensure that robotics in agriculture not only benefits farmers but also addresses consumer needs and societal concerns.

Despite these challenges, the potential of robotics in agriculture remains vast. Projections by the Association for Unmanned Vehicle Systems International (AUVSI) indicate a significant uptick in the adoption of unmanned aerial vehicles (UAVs) for agricultural purposes. By 2020, it is estimated that over 2900 UAVs will be deployed by more than 900 companies worldwide, underscoring the growing interest and investment in agricultural robotics.

Overcoming barriers such as high initial costs and policy reforms is crucial to making robotics in agriculture more accessible and farmer-friendly. Despite the obstacles, the rapid expansion of these tools and technologies in agriculture holds promise for providing valuable insights and information to farmers, ultimately contributing to more informed decision-making and improved agricultural outcomes.

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