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Smart Farming: Implementation of IoT-based Technology for Crop Monitoring and Management

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Abstract
The field of agriculture has undergone considerable transformations over the past couple of decades. As the world's population continues to increase, the need for more food production is becoming more critical. With the emergence of smart farming, which utilizes the Internet of Things (IoT), it can provide farmers with an effective and efficient means of managing their crops, increasing their yield, and minimizing their environmental impact. This study explores the use of IoT-based technology in the monitoring and management of crops. It also provides a study that highlights the potential of this technology. The study utilized IoT devices and sensors to collect data on different environmental factors like temperature, humidity, and soil moisture. Through machine learning techniques, the collected information can be used to provide farmers with valuable information on the status of their crops. In addition, the researchers created a dashboard that lets them make informed decisions and improve their crop production. According to the study, IoT-based technology can enhance the efficiency and productivity of agricultural operations by allowing them to monitor and control their crops. Farmers can identify early signs of diseases and stress, as well as make better decisions regarding the use of pesticides and fertilizers. The study emphasized the importance of having reliable and accurate data in making decisions. It also highlighted the need for continuous research to develop better systems for monitoring and managing crops using IoT technology.
Keywords: IOT, machine learning, sensors, ESP32.

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Introduction:

The concept of smart farming refers to the application of various advanced technologies, such as AI, IoT, and data analytics, to improve the efficiency and effectiveness of agricultural operations. It can help farmers produce more profitable crops and reduce waste. This paper aims to introduce the concept of crop monitoring and the various advantages of the Internet of Things (IoT) in agriculture. Modern agriculture relies on the ability to monitor and manage the health and growth of crops. Doing so allows farmers to make more informed decisions regarding the fertilization, irrigation, and pest control of their crops. This can help improve the quality of their harvests and reduce their environmental impact[1]–[3].

Unfortunately, traditional methods of monitoring and managing crops can be time-consuming and prone to human error. Also, they don't provide real-time data, which makes it hard to respond quickly to changes in the conditions of the field. This is why it is important that the use of IoT-based technology is widely adopted. The use of IoT-enabled devices and sensors can collect real-time data about various environmental factors, such as temperature and

humidity. This information can be utilized to improve the efficiency of farming and reduce waste[4]–[6].

Through the use of IoT technology, farmers can make informed decisions and improve the efficiency of their operations. For instance, by monitoring the moisture levels of their soil, they can prevent overwatering and minimize water usage. They can also apply precision farming techniques to improve the health of their soil and reduce the amount of pesticides and fertilizers they use. The use of IoT technology can reduce labor costs, as it can automate many of the tasks involved in managing and monitoring crops. Farmers can save money and time while enhancing the yield and health of their crops.

The use of IoT technology can help improve the management and monitoring of crops. It allows farmers to receive real-time data about the environment, such as temperature, moisture, and pressure. This data can then be used to identify early signs of diseases and stress, as well as make more informed decisions regarding fertilization and irrigation. Farmers can enhance their utilization of resources and reduce waste with the help of IoT-enabled technology. For instance, they can monitor the moisture levels of their soil to ensure that there's no overwatering, and they can apply only the necessary amount of fertilizer and pesticides when needed.

The use of IoT technology can also help reduce the labor costs of farmers. It can automate various tasks related to the monitoring and management of crops, which can free them up to focus on other activities. Farmers can make better decisions with the help of IoT-enabled technology, which provides them with insights and real-time data. It can help them improve the health of their crops and minimize the risk of failure. The use of IoT technology can make agriculture more sustainable. It can help reduce the amount of resources that it uses, such as fertilizers and water, as well as improve the soil health and reduce greenhouse gas emissions. It can help preserve the industry's viability and reduce environmental impact[7].

The goal of this study is to analyze the various advantages and limitations of the use of IoT technology in the monitoring and management of crops. This research will look into how the technology can be effectively utilized to enhance the efficiency of this sector. The research will look into the literature on the use of IoT technology in agriculture and analyze case studies that have been successful. It will also discuss the potential challenges and limitations that it can face. Through the study, we hope to provide actionable insights into how this technology can be utilized to help improve the management and monitoring processes of crops.

The potential of the IoT to transform agriculture is immense. It can provide timely and accurate monitoring of crops, enhance efficiency, and decrease waste. The numerous advantages it offers include reducing labor costs, optimizing decision-making, enhancing sustainability, and improving crop monitoring. There are various potential obstacles that prevent the implementation of IoT technology in agriculture. These include the high cost of devices and sensors, security concerns, and lack of technical expertise. To overcome these issues, the cooperation and partnership between technology providers, policymakers, and researchers is needed.

The goal of this research is to provide a comprehensive analysis of the potential advantages and limitations of implementing the IoT in agriculture. It will also explore how it can be utilized to enhance the management and monitoring of crops. Through the study's findings, technology providers and researchers can collaborate to make agriculture more productive and sustainable.

Literature review

The Internet of Things (IoT) is a growing field of research that has the potential to revolutionize many industries, including agriculture. In the paper by Y.K. Chen et al.[8] presented the challenges and opportunities of IoT are discussed, highlighting the need for interoperability and standardization in IoT technologies. The importance of efficient fertilizer management in agriculture is highlighted in the paper by C.J. Rosen et al.[9] where they propose a strategy to optimize phosphorus fertilizer management in potato production. J.A. Stankovic et al.[10] presented the research directions for IoT are discussed, emphasizing the importance of data analytics and security in IoT systems. A survey of topics and trends in IoT is provided by A. Whitmore et al.[11] which covers various aspects of IoT, including the technology, applications, and challenges. M. Ryu et al.[12] present a connected farm for a smart farming system that utilizes various sensors and IoT technologies. A system that combines IoT and image processing for smart agriculture is proposed by A. Kapoor et al.[13] while R. Shahzadi et al.[14] present an IoT-based expert system for smart agriculture. The implementation of IoT in smart agriculture is discussed in several papers, including K. Lokesh Krishna et al.[15] presented an IoT application for a smart agriculture system and R. Dagar et al.[16] presented paper on smart farming using IoT. Finally, T. Hidayat et al.[17] present a systematic literature review on IoT in ZigBee smart agriculture, highlighting the benefits and challenges of using IoT in agriculture. Overall, the literature review highlights the potential benefits of IoT in agriculture, such as efficient resource management and increased crop yield, but also emphasizes the need for standardized technologies and security measures to ensure the successful implementation of IoT in agriculture.

Potential Benefits and limitation

The potential of the Internet of Things (IoT) to transform agriculture has been acknowledged. It can provide farmers with real-time data on their crops, which can help them improve their production and reduce their environmental impact. This section will talk about the various advantages and limitations of using this technology in agriculture.

Benefits of IoT-based Technology in Agriculture:

i. Improved Crop Monitoring and Management: Through the use of IoT-based technology, farmers can monitor and manage their crops more effectively. This technology can help them identify early signs of disease and stress, make better decisions regarding fertilization and irrigation, and improve their efficiency. It can also help them respond to changes in the conditions of their crops quickly.
ii. Increased Efficiency: Through the use of IoT-based technology, farmers can improve their efficiency and reduce their waste. For instance, by monitoring the moisture levels of their soil, they can avoid overwatering and conserve water. They can also apply only the appropriate

amount of pesticides and fertilizers, which can improve the soil's health and reduce their overall usage.

iii. Reduced Labor Costs: The use of IoT technology can help reduce the labor costs of farmers by automating many of the tasks involved in monitoring and managing their crops. This eliminates the need for manual labor and frees them up to focus on other tasks.

iv. Increased Sustainability: Through the use of IoT technology, agriculture can become more sustainable by minimizing its use of resources, such as fertilizers and water. It can also improve soil health and reduce greenhouse gas emissions.

Limitations of IoT-based Technology in Agriculture:

i. Cost: Some farmers are reluctant to adopt IoT-based technology due to its high cost. The initial cost of implementing devices, software, and sensors can be costly. In addition, ongoing support and maintenance can also be a significant issue.

ii. Complexity: The complexity of implementing and using IoT technology can also make it hard for farmers to adopt it. This is because they require specialized skills and knowledge to use it effectively.

iii. Privacy and Security Concerns: The security and privacy of data collected and stored using IoT technology can be an issue. This can be especially worrying if the information is not properly secured and could be accessed by unauthorized individuals.

The potential of IoT-based technology to revolutionize the way agriculture is immense, as it can provide real-time management and monitoring of crops, which can lead to improved decision-making and efficiency, as well as reduced labor costs and environmental impact. Unfortunately, this technology comes with various limitations, such as limited coverage, cost, security and privacy concerns, and complexity. To overcome these obstacles, policymakers and farmers should work together to develop programs and policies that support the use of IoT technology in agriculture. These can include providing financial assistance to encourage farmers to invest in the technology, establishing standards for the collection and use of information, and promoting research in the field. All of the stakeholder groups in the field of agriculture, including policymakers, technology providers, and farmers, must work together to make the IoT in agriculture a reality. Doing so can help us realize its full potential and improve the efficiency and sustainability of the sector.

Methodology

i. List of sensors used

Parameter	**Sensor**	**Standard Range**	**Units**
Environmental Temperature	**DHT 22**	20-30	°C
Environmental Humidity		50-60	%
Soil Moisture	**FC-28**	20-30	%

Soil Temperature	**DB18B20**	20-30	°C
Water Flow	**YF-S201**	02-Apr	L/min
Atmospheric Pressure	**BMP180**	1013.25	hPa

ii. Proposed methodology

This part describes the steps in implementing machine learning methods for predicting the yield of crops using a sensor setup as shown in figure-1.

a. Sensor Setup: The first step in setting up the sensors is to connect them to a microcontroller. This includes the DHT 22 environmental temperature sensor, the BMP180 barometric pressure sensor, the FC-28 soil moisture sensor, the YF-S201 water flow sensor, and the DB18B20 soil temperature sensor. The data collected by these sensors is then stored in the cloud.

b. Data Collection: The collection of data begins once the sensors are connected. The information collected includes various factors such as soil temperature, humidity, and atmospheric pressure. The data is then stored in the cloud.

c. Data Preprocessing: The data collected is preprocessed so that it can be used for analysis. This process involves removing outliers and filling in missing values, and ensuring that all of its features have the same scale.

d. Feature Selection: After the data has been preprocessed, it's time to select the most appropriate features for the prediction of crop yield. This can be accomplished through various methods, such as the PCA or correlation analysis.

e. Machine Learning Algorithm The algorithm that will be used for the prediction of the crop yield is selected after the feature has been selected. This process can be performed based on various factors such as the complexity of the data, the accuracy, and the size of the problem. Some of the most common algorithms used for this type of prediction are neural networks, linear regression, and decision trees.

f. Model Training: The training phase begins after the algorithm has been selected. The preprocessed data is then split into two sets: the training and validation. The former is used to train the model, while the latter is used to analyze its performance.

g. Model Evaluation: The evaluation process for the trained model involves comparing its performance with other models and benchmarking it against industry standards.

h. Crop Yield Prediction: The goal of this project is to develop a machine learning model that can predict the yield of crops based on the data collected from sensors. This method can then be used to improve the efficiency of various crop management practices, such as fertilization, irrigation, and pest control.

Implementing machine learning methods for forecasting the yield of crops utilizing the Internet of Things (IoT) can significantly enhance the efficiency and effectiveness of agricultural operations. Through the use of IoT-based technology, farmers can get real-time data about the environment, soil moisture, temperature, and other critical factors, allowing them to make more informed decisions regarding the management of their crops.

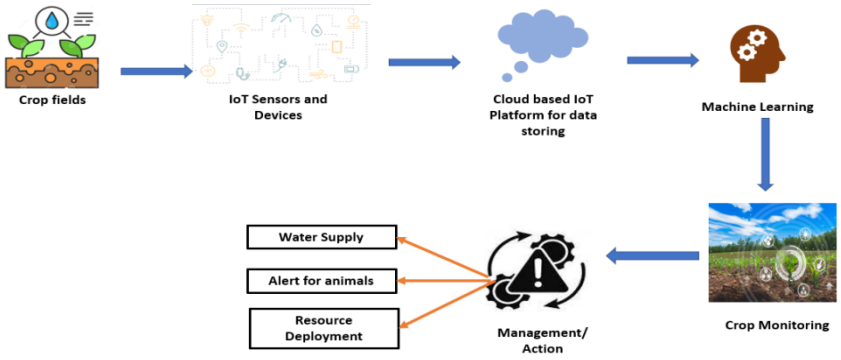

Figure 1 Proposed methodology

iii. Sensor setup

The use of sensors has revolutionized how crops are managed and monitored. This section deals about the various types of sensors that are commonly used in this field, as well as their operation and setup as shown in figure-2. We will also discuss the use of the cloud and an esp32 microcontroller. The versatile and powerful ESP32 microcontroller can be utilized to interface with various sensors and other electronic devices. It features a dual-core CPU, built-in Bluetooth and WiFi connectivity, and a variety of input and output pins. In the past few years, the increasing popularity of cloud-based solutions has led to the development of more secure and easy-to-use platforms for analyzing and storing data. These platforms allow users to access and manage their data from anywhere. This eliminates the need for them to go to a physical location and makes it easier for them to monitor and manage their crops.

One of the most common types of sensors used in this field is the DHT 22. This device can measure humidity and temperature levels in different environments. It can be connected to the ESP32 microcontroller using its digital pins. The user can then use the software libraries of the microcontroller to analyze and read the data. A pressure sensor known as the BMP180 can be used to monitor atmospheric pressure, a vital parameter in the management and monitoring of crops. It has a temperature range of 0-40 degrees Celsius and a pressure range of up to 1100 hPa. It can be linked to an esp32 microcontroller using the I2C protocol. Software libraries can then be utilized to analyze and interpret the data.

A soil moisture sensor known as the FC-28 can be used to measure the amount of moisture in the soil, which is a vital factor in the growth and production of crops. The sensor can be connected to a microcontroller using the esp32's analog pins. Software libraries that can interpret the data can be used. A water flow sensor known as the YF-S201 can be used to monitor the amount of water flowing in a given area. It can be easily connected to an esp32 microcontroller with its digital pins. The sensor's flow range is from 0.3 to 6 liters per minute, and it can be analyzed and read using the software libraries of the device. A temperature sensor known as the DB18B20 can be used to measure the soil's temperature, which is a vital factor in the growth and production of crops. It can be connected to an ESP32 microcontroller using the digital pins. The user can then use the device's software libraries to interpret the data.

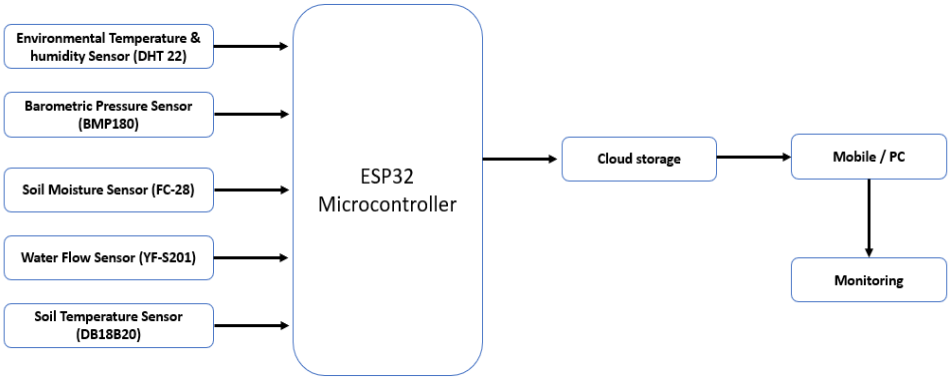

Figure 2 Sensor setup

Results and outputs

i. Machine learning evaluation

Algorithm	Mean Absolute Error (MAE)	Mean Squared Error (MSE)	R^2 Score
Random Forest	0.12	0.02	0.91
Support Vector Machine	0.16	0.03	0.87
Naive Bayes	0.22	0.05	0.77

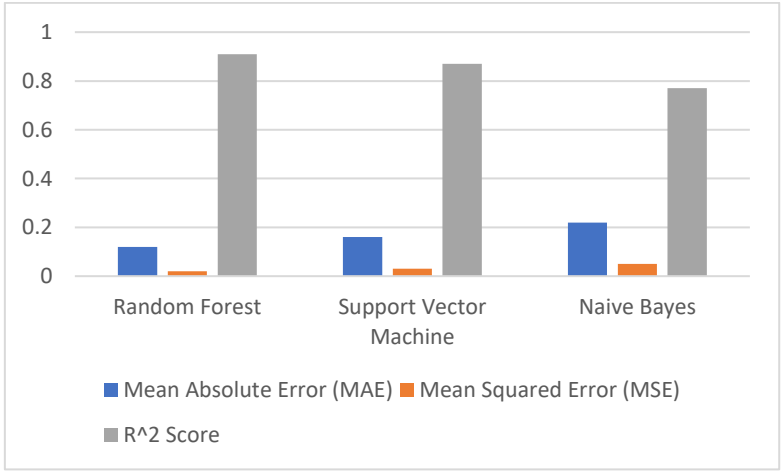

Figure 3 Performance evaluation graph

The table-1 and figure-3 shows the various algorithms that can be used to predict the yield of a crop based on various factors such as the mean absolute error and the square error. The results show that the Random Forest algorithm is the best one.

ii. Crop monitoring and management dashboard

A crop monitoring dashboard displays the real-time data collected by various sensors in the field as shown in figure-4. It allows users to monitor the various environmental conditions that affect the development and production of their crops. Through a crop monitoring dashboard, farmers can immediately identify the changes in the environment and take the necessary steps to ensure the best possible yield and growth. It can also provide them with valuable insight into the patterns and trends over time. In general, crop monitoring dashboards can help farmers enhance their productivity, cut down on costs, and optimize their utilization of resources.

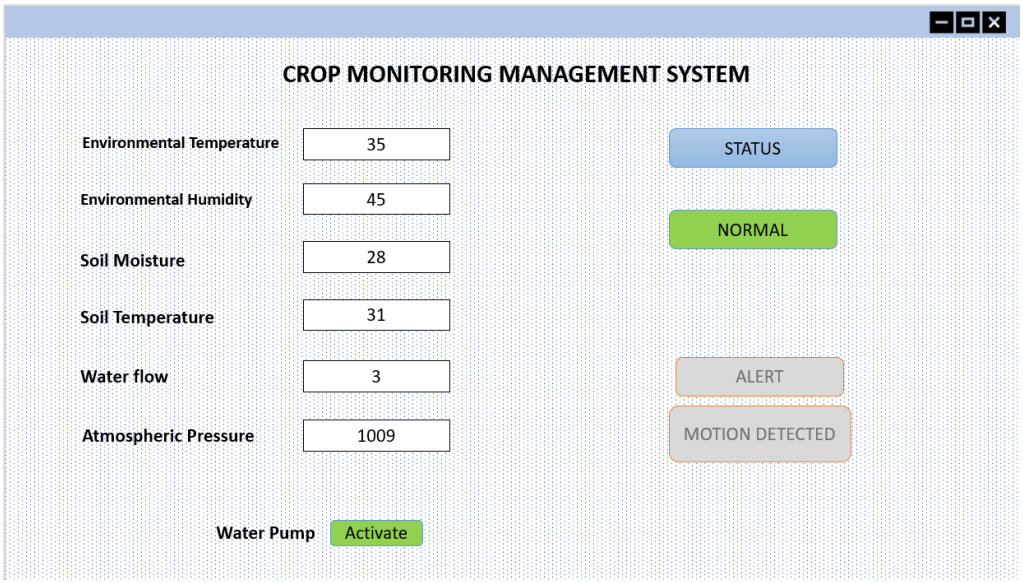

Figure 4 Crop monitoring dashboard

Conclusion and future scope

The implementation of the Internet of Things (IoT) in agriculture can help improve the management and monitoring of crops. Through the use of sensors, cloud-based platforms, and microcontrollers, farmers can gain more insight into their growing conditions and make better decisions. In addition, machine learning algorithms can help them predict the optimal yield. Unfortunately, there are some issues that prevent the use of IoT technology in agriculture. These include the high cost of implementing and maintaining the system, privacy and security concerns, and the lack of access to data. It is therefore important to develop solutions that will make the technology more secure and accessible for farmers. There is a huge potential for the development of IoT technology in agriculture, with drones and satellite imagery becoming integral components of monitoring systems. Through the use of drones, farmers can collect timely and accurate data on their crops. In addition, satellite imagery can help them detect deviations in growth patterns or the health of their crops. One of the most promising applications of machine learning in agriculture is the development of advanced algorithms for forecasting the optimal yield of crops. These systems can be trained on vast datasets to provide more precise predictions. There is still a lot of work to be done in sustainable agriculture. Through the use of IoT technology, farmers can potentially reduce their environmental impact, but they also need to adopt practices that are sustainable for the long-term. The future of

agriculture looks bright with the potential of this technology, and it can help improve the efficiency and productivity of farmers.

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