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Smart Multipurpose Irrigation Monitoring System

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Abstract:

Efficient irrigation is necessary for eco-friendly agriculture, whereas traditional methods lead to waste water and fail to maintain optimal soil conditions. This paper introduces a Smart Multipurpose Irrigation Monitoring System that combines Internet of Things (IoT) technology with a range of sensors to achieve precise, automated water management. A NodeMCU/ ESP8266 microcontroller gathers real-time data from soil-moisture, rain, and DHT temperature–humidity sensors and weather-forecast API provide predictive climate information. This enables farmers to monitor field parameters remotely and hand control operations when necessary. By weather prediction, the system saves water, decreases labor, and promotes healthier crop growth.

Keywords **—** IoT, NodeMCU, ESP8266, Sensors, Weather-forecast API.

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I. INTRODUCTION

The smart multipurpose irrigation management system based on IoT technology stands out as the latest technology launched to counteract issues experienced by conventional irrigation methods in agriculture, particularly in regions with dry climates that suffer from severe water shortages can now be termed a luxury. This technology encompasses several sensors, wireless communication systems, and smart controlling systems that help monitor and observe the soil moisture and environmental conditions of temperature and humidity on a continuous basis. The required irrigation commands based on continuous observation are provided by the system automatically to irrigate or provide water to plants in exact amounts they require to grow, thus ensuring water conservation and preventing any water wastage. In general, there might be sensors of moisture levels and temperature sensors implanted underground in the fields to detect signals reflecting on the required data to microcontrollers or edge computing devices named Raspberry Pi. This required irrigation data can either analyzed by devices themselves or can be transferred to cloud computing devices by respective IoT platforms, and based on environmental conditions of rain or rate of evaporation of water on earth due to evaporation and plant transpiration or evaporation rate of water on earth due to evaporation and plant transpiration or their rate in arid areas, irrigation allotments are executed by actuators.

II. LITERATURE SURVEY

This paper presents the design and implementation of an IoT-enabled intelligent irrigation system for optimal water use and sustainable farming. Efficient IoT-based smart irrigation system design requires an architecture that has three layers: the IoT device layer, the cloud ThingsBoard, and the last layer related to visualization, which requires data representation by the monitoring dashboard for real-time data. Preprocessed sensor data is transmitted through the cloud by the use of HTTP in the format of JSON. This system also supports the facility for the farmer to take instant actions for their fields through email services. Fire detection, smart agriculture, along with other topics, can be considered in future research [1].

The research covers the ways in which IoT technology is improving irrigation through automation and optimization of water distribution in agriculture. This structure will take into account a three-way approach with respect to IoT infrastructure, environment, and economic efficiency. Using the Cochrane method of literature reviews, it will make an examination of literature that exists in smart design and implementation in irrigation technology. Additionally, it will be expected to identify its realm of research with respect to prominent subjects such as soil studies, sensors, communication, or management. The prominent issues in this regard would revolve around durability or prices, user knowledge, data transfer, water conservation, and security features [2].

Smart Irrigation System through weather forecast is an intelligent water optimization and enhancement in the efficiency of irrigation in agricultural farming using IoT. It captures real-time environmental parameters to control the irrigation in precise measurements with the help of Arduino Uno, NodeMCU, and DHT11, soil, LDR, and rainfall sensors. Manual control has been provided in this smart system, which is able to remotely control and monitor through blynk app support with indications that define the parameters. The smart system precisely forecasted the optimal time to irrigate when weather parameters were integrated with OpenWeatherMap, thereby preventing water wastage and crop deterioration through machine learning technology [3].

The review, therefore, identifies the magnitude of the struggle faced globally in the irrigation of agricultural water sources due to the growing population, food, and climate change. There is an insight into how irrigation practices have shifted from the traditional gravity irrigation systems to precision irrigation systems. Furthermore, within this scope, the review considered 150 pieces of literature between the year 2005 and 2024. This considered water-saving systems, IoT, AI, and monitoring systems for water irrigation. There is an insight into the magnitude of various initiatives embraced in smart irrigation controllers to monitor soil, plants, and weather data for agricultural irrigation. That irrigation precision has improved the usage of water for irrigation and hence enhanced sustainable farming. This is according to the SDG [4].

In the context of this work, a low-cost smart Multipurpose irrigation system has been designed in Tuscany, Italy, in the context of tomatoes and melons, aiming at optimizing water usage efficiency under climate change. Beginning from a simple system in the year 2021 to an automated system in the year 2023 based on Evapotranspiration models, the water usage efficiency has been shown to be up to 50% lower than conventional methods, priced below €6000 [5].

It was reliable and flexible, thus providing an appropriate solution for small-scale farming and IRRIOTA, an IoT sensor, and ESP32 microcontroller-enabled affordable open-source irrigation system combined with Google Sheets for decision support. This decisively helps farmers optimize irrigations through simple cloud support and is easily reproducible. Trials of irrigations in kiwi plantations reduced the number by 62.5% without damaging the crops. Its malleability assists in adapting these for other crops and agricultural uses. Improvement in the future might come in increasing the precision of the sensors to a greater degree, solar assistance for autonomy, longer-range communication, and AI approaches taken onboard and useful in data analysis for smart irrigation . Results indicate that, although minor technical problems have arisen, this has strong potential for a sustainable and scalable water management approach in agriculture [6].

The smart home gardening system automates the watering of plants and maintenance of environmental conditions through the use of IoT. The Raspberry Pi, in conjunction with the soil moisture sensor, DHT11, and ultrasonic sensors, monitors soil and weather conditions. The system will be triggered when the level of moisture goes below the desired level, and it will initiate an automatic response by turning on the water pump. The system shows readings and can be controlled using smartphones through the Blynk system. This will ensure water efficiency and sustainability. It can be developed to include advanced functionalities for smart farming in the near future [7].

III. METHODOLOGY

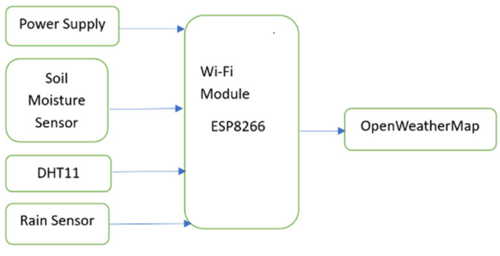

Fig 1. Methodology of Smart Multipurpose Irrigation System

Fig 1 describes the methodology of smart Multipurpose Irrigation Monitoring System.

Power Supply: The power supply is employed in providing power to all the elements in the entire system. It ensures that it provides stable voltages to the ESP8266 and sensor circuits. If the power supply is not employed in any given system, it is expected that it will fail to work or will present some different results. Employment of the power supply can be made in instances where there are fluctuations. It is mainly intended to change the voltage of the mains or battery to a desired DC voltage. Protection circuits can be designed in order to protect against short-voltage protection as well as overvoltage protection. It is normally capable of handling all the currents in the entire project. Employment of backup power supplies, which can also be in the form of batteries or from solar, is normally employed in the entire system that can applicable in the field.

Soil Moisture Sensor: Soil Moisture Sensor: The soil moisture sensor is applied in the resolve of the water level in the soil, therefore the levels of data essential by the ESP8266 Microcontroller. The ESP8266 Microcontroller is crucial in the purpose of whether the soil is dry, wet, or watered. The soil moisture sensor can be made up of using either the resistance method or the capacitor technique for the purpose of the water level contained in the soil. The above soil moisture sensor can be useful in the activation of the pump, compulsory in the waterproofing of the soil. The above soil moisture sensor improves the efficiency of water utilized in the irrigation process by estimating the wastage levels which occur as a result of water utilized in the irrigation process. The above sensor ensures that plants grow in the best manner by utilizing the required water level contained in the soil for the promotion of plant growth. The above sensor can be set near the root of the plants to promote the accuracy levels allied with the levels of water in the soil.

DHT11 (Temperature and Humidity Sensor): DHT11 is a sensor that can read the atmospheric temperature and humidity. This is one of most essential sensors, providing the information needed to understand the environmental situations that plants are subjected to. It includes a thermistor and a capacitive humidity element that produce a digital signal. The ESP8266 then processes this input for use in irrigation or to notify the user of the readings. It works with good accuracy within applications that do not require industrial precision. Monitoring regularly prevents overheating and excessive moisture that could be detrimental to crops. Data from the DHT11 can also be relayed through the IoT dashboard for remote access. It works under changed weather conditions with efficiency, hence suitable for use outdoor installations. Integration of this sensor assures balance in climate control approach in irrigation systems.

Rain Sensor: The rain sensor identifies and measures the intensity of rain to determine irrigation necessity. It prevents irrigation during rain situations by not activating the pump. This thus avoids wasting water by not activating the irrigation whenever there are rain situations. Typically, its functional logic measures water droplet conductivity on its surface. After identifying rain conditions, it immediately transmits a message to the ESP8266 module to stop irrigation immediately. This will assist in water conservation and ensuring efficient smart irrigation schedules. A rain sensor should always be located in an open environment to measure rain accuracy.

Wi-Fi Module (ESP8266): The ESP8266 module will serve as the brain for the entire system. It receives information from all the sensors, that includes soil moisture sensors, temperature and humidity sensors, and rain sensors, and processes the information for decision-making. This module will use the internet via Wi-Fi to support remote control and monitoring through IoT technologies. It interfaces with other systems, including OpenWeatherMap, for information regarding weather conditions. It also has the ability to send notifications and information regarding the status of the sensors to the user's smartphone. Its low cost and power make it vastly required after for use in many IoT automation systems. Its processing and memory make the system run quickly and very efficiently. It relays information between the local sensors and the cloud for smart farming.

OpenWeatherMap: The Internet-based platform that enables weather details to be incorporated into the system by means of ESP8266 allows the user to get actual details of the weather, including the amount of rainfall, level of humidity, and level of temperature, which are all essential details prior to weather change for better decision-making regarding irrigation. Incorporating external weather details eliminates the aspect of repetitive irrigation, as the activities within the system are made informed by all users. ESP8266 pulls down all the details from the APIs, which are more coupled with details from the system, thus improving the adaptation to the details relating to irrigation for users to undertake informed activities related to the forecasts for either system or field maintenance activities. Adding details of global weather into a basic irrigation system turns the system into a smart system.

IV. RESULTS

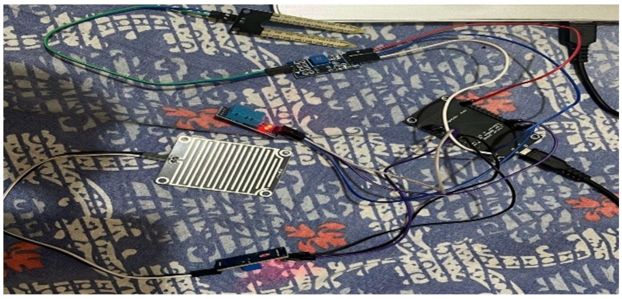

Fig 2. Hardware Connections

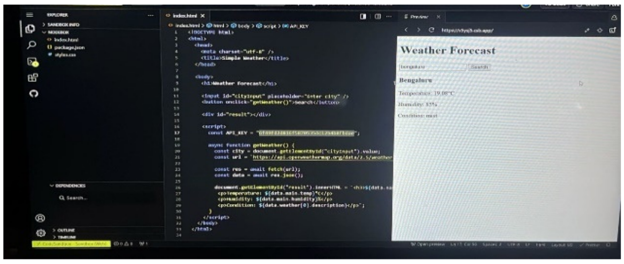

Fig 3. Output of OpenWeather Map

Fig 4. Output of Soil Moisture Content, Temperature, Humidity and Rain Content in the area

Fig 2 describes Hardware connections, Fig 3 describes output of OpenWeather Map, Fig 4 describes output of moisture content, Temperature, humidity and rain content in the area.
OpenWeatherMap API gives the Temperature, Humidity and Condition of a particular area. Whereas hardware components give the soil moisture content, Temperature, Humidity and Rain Content in the surrounded area. OpenWeatherMap API runs with the help of HTML code. And

hardware components run with the help of Arduino IDE. Outputs are displayed through Telegram bot.

V. PERFORMANCE ANALYSIS

Performance	Previous Work	Proposed Work
Microcontroller Used	Arduino Uno with GSM module	ESP8266 Wi-Fi Module
Control Type	Automatic irrigation based on forecast and soil data	Fully automatic and remote-controlled via OpenWeatherMap
Communication Method	GSM-based data transmission	Wi-Fi-based real-time data transfer using OpenWeatherMap
User Interface	Web-based dashboard	OpenWeatherMap (user-friendly and interactive)
Automation Level	Semi-automatic (depends partly on forecast data)	Fully automatic with manual override via app

The differences in the earlier system and the proposed Smart Multipurpose Irrigation Monitoring System clearly explain that a huge development change has been carried approximately in terms of development and functionality. The earlier system uses the Arduino Uno Board, which is linked to the GSM module, resulting in the slow process speed of moving the data as well as a higher energy cost, whereas, in the proposed Smart Multipurpose Irrigation Monitoring System, the ESP8266 Wi-Fi module is used, which facilitates efficient and low-cost wireless communication. The controller approach explains that, in the earlier system, the forecast and soil condition were used for the semiautomatic irrigation, whereas, in the planned Smart Multipurpose Irrigation Monitoring System, automatic as well as remote on-site irrigation process control is possible using the OpenWeatherMap Location Service, which makes the proposed Smart Multipurpose Irrigation Monitoring System easier and more manageable. The communication approach in the proposed Smart Multipurpose Irrigation Monitoring System now differs from the previous GSM module technology-based data transfer process approach from the previous system. The proposed Smart Multipurpose Irrigation Monitoring System differs in terms of providing instantaneous connectivity and controlling processes, which makes this proposed system more useful. The UI design approach of this planned system differs from earlier system approaches, which designed only web. The planned system approach is designed with a mobile facility, which makes this proposed system more attractive. The proposed system design approach clearly guarantees easier approaches as well as greater accessibilities for use. The proposed system, which is named the Smart Multipurpose Irrigation Monitoring System, differs from earlier approaches because it is more automated, more reliable, as well as more interactive.

VI. CONCLUSIONS AND FUTURE WORK

This Smart Multipurpose Irrigation Monitoring System project is an excellent example that illustrates the effective use of IoT technology for improving water irrigation in agriculture. Soil moisture, DHT11, and rainfall sensors connecting the ESP8266 WiFi module ensure that the readings taken are accurate, and the decision made is smart. Including an OpenWeatherMap API ensures the system accounts for the varying weather conditions and irrigates the field only when needed. This project fulfills its purpose by being cost-effective, energy-saving, and reliable, which fits the bill for precision agriculture.

Moving on, it can be further extended in the future through the implementation of machine learning techniques that can forecast soil moisture and water requirements based on various environmental trends. The system can also be made more eco-friendly in terms of power consumption through the integration of solar power, so it is less dependent on any external power source. Moreover, the operation of the camera-based plant monitoring system and fertilizer system can also aid in developing it as an entire ecosystem for smart farming. Cloud analytics and connectivity using voice assistants and AI assistants can also ease the usage of this device.

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