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DEVELOPMENT ON AUTOMATED PLANT WATERING SYSTEM FOR SOIL HUMIDITY

Irni Hamiza Hamzah[1*], Muhammad Salehan Tutor[1], Mohaiyedin Idris[1], Aida Zulia Zulhanip1, Mohammad Nizam Ibrahim[1], Ali Othman[1], Alhan Farhanah Abd Rahim[1]

[1]*Faculty of Electrical Engineering, Universiti Teknologi MARA, Cawangan Pulau Pinang Permatang Pauh, Penang, Malaysia*

**Corresponding author: irnihami@ppinang.uitm.edu.my*

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ABSTRACT

This study presents the development and design process of an automated plant watering system for soil humidity in the potted plants. The study was materialised based on the developed 32-Bit Arduino Uno microcontroller system. Three main transducers used in this project to collect the respective data were soil moisture sensor, humidity sensor and temperature sensor. The LM393 soil moisture sensor and the DHT11 humidity and temperature sensor were placed half the height of the soil in the pot to measure the environment and the surrounding for the soil in the pot. The system was connected with motor pump for irrigation. The motor pump started to water the plants when the soil dried. During this process, the measured data was then being displayed at LCD screen and monitored in real time at GUI created by Visual Basic. The data were displayed in degree Celsius for temperature and for soil humidity in a scale of 0 to 1030. The bigger the scale, the dryer the soil was. As a conclusion, an automated plant watering system was successfully implemented using Arduino Uno to control the soil moisture and capable in monitoring data and analysis the parameters in the garden.

Keywords: Arduino Uno; Visual Basic; potted plants; soil moisture sensor; temperature; humidity sensor

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1. INTRODUCTION

The increasing population in Malaysia especially in rural and urban areas has resulted in limited land. Therefore, people decorate their yard with potted plants in order for them to get the fresh yield crops at their home gardens. Various types of soil are used to grow crops in the potted plants. The most famous type of soil used in the potted is sandy soil and loam soil. Since each type of soil brought various water contents, it is difficult for people to know how much they have to water the plants to make sure the soil is perfectly humid for the growth of the plants.

Biologically, the plants need light, water, carbon dioxide, appropriate temperatures, nutrients (fertilizer), oxygen and time in order to grow (Dursun & Ozden, 2011). Sometimes people tend to water the plants more than the required amount. Too little water is harmful for the plants. If the provided water is less, plants are unable to grow better and susceptible to pests. On the other hand, if it is watered too much, the plants root are prone to rot and other diseases (Bradbury, 2015). Soil water deficits will reduce root growth and leaf growth which affect the reduction of photosynthesis (Boyer, 1970). Light is needed by plants since the light radiation can be transformed to the energy required to evaporate water from leaves and plants (Kramer & Boyer, 1995). Biswas and Prakash, (2013) claim most plants work under normal temperature fluctuations. In general, foliage plants require 70-80 of Fahrenheit (°F) during daytime and 60-68 °F at night time for optimum growth. Changes of temperature and humidity surrounding the garden influenced the plants growth process (Song, 2010 and Xiao et al., 2010). It is pivotal to monitor the environment at the garden and study the temperature and humidity behaviour (Angelopoulos, 2011).

Therefore, installing the automated plant watering system in the garden will provide a good alternative for the plants maintenance. The plants will grow better and dehydration can be avoided. Automated watering system will minimize the job scopes in maintaining the garden and help users in managing their garden. It also helps in optimum utilization of water for irrigation as per requirement of the plants as compared to normal practices carried out by the people (Birajdar & Poddar, 2013). The automated plant watering system would monitor the water intake of the plants by measuring the water content of the soil. The moisture level thus obtained from the sensor will be matched with a predefined value stored in the microprocessor. The moisture sensor will measure the changing of water level in the soil within specific setting time. The data for the moisture soil, humidity and temperature for the environment will be displayed at the LCD and will be analysed to study the changing of soil humidity. If the moisture content in the soil is less than what is required, the microcontroller will invoke a command to water the potted plants immediately. The more the water level in the soil, the lower the resistance will be. When the soil is completely wet, there will be little or zero resistance (Craft, 2013). Measurements from the soil moisture sensor are the best and faster as cpmpared to the manual monitoring (Peters, 2015).

This project focuses on the development and design of an automated plant watering system that fully utilized an Arduino IDE Atmega 328 microprocessor. The design of the system helps to monitor the need to water the plant when the person is not available. It is an intelligent system that will monitor and detect the need to water the plant when the soil moisture is dry. Soil moisture, which is investigated in this project, is contributed by temperature and humidity.

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However, the limitation of this project is the system only works for the type of loam soil and indoor potted plant. The area of the soil analysed in this project is limited to the size of potted with a diameter 18.5cm and height 13 cm. The water will be sprayed to the soil in the pot using a drip irrigation method.

2. METHODOLOGY

Plant watering system would be operated automatically and controlled by microcontroller. The system would be attached with three sensors to collect all the parameters required for the analysis and connected with the motor pump for the irrigation part.

2.1 Project Overview

Figure 1 describes the flowchart for the operation on the system when the power supply was turn ON. Initially, the sensor would begin collecting data from soil and environment surrounding the potted plants. The data were then transferred to the Arduino Uno board for processing. The Microprocessor would then give instructions for the next process. The data were transferred to the CPU, monitored by Graphical User Interface (GUI) and saved as the database in the Microsoft Access. The compilation was done by Microsoft Excel for future reference.

2.2 Hardware Implementation

Digital temperature and humidity sensor known as DHT11 sensor and LM393 soil moisture sensor have been interfaced with microcontroller Arduino Uno. 5V DC power was supplied directly to the Arduino Uno board and sensors. A DC motor pump was supplied by the 9V power, which connected to a motor shield which was used to control the operation of motor pump. It was attached directly to the Arduino Uno. LCD screen and LED indicator act as output devices. The configuration on the system between the Arduino Uno board, motor shield, sensors circuit and DC motor pump is as shown in Figure 2. The serial communication was used for the Arduino Uno and the computer. The computer would act as a receiver to collect all the data from the microprocessor. Then, it would analyse the data and monitor the overall operation system. Table 1 lists all the Arduino Uno ATmege328 pin connections that had been implemented for the all the devices as shown in Figure 2.

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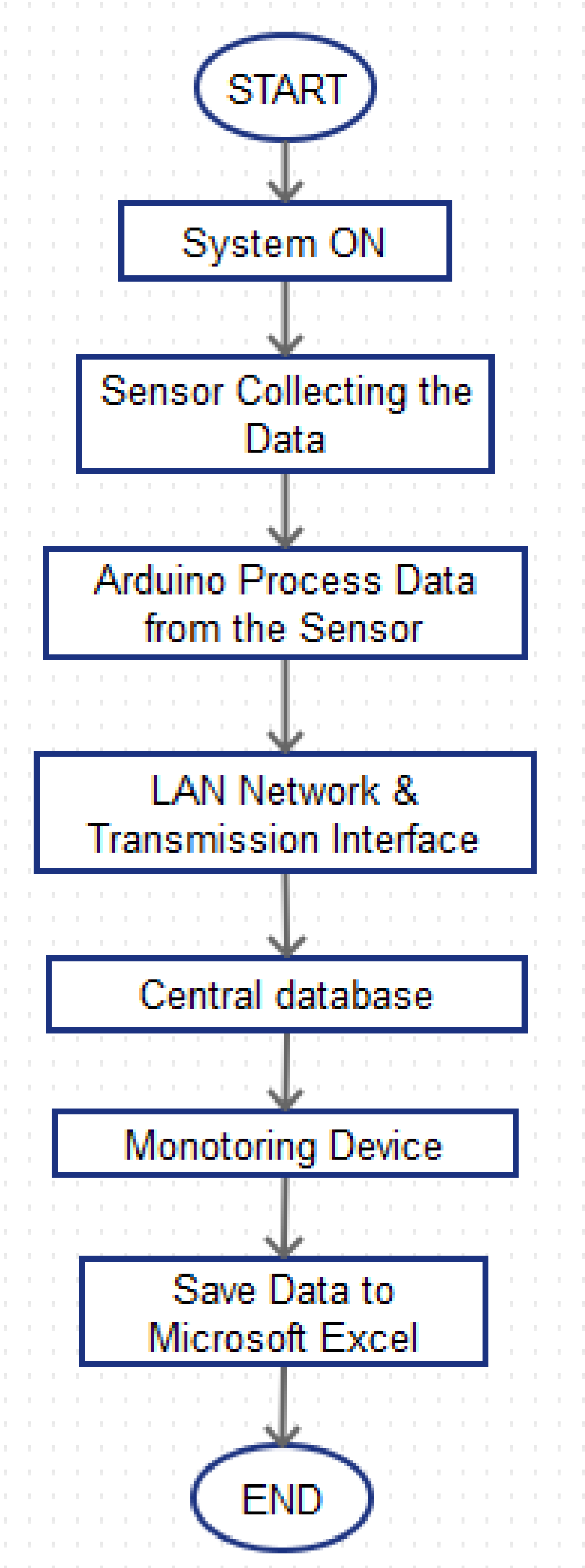

Figure 1: Overall Flow on the Project Implementation.

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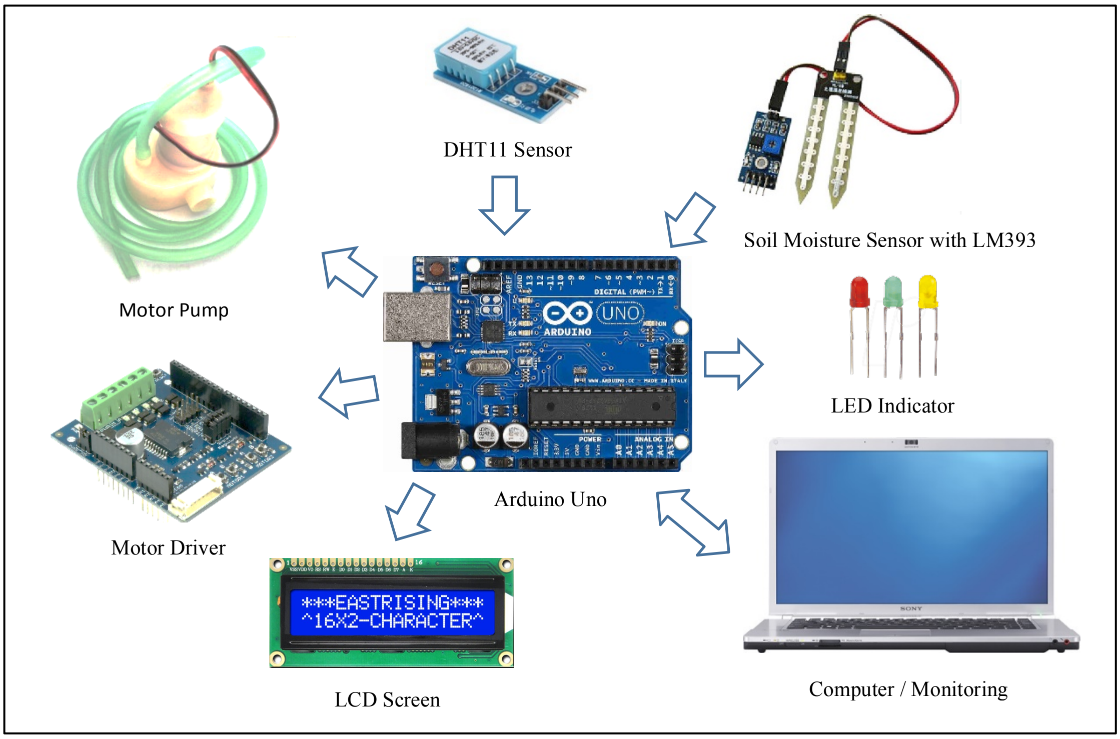

Figure 2: Hardware parts for the automated plant watering system.

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Table 1: Arduino Uno pin connection.

Port/Pin name	Description	Connection to
A0	Input	Soil moisture sensor
D2	Output	LCD
D3	Output	LCD
D4	Output	Cathode of motor pump
D5	Output	Anode of motor pump
D6	Output	LCD
D7	Input	DHT11 sensor
D8	Output	Green LED
D9	Output	Yellow LED
D10	Output	LCD
D11	Output	LCD
D12	Output	LCD
D13	Output	Red LED

The temperature data were presented in degree Celsius while the humidity was presented in percentage. Soil moisture sensor was used to measure water content in the soil. The data was in analog and the moisture level in the soil could be examined by referring to the data produced from the sensor. The range of the data would be from 0 to 1030.

Figure 3 reflects a flowchart on the technical process for the data logger development of LM393 moisture sensor and DHT11 sensor. The digital and analog signal from the sensor were produced during the operation and processed by the microcontroller unit. Then the data were transmitted to the computer as their databases by using USB cable for monitoring system and to perform data collection for future analysis and study. GUI was developed in this project by using VB.net software. It displayed the value of air temperature, air humidity and soil moisture in user's computer. Drip irrigation was used to water the plants as compared to the sprinkler system since it is able to control the water demand (Quezada et. Al., 2011). Water was brought in from DC motor pump where it was submerged in the water container.

2.3 Software Development

This includes Arduino IDE programming, Microsoft Excel, Microsoft Access and Visual Basic. The purpose was to perform automated system and monitor data transferred to the microcontroller. Arduino IDE programming was used to build and generate the coding for the Atmega 328 (microcontroller). It used C language program. Visual Basic is used to build GUI interface for real-time information and data collection. It displayed the temperature, humidity and soil moisture and plot the real time line graph based on all parameters for monitoring and analysis purpose. It also acted as the data logger which collects all the data measured from the sensor and stored it in Microsoft Excel.

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2.4 Arduino IDE using C/C++ Libraries

Figure 4 shows the flowchart on how the measured data would be processed by Arduino IDE. Firstly, the sensor was used to detect the changes. It would be notified via the coding. Input and output pin for each sensor was declared to enable the sensors. The library for the sensor was included in the programming. A loop will check the system for any changes from the sensors. Then, the data would be collected and processed by the microcontroller to be executed. The sensors value was transferred to the system and would be displayed via the computer monitor using VB GUI interface.

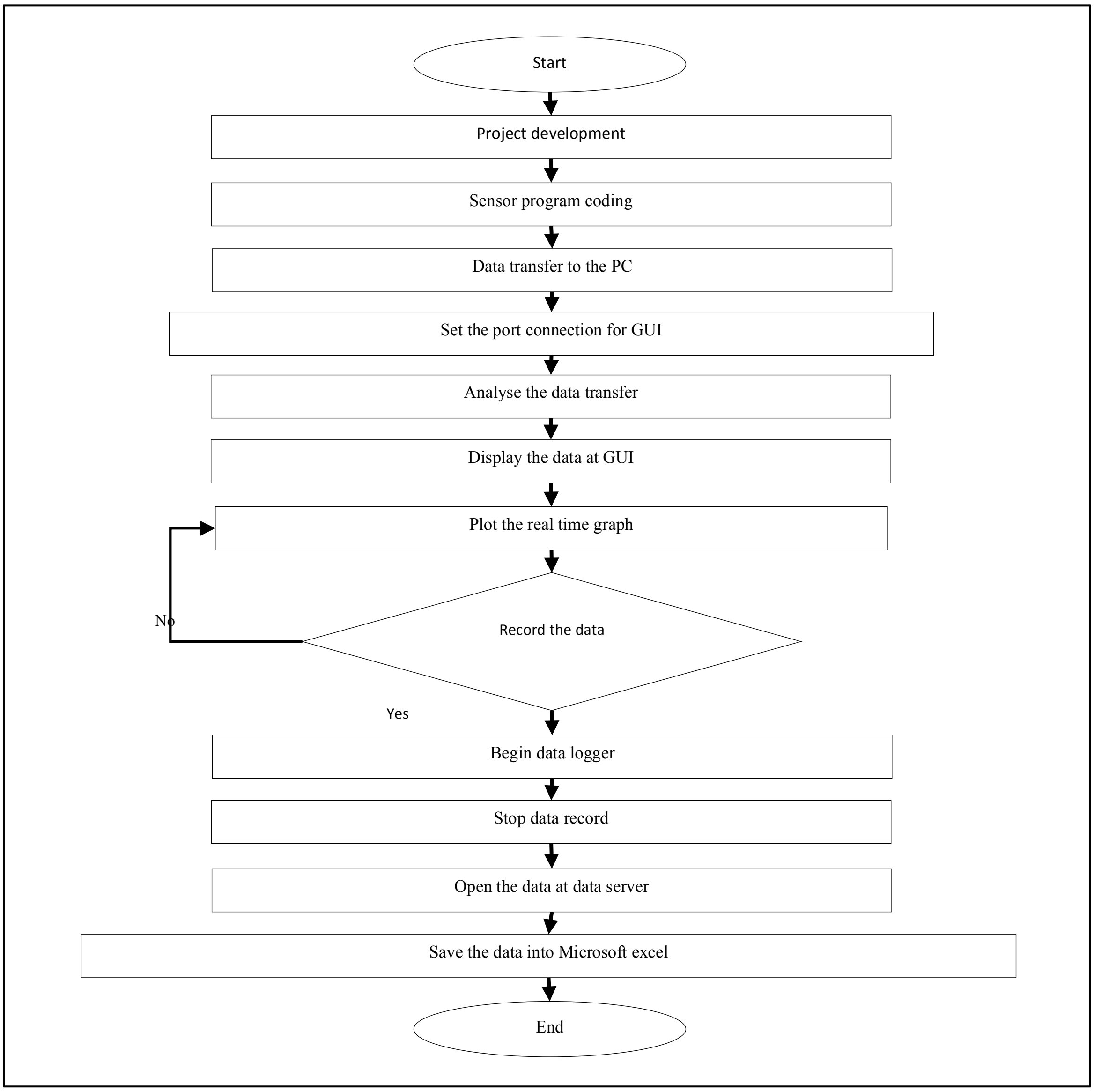

Figure 3: Flowchart for the Development of Data Logger System.

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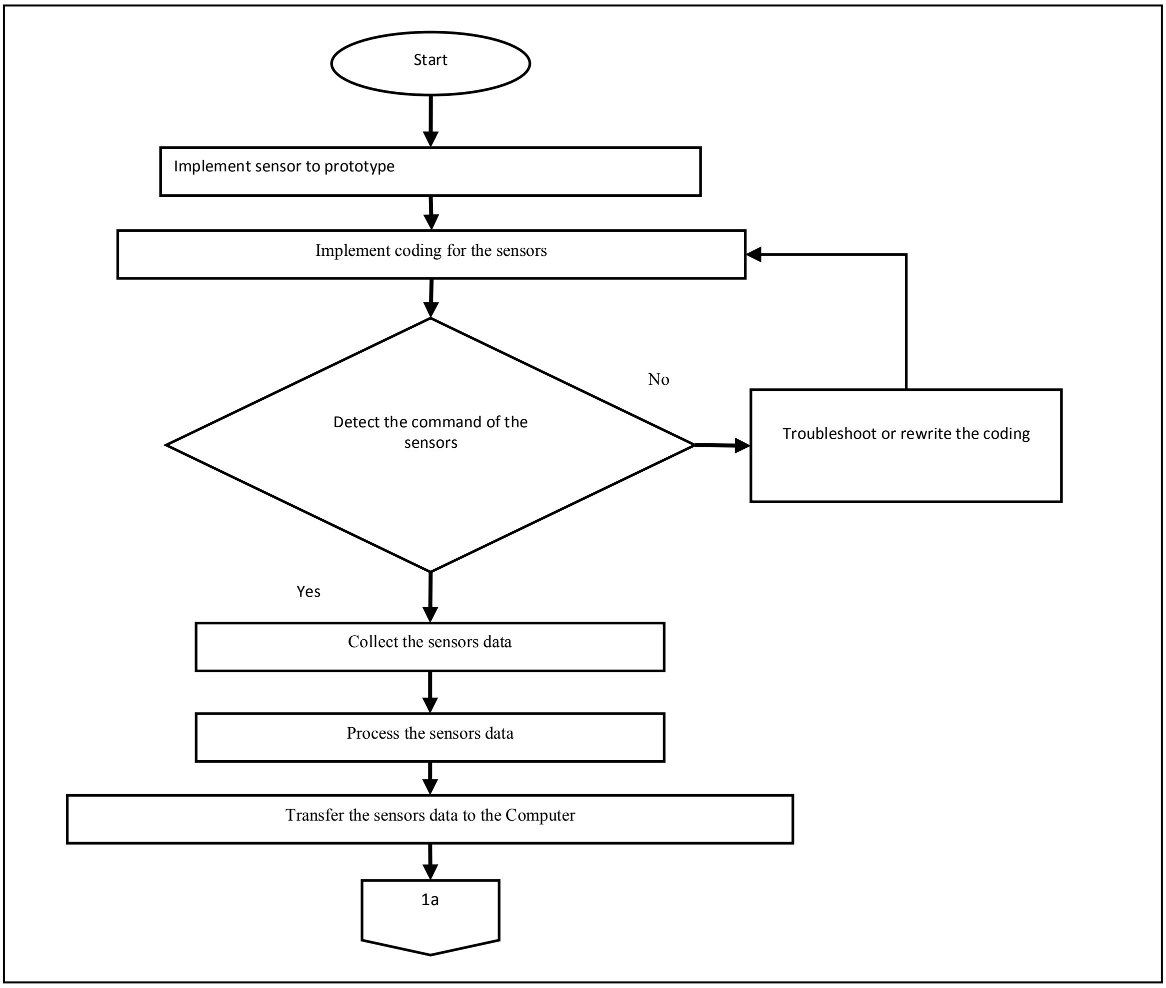

Figure 4: Algorithm Flowchart for Arduino IDE interfaced with Sensors.

2.5 VB Programming

Visual basic (VB) communicates with the Arduino by serial communication. Figure 5 shows the actual interface on the development of GUI monitoring system. This application provides a virtual GUI to be operated on the computer. It lets users test the prototype, develop and test this project in a real-time information and data for monitoring system.

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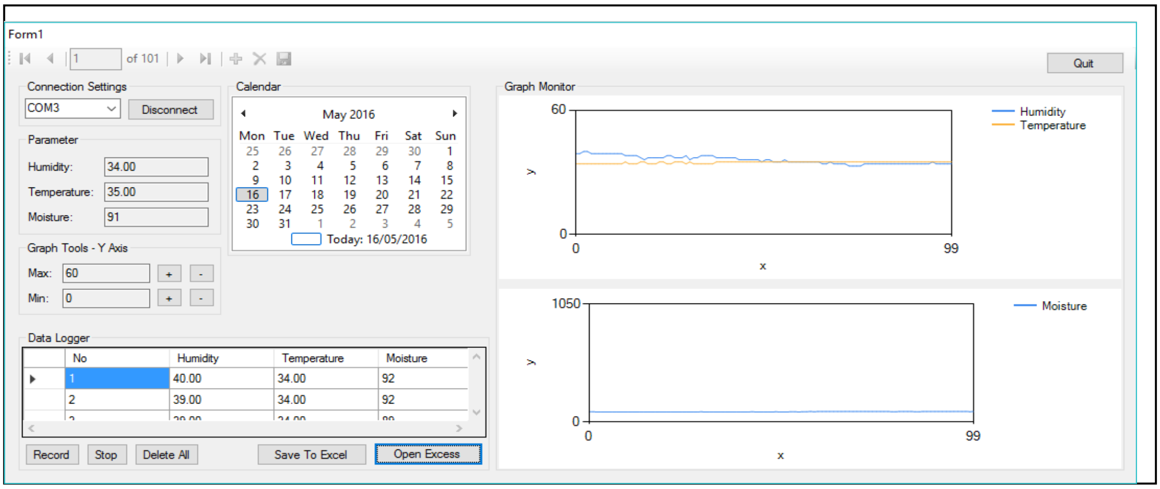

Figure 5: VB GUI user friendly interface for plant watering system.

2.6 Drip Irrigation and Potted Plants

This project only focused on one way of irrigation. Drip irrigation is used to water the plants since the research only covered for the potted plants. Furthermore, drip irrigation system is able to decrease gardening water demand compare to the use of sprinkler system (Quezada et al., 2011). The drip irrigation part for this project is as shown at the red circle in Figure 6. Water coming from the DC motor pump in where it was submerged with the water tank.

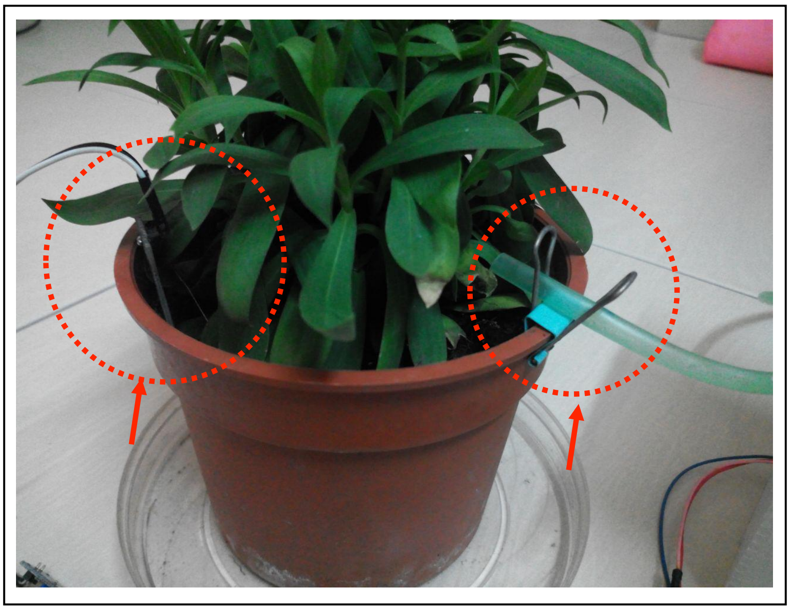

Figure 6: Water drip irrigation method for the potted plants.

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3. RESULTS AND DISCUSSIONS

3.1 Soil Water Content

Loam soil was used throughout the experiment in which it consied of sand (particle size > 63 µm), silt (particle size > 2 µm), and a smaller amount of clay (particle size < 2 µm). Its composition was about 40–40–20% concentration of sand-silt-clay, respectively. Four samples of loam soil were taken for the experiment where the mass of each sample was ±35g. Each of the sample was denoted with A, B, C, and D. The mass of each sample were weighed using weighing balance. Firstly, all the four samples of loam soil were analysed directly after they were collected from the site as tabulated in Table 2. The weight of the container and the site loam soil was denoted by w2. Then, all the samples was placed in the drying oven for 24 hours in 105°C. The weight of the container and the dry loam soil were denoted by w3.

Table 2: Site Loam Soil Moisture Content and Weight.

	Soil Sample for Water Content Test (g)			
	A	B	C	D
Data measured from Soil Moisture Sensor	501	498	476	474
Weight of container, w1 (g)	14.69	14.11	14.09	13.88
Weight of container + wet soil, w2(g)	46.49	46.49	46.49	46.49
Weight of container + dry soil, w3(g)	42.48	42.48	42.48	42.48
Weight of moisture, [w2-w3] (g)	4.01	4.01	4.01	4.01
Weight of dry soil, [w3-w1] (g)	27.79	27.79	27.79	27.79
$\boldsymbol{water\ content},\% = (\boldsymbol{w2}-\boldsymbol{w3})/(\boldsymbol{w3}-\boldsymbol{w1})\times\mathbf{100}\%$	14.43	14.43	14.43	14.43

The average value on the soil moisture for the site loam soil is
= (501+498+476+474)/4
= 487.25

The average moisture content, w is
= (14.43+14.95+14.94+14.29)/4
= 14.65 %

Secondly, all the four samples of loam soil were analysed at a full humidity when they were poured with water as tabulated in Table 3. The weight of the container and the site loam soil is denoted by w2. Then, all the samples were placed in the drying oven for 24 hours in 105°C. The weight of the container and the dry loam soil were denoted by w3.

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Table 3: Full Humidity Moisture of Loam Soil Moisture Content and Weight.

	Soil Sample for Water Content Test (g)			
	A	B	C	D
Data measured from Soil Moisture Sensor	87	89	90	84
Weight of container, w1 (g)	12.37	14.19	14.04	13.69
Weight of container + wet soil, w2(g)	71.11	71.61	71.81	70.94
Weight of container + dry soil, w3(g)	53.48	54.20	54.27	53.66
Weight of moisture, [w2-w3] (g)	17.63	17.41	17.54	17.28
Weight of dry soil, [w3-w1] (g)	41.11	40.01	40.23	39.97
$\boldsymbol{water\ content}$,% $=(\boldsymbol{w2}-\boldsymbol{w3})/(\boldsymbol{w3}-\boldsymbol{w1})\times\mathbf{100}\%$	42.88%	42.88%	42.88%	42.88%

The average value on the soil moisture for the full humidity loam soil is
=(87+89+90+84)/4
= 87.5

The average moisture content, w is
=(42.88+43.51+43.60+43.23)/4
= 43.31 %

The data shows that for the site loam soil as indicated in Table 2, the measured average water content was only 14.65% and the average soil moisture sensor was 487.25, which was in the range of 200-499 that indicated a shortage of water as set in Arduino Microcontroller as in Table 4. On the other hand, the full humidity loam soil as indicated in Table 3 shows the measured average water content to be 43.31% and the average soil moisture sensor was 87.5, which is in the range of 0-199 that is sufficient water as set in Arduino Microcontroller as in Table 4. As a conclusion, the lower the value measured by the soil moisture sensor, the higher the percentage of water content in the soil. Therefore, based on the these results, the moisture range, the condition of water pump and the LED indicator for this system was indicated as shown in Table 4.

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Table 4: Moisture Range Indicator as Programmed by Arduino Microcontroller.

Moisture range	Condition of water pump	LED indicator	Condition of soil
0 - 199	OFF	Green	Sufficient quantity of water
200 - 499	ON	Yellow	Shortage of water
500 - 1030	ON	Red	The soil is too dry

3.2 Humidity and Temperature Sensor

The humidity and temperature sensor was tested in the two conditions which were during morning and evening. The experiments were conducted indoors similarly to the experiment for the soil water content. In the morning the data was taken from 8.00 am to 9.30 am. The results show that the humidity of the environment was decreasing while the time was increasing as shown in Figure 6. The temperature was continuously increased from 32˚C until 38˚C. At the same time, the humidity decreased from 55% to 36%. In the afternoon, the data was taken from 2.00 pm to 3.30 pm. The results show that the humidity of the environment did increase shown in Figure 7. The temperature continuosly decreased from 41˚C until 33˚C. At the same time, the humidity increased from 28% to 42%. The data gathered shows that the sensor and the system is valid to be used for further analysis.

Then, the analysis is conducted for the interval of 12 hours. The analysis started at 6.00 am and ended at 6.00 pm. At this time, the soil moisture was being evaluated on two conditions that were when the soil was attached with automated plant watering system and when the soil was not attached with automated plant watering system. Figure 8 shows two different readings on the soil moisture. For the soil equipped with automated plant watering system, the moisture on the soil could be maintained humid. However, for the second case, the soil moisture sensor shows an increasing value indicated that the soil was continuously getting dried due to no watering activity. Furthermore, the variation of soil moisture level wasaffected by the temperature and humidity surrounding the plant. This is proved by Figure 8. Temperature and humidity changed with respect to time. It is observed that the higher temperature and less humidity was when the time was from 11.30am to 12.30pm since this was the time range where the soil moisture started to dry up.

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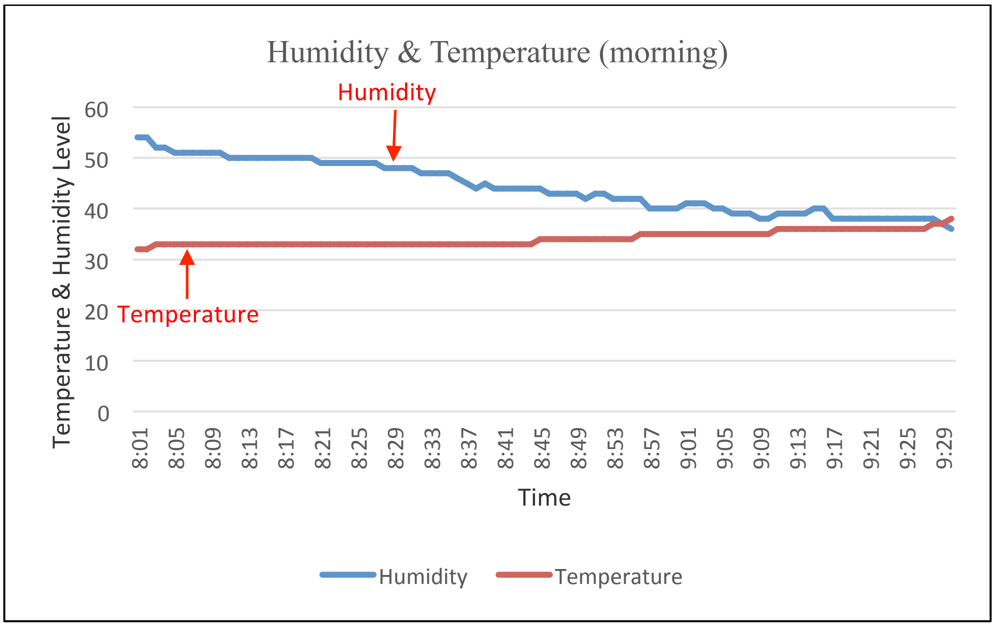

Figure 6: Data changing for the humidity and temperature in the morning.

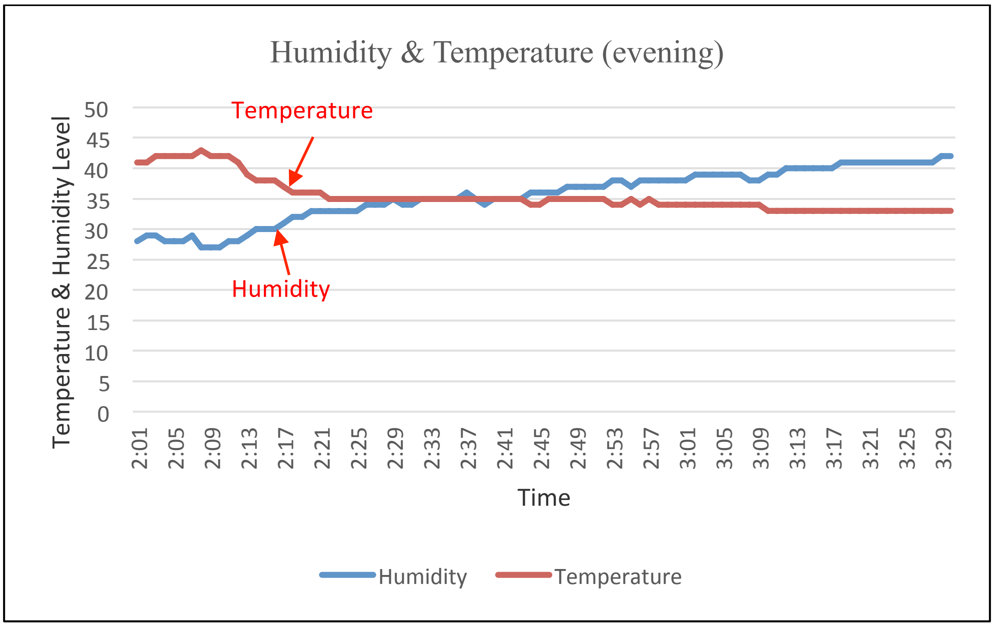

Figure 7: Data changing for the humidity and temperature in the afternoon.

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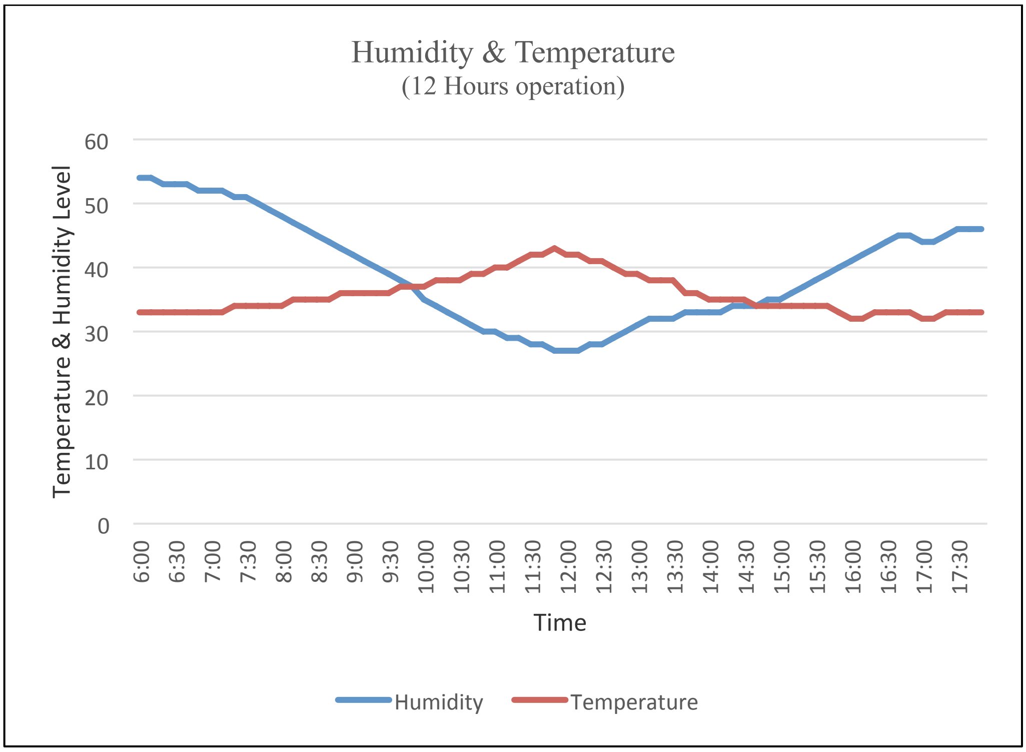

Figure 8: Data changing for humidity and temperature in the interval of 12 hours.

Figure 9 shows a prototype system on this project. It is equipped with LED (red, yellow and green) and embedded with the ARDUINO microcontroller, sensors and hardware connections as shown in Figure 2. Red indicates the extreme dry soil, Yellow would be shortage of water and Green would be sufficient quantity of water.

Figure 9. A Prototype System on the Automated Plant Watering System.

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4. CONCLUSION

This project has implemented an automated plant watering system with the least number of components and complexity. The system used Arduino Uno as the microcontroller. It has been developed to be tested on soil humidity with two types of sensors namely the LM393 soil moisture sensor and DHT11 humidity and temperature sensor. All the measured data from the sensor had been monitored using Visual Basic GUI. The data were recorded in Microsoft Excel.

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