

Smart Irrigation for Efficient Water Management in Agriculture

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Abstract:

This paper proposes the design, implementation, and evaluation of a smart irrigation system that utilizes IOT devices and machine learning to make decisions and also incorporates a multilingual web interface. The system is capable of monitoring environmental factors and making decisions based on the results of the data processed by the trained random forest model, which is used in making decisions in the system to automatically meet irrigation demands and hence reduce water waste and improve crop yield of essential crops such as rice, wheat, and cotton. The system is also efficient in operating offline, and the simulation mode is an added feature of the system. It is therefore clear from the results that the proposed system is an efficient and effective method of water management in agricultural activities.

Keywords: Smart Irrigation, Machine Learning, Internet of Things (IoT) – Soil, DHT11, Arduino, Random Forest, Precision Agriculture, Water Management, Less farmer effort, Sustainable Agriculture, Multilingual Interface.

I. INTRODUCTION:

1.1 Background and Motivation

The agriculture sector is the main consumer of fresh water, which is around 80% of the total fresh water consumption in India[6]. Telangana is a semi-arid region that is plagued with problems of drought, fluctuations in the monsoon season, and increased costs due to excessive irrigation. Current irrigation techniques are either time-based or farmer-intuition-based, which lead to problems of either crop stress or root rot[1].

The Internet of Things (IoT) and machine learning are the answer to the above problems, which involve sensing the environment, learning patterns using historical data, and making real-time irrigation decisions[9]. This project aims to bridge the gap between the above two extremes.

1.2 Objectives

- Implement a wired sensor network using Arduino UNO to sense temperature, humidity, and soil moisture
- Implement a Random Forest classifier on artificially generated data based on Telangana 2025 climate
- Implement automatic control of the relay-based water pump using ML
 - Implement a multilingual real-time web dashboard accessible from anywhere using any browser/device
 - Implement the feature of running in simulation mode without actual hardware

Recent studies on agriculture have highlighted the significant contribution of IoT sensors in the efficient management of irrigation systems. You can do this by considering the things like temperature, humidity, and soil moisture.

II. RELATED WORK:

Recent studies on precision agriculture depicts the importance of IoT sensors for effective and accurate irrigation management[8]. This can be achieved by the monitoring the live environmental conditions such as soil moisture content, temperature, and humidity. This is more efficient than the existing methods. Machine learning algorithms, especially the Random Forest algorithm, are widely used due to their high accuracy in prediction[2].

The existing solutions are mostly based on the cloud computing environment and are not accessible to the rural population[7]. This is where the proposed system is more efficient and accessible to the farmers.

III. PROPOSED SYSTEM:

A. Overview:

The proposed intelligent irrigation system based on IOT using machine learning algorithms that can help increase the efficiency of water consumption while farming(Irrigation) will be the most appropriate option[1]. As such, the proposed intelligent irrigation system based on IoT should use the Arduino Uno microcontroller and sensors for temperature, humidity, and moisture levels. Then, the gathered data from the sensors will be sent to the back-end system built with Python program through serial communication. Subsequently, the collected data is analyzed by the Random Forest classifier, and from there comes out a prediction on whether the machine will fail in the future or not[5]. Finally, this prediction is used to operate the water pump through the relay module.

B. System Architecture:

Smart Irrigation System incorporates a layer-based architecture having three key layers, including User Interface Layer, Field Device Layer, and Web Server Layer that function iteratively in a continuous loop.

User Interface Layer:

Farming personnel employ a smartphone or web-based application to obtain information on sensor reading, crop-related information, and pumping status. Administrator employs a dashboard interface to monitor the system performance and manage the configurations.

Field Device Layer:

Consists of a soil moisture sensor (for sensing the soil), weather API (for rainfall and climate data) and water pump (for irrigation execution).

Web Server Layer:

Functions as the brain of the system. Irrigation controller receives inputs from all the sources and passes on to the ML algorithm (Random Forest) to decide whether there is a need for irrigation[3]. Depending on the result, the decision is made to turn on/off the pump.

Storage of Data:

All information pertaining to sensors, prediction and water usage is stored for monitoring and analysis.

Flow of Data:

Sensors -> Controller -> ML Algorithm -> Decision -> Pump/User Interface -> Data Storage.

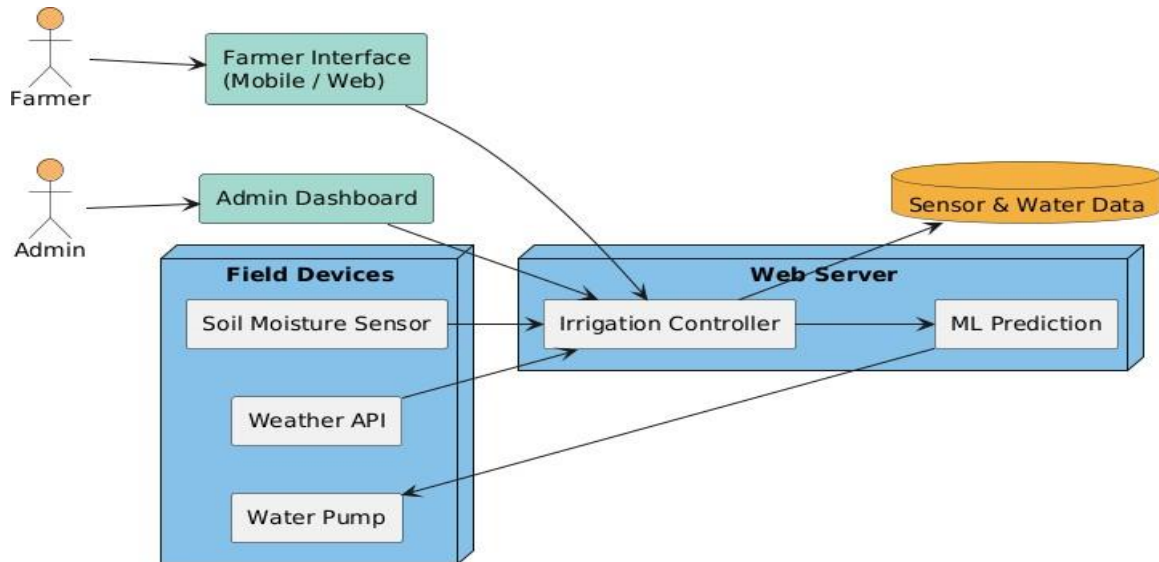


fig.1.System architecture

C. Data Collection Module:

The system constantly receives data regarding various environmental factors such as temperature, humidity, and moisture levels through the connected devices. The data is then processed by the Arduino UNO and sent in an organized way to the backend system for further steps.

Along with the sensors data, the system also gets data of crop type provided by the user(Farmer). Next, the data is preprocessed so that the machine learning algorithm can learn from it to process the data. The data that was collected will be kept for later analysis, which ensure that the predictions are correct and efficient.

IV. IMPLEMENTATION DETAILS:

A. Development Framework

The system has been set up using both hardware and software sides. For styling the frontend of the app, we used HTML, CSS, and JavaScript. For building the backend part of the application, we made use of Python programming language along with Flask framework[4]. We used the Random Forest classifier algorithm for prediction, which is an ensemble learning technique.

B. User Interface

The user interface of the application is a simple dashboard developed by using HTML and CSS. The dashboard will display the data of the sensors and the predictions. The application also includes multilingual support. The application will have a simple interface for the user.

C. System Operation

The application will read the data from the sensors and predict the requirements for irrigation. The application will activate or deactivate the pump based on the predictions made by the application. The application will operate in real time.

D. Testing and Performance

The application is tested for accuracy and reliability. The machine learning algorithm provides high

accuracy for predictions.

V. MODULE SPLIT-UP:

A. Sensor and Hardware Module

It is the job of this module to collect data from the sensors and then transmit it to the microcontroller.

B. Machine Learning Module

This module utilizes the Random Forest algorithm to predict the irrigation requirement based on the input data.

C. Web Dashboard Module

This module is responsible for the real-time interface using the browser.

D. Control Module

This module is responsible for controlling the water pump using the relay.

VI. ALGORITHM

Step 1: Initialize system and load model

Step 2: Read sensor data

Step 3: Preprocess inputs

Step 4: Predict irrigation requirement **Step 5:** Control pump based on prediction **Step 6:** Update dashboard

Step 7: Repeat continuously

VI. PSEUDO CODE:

BEGIN

INITIALIZE system LOAD ML model

WHILE system is running DO READ sensor data

GET crop input PREPROCESS data

prediction ← model output

IF prediction = irrigation required THEN TURN ON pump

ELSE

TURN OFF pump END IF

DISPLAY results END WHILE

END

VII. RESULTS:

The proposed system illustrates the effectiveness of real-time monitoring of the environment and machine-based irrigation systems using a machine learning algorithm for precise water control and minimization of water waste[2]. The proposed system is also user-friendly and accessible for farmers due to the inclusion of multiple languages and voice-based crop selection[7]. The experimental results of the proposed system illustrate the effectiveness of the proposed system for irrigation systems by providing water only when needed for better crop yield. The proposed system is a reliable and practical solution for smart agriculture.

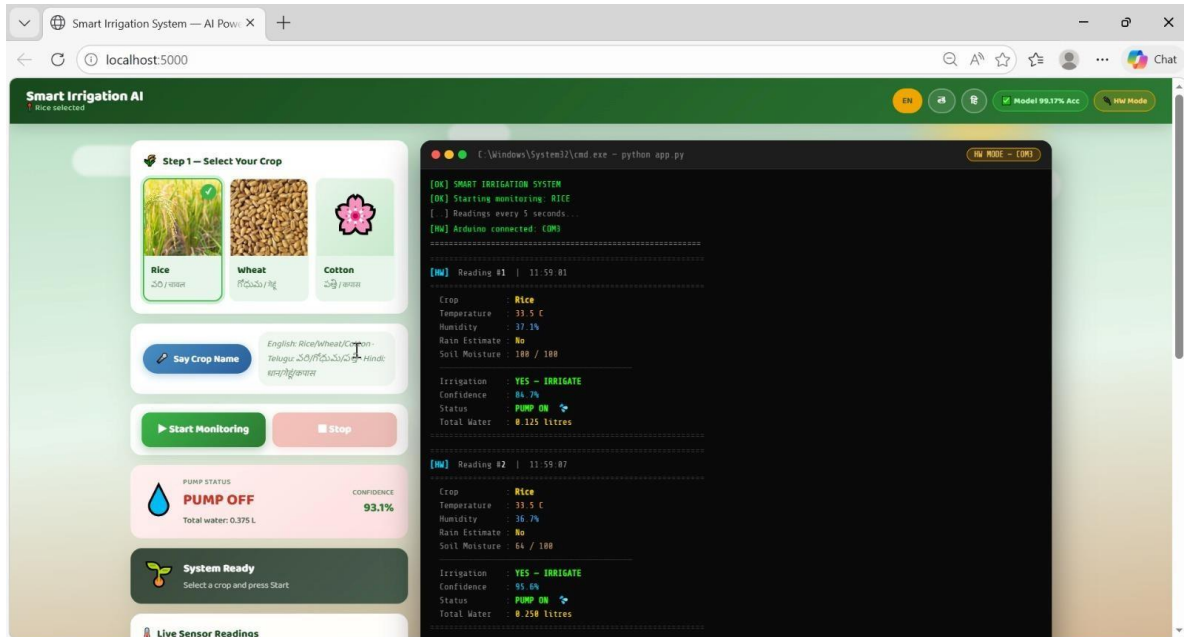


Fig.1. Intelligent Irrigation system interface showing crop selection and real time monitoring of sensor data.

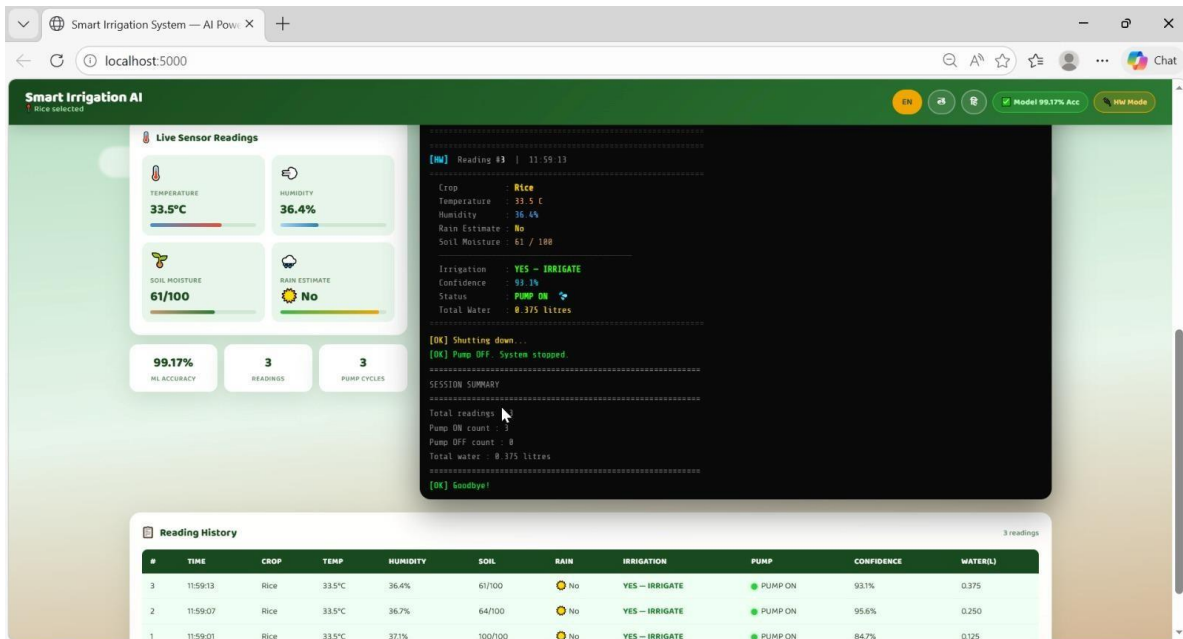


Fig.2. Dashboard for live monitoring of sensor data, irrigation status and data analysis.

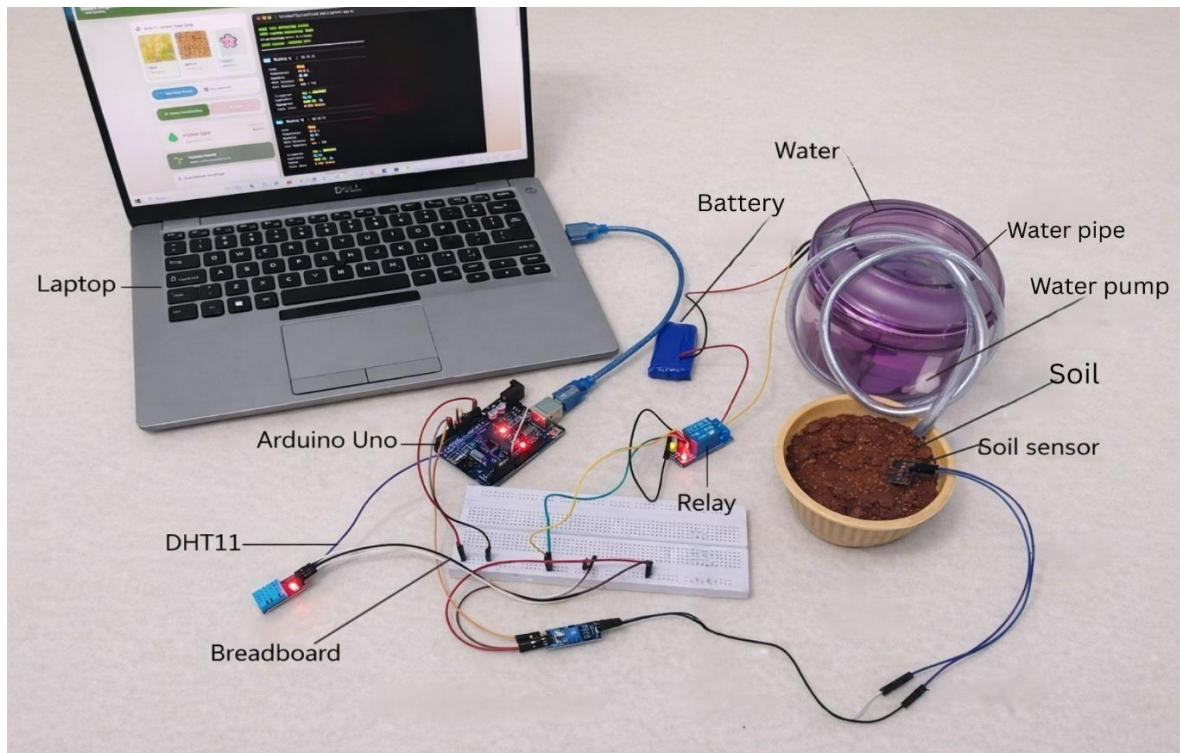


Fig.3. Arduino based plant watering system using soil moisture sensors and relays to control water pumps.

VIII. CONCLUSION:

The suggested smart irrigation system is an example of how IoT technology can be used in farming that is good for the environment and future purpose. It can help farmers to consume less water and get more done[9]. This will make the system very economical and capable of functioning independently, without the need for an Internet connection and without constant supervision by the farmer.

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