The Development of an Automated Irrigation System Using an Open Source Microcontroller

A. Hassan[1], W. M. Shah[1], N. Harum[1], N. Bahaman[1] and F. Mansourkiaie[2]

[1]Center for Advanced Computing Technology, Faculty of Information and Communication Technology, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia.
[2]Faculty of Engineering and Applied Science, Memorial University of Newfoundland, St. John's, Newfoundland A1B3X5, Canada

aslindahassan@utem.edu.my

Abstract—**This paper proposes an automated irrigation using Arduino microcontroller system which is cost effective and can be used in a farm or in an average home garden. The proposed system is developed to be automatically watering the plants when the soil moisture sensor detected water insufficiency in the soil by using the Arduino as the center core. The automated irrigation system is a fully functional prototype which consists of a soil moisture sensor; an LCD display to show the moisture percentage and pump status; a relay module which is used to control the on and off switch of the water pump; and a water pump. When the soil moisture sensor senses the dry soil, it will show the moisture percentage on the LCD display, and the relay module will switch on the water pump automatically to start the watering process or vice versa. Hardware testing is conducted to ensure the proposed system is fully functional.**

Keywords—microcontroller; sensor; automated irrigation system

I. INTRODUCTION

Fresh water is needed for crop and energy production, industrial fabrication as well as human and ecosystem. According to AQUASTAT database, in the year 2010, 69% of the total extracted freshwater is used by the agriculture sector, whereas 19% is used by industrial sector and the rest in used by domestic segment [1]. Therefore, water can be considered as a critical need in the agriculture sector for future global food security [2], [3]. However, continuous increase in demand for water by domestic and industrial sectors and greater concerns for environmental quality have created a challenge to every country to reduce the farm water consumption while sustaining the fresh food requirement [4]. Consequently, there is an urgent need to create strategies based on science and technology for the sustainable use of water. Industrialist and researchers are working to build efficient and economic automatic systems to control water usage in order to reduce much of the wastage.

Irrigation is an artificial application of watering the land for agricultural production. The requirement of water for soil depends on soil properties such as soil moisture and soil temperature.

Effective irrigation can influence the entire growth process and automation in irrigation system using modern technology can be used to provide better irrigation management. In general, most of the irrigation systems are manually operated [5]. These traditional techniques can be replaced with automated techniques of irrigation to use water efficiently and effectively [6]. Conventionally, farmers must be present in their fields to do irrigation process. Nevertheless, nowadays farmers need to manage their agricultural activity along with other occupations. A sensor based automated irrigation system provides a promising solution to farmers where the presence of a farmer in the farm is not compulsory anymore during the process of irrigation.

Article history: Manuscript received 12 March 2019; received in revised form 06 April 201X; Accepted 08 April 2019.

Arduino is a flexible programmable hardware platform and designed to control the circuit logically. Central to the Arduino interface board is the main component of an integrated circuit chip that can be programmed using C++ language [7]–[9]. This micro controller is an AVR type, produced by Atmel firm. The device can read an input, process a program, and produce many outputs based on project requirements. In this paper, the development of an automated irrigation system based on Arduino micro controllers is presented. In this system, a soil moisture sensor is used to detect and check the soil humidity of a plant. Based on the soil moisture level from the soil, the system will let the water pump to automatic water the plant when it is too dry and turn off the water pump when the soil of the plant is wet.

In the previous works related to the automated watering techniques, it can be found that the Arduino based sensors have been utilized for the plant watering system [10]–[12] and automated irrigation systems [13]–[19]. A number of the automated irrigation system proposed have extended their intelligent features such as adapting to weather conditions [20] and. Integrating big data analytics in forecasting water requirement in an irrigation field [21].

An Arduino Based Automatic Plant Watering System is proposed in [10] where the authors developed the Arduino microcontroller used to control two functional components which are the moisture sensors and the motor/ water pump to automatically water the plant. The moisture sensor's function is to sense the level of moisture in the soil whereas the water pump supplies water to the plants. In [13], a smart drip irrigation system using Raspberry Pi and Arduino is proposed for the home automation system. A drip irrigation system makes the efficient use of water where the water is slowly dripped to the roots of the plants through narrow tubes and valves. The water flows from the system can be remotely controlled via email.

II. METHODOLOGY

A. Functional Requirements

Fig.1 shows a functional block diagram of the proposed automated irrigation system. It includes several functional blocks, namely: acquisition block, microcontroller block, automatic functional block, and monitoring block.

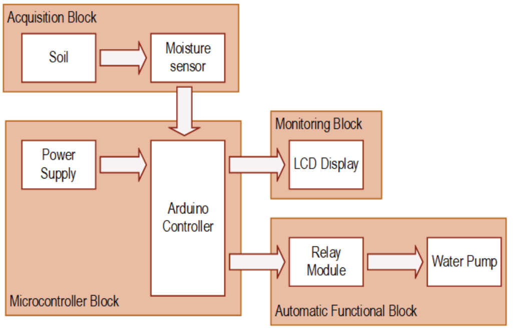

Fig. 1. Functional block diagram

- Acquisition block
  This block consists of one soil moisture sensor which takes the data from the soil. It depends on the moisture level of the soil whether to send high or low voltage to the microcontroller to show that it is wet or dry. When the soil is wet, it will send the low output voltage, whereas when it is dry, it will send the high output voltage. This sensor is directly connected to Arduino microcontroller.
- Microcontroller block
  In this block, Arduino Uno is the microcontroller which is the core hardware of this project. It receives the input from the soil moisture sensor and processes the input based on the requirement coded in the microcontroller.
- Automatic Functional Block
  This block includes the automated watering function of the system. The automated function consists of two main controlling hardware, which is relay module and DC watering pump. The relay is an automatic electric switch that uses an electromagnet to move the switch from OFF to ON or vice versa. The switch controls the electric signal

that passes through the water pump. When the moisture level is below the threshold level, Arduino sends a signal to the relay module to automatically open the path for the electric to pass through the water pump to water the plant. After the system detects the sufficient level of the water in the soil, the relay will close the path for electric and thus the water pump will be stopped immediately pumping the water.

B. High-level Design

Figure 2 shows the system architecture of the automatic irrigation system. From Fig. 2, it is shown that the process starts from the soil moisture sensor. The sensor detects the level of moisture from the soil, and the measured data is sent to Arduino to be processed. Next, the moisture level and the status of the DC pump from Arduino is sent to the LCD screen to be displayed. At the same time, the data will also be sent to relay to signal the water pump to switch on or off.

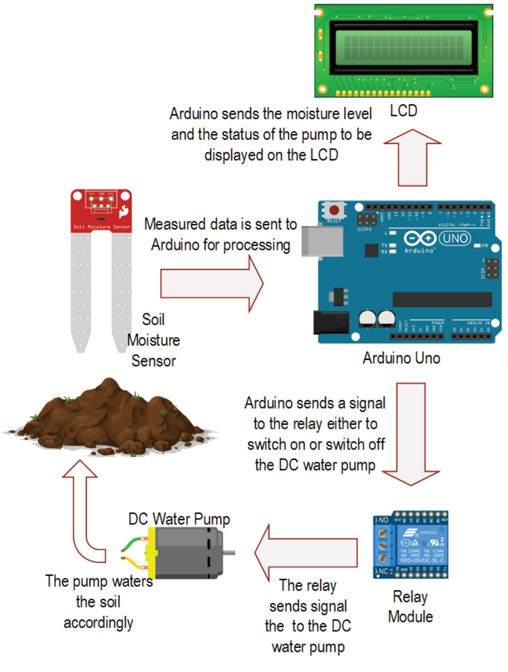

Fig. 2. The system architecture of the Automatic Irrigation System

C. Hardware Requirements

Figure 3 shows the complete hardware schematic of the proposed system which includes the Arduino board and all the necessary attached hardware.

- Arduino Uno Rev3
  The Arduino Uno is an open source microcontroller board which based on the ATmega328P architecture. An Arduino board contain 14 digital input/output pins, 6 analog inputs, a USB connection, and ICSP header, a power jack, a 16MHz quartz crystal and a reset button. The Arduino is the central core of this project as it controls all the hardware that are attached to it. It contains a platform for coding when connecting it to a computer with a USB cable with a self-download software named Arduino IDE.
- Soil Moisture Sensor YL-69
  This sensor is used to detect the moisture level of the soil. When the soil is having water shortage, the module output is at high level, otherwise the output is at low level.
- Liquid Crystal Display (LCD)
  It is a flat panel display that uses light-modulating properties of liquid crystals. The backlight will produce the screen images for showing the content that comes from the coding in the Arduino. In this project, the LCD screen is used to show the moisture level of the soil and the pump status which is set it early in the Arduino board through coding.
- Relay Module
  The relay module is a switch that controlled by an electromagnet. It is used to control the on and off of the DC watering pump by opening or closing the electric path that passes to the watering pump. It is controlled by the code from the Arduino.
- DC Water Pump
  The DC water pump used in this project is H-Bridge type. It is used to water the plant by sucking the water from the source and push out the water from the second hole to make the water process complete. It is controlled by the relay module which can be switch on and off automatically based on the signal sent from the Arduino.

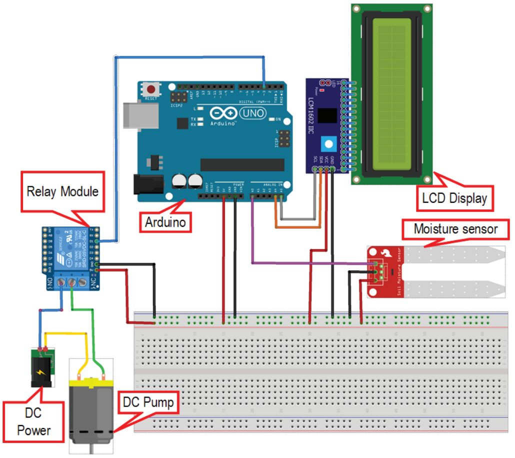

Fig. 3. Schematic for the Automatic Irrigation System

D. Hardware Implementation

From Fig. 4 and Fig 5, it can be seen that the Arduino is the center of this system which connects all the required hardware. The soil moisture sensor measures the level of moisture from the soil, and it is transferred to the Arduino board to process and make decision.

The LCD display shows the value that the Arduino received from the moisture sensor. At the same time, the data acquired is sent to relay module to determine whether to switch on or off the water pump. If the condition is required the water pump to be switched on, the water pipe attached to the pump will begin to draw up the water from the water source and push the water to the other side of water pipe to complete the watering process for the soil.

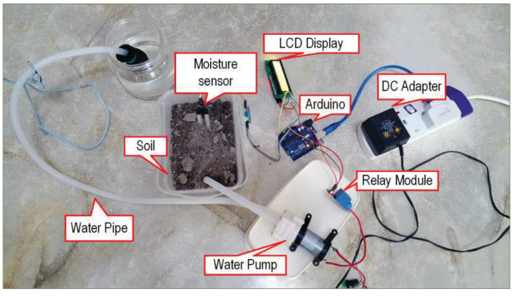

Fig. 4. Hardware implementation for the automatic irrigation system (Top view)

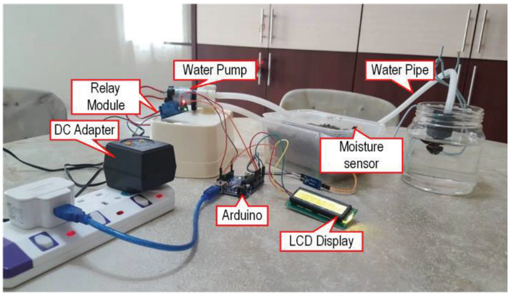

Fig. 5. Hardware implementation for the automatic irrigation system (Side view)

E. The Automated Irrigation System Operation

This section describes the configuration and the code implementation of the automatic irrigation system. As previously mentioned, the system starts with the sensor measures the level of moisture in the soil.

In Fig. 5, the code fragment reads the sensor value from the soil moisture sensor. The value is analog value is then converted into digital value either to be used for switching on the water pump or to be displayed on the LCD screen. The code fragment converts the upper bound 400 into 100% and lowers bound 900 into 0% respectively in the last statement of the code.

```
void readSensor()
{
    sensorvalue=analogRead(A0);
    sensorvalue=constrain(sensorvalue,400,900);
    soil=map(sensorvalue,400,900,99,0);
}
```

Fig. 6. Code fragment for sensor reading

The code fragment in Fig. 6 is mainly for the printing of the percentage that is acquired from soil moisture sensor to determine whether the soil is wet or dry. The value of the sensor also determines whether to switch the water pump on or off. From the code in Fig. 6, it is shown that when the soil moisture percentage is below 38%, the water pump will be switch on automatically, and the LCD screen will show the water pump status is 'ON'. When the soil moisture percentage reaches 47%, the water pump will be switch off automatically, and the LCD screen will show the water pump status is 'OFF'.

```
void loop()
{
        readSensor();
        lcd.setCursor(0,0);
        lcd.print("Moisture = ");
        lcd.print(soil);
        lcd.print("%");

        if (soil <= 38)
        {
                lcd.setCursor(0,1);
                lcd.print("Pump : ON ");
                digitalWrite(WATERPIN,LOW);

                while(soil <= 47)
                {
                        readSensor();
                        delay(100);
                }
        lcd.setCursor(0,1);
        lcd.print("Pump : OFF");
        digitalWrite(WATERPIN,HIGH);
        }
 }
```

Fig. 7. Code fragment for setting the LCD display and water pump switch

III. SYSTEM TESTING

This section describes the test strategy that is used for this project. The test is used to determine whether the hardware and software will be tested early to make sure that it is functioning according to the requirement.

A. *Soil Moisture Sensor Test*

TABLE I. MOISTURE SENSOR TEST PROCEDURE

Test	Soil Moisture Sensor
Test Purpose	To test the sensor values and its functionality.
Test Environment	A glass of water and Arduino IDE.
Expected Step	Step 1: Implement code to determine the moisture level of the soil with Arduino IDE. Step 2: Open the serial monitor in Arduino IDE and see the measure sensor value for the dry condition. Step 3: Immersed the soil moisture sensor into a glass of water and see for the wet condition in the serial monitor in Arduino IDE too.
Expected Result	The soil moisture sensor is light up in the controller when it is switched on, and it can show the lower and upper boundaries of the sensor value in dry and wet conditions.

Figure 8 and Figure 9 show the functionality test for the moisture sensor. In this test, the soil moisture sensor captures high values for dry condition and low values for wet condition. The values of the upper boundary for dry condition are around 893 with 900 whereas the values of the lower boundary for wet condition are around 399 with 400. Figure 10 shows the moisture sensor functionality test for both dry and wet condition.

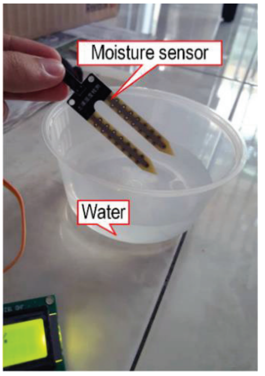

Fig. 8. Moisture sensor test for dry condition

Fig. 9. Moisture sensor test for wet condition

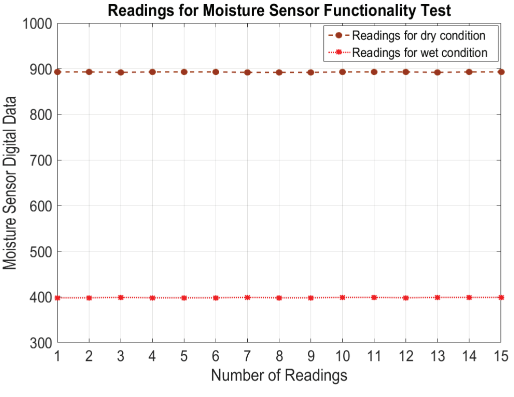

Fig. 10. The result for the functionality moisture sensor test

B. Monitoring System Test

From Fig. 11, it is shown that once the soil moisture sensor is immersed into a dry soil, the LCD display is able to show the content which is the 3% moisture percentage and the pump status is 'ON'. This means that the soil is insufficient of water and the water pump will be switch on to start the watering process.

TABLE II. MONITORING SYSTEM TEST PROCEDURE

Test	Monitoring System
Test Purpose	To test the function of the monitoring system.
Test Environment	Arduino IDE, Soil Moisture Sensor, LCD Display and Soil (Wet and Dry).
Expected Step	Step 1 : Implement code LCD display function using the Arduino IDE. Step 2 : Put the soil moisture sensor into the dry soil and see the content on the LCD screen. Repeat the step 2 by putting into the wet soil.
Expected Result	The soil moisture sensor must be able to differentiate between the wet and dry soil by showing the percentage on the LCD display screen. If the soil is dry the percentage shown should be low, while the soil is wet the percentage shown should be high.

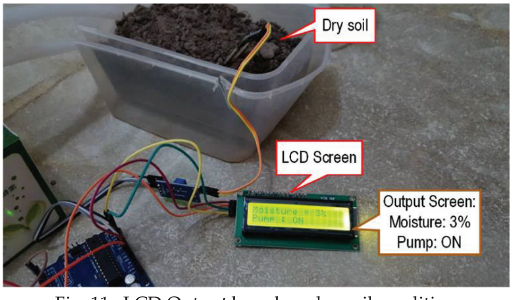

Fig. 11. LCD Output based on dry soil condition

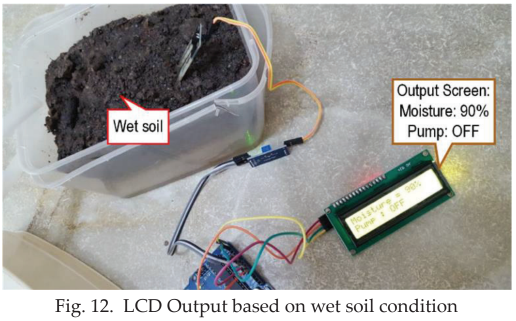

Fig. 12. LCD Output based on wet soil condition

Fig. 12 shows that once the soil moisture sensor is immersed into a wet soil, and the LCD display is able to show the content which is the 90% moisture percentage and the pump status is 'OFF'. This means that the soil is sufficient of water and the water pump will be switch off to stop the watering process.

IV. CONCLUSION

The main purpose of this paper is to propose an automated irrigation system that water the plant without any human control. The implemented automated irrigation system is found to be feasible and cost effective after optimizing the water resources for the agricultural production. Besides the automated irrigation system, the proposed system also provides the monitoring function where users are able to check the soil moisture based on the reading displayed on the LCD. The proposed system has been designed and tested to function automatically. For future works, the automated irrigation system can be configured to measure the moisture level (water content) according to the moisture requirement of the different plants.

ACKNOWLEDGMENT

Special thanks of gratitude to the Universiti Teknikal Malaysia Melaka for sponsoring the fund under the UTeM Short Term Grant with the reference number: PJP/2018/FTMK(1B)/S01628. A high appreciation to Digital Forensics and Computer Networking (INSFORNET) research group under Center for Advanced Computing Technology (C-ACT); and Faculty of Information and Communication Technology (FTMK) the use of the existing facilities to complete this research.

REFERENCES

[1] AQUASTAT, "Water Uses," *FAO*, 2016. [Online]. Available: http://www.fao.org/nr/water/aquastat/water_use/index.stm.

[2] M. A. Hanjra and M. E. Qureshi, "Global water crisis and future food security in an era of climate change," *Food Policy*, vol. 35, no. 5, pp. 365–377, 2010.

[3] A. K. Braimoh, "Global agriculture needs smart science and policies," *Agriculture and Food Security*, vol. 2, no. 1, BioMed Central, p. 6, 2013.

[4] M. Flörke, E. Kynast, I. Bärlund, S. Eisner, F. Wimmer, and J. Alcamo, "Domestic and industrial water uses of the past 60 years as a mirror of socio-economic development: A global simulation study," *Glob. Environ. Chang.*, vol. 23, no. 1, pp. 144–156, 2013.

[5] G. Severino, G. D. 'urso, M. Scarfato, and G. Toraldo, "The IoT as a tool to combine the scheduling of the irrigation with the geostatistics of the soils," *Futur. Gener. Comput. Syst.*, vol. 82, pp. 268–273, 2018.

[6] K. L. Steenwerth et al., "Climate-smart agriculture global research agenda: Scientific basis for action," *Agriculture and Food Security,* vol. 3, no. 1. BioMed Central, p. 11, 2014.

[7] "Arduino - Home." [Online]. Available: https://www.arduino.cc/. [Accessed: 23-Sep-2018].

[8] S. Monk, *Programming Arduino: getting started with sketches,* 2nd Editio. McGraw-Hill Education TAB, 2011.

[9] J. A. Langbridge, "ArduinoTM Sketches. Tools and Techniques for Programming Wizardry," *Electronics*, 2015.

[10] S. V Devika, S. Khamuruddeen, S. Khamurunnisa, J. Thota, and K. Shaik, "Arduino Based Automatic Plant Watering System," *Int. J. Adv. Res. Comput. Sci. Softw. Eng.*, vol. 4, no. 10, pp. 449–456, 2014.

[11] D. Divani, P. Patil, and S. K. Punjabi, "Automated plant Watering system," in *2016 International Conference on Computation of Power, Energy, Information and Communication, ICCPEIC 2016,* 2016, pp. 180–182.

[12] K. K. Kishore, M. H. S. Kumar, and M. B. S. Murthy, "Automatic plant monitoring system," in *2017 International Conference on Trends in Electronics and Informatics (ICEI)*, 2017, pp. 744–748.

[13] N. Agrawal and S. Singhal, "Smart drip irrigation system using raspberry pi and arduino," in *International Conference on Computing, Communication & Automation*, 2015, pp. 928–932.

[14] C. Kumar Sahu and P. Behera, "A low cost smart irrigation control system," in *2nd International Conference on Electronics and Communication Systems, ICECS 2015*, 2015, pp. 1146–1151.

[15] P. Singh and S. Saikia, "Arduino-based smart irrigation using water flow sensor, soil moisture sensor, temperature sensor and ESP8266 WiFi module," in *IEEE Region 10 Humanitarian Technology Conference 2016*, R10-HTC 2016 - Proceedings, 2017.

[16] Š. Koprda, M. Magdin, and M. Munk, "Implementation of microcontroller arduino in irrigation system," in *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 2016, vol. 9771, pp. 133–144.

[17] P. Mohandas, A. K. Sangaiah, A. Abraham, and J. S. Anni, "An automated irrigation system based on a low-cost microcontroller for tomato production in South India," in *Studies in Computational Intelligence*, vol. 676, Springer, Cham, 2017, pp. 49–71.

[18] P. S. Barath, M. Dutta, A. Chaudhary, and M. S. Jangid, "A Novel Adaptive Framework for Efficient and Effective Management of Water Supply System using Arduino," in *Proceedings of the 2014 International Conference on Information and Communication Technology for Competitive Strategies - ICTCS '14*, 2014, pp. 1–4.

[19] D. K. Swamy, G. Rajesh, M. J. K. Pooja, and A. R. Krishna, "Microcontroller Based Drip Irrigation System," *Techno-Societal 2016*, no. 6, pp. 1–4, Dec. 2013.

[20] B. Keswani et al., "Adapting weather conditions based IoT enabled smart irrigation technique in precision agriculture mechanisms," *Neural Comput. Appl.*, pp. 1–16, Sep. 2018.

[21] F. Ahmed, "An IoT-big data based machine learning technique for forecasting water requirement in irrigation field," in *Lecture Notes in Business Information Processing*, 2018, vol. 310, pp. 67–77.