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Smart Irrigation Control System Using Wireless Sensor Network via Internet-Of-Things

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***Abstract*— Nowadays, humans tend to rely on anything that is equipped with automatic control. One of the applications is in the field of agriculture. In order to help in water conservation and less human labor, the researchers designed a smart irrigation control system with the help of wireless sensor networks through the use of a customized server as an Internet-of-things platform. In achieving the objectives of the study, the researchers used both developmental and experimental methods to determine the accuracy and functionality of the system and to measure the water consumption comparison between a smart irrigation control system and conventional method of irrigation. Wemos D1 Mini was used as the main microcontroller of this study. T-test was used as the statistical tool to determine if the experiment results are significant. The design and development of a microcontroller-based wireless sensor network improves the way of irrigation system with effective functionality of every components in the system. The system is accurate in terms of its sensing capabilities and accuracy. Based on the findings of the study, the plants are sufficiently and automatically supplied with certain water requirement.**

Keywords— ESP8266, Internet-of-Things, Server, Smart Irrigation Control System, Wireless Sensor Networks (WSN) Microcontroller

I. Introduction

Agriculture is a procedure of land management used to cultivate domesticated plants and animals for food, fiber, and energy [1]. In agriculture, irrigation is an important method that impacts crop production which is a major source of sustenance to the rising demand of the human population. The labor-intensive method of providing an adequate amount of water to the vegetable crops turns to be overturned to the demands of automation systems. Such as the application of modern technology and the availability of the microcontrollers that are usually suitable for this autonomous service due to their highly-programmable platform.

In addition to this, studies have shown that manual watering is an inefficient technique as this contributes to a high possibility of excessive water consumption and the labor it needs to satisfy the number of plants. Due to matters of collective water demands, high water charges, and the shortage of laborers, owners of vegetable crops field must be cautious in conserving water and adding more labor.

One study says that the need to deal with alternative water delivery technologies leads to efficient and more productive water input [2]. Currently, there are more and more studies that introduce the benefits of adopting a smart irrigation control system.

A sensor-based automated irrigation system provides easy tasks and an efficient solution to the farmers where their presence in the field is not necessary anymore [3]. Hence, a microcontroller is programmed to do the controlling of sensor nodes and the central node for which the solenoid valve is switched to an on or off state based on the received and analyzed data from the sensors. Using a customized server with a unique IP address as an Internet-of-things application, the data is monitored, recorded, and is internet-accessible as the internet is widely used nowadays. An essential way for the farmers to know the update of their field and even control it with a handy mobile device anywhere. [4] [5]

Irrigation usually demands time and also requires human resources as it is the essential practice in agriculture and the major concern to deal in this part. One should be knowledgeable in giving proper irrigation schedule for crops as there must be an understanding of the environmental demand for surface water. Knowledge about the required amount of water in the field is an essential aid in the planning of irrigation schemes, irrigation scheduling, and irrigation management. Technologies of an irrigation system are being developed with an emphasis on smart management of water, advanced features, and automatic or remote control of an irrigation system. This is attained using irrigation controllers that come with many types, which are developed for automatic control of water application to certain lands [6].

The development of a real-time smart irrigation control system offers an increase in agricultural productivity while saving water, although the integration of sensors, irrigation control, data interface, software design, and communication could be a challenging task. An advantage of this system is that a field sensing system does not take extensive time and costs to install and maintain. The system is planned to be implemented using distributed wireless sensor networks using soil moisture, temperature, and humidity sensor real-time sensing to control and store the monitored data [7].

Wireless sensor networks implemented in smart irrigation systems provided provides endless possibilities [8] and gives more flexibility [9].

Different research study implemented an automated drip irrigation system with using Global System for Mobile Communication [6][10][11].

In this project study, an automated and remote irrigation-controlled system is proposed to minimize the water consumption and human intervention in the field while giving the best satisfaction for the crops. Unlike existing studies, the researchers implemented the drip irrigation system using wireless sensor network via Internet-of-things.

The aim of this study is to design and develop an automated and remotely controlled irrigation system using a wireless sensor network with the help of the internet where the presence of the farmers in the field is not compulsory. Specifically, these are the goals set for this study: (a) To design and develop a microcontroller-based wireless sensor network using humidity, temperature, and soil moisture sensors; (b) To analyze and monitor the moisture content of the soil alongside temperature and humidity via a customized server; (c) To evaluate the water consumption of the Smart Irrigation Control System compared to the conventional Irrigation; and, (d) To assess and test of the actualization of the Smart Irrigation Control System in terms of sensing capabilities.

The locale of the study is inside the greenhouse, which has a dimension of 30 feet by 10 feet or an equivalent of 300 square feet, in G.G. Buenaagua Agri Enterprises, Caroyroyan, Pili, Camarines Sur with internet connection speed up to 15 Mbps.

II. Methods

A. Methodology

This study both used developmental and experimental research methods to accomplish its objectives. The researchers used the developmental research method since the study focuses on developing the study prototype through series of steps that include the following: planning, designing the pipe flow of the irrigation system and the device, and preparing the required and suitable parts for the system through a process of construction and experimentation.

The researchers also used an experimental research method to test its accuracy in terms of sensing capabilities and sending data, effectiveness, and functionality of the system. Additionally, the researchers want to determine the difference between the smart irrigation system and the conventional method in terms of water consumption.

B. Design Procedure

Figure 1 represents the design procedure in developing and testing the system. The research study aims to design an innovative smart irrigation control system to support and improve the agricultural land that can autonomously provide a sufficient amount of water to the crops with the use of a wireless sensor network that is monitored via customized server. The researchers opted to use a microcontroller-based irrigation control system with an automated watering system. To program the microcontroller, the Arduino Integrated Development Environment (IDE) is used as a platform. The program is written in C++ language and is operated in a sequential procedure. In hardware and software integration,

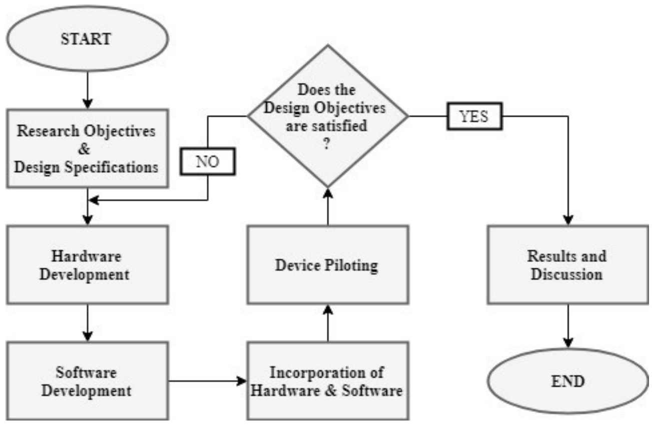

Fig. 1. Design Procedure of the Smart Irrigation Control System

the expected data from the soil moisture sensor is in percentage format since a range of low percentage means dry state and a range of high percentage means otherwise. The data received from the wireless sensor nodes is transmitted and recorded to the central node that is delivered next to the server of the system. The program then reads the other sensor nodes simultaneously until all of the nodes are done.

C. Hardware Development

This research study is represented with the block diagram as an overview of how the system functions. Figure 2 shows the interconnections of every section for the smart irrigation system.

The block diagram of this project study is composed of seven primary blocks, namely: three sensor nodes, central node, DHT22 humidity and temperature sensors, Wi-Fi router, water flow sensor, and solenoid valve and server. The wireless sensor nodes are composed of: WEMOS D1 Mini, which is the main controller of the system; WEMOS D1 Mini Battery Shield, which is the power supply of the device; and soil moisture sensor module, which reads the moisture content from the soil and sends the gathered data thru Wi-Fi connection to the central node. Also, DHT22 shield, which is connected to the central node, measures the reading for the temperature and humidity of the air. Central node is the one responsible for transmitting all the data collected to the server.

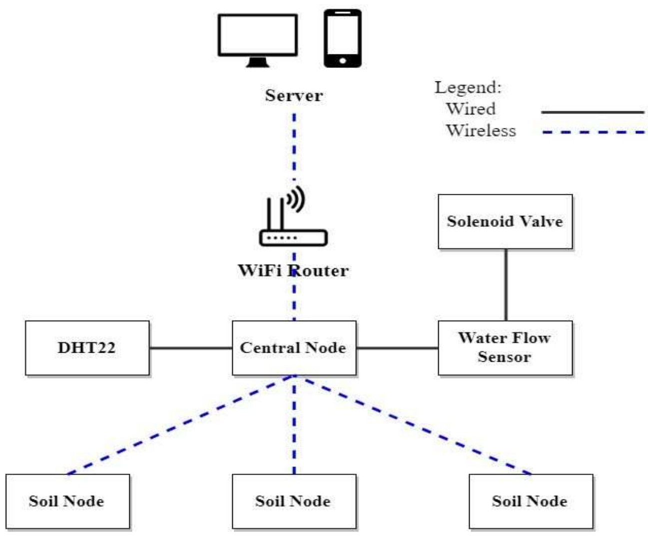

Fig. 2. Block Diagram of Smart Irrigation Control System using Wireless Sensor Networks via Internet-Of-Things

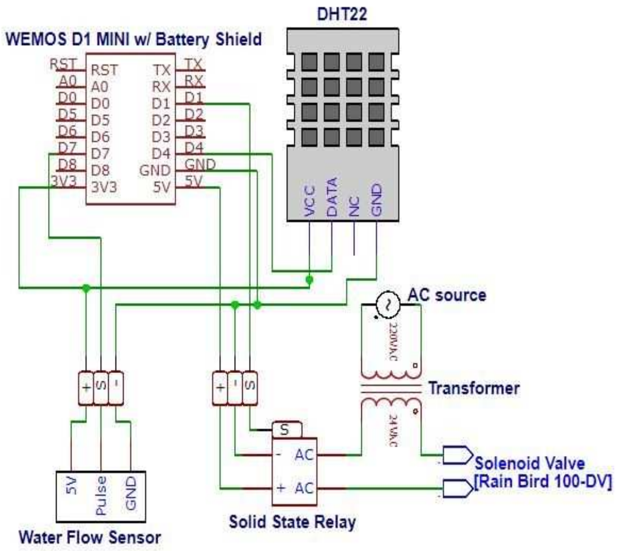

Fig. 3. Schematic Diagram of Central Node

Afterwards, an analysis is made for which if the specified condition is reached, the solenoid valve is turned open or close.

Meanwhile, the water flow sensor, which is connected to the central node, measures the volume rate that flows in the system. The top block of the diagram, which is the server as the IoT application, is the monitoring system of the study where some of the data is stored and displayed.

In designing and developing the hardware, the researchers followed a methodical procedure mentioned below:

For Central Node (see Figure 3):

- Prepare DHT22 shield, WeMos D1 mini battery shield, WeMos D1 mini, one-channel relay module, Rain Bird 100-DV solenoid valve, water flow sensor, universal circuit board, and connectors.;
- Combine DHT22 shield, WeMos D1 mini battery shield, and WeMos D1 mini and connect it to the designed universal circuit board;
- Connect the water flow sensor in the right side of the board with the three-terminal connector (-,S,+) and the relay module (CH1,DC-,DC+) to the other side with three-terminal connector (S,-,+);
- Connect one of the power supply terminals to the AC side of the relay module and the other one to the solenoid valve. Then, the other terminal of the solenoid valve to the other AC side of the relay module;
- Supply a 3.7 Li-ion rechargeable battery to the central node.

For Sensor Nodes(see Figure 4):

- Prepare 3 pcs. for every each of WEMOS D1 mini, WEMOS D1 mini battery shield, soil moisture sensor module and probe;
- Combine every each of WEMOS D1 mini, WEMOS D1 mini battery shield, soil moisture sensor module;
- Connect the soil moisture sensor probe to the soil moisture sensor module's two male connectors;

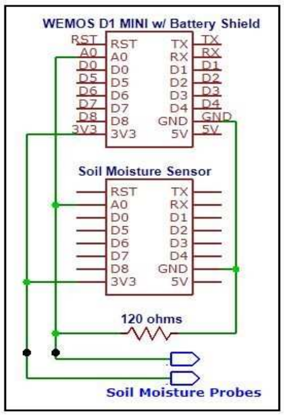

Fig. 4. Schematic Diagram of Sensor Node

- Supply a 3.7 Li-ion rechargeable battery for every set of sensor node.

In order to maximize the capability and usage of the microcontroller and the device, the researchers utilized the use of customized server for the monitoring and storing of data received with the crops soil moisture content, the temperature and humidity, and its water consumptions using the wireless sensor nodes and central node through Wi-Fi communication.

ESP8266 WEMOS Mini D1 board was used as the microcontroller, powered with a 3.7V @2200mAh Li-ion rechargeable battery, wherein every set of sensor nodes and central node instructions set for input and output are programmed and saved.

For sensor nodes, only A0, 3V3, GND pins were used for the soil moisture module. For central node, DHT22 shield is placed on the microcontroller and pins, D1, GND, 5V are used respectively as Digital Read for the solid-state relay where the solenoid valves are connected, and is used as power supply of the relay. A 24VAC power supply was supplied between the connection of relay module in the first AC side and one terminal of the transformer in the step-down 24VAC side. Depending on the reading of the wireless sensor nodes, the data collected are transmitted to the central node for the analysis in order to activate or deactivate the solenoid valves to let the water flow through to the crops.

D. Software Development

For the software development, this study followed the following measures:

- The initial values and conditions are set and the input and output ports are initialized;
- In obtaining consistent results, each sensor reading is calibrated to the driest state;
- After calibration, the program reads the value of the sensors simultaneously;
- The program, then, checks the value returned through the sensor and analyzes the state of the soil;
- If the soil meets the dry state condition, the relay switch activates and the solenoid valve opens. Otherwise, the soil is in wet state condition and proceeds to deactivate the relay turning the solenoid valve off; and,

- The program runs on a loop - checking the moisture content of the soil every second. Every data collected is stored and displayed through the customized server and the customized server has the parameters of knowing the temperature, humidity, soil moisture content and the total water consumption of the system. Also, this features manual and automatic control which can be changed with the minimum and maximum percent of the soil moisture for turning the solenoid valve open or close.

The researchers made a program flowchart in order to visually see the flow of the system and for easy troubleshooting. Three electronic design automation tools, EasyEDA, Proteus and PCB Wizard were used as an aid for developing the prototype. EasyEDA was used to create the schematic diagram of the main components of the prototype which are the microcontroller, soil moisture sensor, DHT22, resistor, water flow sensor, solid-state relay, solenoid valve and transformer. For the schematic diagram of the power supply, the group used Proteus to determine the possible effects of the voltage and current runs to the electronic components. Lastly, PCB Wizard was used to create the layout used for tracing the design in the universal circuit board beforehand for the part of central node.

E. Final Output

The final product of this research study is the Smart Irrigation Control System Using Wireless Sensor Network via Internet-of-Things (IoT) which is composed of two forms of device, namely, the sensor nodes and the central node shown in Figure 5. Both devices have WEMOS D1 Mini with the battery shield as the microcontroller. Sensor nodes also include the soil moisture sensor module that reads the soil moisture content and delivers to the central node for evaluation and central node. It includes the DHT22 shield for the temperature and humidity reading, relay module and solenoid valve for the switching and activation or deactivation for the water flow and water flow sensor for measuring the volume rate of the water running in the pipes.

The customized server of the study is a simple webpage with visible parameters including the measured temperature, humidity, water consumption and soil moisture contents for every sensor node. The home page of the system is shown in Figure 6. Users are required to Login using a valid and assigned username and password to use the webpage and monitor all the parameters of the system in the Admin page shown in Figure 7.

Fig. 5. Smart Irrigation Control System Main Devices: Central Node (left) and Sensor Node (right)

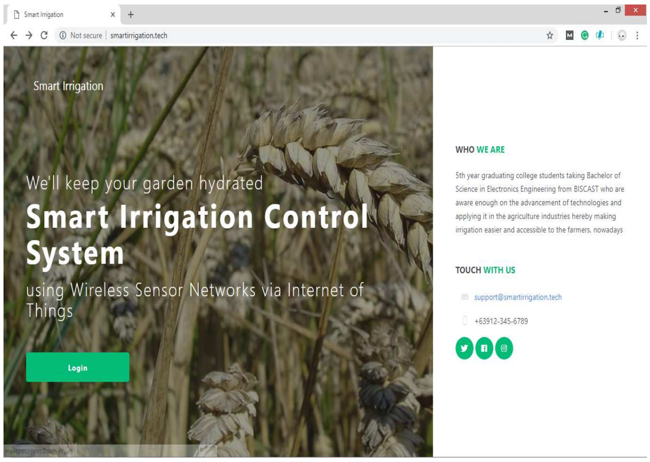

Fig. 6. Home Page of the System

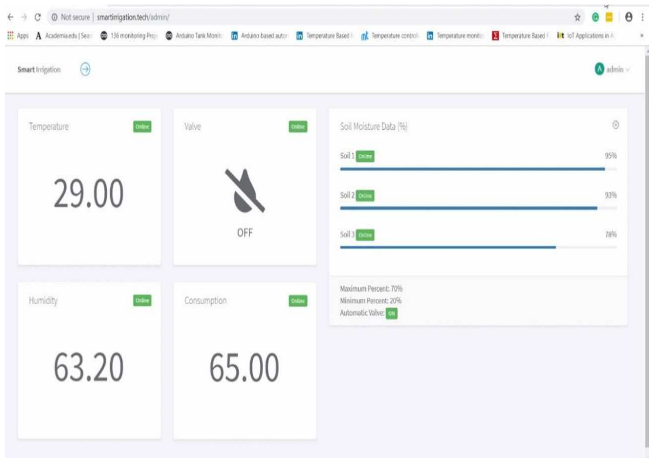

Fig. 7. Admin Page of the System

The customized server of the study is a simple webpage with visible parameters including the measured temperature, humidity, water consumption and soil moisture contents for every sensor node. The home page of the system is shown in Figure 6. Users are required to Login using a valid and assigned username and password to use the webpage and monitor all the parameters of the system in the Admin page shown in Figure 7.

III. RESULTS AND DISCUSSION

A. Sensing Capabilities

To know the sensor nodes sensing capabilities, the researchers conducted ten trials with three setups: soil moisture content less than or equal to 20, range between 20 and 70 and greater than or equal to 70. Table 1 shows the summary of collected data during the experiments.

It was observed that in all setups, the soil moisture readings of each soil sensor node gave an accurate response, since the expected output is the same for the actual output.

B. Comparison between Conventional and Smart Irrigation Control System

The study is composed of two system for comparison of water consumption, the conventional and smart irrigation system. Conventional method having a manual labor for activation or deactivation of the valve and the smart irrigation control system with automatic control using the soil moisture sensors to detect the soil moisture content and analyze the received data activate or deactivate the valve autonomously.

TABLE I. SOIL MOISTURE READINGS FOR MOISTURE CONTENT

Soil Moisture Content (%)	Average	Expected	Actual
⩽ 20	16	ON	ON
between 20 – 70	56.9	STILL ON	ON
⩾ 70	91.43	OFF	OFF

TABLE II. COMPARISON OF WATER CONSUMPTION BETWEEN CONVENTIONAL AND SMART IRRIGATION CONTROL SYSTEM

Trials	Water Consumption (in Liters)	
	Conventional	*Automatic*
Trial 1	22	18.3
Trial 2	22.9	20.5
Trial 3	21	18.9
Trial 4	22.1	20.8
Trial 5	19.8	18.1
Trial 6	18.9	18.1
Trial 7	19.7	18.6
Trial 8	19.9	18.5
Trial 9	20	18.8
Trial 10	21.2	21.6
Trial 11	20.3	20.3

There are 11 trials for both system with controlled variables including the size of the field, data speed rate and the pressure of the water flow entering the system. Table 2 shows the trials made during the experiment

In order to compare the two system for the water consumption, the researchers used T-test for the two groups. This is essential to know if there is a significant difference between the two sampled groups.

To determine if the study is effective in evaluating the water consumption with no difference to conventional irrigation, two hypotheses were formulated:

H_0: There is no significant difference in assessing the water consumption between the Smart Irrigation Control System and conventional irrigation.

H_a: There is a significant difference in assessing the water consumption between the Smart Irrigation Control System and conventional irrigation.

Using the T-test formula, with the computed means and standard deviations for each sampled group, the researchers got an answer of 2.638637066 T-test value having the degrees of freedom of 20 with critical value of 2.086 at significance level of 5%. Since, the absolute T-test value is greater than the critical value, the researchers rejects their null hypothesis that there is no significant difference between smart irrigation control system and conventional system in terms of water consumption which proves that smart irrigation control system is significantly effective than the conventional method.

TABLE III. MEAN, STANDARD DEVIATION, AND T-TEST

Water Consumption	*N*	*Mean*	*Standard Deviation*
Manual	11	20.70909	1.231629
Automatic	11	19.31818	1.240821
T-Test	2.638637066	Degrees of Freedom	20

IV. CONCLUSION

Based on the results of the study, the conclusions drawn are the following: (1) the design and development of a microcontroller-based wireless sensor network using humidity, temperature and soil moisture sensors improves the way of irrigation system with effective functionality of every components in the system. (2) The system is accurate in terms of its sensing capabilities and provides high accuracy for every setup made. (3) The objectives are obtained and achieved during the experiments with certain valuable data and interpretation.

V. RECOMMENDATIONS

Based on the findings and conclusions drawn, these recommendations were proposed for this research:

- The Agriculturist recommended that the designed irrigation system can also be applied to poultry farms aside from farm fields.
- The Agriculture Engineer recommended us to install additional features such as foggers and misters to maintain humidity or temperature control in the greenhouse.
- The greenhouse must be installed with water tank to even store rainwater.
- Consideration of what type of plants, including the plant's water requirement and days of growth must be taken account of.

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