THE USE OF COMPUTER VISION IN PRECISION AGRICULTURE

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Abstract:

Precision agriculture is an innovative farming method that aims to maximize crop yields while minimizing waste. One of the key technologies used in precision agriculture is computer vision, which involves using cameras and sensors to collect data on crop growth and health. This data is then analyzed using machine learning algorithms to provide insights on how to optimize farming practices and improve yields. In this article, we provide an in-depth analysis of the role of computer vision in precision agriculture, with a focus on its applications in crop monitoring, the various types of cameras and sensors utilized in computer vision systems, and the diverse machine-learning algorithms employed to analyze the data collected. Through this analysis, we aim to offer a comprehensive overview of the potential of computer vision to revolutionize the way we grow and harvest crops, and the impact it could have on the future of agriculture.

Keywords:

Computer Vision, Algorithms, Technology, Machine Learning, Agriculture.

INTRODUCTION

Precision agriculture is a solution that aims to address the challenges and limitations of traditional farming methods by leveraging the power of technology. By using various sensors and tools such as drones, satellites, and computer vision, farmers can collect and analyze data to gain valuable insights into crop health, growth patterns, and environmental factors. [1] This enables them to make data-driven decisions about when and how to plant, irrigate, fertilize, and harvest their crops, resulting in improved yields, reduced waste, and lower costs. With the help of artificial intelligence and computer vision, precision agriculture can automate many of these processes, freeing up farmers to focus on more complex tasks and enabling them to maximize their productivity and profitability.

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2. IMPORTANCE OF PRECISION AGRICULTURE

Precision agriculture involves the use of advanced technologies such as sensors, GPS, GIS, IoT, drones, and more to optimize the utilization of natural resources and inputs to achieve specific crop production and quality. Through digital farming and more efficient use of resources and time, farming can become more efficient and consistent. This paper provides an overview of the fundamental elements of precision agriculture, its various components, and its future implications. [2]

Precision agriculture involves a wide range of automated measurements taken at different spatial scales, from individual plants to entire fields, and at various points in time during crop production. Initially focused on yield sensors, precision agriculture has expanded to include tools for mobile measurement, determining plant condition, and identifying possible pest infestations. Wireless communication allows for field data to be transferred to logging software. Precision agriculture technology is intelligent and can aid in environmental protection and sustainable development. Real-time crop processing and fertilizer equipment can be implemented with this technology, along with identifying and registering interventions or treatments of growth stage cultures. During harvest, the technology can help identify and measure quality parameters of the crop, depending on where it is grown in the field. Tagging different batches with all relevant information can aid in food safety and quality assurance. Overall, precision agriculture technology can be a crucial tool in improving crop production and ensuring food safety and quality. [3]

By enabling farmers to make data-driven decisions, precision agriculture reduces the need for guesswork and increases the accuracy of farming practices. This results in greater profitability for farmers, a more sustainable and safer food supply for consumers, and a reduced negative environmental impact of traditional farming methods. The integration of computer vision technologies in precision agriculture further enhances its capabilities. For instance, computer vision can help identify plant diseases and pests, monitor crop growth, and estimate yield, among others.

The use of computer vision in precision agriculture can optimize crop yields, reduce waste, and increase operational efficiency, leading to significant long-term savings and increased yields compared to conventional farming methods. [4] Overall, precision agriculture and computer vision technologies have the potential to revolutionize the farming industry and usher in a more sustainable and efficient future.

3. COMPUTER VISION METHODS IN PRECISION AGRICULTURE

Much precision agriculture work uses some type of sensor to relatively inexpensively obtain information about spatial and temporal changes in crops, soil, weeds, disease, and more. [5] Computer vision is an advanced technology with the capability to identify, locate, and track objects. It has been extensively researched and implemented in various fields, including precision agriculture and industry. Computer vision applications range from automated driving and surface defect detection to object detection and localization, automated harvesting, robotics, crop phenotyping, and crop yield estimation. Automated driving technology enables vehicles to recognize their surroundings and drive without human intervention. However, varying lighting and obstacles, make it an extreme challenge.

For example, it may be difficult to see pedestrians and lane markings accurately. Surface defect inspection technologies can identify and differentiate anomalies from desired features, making them essential in automated production. The aim is to identify and analyze errors quickly and reliably, which is a major challenge. Implementing deep learning techniques for object detection and localization can be challenging due to their high computing power and storage requirements.[6]

The growing accessibility and affordability of computer vision technology represent a significant step forward for the agriculture industry. As the climate and environmental changes continue to affect global food needs, the implementation of AI technology can transform 21st-century agriculture by:

- improving efficiency in time, labor, and resource management;
- enhancing environmental sustainability;
- optimizing resource allocation;
- providing real-time monitoring for better product health and quality.

However, the integration of this technology will require changes in the agricultural industry, and farmers' knowledge must be translated into education about artificial intelligence.

4. APPLICATION OF COMPUTER VISION IN AGRICULTURE

Computer vision allows machines to interpret and perceive visual information similar to humans. In agriculture, computer vision combined with a remote camera provides a non-contact and scalable sensor solution. Its applications in agriculture include AI-driven animal monitoring, visual quality control, automated inspections for quality maintenance, and infrastructure monitoring.

Moreover, computer vision has the potential to improve crop monitoring and yield forecasting by identifying crop health, growth patterns, and potential stressors through image analysis [7]. Computer vision technology enables robots and machines to mathematically perceive their surroundings pixel by pixel, creating algorithms and models to understand images more accurately. This technology has found extensive use across the agricultural and industrial food production sectors. This includes the implementation of sorting systems for a wide variety of crops such as oranges, papayas, almonds, potatoes, lemons, wheat, corn, and rice. [8].

Computer vision models can be trained using datasets to process images of plants, allowing for precise insight into farm activities remotely and precision agriculture is a systemic solution that balances productivity and environmental concerns by increasing economic output while reducing energy requirements and environmental impact.

Figure 1 depicts the use of computer vision technology on tomatoes in disease identification, which is just one example of how computer vision can be used in fruit and vegetable production. By utilizing computer vision technology, farmers and producers can automate the grading, sorting, and quality control of fruits and vegetables.

With the help of computer vision, fruits can be classified based on their size, shape, color, texture, and other characteristics. This enables the sorting of fruits based on their quality, ensuring that only high-quality fruits reach consumers. Cameras can capture images of fruits, and computer vision algorithms can detect defects such as bruises, cracks, and discolorations, after which the system can sort the fruits according to their quality.

Yield estimation is another fruit production application of computer vision technology. Computer vision systems can analyze images of fruit trees or plants to estimate the number of fruits present, their size, and their ripeness. This information is crucial in optimizing the harvesting process, allowing growers to harvest fruits at the peak of their ripeness, which results in high-quality fruit production. In summary, the utilization of computer vision technology in fruit production aids growers in optimizing their production processes, reducing waste, and ensuring that high-quality fruits are delivered to consumers.

Figure 1 - Application of computer vision on tomatoes in disease identification [9].

4.1. COMPUTER VISION APPLICATIONS FOR CROP HEALTH MONITORING AND INSECTS AND DISEASE DETECTION

With the aid of computer vision systems, it is now possible to identify and classify crop diseases and detect physical damage caused by pests and insects. This provides farmers with prompt notifications about unfavorable field conditions, and the system can monitor the spread of diseases or infestations to alert them to any potential risks.

This eliminates the requirement for conventional, resource-intensive scouting practices that are frequently utilized in the industry, which can be both expensive and time-consuming [10]. Computer vision technology is becoming increasingly popular in the agriculture industry as a means to optimize crop yield. Machines can now be trained to detect and pick up damaged or infested crops, reducing waste and improving crop quality. Through the use of color imaging and in-depth analysis, computer vision technology can assist farmers in diagnosing issues with their crop output and taking preventative measures to address them. [11]

Computer vision technology can also aid retailers and farmers in efficiently sorting their crops by ensuring that the correct fruits and vegetables are stored together.

Object detection allows a machine to scan thousands of individual objects as they pass by a sensor, discarding any low-quality crops automatically and freeing up farmers to focus on other tasks. Computer vision technology has a wide range of applications in agriculture, including planting and harvesting, weeding, and detecting plant health issues [12].

Figure 2 shows the result of observing tomato ripeness using computer vision.

The health, yield, and quality of plants are primarily affected by the presence of micro and macronutrients in the soil. Monitoring the growth stages of plants is crucial for enhancing production efficiency. It is essential to comprehend the relationship between plant growth and the environment to make necessary adjustments for improving plant health.

Figure 2 - Observing tomato ripeness using computer vision [13].

The use of unmanned aerial vehicles (UAVs) allows for the collection of aerial data to predict crop and soil conditions, which were previously determined by human observation and judgment. With the help of computer vision technology, these data can be used for intelligent crop monitoring. This data can be analyzed and interpreted using Visual Sense AI, which enables:

- Plant health monitoring;
- Accurate earnings forecasting;
- Detecting malnutrition in crops faster than humans can achieve.

AI models can alert farmers to specific problem areas so they can take immediate action. This technological advance offers a more efficient and cost-effective way of monitoring crops, potentially leading to improved yields and quality, and a more sustainable approach to agriculture.

Manual observation of tomato ripening stages is a labor-intensive process that can be supported by AI in precision agriculture. To achieve this, researchers collect images of tomatoes at different stages and under different lighting conditions. This model outperformed human observation in accurately identifying tomato ripening stages, which eliminated the need for daily field visits by farmers.

In a separate study, researchers developed an algorithm that could accurately assess the ripeness of tomatoes by analyzing the color of five distinct areas on the fruit. The algorithm achieved an impressive detection and classification rate of 99.31%. With AI, farmers can reduce the labor-intensive process of observing and assessing crop growth and maturity, which is challenging and time-consuming. AI can handle much of this work with ease and impressive precision, making precision agriculture more efficient and sustainable.

4.2. PREVENTING CROP DISORDERS WITH COMPUTER VISION

Computer vision technology has proven useful in detecting agricultural disorders, but it also has the potential to prevent them. By using unmanned aerial vehicles (UAVs) equipped with computer vision AI, farmers can automate the spraying of pesticides and fertilizers across large fields with uniform precision. The use of real-time target spraying area detection can improve the accuracy of drone sprinklers and decrease the likelihood of contamination to plants, animals, people, and water resources.

Although there are challenges involved in assigning mission sequences and trajectories to individual vehicles, researchers at Virginia Tech have devised a smart misting system to address this issue.

To detect and remove weeds with precision, the smart misting system employs servo-motor-controlled sprayers and computer vision technology. By utilizing cameras mounted on the sprayers, the system can record the location of weeds and analyze their size, shape, and color. This information is then used to accurately remove weeds through the targeted application. Thanks to the accuracy of computer vision technology, the system can avoid collateral damage to plants and the environment.

In summary, computer vision technology has the potential to revolutionize agriculture by automating spraying processes and reducing the risk of contamination, thereby improving crop yields and ensuring the safety of humans, animals, and the environment. The smart spray system developed by Virginia Tech is an example of how computer vision can be used to deliver precise amounts of herbicides and prevent collateral damage to crops or the environment.

In addition to aiding farmers in identifying and addressing issues with their crops during the growing season, AI computer vision can also assist with post-harvest processes. Computer vision algorithms have the potential to automate the grading and sorting process of harvested produce by analyzing its size, shape, color, and volume. This technology offers superior accuracy and efficiency compared to human inspectors. By using computer vision technology to inspect harvested crops, farmers and distributors can ensure that only the best quality produce is selected for sale, reducing waste and improving profitability.

This process can also be performed at a much faster pace than manual sorting, allowing for more timely delivery of fresh produce to markets and reducing the risk of spoilage. In summary, computer vision technology offers numerous benefits for the agricultural industry, from crop health monitoring to post-harvest processing. With the continuous advancement and widespread adoption of this technology, it is expected to play a progressively significant role in enabling farmers to optimize their crop yields, reduce waste, and enhance profitability.

5. CONCLUSION

From the studies mentioned above, we can conclude that computer vision technology is being increasingly adopted in agriculture as a rapidly developing technology. It is expected that in the future, computer vision technology that relies on large data sets will be widely used in all areas of agricultural production and will be leveraged to address various agricultural challenges. The integration of computer vision technology and artificial intelligence algorithms will enhance the economic, overall, coordination, and automation system performance of agriculture.

In conclusion, precision agriculture is a relatively new approach to agriculture that utilizes modern technologies and techniques, including computer vision, to provide a detailed and comprehensive view of farming practices. Computer vision enables the identification, localization, and tracking of objects and has been applied in numerous fields, including industrial and precision agriculture.

It has the potential to enhance crop monitoring and yield prediction by using image analysis to detect plant health, growth patterns, and potential stress factors.

By optimizing soil use, precision farming helps maintain soil quality and ensures a stable food supply, making it an essential tool in addressing global hunger challenges.

While precision agriculture technologies may appear costly initially, they result in significant long-term savings compared to traditional farming methods, ultimately increasing production. Overall, the use of computer vision in precision agriculture highlights its potential to change the way we grow and harvest crops, and improve the efficiency and sustainability of agriculture.

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