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Robotics In Agriculture

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Abstract:

Agriculture, a crucial component of the global economy, has changed dramatically over the last five decades, driven by the need to meet the demands of a growing population. Precision Agriculture (PA) uses cutting-edge technology to improve efficiency, production, and sustainability by gathering and analysing spatial and temporal information. Robotics in agriculture, particularly robotic grippers, play an important role in automating laborious, filthy, or dangerous operations, however they still struggle to match human agility. Traditional farming methods, without technology, are frequently inefficient, labor-intensive, and economically unsustainable. Automation advancements such as sensors, IoT, robotics, and artificial intelligence have transformed agricultural operations, increasing productivity and management. Various robots, including aerial, ground, and multi-robot systems, are currently used to monitor crops, plant, weed, and fertilise. These technologies deliver several benefits, such as higher efficiency, decreased prices, better crop quality, and enhanced labor safety. However, problems such high initial prices, technical complexity, dependability issues, and data management concerns must be overcome for wider implementation. As technology advances, agricultural robotics will alter farming operations, making them more efficient and sustainable.

Keywords — **IOT, Precision Agriculture (PA), AI, PLF, RTU (Robotic transport unit), GPS.**

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I. INTRODUCTION

Agriculture is a critical sector of the global economy. This activity was adapted along years to fulfil the needs of the world's population, which has duplicated in the last 50 years[2].

The popular term Precision Agriculture, or PA for short, has been defined as "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[3]

Robots and manipulators were designed to replace humans in tasks that were tedious, unclean, or dangerous (Tai et al., 2016; Blanes et al., 2011; Plessen, 2019; Erfani et al., 2019). Robots can struggle with seemingly simple tasks like picking up and arranging objects with diverse forms, sizes, materials, and surfaces (Brown et al., 2010; Syed et al., 2019). A gripper is an end-of-arm tool used on equipment to grasp, carry, and position workpieces. The gripper grasps and releases workpieces by opening and closing fingers driven by electric, pneumatic, or other types of power. Robotic grippers are designed to interact with items and their surroundings by making direct touch with the workpiece (Tai et al., 2016) [1]

According to Reddy and Suresh (2013), robotic grippers are crucial parts of robotic manipulators because they act as the robots' hands during pick-and-place tasks. To grip things securely, it's important to not only contact them but also prevent slips and damage during the picking and placement process (Brown et al., 2010; Ireri et al., 2019). Robotic grippers struggle to match the flexibility of human workers (Pettersson et al., 2010; Lien, 2013). As robots grow more automated, grippers and grasping have become key study areas.[1]

Currently, traditional agricultural practices lead to unprofitable and economically unsustainable farming. Traditional farming without AI or automation suffers from [4]

- Land preparation, irrigation, and seed sowing are time-consuming and labor-intensive processes.
- Requires more human resources to manage farm processes.
- Inaccurate information on weather, soil, and fertilizer use.
- Why Manually monitoring crop health and disease identification is time-consuming and inefficient.
- Weed identification and control are more labor-intensive.
- Traditional pesticide spraying can harm farmers' health and diminish crop output.
- Traditional methods for cutting and segmenting healthy crops and fruits might be time-consuming.

Nof (2023) highlighted improvements in automation technology, including sensors, IoT, robotics, and AI, for field, fruit, greenhouse, and livestock production systems. Agriculture and automation have experienced a shift in size (see Figure 1). Early production systems relied on tiny farms and private production for personal needs, using available resources (e.g., animals and humans)[6].Based on available resources (both animal and human). The introduction of tractors led to greater productivity (phase 1), allowing for larger farmed areas and single-worker production. Industrial mass production led to mechanisation of farm operations, including the adoption of powerful tractors and larger machinery (phase 2). The green revolution brought economical and efficient chemical fertilisers and crop protection products, leading to a significant increase in agricultural production and productivity. Large machinery allows for efficient and consistent processes, yet The integration of sensors, automation, GPS, and farm computers has led to improved production management by providing detailed information on field conditions and crop yield (phase 3).[5] Precision agriculture (PA) and precision livestock farming (PLF) allow for smaller management units, such as subfields or individual animals, maximising productivity (Berckmans, 2017). PA and PLF optimise agricultural processes by modifying activities to meet specific needs at the appropriate time and location. Farm management has become more efficient with data-driven digital technologies and real-time access to external information sources, leading to increased knowledge of production processes and market chains (phase 4). Digital farming (Saiz-Rubio & Rovira-Más, 2020). As technology advances and new applications like ChatGPT and the metaverse develop, farming activities

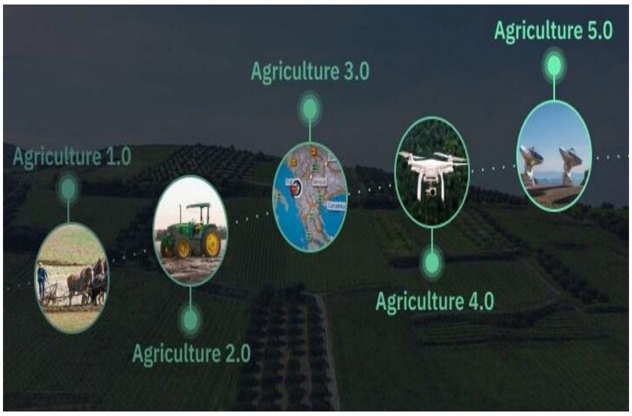

Fig 1: Agriculture Automations

II. TYPES OF ROBOTS WORK IN AGRICULTURE

A. Aerial Robots

Precision agriculture utilises aerial vehicles for crop monitoring, yield estimation, fungicide and fertiliser dosage calculations, and disease detection. Gago et al. (2015) utilised an RGB camera to assess barley development following two nitrogen treatments. Figure 2 illustrates how UAVs equipped with hyperspectral and thermal cameras can enhance agricultural performance, reduce costs, and boost output.[6]

B. ***Ground Robot***

Ground robot strategies primarily target the platform, manipulator, and end effector used in agricultural applications. GPS, odometer, line guiding, and path planning are among the tactics available in these systems (Feng et al., 2012; Sakai et al., 2008). Irie et al. (2009) report that some robots use irrigation pipes or rails to navigate about the field. According to Wan et al. (2010), many end effectors are custom-made, as seen in Figure 3. of tasks to be completed, in addition to the various fruits and vegetables to be handled. It consists of a controller, an arm, an end effector, a mobile platform, a control laptop, and an overhead camera.[6]

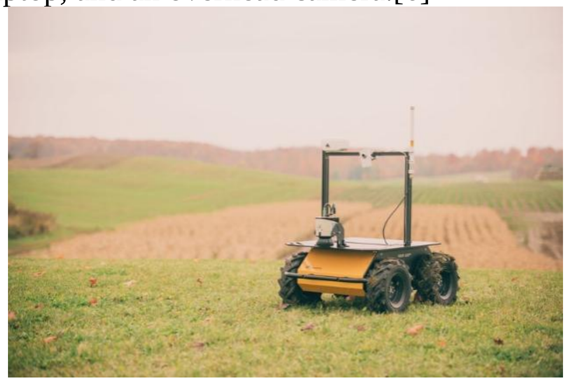

Fig 3: Robot That Operate on Land

C. ***Multi Robot System***

COMPLETE TASKS, REGARDLESS OF COMPLEXITY, WITHIN THE GIVEN TIMEFRAME. ROBOT TEAMS MAY BE more efficient, adaptable, and fault-tolerant than individual robots. Most cases of robot teams conducting agricultural jobs are similar, according to the literature. A fleet of UAVs is commonly used to collect data over wide areas, with various methods for distribution and path planning (Avellar et al., 2015).

III. IMPACTS OF FRUITS AND VEGITABLES HARVESTING ROBOTS.

A. Harvesting

Harvesting robots are designed to harvest crops such as fruits and vegetables. Sensors and cameras detect when crops are ripe for picking. Crops are carefully harvested using robotic arms or other equipment to prevent damage to the produce. Six-axis robots are widely used for choosing. Because they are immobile robots, they are commonly utilised in conjunction with mobile units. This gadget could be a robotic transport unit (RTU) or a mobile robot. Selecting the appropriate end-effector is crucial for an effective harvesting operation. It is recommended to utilise.

Fig 4 : Harvesting Robots for Farmer

arvesting robots are nothing but which are designed to picking fruits and vegetables which shown in (Figure 3) [13]

B. Weeding

These machines eliminate weeds in fields without the need for human intervention. Weed-eradication robots use precision tools and image recognition technologies to locate and remove plants from the ground. Several robots have been created specifically for weeding. These devices skitter across the produce, looking for weeds.

When it sees a weed, it extends its arm to pick, smother, or spray it. Combining articulated and mobile robots can effectively accomplish tasks like weed control.

C. Seeding and Planting

Crop planting is supposed to be mechanised by these robots. Planting and sowing are labor-intensive, repetitive tasks that are perfect for robotics. These robots use GPS and other technology to plant seeds accurately, giving each seed the proper depth and spacing. These tasks are typically performed by self-driving[14]

Figure 5 [16] illustrates a precision wheat sowing robot with four wheels, servo motors, and stepper motors. The trial found that it outperformed usual sowing speeds with a seeding rate above 93%. In [18], writers presented a seeding robot capable of digging, planting, and covering seeds with soil. Additionally, you can add fertiliser and water. Raj et al. [19]

Fig 5: Seeding Robot

D. Fertilizing

Robotic fertilisation is becoming increasingly popular in agricultural applications. Traditional fertilisation processes sometimes involve spreading fertiliser across entire fields, which can lead to uneven distribution and wasted resources. Robots can administer fertiliser directly to soil or plants, reducing waste and ensuring optimal nutrition levels for all plants.[9]

IV. BENEFITS

A. Improved efficiency and productivity.

- Robots can conduct monotonous and time-consuming operations like planting, weeding, and harvesting, freeing farmers to focus on more sophisticated duties.
- 24/7 Operation: Unlike human labour, robots can work constantly without taking breaks, considerably increasing production and assuring timely completion of agricultural activities.[12]

B. Cost Reduction

- Labour Savings: The employment of robots decreases reliance on physical labour, alleviating labour shortages and lowering expenses associated with hiring and training personnel.[14]

C. Improved crop quality and yield

- Consistent Quality: Automated methods enable the consistent application of inputs such as fertilisers and insecticides, resulting in uniform crop quality.[14]

D. Labour Safety and Working Conditions

- Reduced Physical Strain: Automating repetitious and physically demanding tasks relieves the physical strain on human workers, resulting in improved health and well-being.[12]

V. CHALLENGES

A. High initial costs.

- Capital Investment: The initial cost of purchasing and installing robotic systems might be prohibitively expensive, particularly for small and medium-sized farms.[15]

B. Technical complexity.

- Integration Challenges: Integrating robotics into existing farm management systems and practices can be difficult and may necessitate major changes and training.[16]

C. Reliability and durability

- Wear and Tear: Continuous usage in harsh environments causes wear and tear, necessitating periodic maintenance and part replacements.[14]

D. Data Management and Privacy.

- Data Overload: The massive amounts of data produced by robotic systems can be overwhelming and difficult to manage effectively.[17]

VI. CONCLUSION

The advancement of robots in agriculture has enormous potential to transform farming techniques by increasing productivity, efficiency, and sustainability. However, successful integration of these technologies requires overcoming obstacles such as high costs, technological complexity, and data management concerns. As research and development in this subject continues, and farmers and stakeholders adapt to these advancements, agriculture's future appears to be brighter, with the possibility of more sustainable and profitable farming techniques.

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