Transforming Smart Agriculture with IoT: A Review of Components, Sensors and Applications

Sangeetha Arumugam [1] , Kalaivani .S [2]

[1] *Assistant Professor, Department of Computer Science, Dr G R Damodaran College of Science (Autonomous), Coimbatore - 641 014.*
[2] *Assistant Professor, Department of Computer Science, Dr G R Damodaran College of Science (Autonomous), Coimbatore - 641 014.*

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Abstract: The present IOT system will be centred on the subject of agriculture's digitization. The rise of several new firms in the agtech sector that focus on innovative digital technologies in agriculture. The need for development employing emerging technologies in the agriculture area will arise due to the high demand for food, the scarcity of natural resources, and the unpredictability of agricultural production. As a result of the global technology revolution, small farmers are becoming familiar with the most recent developments in mobile networks through smartphones and other related technologies. All of these are contributing to the development of new digitally agriculture systems. We know agriculture is the crucial occupation for the rural people and about 70% of the Indian population depends upon agriculture sector for their livelihood. The major challenge faced due to urbanization in agriculture sector are rise in environmental pollution, climate change, degradation of soil and water quality. And these all factor will directly decrease the income from farming industry that will become the reason for mass migration of rural people to cities. The efficiency of the soil, the monitoring of temperature and humidity, the efficacy of fertiliser, the tracking of equipment, the remote monitoring of storehouses, and other aspects may all be observed with the use of IOT-based sensor technology. A lower cost of progress in agriculture will result from the integration of wireless sensor networks (WSN) and the internet of things (IOT). Smart agriculture tools used to find the result from the IOT-based sensors, which include tracking, humidity, moisture, and temperature sensors. This review provides an overview of Smart Agriculture in IoT, exploring its components, applications, sensors, and challenges.

Keywords: Smart Agriculture tools, IoT, WSN Sensors, Irrigation, Agricul.ture.

1. Introduction

Smart agriculture, also known as precision agriculture, leverages advanced technologies to enhance farming practices, ensuring higher productivity and sustainability. It involves the integration of Internet of Things (IoT) devices, big data analytics, artificial intelligence (AI), and other cutting-edge technologies to monitor, manage, and optimize agricultural activities. The objective is to address the growing global demand for food, cope with the challenges posed by climate change, and improve the efficiency of agricultural practices [1].

Since 60% to 70% of India's economy is based on agriculture, agriculture is important to the country's growth in terms of food production. Groundwater is gradually running out due to unplanned consumption. The Internet of Things (IOT) is another significant development in the history of technology. In the future, IOT will be able to feed billions of people on Earth through its significant contribution to agriculture [2]. There is no need to worry about scheduling irrigation according to crop or soil conditions because the entire system is micro control based and can be controlled from a distance via wireless transmission. The nation is made up of a sizable region of agricultural land. Consequently, what is required is a planned out distributed number of sensor nodes and scattered pumping units to use the water efficiently and pump the water to those specific locations covered by the sensor units [3].

A specific data management architecture is required for the purpose of serving as a reference for research in the sector of agriculture, as new technologies are constantly developing and extensive research is being conducted in this area. Additionally, the most important thing is to keep the information straight, thus it should be well managed for agricultural research purposes. Database management software is used to collect data, which is done in a more secure manner than with file-based systems. The primary concept behind the Internet of Things is to link various electronic sensors via a system and gather data from these sensors later on, which can be retrieved in any way. This data can be transferred to any cloud software, allowing an operator to analyse and process the data that has been gathered [4].

Using techniques like emailing or texting people, the operator can use the data from the cloud programme to alert people. Cloud computing software stores a vast amount of meteorological, soil, and agricultural data in order to quickly and accurately derive insights about a given area. Many years later, this recorded material can still be retrieved or reviewed. The data is carefully examined before offering the ideal requirements or necessities for a farm [5].

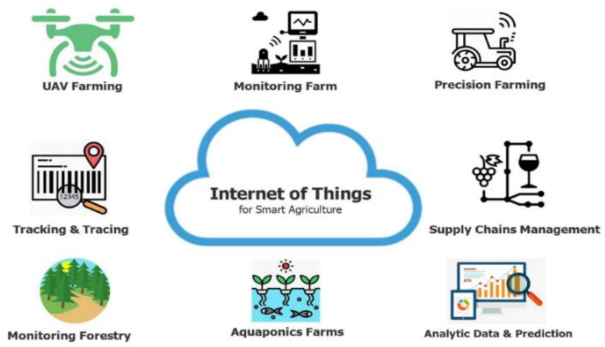

Figure 1: IoT in Smart Agriculture

2. Components of IoT in Smart Agriculture

The components of IoT in smart agriculture involve several key layers and technologies that collectively enhance agricultural efficiency and productivity. Here are the main components.

A. Sensor Nodes and Actuators:

Sensors: These are critical for data collection and include devices that measure soil moisture, temperature, humidity, light intensity, and other environmental parameters. These sensors are often connected to microcontrollers and communicate through wired or wireless networks.

Actuators: These devices perform actions based on data received, such as adjusting irrigation levels, opening greenhouse windows, or activating heating systems [6].

B. Network Layer:

This layer is responsible for data transmission. It employs various communication technologies such as Wi-Fi, Bluetooth, 4G/5G, and specialized IoT communication protocols like LoRa, NB-IoT, and 6LowPAN. The network layer ensures that data collected from sensors reach the processing units and that commands from the control systems are delivered back to the actuators [7].

C. Middleware Layer:

Middleware acts as an interface between IoT devices and applications, managing data aggregation and processing. It hides the complexity of the hardware from the applications, providing a standardized way for software to interact with different types of IoT devices. This layer often utilizes cloud computing, edge computing, and artificial intelligence to offer real-time data processing and analysis [8].

D. Service Layer:

This layer provides common services for IoT applications, such as data storage, anomaly detection, diagnostics, and decision-making support. Technologies used in this layer include machine learning, big data analytics, and cloud services. It helps in generating actionable insights and predictions that aid in making informed decisions about farm management [9].

E. Application Layer:

The application layer is where end-users interact with the system. It includes user interfaces like mobile apps or web platforms that allow farmers to monitor conditions, receive alerts, and control IoT devices remotely. This layer utilizes data from the lower layers to provide comprehensive insights and visualizations, facilitating tasks such as crop monitoring, irrigation management, and pest control.

These components work together to create a robust IoT ecosystem for smart agriculture, enabling precision farming and efficient resource management. The integration of these technologies helps in optimizing agricultural practices, improving crop yields, and reducing environmental impact [10].

3. Sensors used for IoT in smart agriculture

In smart agriculture, various types of sensors are used to monitor and manage agricultural activities more efficiently. Here are some of the key types of sensors commonly used in IoT for smart agriculture.

A. Soil Sensors:

Soil Moisture Sensors: To maximise irrigation, determine the volumetric water content of the soil.

Soil Temperature Sensors: Track the temperature of the soil to promote crop development and seed germination.

Soil pH sensors: Determine the acidity and alkalinity of the soil to guarantee ideal growth conditions for various crops.

Soil Nutrient Sensors: Determine the concentrations of vital nutrients such as potassium, phosphorus, and nitrogen [11].

B. Climate Sensors:

Temperature sensors: Track the outside temperature to shield crops from harsh meteorological events.

Humidity sensors: Determine the amount of moisture in the air to assist in controlling the demands for watering and plant health.

Light sensors: Determine the amount of sunshine a plant receives to maximise its exposure to it.

Rainfall sensors: Use rainfall data to control irrigation times [12]

C. Water Sensors:

Water Flow Sensors: To identify leaks and maximise water use, measure the volume of water passing via irrigation systems.

Water Quality Sensors: Check if the salinity, turbidity, and pH levels of the water are appropriate for irrigation [13].

D. Crop Sensors:

Optical sensors: Measure plant health, chlorophyll content, and disease detection using various light wavelengths.

Multispectral and hyperspectral sensors: Gather information at various wavelengths to assess crop health and identify potential stressors [14].

E. Livestock Sensors:

Wearable Sensors: Track health, location, and activity levels of livestock.

Microchips: These allow for individual animal identification and health tracking.

F. Pest and Disease Sensors:

Insect Traps with Sensors: Monitor pest numbers by counting them to effectively implement control measures.

Disease Detection Sensors: Use alterations in plant biomarkers to find early indicators of plant illnesses.

G. Environmental Sensors:

CO2 Sensors: Measure carbon dioxide levels to ensure optimal conditions for photosynthesis.

Gas Sensors: Detect harmful gases like ammonia or methane, especially in enclosed agricultural environments like greenhouses.

H. Location Sensors:

GPS Sensors: Provide precise location data for equipment and crop mapping.

RFID Tags: Used for tracking livestock and assets within the farm.

4. IoT use cases in smart agriculture

The Internet of Things (IoT) has significantly impacted agriculture by introducing advanced technologies that enhance efficiency, productivity, and sustainability. Here are ten key applications of IoT in agriculture,

A. Monitoring of climate conditions

Weather stations are among the most widely used smart agricultural devices, as they integrate many smart farming sensors. They are situated across the area and gather different types of environmental data before sending it to the cloud. With the measurements supplied, one may utilise them to map the environment, choose suitable crops, and implement the necessary actions to increase their productivity (precise farming) [15].

Some examples of such agriculture IoT devices are allMETEO, Smart Elements, and Pycno.

B. Greenhouse automation

Farmers often manage the greenhouse atmosphere via hand involvement. They may obtain precise real-time data on greenhouse parameters including illumination, temperature, soil quality, and humidity by using Internet of Things (IoT) sensors. Weather stations can autonomously modify the circumstances to fit the specified criteria in addition to obtaining environmental data. In particular, an analogous principle is applied by greenhouse automation systems. Among other IoT agriculture solutions, Farmapp and Growlink provide these kinds of features [16].

C. Crop management

Crop management devices are another kind of IoT product used in agriculture and a component of precision farming. They should be positioned in the field to gather information unique to crop farming, such as temperature, precipitation, leaf water potential, and general crop health, just like weather stations [17].

As a result, you can keep an eye on the growth of your crops and any irregularities to efficiently ward against illnesses or pests that can reduce your production. Arable and Semios are two excellent examples of real-world applications for this use case.

D. Cattle monitoring and management

IoT agricultural sensors are available to monitor the health and record the performance of farm animals, much as crop monitoring. Data on the health, welfare, and physical position of livestock are gathered with the use of tracking and monitoring livestock. These sensors, for instance, can detect unwell animals, allowing farmers to isolate them from the herd and prevent infection. Farmers may save personnel costs by using drones to track animals in real-time. This functions similarly to petcare-related IoT devices [18].

For instance, SCR from Allflex and Cowlar uses smart agricultural sensors (collar tags) to provide information on the herd as a whole as well as temperature, health, activity, and nutrition insights for each individual cow.

E. Precision farming

Precision farming, often referred to as precision agriculture, is centred on productivity and precise, data-driven decision-making. It's also among the most popular and successful uses of IoT in farming. Farmers are able to gather a wide range of data on many aspects of the field microclimate and ecosystem, such as temperature, humidity, illumination, soil quality, CO2 levels, and insect infestations, by utilising Internet of Things sensors. With the use of this data, farmers may save costs, grow healthier and more productive crops, and determine the ideal quantities of water, fertiliser, and pesticides for their plants [19].

For example, CropX builds IoT soil sensors that measure soil moisture, temperature, and electric conductivity enabling farmers to approach each crop's unique needs individually. When paired with geographic information, this technique aids in the creation of accurate soil maps for every field. Similar services are provided by Mothive, which aids farmers in lowering waste, raising yields, and enhancing farm sustainability [20].

F. Agricultural drones

The use of agricultural drones to smart farming is perhaps one of the most exciting developments in agritech. Drones, often referred to as unmanned aerial vehicles, or UAVs, are more capable of gathering agricultural data than satellites and aircraft. In addition to their surveillance capabilities, drones may carry out a wide range of jobs that traditionally needed human labour, such as crop planting, eradicating pests and illnesses, agricultural spraying, crop monitoring, and more [21].

For instance, DroneSeed constructs drones to plant plants in deforested areas. These drones are six times more productive to utilise than human labour. A cost-effective Sense Fly agricultural drone, the eBee SQ, employs multispectral image analysis to assess crop health [22].

G. Predictive analytics for smart farming

Predictive data analytics and precision agriculture go hand in hand. The use of data analytics by farmers helps them make sense of the vast amounts of highly relevant real-time data that IoT and smart sensor technologies provide, enabling them to make critical forecasts about crop harvesting time, disease and pest risks, yield volume, and other related topics. Farming, which is essentially very dependent on the weather, may be made more predictable and controlled with the use of data analytics technologies [23].

For instance, farmers may get crop quality and volume ahead of time, as well as their susceptibility to adverse weather events like drought and flooding, with the use of the Crop Performance platform. Additionally, it lets farmers choose yield features that will enhance crop quality and optimise the amount of water and nutrients available to each crop [24].

5. Conclusion

IoT integration in smart agriculture has shown to have a great deal of promise for improving farming methods sustainability, efficiency, and production. Farmers are now able to obtain real-time insights into crop health, soil conditions, and environmental factors by deploying sensors, automating irrigation systems, and using data analytics. This technical breakthrough lowers labour costs, boosts agricultural yields, and optimises the use of resources like water and fertilisers. IoT adoption in agriculture, however, is confronted with several obstacles, such as high upfront costs, the requirement for technical know-how, and worries about data security.

This paper considered all these aspects and highlighted the role of various components, sensors and applications of IoT in smart agriculture. Future research in this area should concentrate on removing these obstacles by creating affordable Internet of Things technologies and approachable user interfaces that farmers of all sizes may readily embrace. Furthermore, for smooth integration and data interchange, improving the interoperability of IoT platforms and devices will be essential. Enhancing cybersecurity protocols should be a top priority in research to prevent breaches and exploitation of private agriculture data. Furthermore, by utilising developments in artificial intelligence and machine learning, farmers will be able to respond proactively to possible problems by utilising predictive analytics and decision-making processes. IoT has the ability to completely transform agriculture and support sustainable agricultural methods and global food security by carrying out more innovation and tackling these issues.

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