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Monitoring with IoT for increasing agriculture yields

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ABSTRACT

The agricultural sector today is more data-driven, accurate, and intelligent than it has ever been. This contrasts with how some individuals might view the farming process. The quick development of Internet of Things (IoT)-based technology led to the rebuilding of nearly every industry, including "smart agriculture," which moved away from statistical methods and toward quantitative ones. The numerous agricultural practices currently in use are being upended by these revolutionary changes, which also present a number of challenges as well as new opportunities. This article explores the potential of wireless sensors and the Internet of Things (IoT) in the context of agriculture, as well as the challenges that are expected to arise when incorporating this technology with traditional farming practices. In this work, we do a thorough review of wireless sensor-connected Internet of Things devices and communication techniques utilized in agricultural applications. The several sensors that can be used in agriculture, such as those for soil preparation, crop condition, irrigation, insect detection, and other purposes, are listed below. The description of how this technology helps farmers at every stage of agricultural production, from planting to harvesting, packing, and shipping. In addition to other beneficial uses like increasing crop productivity, this article also discusses the use of unmanned aerial vehicles for crop surveillance. Furthermore, innovative Internet of Things (IoT) platforms and architectures used in agriculture are highlighted when suitable. We finish by emphasizing potential research issues and identifying current and future trends of the Internet of Things (IoT) in agriculture based on this thorough evaluation. The Internet of Things (IoT) is a promising technology that is trying to modernize many different fields and provides dependable and effective solutions.
Keywords: Data, Internet of Things, intergrating, sensors, surveillance

1. INTRODUCTION

The rapid advancement of the Internet of Things (IoT) has significantly transformed traditional agricultural practices into smart, data-driven systems. IoT-based solutions are increasingly being deployed to automate farm operations, reduce human intervention, and improve productivity. These systems integrate sensors, communication networks, and intelligent analytics to continuously monitor agricultural environments and make real-time decisions. As a result, farmers can optimize resource usage, enhance crop yield, and reduce operational costs.

At the core of IoT-based smart farming are several essential components, including sensors, actuators, communication networks, cloud platforms, and data analytics tools. Sensors are used to collect real-time data related to soil moisture, temperature, humidity, light intensity, and crop health. This data is transmitted through communication technologies such as Wi-Fi, Zigbee, LoRaWAN, or cellular networks. The architecture of IoT systems typically follows a layered approach, including perception (data collection), network (data transmission), and application (data processing and decision-making) layers. Various network topologies, such as star, mesh, and hybrid structures, are implemented depending on the scale and requirements of the farm.

In addition to networking, IoT-based agriculture is closely integrated with advanced technologies such as Cloud Computing and Big Data Analytics. Cloud platforms provide scalable storage and processing capabilities, enabling farmers to access and analyze large volumes of agricultural data from anywhere. Big data analytics further enhances decision-making by identifying patterns, predicting crop diseases, and optimizing irrigation schedules. These technologies collectively enable precision agriculture, where inputs like water, fertilizers, and pesticides are applied in optimal quantities and at the right time.

Security remains a critical concern in IoT-based agriculture systems. Since these systems rely on interconnected devices and cloud platforms, they are vulnerable to cyber threats such as unauthorized access, data breaches, and device manipulation. Ensuring secure communication protocols, data encryption, and authentication mechanisms is essential to safeguard sensitive agricultural data and maintain system reliability.

IoT applications in agriculture are diverse and continue to expand. Smartphone-based applications allow farmers to remotely monitor farm conditions, receive alerts, and control irrigation systems. Sensor-based systems automate tasks such as soil moisture monitoring, pest detection, and climate control in greenhouses. Technologies like automated spraying, bird and animal deterrence systems, smart irrigation, and weed detection further enhance farm efficiency. These solutions contribute to sustainable agriculture by reducing waste, conserving resources, and minimizing environmental impact.

The concept of “smart” systems extends beyond agriculture to various domains such as smart homes, smart cities, smart energy, and smart grids. In agriculture, “smart” refers to the ability of systems to sense environmental conditions, communicate data, and make intelligent decisions autonomously. These systems rely on interconnected physical devices embedded with sensors and software, forming a global infrastructure that enables seamless data exchange and control. Governments and organizations worldwide are also recognizing the importance of IoT in agriculture and are developing policies and standards to promote its adoption. Several successful implementations demonstrate the potential of IoT in improving crop yield, reducing water consumption, and enhancing farm management practices. However, despite these advancements, there are still open research challenges, including interoperability of devices, energy efficiency, scalability, cost of deployment, and data privacy concerns. IoT-based smart agriculture represents a transformative approach to modern farming. By leveraging connected technologies, data analytics, and automation, it enables precise, efficient, and sustainable agricultural practices. As research and innovation continue to evolve, IoT is expected to play a crucial role in addressing global food security challenges and supporting the development of intelligent farming ecosystems.

2. LITERATURE SURVEY

Nikesh Gondchawar and his colleagues came up with the idea for the work that will be done on smart agriculture that is based on the Internet of Things [1]. Through the implementation of automation and Internet of Things technologies, the objective of this essay is to enhance the intelligence of agricultural practices. The tasks, which include weeding, spraying, and monitoring moisture levels, will be carried out by a robot that is operated remotely and is outfitted with a sophisticated global positioning system-based system. The intelligent management of warehouses, intelligent irrigation with intelligent control, and intelligent decision making based on exact real-time field data are all components that are included in this system. It is accountable for the monitoring of the temperature and humidity levels within the warehouse, as well as the detection of any instances of theft that may occur. The integration of sensors, ZigBee modules, cameras, and actuators with a microcontroller and a raspberry pi will allow for the management of all of the operations to be carried out by a smart device. This will be performed through the integration of these components. Through the employment of raspberry pi and wireless communication, an interface has been successfully formed between all of the sensors and microcontrollers as well as through the three nodes. In this study, information is presented regarding field activities, irrigation problems, and storage problems that are addressed through the utilization of remote controlled robots for smart irrigation systems and smart warehouse management systems, respectively. Other problems that are addressed include storage problems and problems with irrigation.

A description was provided by Rajalakshmi P. et al. [2] regarding the monitoring of the crop field through the employment of soil moisture sensors, temperature and humidity sensors, light sensors, and an automated irrigation system. This was done in order to ensure that the crop field functions properly. The information gathered from the sensors is sent to the web server by wireless transmission. The JSON format is applied for the encoding of the data in order to ensure that the server database is always up to date. When the temperature of the agricultural field and the amount of moisture present in the field both fall below the essential level, the irrigation system will be allowed to operate automatically. Additionally, the messages are sent to the mobile devices of the farmers on a consistent basis, which enables them to monitor the conditions of the field from any area they may be in. There are a number of characteristics that are utilized in this scenario. These include a soil moisture sensor, a temperature and humidity sensor (DHT11), an LDR that is utilized as a light sensor, and a web server (NRF24L01) that functions as both a transmitter and a receiver. This method is 92% more effective than the conventional approach, which indicates that it will be more useful in areas where there is a limited supply of water. Automating the process of storing data from the irrigation system in the MySQL database was accomplished through the utilization of the PHP script. The evaluation of water requirements and a single motor pump leads to a total average power consumption of two amperes per day from the water supply.

Tanmay Baranwal and his colleagues have stated that the primary objective of this research is to guarantee the security and protection of agricultural products by preventing them from being attacked by rodents or insects in the fields or grain storage facilities located in the area. In the event that an issue is discovered, the utilization of security systems makes it possible to provide notifications in real time. Python scripts are applied for the aim of integrating electronic devices and sensors into a system. The algorithm is constructed on the basis of the information that is gathered in order to fulfill the aim of presenting the user with accurate notification and activating the repeller. In the course of the testing procedure, the apparatus is positioned in the corner of a room that is 10 square meters in size. The PIR sensor is responsible for detecting heat, which subsequently triggers the activation of the URD sensor and the webcam. Eighty-four point eight percent of the test scenarios that were attempted were successful, as indicated by the report. It will be helpful to extend the security system in order to prevent rodents from entering grain storage facilities with the intention of preventing their entry.

The aforementioned paper [4] written by Nelson Sales and his colleagues offers a comprehensive summary of wireless sensor networks. The network is accountable for three nodes, which are the acquisition, collecting, and analysis of data. These nodes include the measurement of temperature and soil moisture, in addition to other information of a similar nature. The practice of irrigation in agriculture provides a number of benefits, including a reduction in the amount of water that is used and favorable effects on the environment. When it comes to the Wireless Sensor and Actuator Network, cloud computing is an intriguing alternative since it provides high storage and processing capabilities for enormous volumes of data. This makes it an attractive option. The fields of agriculture, greenhouses, golf courses, and landscaping are going to be the primary areas of concentration for this endeavor. There are three key components that make up the architecture. These components are a user application component, a cloud platform component, and a WSAN component. Specifically, this particular system contains three separate types of nodes: a sink node, a sensor node, and an actuator node. Each of these nodes is responsible for a specific function. SimplitiTI is a simplified protocol for the implementation of WSAN. It accomplishes this by employing a cluster tree topology. In order to discover which plants require water in order to develop properly and make the most of the natural resources that are available, this examines the moisture level of the soil before determining which plants require water.

With regard to their study, Mohammed Rawidean Mohd Kassim and his colleagues [5] provide a description of a Precision Agriculture (PA). A wireless sensor network (WSN) is the most efficient solution for agricultural problems such as optimizing farming resources, giving support for decision making, and monitoring land. These are all examples of agricultural challenges. Using this technology provides farmers with information about the lands and crops in real time, which will assist them in making decisions that are in their best interests. This information will help farmers make optimal decisions. Precision agricultural systems that are based on the Internet of Things (IoT) technology provide an explanation of the hardware architecture, network architecture, and software process control of the precision irrigation system. This explanation is provided by the systems. Within the context of a feedback loop, the software collects data from the sensors, and then, based on that data, it activates the control devices so that they can function in accordance with the threshold value. Additionally, the application of WSN in Pennsylvania maximizes the output of crops while simultaneously maximizing the consumption of water and fertilizer through irrigation. This is accomplished through the use of water and fertilizer. • This study by LIU Dan et al. [6] examines greenhouse technology in agriculture. It shows the design and execution of the technology based on ZigBee technology and makes use of the CC2530 chip. (6) [6] It is the use of this technology that is known as greenhouse technology. The principal application for it is as a system for observation of the surrounding environment. In order to accomplish the tasks of data collection, data processing, data transmission, and data receiving, the wireless sensor and control nodes make use of the core technology known as CC2530F256. Under these conditions, the computer provides the person who is concerned with all of the real-time data through wireless communication. This includes the temperature control and the state of the fans, among other things. In this system, emissions of greenhouse gases are monitored and regulated by the utilization of sophisticated technology. The planting of crops on farms in a manner that is both scientific and balanced is useful when it comes to farms.

3. PROPOSED WORK

The proposed model for smart agriculture aims to develop a real-time monitoring and decision support system that enhances farm productivity and sustainability. This system continuously observes critical soil parameters such as temperature, moisture, and pH, enabling farmers to make informed decisions. In addition to environmental monitoring, the model integrates intelligent advisory mechanisms for pest and disease forewarning, as well as crop disease identification using image analysis. Alerts and recommendations are delivered to farmers through SMS notifications, ensuring timely action even in remote areas.

A key advantage of this system is its ability to provide remote access and control. Farmers can monitor and manage field operations from anywhere at any time using mobile or web-based applications. This significantly reduces the need for constant physical presence in the field and improves operational efficiency. The integration of sensing, communication, and control technologies makes the system highly adaptive and responsive to changing agricultural conditions.

A. System Architecture

The proposed system is structured into three major modules:

- Farm Side Module
- Server Side Module
- Client Side Module

B. Farm Side Module Functions

The farm-side module is responsible for field-level operations and consists of the following six key functions:

Sensing Local Agricultural Parameters

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Various sensors are deployed in the field to measure environmental and soil conditions such as temperature, moisture, humidity, and pH levels. These parameters are essential for understanding crop health and soil quality.

Identification of Sensor Location and Data Collection

Each sensor node is associated with a specific location in the field. This enables precise data collection and location-based analysis, which is crucial for precision agriculture.

Data Transmission for Decision Making

The collected data is transmitted through IoT communication technologies to a central system for further processing and analysis.

Decision Support and Early Warning System

The system analyzes real-time and historical data using intelligent models. It provides early warnings related to pest attacks, diseases, or unfavorable environmental conditions, helping farmers take preventive measures.

Actuation and Control

Based on the decisions generated, automated actions such as irrigation control, spraying, or environmental adjustments are performed. This reduces manual effort and ensures timely intervention.

Crop Monitoring via Camera Module

A camera module is used to capture images of crops for visual inspection. These images are analyzed to detect diseases and monitor crop growth using image processing techniques.

C. Role of ICT in Smart Agriculture

The proposed model is strongly integrated with Information and Communication Technology (ICT), which plays a vital role in modernizing agricultural practices. Agriculture has traditionally relied on experience and repetitive practices; however, factors such as climate change, soil degradation, and pest outbreaks have introduced significant variability. ICT enables the collection, processing, and dissemination of updated agricultural information, allowing farmers to adapt to these changes effectively. Through this system, farmers receive localized and real-time insights, which are essential because agricultural conditions vary significantly across regions. Providing accurate, location-specific recommendations remains a challenging task, but the integration of IoT and ICT helps address this issue by delivering precise and actionable information.

D. Significance of the Proposed Model

The combination of real-time monitoring and historical data analysis enables efficient resource management, including optimized water usage, reduced chemical inputs, and improved crop yield. By leveraging technologies such as the Internet of Things, cloud computing, and intelligent analytics, the system supports sustainable farming practices. Overall, the proposed smart agriculture model offers a comprehensive solution for modern farming challenges. It empowers farmers with timely information, automated control, and advanced decision support, ultimately contributing to increased productivity, reduced risks, and sustainable agricultural development.

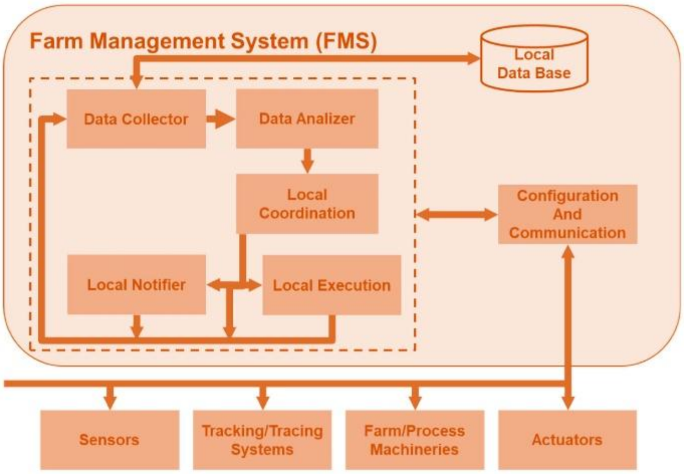

Figure 1. Structural flow of the system

4. EXPECTED OUTCOMES

The proposed smart agriculture system is expected to significantly enhance the efficiency, productivity, and sustainability of farming practices. By continuously monitoring soil parameters such as temperature, moisture, and pH, the system will provide accurate and real-time insights into field conditions. This enables farmers to make informed decisions regarding irrigation, fertilization, and crop management, ultimately improving crop yield and quality. The integration of intelligent advisory models for pest and disease forewarning is also expected to reduce crop losses by enabling early detection and timely intervention.

Furthermore, the use of image-based crop disease identification will improve diagnostic accuracy and minimize reliance on manual inspection. The SMS-based alert mechanism ensures that farmers receive critical updates even in areas with limited internet connectivity, making the system practical and accessible. Remote monitoring and control through mobile and web applications will reduce the need for physical presence in the field, saving time and labor while increasing operational convenience.

The system is also expected to optimize resource utilization by automating actions such as irrigation and environmental control based on real-time data analysis. This will lead to efficient use of water, fertilizers, and pesticides, contributing to cost reduction and environmental sustainability. In addition, the availability of both real-time and historical data will support better planning and long-term decision-making, helping farmers adapt to changing environmental conditions.

Overall, the proposed model, supported by technologies like the Internet of Things and Information and Communication Technology, is expected to deliver a smart, automated, and scalable agricultural solution. It will empower farmers with precise, location-specific knowledge, improve farm management practices, and contribute toward achieving sustainable and modern agriculture.

5. CONCLUSION

The proposed smart agriculture system presents an integrated and intelligent approach to modern farming by combining real-time monitoring, automation, and decision support mechanisms. By continuously tracking essential soil parameters such as temperature, moisture, and pH, the system enables precise and data-driven agricultural practices. The inclusion of pest and disease forewarning models, along with image-based crop disease identification, enhances the ability of farmers to take timely and effective actions, thereby reducing crop losses and improving overall productivity. The architecture, consisting of farm side, server side, and client side modules, ensures seamless data collection, processing, and user interaction. Remote monitoring and control through mobile and web applications provide flexibility and convenience, allowing farmers to manage their fields efficiently from any location. Additionally, features such as SMS-based alerts make the system accessible even in areas with limited internet connectivity. The integration of advanced technologies like the Internet of Things and Information and Communication Technology plays a crucial role in transforming traditional agriculture into a smart and sustainable system. This approach not only optimizes the use of resources such as water and fertilizers but also supports environmentally friendly farming practices. In conclusion, the proposed model offers a comprehensive solution to the challenges faced in agriculture by improving efficiency, reducing manual effort, and enabling informed decision-making. It has strong potential to contribute toward sustainable agricultural development and can be further enhanced by incorporating advanced analytics, machine learning, and scalable cloud-based solutions in future implementations.

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