RESEARCHARTICLE OPENACCESS

IOT Enabled Smart Irrigation System with Crop Health Monitoring

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Abstract:

One of the most important and respected jobs in India is agriculture. It supports most of the rural population. Agriculture makes up 10% of all exports and about 16% of the GDP, showing how crucial it is to the national economy. The main way to supply crops with water, which is essential in farming, is irrigation. However, over-irrigation or poor planning in earlier methods often leads to water waste. Smart irrigation based on the Internet of Things (IoT) is emerging as a practical and effective solution to these issues. The Smart Irrigation System monitors the environment in real time using a variety of sensors, including temperature and soil moisture sensors. The technology ensures that crops receive water only when necessary by automatically switching the water pump ON or OFF based on the soil's moisture content. This automation saves time and energy, decreases water waste, and drastically lowers human intervention. The user's device receives the sensed parameters and the motor's working condition, enabling remote monitoring and control. This technology provides more productive crops and more intelligent farming techniques as well as to effective water management. An IoT-based smart irrigation system with an AI-powered crop disease helper and a web-based dashboard is shown in this project. In order to automate water pump operation and provide effective irrigation, the system tracks data in real time like temperature, humidity, and soil moisture. This method encourages intelligent and sustainable agriculture while increasing water conservation and decreasing physical labor.

Keywords: AI-based recommendation system, Gemini API, smart irrigation, IoT, precision agriculture, and crop disease advisory.

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I. INTRODUCTION

India is primarily an agrarian nation, hence agriculture plays a major role in the country's economy and rural populations' means of livelihood. A sizable portion of India's labor force is employed in agriculture, but also makes a substantial contribution to the country's GDP. However, regular irrigation practices are frequently ineffective, resulting in water waste, uneven crop growth, and low manufacturing. Adopting smarter, technologically advanced solutions is now crucial given the vital role that water plays in agriculture and the growing problems of climate change and water scarcity. Smart irrigation is a contemporary technique that automates the watering process using IoT (Internet of Things) technologies. It entails using sensors to determine the current state of the field, such as temperature and soil moisture sensors. The technology automatically starts a water pump when soil moisture levels fall below a certain threshold and stops it when enough water exists. By ensuring that water is only delivered when needed, this system maximizes water usage and reduces waste. These systems are also perfect for distant or large-scale farms because they can be remotely monitored and operated via apps or web platforms on a computer or smartphone. The design and implementation of such a system employing microcontrollers like the ESP32 or ESP8266, the integration of several sensors, and the deployment of IoT platforms for real-time monitoring are the main objectives of this project.

Increasing irrigation efficiency, lowering labor costs, and improving agriculture's sustainability and intelligence are the goals. In addition to conserving water, this program guarantees steady irrigation, which has a direct impact on crop health and production. Farmers are better able to adapt to changes in the environment and crop requirements when they have access to real-time data and technology. Additionally, smart irrigation can help farming enterprises become more profitable by lowering expenses. In the future, the system can develop to become even more sophisticated and predictive by including AI models. All things considered, smart irrigation is a big step toward driven, contemporary agriculture that supports global sustainability objectives.

II. LITERATURE REVIEW

Due to the growing demand for food and the scarcity of freshwater supplies, effective water management in agriculture is a major global challenge. Conventional irrigation techniques frequently waste a lot of water and are unable to adjust to changing crop requirements or environmental circumstances. To get beyond these restrictions, smart irrigation systems utilizing Internet of Things (IoT), machine learning (ML), and artificial intelligence (AI) technologies have become more popular in recent study.

This review of the literature examines important contributions to the field of smart irrigation, emphasizing the approaches, tools, and findings of current research. A smart irrigation system that uses IoT and cloud-based services to automate water distribution based on soil moisture and environmental data was proposed by Chetan Dwivedi et al. in 2021. The researchers created a system in which sensors gather data in real time, including temperature, humidity, and soil moisture levels, which are then sent to a cloud platform. An Arduino microcontroller determines whether to switch on or off the water pump based on predetermined thresholds. According to the study, this strategy greatly increased crop yield while using up to 40% less water than conventional techniques. The solution's affordability and scalability, which make it practical for small and medium-sized farmers, were also highlighted by the authors [1].

In 2020, M. Gopal and R. R. Ramesh created a precision irrigation system by combining GSM modules for remote monitoring with wireless sensor networks (WSNs). Their technology offered a low-tech communication option for rural areas with poor internet connectivity by enabling farmers to get SMS warnings about the state of the soil and irrigation. According to the authors, a greater variety of users may now use the system thanks to the integration of basic GSM modules. Field testing revealed that the automated system enhanced crop health and water efficiency, illustrating how sensor-based automation combined with fundamental communication technologies can produce reliable and significant smart agricultural solutions [2].

Pranav Patel et al. (2022) presented a machine learning-based irrigation scheduling system that utilizes Support Vector Machines (SVM) to predict irrigation needs. Their model was trained on historical weather patterns, soil types, and crop requirements, and it adapted to real-time sensor inputs to optimize irrigation timing and quantity. The Smart Irrigation System Using IOT threshold-based systems, the ML model dynamically adjusted its predictions to ensure water was only used when necessary. The results demonstrated a 25–30% increase in water use efficiency. The study also highlighted the potential of AI-driven systems in resource-constrained environments, though it acknowledged the need for reliable data collection and preprocessing [3].

A fuzzy logic controller-based irrigation system that takes into consideration several input parameters such soil moisture, temperature, and crop kind was proposed by S. Rani et al. in 2021. In situations where precise thresholds might not be feasible, fuzzy logic offers flexibility in decision-making. The authors showed how fuzzy rules could be tailored for various crops and geographical settings, allowing their method to be used in a variety of farming situations. The assertion that rule-based smart systems are appropriate for unpredictable and changeable agricultural situations is supported by the implementation, which demonstrated notable decreases in both water and electricity use [4].

Using solar-powered IoT sensors and LoRa communication technology, K. Balaji and A. Ramya (2020) presented an energy-efficient smart irrigation system. Because the entire system is powered by solar panels, it can be used in distant and off-grid locations. Sensors and control units communicated using LoRa, a low-power, long-range wireless platform. This setup made it possible to send data in real time over several kilometers without using cellular networks. In addition to offering isolated agricultural zones a sustainable option, the system demonstrated efficacy in energy and water conservation [5].

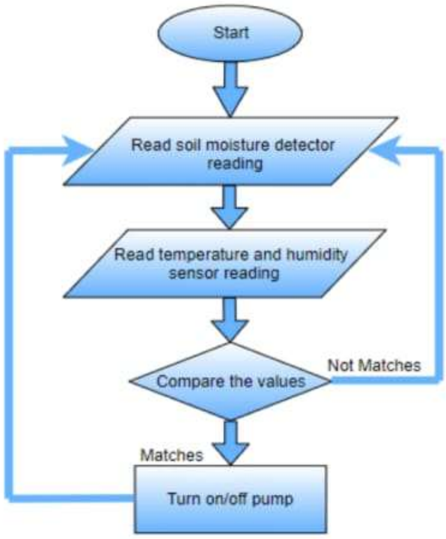
The usage of smart irrigation in greenhouses was studied by Swapnil Thorat and Tejaswini Patil (2021). They put in place a closed-loop control system that used sensor feedback to dynamically modify the lighting, ventilation, and watering. According to their research, smart irrigation combined with climate control systems in greenhouses improved plant development conditions and resulted in considerable water and energy savings. Instead of tackling irrigation in isolation, their research highlighted the significance of holistic system integration [6].

By analyzing time series data of environmental parameters, Vaibhav Kumar et al. (2023) presented a deep learning-based method that uses Recurrent Neural Networks (RNNs) to estimate irrigation needs. Real-time sensor outputs and historical weather data were used to train the model. This method offered predictive capabilities, enabling it to be trained to recognize [7].

IoT-enabled drip irrigation and conventional irrigation techniques were compared by S. Singh and P. Roy (2022). During a cropping season, they installed both systems side by side and monitored variables like water energy consumption, yield, and utilization. With sensors and microcontrollers, the intelligent system produced 20% higher yields while using 35% less water. The study made a compelling case for switching to smart irrigation as an economical and environmentally friendly farming method [8].

III. METHODOLOGY

❖ FLOWCHART



The suggested IoT-based smart irrigation system is intended to automate crop watering by continuously monitoring soil and ambient conditions. Using sensors to gather field data, a microcontroller to evaluate the data, and automatic irrigation system control based on predetermined circumstances are all part of the methodology.

A microcontroller, soil moisture sensor, temperature and humidity sensor, water pump, relay module, power supply, and an Internet of Things platform for remote monitoring make up the majority of the system. To measure the soil's moisture content continually, a soil moisture sensor is installed in an agricultural field. This sensor determines the soil's moisture content and transmits the information to the microcontroller.

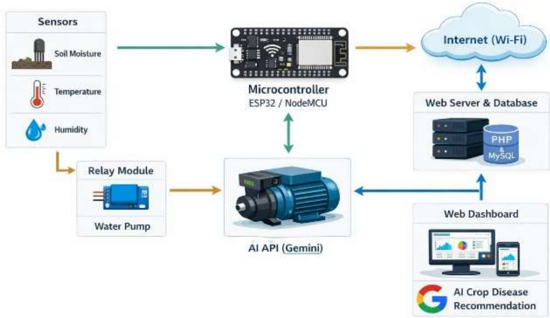
Additionally, environmental factors that could impact crop growth are tracked using a temperature and humidity sensor. The microcontroller acts as the central processing unit of the system. After receiving data from sensors, it processes it in accordance with predetermined threshold values. If the soil moisture level falls below the required limit, the microcontroller automatically activates the relay module, which turns on the water pump. After that, the pump uses an irrigation conduit to provide water to the crops. The microprocessor stops the pump to avoid overwatering when the soil reaches the necessary moisture level.

To enhance efficiency, the system is integrated with an IoT platform that allows farmers to monitor field conditions remotely. Sensor data, including temperature, humidity, and soil moisture, is sent to the cloud via an IoT platform or Wi-Fi module. Farmers can monitor the irrigation operation in real time by seeing this data via a computer interface or smartphone. This feature lessens the necessity of being physically present in the field all the time.

The suggested Smart Irrigation System's software approach combines cognitive decision-making capabilities with real-time sensor data through a web-based architecture. The system's frontend interface is designed to show real-time characteristics including temperature, humidity, and soil moisture via an easy-to-use dashboard. PHP is used for backend processing while MySQL is used for database management.

IV. WORKING

The IoT-based Smart Irrigation System continuously checks soil and ambient conditions through sensors installed in the agricultural area. Real-time data is collected by temperature and soil moisture sensors and sent to an ESP32 microcontroller. The controller checks the soil moisture content to predefined threshold levels after processing this data. The system detects that irrigation is necessary if the moisture content is below the necessary level. After that, the controller instructs the relay module to activate the water pump so that water may reach the crops.



In order to avoid over-irrigation and save water, the controller automatically shuts off the water pump when the soil moisture reaches the target level. Additionally, the ESP32 allows farmers to remotely monitor sensor readings and pump status by connecting via Wi-Fi to an IoT platform or mobile application. If necessary, farmers can manually operate the pump and monitor real-time data. In the end, this automated method improves crop health and agricultural productivity by reducing water waste, minimizing manual labor, and ensuring effective watering.

SYSTEM REQUIREMENT

1) Arduino IDE - used for programming the ESP32 microcontroller
2) Programming Language php - used to write the program for sensor data processing and pump control
3) MySql **-** used for storing sensor data and system records.
4) HTML, CSS**,** JavaScript **-** used to design web dashboard interface.

5) XAMPP Server **-** used to run local server and manage database connectivity.

V. RESULT

The IoT-based Smart Irrigation System was successfully put into place and tested to automate the irrigation process. Using sensors, the system efficiently tracked temperature and soil moisture levels in real time. The ESP32 controller and relay module automatically turned on or off the water pump based on the sensor readings. Additionally, the device made irrigation more effective by enabling remote monitoring and control via the Internet of Things platform. As a result, the system's AI-based recommendations improved overall crop management, minimized manual labor, and reduced water waste.

A.) Experimental System Outputs

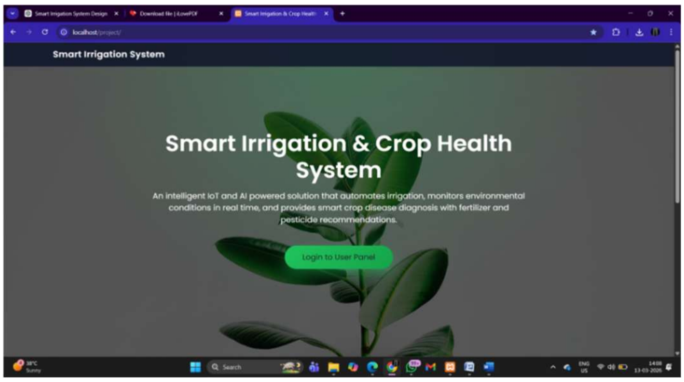


Fig.1 landing page of system

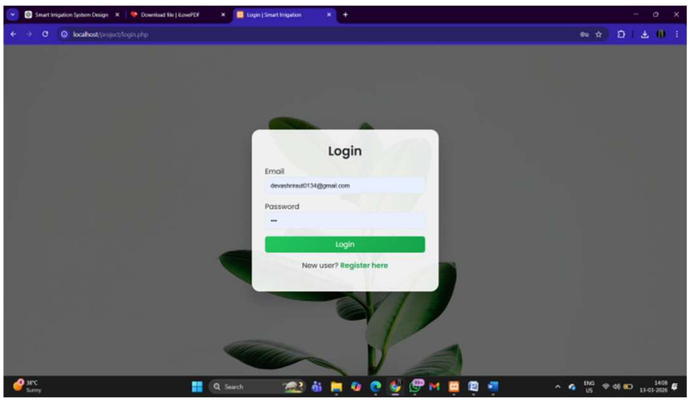


Fig.2 login page of the web page

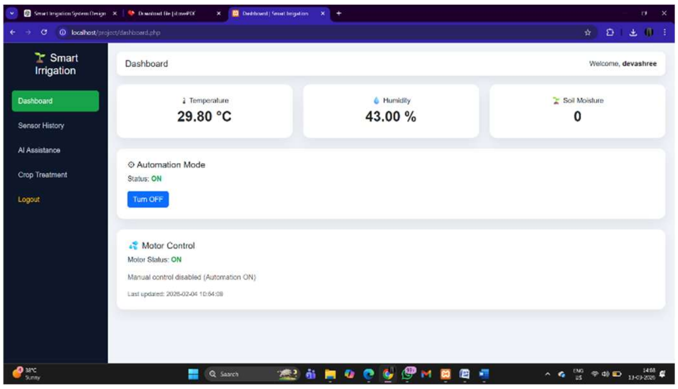


Fig.3 Experimental result on web page

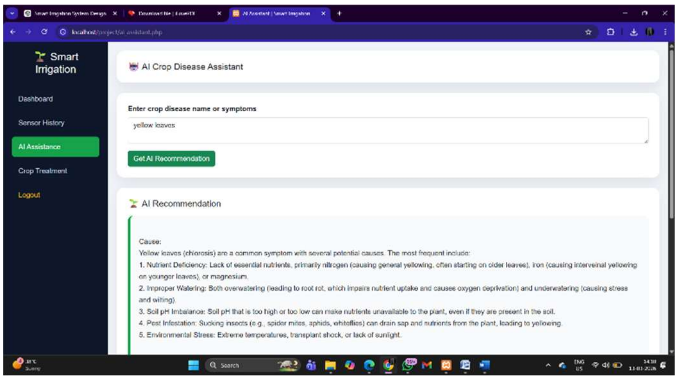


Fig.4 AI recommendation for the crop disease

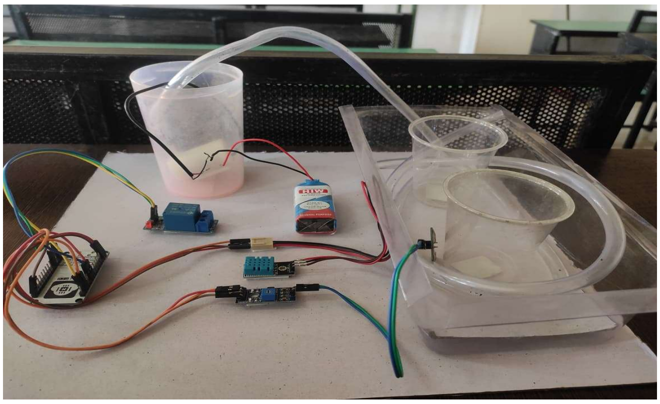


Fig.5 Experimental setup of the project

B.) Experimental Evaluation

TABLE I
Sensor data and system response

Time	Soil Moisture (%)	Temp. (c)	Humidity (%)	Pump status
10.00 AM	20	28	55	ON
11.00 AM	25	30	60	OFF
12.00 AM	30	32	65	ON
01.00 PM	40	34	68	OFF
02.00 PM	45	35	70	OFF

TABLE II
AI based Crop Disease Recommendation

Input symptoms	Predicted Issue	AI Recommendation
Yellow leaves	Nitrogen deficiency	Apply nitrogen rich fertilizer
Brown leaf spots	Fungal infection	Use appropriate fungicide spray
Wilting of plant	Water stress	Increase irrigation frequency
White powder on leaf	Powdery Mildew	Apply sulfur based fungicide
Dry soil condition	Water deficiency	Increase irrigation frequency

VI. CONCLUSION

A sophisticated and clever answer for contemporary agriculture is offered by the IoT-based Smart Irrigation System combined with Generative AI for crop disease prediction. Conventional agricultural monitoring and irrigation techniques don't offer early crop health alerts and demand constant manual labor. The solution helps farmers identify possible crop diseases early on and increases irrigation efficiency by integrating IoT sensors with artificial intelligence capabilities. In this system, sensors such as soil moisture, temperature, and humidity continuously collect real-time environmental and soil data from the agricultural field, which is processed through a microcontroller and stored for further analysis. The irrigation system automatically regulates the water pump using a relay module based on predetermined threshold values to guarantee that crops receive the proper amount of water, minimizing manual work and water waste.

In order to comprehend crop development patterns and climatic circumstances, farmers and researchers can examine historical records of soil moisture, temperature, and humidity thanks to the system's database of sensor data. Better decision-making and effective irrigation planning are supported by this historical data. Furthermore, by analyzing the gathered sensor data and past trends, generative AI models forecast potential crop diseases and offer early warnings, enabling farmers to take preventative measures before the disease spreads significantly in the field.

VII. ACKNOWLEGDEMENT

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VIII. REFERENCES

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