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REVIEW ON APPLICATIONS OF ARTIFICIAL INTELLIGENCE IN AGRICULTURE

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ABSTRACT----------
In this comprehensive review, explore the various applications of artificial intelligence (AI) in the field of agriculture. Discover how AI is revolutionizing crop monitoring, precision farming, agricultural robotics, pest management, and more. Gain insight into the impact of AI on productivity, efficiency, and sustainability in agriculture. We will also discuss the challenges and future trends in this rapidly evolving field.----------

INTRODUCTION

Agriculture has been a longstanding pillar of India's economy, engaging 60% of the labour force and contributing 22% to the national product. Despite the cultivation of multiple crops annually, challenges persist, including financial disparities, lack of education among farmers, and inadequate agricultural practices.

Artificial Intelligence (AI): AI is based on imitating human intelligence, has become indispensable across various industries. In agriculture, AI is crucial for addressing challenges such as climate change, population growth, labour shortages, and food safety.

AI in Agriculture: Precision agriculture, powered by AI, has transformed crop production, harvesting, processing, and marketing. AI technologies, including computer-based systems, aid in field harvesting, health monitoring, weed and pest management, and detecting soil nutrient deficits. These advancements enhance crop yields, reduce costs, and improve efficiency throughout the farming business.

AI technologies are actively employed in crop monitoring, pest control, soil and growing condition monitoring, data organization for farmers, workload assistance, and various other tasks along the food supply chain. AI contributes significantly to plant health detection, planting, weeding, harvesting, and advanced weather analysis in smart farming practices.

Need for AI in Agriculture: The agricultural sector is undergoing a revolutionary transformation by incorporating technology to enhance efficiency and increase productivity. Despite ongoing efforts, challenges persist across the agricultural value chain. The need for AI in agriculture is imperative to address these challenges, optimize operations, and ensure sustainable practices amid growing food consumption and environmental concerns.

Applications of AI in Agriculture

1. Crop and Soil Monitoring: AI plays a pivotal role in enhancing crop and soil monitoring. Drones equipped with cameras collect aerial data, enabling computer vision models to track crop health, predict yields, and detect malnutrition faster than human observation. This time-efficient process allows AI models to alert farmers to specific issues, facilitating rapid intervention.

A. Health Monitoring of Crops: AI applications like "Plantix" utilize image recognition technology for health monitoring of crops. Farmers can capture plant images, and the software provides insights into soil inadequacies, plant pests, and diseases. This information guides farmers in applying better fertilizers to enhance harvest quality.

B. Soil Analysis: AI analyses soil samples to detect nutrient deficiencies, generating accurate soil condition maps. Precision agriculture technology, exemplified by companies like "Precision Hawk," employs drones to collect data on soil conditions, crop health, and weather patterns. AI algorithms process this data, offering comprehensive maps for identifying issues like nutrient deficiencies, soil compaction, and erosion.

C. Agricultural Monitoring: AI-driven crop monitoring systems use cameras and sensors to identify problems like pests, diseases, and nutritional deficiencies. This data informs precise pest management, fertilization, and irrigation strategies, optimizing yields while reducing expenses.

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D. Crop Monitoring Using Drones: Drones, with their autonomous flying capabilities, have become integral to precision agriculture. Equipped with cameras, drones collect geo-sensing data, enabling computer vision algorithms to assess soil conditions, provide aerial perspectives of agricultural fields, and evaluate crop health. Image annotation is employed to label captured photographs.

2. Observing Crop Maturity: In precision agriculture, AI aids in labour-intensive tasks like manually observing wheat head growth phases. Computer vision models, developed by collecting photos of wheat at various stages, outperform human observation, eliminating the need for daily field inspections by farmers.

Crop Price Volatility and Real-Time Monitoring: AI addresses concerns of crop price volatility by utilizing satellite imagery, weather data, big data, and machine learning to assess land, monitor crop health, detect pest and disease infestations, estimate yields, and forecast prices. This technology advises farmers and governments on future price patterns, demand levels, crop selection, and pesticide use.

3. Insect and Plant Disease Detection: AI, through picture recognition technology based on deep learning, detects plant illnesses and pests. It employs image classification, detection, and segmentation algorithms to "keep an eye" on plant health, enabling swift responses to pest control and disease prevention.

A. Disease and Pest Detection: Computer vision, in addition to monitoring soil and crop growth, detects pests and diseases by examining photos for moulds, rots, insects, etc. AI has been used to identify mango black rot and insects like flies, bees, and moths with over 90% accuracy.

B. Diagnosis of Disease: AI forecasts aid farmers in diagnosing plant diseases. Computer vision technologies preprocess plant photos, classify them as diseased or non-diseased, and identify affected areas. This approach is crucial for detecting pests, vitamin deficiencies, and other issues.

C. Disease Control and Prevention: Agricultural management uses AI to predict disease outbreaks based on weather data. AI assesses the likelihood of outbreaks and recommends preventive measures, such as fungicides or pesticides, to protect crops. This proactive approach helps farmers preserve their crops and minimize losses.

4. Intelligent Spraying: AI, coupled with computer vision, contributes to preventive measures in agriculture, particularly in the consistent spraying of pesticides or fertilizers using Unmanned Aerial Vehicles (UAVs). These UAV sprayers offer precision in spraying, minimizing the risk of pollution to crops, humans, animals, and water supplies. Challenges include task sequencing for multiple UAVs, but innovations like smart spray systems with computer vision, as developed by Virginia Tech researchers, enhance accuracy and avoid collateral damage to crops and the environment.

5. Precision Farming: Precision farming, focusing on "Right Place, Right Time, and Right Product," leverages AI for more accurate and efficient agricultural practices. Predictive analytics and yield mapping utilize machine learning to analyse large data sets in real time, aiding farmers in planning crops, estimating yields, and optimizing resource utilization. Determining the optimal time to sow seeds is enhanced through predictive analytics, providing insights into soil health, fertilizer recommendations, and weather forecasts. Crop yield estimates and price forecasts address the challenge of crop price volatility, allowing for informed decision-making.

AI in precision farming utilizes data from sensors, cameras, and other sources to create accurate maps of soil conditions, crop health, and weather patterns. This information guides comprehensive planting, harvesting, and irrigation plans, executed through automated machinery and unmanned aerial vehicles. Examples include AI-powered drones for crop seeding and robots equipped with cameras and sensors for efficient crop harvesting. Auto-farming exemplifies how AI is transforming agriculture by reducing costs, increasing efficiency, and enhancing overall agricultural business operations.

6. Improved Irrigation System

A. Improving Automatic Irrigation Systems: AI algorithms, integrated with IoT sensors, enable real-time self-management of crops' water requirements. Autonomous agricultural irrigation systems conserve water by precisely delivering water based on soil moisture levels and weather conditions, promoting environmentally friendly farming practices.

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B. Detecting Irrigation System Leaks or Damage: AI plays a crucial role in detecting leaks in irrigation systems through pattern recognition and anomaly detection. Machine learning models analyse variations in water flow or pressure to identify potential leaks in real-time, minimizing water waste and preventing crop damage.

C. Water Conservation with Smart Irrigation: AI-driven smart irrigation, incorporating features like solar-powered GPS and pressure control, enhances water efficiency. It allows for precise control of irrigation equipment, reducing wind-drift losses and energy costs. Drip irrigation systems further improve water conservation by directly serving the root zone, minimizing soil evaporation and wind drift losses.

D. AI in Spray Boom and Drip Irrigation: AI applications in spray boom and drip irrigation systems contribute to automation, ensuring efficient water supply and soil water monitoring. Automation, combined with AI, enhances the precision of irrigation, minimizes surplus water delivery, and supports effective field, agricultural, and irrigation system management.

7. Planting (Seeding) and Weeding

A. Autonomous Weeding with BoniRob: AI-powered robots, like BoniRob, use camera and image recognition technologies to autonomously detect and eliminate weeds while preserving valuable crops. By learning from image training on leaf characteristics, BoniRob distinguishes between weeds and crops, providing an environmentally friendly and sustainable solution for weed control.

B. Automatic Weeding with Laser-Powered Robots: AI-driven laser-powered robots offer an innovative solution for automatic weeding. Equipped with cameras and AI software, these robots recognize weeds and use high-intensity lasers to eliminate them without disturbing the soil. This automated approach eliminates the need for manual labour, providing an efficient and effective means of weed control.

8. Automatic Harvesting

Agricultural inefficiencies and slow processes are being addressed through autonomous harvesting devices equipped with computer vision. AI, coupled with machine learning, distinguishes weeds from crops by analysing leaf characteristics, enabling robots for autonomous weeding and harvesting. The technology's efficiency, working around the clock with over 90% success rates, marks a significant advancement in agricultural automation.

AI-driven sorting systems enhance post-harvest activities. Autonomous harvesting robots, equipped with cameras and AI software, accurately recognize and pick fruits or vegetables. The efficiency of these robots surpasses manual sorting, allowing farmers to categorize produce swiftly, meeting diverse market demands. Robots designed for picking various crops, from peppers to strawberries, demonstrate the potential of AI in transforming fruit and vegetable harvesting.

Autonomous tractors add another dimension to agricultural automation. Companies like Rabbit Tractor and Bear Flag Robotics are pioneering autonomous tractor technology, offering remote operation or full autonomy. These tractors enhance efficiency, reduce labour costs, and contribute to increased yields.

9. Farm Animal Monitoring

AI-powered livestock monitoring systems, employing cameras and sensors, revolutionize farm animal management.

A. Animal Health: AI enables precise tracking of cattle health, detecting sickness, parasites, and nutritional deficiencies. Data from cameras and sensors help develop tailored plans for disease prevention, vaccination, and feeding, optimizing health management while reducing costs.

B. Animal Breeding: AI enhances animal breeding strategies by generating precise plans using data from cameras and sensors. Farmers can select optimal animals for breeding, improving overall herd health and increasing yields efficiently.

10. Drone Crop Monitoring

Drones, with autonomous flying capabilities, play a crucial role in precision agriculture. Equipped with cameras, drones gather extensive data, utilizing geo-sensing and computer vision algorithms to assess soil conditions and crop health. Object identification and semantic segmentation in AI models help analyse drone footage, enabling remote monitoring and precise administration of treatments such as fertilizers and insecticides. American Robotics pioneers an autonomous "Robot-as-a-Service" platform, integrating drones for unprecedented insights into agricultural fields.

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11. Labour Productivity and Efficiency

With labour costs accounting for over half of farming expenses, labour shortages impact 55% of farmers, prompting a shift towards less labour-intensive crops. Machine learning and robotics technologies offer promise in automating routine tasks, significantly reducing labour costs. For instance, a single strawberry robot harvester can cover a 25-acre area in three days, replacing the work of 30 agricultural labourers.

Benefits of AI in Agriculture

1. Data-Driven Decision-Making: AI facilitates informed decision-making by leveraging data, optimizing farming practices.
2. Cost-Cutting Measures: Automation and AI-driven technologies help reduce labour costs and increase operational efficiency.
3. Influence of Automation: Robotics and automation technologies enhance productivity, particularly in harvesting.
4. Modified Irrigation Technology: AI-driven irrigation systems optimize water usage in a systematic manner, addressing water scarcity concerns.
5. Disease Surveillance and Control: AI aids in the surveillance and control of diseases, enabling timely interventions.
6. Better Pesticide and Germicide Application: Precision agriculture powered by AI ensures efficient application of pesticides and germicides, minimizing waste.
7. Harvesting Product Sorting and Monitoring: AI improves the accuracy of harvesting, sorting, and monitoring processes, enhancing overall productivity.

Challenges of AI in Agriculture

1. **Limited Understanding and Adoption**
   - Farmers, especially those unfamiliar with tech, often lack a complete understanding of AI.
   - Conventional farming practices persist due to a lack of exposure to AI-related projects.
2. **Large Upfront Cost**
   - Initial expenses for AI solutions may be high, posing challenges for financially strained farms.
   - Small-scale farmers and those in developing nations may find AI adoption financially unattainable.
3. **Resistance to Innovation**
   - Farmer hesitancy to adopt new technology and resistance to innovative methods hinder progress.
   - Encouraging farmers to embrace AI requires incentives, training, and reassurance of safety.
4. **Inadequate Hands-on Experience**
   - Disparities in technical advancement globally impact the accessibility of AI benefits.
   - Technology companies must provide training and support in regions where advanced agricultural equipment is rare.
5. **Time-Consuming Adoption Process**
   - Lack of infrastructure for AI, coupled with hesitancy, slows down the adoption process.
   - Gradual introduction of simpler technologies may ease the transition for farmers.
6. **Technological Limitations**
   - AI is in early stages; accurate models depend on quality data, challenging in agriculture.
   - Infrastructure constraints necessitate gradual farmer involvement to overcome limitations.
7. **Privacy and Security Concerns**
   - Lack of legislation governing AI usage poses legal challenges, especially in precision farming.
   - Cyberattacks and data breaches could disrupt AI-based farming systems, impacting food supply.
8. **Obstacles to Adoption**
   - Perceptions like "AI is too complicated" or "it's too soon for my business" hinder adoption.
   - Effective communication from technology companies is crucial to dispel misconceptions.
9. **Inadequate Experience and Digital Infrastructure**
   - Continuous education is necessary for proper AI implementation.
   - AI technologies can integrate into existing infrastructure, requiring training and support.
10. **Unfamiliarity with AI Robots**
    - Lack of awareness about AI-enabled solutions impedes adoption.
    - Gradual introduction of basic equipment followed by advanced machinery can address unfamiliarity.
11. **Inadequate Knowledge of Upcoming Technologies**
    - Underdeveloped regions face challenges in adopting new technologies.
    - Farmers need assistance in employing and adapting to AI solutions.

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12. Concerns About Privacy and Security

- Absence of defined rules for AI deployment raises legal issues.
- Privacy and security risks, including hacks and breaches, pose challenges.

Summary of Obstacles

• Lack of necessary datasets for AI training in complex agricultural systems.
• Costs associated with AI hardware and software components.
• Handling massive data securely remains a challenge.

CONCLUSION

AI presents a transformative potential for agriculture by addressing challenges related to chemical misuse, labour-intensive tasks, and process efficiency. However, widespread adoption faces hurdles such as limited understanding, upfront costs, resistance to innovation, and technological limitations. Overcoming these challenges requires concerted efforts from technology companies, governments, and educational initiatives to ensure a seamless integration of AI into global farming practices. The benefits of AI in increasing productivity and sustainability make it a crucial element for the future of agriculture, demanding strategic solutions to bridge the current gaps.

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