Design and Development of Smart Irrigation and Water Management System for Conventional Farming

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Abstract. The intention of this project is to develop a smart irrigation and water management system for conventional farming. The project is conducted mainly to improve the irrigation scheduling and also to solve the over watering and under watering issues in traditional irrigation system. These problems can be solved by implementing soil moisture sensor as a smart component in the irrigation system. Smart irrigation system with the implementation of sensory-based system will be able to provide a proper irrigation scheduling, by monitoring the soil and weather condition of the farm. In this project, the sensory system consists of soil moisture sensor, temperature sensor and light intensity sensor, which basically used to monitor soil moisture level, temperature level, and light intensity level at the separate test area. Arduino Mega 2560 microcontroller will process the data from these sensors and a proper irrigation scheduling will be developed based on the data collected. Type of irrigation system that been used in this project is a sprinkler system because it has high uniformity of water distribution to the plant, which able to spread water efficiency and further optimize the water usage during irrigation process. Ultrasonic sensor is also implemented in the system to measure the amount of water used in each irrigation process performed. An offline data storage will be implemented in this project using a micro SD card module, which all the essential information such as sensory system readings and the amount of water used will be recorded and stored into a micro SD card. Thus, it allows user to monitor their farm’s condition, and also gives a better view on what is really happening at their farm.

1. Introduction

Most of the farmer all around the world has implemented an irrigation system at their farm especially in agriculture industry. One major problem arises when the irrigation system does not have an efficient watering schedule, which lead to over use of water. The vice president of The Toro Company and also a general manager of irrigation division, Phil Burkart has mentioned that over watering is one of the largest issues in agriculture industry [1]. The wasteful irrigation systems implemented in the farms are major contributors to water insufficient around the globe and Ute Collier emphasize that efficient irrigation system is the answer to this problem [2]. In addition, over watering also can decrease profits due to a negative yield response [3]. All this problem arises because the traditional irrigation system that been implemented by the farmer does not have the ability to measure the condition of the farm, which means that the system does not consider the plant needs and further leads to the over watering and under watering issues. In addition, the traditional irrigation system also cannot provide an efficient irrigation scheduling which leads to unnecessary irrigation process to occur. Therefore, smart irrigation system (SIS) is developed to overcome all these problems.
This research project is conducted which aims to provide a solution to the over watering and under watering issues, to improve the irrigation scheduling on the farm by implementing soil moisture sensor, and to revolutionize the traditional irrigation system into a fully automated smart irrigation system. Therefore, the SIS can help farmer to have a better control of his/her landscape and irrigation schedule. It can also reduce farmers work as the SIS can make decision independently. The farmers also can save a significant amount of money on water bills as SIS can optimize resources through intelligent control and automation. Also, the farmers can monitor the sensor readings and water usage that been recorded in the data storage.

2. Objectives
The objectives of this research study are stated as follows:
1. Develop a sensory system to monitor the soil and weather condition in separate test area.
2. Deploy an irrigation system for mini farm, which aim to control the over watering and under watering issues.
3. Develop water management system to monitor water usage during irrigation process.
4. Record the essential information during the irrigation process.

3. Scopes
Initially, the targeted plant (Choy Sum) and the important sensors for soil and weather monitoring is selected. Once the targeted plant and type of sensors required are chosen, the proper design is proposed for the irrigation system based on the current irrigation system available and its efficiency and uniformity of water distribution. After taking consideration of the irrigation range and pattern, servo motor and suitable water pump is selected. Implementation of ultrasonic sensor and water tank are also take into account to develop a water management system. In addition, implementation of solenoid valve is considered to control the water flow. Once the mechanisms are able to interface with each other, a micro SD card module is connected into a microcontroller which able to record sensor readings and water usage into a micro SD card. With the budget of RM600 provided by the university, a low-cost smart irrigation and water management system can be developed.

4. Literature Review
4.1 Design and Implementation of a Smart Irrigation System
In an article written by Masaba et al. [4] is about the implementation of a smart irrigation system to improve the water-energy efficiency. In this article, the smart irrigation system (SIS) consists of microcontroller, sensors and integration water pump with the decision-making system. The SIS uses environmental information to decide when and where the irrigation is required. A truth table is developed to help the system determine to irrigate based on the collected environment information. The sensors are placed in the area that requires irrigation and the decision-making system activates the sprinklers. The sensors that been implemented in this project are temperature and moisture sensor which then be used as the parameters for the truth table.

The SIS is made up of an aggregated network of water sprinklers and sensors. The sprinkler is controlled by a microcontroller through the servo motor to enable the communication. The microcontroller will set the angle through algorithm and determine which servo motor should rotate which allows the sprinkler to irrigate only within the set angles. The microcontroller interacts with the sensors by Bluetooth technology. The integrated system of microcontroller, servo motor and sprinkler, and Bluetooth in this research is called Smart Sprinkler (SSP). On the other hand, the microcontroller is collected the readings from moisture sensor and temperature sensor, and further evaluates the data through truth table to determine whether the given region need to be irrigates. The setup between microcontroller and the sensors are called Sensor Data Analyser (SDA). The result of the system is that it can provide effective irrigation schedule and further improved the water-energy efficiency.

4.2 Implementation of Automated Irrigation System
In the article written by Kamelia et al. [5] is about the implementation of automated irrigation system with humidity monitoring. The article will be focus more on the implementation of the soil moisture
sensor YL-69 to the automated sprinkler system. The reading from the sensor will be displayed on LCD screen and further create a graph on the website with the real time. The ESP8266 module is used as data processing and Wi-Fi network server. The sensor reading is transmitted through Wi-Fi network and send it to the web server. The data reading is displayed at the web browser which can be access in the internet-connected computer.

The final testing has been done with various humidity conditions. The test result in this article shows that when the soil moisture level below 50%, the relay will turn on the water pump. It will turn off when the soil moisture level reach 45%. The whole process will take an average of 1.29 seconds of response time. Therefore, the automation system based on the soil humidity level from the sensor is successfully control the water consumption during irrigation process.

In summarization, the previous literature review related to the research topic of smart irrigation system was conducted to generate the final guidance to start the project of the smart irrigation system. From the literature review conducted, the selection of suitable components, implementation of suitable method, and improvements can be done.

5. Methodology

5.1 Improvement from Literature Review

The first improvement that been made from the literature review is that instead of using monitoring one or two parameters, three parameters will be monitored in the project which are soil moisture, temperature, and light intensity. Thus, the irrigation scheduling can be more accurate. The second improvement is the implementation of the water management system to monitor the water usage during irrigation process. This can be done by implementing ultrasonic sensor into the system. The third improvement is the use of offline data storage by using micro SD card module. This data storage method is more reliable compared with Bluetooth and IoT-based data storage. The first reason is that it requires one microcontroller only to operate unlike Bluetooth data storage. The second reason is that it does not require Wi-Fi to operate unlike IoT-based data storage.

5.2 Simplified System Architecture

The figure above shows the simplified system architecture of the smart irrigation system (SIS). The SIS will cover four different separate test areas, and one sensory system will be placed at each of the areas. The size of the whole area is determined by the maximum range of water that can be shot from the irrigation system. Thus, projectile motion of water calculation is performed. The maximum irrigation range obtained is 3.2 meters, using the selected water pump with flow rate of 6 L/min and height of the sprinkler pole of 0.7 meter. Based on the maximum range, the dimension of each separate test area can be determined.
5.3 Block Diagram of the System

![Block diagram of the hardware of the system](image)

Figure 2. Block diagram of the hardware of the system

Since one sensory system consists of one soil moisture sensor, temperature sensor and LDR sensor, thus the quantity of four for each sensor is required to develop four sensory systems. One ultrasonic sensor is used and be placed at the water tank to measure the amount of water after irrigation process. Two relays will be used in the system to control water pump and solenoid valve. Three servo motors are required to develop a sprinkler system; two servos are used to create 360° range, and one servo is used to allow tilt motion. One micro SD card module is used as a medium for data storage together with RTC module.

5.4 Prototype Design

![Design of the irrigation system (left) and Design of the sensory system (right)](image)

Figure 3. Design of the irrigation system (left) and Design of the sensory system (right)

The design and dimension of the final prototype together with the position of each component are shown in Figure 3. The first part (left) of the figure shows the design of SIS, which consist of sprinkler system and water management system. The second part of the figure (right) is the design of a sensory system.

5.5 Algorithm of the SIS

Initially, the system will measure the readings from the sensory system, which consists of soil moisture sensor, temperature sensor, and LDR sensor. The parameters that been measured are soil moisture level, temperature level, and light intensity level. These readings will then be stored into a micro SD card as a data storage together with real time and date. If the light intensity level is less than 25% (which indicates night-time), the 30 minutes’ timer will start counting until zero before the readings from the sensory system is being measured again. There is no irrigation process will be performed during night-time since it can harm the plant, which causes wet foliage, unhealthy plant activity and waterlogging [6]. If the light intensity level is more than 25% (which indicates daytime), soil moisture level will be checked to determine whether the irrigation process is required. If the soil moisture level is below 30%, it indicates that the condition of soil at that particular area is under watering. If this happen, the microcontroller will check the water volume inside the water tank whether it is full by measuring the reading from the ultrasonic sensor. If the water tank is not full, the solenoid valve will be opened through a relay to allow water from the pipe to be delivered into the water tank. Once it reached maximum volume, the solenoid valve will be closed to the cut the water flow from the water pipe. Then, the system will turn on the water pump through a relay to deliver the water to the plant. The irrigation process will be performed with long duration until the soil moisture level hits 70%. When the moisture level reach 70%, the water pump will be turn off to prevent from over watering. Ultrasonic sensor will be measured again to determine the amount of water used, and the data will be stored into micro SD card. In the case that if the soil moisture level is more than 30% but the temperature level is more than 30˚C, short
irrigation will be performed for one cycle and it will take 3 minutes to complete. The purpose of short irrigation is to spread the water on top of the leaves of the plant to prevent the leaves from completely dry. Ultrasonic sensor also will be measured after the short irrigation to determine the amount of water used, and the data will be stored into micro SD card. Then, the program will return its original state and 30 minutes’ timer will start counting until zero before the parameters from the sensory system will be measured again.

6. Results
6.1 Soil Moisture Sensor Testing
Testing of soil moisture sensor is conducted under various moisture level of the soil [7]. The purpose is to determine the under-watering range, optimum range, and over watering range corresponding to the percentage of the water content within the soil [8]. The testing setup and the result is shown in Figure 4.

Based on Figure 4, three watering zones are developed based on the observation during the experiment, and also based on the optimum soil moisture level for the Choy Sum plant. Based on Graph 1, the under watering happen when percentage of water content is in between 0% to 30%, the optimum watering which is suitable for the Choy Sum plant, happen when percentage of water content is in between 30% to 70%, and the over watering happen when percentage of water content is above 70%. Therefore, this data can be used to develop a proper irrigation schedule.

![Figure 4](image)

Figure 4. Testing setup of soil moisture sensor (left) and percentage of water content (right)

6.2 LDR Sensor Testing
LDR sensor is tested under various light intensity to determine the maximum percentage of light intensity value as the beginning of the night-time period, and the minimum percentage light intensity value as the beginning of the daytime period. This information is crucial in developing an efficient irrigation schedule. The testing result shown in Table 1.

| Time   | Percentage of Light Intensity Value (%) | Average Percentage Value (%) |
|--------|----------------------------------------|------------------------------|
| Day 1  | 25                                     | 24                           |
| Day 2  | 24                                     | 27                           |
| Day 3  | 27                                     | 25.33                        |

Table 1 shows that different percentage values are obtained when the light intensity is measured at different day at specific time; 6.25 AM and 6.30 PM. However, the light intensity readings are close to each other. Thus, the average percentage value is calculated, and it will be used to develop irrigation schedule.

6.3 Temperature Sensor Testing
Temperature sensor is tested under various temperature condition during daytime to measure the temperature value at certain time. This information is crucial, as it is one of the parameter used to create an efficient irrigation schedule. The testing also conducted to study the behaviour of the environment temperature in Kuching. Thus, the temperature is measured under sunlight at empty field at every one-hour interval. The testing setup and result are shown in Figure 5.
According to Figure 8, the highest temperature that been measured during testing is 33˚C and the lowest temperature is 24˚C. Based on the characteristic of Choy Sum plant, the plant can survive at temperature up to 31˚C before the leaves are completely dry. Therefore, short irrigation is needed to prevent the leaves from over dry by spraying the water on top of the plant even though the soil is not under watered.

6.4 Irrigation Scheduling

Irrigation scheduling is developed after those three sensors are conducted. In Table 2, long duration irrigation process is performed when the soil moisture level is below 30% and the light intensity level is above 25%, which indicates daytime. Short duration irrigation process will be performed when the temperature is above 31°C to prevent the leaves from extremely dry. No irrigation process will be performed during night time. The system will undergo the checking process again after 30 minutes’ interval using timer.

Table 2. Truth table for sensor data evaluation to determine irrigation process

| Light Intensity Level (%) | Soil Moisture Level (%) | Temperature (°C) | Irrigation Needed? | Duration |
|---------------------------|-------------------------|------------------|--------------------|----------|
| > 25 (Daytime)            | < 30                    | > 31             | Yes                | Long     |
|                           |                         | < 31             | Yes                | Long     |
|                           | > 30                    | > 31             | Yes                | Short    |
|                           | < 31                    | < 31             | No                 | -        |
| < 25 (Night-time)         | < 30                    | > 31             | No                 | -        |
|                           |                         | < 31             | No                 | -        |
|                           | > 30                    | < 31             | No                 | -        |

6.5 Finalized SIS Testing

The finalized design of SIS is tested to achieve the objectives of the project. The SIS testing is conducted at the Swinburne field from 9:00 AM to 3:00 PM. The results for each separate test area are shown in Figure 6.

Figure 6. Smart irrigation system at testing site (Left) and sensory system 1 reading (right)

Figure 6 shows the sensory system reading at the test area A corresponding to time. This data reading is collected from the information that been stored inside the micro SD card (data storage). The
readings that been shown in Figure 9 are temperature level, soil moisture level, and light intensity level. At 9:00 AM, the moisture level of the soil at test area is 24%, which is lesser than the minimum level of optimum range of 30%. In this case, the long duration of irrigation process is required to increase the soil moisture up to the maximum level of optimum range of 70%. At 9:30 AM, the moisture level of the soil is 70%, which is the irrigation process already been performed at the test area. No irrigation process has been taken place at optimum soil moisture level, which is in between 70% to 30%. However, the temperature at 12:00 PM is 32℃. Therefore, short duration of irrigation process is performed at that time even though the soil moisture level is at optimum level. The purpose of the short irrigation is to prevent the leaves of the plant from being extremely dry. At 12:30 PM, the moisture level of the soil is slightly higher than before, which is indicates that the short duration of irrigation process already been performed at the test area. The result for the sensory system 2, 3, and 4 are almost similar with the result of sensory system 1, since the testing is conducted at the open field under the sunlight activity.

6.6 Data storage

During the finalized SIS design testing, all the essential information such as all the sensory systems’ readings and the amount of water used during irrigation process, are successfully been stored inside the data storage.

7. Discussion

Throughout conducting the project, the methodology done for this project has successfully been achieved considering all four objectives. Initially, a sensory system has been developed to monitor the soil and weather condition in separate test area. Based on information stored inside the data storage, it can be concluded that the sensory system that been implemented in the irrigation system was able to monitor the condition of the test area successfully. Thus, the first objective has been achieved, which is to develop a sensory system to monitor the soil and weather condition in separate test area.

The second objective, which is to control the over watering and under watering issues also has been achieved throughout this project. The long duration irrigation process will be performed when the soil is under watered which is below 30%. The irrigation process will stop immediately when it reached 70% to prevent over watering. No irrigation will be performed at night or when the soil moisture at optimum level. Short irrigation will be performed when temperature is too high to prevent the leaves of the plant from being extremely dry. Thus, the second part of the second objective has been achieved through completing this project.

Next, ultrasonic sensor and a water tank is used in the project develop a water management system, which can calculate and monitor the water usage during each irrigation process. The user also can predict the amount of water needed to perform long duration and short duration of irrigation process. Therefore, the third objective has been achieved, which is to develop a water management system to monitor water usage during irrigation process.

In addition, offline data storage has been developed by using micro SD card module, to record and save the readings from the sensory system at each separate test area into a micro SD card. The readings from the sensory system will recorded into the data storage at every 30 minutes’ interval to keep track the condition at the separate test areas. The amount of water used on each irrigation process, and the updated soil moisture level after irrigation process also will be recorded into the data storage through micro SD card, which all important information will be recorded into the micro SD card in text file. Therefore, the fourth objective has been achieved, which is to record the essential information during the irrigation process.

8. Conclusion

In conclusion, the implementation of this project will eventually benefit the farmer especially in agriculture industry. This method also provides alternative solution to control the over watering and under watering issues during irrigation process by monitoring the soil and weather condition of the farm. However, the smart irrigation system does not have the capability to prevent the over watering due to raining season. To counter this issue, the irrigation scheduling will be adjusted by measuring the soil moisture level. The irrigation process will not perform due to high soil moisture level. Thus, unnecessary irrigation process can be prevented. The smart irrigation system able to reduce many resources such as money, workforce, and water consumption as it is able to perform irrigation process
automatically with an efficient irrigation schedule. Hence, it is believed that this idea will revolutionize the agriculture industry. For the future work, the weather forecast system can be implemented in the system to predict when the raining season will happen.

9. References

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