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# Intelligent and Smart Irrigation Control System Using IoT Technology for Smart Farming Application

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## Abstract

The increasing global population and demand for food production have necessitated more efficient water management in agriculture. Traditional irrigation methods, often based on fixed schedules, are inefficient, leading to water wastage and suboptimal crop yields. This paper presents an intelligent and smart irrigation control system using Internet of Things (IoT) technology, which enables real-time monitoring and precise control of irrigation based on environmental conditions. The proposed system integrates sensors for soil moisture, temperature, humidity, and light, which are connected to a central microcontroller. Data collected by these sensors can be processed using machine learning algorithms, specifically the K-Nearest Neighbors (KNN) algorithm, to determine the optimal irrigation schedule. The system features a mobile application for remote monitoring and control, enhancing the flexibility and efficiency of agricultural water management. Field tests demonstrate that the system effectively monitors soil moisture content, temperature and humidity from the field test.

**Keywords:** Internet Of Things; Irrigation; Soil Moisture; Humidity, Machine Learning.

## Introduction

Water management in agriculture is a critical concern given the growing global population and the increasing demand for food production. Traditional irrigation methods, often based on fixed schedules or manual controls, are inefficient and can lead to significant water wastage and suboptimal crop yields. In many regions, over-irrigation leads to waterlogging and soil degradation, while under-irrigation stresses plants, reducing productivity (Elgaali et al. 2023).

Advances in technology have opened new avenues for improving irrigation practices. The Internet of Things (IoT) technology, in particular, offers a transformative approach by enabling real-time monitoring and control of irrigation systems. IoT involves the interconnection of various devices and sensors that collect and transmit data, allowing for intelligent decision-making and automation (Abdelgawad and Yelamarthi 2017).

A smart irrigation control system using IoT technology integrates multiple components, including soil moisture sensors, weather sensors, temperature and humidity sensors, flow meters, microcontrollers, communication modules, actuators, and cloud platforms. This system collects real-time data from the field, processes it using advanced algorithms, and executes precise irrigation schedules based on the analysed data. Such a system not only optimizes water usage but also enhances crop health and productivity. The implementation of IoT-based smart irrigation systems has several benefits which include; water conservation, increased crop yield, cost savings, remote monitoring, and data-driven decisions (Geetha and Gouthami 2017).

Several studies have reported on the design and implementation of IoT-based smart irrigation systems. Hamdi et al. (Hamdi et al. 2021) introduced a system utilizing soil moisture sensors and weather data to automate irrigation processes, enhancing water use efficiency. Similarly, Viyaj et al. (Vijay, Vishal, and College 2015) discussed an IoT-based smart irrigation system that uses sensor data to manage water resources efficiently, highlighting its effectiveness in reducing water wastage. Kiani et al. (Kiani and Seyyedabbasi 2018) proposed a system that employs WSNs and IoT technology for precision agriculture. Their system demonstrated significant improvements in water conservation and crop productivity by leveraging real-time environmental data. This approach underscores the importance of robust communication networks in enabling real-time data collection and decision-making. Saleheen et al. (Saleheen et al. 2022) developed a smart agriculture monitoring system that uses various sensors to collect environmental data. Their system analyzes this data to determine optimal irrigation times, resulting in better water management and improved crop health. Kumar et al. (Kumar, Ranjan, and Saini 2022) further emphasized the role of real-time data in automating and optimizing irrigation, thereby reducing human intervention and enhancing system efficiency.

This paper presents a detailed study of smart irrigation control systems using IoT technology. It outlines the system's architecture, describes its implementation, and discusses the results obtained from field tests. In addition, this paper proposes that the system can be integrated with a machine learning algorithm—specifically, the K-Nearest Neighbors (KNN) algorithm—to determine the appropriate amount of water to be used based on soil conditions. The soil conditions are categorized as dry, moderately dry, wet, and very wet. By incorporating this algorithm, the system aims to enhance water efficiency and reduce operational costs, thereby contributing to sustainable agriculture.

## Proposed architecture implementation

The proposed IoT-based smart irrigation system architecture is designed to optimize water usage in agricultural settings through the integration of advanced sensors, communication modules, and automated controls. Key components of the system include various sensors; temperature, humidity, soil moisture, and weather sensors. These sensors collect critical real-time environmental data. This data is processed by a central microcontroller, such as an Arduino that serves as the system's brain. The microcontroller communicates with an IoT server using a GSM module, enabling remote data transmission and system control. Figure 1 shows the proposed system architecture.

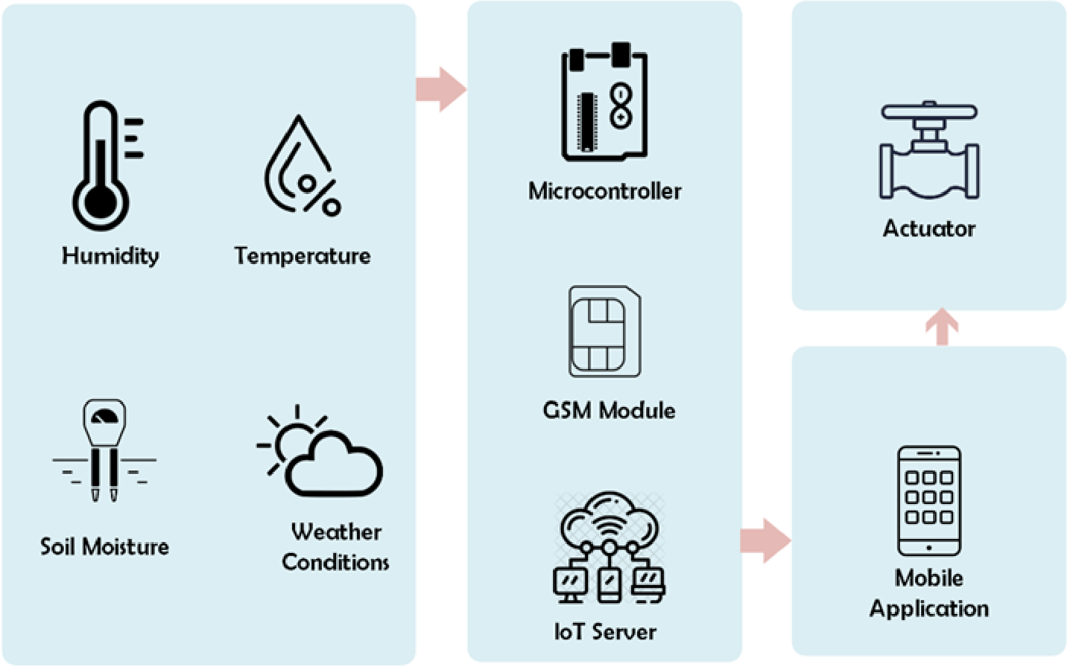


*Figure 1. Proposed System Architecture*

The IoT server acts as the central hub for data storage, processing, and analysis. It employs sophisticated algorithms and machine learning models to analyze the collected data and determine the optimal irrigation schedules. Based on this analysis, the server sends commands back to the microcontroller, which then activates the actuators, including valves and pumps, to deliver precise irrigation. This automated decision-making process ensures that irrigation is based on accurate, real-time data, leading to efficient water usage and enhanced crop health.

In addition to automated control, the system includes a mobile application that provides farmers a user-friendly interface for monitoring and managing the irrigation system. The app allows users to view real-time and historical data, receive alerts and notifications, and manually override automated decisions if necessary. This remote monitoring capability enhances convenience and flexibility, enabling farmers to respond promptly to changing environmental conditions.

### Implementation of the Proposed System

The IoT-based smart irrigation system operates by continuously collecting real-time environmental data through various sensors, including those for temperature, humidity, soil moisture, and weather conditions. The system is implemented using an Arduino UNO (ATmega328p) central microcontroller to aggregate and process data. The microcontroller transmits the data to an IoT server using a GSM module (SIM808) for wireless communication. On the IoT server, advanced algorithms and machine learning models analyze the data to determine the optimal irrigation schedule, considering both current conditions and historical trends. The server sends control commands back to the microcontroller, which activates or deactivates actuators like valves and pumps to manage water flow precisely. A mobile application provides farmers with real-time monitoring, alerts, and manual control options, enabling them to manage the system remotely. Figure 2 shows the complete flowchart algorithm for the smart irrigation system.

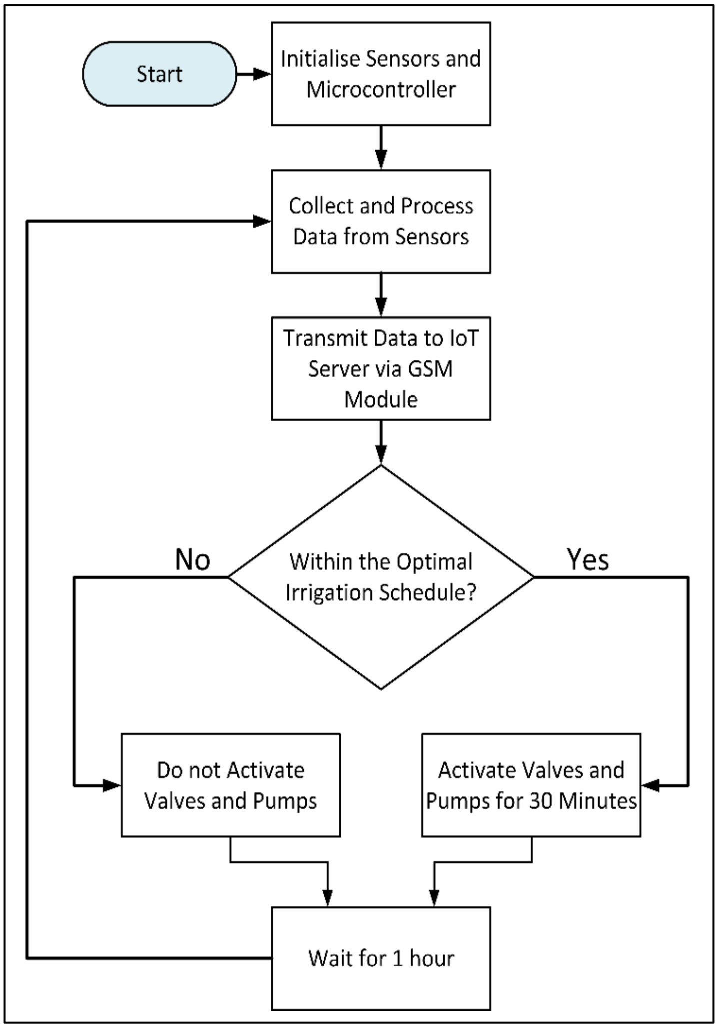


*Figure 2. Flowchart of the System*

The proposed system architecture comprises several key components such as a soil moisture sensor, humidity/temperature sensor, and light sensor. The details are described in the following.

*AM2302 DTH11 Sensor*: The AM2302 (DHT11) sensor is a digital sensor designed for measuring temperature and humidity with moderate accuracy and low cost. It operates within a temperature range of 0°C to 50°C with an accuracy of ±2°C and a humidity range of 20% to 80% with an accuracy of ±5%. The sensor provides a digital signal output via a single-wire bus, simplifying the connection to microcontrollers. It requires a power supply of 3.3V to 5.5V and has a sampling rate of one reading per second (1Hz). The AM2302 (DHT11) is well-suited for basic environmental monitoring applications, offering reliable performance and ease of integration into various IoT projects. Figure 3 shows the DTH11 temperature and humidity sensor.

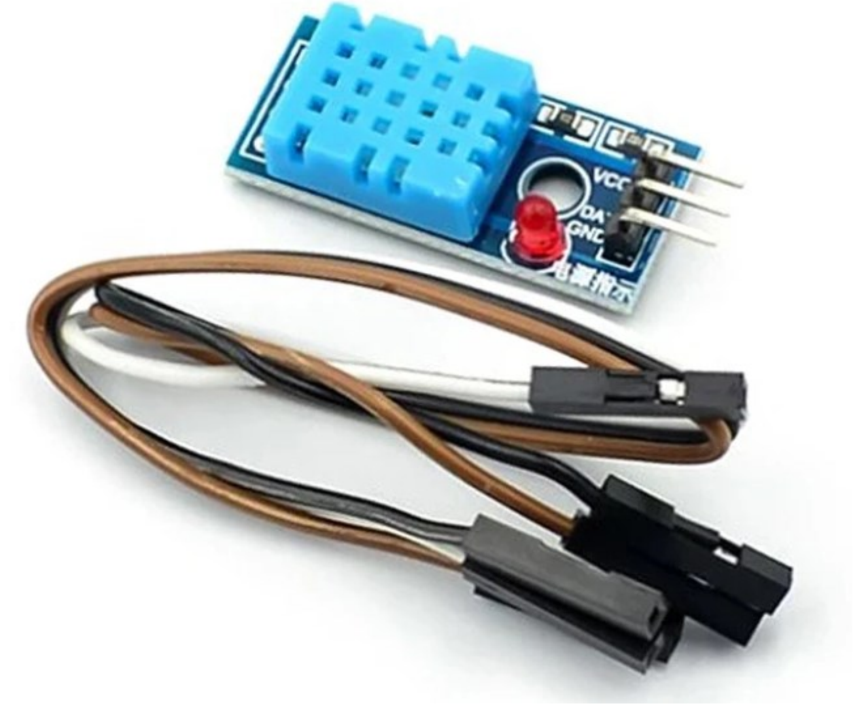


***Figure 3. Temperature and humidity sensor***

*HL-69 Soil Hygrometer Sensor:* The HL-69 Soil Hygrometer Sensor is designed to measure soil moisture levels with precision and reliability. It features two corrosion-resistant metal probes that detect moisture by measuring the electrical resistance between them, producing an analog output signal proportional to the soil's moisture content. Operating at a voltage range of 3.3V to 5V, the sensor is easy to integrate with microcontrollers such as Arduino and Raspberry Pi. It provides real-time analog data that can be used to monitor and manage irrigation systems effectively. The sensor's durability and straightforward setup make it ideal for various agricultural applications, ensuring optimal soil moisture for healthy plant growth and efficient water use. Figure 4 shows the HL-69 soil hygrometer sensor.

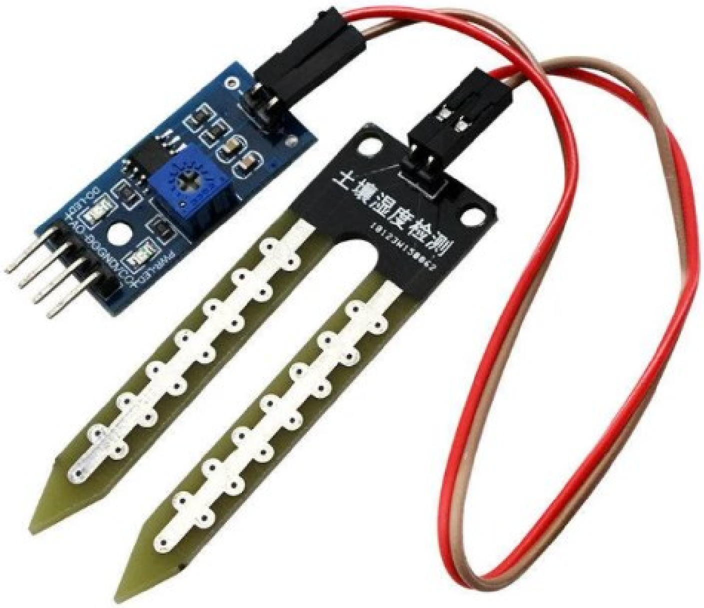


*Figure 4. Moisture sensor*

*BH1750 FVI Light Sensor:* The BH1750 FVI Light Sensor is a high-precision digital sensor designed to measure ambient light intensity across a wide range of 1 to 65535 lux. It operates efficiently at a power supply voltage of 2.4V to 3.6V, making it suitable for energy-sensitive applications. The sensor outputs digital data via the $I^2C$ communication protocol, ensuring precise and reliable data transfer. It features high resolution, capable of detecting very low light levels, and low power consumption, which is ideal for continuous monitoring in IoT applications. These characteristics make the BH1750 FVI Light Sensor an excellent choice for integrating into smart irrigation systems and other applications where accurate light measurement is critical. The Soil Moisture sensor (HL-69) is inserted into the soil which senses the moisture level of the soil. The DHT11 sensor senses the surrounding humidity and temperature. The Motor Driver controls the water pump. The above-mentioned components are connected to the ATmega382p which is a microcontroller unit. It is connected to the cloud environment through SIM808 to store the data. An app is developed which helps in controlling and monitoring the respective parameter values of moisture, temperature, and humidity. Based on the soil moisture level the pump turns ON or OFF automatically. These parameters are finally displayed in a dashboard on the device screen. The proposed smart IoT system which employs some sensors to gather data from the environment is shown in Figure 5.

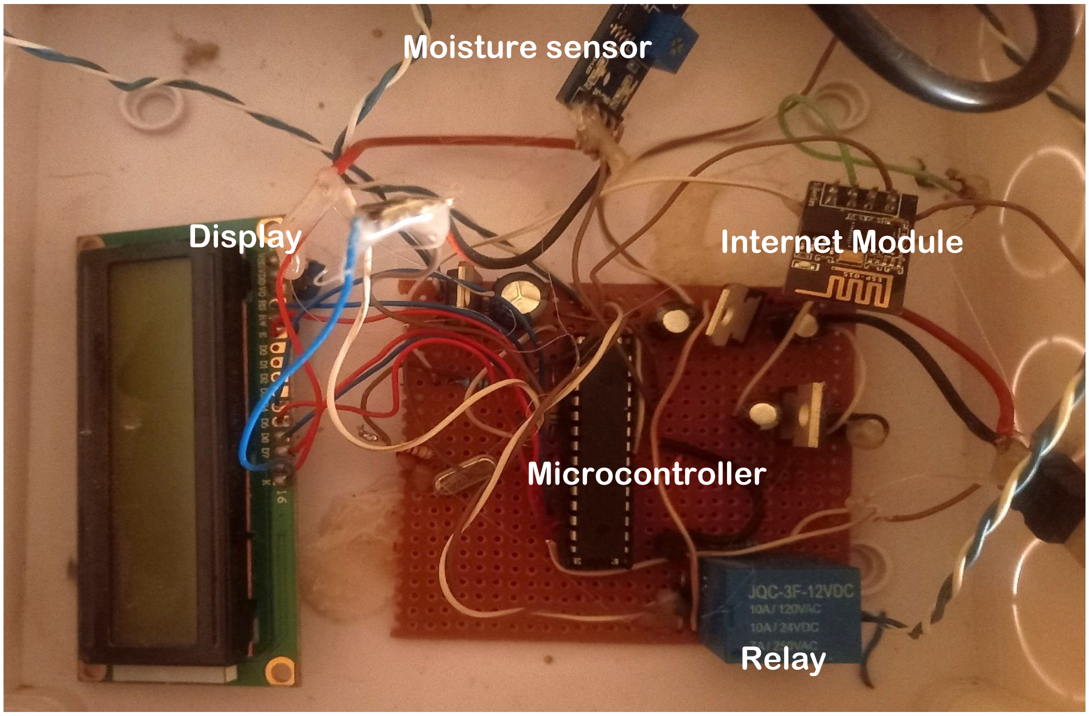


*Figure 5. Hardware prototype*

The water requirement level can be predicted using machine learning techniques, specifically the K-Nearest Neighbors (KNN) algorithm. KNN is a type of supervised learning method that uses the entire dataset to predict the outcome for a new, unseen data instance. The algorithm works by identifying the "k" closest neighbours within the dataset that are most similar to the new data point. This similarity is determined by comparing the new instance with all existing data. For example, if "k" is set to 3, the algorithm will consider the three most similar neighbours and assign the most frequent class label among them to the new data instance.

The Euclidean distance between new data $X$ (3 features involved to predict the resultant class, $A$, $B$, $C$) and each existing point $P_n$ in the input dataset is given as:

$$Euclidean\ distance = \sqrt{(XA - PA)^2 + (XB - PB)^2 + (XC - PC)^2} \quad (1)$$

The system is fully automated, with sensor data collected from the field being processed based on the trained machine-learning model. This model is developed using characteristic sensor values. Table 1 outlines four categories: highly needed, needed, average, and not needed, which correspond to different levels of soil moisture detected by the HL-69 hygrometer, as well as temperature and humidity levels measured by the AM2302 DHT22 sensor. The AM2302 DHT11 sensor measures humidity in the air from 20% to 80% and temperature from 0°C to 50°C.

**Table 1. Sensor data class**

| Soil Moisture (%) | Temperature ($^0$ C) | Humidity (%) | Class |
|---|---|---|---|
| **< 30** | > 40 | <30 | Highly Needed |
| **30–40** | 35–40 | 30–40 | Needed |
| **41–60** | 25–34 | 41–60 | Average |
| **61–80** | 20–24 | 61–80 | Not needed |

A Semantic Data Model (SDM) is developed to incorporate and manage real-world data effectively. It utilizes logical layers to categorize concepts and assess information. By using propositional logic systems within an ontology, informed decisions can be made based on the extracted results. Our ontology includes concepts for predicting water requirements based on soil nature based on dry, moderately dry, wet and very wet. These parameters form structured data, allowing us to query the ontology and make decisions based on this information. The architecture of our decision support system is illustrated in Figure 6. It provides information on the nature of the soil and determines its watering requirements by leveraging soil ontology.

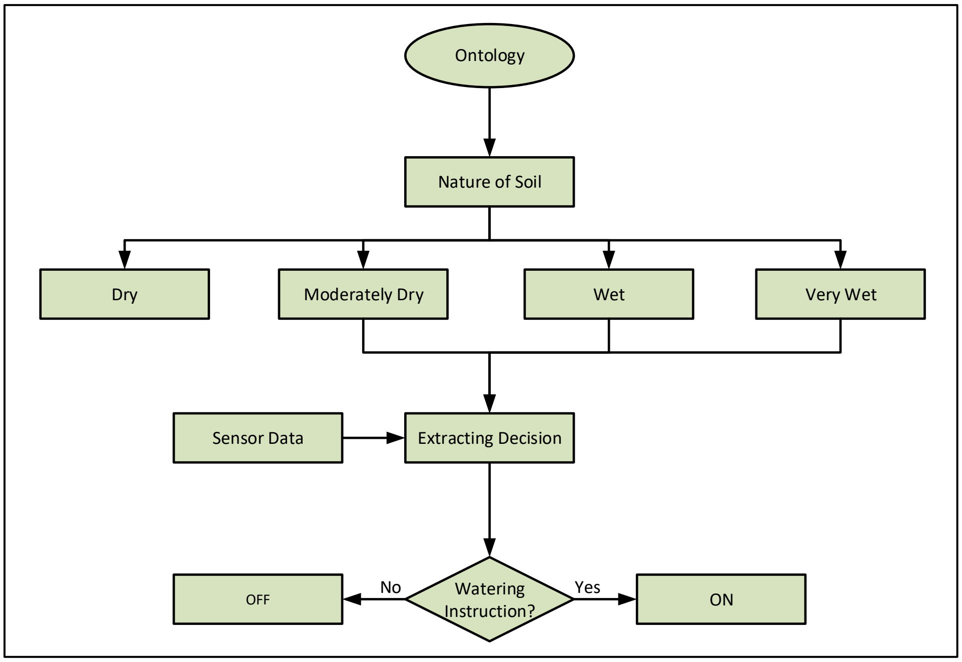
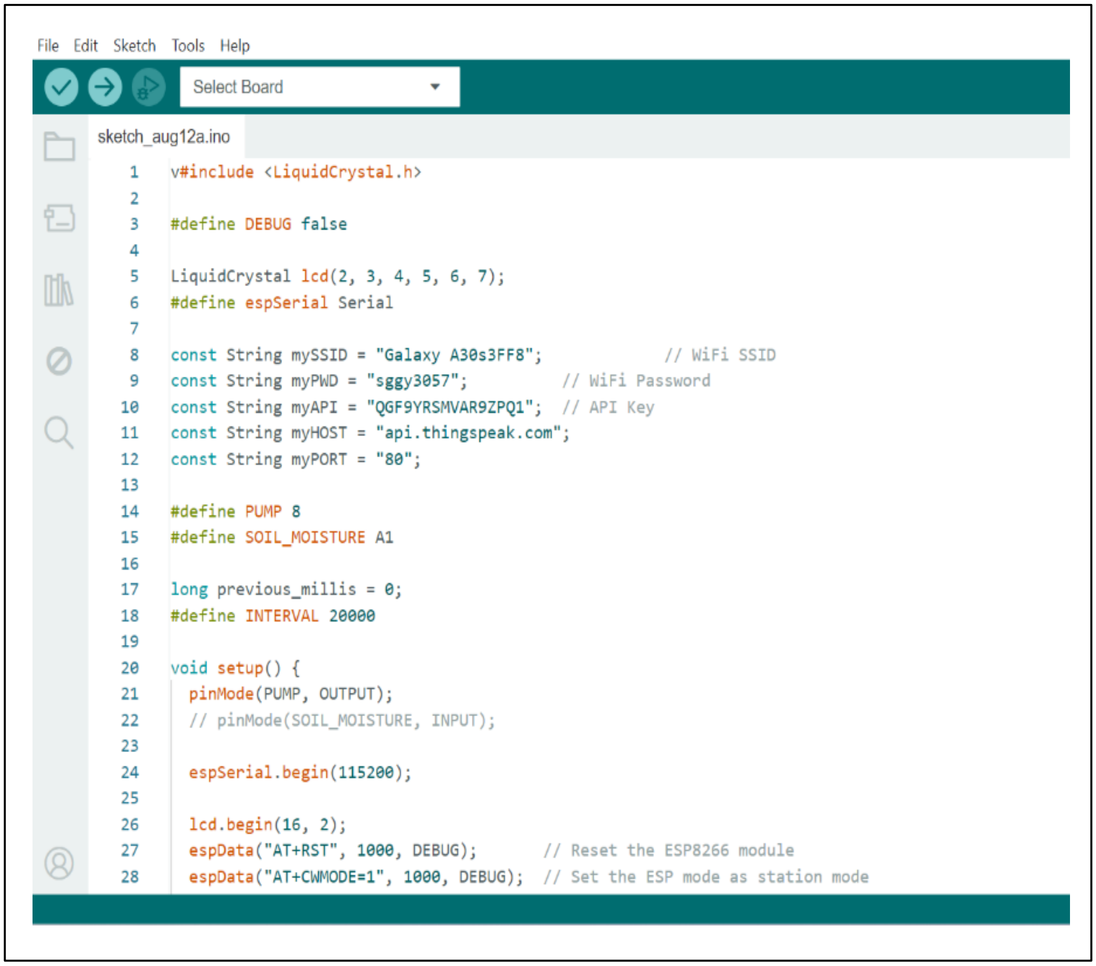


*Figure 6. Inference rule*

## Results and discussion

In the process of deploying the trained model and sensor data, we define routes to where an HTTP request is handled. The data travels in the system from one side (perception layer) to the other. The code shown in Figure 7 is responsible for sending the sensor data from the sensor-Arduino side to the processing layer section. A link is also established where data on temperature, humidity, and soil moisture are transferred.



```
v#include <LiquidCrystal.h>

#define DEBUG false

LiquidCrystal lcd(2, 3, 4, 5, 6, 7);
#define espSerial Serial

const String mySSID = "Galaxy A30s3FF8";             // WiFi SSID
const String myPWD = "sggy3057";         // WiFi Password
const String myAPI = "QGF9YRSMVAR9ZPQ1";  // API Key
const String myHOST = "api.thingspeak.com";
const String myPORT = "80";

#define PUMP 8
#define SOIL_MOISTURE A1

long previous_millis = 0;
#define INTERVAL 20000

void setup() {
  pinMode(PUMP, OUTPUT);
  // pinMode(SOIL_MOISTURE, INPUT);

  espSerial.begin(115200);

  lcd.begin(16, 2);
  espData("AT+RST", 1000, DEBUG);      // Reset the ESP8266 module
  espData("AT+CWMODE=1", 1000, DEBUG);  // Set the ESP mode as station mode
```

Figure 7. Code for sensing sensor data

Figure 8 illustrates the sensor data collected during a sample test run using the provided code. Figure 8(a) displays soil moisture levels recorded by the HL-69 sensor in the test section, while Figures 8 (b) and (c) show the temperature and humidity values recorded in the section by sensor DTH11. As depicted in the graphs, when the soil moisture falls below 40%, water is supplied to the corresponding section until the moisture content starts to rise.

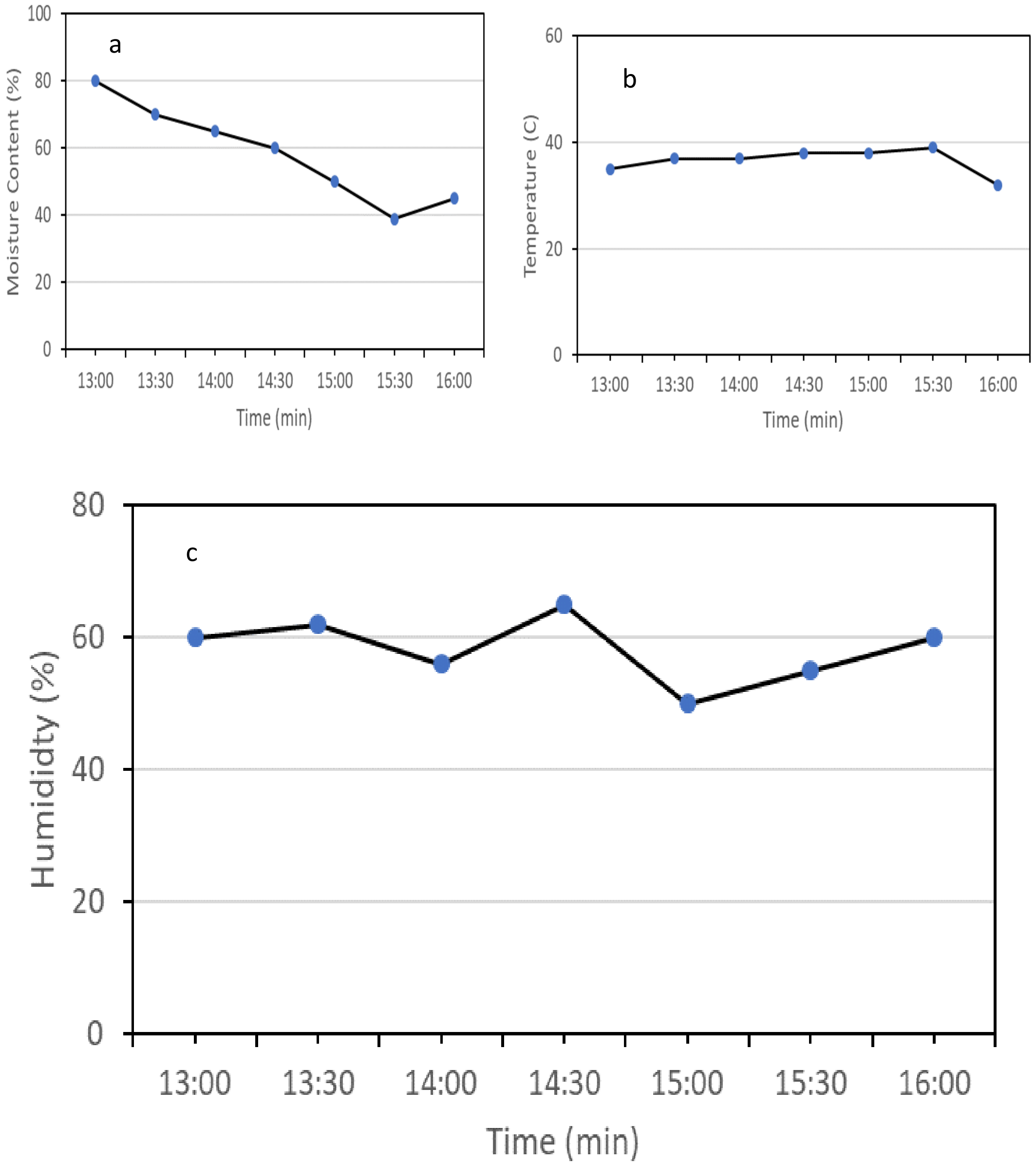


*Figure 8. (a) Soil moisture (b) Temperature and (c) Humidity rate*

A mobile platform is provided to the farmers parameters such as the condition of the soil, temperature, humidity and soil moisture can be put on view in a dropdown, and users can select from these and send the command to the device in the field. Codes for these parameters can be transferred from the mobile application interface to the server to which ontology is attached. Decision extracted from the ontology section along with the sensor values then reaches the main IoT server where the machine learning algorithm (Table 2) can be installed.

***Table 2. Algorithm for the amount of water***

| | |
|---|---|
| **Step 1** | **Input;**<br>**Soil Conditions – Dry, Moderately Dry, Wet, Very Wet** |
| **Step 2** | Threshold:<br>Check the threshold for soil conditions |
| **Step 3** | Decision process;<br>Check soil conditions and apply decision |
| **Step 4** | Output;<br>Amount of water to apply |

## Conclusion

In conclusion, the intelligent and smart irrigation control system using IoT technology offers a significant advancement in agricultural water management. By integrating real-time environmental data with machine learning algorithms, the system optimizes water usage, enhances crop health, and reduces the need for manual intervention. Implementing the K-Nearest Neighbors (KNN) algorithm can further refine irrigation schedules, ensuring that water is applied efficiently based on specific soil conditions. The remote monitoring and control capabilities provided by the mobile application add to the system's versatility, allowing farmers to respond promptly to changing conditions. Field tests confirm the system's effectiveness in monitoring soil moisture, temperature, and humidity. As such, this IoT-based smart irrigation system represents a promising solution for addressing the challenges of modern agriculture and promoting sustainable farming practices.

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## References

Abdelgawad, Ahmed, and Kumar Yelamarthi. 2017. "Internet of Things (IoT) Platform for Structure Health Monitoring." *Wireless Communications and Mobile Computing* 2017. https://doi.org/10.1155/2017/6560797.

Elgaali, Elgaali, Jamil Al Titi, Ahmed Ismail, and Omer Alhajri. 2023. "Smart Irrigation System Using Arduino." *2023 Advances in Science and Engineering Technology International Conferences, ASET 2023*. https://doi.org/10.1109/ASET56582.2023.10180638.

Geetha, S., and S. Gouthami. 2017. "Internet of Things Enabled Real Time Water Quality Monitoring System." *Smart Water* 2 (1): 1–19. https://doi.org/10.1186/s40713-017-0005-y.

Hamdi, Mohammed, Asif Rehman, Abdullah Alghamdi, Muhammad Ali Nizamani, Malik Muhammad Saad Missen, and Muhamamd Ali Memon. 2021. "Internet of Things (IoT) Based Water Irrigation System." *Int. J. Online Biomed. Eng.* 17 (5): 69–80. https://doi.org/10.3991/IJOE.V17I05.22081.

Kiani, Farzad, and Amir Seyyedabbasi. 2018. “Wireless Sensor Network and Internet of Things in Precision Agriculture.” *International Journal of Advanced Computer Science and Applications* 9 (6): 99–103. https://doi.org/10.14569/IJACSA.2018.090614.

Kumar, Amit, Praful Ranjan, and Vaibhav Saini. 2022. “Smart Irrigation System Using IoT.” *Advanced Series in Management* 27 (March): 123–39. https://doi.org/10.1108/S1877-636120220000027009/FULL/XML.

Saleheen, Md M.U., Md S. Islam, R. Fahad, Md J.B. Belal, and Riasat Khan. 2022. “IoT-Based Smart Agriculture Monitoring System.” *4th IEEE International Conference on Artificial Intelligence in Engineering and Technology, IICAIET 2022*. https://doi.org/10.1109/IICAIET55139.2022.9936826.

Vijay, V, H Vishal, and Easwari Engineering College. 2015. “Regulation of Water in Agriculture Field Using Internet Of Things.” *IEEE International Conference on Technological Innovations in ICT for Agriculture and Rural Development (TIAR 2015)*, no. Tiar: 112–15. https://doi.org/10.1109/TIAR.2015.7358541.