Smart Irrigation Controller Using Soil and Weather Analytics

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Abstract : The Smart Irrigation Controller Using Soil and Weather Analytics is an Internet of Things-enabled technology that is used to conserve water and make irrigation easy. The traditional ways of irrigation are usually wasteful due to the lack of monitoring the real soil moisture content. This project utilizes the ESP32 microcontroller for automatic irrigation control depending on soil moisture and environment readings. The soil moisture sensor helps determine the moisture content in the soil while the DHT11 sensor helps measure the temperature and humidity of the environment. There is a water level sensor to monitor the amount of water available in the storage tank. All the sensor readings are then transmitted to the ESP32 and further decision-making takes place according to the data. When the soil is dry and there is plenty of water in the tank, the ESP32 turns the water pump on using the relay module. In cases when the soil moisture is enough or there is little water in the tank, the water pump stays off. Thus, it prevents the unnecessary water supply and ensures protection of the pump. It saves water from being wasted, saves electricity, and saves from manual labor as well. It is a very simple and economical technology for modern farming. For future improvements of the system, we can integrate the forecast data, sensors for rain, solar power, mobile alarms, and machine learning into it. Consequently, this project provides the means for efficient water usage in agriculture.

Key Words: Smart Irrigation, , Soil Moisture Sensor, Weather Analytics, DHT11 Sensor, Water Level Monitoring, Automatic Irrigation,.

INTRODUCTION

It should be noted that agriculture is the most vital process that takes place in the world as it supplies people with food and supports livelihoods of thousands of people. Water is the most vital element that helps plants grow well, so irrigation should be provided to provide plants with necessary moisture and increase crop production. Nevertheless, the problem of water shortage, the problem of irregular rainfall, and the problem of increasing water demand make a great problem for farmers. The traditional irrigation systems include manual irrigation and fixed-time irrigation, which are still used in agricultural processes. They require the constant involvement of humans in the process and cause the problem of overwatering or underwatering as they do not take into consideration the real state of soil moistness and changing of weather. Overwatering causes water wasting, increases electricity spending and leads to improper development of plants. Underwatering reduces the plant growing and influences crop production. Advancements in embedded systems and IoT have made it possible to enhance farming practices using automatic monitoring and control techniques. An IoT-based irrigation technique employs sensors, microcontrollers, and communication systems in order to gather environmental data and make appropriate irrigation decisions. Such devices enable reduction of water wastage, improve irrigation processes, and limit manual labor. The Smart Irrigation Controller Using Soil and Weather Analytics was designed in order to create an inexpensive and automatic solution to such problems. The project is based on the ESP32 microcontroller, which will be responsible for gathering sensor data and controlling the water pump. Using the combined information from soil moisture and environment will make irrigation decisions more effective compared to the decisions based only on time.

The proposed system consists of an ESP32 microcontroller, a soil moisture sensor, a DHT11 temperature and humidity sensor, a water level sensor, a relay module, and a water pump. The soil moisture sensor measures the moisture content in the soil and helps determine whether the plants require additional water. The DHT11 sensor measures the surrounding temperature and humidity, providing information about the environmental conditions that may influence irrigation requirements. The water level sensor monitors the water available in the storage tank and helps prevent the

pump from operating when the water supply is insufficient. The ESP32 receives the readings from these sensors, processes the information, and determines whether irrigation is necessary. When the soil moisture level indicates that the soil is dry and sufficient water is available in the tank, the ESP32 activates the relay module to switch on the water pump. The pump then supplies water to the plants through the connected pipes. When the soil reaches a suitable moisture level or the tank water level becomes too low, the controller switches off the pump. This automatic operation reduces unnecessary water usage, prevents pump dry-running, and decreases the need for continuous human supervision. This technique can be applied to small-scale farms, home gardens, greenhouses, nurseries, and any other agricultural practices that need effective water management. This technique is supposed to be very easy, economical, and applicable through easily available electronic components. In addition, the suggested method gives way for future development of the system that will include incorporation of live weather forecasting data by means of online weather API, installation of a rain sensor, use of solar energy as a source of power, and sending information about the pump performance and low water levels via the mobile application. In addition, machine learning algorithms can be included in future systems in order to predict the irrigation needs using soil and weather analytics. Even though in the current system, all the work is being done on the basis of sensor data, those improvements can make the system more responsive to environmental changes. In conclusion, the Smart Irrigation Controller Using Soil and Weather Analytics is aimed at increasing irrigation efficiency, saving water and electricity, and reducing the efforts of farmers.

HISTORIOGRAPHY AND RESEARCH GAPS

Irrigation system design has evolved from conventional irrigation techniques to an advanced irrigation design involving the use of sensors, microcontrollers, and IoT technology. Previously, irrigation involved the use of rainfall and manual observation to irrigate farms. This technique relied on manual intervention and often led to inefficient utilization of water resources or under-watering. The use of soil moisture sensor in irrigation system design was developed to monitor soil moisture levels and control the water pump automatically. Sensors for monitoring temperature and humidity in the atmosphere were also incorporated into irrigation system designs. The invention of microcontrollers such as Arduino and ESP32 helped in designing cost-effective and simple irrigation systems. Incorporation of IoT technology in irrigation designs has improved on the capability of irrigation systems to have wireless communication and remote control features.

In spite of all of these advancements, there are still some gaps in the existing irrigation systems. Many basic systems rely on just soil moisture measurement and fixed-time schedules but do not account for the simultaneous occurrence of different environmental conditions. There are also some systems that do not measure the water level and hence might start the pumps even though there is no water in the tank. The lack of incorporation of the live weather forecast into the process might cause unwanted irrigation in case of rainfall. Moreover, expensive parts, limited internet access, and the need for extended tests in the field might influence the usability of advanced irrigation solutions. As such, there is a need for the development of an efficient irrigation controller that incorporates soil moisture monitoring, environment sensors, and water level detection. The developed Smart Irrigation Controller Using Soil and Weather Analytics will address the mentioned needs as it utilizes ESP32 microcontroller, soil moisture sensor, DHT11 temperature and humidity sensor, water level sensor, relay module, and water pump. The system will switch on the pump in case the soil is dry and there is enough water in the tank and vice versa.

Such a system is designed to reduce water wastage, avoid pump dry running, conserve electricity and reduce the need for human labor. The system could be improved through adding live weather forecasting, machine learning-based prediction for irrigation and solar energy. Testing needs to be done to determine its effectiveness in reducing water and energy usage.

PRIMARY SOURCES AND METHODOLOGY

Sources of information for the project “Smart Irrigation Controller Using Soil and Weather Analytics” include data from sensors, output from the microcontroller, specifications of hardware components, and observations taken while running the system. These sources provide information about soil moisture conditions, environmental changes,

availability of water, and performance of automatic irrigation systems. The overall objective of the project is to design a low cost and easy to use irrigation controller which provides water depending on soil moisture conditions and saves water.

The traditional irrigation systems need manual operations of pumps or scheduling of watering operations. The process causes wastage of water, consumes more electricity and needs continuous monitoring by a person. For that reason, the current system uses embedded technology along with sensors to make irrigation management better. The ESP32 microcontroller serves as the processing unit and collects data from attached sensors. The inputs from the sensors and the response from the controller form the primary sources of information for the assessment of the performance of the system. Technical data sheets and user manuals for ESP32, soil moisture sensor, DHT11 sensor, water level sensor, relay module, and water pump are other sources of information. The technical data sheets have information on the working principle, electrical specifications, connections, and limitations of the selected components. One of the key sensors is the soil moisture sensor as it detects the moisture content of the soil. The output from this sensor is useful in determining the condition of the soil whether it is dry or contains enough moisture. It gives inputs to the ESP32 microcontroller, which compares the values with the set threshold to determine if irrigation is needed. The second type of sensor used is the DHT11 sensor which gives the measurements of temperature and humidity of the environment. While the above measurements give an extra input about the environmental condition that affects the plants' need for water, the temperature and humidity measurements cannot give the full requirements of irrigation of the crops.

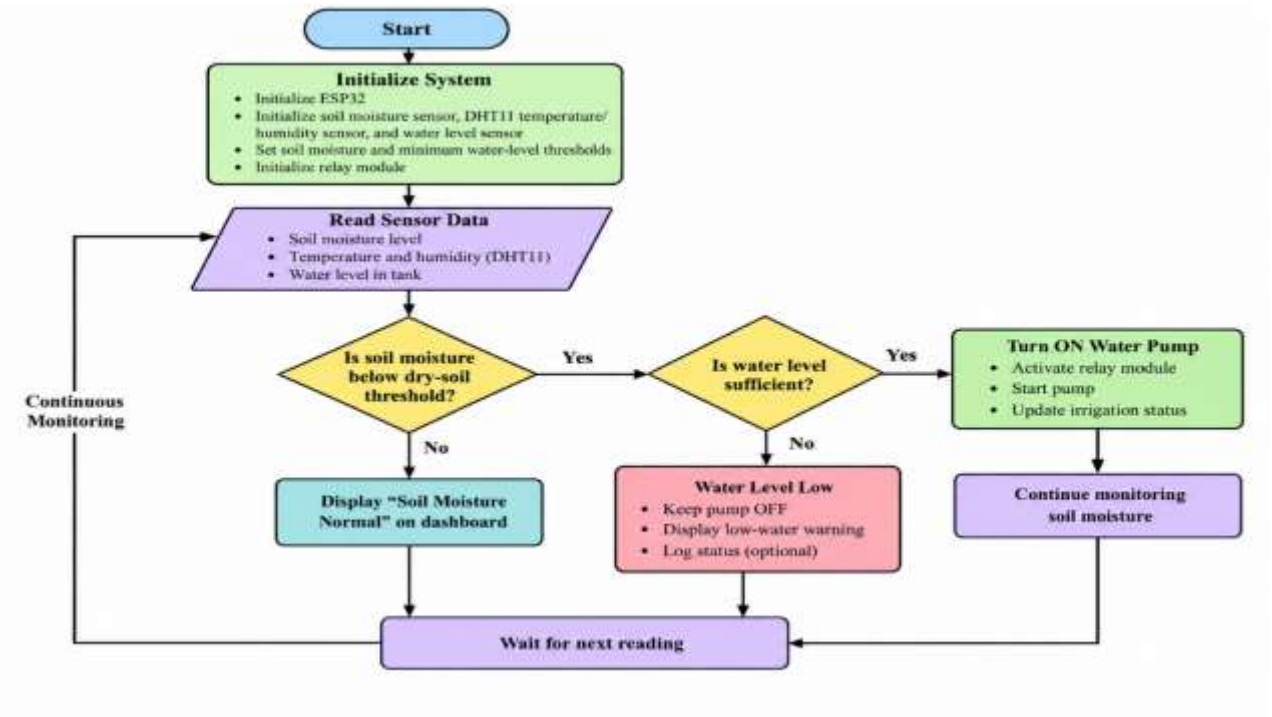


Fig.1 work flow diagram

Water level sensor is used to measure the amount of water in the storage tank or reservoir to avoid running the water pump without enough water. Relay module works as a switch controlled electronically from the ESP32 microcontroller output to the water pump input. According to the sensor outputs, the ESP32 microcontroller gives the control signals to the relay module to switch on or off the pump. Suitable power supply is applied to run the electronic parts and the pump.The methodology starts by identifying the major issues associated with the use of the existing irrigation systems. Such issues include wastage of water, manual pumping of the water, lack of adequate monitoring of the moisture in the soil, and the possibility of the pumps running dry due to lack of water in the tanks in figure 1 . Having identified such issues, the system requirements are specified, and the appropriate electronic components are selected. In the selection of the components, the ESP32 is chosen as the controller because it enables interfacing of the sensors and programmable control and has wireless capabilities. The soil moisture sensor, DHT11 sensor, and water level sensor are then interfaced to the appropriate input pins of the ESP32. The relay module is interfaced to an

appropriate output pin to be able to control the water pump. The connection of the circuit is done carefully to make sure that the sensors, the controller, relay, and the power source are all connected correctly. The control algorithm is programmed after connecting all the hardware components through the Arduino IDE. The algorithm is supposed to monitor soil moisture level, check for water availability, and decide whether irrigation will be done or not. For this purpose, the soil moisture level threshold is used to differentiate between dry soil and adequately moist soil. This threshold must be determined and customized depending upon the needs of the targeted plants.

Table 1: Sensor Inputs and System Responses

S. No.	Input Condition	ESP32 Decision	System Output
1	Soil moisture is below the threshold	Check the water level	Proceed to the water availability check.
2	Soil is dry and water is sufficient	Activate the relay	Water pump turns ON.
3	Soil is dry and water level is low	Keep the relay OFF	Low-water warning is displayed.
4	Soil moisture is sufficient	Keep the pump OFF	Normal soil moisture status is displayed.
5	New sensor readings are available	Evaluate the conditions again	Continuous monitoring continues.
6	Temperature or humidity changes	Read and monitor DHT11 values	Environmental data is available for monitoring.

The control procedure is very simple and depends on a straightforward decision-making approach. In case of dry soil moisture and availability of sufficient water in the storage tank, the ESP32 turns ON the relay module and water pump. Thus, water is supplied to the plants via the pipes/tubing system. Once the soil becomes adequately moist, the controller shuts off the pump. Moreover, the pump stays switched off in case of water levels being too low even if the soil needs irrigation. This situation ensures proper functioning of the pump as well as minimizes the risk of damaging it due to insufficient amount of water during its operation. Once the program has been created, the system is put through the tests under various conditions concerning soil moisture and water presence. First, there is the condition of dry soil and water availability in the tank, which makes the pump turn on. Second, there is the condition of moist soil and water availability in the tank, which means that the pump will not turn on. Third, there is low water levels in the tank; hence, the pump will not operate regardless of the soil moisture requirements. The temperature and humidity data are also taken into account while conducting the test. Sensor readings, operation of the pumps, and the reactions of the controller are verified for identification of any problems with connection, incorrect readings, or programming. In case of malfunctioning of the system, the connections of the sensors, threshold values, programming, and operation of relays are reviewed and corrected. The obtained data from the tests can be presented in the form of tables for evaluation purposes. Every entry can consist of the soil moisture value, temperature, humidity, state of water in the tank, expected state of the pumps, actual state of the pumps, and reaction of the controller. By comparing the expected and real responses, one can establish whether the system works in accordance with the control scheme. The evaluation process will cover such aspects as sensors' operation, automatic switching of the pumps, low water protection, consistency of control decisions, and stability of the system. Evaluation of the system can also be performed in comparison with the conventional methods of irrigation. Nonetheless, it is necessary to measure some parameters for

reliable comparison. Water consumption can be measured during some period of time, while electricity consumption can be predicted or measured with appropriate devices. It is also possible to track the number of successful pump operations as well as the behavior of the controller in various conditions. Measurements are required before making any quantitative statements regarding water savings, electricity saving or irrigation improvement. As real experimental data should be collected from the implemented system, any expected responses should not be considered as completed experimental results. The current approach concentrates only on sensor measurements and automatic pumping of the water with the ESP32 microcontroller. While project title mentions the weather analysis, the basic version of the system collects only the temperature and humidity values with the DHT11 sensor, without live weather forecast data.

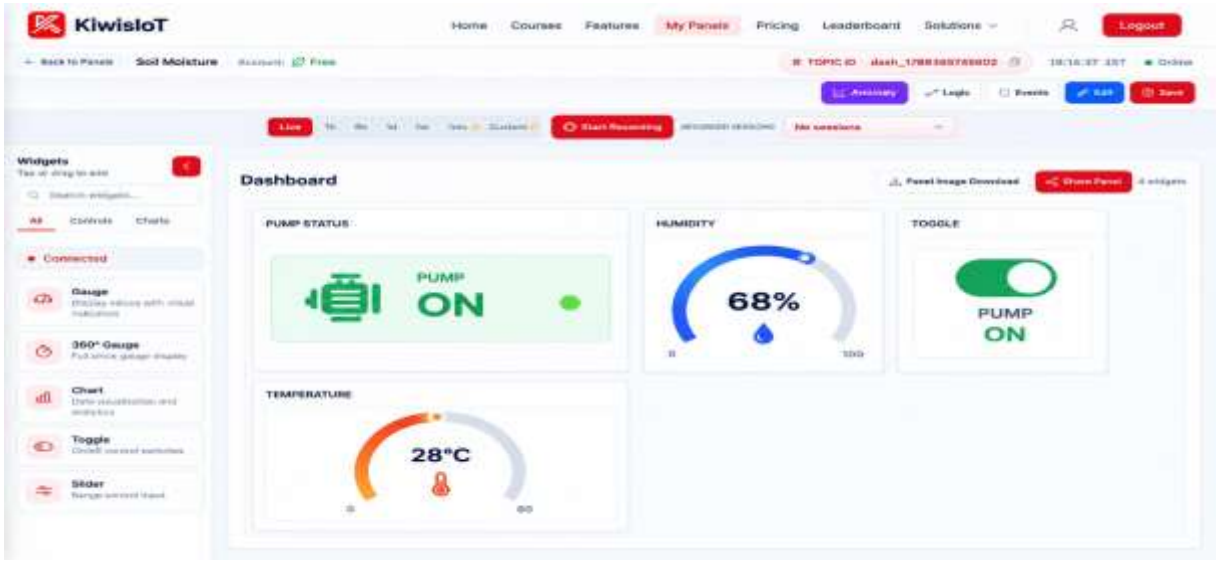


Fig.2 output status

In future, it is possible to integrate online weather API to collect forecast temperature, humidity and precipitation data. This data can help the controller to avoid unnecessary irrigation in case of precipitation prediction, provided that forecast data are evaluated along with the soil and plants needs. Other potential enhancements to be considered may be the use of solar energy with a battery backup, mobile notifications, remote monitoring, rain sensors, and several irrigation zones.

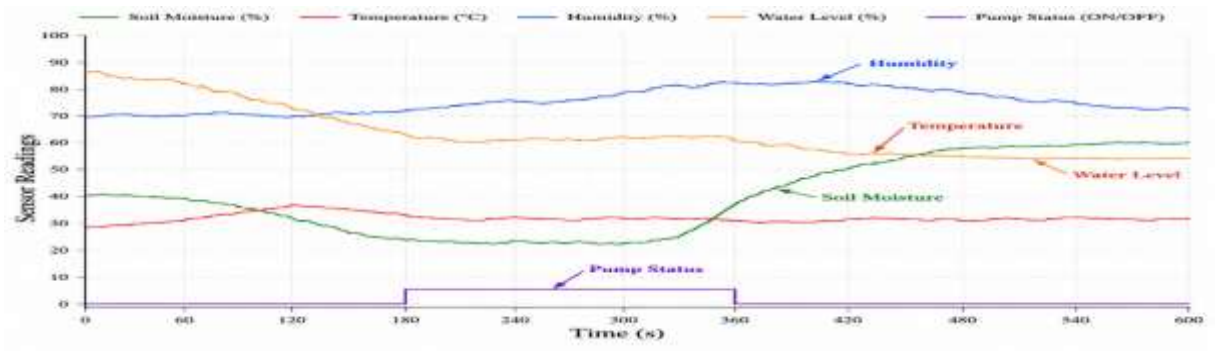


Fig.3 Response graph

These upgrades need to be added separately and tested in order to be considered as part of the list of the completed capabilities of the device. In general, both the main sources of information and the methodology offer an appropriate methodology for the design, construction, programming, and evaluation of the Smart Irrigation Controller Using Soil and Weather Analytics. This project involves such elements as sensors technology, embedded control, and automatic operation of the pump in order to minimize unnecessary watering, manual labor, pump dry running, and irrigation process overall.

RESULTS AND DISCUSSION

The Smart Irrigation Controller Using Soil and Weather Analytics is aimed at automating the process of irrigation and improving water management by means of the ESP32 microcontroller and various sensors. The soil moisture sensor is responsible for detecting the moisture condition of the soil, DHT11 is used for measuring the temperature and humidity, while the water level sensor helps to determine whether there is enough water in the storage tank. The data obtained from the sensors will be analyzed by the ESP32 which will decide whether irrigation is needed.

If there is no moisture in the soil and enough water in the storage tank, the ESP32 will turn on the relay module and the water pump. In case when there is enough moisture in the soil or water level is low, the water pump will stay switched off. This type of control will allow to avoid unnecessary watering and prevent the pump from running without water. Automatic control may decrease the amount of labor and increase convenience of farmers and gardeners. This system can be used in small farms, in private gardens, in greenhouses and nurseries due to the common electronics used in it. When you combine soil moisture sensing and water level sensing, you will have more control compared to the basic irrigation system with timer only. The temperature and humidity sensors give us some additional information about the environmental condition but are not capable of giving us the total water requirement of crops. But there is one more feature of ESP32 that allows for the future enhancement of the system due to its ability to connect wirelessly. Integration with weather forecast, mobile alerts, solar energy and machine learning can help us make better irrigation decisions and monitor the process. But the real efficiency of the system can be checked only in practice. As there have been no actual experimental results that have been presented, it is too early to make claims about how much water and energy will be saved. Nevertheless, this system is a realistic solution to the problem of automatic irrigation systems.

CONCLUSION

The Smart Irrigation Controller Using Soil and Weather Analytics is an IoT project that is aimed at managing irrigation and reducing water wastage in agriculture. This project incorporates an ESP32 microcontroller to sense moisture in the soil, soil temperature, humidity, and availability of water by using sensors. The soil moisture sensor can be used to determine if there is a need for watering the soil. The DHT11 sensor is used to sense the temperature and humidity of the surroundings. Water level sensor is used to determine the presence of water in the storage tank and protects the pump from being run without enough water. According to the data collected by the sensors, the ESP32 automatically determines the decision for irrigation and operates the pump with the help of the relay module. If the soil is dry and there is enough water, the pump is turned ON. Otherwise, it is turned OFF. With this automation process, the requirement of constant human presence becomes less and unnecessary pumping of water can be avoided. Unlike traditional irrigation processes which use manual methods or fixed-time irrigation schemes, the presented method takes into consideration the soil moisture levels and water availability while controlling the irrigation process. The design has been made with the use of commonly available electronic parts and hence is appropriate for small farms, personal gardens, greenhouses, and nurseries. The design serves as a good learning tool regarding embedded systems, sensor interfacing, IoT applications, and automated control processes in agriculture. Temperature and humidity measurement have been used to add environmental parameters that will be considered for future improvement in irrigation process. However, at present the system is mostly dependent on sensor readings and control conditions.

So more development needs to be done for better decision making related to irrigation according to weather conditions and requirements of different crops. In future, real-time weather forecasting can be incorporated by using weather API. Machine learning methods can be employed to determine irrigation needs, while solar energy will serve as an alternate source of power for farms. Notification services via mobile apps can also be incorporated into the

system to alert users about the working of the pump and low water level. Further tests will have to be conducted on various soil types, environmental conditions, and irrigation needs to determine the reliability of the system, its water consumption, and its energy efficiency. As the experimental results have not yet been obtained, the exact amount of water and energy saved will have to be established through practical tests. In general, the suggested project presents an economical way to automate the irrigation process and leaves room for improvements.

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