SMART IRRIGATION SYSTEM

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***Abstract*—The Internet of Things (IoT) has revolutionized various industries by introducing smart technology. One such industry is agriculture, where IoT has the potential to contribute to the economic growth of any country. In particular, automated irrigation systems have become crucial for farmers as they allow remote monitoring of water requirements. The aim of this study is to develop a precise crop water requirement monitoring system and irrigation prediction using Machine Learning Algorithms. The Smart Irrigation System presented in this research paper integrates temperature and soil moisture sensors with RFID (Radio-Frequency Identification) tags for plant identification, coupled with logistic regression for data processing and analysis.Machine Learning models including Decision Tree, K-Nearest Neighbour, Random Forest, and Logistic Regression are employed to analyze the data and accurately predict irrigation needs. Among these models, the Logistic Regression Model demonstrates an impressive accuracy of 95%, a precision of 93.75%, and a recall of 100%.**

***Index Terms*—Smart Irrigation System, IoT (Internet of Things), Temperature Sensor, Soil Moisture Sensor, RFID Tags, Logistic Regression,NodeMCU,Edge Computing.**

I. Introduction

The agricultural sector in India is crucial for the country's economic growth and nation-building. However, many farmers encounter challenges such as small land holdings, harsh weather conditions, and limited access to technology. Often, farmlands are located far from farmers' residences, making it difficult to monitor crops and prevent intrusions.

The success of crop production is heavily dependent on irrigation and varying climatic conditions, which can lead to crop spoilage due to inadequate water supply. To address these issues, the implementation of smart monitoring and protection techniques is essential. Predictive tools can help optimize irrigation practices and safeguard crops from water-related problems. By utilizing machine learning algorithms, farmers can accurately predict the best time for irrigation, ensuring better crop yields.

Smart Irrigation Systems are a significant advancement in agricultural technology that utilize IoT sensors, data analytics, and automation to revolutionize water management in farming practices. In the past, irrigation in traditional agriculture relied on manual methods or basic timer-based systems, which often led to inefficiencies, water wastage, and suboptimal crop yields. However, with the increasing challenges posed by climate change, water scarcity, and the need for sustainable agricultural practices, the adoption of smart irrigation systems has gained prominence as a solution to address these issues.

The concept of smart irrigation is based on the understanding of the crucial role water plays in crop growth and productivity. By integrating various technologies, smart irrigation systems can monitor and manage water resources more effectively, ensuring that crops receive the appropriate amount of water at the right time. These systems utilize sensors such as temperature sensors, soil moisture sensors, and RFID tags to collect data on environmental conditions, soil moisture levels, and plant characteristics. This data-driven approach enables precise and targeted irrigation, minimizing water usage while optimizing crop health and yield.

The concept of smart irrigation systems originated from the convergence of advancements in sensor technology, data analytics, and automation. It signifies a significant shift from reactive irrigation methods to proactive and intelligent water management strategies. The rise of IoT has played a crucial role in enabling seamless connectivity between sensors, actuators, and control systems, enabling real-time monitoring and control of irrigation processes.

When compared to traditional manual farming practices, smart irrigation systems offer numerous benefits. They reduce labor costs associated with manual irrigation, minimize water wastage, enhance crop quality and yield, and support sustainable farming practices. Moreover, the integration of predictive analytics and machine learning algorithms, such as logistic regression, enhances decision-making capabilities, enabling optimized irrigation schedules based on data-driven insights.

A. Motivation

The need for smart irrigation systems is underscored by several factors. Firstly, water scarcity is a pressing global concern, especially in arid and semi-arid regions where agriculture heavily relies on irrigation. Smart irrigation systems offer a means to conserve water by avoiding overwatering and dynamically responding to changing soil conditions and weather patterns. Secondly, conventional irrigation methods often result in uneven water distribution, leading to issues such as waterlogging, soil erosion, and nutrient leaching. Smart irrigation technologies address these challenges by providing uniform water distribution and promoting efficient water usage.

B. Objectives

Within this research paper, we present a comprehensive study on the development and implementation of a Smart Irrigation System that utilizes temperature sensors, soil moisture sensors, RFID tags, and logistic regression for data processing and analysis. The primary objective of this system is to showcase the effectiveness of smart irrigation in conserving water, improving crop productivity, and promoting sustainable agricultural practices.

II. Related Works

A. Existing Work

The utilization of a Soil Moisture Sensor, Arduino, and machine learning algorithms such as Decision Tree and KNN is employed. The Soil Moisture Sensor is responsible for detecting the moisture level in the soil and transmitting this information to the Arduino. Subsequently, the Arduino forwards this data to the External Cloud for analysis, utilizing machine learning algorithms like Decision Tree and KNN. Once the data has been processed, the microcontroller emits a signal to activate or deactivate the water pump, depending on the outcome provided by the algorithms.

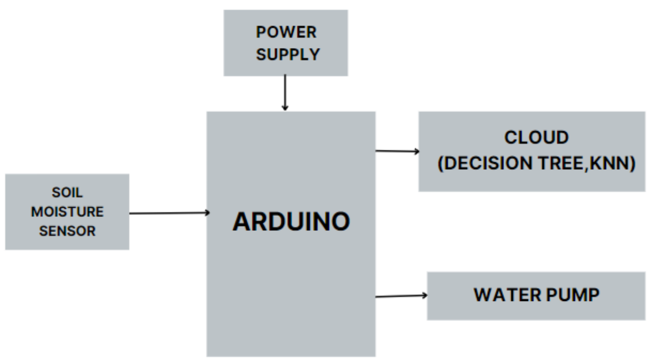

Fig. 1. Architecture of Existing Work

B. Drawbacks

Arduino boards usually come with restricted resources, including limited RAM and flash memory and arduino boards frequently need extra modules or shields to incorporate connectivity features like Wi-Fi or Bluetooth.External Cloud is used for data processing instead of Edge Computing which results in increased time for data transfer and required actions to be performed.Usage of decision trees which can be susceptible to overfitting, particularly when they are intricate and deep. This implies they might excel on the training data but struggle with new, unseen data.Decision trees might face challenges in capturing intricate nonlinear connections between features and the target variable.

III. Methodology

A. Sensors

Sensors are the fundamental components that capture data from the physical world, ranging from temperature and humidity sensors to more specialized ones like soil moisture sensors in agriculture or heart rate monitors in healthcare. These sensors provide real-time information that is crucial for making informed decisions and optimizing processes.Sensors play a vital role in gathering essential data about environmental conditions such as soil moisture levels, temperature, and humidity. These data points are then processed and analyzed to determine the optimal watering schedules for crops, ensuring efficient water usage and maximizing crop yield. For instance, temperature sensors can help in identifying temperature variations that impact plant growth, while soil moisture sensors provide insights into soil conditions for better irrigation management.

B. Edge Computing

Edge computing refers to the paradigm of processing and analyzing data closer to its source, typically at the edge of the network where data is generated. This approach is introduced as a response to the growing need for real-time data processing, reduced latency, and enhanced reliability in various applications. Unlike traditional cloud computing, where data is sent to centralized servers for processing, edge computing brings computation capabilities closer to the devices or sensors that collect the data, minimizing the time and bandwidth required for data transmission.

One of the key advantages of edge computing is its ability to handle data processing tasks locally, without relying solely on distant data centers. This is particularly beneficial in scenarios where real-time decision-making is critical, such as in IoT (Internet of Things) applications, smart cities, healthcare systems, industrial automation, and, notably, in agricultural systems like smart irrigation.

C. Components

1) Soil Moisture Sensor: The Soil Moisture sensor quantifies the water content by assessing the permittivity of water in the soil through capacitance measurement. Subsequently, the moisture data is transmitted to the microcontroller unit for analysis and generation of essential signals.

2) Temperature Sensor: Temperature sensor is used to measure the temperature of the environment of the field. A Popular temperature sensor that can be used in a smart irrigation system with a NodeMCU is the DS18B20 digital temperature sensor. This sensor is widely used in IoT applications due to its accuracy, digital output, and ease of integration with microcontrollers like the NodeMCU. The DS18B20 sensor communicates over a one-wire interface, which means it requires only one pin on the NodeMCU for both power and data communication. This makes it convenient for connecting multiple sensors to the NodeMCU without using too many pins.

3) RFID Tags: RFID (Radio-Frequency Identification) tags or chips can be attached to individual plants. Each tag contains a unique identifier that corresponds to specific information about the plant. RFID readers installed in the irrigation system can read the tags as plants move within range. The readers capture the unique identifiers from the tags and transmit this data to a central control system or database.

4) NodeMCU: NodeMCU is a microcontroller which is often used for IoT (Internet of Things) projects due to its built-in Wi-Fi connectivity and relatively low cost. It can be used in a smart irrigation system to automate and optimize the process of watering plants based on various factors such as soil moisture levels, temperature, and plant types. This can control actuators such as pumps that regulate the flow of water to the plants. When it determines that irrigation is required based on the sensor data, it activates the appropriate pumps to start watering. Machine Learning Algorithms are used here to analyse the incoming data and send the appropriate signals to the microcontroller.

5) Relay: Within a smart irrigation system, a relay serves as a mechanism that regulates the electrical flow to turn on or off irrigation elements like pumps, valves, or sprinklers. It functions as a remote-controlled switch operated by the software or sensors of the intelligent system. This automated process plays a crucial role in enhancing water efficiency and preservation in agricultural or garden environments.

6) Thingspeak: Thingspeak provides a platform for IoT devices to gather, analyze, and display data instantly. It is suitable for monitoring and managing different aspects of irrigation in a smart system. Devices like NodeMCU, with sensors like soil moisture and temperature sensors, collect environmental data crucial for irrigation. The sensor data is stored in Thingspeak's cloud database.

7) Blynk Application: Blynk is a well-known IoT platform that enables users to develop personalized mobile applications for managing and overseeing IoT devices and projects. It offers a user-friendly interface and a variety of features that make it ideal for integrating with smart irrigation systems. The application can present real-time information, including soil moisture levels, temperature, plant names, and water flow status. With Blynk, users have the ability to remotely monitor and control their smart irrigation system from anywhere as long as they have an internet connection.

They can easily check sensor statuses, activate or deactivate irrigation pumps or valves, and make adjustments on the move using the mobile app. Blynk also supports push notifications and email alerts, ensuring that users promptly receive notifications regarding critical events such as low soil moisture levels or excessive water. This feature greatly aids in timely intervention and maintenance of the smart irrigation system.

8) Machine Learning: Machine Learning(ML) is a subset of Artificial Intelligence(AI) that are classified into supervised learning, unsupervised learning.Many Algorithms like Decision Tree,Random Forest,KNN were used for the analysis of the data but the results were better when Logistic Regression is used to predict.Logistic regression is a statistical method used for binary classification tasks, where the goal is to predict the probability that an instance belongs to a particular class (e.g., yes/no, true/false, 1/0). It's widely used in various fields such as machine learning, statistics, and data analysis.

Logistic regression uses the logistic (or sigmoid) function to map the linear combination of input features to a probability score.

D. Architecture

In this work of Smart Irrigation System,a NodeMCU is used with input Temperature,Soil Moisture Content and Type of Plant.Temperature Sensor measures the temperature of the atmosphere of the field.Soil Moisture sensor estimates the amount of water content of the soil.RFID tags helps in identifying the type of plant.Leveraged Edge Computing for efficient processing i.e. the data is processed in the microcontroller itself instead of transferring the data to cloud which helps in reducing latency and faster results.Trained the model with Logistic Regression to enhance accuracy.

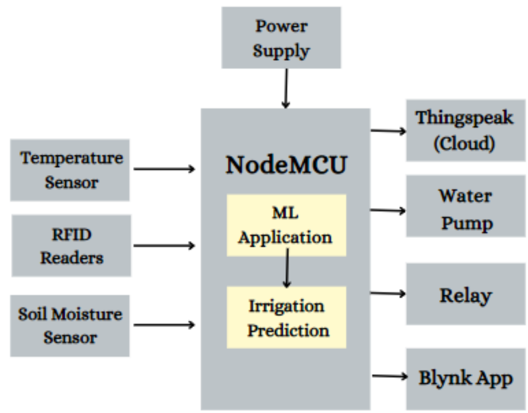

Fig. 2. Architecture of Proposed Methodology

E. System Workflow Overview

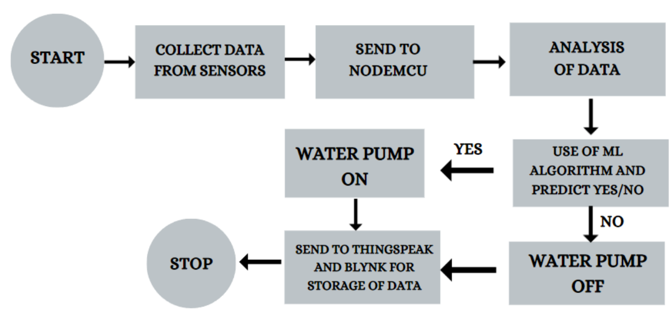

Fig. 3. Flowchart of Working Model

The temperature sensor, soil moisture sensor, and RFID tags are utilized to collect the data. Subsequently, the data is transmitted to NodeMCU for analysis through machine learning algorithms. Based on the analysis, a decision is made whether to water or not, and a signal is sent to activate the pump. The collected data is then sent to ThingSpeak Cloud and Blynk App from NodeMCU using its built-in WiFi module, where it is stored. The connected sensors gather data at regular intervals of 1000 milliseconds.

IV. Results

Logistic regression offers several advantages over decision trees, random forests, and k-nearest neighbors (k-NN) and it can handle large datasets efficiently, especially compared to k-NN, which requires storing the entire dataset for prediction. Logistic regression's computational complexity is generally lower, making it more scalable for large datasets. and is less prone to overfitting.In this model,we have achieved 95% Accuracy with 93.75% Precision and 100% Recall.

ARCHITECTURE	ACCURACY(%)	PRECISION(%)	RECALL(%)
DECISION TREE	85.71	89.21	86.71
RANDOM FOREST	91.02	90.57	86.02
K-NN	93	91.36	97.8
LOGISTIC REGRESSION	95	93.75	100

Fig. 4. Comparision Table

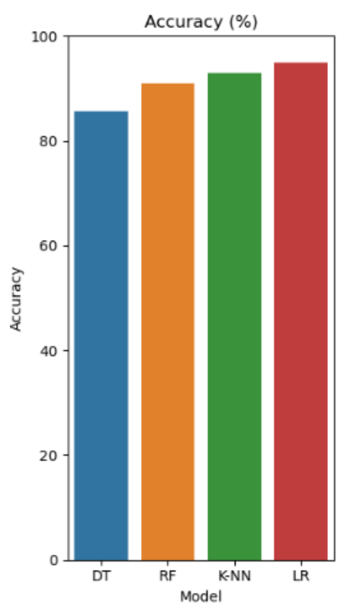

Fig. 5. Accuracy

The accuracy comparision for different models are depicted using a bargraph.Highest accuracy is achieved by Logistic Regression with 95% and the least by Decision Tree with 85.71%.

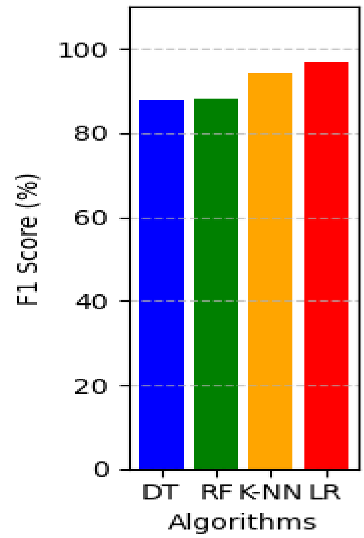

Fig. 6. F1 Scores

The above graph gives a detailed picture of how F1 Scores are for the four different models.

Set of these 4 algorithms are applied by considering three parameters i.e type of plant,temperature and soil moisture. From the application of Logistic Regression algorithm, highest accuracy is obtained.In comparison,the accuracy of prediction is less by using Decision Tree and Random Forest model.K-NN predicts more accurately with 91% in comparison to Decision Tree and Random Forest whereas Logistic Regression model gives the highest accuracy with 95% in comparison with other three models on this work. So, Logistic Regression can be used for best prediction.

V. Conclusion

A Smart irrigation system has been developed utilizing NodeMCU as the microcontroller and sensors such as temperature and soil moisture to collect the necessary data. The incorporation of NodeMCU has enabled us to transmit the data to the cloud effortlessly, thanks to its built-in WiFi module. The collected data is then analyzed using a machine learning algorithm within the NodeMCU itself. This implementation of Edge Computing has significantly improved the speed of obtaining results. Through our experimentation, we have found that Logistic Regression yields the best results. Based on the algorithm's prediction, the water will be pumped accordingly. The pump will turn on or off based on the water requirement for the crops. The database will be stored in ThingSpeak, and users can access the data using the Blynk app.

VI. Future Scope

- The system has the potential to be enhanced by utilizing a more advanced microcontroller, such as RaspberryPi.
- To leverage a more advanced dataset, various cloud platforms like Microsoft Azure, AWS, etc. can be employed.
- The model can be trained to adapt to the updated data, ensuring its accuracy and effectiveness.

- In the future, this intelligent irrigation system can be applied not only in drip irrigation but also in Floriculture.
- For a more comprehensive approach to irrigation management, it is advisable to integrate additional sensors like humidity sensors, rain sensors, or light sensors to gather more detailed data.
- To optimize energy consumption within the system, implementing energy-efficient techniques such as sleep modes, low-power sensors, or solar-powered solutions is recommended.

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