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Robotic Automation and AI in Agriculture

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OBSTRACT- this article examines many aspects of robotics and artificial intelligence (AI) in agriculture. It starts with a succinct definition of robotics and artificial intelligence (AI), then goes on to briefly discuss their historical growth in conjunction with the advancement of precision agriculture, which includes unmanned ground vehicles (UGVs) like autonomous tractors. Reviewing current agricultural technologies, the majority of the paper focuses on the use of robots for a range of tasks, including field prep, planting, tending to plants. .The evaluation also covers technology for controlled environment agriculture (such as greenhouse farming, in vitro culture, and gene banks) and contains case studies on the application of robots and AI. It also evaluates the cost-effectiveness of these technologies. In conclusion, the paper considers the development and influence of robotics and artificial intelligence (AI) in agriculture in several regions, including Asia (Singapore, China, and India), the USA, Canada, Europe, and Australia. It also provides concluding conclusions and future prospects.

INTRODUCTION Modern technology are being embraced by agronomy more and more in an effort to enhance crop management and productivity for food, fiber, and energy. A major step toward precision agriculture has been made with the integration of robotics and artificial intelligence (AI) into agronomy. This allows for the incredibly accurate and efficient monitoring and management of every facet of farming, from plant development to soil health. This method enhances agronomy's emphasis on comprehending and regulating the complex interplay between biotic and abiotic elements in ecosystems. These developments do, however, also bring with them difficulties with cost, adaptability, and the requirement for specific skills. Furthermore, they raise crucial questions about how agronomists will be educated in the future and how these technologies can support fair and sustainable food production, particularly in light of global concerns like climate change.

The main goal is to address the significant challenge of agronomy's integration of robotics, automation, and artificial intelligence (AI) to increase agricultural productivity, resilience, and sustainability. Given the increasing need for food on a worldwide scale, the effects of climate change, and the requirement for sustainable agricultural techniques, this integration is imperative. Autonomous tractors, drones for precise crop monitoring, and robotic harvesters are examples of recent robotics advancements that drastically lower labor requirements and improve resource efficiency. Predictive analytics has been improved by AI and machine learning, which offers useful insights into crop health, yield forecasting, pest and disease management, and soil health monitoring. These insights help agronomic decision-makers make better educated decisions.

Advances in robotic systems for planting, harvesting, and crop management:

By automating some processes, farmers may now control crop production more effectively while using less energy and spending less money. Researchers and farmers are interested in developing agricultural automation systems because of the lack of agricultural labor, the aging farming population, and growing wages. The creation and execution of these systems have been propelled by selfgoverning robots and farming equipment, such tractors fitted with chisel plows, planters, cultivators, and cultipackers. A number of agricultural robots and machinery are now in development to increase farming operations' automation-based efficiency. Depending on the type of land and operational requirements, there are major differences in the application of automation and robots in agriculture. Different kinds of technology must be used to overcome the unique limits of different robots and vehicles. For example, because robotic systems are sensitive to mud and water, they may not be able to withstand harsh agricultural conditions. Tractors are the ideal choice in these situations because of their relative endurance against external variables that can harm electronic components and their capacity to manage muddy terrain. Tractors are less suitable for smaller plots where mobile robots work better because of their size, which makes them more appropriate for larger areas. However, because of their high risk, drones are less useful in enclosed locations like greenhouses and are more appropriate for open areas and are less useful in enclosed environments like greenhouses. Different agricultural operations are used as the basis for categorization in order to better understand the present applications of automation and robots in agriculture.

PLANTING

Planting is the process of starting seeds or young plants to grow in the ground. Because various plants require varying spacing in order to maximize production and improve growth, this technique requires a high degree of precision. Farmers have always planted by hand, which takes a lot of time and labor because it requires accurate placement over wide regions. Planter machines have been created in order to overcome these difficulties. The farmer operates these devices, which automate the planting procedure and guarantee that the seeds are inserted into the ground at the proper intervals.

Autonomous systems have been created for a number of crops, including corn

[1, 2, 3, 4, 5, 6, 7], wheat [8, 9], sugarcane [10], and vegetables [11], in order to overcome the drawbacks of manual planting methods. Several important factors must be taken into account while designing an effective autonomous planting system [1].

Initially, the robot or vehicle needs to be able to navigate difficult terrain and move precisely in a straight line. Maintaining uniform seeding depends on this accuracy, which affects later procedures like inspection and harvesting.

The system then needs to take soil moisture into account, since it can have an impact on the digging operation. Since different seeds have different digging depth requirements, the system must account for variations in soil moisture and compaction in order to maintain a constant digging depth.

To improve planting consistency, a seed metering unit control system was developed in research [2–3, 8].

According to [7], in addition to employing GPS technologies for effective seed sowing, a high-speed camera has been created to guarantee consistent seed spacing. This system uses a Fuji F660EXR camera to track the trajectories of falling seeds at a frame rate of 320 frames per second. A Unissem pneumatic planter’s outlet is where the camera is installed. Operating within a speed range of 3 to 4.5 km/h, the results show that the seed spacing uniformity is highly effective, obtaining a 95% confidence level.

Inspection -

Plants are inspected in agriculture to look for illnesses or flaws in their quality. Plant diseases have a major negative effect on output and cause financial losses. Plants and their products might suffer from the dynamic nature of agricultural surroundings, which are typified by variations in temperature, humidity, water levels, disease outbreaks, and pest infestations. These problems have the potential to cause serious, irreversible harm if they are not resolved quickly [12].

Farmers used to rely on physical observation and their visual senses to identify anomalies in plants. But this eye assessment becomes less effective as the farming population ages, necessitating mechanization. Computer vision technology is becoming more and more common as a replacement for human vision in inspection processes.For detailed inspection duties, computer vision, an advanced image processing technology, offers great potential in replacing human eyesight [13]. Growing interest in non-destructive approaches for food assessment, improved computer capacity, and falling equipment costs have all contributed to its increased acceptance in agriculture [14]. The main applications of computer vision systems are in the diagnosis of plant diseases and the evaluation of product quality. A variety of computer vision applications for agricultural.

In agricultural inspection, the use of the Internet of Things (IoT) to track plant diseases in real time is growing. With the use of this technology, sensory data from the farm, such as moisture, temperature, humidity, and soil pH levels, is gathered and photographs are taken. The data is then displayed on websites or mobile apps. This enables farmers to correct problems before they worsen and become widespread outbreaks of diseases like powdery mildew, late blight, and early blight.

Maintaining the quality of agricultural products and identifying diseases depend heavily on the inspection procedure. Reducing the inefficiencies related to farmers' manual inspections requires automating this procedure. Usually, an autonomous inspection involves mounting a camera on a mobile robot, drone, or stationary platform. Future improvements in food security are facilitated by this method, which improves the precision and effectiveness of quality control and disease prevention.

SPRAYING-

In agriculture, spraying is a popular technique for misting fine fertilizer, growth media, or pest-control chemicals onto plants to promote growth and manage diseases. Traditionally, to control the spread of illness, these chemicals are sprayed evenly over all fields. Nevertheless, this strategy may prove to be ineffective since illnesses and pests frequently manifest unevenly, especially in the initial phases of their growth [16].

Over the past 20 years, selective spraying has been created and investigated as a way to alleviate this problem and lower the cost of pest-control agents [17–18]. Automatic selective spraying systems aim to apply pesticide exactly where and when it is needed. These systems are usually controlled by cutting-edge machinery or mobile robots. This targeted spraying's primary objective is to reduce the amount of pesticide used while delaying the start and spread of infections.

Research is concentrating on enhancing navigation management to minimize robot operating expenses, including time and energy, while maintaining precise location tracking, in addition to lowering the usage of pesticides. This line of inquiry is essential to enabling robots to spray with precision and at the lowest possible cost of travel.

The Non-dominated Sorting Genetic approach with Reference Point-Based Optimization is a multi-objective approach that is introduced in literature [19] to address these issues. The objective of this method is to maximize the travel time, distance, and routing angle, among other factors. Other research [20–21] explore various speeds to determine the optimal pace for composite spray operations, looking at how robot travel speed affects the mass discharge flow rate of pineapple leaf fiber.

Farmers must replace human labor in spraying operations to reduce their chance of coming into contact with dangerous chemicals. The adoption of automated spraying systems is becoming more and more viable as automation technology advances, with the goal of treating plant diseases while cutting expenses. To guarantee that automation in spraying operations produces significant benefits for farmers, especially in managing plant diseases and safeguarding future food supply, more study is needed. To create spraying solutions for agricultural applications that are more effective, researchers are always improving and refining the methodologies and techniques that are currently in use.

Harvesting -

-Harvesting in agriculture is the process of gathering crops for sale or processing. This procedure is frequently labor- and time-intensive since it calls for close observation and repetitive operations. As a result, during the past few decades, a lot of work has gone into creating autonomous harvesting devices. Strawberries ,apples , tomatoes , kiwis , capsicums , grapes , lychees , citrus fruits , pumpkins , and heavy crops [22] are among the crops for which various implementations have been investigated. The majority of these systems use a variety of strategies and cuttingedge hardware and software structures to improve harvesting accuracy.

There are various important steps in an autonomous harvesting process. The mobile robot must first locate the intended harvesting site for the crop. After that, the robotic arm carefully moves in the direction of the objective while dodging obstructions. Lastly, the harvesting process is carried out. Usually, this involves gripping the fruit, chopping off the stem, and placing the gathered fruit inside a robot compartment.

In order to create effective harvesting robots, researchers work to overcome the particular difficulties that arise at each stage of the autonomous harvesting process. The improvement of target position detection for harvesting has been the focus of recent work. A lot of these devices locate fruits using visual technology. However, because of their inherent diversity and the difficulties presented by loosely organized settings with changing lighting and object occlusion, vision systems must be able to handle the complexity of detecting different objects. As a result, several vision algorithms are used to address certain issues with target detection during the harvesting process [23].

In agriculture, harvesting is essential since the way it is done can have a big impact on the quality of the product that is collected, especially considering how fragile many crops are. Even with excellent growing conditions, plants can still lose quality if harvesting is done incorrectly, especially when using robotic and automated methods.Consequently, continuous research endeavors to enhance robotic and automation methodologies in the harvesting process to guarantee that they rival or surpass conventional human approaches in efficacy. The objective is to harvest crops quickly and efficiently while preserving or improving their quality.

AGRICULTURAL AUTOMATION AND ROBOTICS: CHALLENGES AND NEXT PHASE:

It is anticipated that by 2025, the global market for agricultural automation and robotics would have grown from USD 7.4 billion in 2020 to USD 20.6 billion [24]. The desire for increased productivity, the need to reduce labor, and population expansion are some of the causes driving this growth. In order to take advantage of these prospects, technology needs to mature to the point where it can be relied upon and strengthened for a range of agricultural activities.

Therefore, current research endeavors to tackle many obstacles linked to the integration of automation and robotics in a range of agricultural settings and circumstances. This section will discuss the primary obstacles that researchers must overcome in order to create dependable agricultural systems and will also detail the expectations that farmers have for these cutting-edge technology.

For farmers thinking about investing in robots and automation, cost is still a major worry despite the numerous obstacles that come with different agricultural businesses. A lot of farmers are reluctant to spend money on technologies that might not pay off in the long run. Thus, the development of multifunctional, economically viable agricultural robots must be the primary emphasis of agricultural researchers.

The modular robotic design approach is a promising method that provides resilience and versatility. Because modular robots allow for upgrades and reconfigurations instead than requiring whole new systems, they may be tailored for various activities and situations, potentially lowering overall costs. This method guarantees that modern robotics can adjust to changing agricultural conditions and demands while also making the technology more accessible.

CONCLUSION

In order to guarantee food security in the future, robotics and automation in agriculture are essential. With the use of robotic systems, farmers may carry out agricultural chores more productively. By utilizing cutting-edge technology, they can minimize operating expenses and labor requirements by completing duties like planting, inspecting, spraying, and harvesting. These technologies are intended to optimize agricultural processes by imitating human labor behaviors.

Because various agricultural operations have distinct needs depending on the type of plant and the environmental circumstances, research is still being done to improve the accuracy and efficiency of autonomous systems. Even with the advancements, there are still a number of obstacles to overcome, and thorough research is required to find effective solutions. A comprehensive autonomous agricultural robotic system can be developed by combining innovations from different agricultural operations. A system like this would provide reliable and effective solutions to farmers all across the world, with the ultimate goal of raising agricultural productivity and enhancing food security in the future.

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