

An IoT and AI-Based Smart Plant Care and Monitoring System for Real-Time Crop Recommendation and Intelligent Decision Support

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Abstract—The fast progress of the Internet of Things (IoT) and Artificial Intelligence (AI) has allowed the creation of smart farming and gardening applications that can be used to improve production, sustainability, and the precision of decisions. The conventional methods applicable in farming and plant care make use of manual observation, the most suitable method, but frequently result in the inefficient utilisation of water, fertilisers, and land materials. In this paper, the design, implementation, and evaluation of an IoT and AI-based Smart Plant Care and Monitoring System, including real-time environmental sensing, machine learning-based crop and fertiliser recommendations, and an AI-powered chatbot to interact with the farmer, have been presented. The suggested system gathers real-time temperature and humidity data from sensors connected to a microcontroller and sends it to a Flask server on the cloud. To improve accuracy in decisions, soil moisture and pH parameters are added. There is the use of a Random Forest machine learning model is used to forecast appropriate crops and fertilisers according to the environmental conditions, and a chatbot built using Naive Bayes is used to give instant replies to queries posed by farmers. An online dashboard can also be used to monitor and communicate in real-time. The system has been experimentally tested to enhance the selection accuracy of crops, thereby lowering the workload on the hands of the people and ultimately allowing sustainable farming processes. The offered architecture is scalable, inexpensive and can be applied both to smart farming and to residential gardening.

Index Terms—Internet of Things (IoT), Smart Agriculture, Plant Monitoring, Machine Learning, Crop Recommendation, Artificial Intelligence, Chatbot.

I. INTRODUCTION

Agriculture is the backbone of food security and economic growth, especially in developing nations like India. The agricultural sector has a number of problems, including climate change, unpredictable weather, lack of water, poor-quality soil, and the absence of timely information. Agriculture has traditionally been performed according to farmers' experience and occasional field observations. As a result, the improper selection of plants, ineffective watering systems, and improper use of fertilisers reduce agricultural production. The recent developments in IoT technology have turned traditional agriculture into smart agriculture by implementing continuous field condition monitoring systems. The environmental factors, such as humidity, temperature, soil moisture level, and so on, are measured using sensors in IoT-based technologies. Data gathered in real-time may be saved and processed on cloud-based platforms in order to inform farmers about present field conditions. Machine Learning techniques have greatly improved agricultural decision-making systems by predicting complex interactions between environmental parameters and agricultural data. Based on such interactions, ML-based recommendations allow selecting appropriate plants and fertilisers depending on the

field's environmental situation. Moreover, the advent of AI technologies in agriculture has brought about the concept of a conversational AI by integrating chatbot assistance systems to facilitate communication between people and the agricultural environment. This way of communication allows for quick and easy access to agricultural information from a chatbot application. This paper will introduce the design of an IoT and AI-based Smart Plant Care and Monitoring System by integrating real-time environmental data gathering, machine learning-based crop recommendation, fertiliser suggestion, and chatbot assistance in agriculture.

II. LITERATURE REVIEW

The use of IoT technology in agriculture has greatly enhanced the monitoring and management of environmental factors involved in growing plants. Various scientists have used IoT technologies to monitor plants using sensors for collecting real-time information like temperature, humidity, soil moisture, and light. The technology allows for the continuous monitoring of field conditions, and it makes decision-making regarding the irrigation and management of crops easier. The use of IoT technology has been shown to make agricultural work less laborious and resource-intensive and to generally increase efficiency in agricultural processes. Besides, cloud technology has been incorporated into the IoT to enable remote monitoring and visualisation of data [1], [2], [4], [5]. Apart from environmental monitoring, IoT technology has also found extensive use in automated irrigation systems. Scientists have come up with automated irrigation schemes, based on sensors, which enable irrigation based on the moisture in the soil. These irrigation schemes are not only able to conserve water but also ensure more effective irrigation, with minimum human interference. Many reports have stated that automated irrigation systems may aid in sustainable agriculture practices, as these systems ensure that the crops get enough water at

the right time. Integration of technologies such as wireless communications and cloud services has made these systems more reliable and easy to access [2], [7], [8]. Recently, ML has seen much attention being used in the field of agriculture for recommending appropriate crops. Many ML techniques, such as Decision Tree, Support Vector Machines, Random Forest, and Neural Network models, have been used in analysing soil and environmental parameters for recommending the appropriate crops. Amongst all these techniques, the Random Forest model has been receiving more attention because of its robust nature and high accuracy in making predictions. With the help of historical as well as real-time data about agriculture, ML models can help farmers in selecting crops that are more appropriate in a particular environment [9], [11], [12], [13]. Application of Conversational Artificial Intelligence in agriculture has attracted interest owing to its ability to help farmers gain instant information. There exist several chatbots designed specifically to offer answers to questions regarding crop growth, fertilisers, irrigation techniques, and disease control. The use of AI in such chatbots is supported by the utilisation of NLP and machine learning technologies. As a result of the instant provision of answers in an easy-to-use interface, the need to seek the expert opinion of agriculturists on such routine questions may be eliminated. Modern research indicates the promising role of AI-based chatbots in agriculture [14], [15]. While substantial developments have already been achieved in IoT-based monitoring, smart irrigation, crop recommendation using machine learning, and agricultural chatbot solutions, the current systems mainly concentrate on a particular feature instead of offering a holistic solution. While some systems specialise in environmental monitoring, there are other systems that specialise in either crop prediction or farming support separately. The lack of cohesion in these aspects can negatively affect the usability of such systems in the real world. It is under these circumstances that the

proposed research will incorporate all these features into one system, which will include environmental monitoring, machine learning-based crop prediction, fertiliser recommendations, and chatbot support. The idea is to integrate these aspects to make the process of decision-making and the interaction easier for smart plant care and agricultural monitoring [5], [7], [12], [15].

III. SYSTEM ARCHITECTURE

The architecture of the IoT AI-based Smart Plant Care and Monitoring System is modular and layered in order to provide real-time monitoring, intelligence and interaction with users. This architecture includes sensors, processors, communication modules, machine learning algorithms and the web interface in one system. This Architecture has four main layers, which include: Sensing Layer, Communication and Processing Layer, Intelligence Layer and Application Layer.

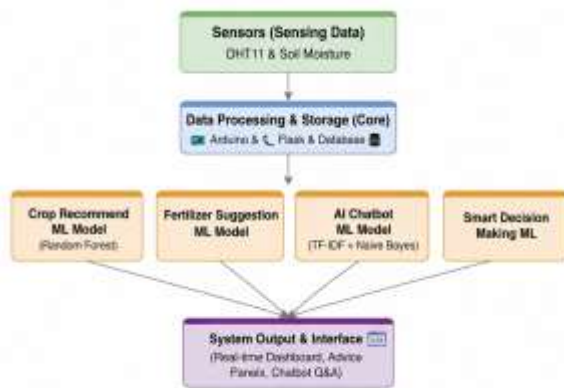


Fig. 1. System Architecture of the Proposed IoT and AI-Based Smart Plant Care and Monitoring System

A. Sensing Layer

The sensing layer collects real-time environmental information from the surroundings. The DHT11 sensor measures temperature and humidity, the soil moisture sensor monitors soil moisture level, and the active buzzer creates an alarm when an abnormal situation arises. All these components are linked to an Arduino

microcontroller through which data collected by these sensors is further processed.

B. Communication and Processing Layer

The communication and processing layer plays the role of the intermediary between the sensing and intelligent services. Data obtained from sensors using the Arduino device is transferred to the processing engine using serial communication. The backend service created using the Flask framework receives, validates, and processes incoming data. RESTful APIs facilitate communication between backend and frontend services.

C. Intelligence Layer

The intelligence layer uses machine learning and artificial intelligence methods to make decisions. The Random Forest classifier is applied to recommend crops depending on environmental factors like temperature, humidity, soil moisture, and pH value. Furthermore, the chatbot built using TF-IDF Vectorizer and Multinomial Naive Bayes algorithm helps farmers get agricultural information and solutions to their queries.

D. Application Layer

All the layers contribute together in order to form a seamless smart agriculture system that will be able to monitor the environment, give intelligent advice and interact efficiently with the user. Furthermore, the modular design makes it scalable, so other sensors can be added in the future as well.



Fig. 2. Hardware Components Used in the Proposed System

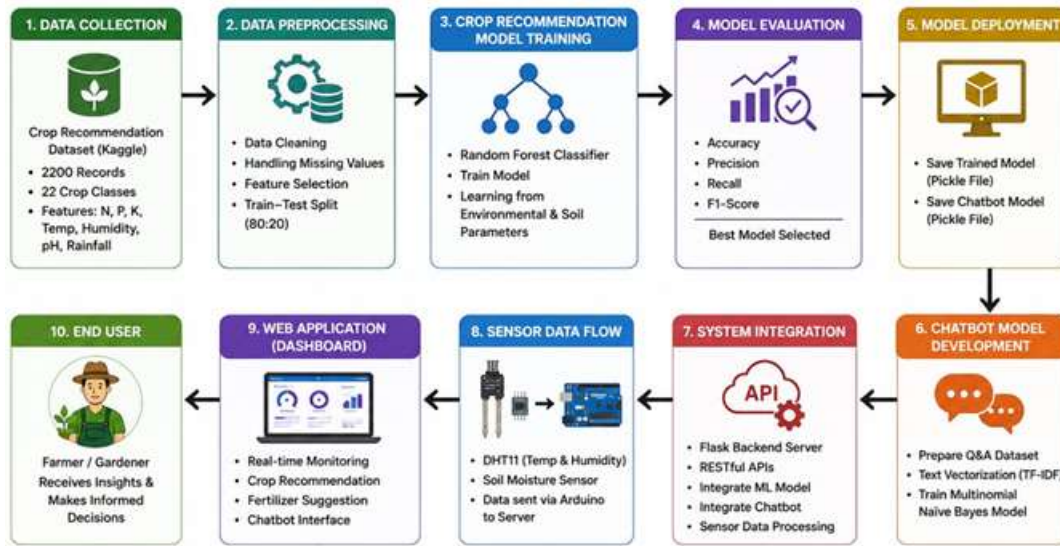


Fig. 3. Overall workflow of the proposed IoT and AI-based smart plant care and monitoring system.

IV. METHODOLOGY

The methodology involved in developing the proposed IoT and AI-based smart plant care and monitoring system is designed in such a way that ensures the proper collection of accurate data, efficient processing, intelligent decision-making, and robustness of the system. The methodology involves four main stages, which are as follows: Data Collection and Preprocessing, Crop Recommendation Model Development, and Chatbot Model Development.

A. Data Collection and Preprocessing

This crop recommendation model is built on the public Crop Recommendation Dataset provided by Kaggle. It contains 2,200 entries across 22 different crops and consists of important parameters of agriculture, including Nitrogen (N), Phosphorus (P), Potassium (K), temperature, humidity, pH level, and rainfall. To build an efficient model, the dataset had to be preprocessed first in order to eliminate errors and increase accuracy. This includes data cleaning, validation, and feature selection. Then, the preprocessed data was split into training and testing datasets based on the 80/20 split ratio.

B. Crop Recommendation Model

A random forest classifier algorithm was chosen for the selection of crops as it has high accuracy, is robust, and can manage the non-linear relations between the various parameters of agriculture. This model was trained using the data related to environmental and soil parameters for predicting the optimal crop for planting. This trained model uses various input parameters like temperature, humidity, soil moisture, etc., related to agricultural parameters and predicts the crop recommendation for planting. Evaluation of the model was done using various performance metrics like accuracy, precision, recall, and F1 score. Once successfully evaluated and trained, the model was saved to be used further in the system.

C. Chatbot Model Development

A chatbot based on AI technology was created to help users by providing information regarding agriculture along with the system. A question-answer dataset was created using agricultural questions and system questions, which were used in training the AI-based bot. For the text data that was gathered, the TF-IDF algorithm was utilised to transform text into numerical form. Then the

Multinomial Naive Bayes model was trained using the collected dataset for recognising user intent and responding to them.

D. System Integration

The machine learning model as well as the chatbot models that have been trained were saved as Pickle objects and then deployed within the backend server using the Flask framework. The sensor data obtained from the Arduino board was communicated to the server for further processing. The REST APIs were used to communicate between the frontend dashboard, machine learning model, and the chatbot services. Using the system, it will be possible to monitor environmental conditions, crop recommendations, fertilisers, and chatbot services from one web application. The overall workflow of the proposed methodology is illustrated in Fig. 3. The workflow begins with data collection and preprocessing, followed by model training, evaluation, deployment, and integration with the web-based monitoring platform.

V. IMPLEMENTATION

The IoT and AI-Based Smart Plant Care and Monitoring System was developed by implementing sensors, machine learning algorithms, a chatbot, and a web-based platform for monitoring purposes. The development of this IoT solution included the following functionalities: environmental monitoring, crop recommendation, fertiliser recommendation, and user support services.

A. Hardware Implementation

Environmental sensing and alarm devices attached to the microcontroller formed the hardware layer of the project. Temperature and humidity readings were collected using the DHT11 sensor, whereas a soil moisture sensor was used to collect soil moisture readings. An active buzzer was used to raise alerts in case any irregularities were detected in the environment. These sensors were attached to the microcontroller to facilitate

data collection and transmission. The processing module used to coordinate data communication and other activities within the modules comprised the Arduino UNO.

B. Backend and API Development

The backend of the suggested system was built using the Flask framework in Python. Flask APIs were created in order to obtain sensor values and process the incoming data for establishing a communication channel between different parts of the system. In order to allow a smooth interaction between hardware sensors, machine learning models, chatbots, and the monitoring dashboard, RESTful APIs were employed.

C. Machine Learning Deployment

The crop recommendation module was created using the Random Forest classifier algorithm. Serialisation of the trained machine learning model was done using Pickle and included in the Flask application server. Environmental and soil variables were used as input to the model to predict the most appropriate crop for farming. The deployment allows for smart suggestions to be made instantly, depending on prevailing environmental conditions.

D. Intelligent Decision Support Module

The intelligent decision support system uses a combination of machine learning and conversation-based artificial intelligence techniques for supporting decisions in agriculture. The Random Forest model suggests crops, while fertilisers are suggested to increase crop productivity and maintain soil health. Apart from that, an AI-based chatbot has been incorporated into the system using the TF-IDF vectorisation technique along with a Multinomial Naive Bayes classifier. This helps in answering questions related to agriculture.

E. Real-Time Monitoring and Data Management

This system will constantly collect environmental data from the sensors and process

the data on the backend server. After processing, the data will be visualised by the monitoring system in terms of temperature, humidity, moisture content of soil, crop recommendation, fertiliser advice, and chatbot interactions. The monitoring platform will ensure that users can conveniently monitor their plants, get smart advice and make sound decisions.

VI. RESULTS AND DISCUSSION

A. Performance Metrics

The performance of the proposed crop recommendation model was evaluated using four standard classification metrics: Accuracy, Precision, Recall, and F1-Score.

- Accuracy: Measures the overall correctness of the model by calculating the ratio of correctly classified instances to the total number of instances.

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (1)$$

- Precision: Indicates the proportion of correctly predicted positive observations among all predicted positive observations.

$$Precision = \frac{TP}{TP + FP} \quad (2)$$

- Recall: Measures the proportion of correctly predicted positive observations among all actual positive observations.

$$Recall = \frac{TP}{TP + FN} \quad (3)$$

- F1-Score: Represents the harmonic mean of Precision and Recall, providing a balanced evaluation of model performance.

$$F1-Score = \frac{2 \times Precision \times Recall}{Precision + Recall} \quad (4)$$

where TP denotes True Positives, TN denotes True Negatives, FP denotes False Positives, and FN denotes False Negatives.

The performance of the proposed crop recommendation model was evaluated using standard machine learning metrics including accuracy, precision, recall, and F1-score. These

metrics were selected to assess the effectiveness and reliability of the model in recommending suitable crops based on environmental and soil-related parameters.

TABLE I PERFORMANCE EVALUATION OF THE PROPOSED CROP RECOMMENDATION MODEL

Model	Accuracy	Precision	Recall	F1-Score
Random Forest	99.09%	98.97%	99.02%	98.99%

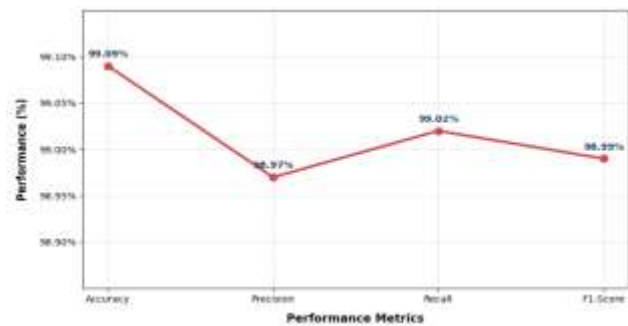


Fig. 4. Performance Metrics of the Crop Recommendation Model

As evidenced from Table I and Fig. 4, the Random Forest Classifier performed exceptionally well, achieving high scores for all performance metrics. The model managed to achieve an accuracy of 99.09%, precision of 98.97%, recall of 99.02%, and F1 score of 98.99%. The results obtained above highlight the efficiency of the designed prediction model in accurately recommending suitable crops according to the environment and soil-related features. The superior performance of the model is due to the quality of the training set used as well as the ability of the Random Forest Classifier to recognise the relationships between various agricultural parameters. Moreover, since the values of all performance metrics are almost similar, it can be concluded that the prediction model is highly stable and reliable. Apart from the prediction process, the implemented integration monitoring system successfully showcased the realtime readings of various environmental parameters such as temperature, humidity, and

soil moisture. Additionally, the chatbot module allowed obtaining quick answers to any questions related to agriculture. Thus, the experiments proved the efficiency of the suggested IoT and AI-based Smart Plant Care and Monitoring System.

VII. CONCLUSION AND FUTURE SCOPE

The integration of Internet of Things (IoT) and Artificial Intelligence (AI) has significantly enhanced the capabilities of modern agriculture by enabling intelligent, data-driven decision-making. This paper presented an IoT and AI-based Smart Plant Care and Monitoring System that integrates real-time environmental monitoring, crop recommendation, fertiliser suggestion, and an AI-powered chatbot within a unified framework. The proposed system collects environmental parameters, including temperature, humidity, and soil moisture, through IoT sensors and utilises a Random Forest machine learning model to recommend suitable crops based on current conditions. Additionally, the chatbot provides instant agricultural guidance, improving user interaction and accessibility. Experimental results demonstrate that the proposed methodology achieves high prediction accuracy while supporting efficient resource utilisation and sustainable agricultural practices. By combining monitoring, prediction, and intelligent assistance into a single platform, the system simplifies plant management, enhances decision-making, and reduces manual effort. Despite its promising performance, the proposed system offers several opportunities for future enhancement. Additional sensors, such as light intensity, soil nutrient, rainfall, and pH sensors, can be incorporated to improve monitoring accuracy and recommendation reliability. Advanced deep learning techniques may be employed for crop yield prediction, plant disease detection, and stress analysis. Furthermore, deploying the system on cloud platforms with mobile application support would improve scalability and accessibility. Integrating weather forecasting APIs

and satellite data can further enhance decision-making by providing comprehensive environmental insights. Finally, extending the chatbot with multilingual capabilities and advanced natural language processing techniques would improve user experience and accessibility. These enhancements will contribute to the development of more intelligent, scalable, and sustainable smart agriculture systems.

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