User-Friendly Agriculture System Control Using Mobile Application

Aasiya Jamadar[1], Heramba Koli[2], Jeevan Patil[3] , Pranoti Nage[4]

[1]*Student, Atharva College of Engineering, Dept. of Information Technology, Mumbai*
[2]*Student, Atharva College of Engineering, Dept. of Information Technology, Mumbai*
[3]*Student, Atharva College of Engineering, Dept. of Information Technology, Mumbai*
[4]*Professor, Atharva College of Engineering, Dept. of Information Technology, Mumbai*

Abstract - *A smart IoT-based irrigation system is designed and implemented to enhance water management in agriculture by utilizing real-time sensor data. The system automates irrigation processes, applying water precisely when required, and enabling efficient control through SMS-based remote monitoring. This innovative approach helps farmers manage water distribution effectively, reducing manual effort and preventing excessive water usage. By supporting sustainable agricultural practices, the system contributes to resource conservation and improved productivity.*

Key Words: **IoT irrigation, smart farming, water management, automation, SMS-based control.**

1. INTRODUCTION

Irrigation plays a crucial role in modern farming by ensuring crops receive the necessary water for optimal growth. However, many agricultural regions depend on unpredictable rainfall, which can lead to crop losses or reduced yields. To mitigate this, irrigation systems are employed to provide consistent and controlled water supply. Traditional methods, while effective to an extent, often demand significant labor and may result in excessive water use, particularly in areas facing water scarcity [1].

To address these issues, advanced embedded systems have been integrated into irrigation solutions. These systems enable precise and automated water delivery, ensuring crops receive the exact quantity needed at the right time, thus minimizing waste [7]. Moreover, combining these systems with mobile applications and SMS technology empowers farmers to monitor and manage irrigation remotely, offering greater flexibility and efficiency [8]. This innovative approach enhances resource utilization, boosts crop productivity, and reduces manual intervention.

2. NEED AND MOTIVATION

The growing global population has intensified the demand for food production, placing immense pressure on agricultural practices to improve efficiency. At the same time, the challenge of water scarcity has necessitated more sustainable water usage in farming. Conventional irrigation techniques often fail to address these challenges adequately, leading to significant water loss and higher labor demands [3].The adoption of embedded systems in irrigation aims to overcome these limitations by providing precise control over water management. Automation reduces reliance on manual labor while optimizing water use, ensuring that crops are irrigated efficiently [7]. Additionally, integrating mobile technology allows farmers to remotely monitor and manage irrigation processes, saving time and improving operational efficiency [8]. This technology-driven approach not only enhances productivity but also supports sustainable agricultural practices by conserving vital resources.

2.1 Basic Concept

The central concept of embedding automation in irrigation systems is to optimize water delivery using real-time data. Key components include sensors to measure parameters like soil moisture and temperature, and controllers that process this information to regulate water flow. The system applies water only when required, tailoring the amount to crop-specific needs.

Furthermore, the integration of mobile applications and SMS-based communication allows farmers to stay informed and make adjustments remotely. For instance, a farmer can modify schedules or deactivate the system during unexpected rainfall, preventing over-irrigation. This intelligent and automated approach reduces errors, conserves water, and supports better crop growth, ultimately leading to increased agricultural productivity.

3. LITERATURE REVIEW

Smart irrigation systems have gained significant attention as a solution for optimizing water usage and improving agricultural efficiency.

Sahu et al. [1] proposed a cost-effective smart irrigation control system that efficiently automates water management using basic electronic components and control logic. Inui et al. [2] introduced IoT technologies and a software development framework, emphasizing their transformative impact on agricultural applications. Reka et al. [3]developed an IoT-based smart greenhouse farming system, which leverages environmental sensors for optimized crop production.

Katyal and Pandian et al. [4] compared conventional and smart farming techniques, highlighting the superiority of IoT-enabled solutions in terms of water conservation and productivity. Krishnan et al. [5] introduced a fuzzy logic-based smart irrigation system that uses IoT to ensure efficient water usage, demonstrating its applicability in various agricultural contexts.

Recent research has focused on integrating IoT with cloud computing for real-time control and data analytics. Naeem et al. [6] presented a smart irrigation system utilizing IoT to enable remote monitoring and control, particularly in water-scarce regions. Similarly, Morchid et al. [7] designed an IoT-based smart irrigation management system that employs telemetry data and embedded systems to enhance agricultural water security. Et-taibi et al. [8] explored cloud and IoT-based architectures for improving water management, showcasing the effectiveness of such systems in precision agriculture.

Vallejo-Gomez et al. [9] conducted a systematic review of smart irrigation systems, identifying trends in sensor technology, communication protocols, and system scalability. Keerthana et al. [10] implemented an IoT-based automated irrigation system, demonstrating its potential in automating agricultural activities with minimal human intervention. Gamal et al. [11] provided an overview of smart irrigation systems, discussing their design considerations and impact on sustainable farming practices.

Wireless sensor networks (WSNs) have also played a pivotal role in advancing smart irrigation systems. Srivastava et al. [12] proposed a WSN and IoT-based smart irrigation system, showcasing its effectiveness in real-time environmental monitoring and control. Obaideen et al. [13] reviewed IoT-enabled smart irrigation systems, emphasizing their role in enhancing water-use efficiency and reducing operational costs. Tace et al. [14] combined IoT with machine learning to create an intelligent irrigation system capable of predicting water needs based on environmental and soil conditions.

The above studies collectively demonstrate the potential of IoT, WSNs, and machine learning in revolutionizing irrigation systems, making them more efficient, scalable, and sustainable.

4. METHODOLOGY

4.1 Objective and scope

The primary goal of this system is to deliver an efficient and automated irrigation solution that reduces water wastage and manual effort. The system integrates hardware and software to create a cost-effective, user-friendly platform accessible to farmers. Its scope encompasses hardware design, sensor integration, and software development to provide real-time control and monitoring.

4.2 Hardware Architecture

Microcontroller (ESP32): The ESP32 acts as the central processing unit, handling inputs from sensors and executing commands received through SMS or the mobile application. It triggers actions like activating the water pump or solenoid valve and supports GSM and WiFi communication for both local and remote operation.

230V to 5V Converter: Converts standard mains AC power (230V) to 5V DC to power low-voltage components, including the ESP32.

SMPS 24V 2A (Switch Mode Power Supply): Supplies stable 24V DC power to high-energy components such as the water pump and solenoid valve.

GSM Module (SIM800L): Provides SMS-based communication for remote control, ensuring functionality in areas without internet access.

WiFi Module (Integrated in ESP32): Enables real-time online communication by connecting to Firebase Realtime Database. This connection supports updates to motor and valve states and displays sensor data in the mobile app.

Relay: Functions as an electronic switch, controlling high-power devices like the water pump and solenoid valve based on microcontroller signals.

Optocoupler: Provides electrical isolation between high-voltage and low-voltage sections, protecting the microcontroller from potential power surges.

Water Pump: Pumps water to the fields, activated by the relay when irrigation is required.

Solenoid Valve: Regulates water flow, opening and closing as directed by relay activation.

DHT11 Sensor: Measures environmental conditions, such as temperature and humidity, providing data to optimize irrigation schedules.

Soil Moisture Sensor: Determines soil moisture levels, sending data to the microcontroller to inform irrigation decisions and automate water flow.

LED Indicators: Offer visual feedback on system states, such as power, data transmission, and activity.

2-Pin Connectors and Jumper Wires: Facilitate secure and flexible connections for sensors, modules, and components during prototyping and implementation.

Resistors and Capacitors: Protect components by limiting current, stabilizing voltage, filtering noise, and ensuring smooth operation.

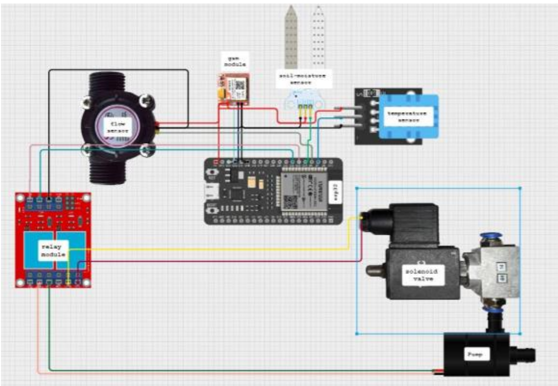

Fig -1: Circuit Diagram of the system

4.3. Software Architecture

Mobile Application:

User-Friendly Interface: A simple, intuitive interface allows users to send commands and monitor system status effortlessly.

Real-Time Monitoring: Displays sensor readings (e.g., soil moisture, temperature, humidity) and the operational status of the motor and valve.

Online Control: Synchronizes with Firebase for seamless functionality over WiFi.

Offline Control: Provides SMS-based command capability for areas without internet connectivity.

Firebase Realtime Database:

Data Synchronization: Ensures real-time updates between hardware and the mobile application.

Data Storage: Maintains records of sensor readings, actuator states, and user activity logs.

Scalability and Security: Supports future expansion and provides secure access with authentication and database rules.

Communication Logic

WiFi Communication: Enables the ESP32 to connect to Firebase for real-time updates and control.

SMS Communication: Allows the GSM module to process commands offline.

Control Flow and Decision:

Command Processing: Handles online commands fetched from Firebase and parses offline commands received via SMS.

Actuator Control: Activates the relay to control the water pump and solenoid valve based on user inputs or sensor data.

Sensor Data Feedback: Continuously collects data from sensors, updates the database, and displays it on the mobile application.

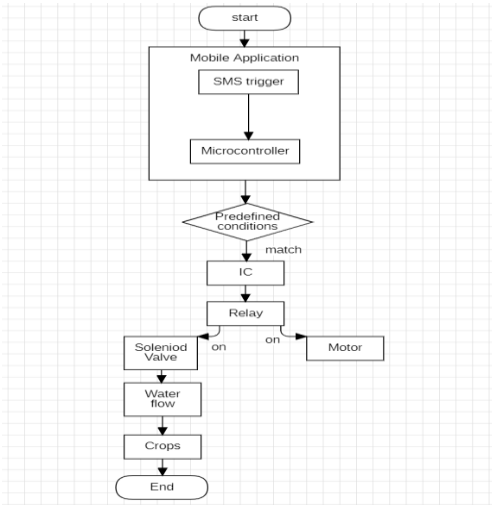

Fig -2: Control Flow Diagram

4.4. Implementation

The smart irrigation system enables users to control and monitor water flow to crops remotely through multiple communication methods and intelligent automation. The system is designed to enhance efficiency and ensure optimal water usage while providing additional functionalities for improved agricultural management.

1. SMS Control : In offline scenarios, users can operate the irrigation system by sending predefined SMS commands. The GSM module receives these commands and forwards them to the microcontroller for processing. The microcontroller evaluates the commands against predefined conditions and sends appropriate signals to the relay. The relay then activates or deactivates the motor and solenoid valves to manage water flow efficiently. This offline functionality ensures the system remains operational even in areas with limited or no internet connectivity.

2. Mobile App: For a more user-friendly experience, a mobile application was developed using Android Studio, with Firebase Realtime Database facilitating cloud-based data exchange.

Through this app, users can:

- Remotely activate or deactivate the irrigation system over the internet.
- Monitor real-time sensor data, including soil moisture, temperature, and humidity levels.
- Receive alerts when sensor readings indicate conditions requiring attention.

The mobile application improves accessibility by allowing farmers to manage irrigation from any location with an internet connection.

3. Weather-Based Monitoring : A weather display feature has been integrated into the application, enabling users to search for and access real-time weather information based on location. By analyzing weather conditions, farmers can make data-driven decisions about irrigation scheduling, preventing unnecessary water use during expected rainfall.

4. Plant Disease Detection Using Machine Learning : To assist farmers in crop health management, the system incorporates a machine learning-based plant disease detection module. Users can upload images of plant leaves, and the trained model predicts potential diseases based on image analysis. This feature provides early disease detection, allowing timely intervention and minimizing crop damage.

Dataset: The PlantVillage dataset consists of 54303 healthy and unhealthy leaf images divided into 38 categories by species and disease.The dataset consists of RGB images and provides a diverse set of leaf conditions, enabling the model to learn from various disease patterns.

Image Processing and Data Augmentation : Before training the model, images undergo preprocessing to improve model generalization and prevent overfitting. The preprocessing steps include:

Rescaling: Images are normalized by dividing pixel values by 255 to scale them to a 0–1 range.

Shear Transformation: Randomly distorting images to make the model robust to small variations.

Zooming: Applying random zoom-in effects to train the model on different perspectives.

Width and Height Shifts: Random translations to prevent over-reliance on a single location in images.

Fill Mode: Filling newly created pixels after transformation with a nearest-neighbor approach.

Model Selection and Transfer Learning : In this implementation, MobileNet is used as the base model due to its efficiency and ability to generalize well for mobile applications. MobileNet is a lightweight CNN architecture optimized for embedded and mobile vision applications. It utilizes depth-wise separable convolutions, reducing the number of parameters compared to traditional CNNs while maintaining accuracy. Pre-trained ImageNet weights are used to leverage feature extraction capabilities, avoiding the need to train the entire model from scratch.

5. Automated Irrigation Scheduling : An automated scheduling feature allows users to define irrigation start and stop times directly through the mobile application. The system then autonomously controls water distribution based on these pre-set schedules, reducing the need for manual supervision. This ensures efficient irrigation practices, optimizing water usage while maintaining soil moisture balance.

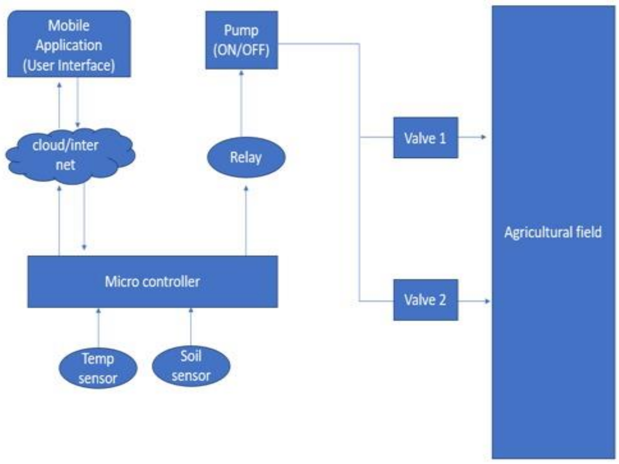

Fig -3: Block diagram of the system

5. RESULT AND DISCUSSION

The smart irrigation system effectively integrates SMS-based control, a mobile application, and machine learning to optimize water management in agriculture. By incorporating GSM and WiFi modules, the system ensures seamless operation in both online and offline modes, allowing farmers to manage irrigation remotely via SMS in remote areas or through a mobile app using the internet.

The first step is to login in the mobile with phone number and password. Fig 5. Once a user is logged in the dashboard screen appears. Fig 6. The user can view weather by searching the name of the location for which user wants to view weather, control the motor and valve to turn on and off through app as well as offline mode, use plant disease detection feature in which user can upload an image from gallery or click picture using camera to classify or detect the plant disease. The app also allows users to view status about the irrigation system which includes temperature, soil moisture level and water flow. Users can also update their password for login. Fig 7, Fig 8, Fig 9, Fig 10, Fig 11.

The application is powered by Firebase Realtime Database, which ensures seamless data synchronization across devices. This allows users to access real-time updates on system parameters, irrigation schedules, and sensor data, improving decision-making and overall system efficiency.

For the Plant disease detection feature, The plant disease detection model showed significant improvement as training progressed. Initially, the accuracy was 27.31%, but with each epoch, the model learned better, reaching an impressive 93.52% training accuracy and 95.06% validation accuracy by the final epoch. The loss values also dropped steadily, starting at 2.8783 and reducing to 0.1992, meaning the model made fewer mistakes over time. Similarly, the validation loss decreased from 0.7801 to 0.1498, indicating that the model was learning effectively and performing well on unseen data.

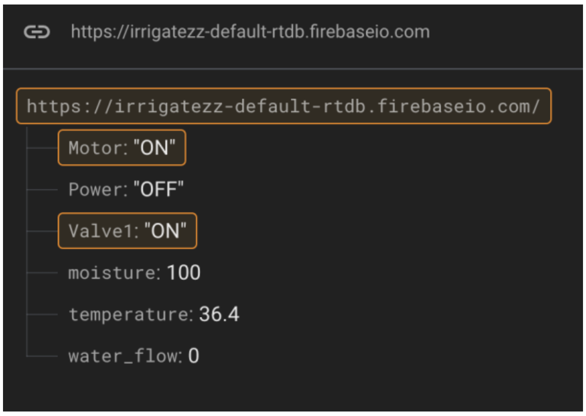

Fig -4: Firebase Realtime Database

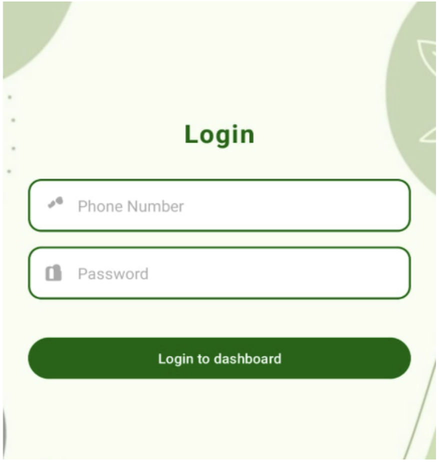

Fig -5: Login Page

Fig -6: Dashboard Page

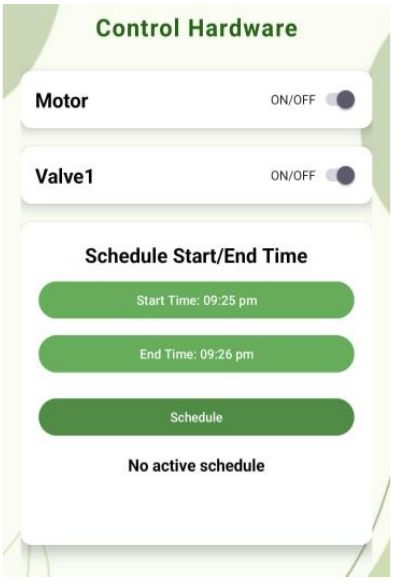

Fig -7: Hardware Control Page

Fig -8: Weather Page

Fig -9: Plant Disease Detection

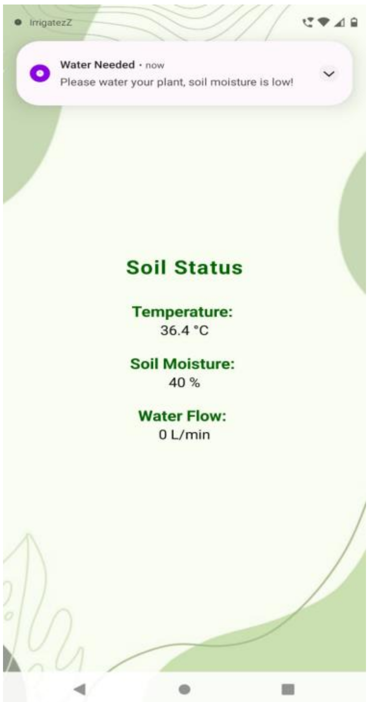

Fig -10:Status Page

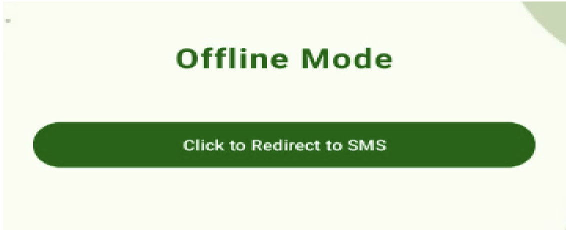

Fig 11: Offline Page

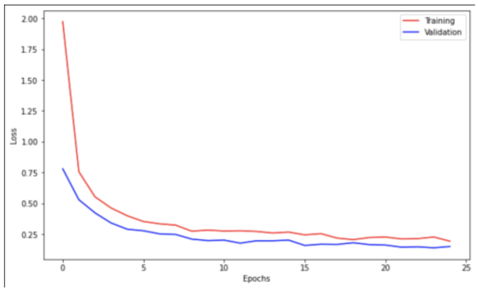

Fig -12: Loss Graph

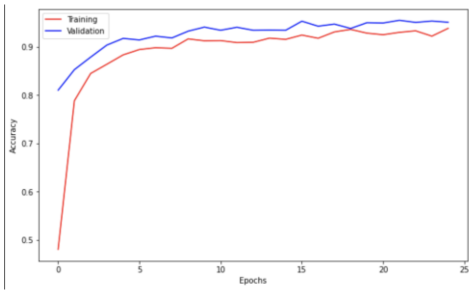

Fig -13: Accuracy Graph

6. CONCLUSION

The development of smart irrigation systems has emerged as a transformative solution to address the critical challenges of water scarcity and inefficient agricultural practices. This research integrates IoT technologies, mobile application development, and real-time data analytics to create a user-friendly and versatile irrigation control system. By employing a hybrid communication model leveraging GSM for offline controls and WiFi with Firebase Real-Time Database for online operations, the system ensures uninterrupted functionality across various connectivity scenarios.

The integration of sensors, such as soil moisture and DHT11, enables precise environmental monitoring, while actuators like water pumps and solenoid valves ensure efficient water delivery. The Android application serves as an intuitive interface, empowering users to monitor and manage irrigation with ease. The proposed system not only enhances water-use efficiency but also supports scalability and adaptability for diverse agricultural needs.

This research contributes to the growing field of IoT-based smart agriculture by providing a cost-effective and accessible solution. Future work may explore advanced data analytics, machine learning for predictive irrigation, and solar-powered systems to further optimize resource usage and ensure sustainability. Through this system, the potential to revolutionize modern farming practices and promote sustainable agriculture is brought closer to realization.

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