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Smart Irrigation System

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Abstract: Nowadays, evolving technologies have contributed significantly to enriching the field of agriculture. The automation process is integrated to drive devices to work independently and communicate by including smart technologies and devices with which a multitude of tasks are executed without a human hand. Thus, this work introduces an automatic irrigation system based on smart sensors that can be used in a moderate and economic way to monitor the mint or any kind of plant by integrating some connected electronic devices and other advantageous instruments widely used in the field of IoT. This system includes a soil moisture sensor placed in the root zone of the plant, a temperature sensor, and a water flow sensor connected to the valve of the water pumping motor. These sensors are integrated with an Arduino UNO microcontroller, relay module, DC pumping motor, and power battery. In other words, the behavior of this automated system is encapsulated in detecting the soil moisture and the temperature level and automatically switching the pumping motor to ON or OFF in relation to the soil moisture state at a controlled timing. The sensed data is transmitted to a computer to be included in the CSV dataset from which graphs are generated for analysis during one day of recording. Generally, this kind of automated irrigation system could be easily applied to small gardens, nurseries, or greenhouses. Recently, innovative solutions have been incorporated for reducing costs, saving time, and optimizing the use of resources.

Keywords: IoT, Microcontroller, Smart Irrigation, Soil Sensing.

1. INTRODUCTION

Forever, Water sources are a vital need in human daily life. Approximately, up to 85 % of the water worldwide is employed in farming. Regarding the exponential population and globalization growth rates, water consumption is also increasing in a very fast way. Thus, reducing water consumption in agriculture while providing fresh and healthy food is a challenging matter. Hence, the critical necessity to build reliable strategies founded on the advancement of science and technology raises more and more the need to make the use of water resources sustainable, taking into consideration agronomic, managerial, technical, and institutional progress. In the same context, referring to (Jha *et al.*, 2019) the Internet of Things is an evolved technology participating in the development of several fields not only by improving efficiency, productivity, and the global economy but also by saving time and reducing human intervention and cost (Srinivasan *et al.*, 2019). IoT is the network of devices that operate and communicate independently to transfer information without human interruption. Thus, to improve the yield productivity, the synergic action of IoT with cultivated fields leads to automated smart farming. Therefore, it plays a primordial role, particularly in the precision farming landscape. As such, irrigation requires knowing how much water to apply and when and under what circumstances to apply it. Knowledge of a soil's water-holding capacity and the crop's water requirements can provide the answers. Besides, this paper presents a smart irrigation system that involves soil moisture, temperature, and water flow sensors integrated with an Arduino microcontroller to monitor the soil state of the mint vase. The proposed system provides optimum irrigation by switching the pumping motor automatically through the relay module, depending on a threshold value of soil moisture and temperature. The system is quite functional, and the perceived results are very encouraging.

2. RELATED WORKS

Up to date, there are a multitude of systems dedicated to saving irrigation water in various crops' farming, from preliminary to deep technical-advanced ones. For instance, an automated irrigation system that uses a wireless sensor network and GPRS module was created to optimize water use for agricultural crops. It puts in place, in the root zone of the plants, a distributed wireless network of soil moisture and

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temperature sensors and a gateway unit for handling the sensors' information, controlling actuators, and transmitting data to a mobile application. Data inspection and control of water scheduling are allowed using an application through a duplex communication link based on a cellular-Internet interface. Also, the use of solar power in this irrigation system is done by photovoltaic panels. The system has a significant prospect of being installed in geographically sheltered locations characterized by limited available water because of its capacity to provide better irrigation monitoring with conservation of water (Shah *et al.*, 2019). Likewise, an intelligent system dedicated to predicting the irrigation water needs of a field is designed based on the ground sensing measurements such as soil moisture and soil temperature, along with the climatic forecast data available on the Internet like precipitation, air temperature, humidity, and UV for the near future, including open-source technologies. The data is wirelessly acquired and deployed on the cloud using web services and analyzed by a web decision support system providing real-time information (Velmurugan *et al.*, 2020). Moreover, a cloud-connected, secure multi-crop smart irrigation system (SMCSIS) is proposed by (Samawi, 2021)to optimize water consumption and to handle the over-irrigation issue resulting from weather changes and causing precipitation after irrigation. The system constructs a real-time irrigation decision based on the predicted soil moisture estimated at the current moment of precipitation. The soil moisture prediction is performed depending on the analysis of the data sensed by the soil moisture sensor and the evaporation prediction. The evaporation is predicted using an artificial neural network trained on five factors (air temperature, wind speed and direction, UV, and humidity). Furthermore, according to (Fatima, Siddiqui and Ahmad, 2021) an IoT-based Smart Greenhouse system is designed with a novel monitoring combination including warning, automation, disease forecast, and cloud repository, by employing a readily deployable complete package. It continually maintains dynamic conditions such as temperature, humidity, and soil moisture state to improve the crop yield and to guarantee an instantaneous reaction in the event of abnormal conditions. In addition, it includes an automatic irrigation and leaf image analysis module based on an efficient deep learning model for disease identification. The evolving scarcity of freshwater resources across the world has spawned a crucial need for their optimum consumption, especially in agriculture. The Internet of Things (IoT) is in the keen interest of developing smart and automated systems, benefiting from specific data sensing devices and smart processing, which have bridged the gaps between the cyber and physical worlds. IoT-based smart irrigation systems can assist farmers in their agricultural activities by optimizing both irrigation water resources and time.

3. THE PROPOSED SYSTEM

3.1 An overview

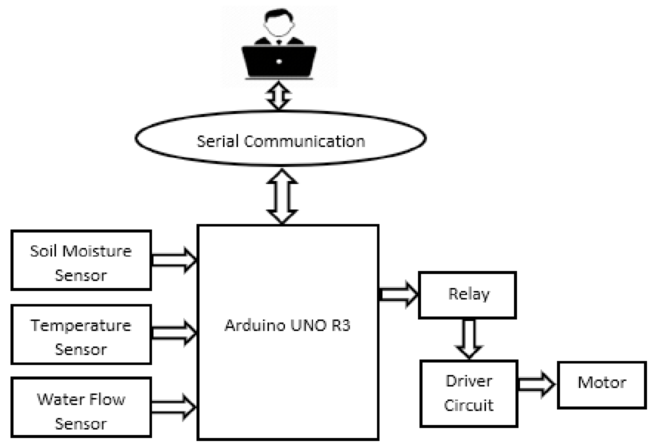

Figure 1. The smart irrigation monitoring system architecture.

Currently, agriculture is encountering many issues due to the challenges of sustainable water resource system design. A smart irrigation system has been proposed in order to support farmers in overcoming their daily hardships. In this system design (Fig. 1), we intend to automate the irrigation of the mint by monitoring the soil state of the plant vase. We have integrated soil moisture, temperature, and flow sensors with the input pins of the Arduino and the relay module connected to the water pump to collect hourly measures in the CSV file via serial communication.

3.2 Circuit diagram

In the circuit diagram presented in (Fig. 2), we have integrated a resistor of (4.7K Ohms) with the color codes of Yellow, Violet, Red, and Golden between the digital data pin and the VCC (5V Pin) of the one wire waterproof temperature sensor (DS18B20) injected in the field. We have also integrated the soil moisture sensor injected into the soil of the mint vase, the submersible water pump (3.3-5V), the water flow sensor "YF-S201" with (water pressure <1.95), and a working range of (1-30L/min), and a WH Battery (5V) connected to the Arduino using the (9V/5V) Battery Adapter present in (Fig. 6). To collect the data, we used the serial monitor by connecting the Arduino UNO to the computer via a USB cable.

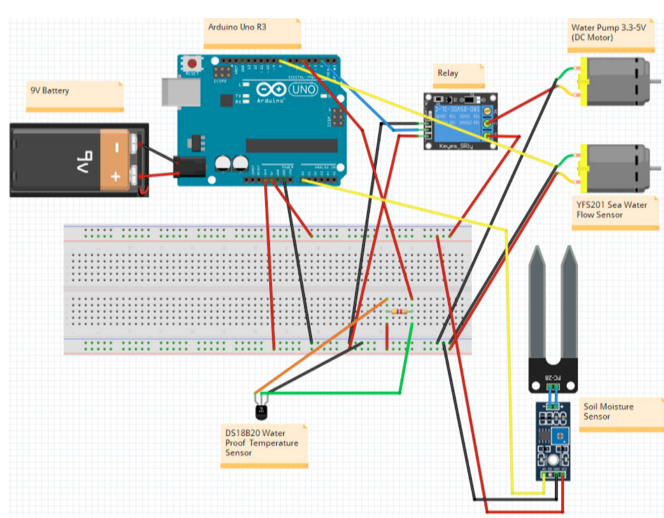

Figure 2. The circuit diagram of the proposed automatic irrigation system.

4. MATERIALS AND METHODS

4.1 Soil water content measurement

The regulation of terrestrial freshwater supply ensured by the soil constitutes a primordial ecosystem process. Therefore, the percolating water through the soil goes through several operations, including filtration, storage for plant utilization, and redistribution across flow directions to groundwater and surface water layers. Just as the soil influences the sustainability of water resources regarding both quantity and quality, hydrologic processes in the soil serve as the major basis for numerous characteristics of terrestrial and freshwater aquatic life.

Soil moisture is a crucial factor in the growth of plants because of its ability to regulate most soil aspects like temperature, availability of nutrients, salinity, and the existence of toxic substances. Moreover, it gives structure to the ground and plays a primordial role in stemming soil erosion. As such, the soil wetness level is a critical indicator of the soil state and the overall circumstances of the land system. Hence, it determines land-use suitability (Tam, Nyvall and Brown, 2005).

In agriculture, irrigation is the main process contributing to the growth of crops and yield. The soil water storage (SWS) capacity constitutes a basis for plant watering, which is defined as the effective amount of water that is infiltrated into the root depth of the crop and accessed during its stages of development. The deeper the rooting depth, the larger the reservoir of water saved in the soil, and thereby, a larger volume of water is readily available for the plant to consume between irrigations. Excessive irrigation applied to the soil can lead not only to a loss of water by deep percolation but also to the leaching of nutrients outside the root zone. A piece of the stored water in the soil is used by the plant without being under stress. Otherwise, the crop should be irrigated once this amount of moisture has declined due to deep percolation or evapotranspiration (Moorberg and Crouse, 2021).

4.2 Sensors and electronic devices

Sensors are devices dedicated to detecting environmental fluctuations and sending the measured information to another connected device, usually the main control system (micro-controller or electronic computer processor). Analog sensors are devices that produce a continuous output electric signal or voltage that is symmetrical to the input quantity being measured, such as humidity, pressure, or speed, while digital sensors are devices that produce discrete output electric signals or voltages that are a digital indication of the quantity being measured. Digital sensors deliver a binary output signal ('0' or '1') or in a logical form ("ON" or "OFF") (Chakraborty, 2020). The circuit diagram illustrated in (Fig. 8), integrates the main components:

The soil moisture sensor presented in (Fig. 3): characterized by a working range of (0 to 1023 ADC value) used to measure the moisture content of the mint soil. It consists of two conducting probes that can detect the moisture content in the soil proportionally to the change in resistance between the two conducting plates.

Figure 3. Soil moisture sensor.

The temperature sensor (DS18B20) present in (Fig. 4) is a digital temperature sensor characterized by a working range of (-55 to 125 °C), an accuracy of (+- 5%), integrated with a resistor of (4.7KΩ) with an accuracy of (+-5%), shown in (Fig. 4), and employed to measure the temperature of the mint soil.

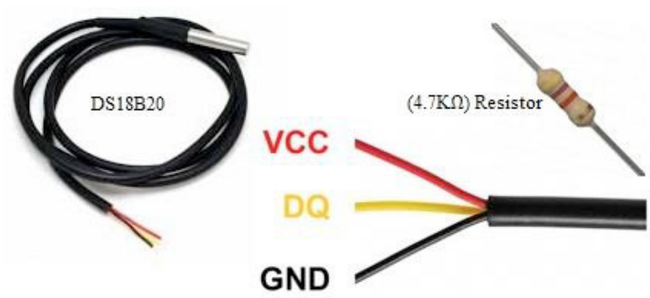

Figure 4. Temperature sensor (DS18B20).

The Sea YF-S201 water flow sensor illustrated in (Fig. 3) is characterized by a water pressure inferior to 1.95, and a working range of (1-30L/min), and is connected to the pipe of the submersible water pump shown in (Fig. 5) to measure the water flow. The water flow sensor generates an electric pulse with every revolution through its integrated magnetic hall effect sensor that is sealed off from the water and allows the sensor to stay safe and dry. The water pump is a direct current (DC) motor, belonging to a class of rotary electrical motors that generate mechanical energy from electrical energy.

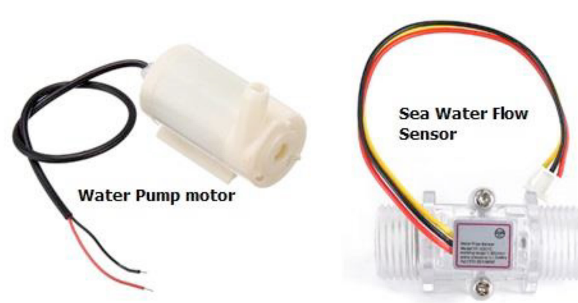

Figure 5. Water flow sensor (Sea YF-S201).

The Arduino UNO, shown in (Fig. 6), is a microcontroller board based on the ATMEGA 328P, which includes 32kB of flash memory for code storage. Its panel has 14 digital pins for input and output, 6 analog pins for input, a reset button, USB, a (16 MHz) quartz crystal, and an ICSP circuit. Usually, Arduino software is used for programming the Arduino UNO board.

Figure 6. Arduino UNO Board.

Relay module Shown in (Fig. 7) is an electrically operated switch which is employed in controlling a circuit through a distinct low-power signal. They are even used to protect electrical circuits from overload by integrating calibrated operating aspects, and sometimes multiple operating coils are used to protect electrical circuits from overload. As portrayed in (Fig. 8) the Arduino Uno is connected to the water pump motor via the relay. Here, the relay plays the role of switching the water pump ON or OFF related to the signal received from the Arduino board.

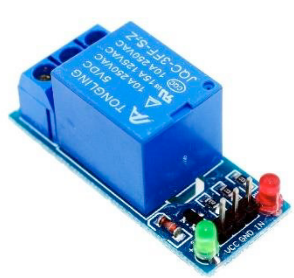

Figure 7. Rely module.

Using the power supply illustrated in (Fig. 8), we have tested connecting the Arduino board to the HW battery (9V) through the (9V/5V) Battery Adapter to supply the circuit with the electrical voltage instead of serial communication to make the system independent.

Figure 8. Power supply battery.

4.3 Arduino IDE software

The Arduino IDE is an open-source Integrated Development Environment (IDE) written in the Java programming language and is compatible with Windows, MacOS, and Linux, supporting the "C" and "C++" programming languages based on special code structuring rules and providing an enriched library of wiring schemes, integrating many input and output techniques. The Arduino software allows smoothly writing and uploading controlling code to any kind of Arduino board (Fezari and Dahoud, 2018).

5. RESULTS AND DISCUSSION

5.1 Work flow of the system

At first, the water pump is configured to be disabled, then if the sensed values go beyond the threshold values set in the program (soil moisture< field capacity = 360 = 64.80% or temperature > 30°C), it turns ON and irrigates the soil of the mint vase. Whenever the pump is turned ON, the flow sensor restarts measuring the irrigation flow, the horologe sleeps for (5 seconds: configurable), then the measures are recorded again until the soil moisture outperforms the field capacity. This time control allows an optimized irrigation time which optimizes the amount of water flowing to the field by minimizing the water loss that may be related to a long period of irrigation time before restarting the sensing and the threshold verification. In the case where the soil moisture exceeds the configured field capacity level, the pump turns off, and the horologe sleeps for (1 hour) before repeating the iteration. This process can be summarized as follows:

- Step 1: Start.
- Step 2: The system can be initialized on the Arduino UNO board.
- Step 2: The clock date is initialized on the Arduino UNO board, and the water pump is set to OFF.
- Step 3: The soil moisture sensor checks the soil moisture level constantly.
- Step 4: The temperature sensor constantly senses the temperature level.
- Step 5: The water level sensor constantly checks the water level of the motor.

- Step 6: The microcontroller updates the current date and checks for the threshold condition. If the water content level is inferior to the field capacity level (360) of the mint vase, which means that the soil becomes dry or the temperature surpasses (30°C), then the relay that is connected to the Arduino UNO will turn ON the motor to irrigate the field. The delay is set to (5 seconds) to repeat step 3. Otherwise, if the threshold condition isn't satisfied, the motor will be turned OFF, and the delay will be set to (1 hour) before repeating step 3.

5.2 system design

The farmer will be intimated about the current field state based on the data stored in the CSV file throughout the serial communication. (Fig. 9) portrays the results of the physical design of our proposed smart irrigation system experimented during (1 day) of recording from (1/18/2022 at 18:18:55) to (1/19/2022 at 18:24:36); on the basis of the Arduino and smart sensors technology. When the program was loaded onto the Arduino board, all of the soil moisture, temperature, and water flow sensors started to display the values in the serial monitor. According to the state of the mint bowl, the pump is turned ON by the Arduino through the relay module and the water flows throughout the pipe to the ground of the vase.

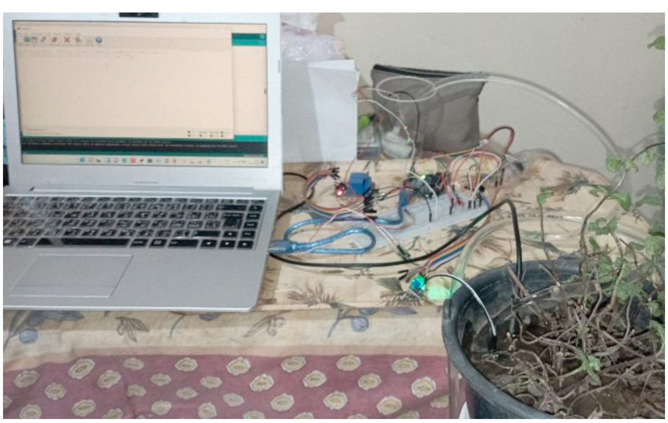

Figure 9. The designed Automatic Irrigation System.

5.3 Results of the data sensing

As shown in (Fig. 11), the temperature didn't reach the threshold of (30°C), thus when the soil moisture surpassed the field capacity (360) as illustrated in (Fig. 10), the pump was turned ON, the water flow reached (144 L/Hour) in (5 seconds) of irrigation and the water flow measure has been sensed again (144 L/Hour) after a sleep time equal to (5 seconds). The measures are sensed repeatedly after each sleep time of (5 seconds) until the soil moisture exceeds the field capacity threshold (363 > field capacity), then the pump is turned OFF and the measures are recorded again after a sleep time equal to (1 hour). (Fig. 11) shows the temperature fluctuations.

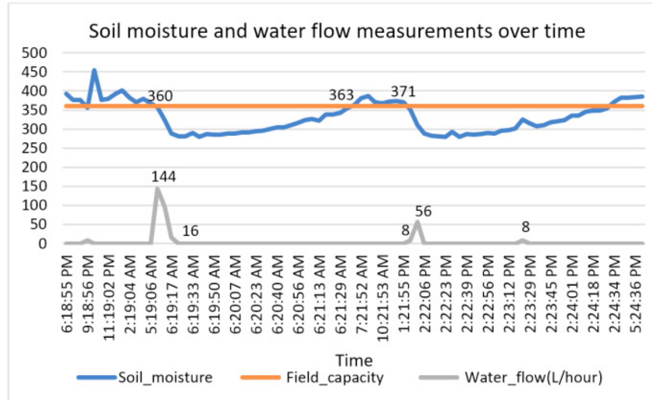

Figure 10. Soil moisture changes and water flow fluctuations over time.

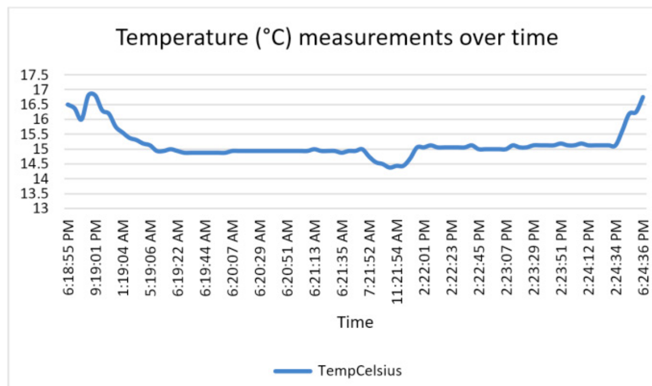

Figure 11. Temperature fluctuations over time.

6. CONCLUSIONS

Ultimately, a reliable smart irrigation system based on the Arduino UNO board was designed. The microcontroller circuit has been deployed using smart sensors to monitor the soil state of the mint plant. This circuit included an Arduino UNO, a relay, temperature, soil moisture, and water flow sensors, a motor (5v), and a battery. The circuit is fully operating, and we validated the effectiveness of this system on a mint vase for one day of recording. After studying the sensed data consolidated in a CSV file on the computer via serial communication, we concluded that the irrigation time that is controlled using the configurated repeated sleeping time equal to (5 seconds) and the delay of (1 hour) after turning the pump OFF is quite efficient to optimize water consumption while keeping the mint safe. Therefore, this system employs soil sensing technology to control the irrigation of the soil of the plant, which prevents and overcomes intense or poor irrigation, and it could be a potential tool for farmers to save time and reduce their intervention and cost. Nevertheless, serial communication, limited power battery support, and limited graphic design using consolidated files are still not good choices for long-term monitoring. Hence, investing in remote sensing using Bluetooth or WIFI technology using GPRS modules or other networking or power supply devices, integrating other smart sensors for precipitation or salinity, and integrating an IoT open-source web platform could be the future perspective of this work.

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