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Agricultural Internet of Things (AIoT) for Intelligent Farming

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Abstract

Agriculture is essential to humanity's existence. Many methods have been explored to boost agricultural yield. Conversely, bad weather and frequent insect infestations reduce agricultural production. Integrating modern technologies like sensors, The Internet of Things (IoT) brings intelligent farming to agriculture. This uses sensors, technological advances, and data analysis to maximize agricultural yields, resource utilization, and sustainability. This innovative method enables farmers to immediately monitor soil quality, weather, and crop status to make educated choices. Smart farming using IoT technology may improve operational efficiency, food security, and conventional farming practices in a changing agricultural ecosystem. Global studies has shown the need of employing IoT intelligent sensors to monitor moisture, temperature, humidity, and the soil's composition for crop development. Additionally, computerized sensors monitor greenhouse gases including methane, carbon dioxide, and others. Smart farming also monitors soil nitrogen levels, helping farmers estimate fertilizer needs. IoT gadgets like UAVs help monitor agricultural pests and illnesses. Smart farming has drawbacks despite its potential. Big implementation costs, data security concerns, and farmers' lack of digital literacy are the restrictions. If economic tactics, encryption, and technology are used, the IoT might ease smart farming.

Keywords: Intelligent farming, IoT, Sensors, Crop analysis, Monitoring.

Introduction

Technology enhances agricultural output and efficiency in the practice of precision agriculture. Artificial Intelligence (AI) represents technological advancements that are rapid in modern times. AI has found many applications in areas such as the advancement of robots and the monitoring of environmental conditions. AI technology has wide-ranging applications in several fields such as healthcare, autonomous vehicles, imagery from satellites, topography mapping, environmental monitoring, and healthcare systems [1]. The use of AI has resulted in significant progress in the development of robots on a global scale, leading to the simplification of daily tasks and enhancing overall quality of life. AI-facilitated automation in several sectors, such as agriculture, would provide superior-quality products while minimizing environmental impact.

The IoT[2-3] is a significant catalyst for this transformation. The IoT facilitates the connection of items and organizations to the internet, enabling the collection and analysis of data to enhance decision-making. Artificial intelligence technology has the potential to enhance several fields such as health devices, driverless automobiles, satellite images, terrain visualization, climate change monitoring, and health services. The progress of AI has expedited the proliferation of robots worldwide, resulting in a streamlined and much-enhanced standard of living. The use of AI in many sectors, such as agriculture, will lead to the automation of processes, resulting in the creation of superior-quality products while minimizing negative impacts on the environment. By using a diverse array of advanced sensors, artificial intelligence can analyze data in real time with enhanced accuracy. Artificial intelligence has greatly enhanced the efficiency of several technologies, leading to more accurate and refined outcomes. The IoT is an advanced technology that emerged from the integration of AI with intelligence sensors. The IoT acts as a central point for wireless systems, while AI rapidly analyzes data and generates appropriate outcomes. This technique is widely used in almost all areas of scientific research and exploration. Digital technologies built around the Internet of Things have the potential to create innovative models that may enhance the manufacturing of goods for consumers, including agricultural products. Agriculture is a crucial component of human civilization. Over time, there have been enhancements made to increase agricultural productivity. Furthermore, contemporary technologies have been utilized in the domains of agriculture, gardening, and forestry to enhance the surveillance of plant growth, diseases, and the prevalence of harmful pests. AI as well as IoT are both finding growing uses in agriculture. These technologies may assist in solving various issues, including identifying the optimal time for harvesting, detecting pests, and assessing soil conditions [4]. AI and the IoT provide significant prospects for instant monitoring of many elements, such as humidity, temperature, pollution, water levels, soil condition, radiation, and more. Smart farming enhances precision by streamlining the management of agricultural activities and allowing prompt decision-making using collected data [5]. The use of the IoT has the potential to not only save farmers' earnings but also cut down on the amount of resources that are wasted. The IoT and smart sensors may also be combined with a wide range of already existing equipment, which has the potential to significantly improve agricultural productivity by making it easier to accurately diagnose illnesses that affect crops. Precision farming utilizes IoT technologies to monitor agricultural components. The IoT provides real-time data related to the status of the crop, the environment, and the soil. This data is used to enhance environmental conservation and guarantee the ongoing sustainability of agricultural productivity. There is the possibility of transforming irrigation into an intelligent irrigation system, that would greatly accelerate the irrigation process within a short timeframe. In order to efficiently collect vital data on important agricultural factors such as insect infestation, soil condition, and water availability across a large region within a limited timeframe, UAVs, or unmanned aerial vehicles, are used [6].

The Farm management system is an integrated strategy that combines AI as well as IoT to ensure efficient coordination. To improve the quantity as well as the quality of agricultural production, a more sophisticated tracing system may be used to evaluate various physical, chemical, and biological aspects related to agriculture. It is more labor-efficient and employs real-time data processing capabilities. Due to this, the System can aid in the conservation of both the excellence and the durability of agricultural goods while necessitating less effort and time. An IoT-enabled automated decision-making system can significantly reduce human intervention in agricultural field management. The decision-making system [7] is the core component of every accessory that may be responsible for the efficacy or lack thereof of the AI algorithm. The combination of IoT and IT can surpass decisions made by humans in terms of accuracy and data processing. AI, or artificial intelligence, is a system that can do tasks similar to human intellect, such as recognizing voices, seeing pictures, making judgments, and processing data automatically.

Intelligent sensors are used to precisely monitor many physicochemical characteristics in agricultural fields, such as relative humidity, water and temperature contents, fertilizer contents, quality of soil, and concentrations of greenhouse gases. Additionally, a lecture will be delivered about the ramifications of intelligent traps equipped with high-resolution cameras. The deployment of devices based on the IoT will be extensive, and the last section of the article will focus on the current obstacles being encountered and the possible remedies for these concerns.

Data Collection from Intelligent Sensors:

Due to significant progress in technology, semiconductor production, and technology for communication, a new type of sensor called "smart" sensors has been developed. These sensors[8] are considered state-of-the-art as they can wirelessly communicate from a remote location. They can interact and connect with other devices via a computerized data processing network. Hence, "intelligent" sensors are very effective at detecting patterns and relationships in unprocessed data, as well as establishing causal connections among various parameters. However, later iterations of networked sensors were improved by including intelligence to do computations in addition to collecting data. Previous iterations of sensor networks were limited to sensing capabilities, however subsequent versions included advanced intelligence. The internal structure of an intelligent sensor consists of essential components including a micro controller, a digital-to-analog converter, an electronic communication link, memories, and a power supply. These components may consist of one or more sensors. A smart sensor node is composed of three essential components: a physical transducer, a storage core or CPU, and a network interface. The functioning of the node relies on these three basic components. An electrical signal is produced when the physical transducer detects the physical features, which are then converted into an electrical signal. The ADC facilitates the generation of digital information that may be utilized by the processor. The microcontroller, often serving as the processor, is responsible for performing signal processing operations on the detected data and transmitting the created data to the network. Enhancing the efficiency of satellite imaging may be achieved by using IoT-linked smart sensors, which possess the capacity to promptly process and evaluate data. Both passive and active sensors may be employed in remote sensing applications to monitor many aspects of agriculture. The IoT enables the use of smart sensors for many applications like as forecasting the weather, soil monitoring, landscape topology analysis, insect manifestation tracking, and soil quality assessment [9]. AI technologies serve as the basis for smart sensors, enhancing the precision of their operations. The implementation of precision agriculture relies on LiDAR-based sensing technology, which offers data that is both highly accurate and instantly available.

Furthermore, it offers fundamental knowledge on the diseases and conditions that impact plants, including drought. The implications of the IoT could be seen in a wide range of occupations, including tasks such as data collection, processing, and analysis. Furthermore, IoT devices have been used to carry out extensive studies on various environmental conditions, such as contamination of water, pollution, soil quality assessment, radiation levels, and numerous other issues. Remote sensing using the IoT entails the use of several devices for processing, detecting, and transmitting signals. These devices are interconnected via a shared cloud, enabling the seamless exchange of data back to the source site. RFID technology is being integrated with sensors to provide sensing capabilities for "smart environment" applications. An RFID system consists of three main components: a reader, an identifying device, as well as an antenna. The recorded data on the tag may be quickly accessed using this technology, which establishes a radio link between the tags and the reader. The current availability of RFID technology, enhanced with sensing components, offers significant potential for remote monitoring of environmental stimuli, including temperature, the humidity [14], as well as other crucial factors for agricultural activities.

Agriculture and IoT:

The IoT, intelligent sensors, especially AI offer great potential to record real-time data and analyze it for monitoring the soil condition, water content, crop quality, and agricultural yield on a specific site [15]. Smart farming, defined by enhanced production, replaces conventional agricultural techniques via IoT and intelligent sensors. The IoT facilitates using agricultural devices to assess crop quality, soil condition, fertilizer needs, soil erosion, and soil fertility. Furthermore, it aids in guaranteeing the integrity of the seeds, offers visual irrigation, and oversees the crop's progress at various growth phases. Utilizing real-time data obtained from remote sensing as well as the IoT is very beneficial for the practice of precision farming and forestry. Several techniques, including infrared thermography and smart sensors, have been created to assess the topological features of agricultural land. IoT and intelligent soil moisture meters are used to evaluate the preharvesting as well as postharvesting conditions of farming areas. Deep learning algorithms are used to evaluate data collected from various sensors. Connected sensors using IoT, ZigBee, and Arduino can potentially be used to precisely assess humidity, temperature, quality of soil, and crop types in a specific area [16]. Hence, the IoT can analyze data to anticipate and prepare for a rise in farming and crop output. Smart farming relies on the integration of the IoT with UAVs, or unmanned aerial vehicles, to achieve increased productivity with less human involvement.

The global interest in the development and implementation of microprocessors is driven by the goal of automation and intelligently managing the activities of the IoT. By using satellites and GPS systems, it is possible to get crucial data that enables precise and immediate tracking of field cultivation, water availability, and fertilizer needs in several developed countries. This monitoring is conducted in several nations. The integration of the agricultural IoT as well as expert systems has the capacity to aid farmers in enhancing their planting and crop management methodologies [17]. Currently, much of the technology that is being created and utilized is focused on gathering data on agriculture and crop output, monitoring environmental conditions, and tracking animal movements. The developments in the field of electromagnetic sensors, biosensors, and physical attribute sensors are very important for the agricultural industry. Biological[18] sensors can detect components that are dependent on biological factors in the external environment, while physical asset sensors use devices that are responsive to alterations in the physical surroundings.

Given the increasing scarcity of water in the contemporary world, careful consumption of water is very significant. The Smart Irrigation Decision Support System represents an innovative method that has shown considerable potential in efficiently controlling water resources in agricultural areas. Two distinct machine-learning techniques have been proposed to achieve system. The methods [19] used include the use of partial least squares regression in conjunction with a system for adaptive neuro-fuzzy inference. The efficacy of this technique has been shown by its implementation on three prominent citrus tree farms situated in Spain. The primary characteristic of the system is its use of continuous soil measurements to supplement climatic data, resulting in precise predictions of crop watering needs [20]. This stands in contrast to earlier studies that focus just on meteorological variables or fail to indicate the specific water needs of the crops.

Farming monitoring system with IoT:

The integration of the IoT into the soil, the microclimate, as well as crop sensing, has brought about a significant shift in the way agricultural monitoring is conducted. In the past, monitoring crops was a subjective task that depended on specialized knowledge. Currently, crop monitoring involves the use of quantitative methods and relies on data analysis. The IoT enables technology enables farmers to precisely monitor the condition and growth of their crops [5]. Another advantage it offers to agricultural workers is the capability to monitor insect infestations and plant diseases in real time. The use of IoT-tagged devices for real-time data collecting and processing provides a valuable advantage to farmers and researchers in effectively managing crop cultivation, and applying fertilizer, irrigation, and plant surroundings [21]. Sensors put in the field are the primary element of IoT-driven intelligent agricultural monitoring systems. These sensors gather data on various environmental conditions. The characteristics include humidity, soil moisture, temperature, and nutrient levels. These sensors are often interconnected over a network, allowing real-time data transmission to centralized cloud storage. Subsequently, the data collected from the sensors is subjected to machine learning as well as multiple additional data analytics techniques to provide valuable insights on the crop's health, growth rates, and potential yield. Farmers may use the information provided here to make informed choices on crop management, including gathering, controlling pests, and irrigation. Wireless technology may be used to alert administration and farmers about equipment malfunctions and initiate the process of resolving the problem. Furthermore, a computerized repair tool can aid in the decrease of energy use, the speeding up of processing of data, and the enhancement of actuation. The agriculture industry is increasingly using unmanned aerial vehicles that are enabled by the IoT. These technologies allow farmers to get real-time landscape photography, while also supporting a smooth workflow for analyzing and conserving data. In addition, IoT systems are effective in monitoring various agricultural environmental factors, including plant morphology, air temperature, light intensity, soil moisture content, humidity, carbon dioxide concentration, pH values, and water utilization efficiency in crops.

In 2019, Abba et al. conducted a performance evaluation of a Smart IoT-based water monitoring and control system. The findings of the assessment were deemed satisfactory. The choice of loamy as well as sandy soils was made by their prevalence and suitability for agricultural practices requiring autonomous irrigation.

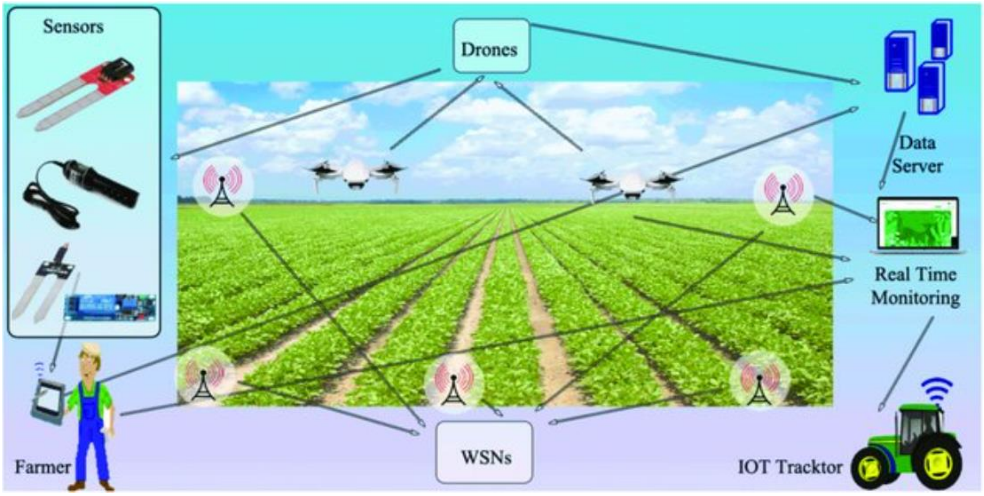

Figure 1:Integrating the IoT and smart sensors in precision farming

The system counting was calibrated to an interval of 0 to 300, and various moisture values were recorded using several counter configurations. Due to the application of irrigation, it was observed that the soil exhibited a reduced rate of water absorption. It is noteworthy because, at a certain point, it also contained water, causing the water pump to repeatedly shut off. The study showed that the IoT-based smart watering monitoring and management system effectively operates during the irrigation of farms with loamy soil. Furthermore, the irrigation pump was deactivated once the moisture level surpassed 400% [23], leading to a decrease in electricity expenses.

The IoT has become more popular for detecting various meteorological attributes, such as humidity, temperature, and soil moisture. The IoT provides real-time data on the environmental conditions in vineyards and wineries, allowing for more effective agricultural operations via the use of WiFi networks and smart sensors [25]. The IoT, when connected to sensors, will autonomously send a notification to the administrator if there is a significant deviation in the essential environmental parameters over the predefined limit. This will enable the administrator to undertake the necessary measures to address the imminent difficulties. IoT devices with advanced sensors are increasingly being used in cucumber farming to identify cryogenic dangers and monitor surroundings in real time. This method utilizes IoTsensors to identify temperature levels. When the temperature falls below a pre-established threshold, an alert message is promptly sent to the administrator. This gives the supervisor the capability to activate heating equipment with the purpose of safeguarding plants from cold shock. One may also integrate the IoT with external weather forecasting services to get forecasts on future weather conditions and proactively take measures to mitigate any adverse climate changes.

By integrating IoT technology with sophisticated sensors, it becomes feasible to monitor several aspects of agricultural soil that are crucial for the growth and progress of plants. The IoT can sense and measure the amount of moisture, temperature, and nutrient levels in the soil, and then transmit this data to farmers [26]. Farmers may remotely calibrate and retrieve this data, enabling them to effectively safeguard crops against diseases and pests. Implementing intelligent agriculture methods may provide benefits for farmers. By integrating IoT technology with sophisticated sensors, it becomes feasible to monitor several aspects of agricultural soil that are crucial for the growth and progress of plants. The IoT can sense and measure the amount of moisture, temperature, and nutrient levels in the soil, and then transmit this data to farmers. Farmers may remotely calibrate and retrieve this data, enabling them to effectively safeguard crops against diseases and pests. Implementing intelligent agriculture methods may provide benefits for farmers [27].

Advanced agricultural sensors for future applications :

The usage of numerous sensors is revealing potential implications for the advancement of smart farming. These sensors may potentially aid in the automatic harvest of crops, the surveillance of the external environment, and the quantification of yields of crops for agricultural reasons. Smart sensors are a kind of sensor that has been integrated with semiconductors, known as smart sensors. Intelligent sensors may be used in agricultural settings to automatically collect various data relating to environmental conditions and other agricultural information. This data can then be stored in drives. Microprocessors enable the computation of this data to simplify its interpretation and analysis. Intelligent sensors play a crucial role in the IoT, facilitating the interchange of data across the internet.

The system comprises a network of wireless devices and actuators, which may range from a small number to a large number of nodes connected to specific sensor hubs. A smart sensor consists of a sensing device, microprocessors, and wireless communication technology. These components enable remote monitoring of several agricultural factors. To enhance the functionality of smart sensors, it is possible to integrate them with supplementary components, such as amplifiers, and transducers, which are analog into digital converters and filters.

Challenges

Global research on the IoT and sensor-based smart farming have consistently shown favorable outcomes. IoT technology has been used in some minor agricultural regions. However, the execution of the identical project on a large scale has not been finished as of now. The financial cost associated with deploying and installing IoT sensors and accessories over a large agricultural region is a major impediment that has emerged throughout this process. Furthermore, there is an absence of assurance about the correlation between the level of profitability achieved and the expenses associated with the implementation process. The expenses related to acquiring hardware, installing software, and managing the system are all substantial expenditures connected with the implementation of IoT-enabled technologies. Additional charges will be incurred for energy consumption, system maintenance, service registration, and the employment of personnel involved in operating the combined hardware devices and associated software. Efforts must be made to educate farmers worldwide about technology to allow the global adoption of the IoT. The underutilization of smart systems in agriculture may be attributed to a lack of adequate information and literacy regarding the scopes, methods of action, and implementation of IoT technology in farming. The introduction of IoT-connected smart sensors as well as accessories in rural agricultural regions, where farmers have little familiarity with new technology, may provide significant difficulties. Government policymakers must develop economic strategies to ensure that farmers in rural areas can effectively and efficiently utilize the IoT technology on their farmlands.

The adoption of large-scale IoT and automated systems may be impeded by concerns about data privacy and security. Malicious individuals can modify data stored on cloud servers to do damage to automated agricultural operations in farmlands. Assaults on agricultural land may have a detrimental effect on output and insufficient environmental stewardship. The slow acceptance of smart agricultural systems is partly due to worries about the security of IoT data. An imperative encryption solution is essential for safeguarding vital information and digital systems from assaults in the realm of smart farming. Utilizing robust cryptographic algorithms and generating strong encryption keys may effectively mitigate cyber attacks on cloud-based systems. Alternative approaches, such as combining multiparty computation with homomorphic encryption, or blockchain technology, have the potential to provide reliable outcomes. An important concern associated with IoT devices is their frequent placement in outdoor environments. Consequently, they experience a range of harsh weather conditions such as intense precipitation, dust storms, strong winds, extreme temperatures, and more.Unfavorable climatic conditions might cause complicated devices to unexpectedly face mechanical component failures. Therefore, manufacturers of IoT devices for smart agriculture should use raw materials that can endure adverse weather conditions. This will enhance the durability of the sophisticated devices, leading to increased reliability in manufacturing.

Conclusion :

The IoT holds immense promise for the future development of intelligent agriculture. One may use advanced sensors specifically developed to monitor environmental factors such as moisture, temperature, and rainfall to achieve optimal agricultural yield. IoT-enabled devices may be used to monitor the quantity of water and nitrogen in soil. Moreover, it is possible to effectively monitor evapotranspiration rates to enhance the monitoring of crop health, which is contingent upon the levels of CO_2 (carbon dioxide) present in agricultural regions. Additionally, the growth of pests may be managed by using IoT-enabled devices that have been fitted with cameras with excellent resolution and other supplementary components. This may aid in reducing the incidence of pest infestations. The high expenses associated with procuring and upkeeping intricate hardware and software pose significant obstacles to the widespread adoption of IoT-enabled smart sensors in the field of agriculture. However, there are several advantages linked to this implementation. Another concern is that farmers living in rural areas lack sufficient knowledge about their utilization of IoT technologies. Lastly, hackers can disrupt the computerized intelligent farming system by inflicting harm on the cloud servers responsible for storing crucial data.

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