A Hydrid IOT and Machine Learning Approach for Crop Recommendation Using a Voting Ensemble Model

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Abstract - This paper presents a hybrid Internet of Things (IoT) and Machine Learning (ML) framework for intelligent crop recommendation, leveraging ensemble-based predictive modeling. Agricultural productivity in developing regions is often hindered by poor soil management, unpredictable weather, and lack of timely crop guidance. The proposed system integrates IoT-enabled environmental monitoring with a voting ensemble model that combines the predictive strengths of multiple algorithms, including Random Forest, Support Vector Machine (SVM), and Gradient Boosting. Real-time data such as soil moisture, pH, temperature, humidity, and rainfall are collected through IoT sensors and stored in a cloud-based platform for processing. The ensemble model dynamically recommends the most suitable crop for the current environmental conditions, enhancing decision accuracy and farm efficiency. Experimental results demonstrate that the hybrid model achieves improved precision, recall, and F1-score compared to individual models, indicating strong potential for sustainable smart farming applications.

Key Words: IoT, Machine Learning, Crop Recommendation, Voting Ensemble, Smart Agriculture, Data Analytics.

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1. INTRODUCTION

Sustainable agriculture relies on effective crop selection based on environmental, soil, and climatic parameters. However, farmers especially in resource-limited settings often depend on traditional knowledge rather than data-driven methods, leading to suboptimal yields.IoT and Machine Learning have emerged as transformative technologies in smart agriculture. IoT devices can collect live environmental parameters, while ML algorithms can analyze this data to provide actionable insights. However, single-model predictive systems often face challenges like overfitting or limited generalization.

To overcome this, our proposed system integrates a voting ensemble model combining multiple ML algorithms to improve prediction reliability. Coupled with IoT-based data acquisition and cloud-level analytics, the system provides accurate, real-time crop recommendations and supports precision farming initiatives.

2. LITERATURE SURVEY

Many researchers have developed crop recommendation systems using machine learning techniques. Random Forest algorithm provides high accuracy in classification problems related to agriculture. Support Vector Machine (SVM) is widely used for predicting crop yield based on soil parameters. K-Nearest Neighbour (KNN) algorithm helps in classification based on similarity between data points.

IoT based smart agriculture systems use sensors to monitor environmental conditions such as temperature, humidity, and soil nutrients. Previous research shows that combining multiple machine learning algorithms improves prediction accuracy compared to using a single algorithm.

Recent research focuses on integrating Internet of Things (IoT) technology with machine learning to collect real-time environmental data such as soil moisture, temperature, humidity, and NPK values. IoT sensors continuously monitor field conditions and send data for analysis. Many researchers have used ensemble learning methods to improve prediction performance. Voting Ensemble Model combines multiple algorithms such as Random Forest, SVM, and KNN to produce more accurate results. This method reduces prediction error and increases reliability in crop recommendation systems, helping farmers make better decisions and improve crop yield.

With the advancement of smart agriculture, IoT-based systems are widely used to collect real-time field data through sensors. These systems measure parameters such as soil moisture, temperature, humidity, and nutrient levels. Researchers have found that combining multiple machine learning algorithms using ensemble methods improves prediction accuracy compared to individual models. This approach helps farmers make reliable decisions and increases crop yield.

3. EXISTING SYSTEM

The existing system, crop selection is mainly based on traditional farming knowledge and experience of farmers. The decision about which crop to grow depends on general factors such as season, water availability, and soil type. However, these methods may not always provide accurate results because environmental conditions change frequently.Some existing crop recommendation systems use machine learning algorithms to predict suitable crops based on soil and climate data. These systems usually apply a single algorithm such as Decision Tree, Naive Bayes, or Support Vector Machine for prediction. Although these methods provide better results than traditional approaches, prediction accuracy may still be limited due to the use of only one model.

Many existing approaches do not use real-time data collected from IoT sensors and mainly depend on stored datasets. Due to changes in soil nutrients and environmental conditions, the prediction accuracy may be reduced. Also, systems that use only a single machine learning algorithm may not provide reliable results. Because of these limitations, farmers may not always get the best crop recommendation, which can affect productivity and efficient use of agricultural resources.

Limitations: The existing crop recommendation systems mainly depend on traditional methods or single machine learning algorithms, which may not provide high accuracy. Most systems do not use real-time data collected from IoT sensors, so the recommendations may not reflect current soil and environmental conditions.

4. PROPOSED SYSTEM

The proposed model introduces a hybrid approach that integrates Internet of Things (IoT) technology with Machine Learning algorithms to provide an accurate crop recommendation system. IoT sensors are used to collect real-time agricultural data such as soil moisture, temperature, humidity, and essential nutrient values including Nitrogen (N), Phosphorus (P), and Potassium (K). These parameters are important for identifying suitable crops based on soil fertility and environmental conditions.

The collected data is given as input to machine learning algorithms such as Random Forest, Support Vector Machine (SVM), and K-Nearest Neighbour (KNN), which analyze the dataset and predict suitable crops. To improve prediction performance and accuracy, a Voting Ensemble Model is applied, which combines the outputs of all individual algorithms and selects the final crop recommendation based on majority voting. This integrated system helps farmers make better decisions by providing reliable crop suggestions based on real-time data. The proposed model supports smart agriculture by improving productivity, reducing risk, and ensuring efficient use of available resources.

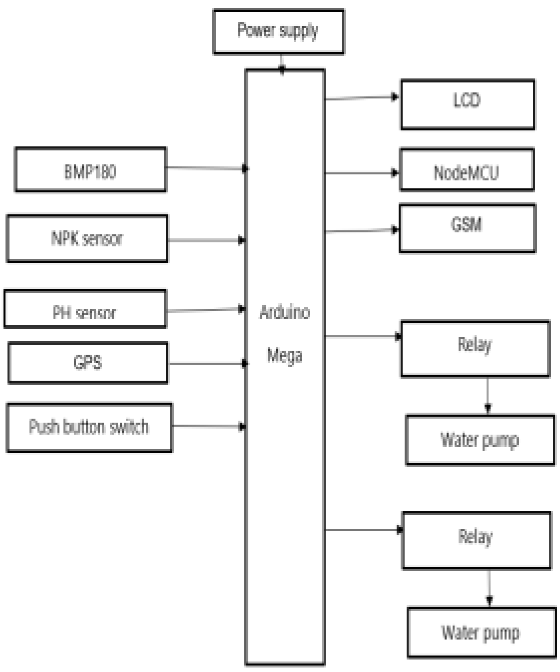

Fig.1: Block diagram of proposed system

5. IMPLEMENTATION AND RESULTS

The Fig.2 shows the complete hardware setup of the proposed smart assistive system designed for visually impaired users. email during emergencies when the alert button is pressed. The system is implemented using IoT sensors and machine learning algorithms. Soil parameters are collected using sensors and stored in the dataset. Machine learning models are trained using agricultural data.

Random Forest, SVM, and KNN algorithms are applied to predict crop recommendations. The voting ensemble method combines predictions and produces final result.Experimental results show that the voting ensemble model provides higher accuracy compared to individual algorithms. The system improves crop selection and helps farmers increase yield.

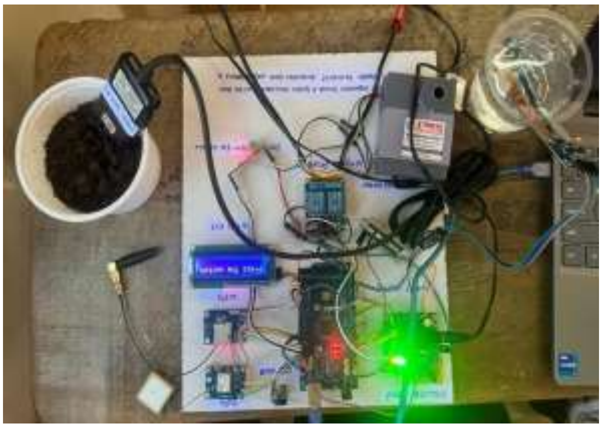

Fig.2: Hardware set up of proposed system

The proposed system is implemented using a combination of hardware sensors and a microcontroller-based setup integrated with machine learning. An Arduino board acts as the central controller, interfacing with multiple sensors such as the NPK sensor for soil nutrients, a pH sensor for soil acidity, and additional modules for environmental parameters. A GPS module is used for location tracking, while a GSM module enables communication. The collected data is displayed on an LCD screen, and a relay module is used to control external devices like a water pump. All sensor values are continuously monitored, processed, and sent for machine learning-based prediction, forming a hybrid IoT and ML-based smart farming system.

The output is displayed on the LCD, guiding farmers in selecting suitable crops and managing irrigation effectively. The relay-based automation helps in controlling water supply, reducing manual effort. Overall, the system improves decision-making, increases efficiency in resource usage, and demonstrates better accuracy compared to traditional methods, making it a reliable solution for smart agriculture. The developed system demonstrates an efficient integration of IoT and machine learning for smart agriculture. By combining real-time sensor data with models like SVM, KNN, and Random Forest, it provides accurate crop recommendations and supports better farming decisions.

Fig.3: Object identification and returning the object name

Fig.4: Emergency Alert Email Containing GPS Location

6. DISCUSSION

The proposed system shows a significant improvement over traditional crop recommendation methods by integrating real-time data collection with machine learning techniques. The use of multiple models like SVM, KNN, and Random Forest helps in improving prediction accuracy, as each algorithm contributes differently to the final decision.

However, the system also has some limitations. The accuracy of predictions depends on the quality and size of the training dataset, and sensor calibration plays a crucial role in obtaining reliable data. Environmental factors and hardware constraints may affect performance in real-world conditions. Despite these challenges, the system demonstrates strong potential for further enhancement, such as integrating cloud storage, mobile applications, and advanced deep learning models to make it more robust and scalable for large-scale agricultural use.

7. CONCLUSION

The proposed system successfully integrates IoT and machine learning to develop a smart crop recommendation solution. By utilizing sensors to collect real-time data on soil nutrients, pH, temperature, and humidity, the system provides accurate and timely crop suggestions using models like SVM, KNN, and Random Forest. This approach enhances decision-making, reduces manual effort, and optimizes the use of resources such as water and fertilizers.

Overall, the system proves to be more efficient and reliable compared to traditional methods. It has the potential to improve agricultural productivity and support farmers in achieving better yields. With further improvements like cloud integration and mobile-based monitoring, the system can be expanded into a more advanced and scalable smart farming solution.

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