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IoT and AI-based Plant Monitoring System

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Abstract

Plants play a vital role in the environment because it provides health support through absorbing the carbon dioxide and releasing the oxygen to the atmosphere. Although, it is required to maintain the proper plant growth and health as well as provide the appropriate monitoring. To overcome these concerns, an Artificial Intelligence (AI) and Internet of Things (IoT) based solution is proposed to monitor the plant's growth and health. This study demonstrates the real-time monitoring of the plants via environmental sensors such as DHT 11 and soil moisture sensors. Real-time values stored in the cloud server and applied the machine learning models to predict the plant's growth. The Statistical parameters such as RMSE, MAE are used to analyze the resulting outcome from the system.

Keywords

Internet of Things

Plant monitoring,

Artificial Intelligence,

Smart Technology,

DHT11

1. Introduction

Plants play an essential role in conserving the ecological cycle and maintaining the pyramid of the food chain [1]. The rapid advancement of technology has reshaped and refined every aspect of the human lifestyle, especially the agriculture industry. These days, people prefer to stay connected with the internet while doing their regular activities such as watching television, cooking, etc. There are dozens of beneficial technologies introduced in the agriculture industry; the Internet of Things (IoT) and Artificial Intelligence are the real game-changers [2]. In developing countries such as Asia and southeast Asia, people live through hunger from food shortages [3]. In addition, nearly 10 million people died only from insufficient food supply. The amount of food production has reduced because farmers still prefer traditional technology instead of the latest technology and gadgets. To meet the demands of regular food, some people liked to do farming in their gardens. IoT and AI technology can help to overcome this highlighted issue. The concept behind IoT technology is to set up mutual communication between the devices via the internet. It is a vast network that connects people and different connected things to collect and share data. The connected devices have in-built sensors that are associated with IoT platforms to access the data from the devices and apply the different analytics to achieve and present valuable information from the device's data. Author [4] proposed an IoT-based solution for the plant monitoring system. The parameters used in this study are temperature, humidity, and intensity of light. Moreover, stored in the cloud server can be accessed through the smartphone. Tangworakitthaworn [5] presented a game-based learning system for plant monitoring. The proposed method is categorized into three parts: 1) real-time plant caring 2) learning based on the game platform and IoT technology. The experimental setup is used to monitor and analyze the satisfaction of the learner. In [6], a remote monitoring system is introduced that is further integrated with the IoT technology to monitor the plants' soil moisture. The main objective behind this research to elaborate the lifetime of the network and algorithm used in this study to achieve that outcome are exponential weighted moving average (EWMA). Pavel [7] introduced IoT-based solutions to classify the plant's diseases and monitor real-time parameters such as air temperature, humidity, pH, soil moisture, and an update in the MySQL database. Support vector model (SVM) model is deployed to classify the color features, shape, and texture. Authors [8] deployed the smart home automation technology in the water system of the plants. The mainboard used in the system is ESP8266, an in-build Wi-Fi module to set up communication with another device. IoT system's ability is limited up-to monitor and storage of real-time data. However, data analysis is not up to the mark with only IoT systems. AI techniques can overcome these highlighted issues, and a combination of the AI and IoT-based plant monitoring system provides a detailed extraction and analysis of collected data. Singh [9] presented AI integrated IoT solution to increase the yield in crop production. This study is categorized into two parts: 1) collecting data via IoT network and 2) applying six machine learning models. Moreover, the real parameters used in this study are atmospheric humidity, temperature, soil moisture, soil temperature, and light intensity. Ragavi [10] proposed AI sensors integrated with IoT application that helps to monitor the crop field. The sensors deployed in this study are optical sensors, electrical sensors, HTE mix sensors. Bhanu [11] presented an IoT solution to monitor crop yield through the atmospheric temperature, humidity, soil moisture, and soil temperature. Email-based service deployed in answer to alert the farmers about any mishappening that occurs. Machine learning algorithms such as Naive Bayes classification are also used to analyze the collected data from the cloud server. There are many IoT, and AI solutions proposed to monitor the actual condition of the plants. In this study, a hybrid approach based on AI and IoT is proposed that helps to monitor the real-time condition for the plants and predict these parameters through the statistical parameters used in this study. The main contribution of this study as follows:

- Design and Developed IoT based real-time plant monitoring system.
- Two different machine learning models are applied for the prediction.
- Real-time cloud servers such as ThingSpeak are used to collect and store IoT data.
- Statistical parameters were used to monitor the performance of the applied model.

The paper's organization is as categories: Section 2 discusses the machine learning model used, Section 3 represents the architecture of the system. Section 4 describes the results and discussion, and Section 5 concludes the paper.

2. Artificial Intelligence Models

a. Artificial Neural Network (ANN)

Artificial Neural Network (ANN) [12] is an AI research domain using machine learning. [13] started research towards ANN and presented a mathematical model of the establishment and refinement of neuronal activities in the brain. [14] illustrated the learning procedure of the human brain with the use of reinforcement learning. The main purpose behind the research in the domain of ANN is to construct a machine learning-based system that can study and analyze the bioelectrical activities and biological model of the brain. ANN architecture for supervised learning is presented as follows (Figure 1). ANN architecture is categorized into four different layers: Input Layer, Hidden Layer, Optional Layer, and Output Layer. The input layer consists of input elements that represent the independent variables. In the hidden Layer, weighted connection is set up between the nodes in the adjacent layer and also works as a processing layer. Optional layers are the hidden processing layer used for extra processing if required. Output layer consists of more than one layer to represent or show the dependent layer. In the given architecture, every input element is associated with all other processing elements in the hidden layer and further connected repeatedly until it reaches the output layer. These elements take some value called a weight that helps to adjust the learning in the network. In addition, ANN works as an intelligent recognition network machine [15].

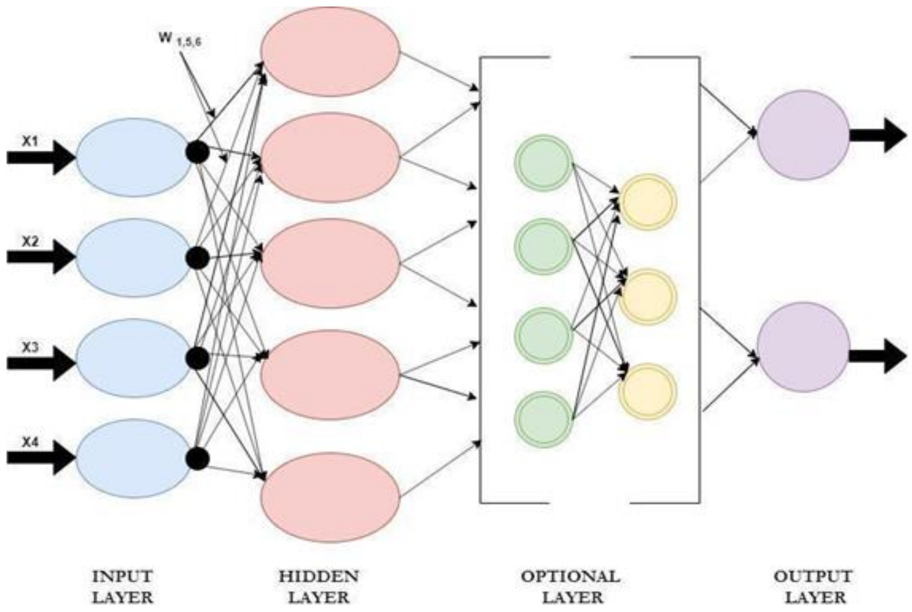

Figure 1. Architecture of ANN

b. Support Vector Machine (SVM)

Support vector machines (SVM) [16] are the models based on supervised learning that is associated with learning algorithms that provide a useful pathway to analyse data based on classification and regression analysis. The success behind the SVM [17] [18] as follows:

- With a minimum number of features, the ability of SVM is more as compared to other model techniques;
- Model robustness is more as compared with the error of model;
- The computational time of SVM is less as compared to the other models’ techniques such as neural network and SVM efficiency is more as compared to other models.

SVM architecture (Figure 2) is categorized into three different layers: 1) Input Layer 2) Hidden Layer 3) Output Layer. Layer 1 or input layer consists of training instances that are connected to the hidden layer for processing the prediction of learning and are further connected to the output layer with biasing input variables [19].

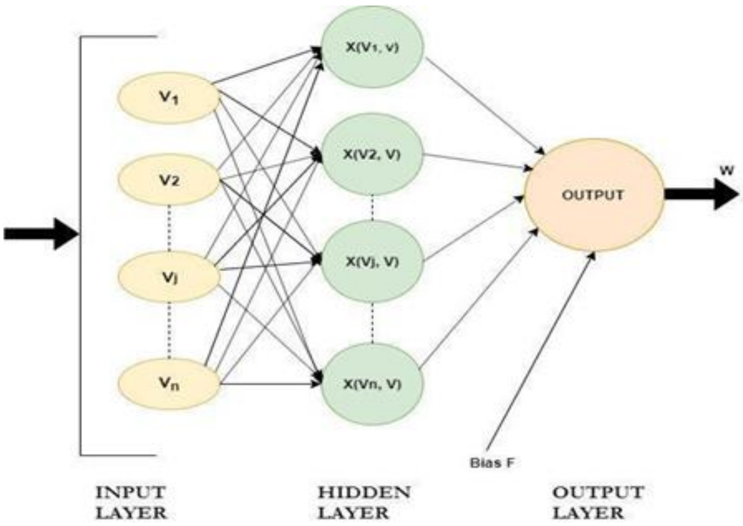

Figure 2. Architecture of SVM

3. Methodology

In this section, architecture of the proposed solution is discussed as follow (see in figure 3):

- Sensors: In this study, two different sensors are used to monitor three environmental parameters such as atmospheric temperature, humidity and soil moisture. The sensors are discussed as follow:

  a. **DHT11:** The DHT11 [20] is a combined temperature and humidity sensor. The sensor is equipped with the dedicated negative temperature coefficient for the temperature measuring. This sensor is pre-calibrated from the manufacturer and ready to interface with any processing unit. It is enough to measure the temperature and humidity from 00 C to 500C and 20% to 90% respectively.

  b. **Soil Moisture Sensor:** Soil moisture [21] is used to measure the moisture present in the soil. This sensor has two metallic pad works as a probe for the sensor as well as acts as a variable resistor. These two long pads conduct a percentage of the water inside the soil. More water means more conductivity between the pads, less resistivity and higher voltage is out from the sensor.

- Processing Unit: The processing unit is the major component in any kind of IoT system. It is used to fetch the data from the sensors, then process into valuable and readable form and lastly it helps to transfer into cloud or other devices via bluetooth or WiFi communication. In this study, ESP32 [21] is the main processing unit that helps to capture the sensor's data, then processed and sent to thingspeak cloud.

- IoT Cloud Server: ThingSpeak [22] is an open source IoT platform that provides their API to send, store and fetch data through the use of MQTT and HTTP protocol. The main services provided by the ThingSpeak platform are multi sensor data logging, providing GPS coordinates and social network of things.

- Artificial Intelligence Models: There are two AI models used in this study i.e. ANN and SVM (discussed in Section 2).

- Evaluation Parameters: In this study, Performance evaluation of the models is performed using statistical methods such as Root Mean Square Error (RMSE), Mean Absolute Error (MAE). MAE and RMSE provide the error of the model used for training. In addition, this evaluation technique values directly depend on model selection capability such as small value means the model is as good and performs better. These statistical methods are calculated from equations (1) and (2)

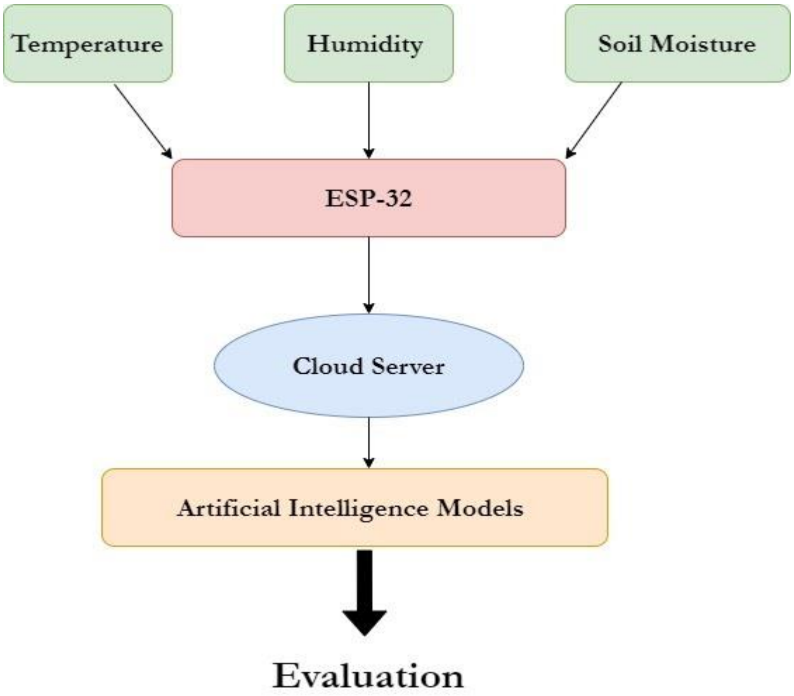

Figure 3. Architecture of Proposed Solution

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{K=1}^{N}(X_A - Y_A)^2}, \quad (1)$$

$$\text{MAE} = \frac{1}{N}\sum_{K=1}^{N}|X_A - Y_A|, \quad (2)$$

where X and Y are actual and predicted values.

4. Results and Discussion

In this section, results achieved from the experiment are discussed. Figure 4 represents the developed module to fetch the data from the sensors, processed and registered every value at ThingSpeak cloud.

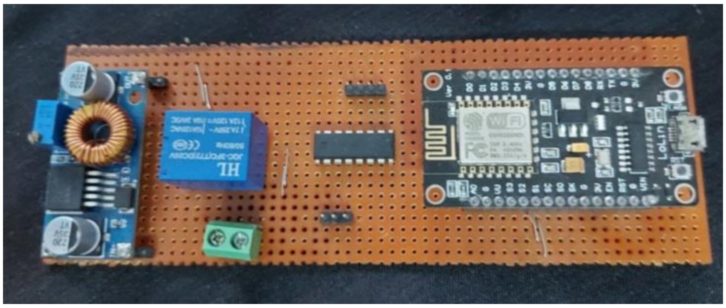

Figure 4. Developed module

Figure 5 represents the data registered at the ThingSpeak cloud. In this study, three different variables such as atmospheric temperature, humidity and soil moisture are used. Figure 6 represents the deployed module on the real time environment to collect the data for the further analysis.

Figure 5. Collected Data at ThingSpeak from different sensors

Figure 6. Deployed final product

Data is retrieved from the ThingSpeak cloud. Applying the pre-processing techniques to remove the unwanted values or blank values. In the next step, preparing dataset for splitting between train and test sets. Two different models such as ANN and SVM are applied to the prepared dataset. The dataset is based on the timeseries include atmospheric temperature, humidity and soil moisture variable and dataset split into 80:20 for train and test set respectively. RMSE value for the ANN and SVM are 27.2198 and 42.1498 and MAE value for the ANN and SVM are 31.9681 and 34.9675 respectively.

5. Conclusion

Plants play an essential role in our daily lifestyle and sustain our ecological lifestyle. It is mandatory to maintain their proper growth and sufficient amount of water for their healthy life. An intelligent plant monitoring system is developed in this study, which is enabled with IoT and AI technology. Three essential parameters such as atmospheric temperature, humidity, and soil moisture are real-time measured and sent to the cloud server for further analysis. Two different machine learning models namely ANN and SVM were deployed in this study. To analyse the machine learning models, two statistical parameters are used, such as RMSE and MAE

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