DEMAND-OPERATED PLANT WATERING SYSTEM

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in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "DEMAND-OPERATED PLANT WATERING SYSTEM" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name :

Date :

APPROVAL

I hereby declare that I have checked this report entitled "DEMAND-OPERATED PLANT WATERING SYSTEM" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature	:	....
Supervisor Name	:	....
Date	:	....

DEDICATIONS

To my beloved mother and father

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While conducting my final year project, I was in contact with many people and they have directly and indirectly contributed towards my understanding and thought.

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ABSTRACT

In this new era, agriculture has improved a lot with advanced technology. As we all know, water is crucial as it helps plants to grow. Yet, freshwater resources are depleting and manual watering is exhausting, time-consuming and not efficient. Having to water the plants every day at the desired periods is a challenge. Besides, some timer-based watering systems have no means of controlling suitable soil moisture. Plus, the plants will constantly be watered once soil moisture drops below the threshold for some simple automated plant watering system and irrigation scheduling is usually available for the large-scale farm with a more complex system. Therefore, a demand-operated plant watering system using Arduino with time setting function and soil moisture feedback for the indoor small-scale vegetable garden has been designed and developed to solve the problems. The performance of the system has been accessed and analysed also in terms of time and soil moisture control. To design a demand-operated plant watering system, a microcontroller Arduino has been programmed to control all the inputs and outputs. An LCD display was used to show the date, time, soil moisture level and water level while some pushbuttons were used to set the watering time. Soil moisture sensor and water level sensor were used as the feedback to the system. A water pump was used to supply water to the plant from the water container and a buzzer was used to alert the user when the water level is low. From experiment 1, 70 % of soil moisture was determined as the threshold level to water the plants. From experiment 2, it was proven that the plant watering system able to water the plants at the set time by providing soil moisture slightly higher than the threshold.

ABSTRAK

Dalam era baru ini, pertanian telah bertambah baik dengan teknologi canggih. Seperti yang kita ketahui, air adalah penting kerana ia membantu pertumbuhan tanaman. Namun, sumber air tawar kini tengah berkurang dan penyiraman secara manual amat meletihi, buang masa dan tidak efisien. Menyiram pokok bunga atauan tanaman setiap hari pada masa yang dikehendaki adalah satu cabaran. Selain itu, beberapa sistem penyiram berasaskan pemasa tidak mempunyai cara untuk mengawal kelembapan tanah yang sesuai. Di samping itu, beberapa sistem penyiraman tanaman automatik akan sentiasa menyiram tumbuh-tumbuhan apabila kelembapan tanah jatuh ke tahap tertentu dan penjadualan penyiraman biasanya dipakai oleh ladang berskala besar dengan sistem yang lebih kompleks. Oleh itu, satu sistem penyiraman tumbuhan berdasarkan Arduino dengan fungsi penetapan masa dan maklum balas kelembapan tanah untuk kebun sayur-sayuran dalaman berskala kecil telah direka bentuk untuk menyelesaikan masalah-masalah tersebut. Prestasi sistem juga telah diakses dan dianalisis dari segi kawalan masa dan kelembapan tanah. Mikrokontroler Arduino telah diprogram untuk mengawal semua input dan output system penyiraman tumbuhan tersebut. LCD telah digunakan untuk menunjukkan tarikh, masa, tahap kelembapan tanah dan paras tangki air sementara beberapa butang telah digunakan untuk menetapkan masa untuk menyiram. Sensor kelembapan tanah dan sensor paras air telah digunakan sebagai maklum balas kepada sistem. Pam air telah digunakan untuk membekalkan air kepada tumbuh-tumbuhan dari bekas air dan buzzer telah digunakan untuk mengingatkan pengguna apabila paras air rendah. Dari eksperimen 1, 70% kelembapan tanah telah ditentukan sebagai paras ambang untuk menyiram tumbuhan. Dari eksperimen 2, sistem penyiraman tumbuhan ini dapat menyiram tumbuhan pada masa yang ditetapkan dengan kelembapan tanah yang lebih tinggi sedikit daripada paras ambang.

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LIST OF SYMBOLS AND ABBREVIATIONS

ADC	-	Analog-to-digital converter
RTC	-	Real-time clock
I/O	-	Input/output
PWM	-	Pulse Width Modulation
LDR	-	Light Dependent Resistor
UV	-	Ultraviolet
USB	-	Universal Serial Bus
GUI	-	Graphical user interface
LCD	-	Liquid crystal display
IDE	-	Integrated development environment
CAD	-	Computer-aided design
NO	-	Normally open
NC	-	Normally closed
LED	-	Light-emitting diode
PID	-	Proportional-integral-derivative
EEPROM	-	Electrically Erasable Programmable Read-Only Memory
SDA	-	Serial data
SCL	-	Serial clock

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CHAPTER 1

INTRODUCTION

1.1 Motivation

In this day and age, the development of agriculture has improved tremendously. With advanced biotechnology, a variety of plants have been cultivated. One of the important elements for the plants to grow is water. Water seems abundant on our planet; however, less than 1% of the world's liquid freshwater is available for human use and about 70% of it is used for irrigation [1]. Figure 1.1 shows freshwater is used for irrigation of vegetable farm.

Figure 1.1: Vegetable farm

Apart from that, the manual irrigation method is exhausting, time-consuming and not efficient. Moreover, even the maintenance of a small garden can be a tedious job for most people [2]. Often, people do not have much time to perform watering since it is a daily routine which requires quite some time. Figure 1.2 shows the plants in the garden are watered manually by using a watering can.

Figure 1.2: Backyard garden

For indoor plant hobbyist, they might be lazy to water their potted plants sometimes or do not have time to do so due to a tight schedule. Plus, people tend to forget to water their plant and unable to do watering while they are away for vacation [3]. In fact, manual watering can lead to wastage as too much water might be poured for some area. In the age of advanced electronic, human life should be made easier and more comfortable with the aid of an automated system. Figure 1.3 shows some vegetables are grown indoor by using planter box or pots.

Figure 1.3: Indoor vegetable garden

1.2 Research background

Irrigation is an artificial application to water crop instead of depending on rainfall solely by different means such as bringing in water from pipes, canals, sprinklers and so on. Irrigation promotes crop growth and quality in areas which have uncertain rainfall and uniformity is the key to maximize irrigation effort. Irrigation was practiced in many parts of the world during ancient civilization.

The very first method may be farmers carrying buckets of water from rivers or wells to water their crops followed by the building of irrigation canals, dams, dikes, and water storage facilities [4]. Moreover, aqueducts which carry snowmelt from the Alps was constructed by Ancient Rome for washing, drinking and irrigation purpose [4].

Nowadays, tanks, wells, and reservoirs such as aquifers, basins which collect snowmelt, lakes, and basin formed by the dam are used to provide water for the crops. The water stored in the reservoir is delivered to the field by canals or pipelines with the aid of gravity or water pump [4].

Several methods are implemented for irrigation such as flooding the whole field, channeling water between rows of plants, spraying water via large sprinklers, or letting water drop onto plants through holes in pipes. In addition, irrigation scheduling is a crucial process where the timing and amount of water to be applied to the crops are decided by the irrigator.

However, the crop water requirement for different growth stage and climate is the main challenge as it might lead to over or under watering. To avoid that, methods include plant observation, feel and appearance of the soil, using soil moisture monitoring devices, and estimating available water from weather data can be used.

Soil moisture content is the quantity of water it contains [5]. In fact, soil moisture content plays a dominant role in ground recharge, agriculture and soil chemistry. For example, the optimum soil moisture content is beneficial for plant growth. Furthermore, soil water is an important medium in supplying nutrients to the plants as soil water dissolves salts and minerals and hence the solution can be absorbed by the roots of the plants. Besides, other advantages of soil moisture include soil temperature regulation, essential for photosynthesis, helps in chemical and biological activities of soil and so forth.

1.3 Problem statement

Generally, most people use a timer-controlled plant watering system which has no means of controlling the suitable soil moisture required by the plants. Overwater will occur frequently under such condition where too much water may rot the root while too less water may, on the other hand, restrict the transport of nutrients to the plant. Commonly, plants are required to be watered twice a day. Usually, the desired periods are in the morning and in the evening. Some current plant watering system is fully automated where the plants will be watered constantly when the soil moisture drops below the threshold and hence the user has no control over the period to water the plant. Besides, irrigation scheduling is available for some large-scale farm with a more complex system. It is hypothesized that a demand-operated plant watering system with timer setting and soil condition feedback for the indoor small-scale vegetable garden is able to cater the water requirements of the plants, allow the user to decide desired periods of watering as well as save water and time.

1.4 Objectives

The purposes of this project are:

- To design and develop a demand-operated plant watering system using Arduino with time setting function and soil moisture feedback for the indoor small-scale vegetable garden.

- To assess and analyse the performance of the demand-operated plant watering system in terms of time and soil moisture control.

1.5 Scope of work

The scope of work in this project focuses on the design and evaluation of a suitable plant watering system for the indoor vegetable garden. The coding and simulation of the system are done before building the hardware to know workability of the system. The functionality of the system is tested for the chili plant placed at an indoor vegetable garden. 2 experiments are designed to test the plant watering system as well.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

It is a well-known fact that agriculture supplies food source and human needs food to survive. Hence, agriculture has been developing with the advancement of technology nowadays. Watering is the key element when it comes to complementing water for plants when rainfall is insufficient. Besides, different plants have different water needs. For example, a cactus will require less water than a rose bush [6]. Plus, plants that are drought tolerant will need to be watered differently than plants requiring a lot of water [7]. A systematic demand-operated plant watering system is absent. To look into the matter, it is crucial to study recent research journals to obtain a better idea. The literature review is anticipated to provide greater insight and discover the potential of integrating various methods from different plant watering system.

Based on the journals, the three problems identified are wastage of scarce water resources, unequal distribution of water during irrigation which leads to damages for the plants, as well as a challenge to keep the plants alive and healthy as it is a time-consuming and tedious job to water the plants. Predictions are that by the year 2025, one-quarter of the world's population will face severe water shortage [2]. Thus, it is imperative to utilize current technology to minimize water loss through irrigation. Sometimes watering done was not compatible with the water necessity of plants [8]. For example, plants tend to die from excessive irrigation or the other way around. Watering for a small garden is already a tedious task. Farmers do not have much time to carry out irrigation on a daily basis since they have some other tasks to be done as well. For instance, pest control and harvest can consume quite some time.

Thus, the subsections as followed are meant to study and review the advantages and disadvantages of different modules.

2.2 Review of exteroceptive sensors

The sensor is an important element in designing a system as it acts as the input of the system with constant feedback. Sensors inform the system about the status of a certain parameter so that certain actions can be done upon it.

Soil moisture sensors measure the volumetric water content in soil [9]. A soil moisture probe is made up of multiple soil moisture sensor [10]. Generally, the technologies used in soil moisture sensors can be frequency domain sensors such as capacitance sensor, neutron moisture gauges which make use of the moderator properties of water for neutrons or electrical resistance of the soil. The volumetric water content in soil is measured by soil moisture sensor indirectly by using the property of soil including dielectric constant, electrical resistance or interaction with neutrons.

For the capacitance sensor, the soil is used as a dielectric which relies on the soil moisture content. However, variations in soil salinity, temperature, water, and bulk density can have an impact on the measurement. In spite of that, good accuracy and precision can still be achieved under certain condition and some sensors have been widely used in the scientific field as well.

For a resistive type sensor, less corrosive galvanized irons are used for the probes. The two metal conductors which spaced apart serve to measure the soil electrical conductivity. The current passes through the probes where the resistance varies in accordance with soil moisture content. Yet, the dissolved salts can alter the water conductivity and thus affect the measurements. Moreover, there is another type of sensor which measure the water potential and it is called soil water potential sensor which includes tensiometer and gypsum blocks. Figure 2.1 shows the resistive soil moisture sensor.

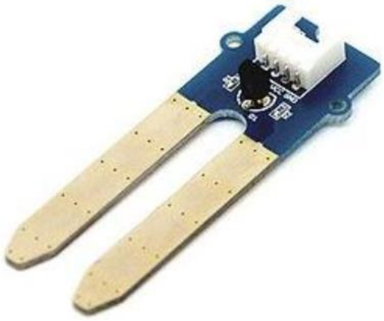

Figure 2.1: Soil moisture sensor [11]

Multiple sensors can be used to control irrigation of an individual zone or vice versa. For the case of one sensor controlling multiple zones, those zones are usually the driest where water is most needed. There are some common rules for the burial of the soil moisture sensors where it is better to bury the sensor near the root zone of the plants as roots absorb water.

For instance, the sensors for turfgrass are usually buried about three inches deep. Besides, sensors need to be in good contact with the soil after burial where there should be no air gaps surrounding the sensor and soil should be packed firmly but not excessively around the sensor [9]. Furthermore, it is advisable to bury the sensors in the zone that requires water the most for the case of one sensor controlling the whole irrigation system to make sure all zones acquire sufficient water. Normally, the zone is the area with the most sun exposure. To avoid over compaction of the soil around the sensor, it is not recommended to bury sensor in high traffic areas also.

Anil et al. set two thresholds for the soil moisture sensor which are 85 for lower threshold and 160 for the upper threshold while Lekjaroen et al. set the threshold of 20% and 80%. The threshold value is based on the ADC value of the sensor ranged from 0 to 255. The water pump turns on when the soil moisture goes below the lower threshold and turns off when the upper threshold has reached. In this way, a minimum soil moisture level can be maintained.

Soil temperature sensors obtain measurement through digital thermometer DS 1822 where analog temperature value is converted to 12-bit digital word and stored in 2-B temperature registers. Irrigation is needed when the temperature threshold is exceeded. For example, Gutiérrez et al. set a maximum soil temperature threshold of

30 °C to activate the irrigation pump for the desired period. Soil temperature is correlated with the soil moisture content but measuring the soil temperature does not fully represent water is needed by the plants.

On the other hand, humidity and temperature sensors are used to check the surrounding humidity and temperature. The magnitude of humidity and temperature can influence the health of the plants. Too high or too low temperature and humidity reading can be bad for certain plants [12]. User can always monitor the status of the plants through these sensors. Same goes to humidity and temperature sensor, these parameters affect the soil moisture level indirectly.

Some other sensors such as a light detection sensor or LDR sensor detects the presence of sunlight. UV diode complements such sensor to provide artificial sunlight as an energy source for plants when sunlight is absent or weak. Sandberg et al. installed a light detection sensor to detect sunlight and UV diode to provide artificial sunlight for the plant watering system. The rain sensor is another type of sensor which detects the presence of rainfall to prevent redundant irrigation. Regarding the usage of the rain sensor, it is more applicable for outdoor plantations as they are exposed to rain.

From the above review, functions of various sensors have been understood. It is found that soil moisture sensor has a direct connection with the watering status of the plants. In addition, measurements of both capacitive and resistive soil moisture sensor are affected by the soil conditions. On the contrary, other sensors such as humidity sensor and temperature sensor have an indirect link to the plant watering system as they serve to complement the plant watering system for better accuracy. For the LDR sensor and rain sensor, it is more suitable to apply these sensors for outdoor plantations.

2.3 Review of electronic control mechanism

In designing a system, a microcontroller acts as the brain of the system. The microcontroller decides the action of output based on the feedback from the input as programmed. All sensors and actuators will not work without the instructions from the microcontroller. Hence, it plays a vital role in controlling the whole system.