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A Detailed Survey on Smart Agriculture Pest Controlling System

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Abstract: *With the rapid advancement of technology, smart agriculture has emerged as a promising solution to address various challenges in traditional farming practices. One critical aspect of smart agriculture is pest control, which significantly impacts crop yield and quality. This paper presents a comprehensive survey on smart agriculture pest controlling systems, aiming to analyse existing technologies, methodologies, and trends in this domain. The survey encompasses various aspects including sensor-based monitoring, data analytics, decision support systems, and precision application techniques. Furthermore, it examines the integration of Internet of Things (IoT), machine learning, and remote sensing techniques in pest management practices. By synthesizing insights from a wide range of research studies and commercial applications, this survey provides valuable insights for researchers, practitioners, and farmers to understand the current landscape and future directions of smart agriculture pest controlling systems.*

Keywords: *IoT, smart agriculture, pest controlling system, machine learning.*

1. Introduction

Internet of things (IoT) is a term that enables us to utilize technologies, work together, communicate each other, provide real time data from sensors wirelessly for processing, and provide more valuable information for efficient decision making in the corresponding research field [1]. IoT is dramatically a developing technology in application areas like healthcare, defence, industry, agriculture and so on the features of IoT are unlimited in such a way that it can be utilized for the development of civilization to make and lead a better life [2]. To implement IoT one need to have knowledge on research area with the hardware equipment's and possibilities with connection to internet for accessing the devices [3]. Recently, IoT has been applied in many sectors. The sectors using IoT are Smart Home, Smart City, Smart Environment and Smart Agriculture [4]. An interesting thing about IoT implementation is that IoT can give accurate information through its sensor inside IoT system. In health care service, Smart Agriculture is not only used for agricultural food but also pest detection. By using IoT implementation based methods, a farmer can be helped in tackling pest problems [5]. It is because pest problems can be found in every rice fields. Various kind of pest that are attacking rice fields are rat, slug, plant hopper, stink bugs, and birds [6].

Crop production is closely related to the presence of pest's plant diseases [7]. Pests often hide behind the leaves of plants during the day to avoid the heat and appear on the leaves in the evening or at night. Therefore, it is not easy to observe their presence on crops during the day [68. When farmers become aware of pest damage, pests have often multiplied and spread uncontrollably. At this stage, a large quantity of pesticides is required to spray the crops to eliminate the pests and reduce agricultural damage [9]. However, once the crops have been sprayed with pesticides in the growing season, pesticide residues remain even after washing. Crops often suffer from bacterial infections due to pests that result in large-scale crop diseases [10]. To prevent such conditions, it is necessary to burn the infected crops to prevent the spread of the bacteria. However, this approach causes significant damages in agricultural production without effectively resolving pest problems. Therefore, the goal of this research is to apply the AIoT [11] and deep learning technology to an environmental analysis of crop growth and the prediction of pest occurrence to improve the productivity of crops and reduce the size of the agricultural workforce [12].

In order to meet the current global needs of humanity, new solutions and technologies are constantly being proposed and implemented. This has led to the advent of the Internet of Things (IoT) [13]. IoT is defined as the network of all objects that are embedded within devices, sensors, machines, software and people through the Internet environment to communicate, exchange information and interact in order to provide a comprehensive solution between the real world and the virtual world. In recent years, IoT has been applied in a series of domains, such as smart homes, smart cities, smart energy, autonomous vehicles, smart agriculture, campus management, healthcare, and logistics [14]. An illustration of rich and diverse IoT applications for smart agriculture is provided in Figure 1.

Agriculture is the cultivation and breeding of animals, plants and fungi for food, fibre, bio fuel, medicinal plants and other products used to sustain and enhance life [15]. The ultimate need of the hour for a developing nation is the key for “Betterment in agriculture”. Pest attack poses to be a threat to agriculture. Mostly, these pest attacks lead to product loss. Hence, a Proper pest detection system is mandatory for an efficient and effective detection of pest attack [16]. This exposition proposes a system that advances an embedded system with GSM module. Using the anticipated system, detection of the pest attack could be monitored effectively

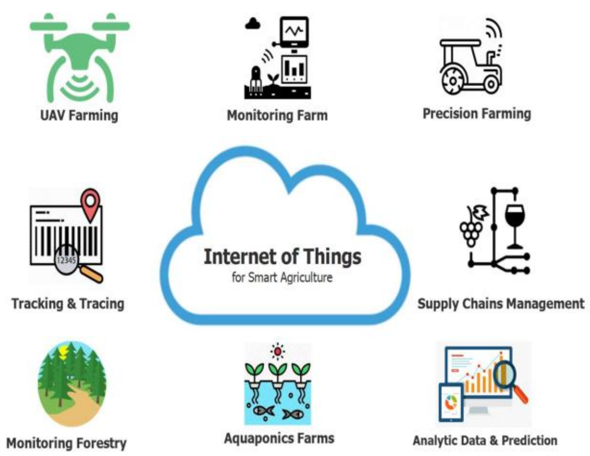

Figure 1: IoT for smart agriculture

The captured image is compared with the original healthy leaf. After the processing of all the above values the disease is identified and intimated to the farmer. The images are processed using image processing [17]. The captured image is compared with the original healthy leaf. After the processing of all the above values the disease is identified and intimated to the farmer. The images are processed using image processing [18].

The use of Raspberry pi has many advantages such as inbuilt Wi-Fi, Bluetooth, high processor code and mainly image processing can be done which is not possible when other processors are used.

2. IOT in Agriculture

IoT devices have been investigated for their use in agriculture in developed countries. In recent times, IoT solutions have made their mark in many areas of human life, the environment, and industries. These IoT devices are also capable of exchanging data with their gateway. Smart agriculture is a major IoT application area along with smart health care, smart cities, smart industries, autonomous vehicles, smart homes, and others. Authors in [19] designed an IoT-based agriculture framework that explains the relationship between pests, diseases, and weather parameters. In a detailed IoT technology discussion related to agriculture [20], the researchers discussed several aspects of IoT technologies and their possible use in smart agriculture. The authors in [21] discussed the selected aspects of IoT in agriculture, sensors, and network technologies, while in [22], the authors discussed integrated pest management technologies and their standard communication protocols. A unique concept and use of IoT were discussed in [23, 24] based on various surveys, where researchers discussed IoT as an ontological tool in integrated pest management. In another study [25], the authors presented an IoT-based smart farming framework with five major components including data acquisition, platforms, processing with visualization, and complete system management. The rapid technological development in recent years in IoT technologies is going to play a vital role in many agriculture-related applications [26, 27].

Most authors, as cited previously, argued that most IoT architectures consist of four layers. These layers include all the main components of any IoT solution. In another study [28], authors proposed an IoT-Enabled IEEE 802.15.4 WSN Monitoring Infrastructure-Driven Fuzzy-Logic-Based Crop Pest Prediction. In this proposed architecture, pests/diseases are identified with the help of various weather factors. In [29], authors suggested an IoT-based cotton pest prediction and response system.

3. Smart Agriculture Pest Controlling System

A Smart Agriculture Pest Controlling System employs modern technology and data-driven approaches to efficiently monitor, detect, and manage pest issues in agricultural settings. Here's a simplified outline of its components and functionalities:

Sensor Networks- Utilize a variety of sensors such as temperature, humidity, soil moisture, and pest-specific detectors placed strategically throughout the farm. These sensors continuously collect data on environmental conditions and pest activities.

Data Collection and Analysis- Gather data from sensor networks, drones, satellites, weather stations, and historical records. Employ data analytics techniques including machine learning algorithms to analyze the data for identifying patterns, pest hotspots, and early signs of infestations.

Pest Identification and Monitoring- Implement image recognition technology and AI algorithms to identify pests and their damage on crops. This can be achieved through image processing of photos taken by drones or ground-based cameras.

Decision Support System (DSS)- Develop a DSS that processes the analyzed data and provides actionable insights to farmers. This system can suggest appropriate pest control strategies, including timing and type of intervention, based on real-time data and historical trends.

Precision Pest Management- Integrate precision agriculture techniques to deliver pest control measures precisely where and when needed. This could involve targeted spraying of pesticides, deployment of pheromone traps, or release of biocontrol agents in specific areas of the farm.

Biological Control Methods- Promote the use of biological control agents such as beneficial insects, fungi, or nematodes to manage pest populations naturally. Monitor the effectiveness of these agents and adjust their deployment based on real-time data.

Integrated Pest Management (IPM)- Advocate for an IPM approach that combines multiple pest management strategies, including cultural, biological, physical, and chemical methods. The system should support farmers in implementing IPM practices tailored to their specific crops and pest challenges.

Real-time Alerts and Notifications- Develop a system for sending real-time alerts and notifications to farmers via mobile apps or SMS when pest thresholds are exceeded or adverse conditions are detected. These alerts can prompt timely actions to prevent or mitigate pest damage.

Remote Monitoring and Control- It enables farmers to remotely monitor their fields and control pest management devices through mobile or web-based platforms. This allows for proactive management even when farmers are not physically present on the farm.

Data Security and Privacy- Ensure that data collected from farms are securely stored, processed, and shared in compliance with data protection regulations. Implement measures to safeguard sensitive information and maintain the trust of farmers in the system.

By integrating these components into a cohesive system, Smart Agriculture Pest Controlling Systems empower farmers with the tools and knowledge needed to tackle pest challenges effectively while minimizing environmental impacts and optimizing resource use.

4. Literature Review

Denis O. Kiobia et al. in [1] explore AI and IoT integration for detecting cotton pests, achieving 70-98% accuracy but facing challenges in targeting diverse species. Azfar et al. [2] propose a real-time CFM detection system using IoT and drones, aiming to reduce pesticide use. Mathia et al. [3] suggest an IoT solution for smart farming, focusing on irrigation and disease detection via ML algorithms. Mini et al. [4] introduce a cost-effective IoT-based smart agriculture robotic system, enhancing resource usage and crop yield. Naresh and Munaswamy [5] advocate for modernizing farming with sensor-based automation, promoting efficiency and cost-effectiveness. Gupta and Nahar [6] present a hybrid ML-IoT model for yield prediction, achieving promising results with various metrics. Taufik Hidayat et al. [7] propose a review on pest detection systems using Blockchain and IoT to enhance pest management, aiming to reduce human error and increase harvesting efficiency. Kaushik Sekaran et al. [8] develop an architectural framework integrating IoT with cloud computing for real-time crop monitoring, achieving up to 98% accuracy in field tests. Amjad Rehman et al. [9] evaluate smart agriculture using IoT, highlighting its benefits, obstacles, and potential solutions to enhance crop yield and save resources. Ching-Ju Chen et al. [10] combine AI, image recognition, and IoT for pest identification, achieving 90% accuracy and reducing pesticide usage. Ahmed Khattab et al. [1]] develop an IoT-based monitoring system for precision agriculture, enabling early prediction of epidemic diseases and reducing chemical applications. Aman Jain and Abhay Kumar [12] propose modernizing agriculture practices using cloud-managed sensors to improve water conservation and crop quality. Avinash Kumar et al. [13] propose a Recommendation System to assist farmers in crop selection and pest management, achieving better accuracy with SVM classification. Imrus Salehin et al. [14] develop a sensor-based pest detection system, sending alerts to farmers' mobile devices, improving efficiency, and reducing costs. B. Vijayalakshmi et al. [15] introduce a system for automatic pest detection and notification using temperature and humidity sensors, Raspberry Pi, and GSM module, aiding in early disease identification and pesticide optimization. Kasara Sai Pratyush Reddy et al. [16] propose a smart irrigation system using IoT and decision tree algorithm, predicting water requirements and sending alerts to farmers for efficient water management. Bammidi Deepa et al. [17] create an automated agriculture system using IoT to monitor and optimize farming conditions, improving yield and resource usage. Adithya Vadapalli et al. [18] upgrade agriculture farms with WSN & IoT, enabling remote monitoring and control of agricultural parameters, leading to increased crop production. Demin Gao et al. [19] design an agriculture framework integrating UAVs and IoT for pest/disease detection, utilizing spectrum analysis technology to analyse crop damage and improve agricultural management.

Table 2.1 summarizes the key aspects, methods, and findings of each study in a structured format for easy reference.

Table 2.1: Summary of Recent works on smart Agriculture Pest Controlling System

Authors with Reference No.	Focus	Method/Technology	Findings/Key Points
Denis O. Kiobia et al. [1]	AI and IoT in detecting cotton insect pests and beneficial insects	Camera/microphone sensors, deep learning algorithms	- Insects detection accuracy: 70-98% - Challenges: Identifying immature and predatory insects, location of insects, data size, species similarity
Saeed Azfar et al. [2]	Real-time detection of Cotton Flying Moths (CFMs) with IoT-based system	Infrared sensors, Zigbee communication, Arduino Mega	- Prototype detects CFMs and alerts spraying drones - Testbed and simulation suggest effectiveness and suitability
Senthilkumar Mathia et al. [3]	IoT-based solution for smart farming	Machine learning algorithms, IoT	- Automatic irrigation and disease detection - Use of KNN and SVM algorithms - Future work: Combine clustering algorithms for improved accuracy
Ajit Divakaran Mini et al. [4]	IoT-based smart agriculture robotic system	Soil sensors, wireless controls, IoT platform	- Monitors temperature, humidity, soil moisture - Enables real-time control via mobile app - Cost-effective and sustainable
Muthunoori Naresh and P Munaswamy [5]	Modernization of traditional irrigation practices	Cloud services, sensors	- Automation of field monitoring and product conditions - Water and labor saving - Based on parameter values, farmers can decide on fungicides and pesticides
Akanksha Gupta and Priyank Nahar [6]	Hybrid ML model with IoT for yield prediction	Machine learning algorithms, IoT	- Two-tier ML model for soil quality and yield prediction - Use of various metrics for performance evaluation
Taufik Hidayat et al. [7]	Pest detection using Blockchain and IoT	Blockchain, IoT	- Blockchain verifies pest data, automates alerts - IoT monitors and identifies pests - Aim: Improve detection accuracy and reduce human error
Kaushik Sekaran et al. [8]	IoT integration for crop monitoring	Cloud computing, IoT sensors	- Real-time analysis of crop data - Increased productivity through resource optimization
Amjad Rehman et al. [9]	IoT applications in smart agriculture	Wireless sensors, UAVs, cloud computing	- Automation of agricultural processes - Improved productivity and quality - Overcoming obstacles in smart agriculture
Ching-Ju Chen et al. [10]	AI and IoT for pest identification	Image recognition, environmental sensors, AI models	- AI-driven pest identification with high accuracy - Precision in pesticide application
Ahmed Khattab et al. [11]	IoT-based monitoring for precision agriculture	Wireless sensor network, AI algorithms	- Environmental monitoring and disease prediction - Reduction in chemical applications and high-quality crops
Aman Jain and	Modernization of	Cloud management, sensors	- Remote monitoring and control of farming

Abhay Kumar [12]	traditional agricultural practices		conditions - Water and labor conservation
Avinash Kumar et al. [13]	Recommendation System for crop selection and pest detection	Machine learning algorithms	- SVM model for accurate pest detection and crop recommendation
Imrus Salehin et al. [14]	Pest detection using various sensors	Sensors, central database	- Detection and alerting of pests via mobile - Testing shows efficiency and potential for widespread use
B. Vijayalakshmi et al. [15]	IoT-based pest detection and notification	Temperature/humidity sensors, Raspberry Pi, GSM module	- Automatic pest identification and alerting - Minimized pesticide use and accurate disease detection
Kasara Sai Pratyush Reddy et al. [16]	Smart irrigation system with machine learning	Sensors, microprocessor, decision tree algorithm	- Efficient water usage through predictive irrigation - Decision tree model for water supply optimization
Bammidi Deepa et al. [17]	Automated agriculture system using IoT	IoT sensors, cloud computing	- Monitoring and optimization of farming conditions - Improved resource usage and yield
Adithya Vadapalli et al. [18]	Upgraded agriculture farm with WSN & IoT	Wireless sensor networks, IoT devices	- Improved crop production through better monitoring and control - Enhanced communication and data transfer between nodes
Demin Gao et al. [19]	Agriculture framework for pest/disease analysis	UAVs, spectrum analysis, IoT	- UAV-based analysis of pest/disease occurrence - Deployment in China's Yangtze River Zone for disease susceptibility analysis

5. Applications of Smart Agriculture System

Precision farming, animal monitoring, and greenhouse monitoring are a few agricultural businesses utilizing the Internet of Things. Every element of traditional farming operation may be substantially improved by combining cutting-edge sensors and Internet of Things technology. At the moment, the Internet of Things' (IoT's) and wireless sensors' harmonious incorporation into smart agriculture can catapult agriculture to formerly inconceivable heights. Appropriateness of land, pest monitoring and control, irrigation, and yield optimization are just a few of the conventional agricultural issues that IoT may assist in resolving through the implementation of smart agriculture approaches. Figure 2 illustrates the comprehensive paradigm of smart agricultural monitoring system applications, facilities, and sensors. Agriculture applications are classified as IoT agricultural apps, smart phone-based agricultural apps, and sensor-based agricultural apps. Wireless sensor networks (WSNs) have recently been used to enable IoT applications for smart agriculture, including irrigation sensor networks, frost event prediction, precision agriculture and soil farming, smart farming, and unsighted object recognition, among others. Significant instances of how new technology assists in the general improvement of efficiency at various stages are included here.

Monitoring of Soil Moisture and Water Levels- Soil monitoring has developed into one of the most challenging agricultural areas, both for manufacturers and farmers. Numerous environmental issues associated with soil monitoring affect agricultural yield. When these sorts of obstacles are correctly identified, farming patterns and methods become readily understandable. The soil's moisture content, wetness, fertilizer application, and temperature trends are all being monitored. Soil's moisture environment management system uses soil humidity and moisture sensors.

System of Irrigation Monitoring- Numerous studies have been conducted on a smart irrigation system. Food production technology must significantly improve to keep up with the growing demand for food. Numerous experts have worked diligently to create an alternative to irrigated farming. These efforts, however, have not yet resulted in a feasible solution to the irrigation system's present problems. At the moment, crop irrigation is carried out manually and by established customary practices. When crops are given less water, they grow slower and absorb less calcium. Frequent irrigation kills roots and wastes water. As a result, accurate irrigation of crops becomes a considerable difficulty [13].

Figure 2: General paradigm of smart agriculture

Fertilizer Administration- An IOT-based technique yields using backpropagation and a random forest algorithm. It recommends fertilizer application rates and exclusively monitors atmospheric data via a mobile network and pump on/off action. The suggested technique utilizes a segmented tank to collect NPK fertilizer and water. The user can select one of three modes (manual, auto, or smart

Crop Diseases and Pest Control- Human operators frequently monitor insect pests via time-consuming and costly onsite inspections, which results in low spatial and temporal resolution. Remote monitoring has been possible due to advancements in remote sensing, electronics, and informatics. Monitoring costs and effectiveness can be optimized through the deployment of camera equipped traps. With minimum human intervention, image analysis algorithms can locate and count insect pests captured in traps automatically.

Yield Monitoring, Forecasting and Harvesting- The AWS IoT platform has been proposed for crop prediction using temperature and rainfall monitoring. The Raspberry Pi is utilized as a gateway for remote monitoring in this study. Raspberry Pi can connect with sensors to operate applications, such as the DHT11 Temperature Sensor and Soil Moisture Sensor, which forecasts temperature and rainfall ranges.

Climate Conditions Monitoring- In farming, the weather is extremely important. Incorrect climate knowledge can have an impact on crop quality and quantity. On the other hand, farmers may use IoT solutions to put sensors in the field, including humidity sensors, temperature sensors, rainfall sensors, and water level sensors, to collect real-time data from the environment. These sensors monitor the state of crops and the environment in which they grow. If a worrying environmental situation is discovered,

6. Challenges for Pest Detection through IOT-Filled Devices

The challenges that remote devices for pest detection in the field may encounter include high power consumption, network issues, inadequate security, service expiration, physical hardware defects, software failure, and changes in ambient conditions, as demonstrated in Table 2. The origin of a particular challenge on a device may change occasionally and depend on the design of that device. If necessary, the suitable operating IoT device installed on-site should be characterized by high performance with minor faults. In the process of avoiding drawbacks for field devices,

Table 2: Challenges of IoT field devices, sources, and proposed solutions

Solution	Source	Solution
Power consumption	High-power requirements of networking devices, micro-controllers, and embedded computers	- Scheduling tasks, creating intelligent software with the fewest computations possible, and making idle mode. - Low data rates may be achieved with good energy economy when short-range communication is used at transmission distances of less than 20 m [59] - Based on the installation site and operation goal, IoT sensor nodes can be set up as reduced-function gadgets that only talk to full-function devices.
Failure to execute software	Limitation of software and poor processing power in case of rapid data processing over wide range of sensor data sources	Comprehensive software testing before deploying
Service expiry fault	Applications failing because of expired or terminated cloud services	Payment renewal of application services such as internet bundle and app services should be configured to the automatic payment mode

Network faults	Network breakdowns, packet loss or corruption, congestion, or a problem with the destination node and connection issues that result in lost or incorrectly sent data	- The design should include fault tolerance - The design should include retrying failed packages and real-time reporting
Security	Security for devices and data privacy	- Access control, authentication, and authorization techniques - Make data encryption before transmission
Physical faults of hardware	Issues with sensors, processors, memory, storage, and power supply	The device should be calibrated and undergo robustness testing before deployment
Data cost	High cost of transmitting images	Reduce the frequency of sending images
Changes in environmental conditions	Extreme weather conditions such as rain, extremely hot or low temperatures, wind, and other extreme situations	Add weather check sensors and modules

7. Conclusions

In conclusion, this detailed survey on smart agriculture pest controlling systems highlights the significant progresses made in integrating technology to revolutionize pest management practices in farming. The synthesis of existing research and commercial applications underscores the diverse array of technologies and methodologies employed, ranging from sensor-based monitoring to advanced data analytics and precision application techniques. The integration of Internet of Things (IoT), machine learning, and remote sensing techniques has enabled more efficient and targeted pest control strategies, leading to improved crop yield, reduced environmental impact, and enhanced sustainability in agriculture. Moreover, fostering collaboration among stakeholders, including researchers, farmers, industry partners, and policymakers, will be essential to drive innovation and facilitate knowledge exchange in this rapidly evolving field. Looking forward, the insights gleaned from this survey provide a foundation for future research directions and technological advancements in smart agriculture pest controlling systems. By leveraging the transformative potential of technology, we can continue to enhance the resilience, productivity, and sustainability of agriculture, thereby contributing to global food security and environmental stewardship.

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