Urban Garden Watering System Using Internet-of-Things

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Abstract

The viral phenomenon of plant gardening and parenting is the current trend in coping with quarantined and lockdown during Covid-19. This is when Internet-of-Things (IoT) can become more useful. With the rise of IoT, microcontrollers became a staple with regards to IoT projects. A microcontroller is a computer on a single integrated circuit that includes a CPU, RAM, ROM, and I/O ports; some famous examples are the Raspberry Pi and the Arduino Board. Raspberry Pi is a low-cost and credit card size computer, enabling people of all ages to learn computer programming. Smart-Agriculture is an advanced agricultural system that has been broadly polished in developed nations to address the difficulties of increasing demand for food. Smart farming includes a variety of communication and information technologies to improve the quality and quantity of crops. This study is about the development of an automated watering system for urban gardens. This includes automatic watering on the garden plots based on current soil conditions or soil moisture. The developed system went to a series of designs and analyses and passed all functionality testing.

Keywords
Urban Gardening, Watering System, Internet-of-Things, Soil Moisture, Humidity.

1. Introduction
In this Covid-19 pandemic time, a lot of people are confined to their homes and trying to cope up with quarantine and lockdown periods. The adjustment made in dealing with stress of an individual towards a drastic change of habits or environment turned to current trend of growing plants in our own yard or even inside the house (Sunga and Advincula,. 2021) (Omadlao et al. 2020). Plant growing or parenting has been popular practice that gives therapeutic effect in decreasing anxiety and discomfort in home confinement (Rivas and Biana. 2021).

The continuous development of the concept of the Internet -of-Things (IoT); rapidly improves our way of living through many innovations, which allow the interaction of mundane things via the Internet. With years of development history, IoT continues to give birth to new technologies (Palatella et al. 2016). Internet -of-Things (IoT) plays an essential role in connecting and making easy access to previously not connected systems to the Internet (Rao. 2017). Using microcontrollers, this paved way to the development of automate labor-intensive tasks using a Raspberry Pi regarding urban gardening, which becomes popular in response to crises (Camps-Calvet et al. 2015).

Smart-agriculture is a complex agrarian system that has been widely refined in developing countries to meet the challenges of rising food demand. To increase the quality and quantities of crops, smart farming employs a variety of contact and information technology. The automation of a watering system will reduce the cost of energy, time, and amount of water utilized (Kamelia. 2018). The possibility of urban gardening has grabbed the attention of Filipinos as a possible alternative food source, the rise of urban gardening has also been gaining government support; the Department of Agriculture-Bureau of Agricultural Research has launched a series of urban farming campaigns, which include providing seeds and hosting online seminars for aspiring gardeners, aiming to encourage the public to take up the practice at home (Roa et al. 2016), either for residential or business purposes. Urban Gardening is one of the perfect choices in present-day agribusiness when the land zone for modern agriculture has turned into a genuine concern, particularly in the urban region. Urban gardening is a procedure of developing plants of each kind inside an urban domain, soil, or planters.

This developed system in intended for urban gardening with automated wagering systems that is based on soil moisture and humidity. This system was designed to automatically release water based on the garden plot's current soil condition. The system could also accommodate a water silo to store water due to the usage of relays. The developed system also provides an option that manually release water if they feel that they need to, which can be viewed and controlled by the plant owner or the gardener using a web application.

The main objective of this study is to use Internet -of-Things (IoT) in urban garden watering system based on plant's soil moisture and humidity. The developed system is a web-based application developed using HTML (Li et al, 2018) and Python (Kumar and Panda. 2019). The system collects its data from the sensors attached and microcontrollers installed. The garden owner has a web access of data logs and timesheets for watering decision of plants. The system is deployed on a Raspberry Pi with a Raspbian OS installed. The system used soil moisture and humidity attached near the plant for pot-based gardens or in the center of the plot to monitor when to stop the release of water when the set threshold is reached.

The system used a DHT22 sensor to monitor the humidity and temperature of the garden plots and, in doing so, send the gathered data to the Raspberry Pi. The sensor inserted at the root level to accurately read the plants' soil moisture. The Raspberry Pi has three major parts in this project; first is the attached DHT22 sensor which tells the system when to deploy water and when to stop, second is the Raspberry Pi that will execute appropriate action based on the data received from the sensor mentioned and lastly, the data collected sent updates and logs via the Internet connection for monitoring in the web application. The Raspberry Pi controls a 12v water valve solenoid attached to the irrigation system's piping and activate or deactivate the flow of water to the sprinkler system.

2. Literature Review

The study about real time water system by Deshpande et al. boasts its advantages as it saves labor, water, and energy. It also increased the efficiency of irrigation as it controls the operations related to irrigation (irrigation economic control). Most importantly, it reduces maintenance costs (fault detection and protection of the irrigation system's different components). And last but not least, it increases production due to optimization of irrigation (Deshpande et al,.2019). This project aims to help gardeners or gardeners in agriculture for passive work; it mainly reduces the work of those while still maximizing and increasing the land's productivity. It monitors and acts on itself to provide for the garden and or farm; with this system, it comes in handy as it is automated. Overall, this system is not about the plant itself but the productivity that the garden or farm can achieve. Still, this relies significantly on how the plants in the environment work, and it also provides and cares considerably for the products. Upon testing, this system proves that to use its full potential if the plants within its area are the same, different vegetables, fruit or plants vary on its life stage; thus, some become ripe while the others are not yet at their peaked.

Irrigation has an essential role in maintaining a farm and can largely contribute to its overall operational cost. Using automation for the irrigation system, a farm can decrease its water wastage and not require human intervention. This automation will benefit the farm and help the environment since it will effectively use water and limit wastage (Nkosi and Chowdhury. 2018). The system uses a Raspberry Pi as its processor and use sensors to monitor the soil's temperature and dampness levels. The processor will gather all the sensors' data and adjust the amount of water needed to be sprayed on the farm. When deploying the water, the parameters will be pre-programmed on the processor, mainly using python language. This project was successful in meeting its goals. The system successfully read the soil's dampness levels, and the system adjusted the amount of water being deployed. It managed to minimize water usage of the farm and, in turn, decreased the farms' costs in terms of water usage. The use of the soil moisture sensor and temperature humidity sensor is excellent as it balances the surrounding environment of what the plant needed; however, upon testing, devices which include boards that easily rust when exposed to the said environment are not ideal for this scenario.

An automated watering system that detects its surrounding environment to gauge what plants needed. This research focuses mainly on how the plant grows based on the environment that it is planted. Different plants vary with the weather in their study, like if it is too hot and dry, too cloudy, and wet, and too cold and freezing. This setup requires a monitored room for plants to grow on their whole. It maximizes their growth because it measures their surroundings and monitors the plant's health if it needs water or more sunlight if it is dry or lacks nutrients. This research focuses mainly on the plant's health and how to fully attain what plants can in a small amount of time (Alpay and Erdem. 2018). By utilizing the environment's temperature, this device captures and gathers the data necessary for adjusting, watering, and providing sunlight sufficient on what the plant needed based on the said data collected. The diagram shows that it works both ways on sensing the temperature and soil moisture to detect what the plants needed most.

Simple mobile applications perform a specific task and are much more efficient since it is convenient. Using this technology together with the Internet, it has grown to be a powerful software. Applications connected to the Internet can be used as controllers for wireless networks and data processors such that in a farm setting where there is an Internet integrated system. Using a mobile application, a user can control and monitor a farm irrigation system (Divani et al. 2016).

Python is a programming language developed in 1989; it is between object-oriented and functional design patterns. It is like C language in that it uses many features, class definitions, iterated libraries, components, functions, and objects. Python is more common in the programming world; 1008 lines of code in C or C++, in Python with only 100 lines (Kumar and Panda. 2019).

Urban gardens are farms that are primarily in an urban setting. At present, 54% of the population lives in an urban environment; thus, there is an increase in the demand for agriculture in this urban setting. Technological advances have made innovations in helping and monitoring the agricultural process making the garden a smart, independent, and productive space (Carrión et al. 2018).

3. Methods

This project used a prototyping model as the main structure. A project that uses this model will have an easier time implementing this since each phase is finished before proceeding to the next phase. This kind of model is much more lenient when it comes to errors encountered since if an error is found, we can go back to the previous step.

3.1 Systems Design and Analysis

In designing the system, this study followed the research of Ferrarezi et al. (2015) that uses the relationship of volumetric water content (VWC) and adapting low-cost microcontrollers. Another major reference of this study is from Kodali et al (Kodali and Sahu. 2016) which uses soil moisture sensor detection in an irrigated garden design.

The focus of the automated watering system is to assess the soil moisture and humidity of the plant in an urban set-up in managing and monitoring urban gardens. The watering automation process of this study used the data gathered on the DHT22 and the soil moisture sensor in deciding what the watering system will do; it will adjust accordingly based on the soil humidity reading.

This system is required to have an Internet connection so that the database logs are constantly being updated. With a web application, the user can access the system and can monitor the live humidity levels, and have the option to open the irrigation system manually. The system was designed with a solenoid valve bypassed on the existing water supply; with this, the system has control over the irrigation system. The sample screen design of the system is shown in Figure 1. The circuit connection is shown in Figure 2.

Using data collected from the sensors, the system will decide how much water is to be released by controlling a solenoid connected to the water junction; the amount of water will depend on a set threshold that is set depending on the plant planted or manually by the user. The system will use a moisture sensor to know whether the soil has sufficient water levels. The system automatically adjusts the soil humidity threshold to compensate for the change in the environment; it takes the reading from the temperature sensor and ambient humidity sensor and adjusts the soil humidity threshold by +-5%; this allows the system to provide more water to the plants during hot days or low humidity days and less during cold and highly humid days.

The system will also display all data logs on a web application, and the user can manually activate the system using the web application with the following module or parts:

Home Page - The home page is the main control page of the system; here is where the users can manually release water if they want to, check live soil status, and enable or disable the system's auto watering capabilities. The users would also have access to the data logs page from the home page.

Data Page - The data page is where the previous water releases are recorded; this where the users can monitor/double-check if their plot is already watered for the day. The system's developed design has the users in mind, the gardeners, for them to integrate it into their daily gardening routine, an easy-to-use, understand, and practical for their everyday use user interface is essential.

Settings Page - The Settings page allows the users to set the soil moisture sensor threshold manually or choose the type of plant provided from the dropdown. The settings page also displays the current soil moisture threshold.

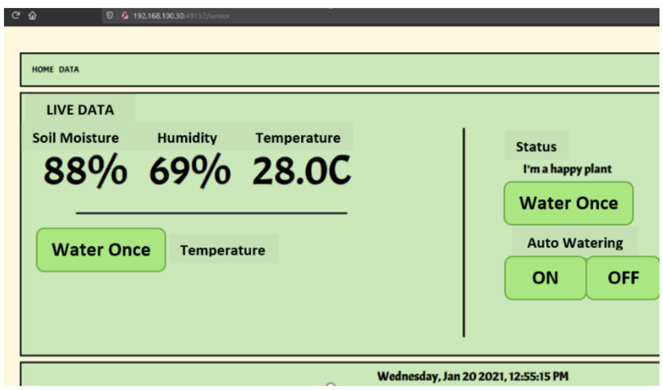

Figure 1. Sample Screen Design of the System

Figure 2. Circuit Connections

3.2 Deployment

In order to transform the data into a readable user interface format by adding the sensors and servers' codes. The system used the Raspbian OS to program the Raspberry Pi. Raspbian used Python as its programming language. The first version only had analog readings from the sensors, this became a problem since the system can only tell whether the soil is wet or not. The remedy made is to add an MCP3008 IC to convert the analog reading into a digital one. The second version had problems displaying previous watering logs. This is where an additional data storage for the earlier records was implemented and used to enhance the user interface of the system. The last version and final prototype version used the temperature and ambient humidity sensors as variables to change the set soil humidity threshold. The web application contains the following modules:

Processing Module - Using the Raspberry Pi as the central brain for the system where all the information is collected and then processed, a corresponding action is pre-programmed.

Sensor Module - The humidity sensor is used in acquiring the water-to-soil ratio and is then sent to the processing module.

Application Module - This module is where users access the system using a web application.

3.3 System Testing

The system was tested after the coding and implementation were done to identify some bugs or issues. The prototype was deployed using a smaller setup to test whether the concept and wiring are all working. Next, an initial deployment of the system was conducted. Functionality testing and usability testing was done in order to complete this study. In all aspects of functional requirements, the developed system passed all test cases until its fourth iteration.

The study conducted a user acceptance testing (UAT) on two groups of respondents with demonstration. The respondents of the study are those individuals who are engaging in urban gardening. Two sets of usability testing were administered. Both are interested in automated watering system in the city. The first set of respondents are those involved in the planning phase of this system, mostly agriculturist. The second group of respondents are not included in the planning phase and without prior knowledge about the system. Due to the Covid-19 pandemic, the demonstration was virtually conducted. The user acceptance questionnaire was administered through the use of Google forms in order to gauge the approval of the respondents in the developed and demonstrated automated watering system.

4. Data Collection

4.1 Data Gathering

An interview was conducted with an agriculturist to gain insight into the gardeners' daily routine and what could be done to help them with the watering task. The study also conducted a test on two groups of people for demonstration. First, it reached out to those same individuals who answered the previous survey about urban gardening struggles to demonstrate to them the automated watering system that has been developed from the information gathered from them. The second group involves those that did not participate during the planning phase; hence these groups are the agriculturists that were demonstrated without prior knowledge about the system. Upon observing the used soils for gardening, this resulted to gathered an unequal amount of data and compared to the studies and analysis done from the previous research. Upon further observation, it was noticed that it has something to do with the type of soil used and significantly affects the humidity and moisture. Different types of soil include clay, sandy, silty, peaty, chalky, and loamy. Upon further experimenting and testing about soil types, it was highly suggested that the best soil for agriculture would be loamy soil for it gives the plants more health benefits and it has a more stable output of its humidity and moisture level.

4.2 Data Processing

This project aims to utilize tools such as the Raspberry Pi to combine that with the attached sensors to monitor and detect changes in the environment. The system uses a DHT22 sensor that monitors the garden plots for humidity and, in doing so, will send the gathered data to the raspberry pi. The sensor would be inserted at the root level to read the available soil moisture accurately. The raspberry pi has three major parts in this project; 1st is the attached DHT22 sensor that will tell the system when to deploy water and when to stop, 2nd is that the raspberry pi will take appropriate action based on the data received from the sensor mentioned, and 3rd is that it will send logs via the Internet for the user to monitor using the web application. The conceptual framework of the study is shown in Figure 3.

Using data collected from the sensors, the system will decide how much water is to be released by controlling a solenoid connected to the water junction; the amount of water will depend on a set threshold that is set depending on the plant planted or manually by the user. The system uses a moisture sensor to know whether the soil has sufficient water levels (Bhardwaj et al, 2018) (Dagar et al, 2018). The system automatically adjusts the soil humidity threshold to compensate for the change in the environment; it takes the reading from the temperature sensor and ambient humidity sensor and adjusts the soil humidity threshold by +-5%; this allows the system to provide more water to the plants during hot days or low humidity days and less during cold and highly humid days (Codeluppi et al, 2019) (Giri et al, 2017). The system also displays all data logs on a web application, and the user can manually activate the system using the web application (Ismail and Thamrin, 2017) (Lin et al, 2018). The initial pot-based circuit connection is shown in Figure 4.

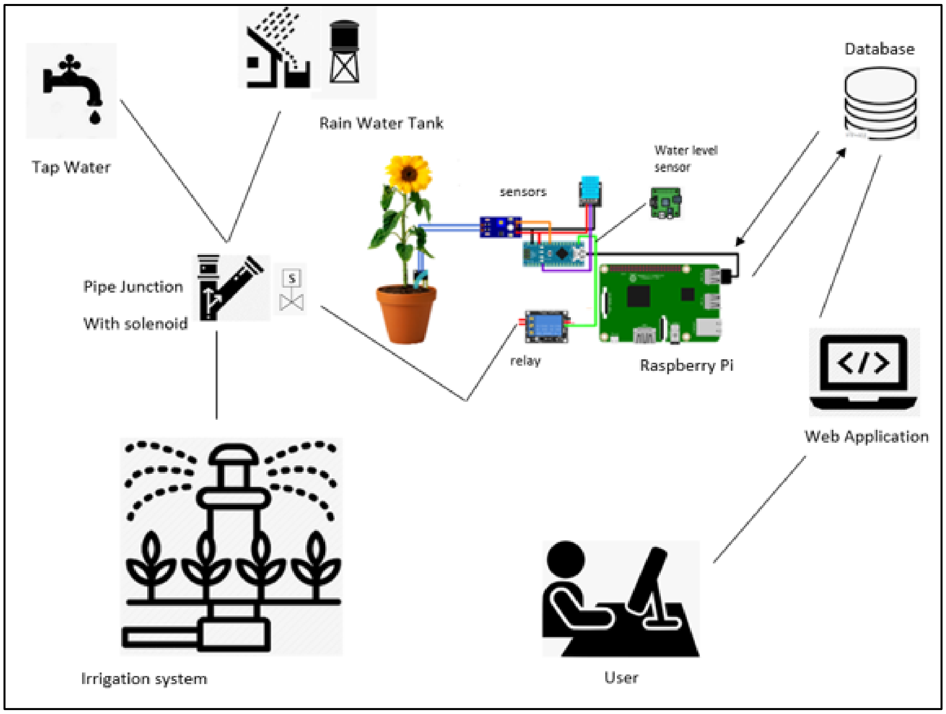

Figure 3. Conceptual Framework

Figure 4. Initial Pot-based Prototype

5. Results and Discussion

After the user acceptance answers were tallied, the result shows that both group of respondents were satisfied and approved the design of the developed system. When it comes to the device's user interface (UI), a respondent stated that it has a simple and not complicated yet effective design. The first group claims that it is reliable, and that the system received positive reviews. Still, these are the group of people interviewed before the system was created, and their ideas were considered when building the system. Based on the UAT from the group 2 respondents, some would still be improved but the developed system still achieved its objective. The user acceptance testing (UAT) result is shown in Table 1.

Table 1. User Acceptance Testing Result

Survey Criteria	**Score group 1**	**Score group 2**
User Interface		
Readability of the texts	80%	76%
Colors used	80%	76%
Icons and Logos	80%	73%
Logical Design	100%	83%
Overall Design	80%	76%
System functionalities		
Overriding the system's auto function.	100%	100%
Soil Humidity Accuracy	100%	100%
Accuracy of Data	100%	100%
Response on the Web App	100%	100%
System's reliability on maintenance	100%	100%
System's soil moisture maintenance	100%	100%
System's reading parameters	100%	100%
System's Display Assistance	100%	100%
System's usability in providing help	100%	66%
System's Reliability	80%	100%
On Promoting a faster gardening routine.	60%	100%

6. Conclusion

This study focuses on developing a way to assist gardeners in managing, monitor, and water their gardens. Interviews, published journals, and articles were used as a reference in establishing the objectives of the study. The study's finding shows that setting a more precise and consistent amount of water-to-soil ratio regardless of the plot's ambient humidity and temperature would benefit the target users. The amount of water available to the plants depends on the type/mix of soil on the plot and how much water it can hold, preferably loam soil which holds the optimal soil moisture for most plants. The study created a system that monitors the plot's soil moisture and automatically releases water based on the set threshold; the set threshold automatically adjusts depending on the ambient humidity and temperature of the plot. The developed system accurately display the soil's humidity; the system uses a soil moisture sensor to detect the plot's accurate water-to-soil ratio. The system is also not releasing water if the water-to-soil ratio is above the set threshold. Based on the testing results, the system developed passed all its test cases. Also, the user acceptance test (UAT) results show that the system functionality requirements were met and achieved.

An automated watering system that is deployed in an urban garden setting help in managing the garden. Based on the result of user acceptance test, all respondents gave positive remarks and agreed that the system could provide significant help in aiding the watering process. The positive feedback from the target users reflect that 80% agreed that the system would promote a faster gardening routine. The gardeners, also locally known as plantitos and plantitas noted that the system would ease the watering process and promotes a faster and more consistent gardening routine.

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