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Development of an Automated Drip Irrigation System using Arduino Microcontroller for Sweet Corn

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Abstract: This study proposes an automated irrigation system using an Arduino microcontroller that is cost-effective and reliable for use in planting. The proposed drip irrigation system was developed to automatically irrigate the sweet corn seedlings from 0–4 weeks of age by detecting water insufficiency based on the moisture percentage of the soil used. The automated irrigation system was a fully functional prototype where the crop was irrigated automatically when the soil moisture sensor sensed a soil moisture value below 40%. The system consists of Arduino microcontroller, sensors to monitor soil moisture, ambient temperature and humidity; an LCD display to show the sensors readings; a relay module that is used to control the on and off switch of the water pump. The performance of the automated system development was then evaluated to ensure proper irrigation. The relay module was found switched on the water pump automatically to start the watering process when the soil moisture value below 40%. The data on soil moisture percentage (%), ambient temperature (°C), and ambient humidity (%) was displayed on an LCD screen that allowed real-time monitoring. The range of temperature and humidity were recorded around 31^{0}C to 40^{0}C and 62% to 80% respectively affecting the reduction of soil moisture percentage from 80% to 44%. In conclusion, an Arduino Uno-based automated plant watering system has been successfully installed and performed.

Keywords: Microcontroller; sensors; automated irrigation system; sweet corn; irrigation management.

1. Introduction

Precision irrigation involves the controlled application of water to crops in order to optimize both water usage efficiency and crop productivity. This approach utilizes technologies such as soil moisture sensors, weather data and computerized irrigation systems to deliver the amount of water at the right time and in the right location within the field. The main goal of precision irrigation is to minimize water waste, reduce energy consumption and enhance crop yields by ensuring that plants receive the amount of water they require for growth (Kumar et al., 2021).

Numerous studies have explored into the advantages and obstacles associated with precise irrigation. For instance, Zhang et al. (2019) demonstrated that techniques like drip irrigation and deficit irrigation can greatly improve both water usage efficiency and crop yield across systems. Similarly, recent work by another researcher highlighted how precision irrigation holds potential for mitigating water scarcity issues while concurrently promoting agricultural practices within regions constrained by limited water resources. These studies underscore the significance of irrigation as a means to address challenges related to water resources while fostering sustainability within agriculture. Furthermore, researchers have also explored the integration of irrigation with sustainable agricultural practices, in various literature sources. For example, research conducted by Wang et al. (2018) explored how precision irrigation and conservation tillage work to impact soil moisture levels and crop growth. The study showed that integrating these practices can bring about advantages, for crop production and offers a promising solution for improving water use efficiency and crop productivity in agriculture. It is seen that by leveraging advanced technologies and scientific knowledge, precise irrigation systems can play a crucial role in sustainable water management and agricultural development. The existing body of research provides valuable insights into the benefits and potential synergies of precise irrigation with other sustainable farming practices, highlighting the importance of continued exploration and implementation of precision irrigation strategies in agricultural systems.

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Precision irrigation that meets the crop needs is essential for crop to promote healthy growth. The lack of water in the soil may cause the leaves to become wither, dry and wrinkled while the excessive water is a waste beside the plant is susceptible to fungal or root disease (Li et al., 2020). Like other crops, the water consumed by sweet corn depends on the evapotranspiration rate (ET) of the crop, which influenced by many factors such as crop growth stage, relative maturity, weather conditions, soil water holding capacity and soil water content (Dan & Mark, 2021; Kranz et al., 2008). The water that losses from soil and crop occur simultaneously makes the prediction of evapotranspiration complex (Mark et al., 2017). Kranz et al. (2008) has outlined that the water requirement of corn should be applied according to its growth stage. It was highlighted that the highest water usage was when the corn at early tassel until kernel blister stage (0.32 inches/day) without stating the type of soil used for planting. While according to Greg (2007), the soil moisture was suggested to be consistently near 75% or more (for sandy soil) throughout the planting season. The different location also suggested different crop water requirement due to the different climate between locations. This was addressed by Lyndon and Peak (2016) who has proposed the corn water requirement according to the specific state. As for non-seasonal country like Malaysia, the Department of Agriculture, Ministry of Agriculture and Agro-based Industry has published a guideline for sweet corn water application according to the soil type which will be taken as a reference in this study.

Therefore, in order to promote the healthy growth of a plant, increase the yield and at the same time reduce the waste of water, it is therefore essential to supply the precise amount of water according to the plant's needs (Sharma et al., 2021). This study was conducted with the aims to develop the precision irrigation system specifically for the sweet corn seedlings according to the water requirement of the crop. The performance of the developed system was then evaluated to meet the objective of precision irrigation. The development utilized advanced technologies of Arduino IDE Atmega 328 microprocessor, Arduino IDE software, soil moisture sensor, temperature and humidity sensor, LCD display, a relay and a water pump. The system was coded using C++ programming language.

2. Materials and Methods

2.1 Location

The research was conducted at Universiti Teknologi MARA, Jasin Campus, Melaka.

2.2 Crop Planting Arrangement

Sweet corn seedlings were planted in the 16' x 16' polybag with a distance of 0.3m from each polybag (Fig. 1). The loam soil was used as a planting media.

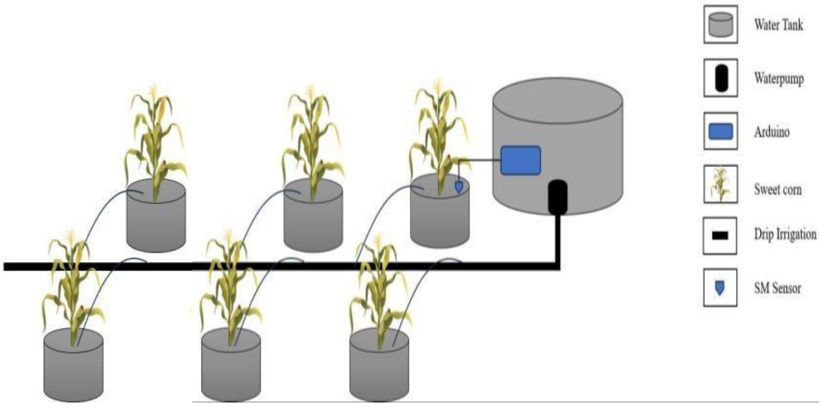

Fig 1: Planting arrangement of sweet corn seedlings

2.3 Determination of Crop Water Requirement

For the sweet corn, the information of soil water status was extracted from publication published by the Department of Agriculture, Ministry of Agriculture and Agro-based Industry (Jabatan Pertanian Malaysia, 2008). From the table, for loam soil, the reading of tensiometer that show a good state of water availability for plant growth is between 20 to 50 centibar. To translate the value of soil moisture in centibar to percentage, preliminary research was done to get the correlation between centibar and percentage unit using manual tensiometer and soil moisture sensor. It is depicted in the Table 1.

Table 1: Tensiometer value (centibar) and percentage (%) of loam moisture status

Loam Moisture status	Soil Moisture	
	Tensiometer Value (centibar)	Percentage (%)
Excess Water	10.00	90.00
Water available for plant growth	20.00	80.00
	30.00	71.00
Good Aeration	40.00	66.00
	50.00	40.00
Need Irrigation	60.00	30.00
	70.00	25.00

2.4 Functional Block Diagram and Hardware Requirements

Fig. 2 depicts a block diagram of the automated irrigation system's functional components. It consists of a number of functional blocks, including an acquisition block, a microcontroller block, an automatic functional block, and a monitoring block.

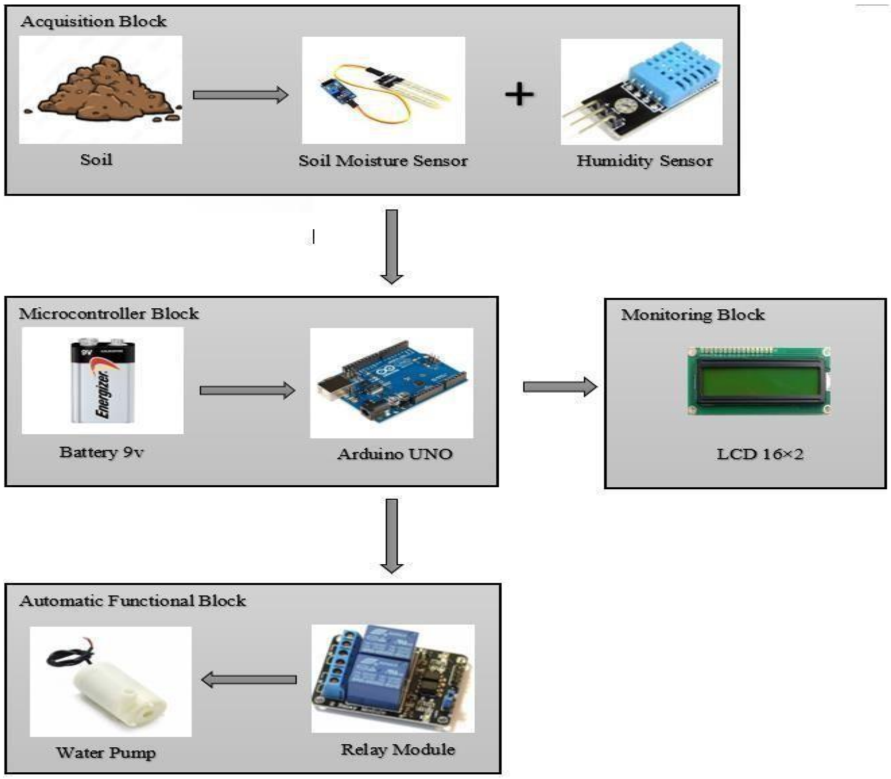

Fig. 2: Functional Block Diagram

2.4.1 Acquisition block

The block contains one DHT-11 humidity and temperature sensor that collects the ambient temperature and humidity and one YL-69 soil moisture sensor that collects data of soil moisture. The analog voltage was sent to the microcontroller from the sensors to indicate the conditions of soil moisture and ambient temperature and humidity. These sensors connected directly to Arduino microcontroller.

2.4.2 Microcontroller block

The block contains Arduino Uno that serves as the central microcontroller for this project to operate the motor pump and to monitor various system. The Arduino Uno is an open-source microcontroller board designed by Arduino.cc that uses the Microchip ATmega328P microcontroller. The board has a number of digital and analogue input/output (I/O) pins that will connect to various expansion boards (shields) and other circuits. It contains 20 digital I/O pins, a 16 MHz resonator, a USB connection, an influence jack, an in-circuit system programming (ICSP) header, and a push button. Arduino received the input from the sensors and processed it according to the requirement coded in the microcontroller.

2.4.3 Automatic Functional block

This block contains the system's automated irrigation function. The automated function consists of the relay module (5 V) and the DC irrigation pump (R385 DC 12V) with discharge rate of 1.2L/min as the primary controlling hardware. The relay is an electric switch that switch from OFF to ON or vice versa depending on the signal given by Arduino. The signals given by Arduino allows the relay to autonomously open the path for water pump to water the plant when the soil moisture falls below the threshold level and close the path to stop the pump from watering the plant when there is sufficient amount of moisture in the soil.

2.4.4 Monitoring Block

This block contains 16 x 2 liquid crystal display (LCD) that display real time sensor value of percentage of soil moisture and ambient temperature and humidity.

2.4.5 Other required hardware and software

Other required hardware used in the system were drip irrigation tools that have been used as a medium to deliver water from the tank into the soil for watering directly to the root of the plant, jumper as a basic cable with connector pins at both ends to link the component of the electronic circuit,12 V power supply adaptor to supply electrical power to the system and breadboard. For software, The Arduino Integrated Development Environment, also known as Arduino Software (IDE) was used to connect to the Arduino hardware to facilitate communication and application uploading. The software consists of a text editor for writing code, a message box, a text terminal, a toolbar with buttons for commonly performed duties, and a series of menus. Fig. 3 shows the complete hardware schematic which includes the Arduino board and all the necessary attached hardware.

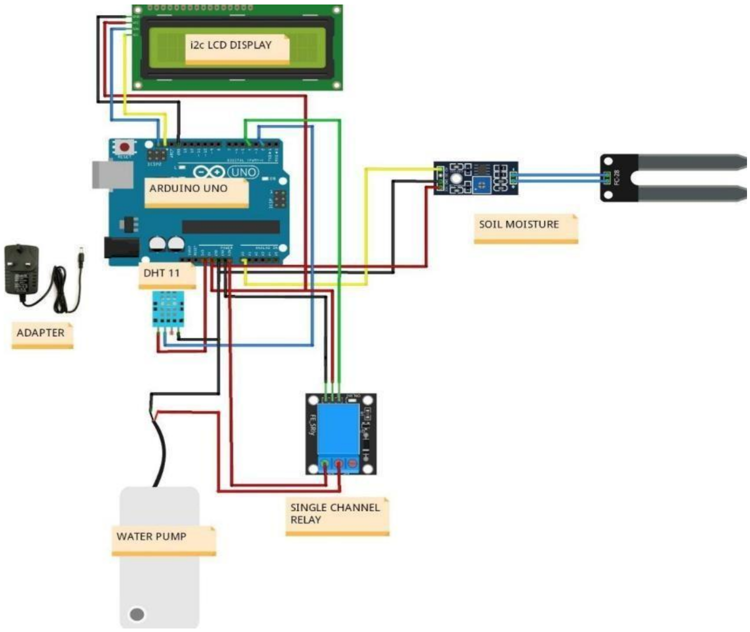

Fig. 3: The schematic diagram of an automated irrigation system

2.5 System Workflow

Fig. 4 presents the workflow of the system. The workflow began with sensor detection of soil moisture and ambient temperature and humidity. Depending on the soil's moisture percentage, this sensor's output module sent the low or high voltage to the Arduino. By referring to the Loam soil moisture status shown in Table 2.1, the percentage of 40% and below indicated that the soil is in a dry condition and the irrigation is needed while if the percentage indicated 41% to 80% presents the soil is in wet condition and no irrigation needed. The relay is a switch to control on/off water pump for irrigation. The relay was activated when the soil in dry condition and the water pump was switched on. The indication of the activation was presented by two led bulbs (green and red) lighted up. The indication of non-activation of pump represented by one led bulb (red) lighted up. The value of ambient temperature and humidity were shown in LCD on real-time based.

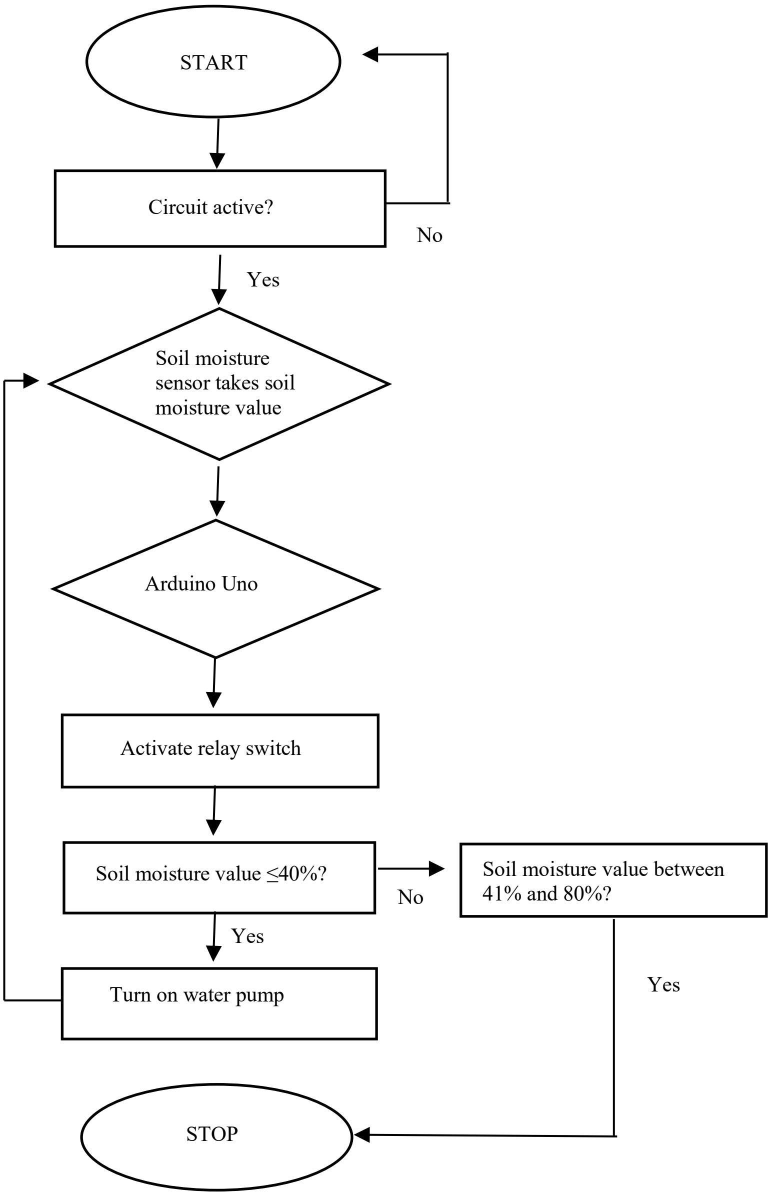

Fig. 4: The system workflow of an automated irrigation system

2.6 System Testing

Table 2 describes the test strategy that is used for this project. The purpose of the test was to determine the performance of the whole developed system to function according to the requirement. The test environment involves the hardware and software of the systems including Arduino, soil moisture sensor, LCD display and soil (wet and dry). The test procedure and expected result is depicted in the Table 2.

Table 2: System test procedure

Test Procedure	Step 1: Implement code of LCD display using Arduino. The real-time value of ambient temperature, humidity and percentage of soil moisture should be displayed on LCD screen. Step 2: Put the soil moisture sensor into the dry soil. The value of soil moisture should be displayed on LCD screen. Observe the activation of water pump and light bulb. Step 3: Put the soil moisture sensor into the wet soil at few different percentages. The value of soil moisture should be displayed on LCD screen. Observe the activation of water pump and light bulb.
Expected Result	The LCD display must be able to display the real time value of ambient temperature, humidity and the percentage of soil moisture. The soil moisture sensor must be able to differentiate between the wet and dry soil by showing the percentage of soil moisture on LCD screen. The water pump must be able to turn on if the soil moisture value given by soil moisture sensor is ≤ 40%. The activation of water pump must be indicated by red and green light bulbs. The water pump must be able to turn off if the soil moisture value is between 41% to 80%. Non-activated water pump must be indicated by red light bulb.

3.0 Results and Discussion

3.1 System Implementation

The system was experimented for sweet corn seedlings to check the reliability of the system together with drip irrigation set up (Fig. 5). The performance of the system was evaluated based on the expected result outlined in Table 2. The results were depicted in the Fig. 6 and 7.

Fig. 5: The implementation of automated drip irrigation system

Based on the system test procedure outlined in the methodology, the output from the system should meet the expected result given in Table 2. The test was started with 2 samples of wet soil that has range of soil moisture between 41% to 80%. From Figure 6, it can be seen that the real-time value of ambient temperature, humidity and percentage of soil moisture were displayed on LCD screen. The soil moisture sensor has shown the ability to differentiate the value of two samples and the value was shown on the LCD screen. The soil moisture percentages for 2 samples were between 41% to 80%, thus, based on the predetermined value set in the Arduino the relay had remained off and it was indicated by the red-light bulb. There was also no activation of water pump, thus no water flow to irrigate the crop.

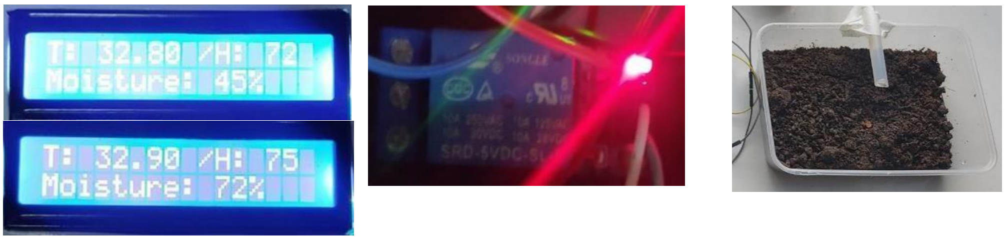

Fig. 6: LCD, relay and water pump output when the soil is wet

The same procedure was repeated to the dry soil that has the soil moisture percentage of below 40%. The LCD screen has shown the ability to display real-time values of ambient temperature, humidity and soil moisture percentage. The soil moisture sensor worked well by detecting the value of soil moisture percentage and it was displayed on LCD screen. As the soil moisture percentage was below 40%, due to the predetermined value set in the Arduino, the relay was turned on and indicated by red and green bulbs. The water pump was turned on and the water flowed to irrigate the crop.

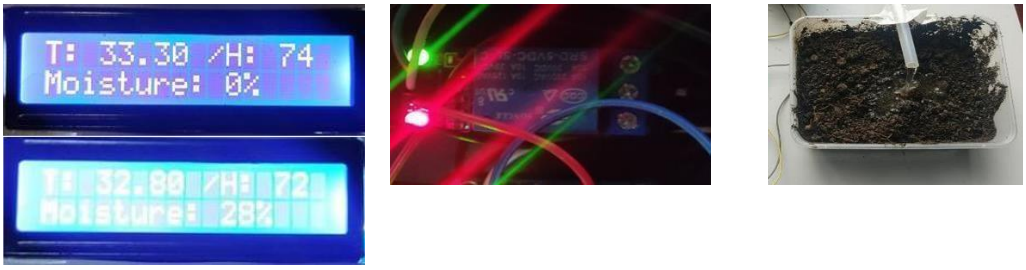

Fig. 7: LCD, relay and water pump output when the soil is dry

From the results, the system was successfully developed and worked as intended. The installation of the system is seen uncomplicated and suitable to assist smallholders in irrigation management. Furthermore, the predetermined threshold value set in the software can be adjusted accordingly depending on the suitability, makes the system appropriate to be installed for any crops. The result also demonstrates the capability of the system to supply precise amount of water according to the specific needs of crop, effectively avoiding issues of both water deficiency and excess water during application. In addition, it needs to be noted that, the automated system needs to be incorporated with good nutrient management for optimal growth and yield.

4.0 Conclusion

The developed system was tested to function automatically, and it was found to be reliable in optimizing the water input for crop production. The system was also providing the monitoring function for the user to easily check the soil moisture and ambient temperature and humidity. For future works, the system can be integrated with mobile monitoring system using IOT based on application-controlled monitoring system.

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Conflict of Interest

The authors declare no conflicts of interest.

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