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# Prospects and Potential Impacts of Cloud Robotics in Ameliorate Agricultural Farm Produce: A Case of India

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***Abstract*—Using contemporary technology like sensors, cloud robotics, and data analysis, robotics farming systems replace laborious tasks with continually automated procedures. The most recent developments in Indian agricultural robots are reviewed in this study on farming robotics, with a focus on systems that are employed for autonomous weed control, and harvesting. The issues in robotics farming include the diagnosis of plant diseases, work planning algorithms, digitalization, and sensor optimization. Some of the major points of robotics farming were emphasized, including multi-robots, humanoid robot collaboration, and environment reconstruction using aerial pictures and ground-based sensors enabling the building of virtual farms. Research in agricultural field robotics has indicated that one trend and area of interest is developing a network of small-scale robots and drones that work together to optimize farming inputs and uncover hidden or suppressed information. An autonomous framework with multiple inexpensive, simple-axis manipulators may be quicker and more effective in robotic harvesting applications than the expensive, professionally designed manipulators that are now in use. Even if robots are becoming an essential component of contemporary farms, we conclude that it is reasonable to anticipate a fully automated farming system with the help of cloud robotics in the future.**

***Index Terms*—Agricultural Robots,Cloud Robotics,Precision Farming**

## I. Introduction

Automation of agricultural operations is a demand of time to improve productivity with the help of cloud robotics and sensor technology. In recent years, the development of autonomous robotics systems in agriculture has experienced increased interest. Many IoT and Cloud Robotics researchers started developing more rational and adaptable devices for agricultural operations.A proposal was adopted in the field of agricultural autonomous devices to replace traditional large tractors with several compact, efficient autonomous machines. Furthermore, since the control in such a system is more suited to stochastic requirements, it may lessen the overuse of chemicals and excessive energy and input consumption, potentially having a negligible effect on the environment. Several field operations can be executed by autonomous robotics devices, giving more benefits than conventional machines. Most of the researchers are working on autonomous robotics device design for precision agricultural mobile robots. The design works on implementing three different verticals namely 1. Mobile or cloud robot navigation 2. Implements (Framework and Applications) 3. Sensor modules. Mobile robots are being designed in several countries, including the USA, EU, Denmark, Australia, Finland, India, and others, under these verticals, mostly to acquire agricultural farming over commercial industries.

Research groups have developed different specialized navigation techniques like an odometer, vision-based, sensor-based, inertial, active beacon, GPS, map-based, and landmark navigation techniques to operate robots under unified control for farming. This technique is used for applications like seedbed preparation, seed mapping, seed placement, reseeding, crop scouting, weed mapping, robotic weeding control, microspraying, robotics gantry, robotic irrigation, etc. .The current state of autonomous agricultural robots developed in India and other nations is discussed in this paper. Additionally, the extent of novel developments in agricultural robot design.

## II. Curent scenarios of Agriculture system in India and Factors Affecting

The projected world's population to grow to more than 9.15 billion by 2050. Thus, the task for the ensuing decades will be to create a highly productive agricultural management system while maintaining environmental quality to meet the demands of the growing global population. The majority of emerging nations, including India, struggle with a labor deficit in agriculture. Many young people from rural areas are moving to cities in search of better opportunities. Because of labor scarcity, agriculture operations are consequently delayed during their busiest times. In agricultural operations, power sources like human, animal, and mechanical are employed for tasks in-

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cluding preparing the seedbed, tillage, planting or transplanting, applying fertilizer and chemicals, managing intercultural activities, and harvesting. On Indian farms, the average power availability is 2.02 kW/ha. Agricultural machinery powered by humans, animals, or machines is unable to maximize time, money, or any other input. The majority of farm machinery is powered by the tractor, which is the primary machine power source. The tractor serves as a prime mower for the majority of farm operations, to which other implements are attached. The majority of farmers still utilize the conventional animal-operated country plow, despite its low yield and increased field operations requirements. Tractor power is used for the seeding procedure, which uses an inclined plate planter and zero till seed drill. Plant protection and intercultural operations demand a high degree of accuracy and input. A precession applicator is necessary for seed placement at the ideal depth for improved germination rate. Currently, hand tools like the wheel hoe and conoweeder are the major tools used in intercultural activities, especially in paddy fields and horticulture crops. The two tools are drawn by hand. Nutrient management, on the other hand, is a crucial process for increasing agricultural output while maintaining sustainability. The majority of farmers in underdeveloped nations apply nutrients by hand, often in an erratic manner by tossing them into the field without considering how readily available they already are. Fertiliser can be delivered more easily and uniformly with the help of certain instrumental setups.

## III. Types of robots in agricultural robotics

### A. *Sweeper robot*

SWEEPER's main objective is to put the first generation greenhouse harvesting robots onto the market. SWEEPER optimises the cultivation system by simplifying the harvest through the use of a robot. In order to improve the level of the robot's cognitive skills, crop models will be used to determine the approximate location of the peppers. This 'model-based vision' will improve and accelerate fruit detection. Based on the insights from the CROPS project, sensors will only be placed on the gripper.

### B. *Wed control and targeted spraying robots*

Weeding robots, as the name implies, locate and remove weeds from fields that have been cultivated. These robots are intended to assist farmers in managing weed infestation more successfully and, in many cases, more sustainably. They represent an intriguing nexus of artificial intelligence, robotics, and agricultural technology.

## IV. Prototype and professional field robots

A wide variety of field robots are employed in agriculture, and new models are created daily. Thus far, the eight most common varieties of field robots are as follows.*Precision Agriculture*

Precision agriculture methods are made possible by these research field robots, which are employed on small farms or vineyards. They are frequently employed to independently track biological parameters such as leaf area indexes (LAI), photosynthetic activity, soil respiration, and others.

### A. *Pollution Monitoring*

These days, some field robots are capable of keeping an eye on the pollution that agriculture produces on the ground. These robots help farms lessen their environmental impact by measuring emissions of nitrous oxide and carbon dioxide.

### B. *Livestock Ranching*

The large ranches use a new kind of field robot for animal herding. The animals are also observed by these robots, who make sure they have adequate space to graze and are in good health.

### C. *Weed Control*

To eradicate weeds, field robots equipped with herbicide delivery systems may traverse a farm on their own and apply precisely timed herbicide sprays. This method helps stop the growth of weeds resistant to herbicides and lessens the amount of herbicides that are applied to crops.

### D. *Nursery Automation*

In crop nurseries, field robots are mostly utilized for moving plants across big greenhouses. These robots enable crop nurseries to become much more efficient while also assisting in addressing the rising labor crisis.

### E. *Crop Harvesting*

Specialized field robots can harvest crops more quickly by working around the clock; in certain situations, they can accomplish the same amount of work as about thirty workers.

### F. *Fruit Harvesting*

In addition to harvesting crops, fruit is now also being harvested by field robots. Robots have a famously hard time plucking fruit. With the help of their sophisticated vision systems, these field robots can recognize fruits and safely pick them up.

*G. Planting and Seeding*

Field robots with 3D vision systems are a developing application that can correctly precisely plant and seed crops for ideal growth, mostly for vineyards and lettuce farming.

**GENERAL PURPOSE ROBOTS FOR FIELD SCOUTING AND DATA COLLECTION**

Field scouting robots must overcome several transdisciplinary obstacles to deliver accurate measurements and data that crop models and precision agriculture can use. In addition to the inherent biological and physical variety that comes with farm fields and orchards, scouting robot platforms need to be adaptable, versatile, and reasonably priced to be deemed practical for usage on a commercial scale. These robots have the potential to significantly lower production costs, boost productivity and quality, and enable customized plant and crop treatments if they are properly integrated and put into practice.

## V. HARVESTING ROBOTS

The need for efficient and sustainable agricultural operations has grown as a result of the growing global population and the resulting demand for food production. The employment of robots for agricultural harvesting is one sector that has shown rapid development in recent years. Robots that harvest crops for agriculture are therefore growing in popularity since they provide benefits including improved precision, efficiency, and lower labor costs.

## VI. MULTI-ROBOT SYSTEMS FOR DIGITAL FARMING

Agricultural robotics holds great promise in addressing issues related to digital farming, labor scarcity, and diminishing profitability. In real planting scenarios where no leaves and occluded fruits were trimmed or removed, early tests with one of the newest automated harvesting technologies, the Harvey[28] robot, have already demonstrated a success rate of 65 percent and a detachment rate of 90 percent for sweet pepper harvesting. With the help of autonomous field agent robots that gather and monitor data, farmers can make informed decisions by accessing upstream photos and real-time, comprehensive information on their fields and crops. By growing smarter, identifying sources of variability in the field, using less energy, and adjusting their performances for more flexible tasks, agricultural robotics is advancing farming techniques into a new phase. They are now a crucial component of the overall strategy for the production of crops and vegetables in the future, such as the construction of automated plant factories for the production of vegetables in Antarctica or the growth of plants in space. The current trend in food production involves the replacement of expert labor with robotic arms and mobile platforms, as well as automated farming techniques, tiny Agri-cubes, and cultivation systems with little human interface.

## VII. WEED CONTROL ROBOTS

Robots are being utilized more and more in contemporary agriculture to pull weeds. To differentiate between what is and is not a weed, they employ computer vision. When they come across weeds, they deal with them in different ways: some spray, some dig them out, and some use a laser to zap them.

**RESEARCH AND DEVELOPMENT IN AGRICULTURAL ROBOTICS**

*A. Precision Farming*

Sensors, cameras, and other technology are installed in agricultural robots to gather information on crop health, environmental variables, and soil conditions. By using this data, inputs like herbicides, fertilizer, and water may be optimized, resulting in more accurate and productive farming techniques.

*B. Crop Monitoring and Management*

To track crop development, identify pests and illnesses, and administer remedies as necessary, robots can independently traverse fields. By allowing for targeted treatments and early problem detection, this real-time monitoring helps to increase yields while decreasing crop losses.

*C. Autonomous Machinery*

Agricultural robots are being designed to do a variety of activities, like planting seeds, weeding, and harvesting crops, that are currently completed by human labor or huge machinery. These self-sufficient devices can operate continuously without experiencing fatigue, resulting in enhanced productivity and reduced labor expenses.

*D. Harvesting Robots*

Robots are being designed to automate the harvesting process for various crops, including fruits, vegetables, and grains. These robots use computer vision and robotic arms to identify and pick ripe produce with precision, reducing the need for manual labor and minimizing damage to crops.

*E. Drone Technology*

Drones equipped with cameras and sensors are used for aerial surveillance of farmland, providing farmers with valuable insights into crop health, irrigation needs, and pest infestations. Drones can cover large areas quickly and are particularly useful for monitoring crops in remote or inaccessible locations.

*F. Data Analytics and Decision Support*

research and development efforts also focus on developing

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algorithms and software tools to analyze the vast amounts of data collected by agricultural robots. These analytics tools provide farmers with actionable insights and decision support, enabling them to optimize farm management practices and maximize productivity.

The overall goal of agricultural robotics research and devel- opment is to transform the food production process by utilizing cutting-edge technologies to increase farming's productivity, sustainability, and resistance to problems like labor shortages and climate change.

## VIII. Challenges of Robotics for Precision Agriculture

The study, design, development, and deployment of robotic technologies especially suited for uses in the agricultural industry are referred to as agricultural robotics research and development. With the use of these technologies, farming will be more productive, efficient, and sustainable overall. Various chores associated with farming will be automated. In agricultural robotics research and development, some important areas of attention are as follows:

Unmanned Ground Vehicles (UGVs), autonomous tractors, and drones are examples of autonomous vehicles that are being developed for agricultural operations like planting, spraying, and harvesting.

### A. Sensing Technologies

incorporating sophisticated sensing technologies for crop, soil, pest, and disease monitoring, such as cameras, LiDAR, multispectral/hyperspectral imaging, and sensors.

### B. Data Analytics

Processing and analyzing the massive volumes of data gathered from sensors and other sources using data analytics, machine learning, and artificial intelligence techniques to enable real-time decision-making.

### C. Manipulation and Actuation

Designing robotic arms, grippers, and actuators capable of performing delicate tasks such as fruit picking, pruning, and sorting with precision and efficiency.

### D. Crop Monitoring and Management

creating mechanisms for ongoing observation of crop health, development, and environmental factors in order to facilitate prompt intervention and efficient resource management.

### E. Weed and Pest Control

Developing robotic systems to apply pesticides, herbicides, and biological control agents precisely and with maximum targeting in order to minimize chemical use and lessen the environmental effects.

### F. Field Mapping and Navigation

Developing mapping and navigation systems that allow agricultural robots to move across dynamic, complicated settings efficiently, avoiding obstacles and choosing the best route.

### G. Energy and Sustainability

investigating how to employ lightweight materials, re- newable energy sources, and optimized operating tactics to make agricultural robotics more environmentally friendly and energy-efficient.

## Challenges of Robotics for Precision Agriculture

Robustness in Unstructured Situations: Robots face difficulties in terms of navigation, sensing, and manipulation in agricultural situations since they are extremely dynamic and unstructured.

Data management and integration: It can be difficult to integrate data from many sources, including sensors, satellites, and weather forecasts while maintaining data confidentiality, compatibility, and quality.

### A. Interoperability

Facilitating smooth integration and cooperation by guaranteeing compatibility and interoperability between various robotic platforms, sensors, and farm management systems.

### B. Cost-effectiveness

Creating affordable robotic solutions that take into account initial investment, maintenance, and operating costs while providing farmers with real benefits.

### C. Regulatory and Ethical Considerations

Addressing legal concerns about the use of robotic technologies in agriculture, such as privacy issues, safety regulations, and moral issues around automation and employment displacement.

### D. Adaptability and Scalability

Creating robotic systems that are scalable to satisfy the many demands of farmers around the world and that can adjust to various crops, farm sizes, and management techniques.

### E. User Acceptance and Training

Ensuring user acceptance and giving farmers and agricultural workers the necessary guidance, assistance, and training to enable them to successfully apply and incorporate robotic technologies into their operations.

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*F. Environmental Impact*

Evaluating the influence of robotic systems on the environ- ment concerning energy use, emissions, soil compaction, and biodiversity preservation, and creating plans to reduce adverse consequences.

## IX. Digitalization, Automation, and Optimization

Key trends in the agriculture sector that are revolutionizing it include digitalization, automation, and optimization. These developments are resulting in what is sometimes called ”smart farming” or ”precision agriculture.” Below is a summary of every facet:*Digitalization*

Utilizing digital technologies to gather, organize, and evaluate data about many facets of farming operations is known as the digitalization of agriculture. Data on crop health, weather patterns, soil conditions, machinery performance, and market trends are all included in this. Farmers can now make data-driven decisions, maximize resource utilization, and increase output and efficiency thanks to digitalization. Digital technology used in agriculture includes, for example:

• Software for farm management, which helps with activity planning and monitoring. • Geographic Information Systems (GIS), which are used to map field boundaries and soil qualities. • Remote sensing technologies for gathering data and images from fields, such as satellites and drones. • Sensor technologies that provide real-time crop health, nutrient level, and soil moisture monitoring.

*B. Automation*

Automation is the process of carrying out operations that have historically been completed by humans using robotics, machines, and control systems. Automation is used in agriculture for several tasks, including pest management, irrigation, planting, and harvesting. Automated systems can perform better than human labor in terms of precision and consistency while also being more cost-effective. Instances of agricultural automation include:

• Planting and seeding systems that are automated. • Automated fruit and vegetable harvesting devices. • Irrigation systems using actuators and sensors to provide water precisely. • Self-driving cars for agricultural tasks like applying fertilizer or insecticides.

*C. Optimization*

In agriculture, optimization aims to minimize inputs, maximize yields, and lessen environmental impact by using advanced analytics and data-driven decision-making. Large datasets are analyzed as part of the optimization process to spot trends, distribute resources as efficiently as possible, and boost productivity. Farmers can increase output while lowering waste and environmental deterioration by optimizing their farming operations. Agricultural optimization approaches include, for example:

• Using predictive analytics to estimate market demand and crop production. • The careful application of inputs, such as insecticides and fertilizers, taking into account regional varia- tions in crop and soil conditions. • Adaptive control systems, which modify agricultural methods instantly in response to shifting environmental circumstances. • Integrated manage- ment approaches that maximize cover crops, crop rotations, and other environmentally friendly techniques.

In general, major advances in agriculture are being driven by digitalization, automation, and optimization, which allow farmers to produce more food in a more sustainable way and with fewer resources. These technological advancements hold promise for addressing the problems associated with feeding the world’s expanding population while reducing the effects of resource shortages and climate change. Robots can delegate computing, storage, and communication responsibilities to a centralized cloud infrastructure through the notion of cloud robotics. This allows robots to access a large array of compu- tational resources and exchange knowledge with other robots and systems. Within the field of farm robots, cloud robotics presents numerous advantages and uses:

## X. Cloud robotics and agriculture robotics

Cloud robotics is the application of internet technologies such as cloud computing, cloud storage, and others to the robotics domain. One of the main advantages of cloud robotics is its ability to provide massive amounts of data to robotic devices without the need for direct integration through onboard memory.

In order to guarantee data integrity and security in cloud computing, this notion suggests incorporating a child cloud and a base cloud into a multi-cloud architecture. The following are the sub-systems of the multi-cloud architecture:

Child Cloud: The child cloud can be classified as a SaaS (software as a service) cloud computing model since it can be established with software that is centrally developed. The kid cloud is made up of several systems connected to one another over a local area network (LAN). The child cloud can be accessed by internal users via the same LAN, while external users can use GPRS services to access the child cloud through devices that support a web browser. As a result, this paradigm allows several users to access the kid cloud at once. Additionally, the kid cloud protects data security by requiring user authentication to access the cloud. Only once the necessary authentication has been completed may a user access data. Because the administrator performs this, a user is limited to accessing his data within the child cloud.[7,8]

Base cloud: The Base Cloud and the Child Cloud both use the same SaaS (software as a service) cloud model. The base cloud is used to maintain an encrypted backup of the data

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and information kept in the child cloud. This comes after the administrator has segmented and encrypted the data that was extracted from the child cloud. To guarantee data integrity, only the administrator has control over the base cloud. In the base cloud, each divided data set, or chunk, is kept in a different system. Should data be obtained from the base cloud, the administrator receives the encrypted and segmented data and decrypts and re-segments it before delivering it to the user. As a result, the suggested system technique uses Linux as the operating system to provide an architecture that is safe and dependable while also ensuring the security and integrity of data stored in the cloud.[7,8]

The subject of science and engineering devoted to the design, development, and use of robotic systems and automa- tion solutions especially suited for agricultural applications is known as agriculture robotics. These robots are made to do a variety of jobs in the agricultural industry, including harvesting, planting, weeding, spraying, keeping an eye on animals, and managing them. The goal of agriculture robotics is to reduce the need for human labor and tackle issues like

environmental degradation and labor shortages while incr ing farming operations' productivity, efficiency, sustainabi and profitability.

*A. Data Storage and Processing*

Large amounts of data are produced by agriculture rob numerous sensors and cameras when they monitor cr gather environmental data, or tend to livestock. By storing a processing this data in the cloud, cloud robotics frees up robot's onboard computer resources. This makes it poss to do more in-depth analysis and make decisions in real-t using the combined data.

*B. Machine Learning and AI*

Utilising artificial intelligence and machine learning al rithms to analyze agricultural data is made easier by cl robotics. Agriculture robots can carry out sophisticated t including image recognition for pest and disease identificat crop yield prediction, and irrigation strategy optimization utilizing cloud-based AI services. Access to strong AI mo and training data is made possible by the cloud, which c help agricultural robots perform better over time.

*C. Collaborative Learning*

Robots can exchange insights and knowledge via centrali cloud systems thanks to cloud robotics. For instance, on robot picks up skills like effective field navigation or w identification, it can impart these abilities to other ro functioning in various areas. Solutions for agricultural robo are developed and implemented more quickly thanks to t

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collaborative learning methodology.

*D. Remote Monitoring and Control*

With cloud robotics, agricultural workers and farmers c monitor and manage robots remotely from any location w internet connectivity. Users can modify robot settings, mon the status of field activities, and get real-time alerts and n fications through mobile applications or web-based interfa The flexibility and efficiency of agricultural operations are improved by this remote accessibility, particularly in large- scale farming operations or rural places.

*E. Scalability and Flexibility*

Scalability provided by cloud robotics enables agricultural organizations to deploy and operate robot fleets more effi- ciently. Cloud-based management tools make the deployment and maintenance process easier, whether it's updating software and algorithms across numerous robots at once or adding new robots to the fleet. Furthermore, cloud robotics systems are flexible enough to change with the needs of agriculture and incorporate new features and technological developments in the future.

All things considered, cloud robotics has enormous po- tential to transform agriculture by enabling more intelligent, connected, and productive agricultural methods. Agricultural robots have the potential to enhance food production systems' productivity, sustainability, and resilience by harnessing the power of the cloud.

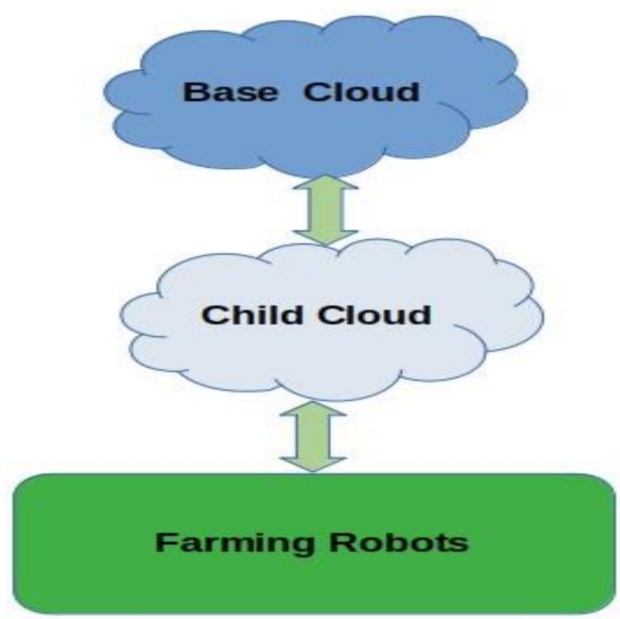


Fig. 1. Architecture of Cloud Farming Robots Network

## XIV. ANALYSIS OF THE WORK

Automation of Laborious Tasks: Robotics farming systems leverage contemporary technology like sensors, cloud robotics, and data analysis to automate tasks traditionally performed by human labor. This automation aims to reduce manual effort and increase efficiency in farming operations.

Focus Areas: The study specifically reviews developments in autonomous weed control and harvesting systems within Indian agriculture. These areas are crucial for improving productivity and reducing reliance on manual labor.

Challenges: The analysis identifies various challenges in robotics farming, including the diagnosis of plant diseases, development of efficient work planning algorithms, digitalization of farming processes, and optimization of sensor usage. Addressing these challenges is essential for the widespread adoption of robotics in agriculture.

Key Emphases: The study emphasizes the importance of multi-robot systems, collaboration between humanoid robots, and the use of aerial imagery and ground-based sensors for environment reconstruction. These technologies enable the creation of virtual farms and enhance farming precision.

Trends: One significant trend highlighted in the research is the development of networks comprising small-scale robots and drones that collaborate to optimize farming inputs and gather valuable data. This trend indicates a shift towards decentralized and interconnected robotic systems in agriculture.

Harvesting Applications: The study suggests that an autonomous framework featuring multiple inexpensive, simple-axis manipulators may outperform expensive, professionally designed manipulators in robotic harvesting applications. This approach could improve the efficiency and cost-effectiveness of harvesting operations.

Future Outlook: While robots are increasingly becoming essential in modern farms, the study anticipates a future where fully automated farming systems, powered by cloud robotics, become commonplace. This suggests a vision of highly efficient and autonomous agricultural operations driven by advanced robotics technology.

## XV.CONCLUSIONS

Agriculture robots have seen a sharp increase in interest recently. The amount spent and the amount of study being done on the topic are growing almost exponentially worldwide. These include image processing, navigation, and other robotics difficulties unique to agriculture that agricultural robots must overcome. But even with these advancements, agricultural robots are still a long way from becoming fully functional. This suggests that further resources, such as cloud robotics, are required. This would give the field robots dependable wireless access, useful HRI capabilities for interacting with humans, and a framework for sharing and reusing robot software. Such infrastructure is currently exceedingly difficult to create, and it may be prohibitively expensive in terms of both technology and monitoring. Consequently, this makes agriculture robots unfeasible and impractical. Thus, the secret to deploying agricultural robots is to come up with a fresh, workable, and trustworthy plan for setting up the necessary support infrastructure.

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