IoT Based Drip Irrigation and Soil Monitoring System

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Abstract. Water is an important resource required by all living things to stay alive. Water conservation is an important agenda throughout the world. Agriculture sector consumes lots of water resources to grow crops, vegetables and etc. Hence, a water saving irrigation system is desirable. The main objective of the project is to design and develop a prototype for an IoT-based drip irrigation and soil monitoring system. The system can be used to control and monitor the drip irrigation process according to soil moisture levels and also provides a notification to alert the user whenever the water level on the water container is low. There are three soil moisture sensors used to detect the soil moisture level from three different flower pots. The Arduino Nano which will automatically turn on submersible water pumps for drip irrigation when the moisture level detected is less than 20%. Furthermore, right-angle flip switch water level sensor is used to monitor the water level of the water container. Whenever the sensor detects that the water level is low, then a notification is sent to the user via BLYNK app. The system is able to communicate with the BLYNK app which is the IoT platform used to provide all of live stream data from the sensors to let user know on the changes occurred to the surrounding such as temperature, relative humidity, light intensity besides soil moisture levels.

Keywords: Drip Irrigation · IoT Based · Moisture · BLYNK · Arduino NANO

1 Introduction

The changing dynamics, non-linearity of soil moisture content, as well as other weather and plant variables require real-time monitoring and accurate predictive model for effective irrigation. The effect of global warming and droughts are becoming more common, putting an unprecedented strain on the availability of water supplies. Besides, the rapid urbanization, population growth, and the expansion of industry and agriculture increase the need for freshwater supply.

Automated Irrigation Systems are commonly used in the large scale of plantation industry. However, the problem of uneven distribution of agricultural products or low productivity of plants is still a well-known problem around the world. The few vital needs for plants are light, water, air, nutrients, proper temperature and enough space to grow well.

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Automatic watering system is not a new invention, and the recent studies revealed that the watering system has been integrated with the latest technology of WIFI and Internet of Things [1–15]. The creation of Internet of Things (IoT) platform has enable connectivity to various sensors/components to the Internet. The main purpose for doing so is to exchange info and communication for intelligent identification, tracking and monitoring [13].

Irrigation, also known as watering is an essential process for the plants by controlling the amount of water to land for crops, landscape plant, potting plant and lawns. Drip irrigations become a popular agricultural watering system nowadays due to its great efficiency in reducing water usage. Drip irrigation is a type of micro irrigation system allowing water and nutrients to drip slowly to the roots zone of the plant in the right amount and at the right time. Drip irrigation is the most efficient water and nutrient delivery system for growing plant [1, 6].

The most common sensors that are used for soil monitoring system are soil moisture sensor, humidity sensor, temperature sensor and pH sensor [2, 5, 7, 9–13]. For some other projects, researchers may also include smoke sensor [1, 2, 7] to detect fire that happen on field or infrared sensor to detect unwelcome trespasser [2].

Some projects are using GSM module [1, 2, 5], where the user can get notification through SMS or email regarding the status of plant watering. Others [6, 7] use PC interface to view the input of the sensors and status of water pump. There are also some latest projects with the usage of smartphone apps. The most common IoT platforms are ThingSpeak and BLYNK [3, 12, 14, 15]. ThingSpeak is an IoT analytics platform which allows data access by providing an API to both the devices and social network. ThingSpeak works with Matlab Simulink, Arduino, Raspberry Pi, ESP8266, Things Network and etc. which allow user to aggregate, visualize, and analyze live data streams in the cloud. BLYNK is another IoT platform which allows user to build interfaces for controlling and monitoring your hardware projects from iOS and Android device. BLYNK is able to support web based and phone application with GUI [16].

Unlike the project that utilizes GSM module for SMS or email alert, BLYNK and ThingSpeak are able to display data from sensor and status of devices in more interactive format. Besides that, user is also able to control the hardware through these platforms remotely.

On the other hand, due to the Covid-19 pandemic, a lot of countries have issued movement control or lock down policy. This leads to home gardening blooms around the world [17]. According to research of Simone Novaes Reis et. al [18], the practice of gardening leads the brain to produce stimuli, it is able to bring happiness, hope through the contact with nature. Therefore, gardening is not just a hobby, it is also a therapy to improve the physical and mental well-being of people. More and more people are spending their time in gardening and this makes the automated irrigation system growing in demand because it will help planters to water their plants automatically when they are busy with works or on vacations at the post pandemic era.

A properly designed, installed, and managed, drip irrigation may help to achieve water conservation by reducing evaporation and deep drainage when compared to other types of irrigation such as flood or overhead sprinklers since water can be more precisely applied to the plant roots. In addition, drip can eliminate many diseases that are spread through water contact with the foliage. Finally, in regions where water supplies are severely limited, there may be no actual water savings, but rather simply an increase in production while using the same amount of water as before.

The main objective of this project is to automate the drip irrigation process based on the soil moisture levels by using IoT. The project will be based on the existing systems and we are trying to integrate the system with the Arduino Nano, ESP8266 (WIFI Module), where moisture sensor, LDR, humidity and temperature sensors will keep monitoring soil condition and the surrounding changes. Meanwhile, Arduino Nano will control the ON/OFF of the water pump based on the input from the soil moisture sensor.

The simple and user friendly BLYNK GUI has been developed to retrieve and display input data from all sensors through the ESP8266.

At the same time, the water level sensor of the water storage tank will always monitor the water level. When the water level is low and the pump in operating condition, the red LED will start blinking the 3 orange LEDs will turn on automatically, hence, there will be a notification alert send to the user.

The hardware of the project also can be used for gardens, mini gardens at home or also at large farms. An automated irrigation and soil monitoring system not only achieves water preservation but also helps the farmers/workers to monitor and preserve the soil structure and keep the plants absorbing the nutrients easily and effectively.

2 Prototype Design Overview

The whole framework is controlled by Arduino Nano as shown in Fig. 1. The Arduino Nano undertakes all information changing of various sensors and controlling the pump via the Darlington transistor. NODEMCU ESP8266 is an open-source IoT platform, and includes firmware which runs on the ESP8266 Wi-Fi SoC (system on chip). The ESP8266 will transfer all of the necessary data to BLYNK and then it will also receive feedback from the BLYNK app.

The YL-69 Soil Moisture Sensors as shown in Fig. 2 are used to detect the difference of the soil moisture levels. The soil moisture sensor is usually used to detect the humidity of the soil and can be used to determine the quantity of water stored in the soil horizon by measuring the water content in the soil. This can be done when the two probes of the soil sensor sense the changes in the soil moisture level in the soil as the two probes allow the current to pass through the soil. The soil moisture sensors will send the data to Arduino Nano whenever there are changes in the soil moisture level, hence, the Arduino Nano will process the data (digital) then it will turn on the submersible water pumps automatically. Besides that, the soil moisture data will be sent to Arduino Nano and processed by ESP8266 and lastly, the data will be displayed on BLYNK.

DHT11 sensor is the second input sensor being used in the project. It helps to measure, calculate and detects the surrounding temperature and also the humidity (RH%) value. Reading from sensor DHT11 will be sent to Arduino Nano and ESP8266. After processing is done, the graphical user interface on BLYNK will show the latest data so that the user can see it. At the same time, LDR sensor is used to detect the light, the virtual LED in BLYNK app will turn on or off depending on the intensity of light.

The water level sensor installed at the water container will send out the electrical signal to the Arduino Nano whenever the water level is low. Arduino Nano will trigger the ESP8266 to send the data to the BLYNK app which in turn the BLYNK app will trigger the notification function to turn on the notification and it will send out the message to alert the user.

The program starts by initializing all of the input and output, serial communication and WIFI communication before executing the main program.

With reference to flowchart in Fig. 3, there are 3 moisture sensors and 3 water pumps that are used for 3 different flower pots. The water pump will only be turned on

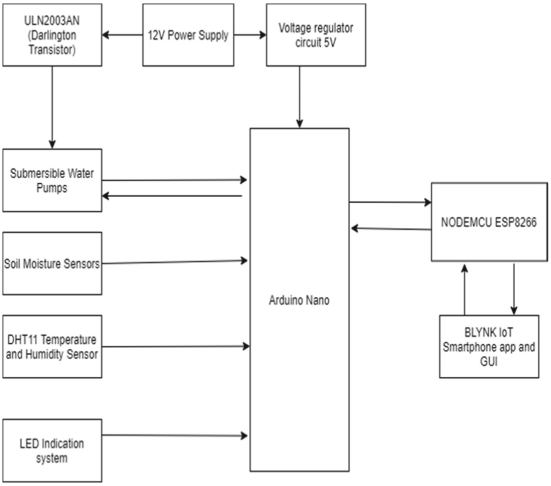

Fig. 1. Block Diagram for the system

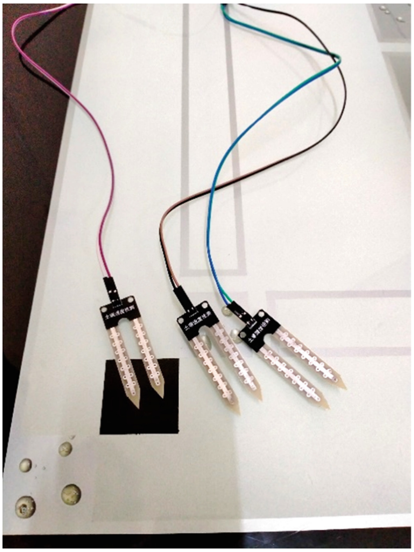

Fig. 2. YL69 moisture sensors

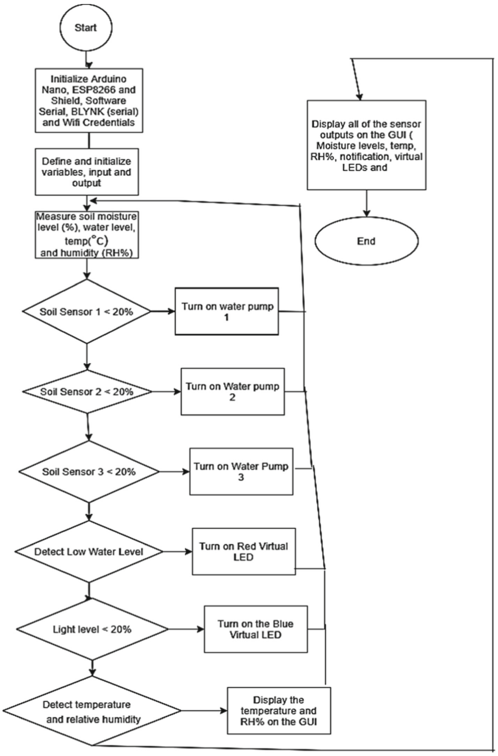

Fig. 3. Flow chart of the system

if the moisture in the soil is below 20% threshold value and the pump will not work if the soil moisture level is more than 20% of the threshold value. This can prevent the over-irrigation to happen.

DHT11 sensor will keep monitoring the temperature and humidity of the surrounding while LDR sensor is used to detect light. All data will be processed and sent by NODEMCU ESP8266 to smart phone. Hence users can view at BLYNK platform on their smart phone.

On the other hand, if the water level in the water tank is below the threshold value, a notification message "**Water Level Low!**" will be sent to user's handphone as reminder to refill the water storage. At the same instant, Arduino Nano will also turn on the LED blinking function which is the LED alert system and the red LED will start blinking nonstop until the user has fully fill up the water container. The hardware is as shown in Fig. 4.

2.1 GUI Development

BLYNK is a user-friendly platform where the user can easily develop their own app using pre-designed widgets to monitor and visualize sensor data, remote control electronics devices and receive notifications.

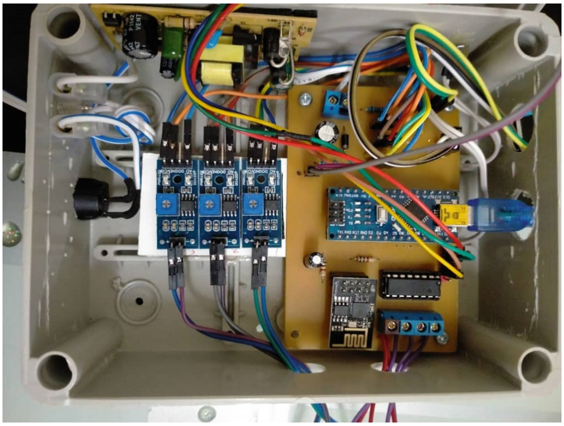

Fig. 4. Hardware development

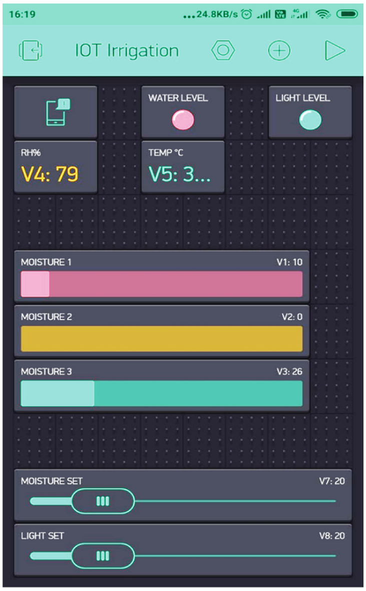

Fig. 5. GUI Interface of BLYNK

By interface the BLYNK with Arduino by using the WIFI features of the ESP8266 itself, the GUI design is shown in Fig. 5.

Figure 6 shows the setup for soil moisture sensors in BLYNK app. The first moisture sensor will be assigned as virtual pin V1, second sensor as V2 and third sensor as V3, respectively. The moisture level will be normalized from 0 to 100% on the horizontal bar in Fig. 7. Since the reading rate is a pulse type so whenever there is a change occurred and sense by the sensor, it will give its output to the virtual pins assigned.

The soil moisture values are used to compared with the *moistSetpoint* which is set to 20% in the program for all 3 moisture sensors. However, the threshold value can be changed in the program based on the water requirement for different plants. Whenever the soil moisture sensor detected moisture level of less than 20% then the submersible water pumps will start to work and also will start to do the irrigation process for the flowerpots.

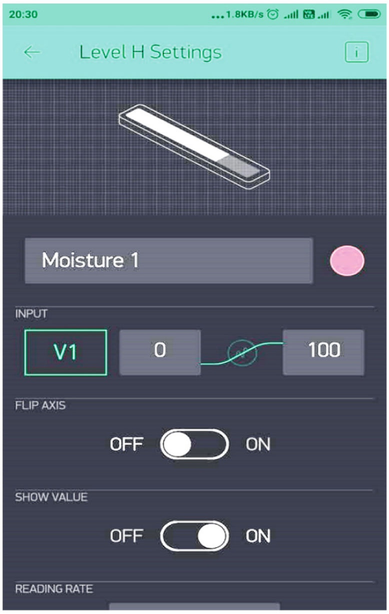

Fig. 6. Moisture sensor set up


```
Blynk.virtualWrite(V1, moist1Percent);
Blynk.virtualWrite(V2, moist2Percent);
Blynk.virtualWrite(V3, moist3Percent);
```

Fig. 7. The output for soil moisture sensors

Furthermore, if water level in the container is lower than the pre-set value, it will notify the user by turning on the virtual LED light and issue a notification message on mobile phone as shown in Fig. 8. User have to press the ok button to stop the water pump and refill back the water in the container.

The value display widget has been used to display the surrounding temperature. The output from temperature sensor has been assigned to virtual pin 5 (V5), the range from 0–50 °C and named it as Temp °C. BLYNK app will continue to read the values input from the sensor and this only can be done when the DHT11 library is used. The setting for display widget can be seen in Fig. 9 together with the output reading.

Similar setting is used to display RH% by selecting the display widget but now have to change the color from blue to orange and utilize the input to virtual pin 4 since it has been already assigned in the code and the *dht.readHumidity()*; is used for humidity reading. The selected reading rate is push reading rate so that there won't be a delay for 5 s to get the data. The range of the humidity is between 0–100% Fig. 10 shows the setting and output display on app.

3 Results and Discussions

The prototype of drip irrigation and soil monitoring has undergone few experiments for 3 different pot of plants as shown in Fig. 11.

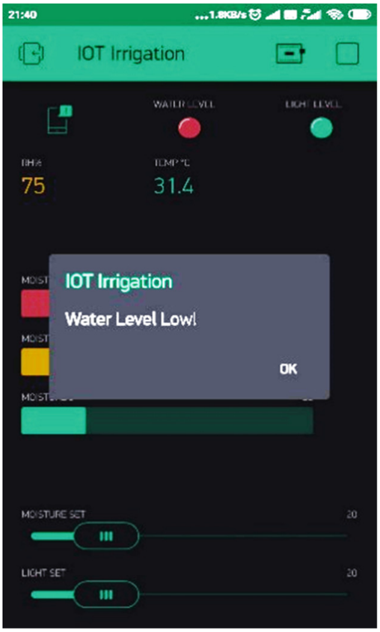

Fig. 8. Notification message for low water level on storage tank

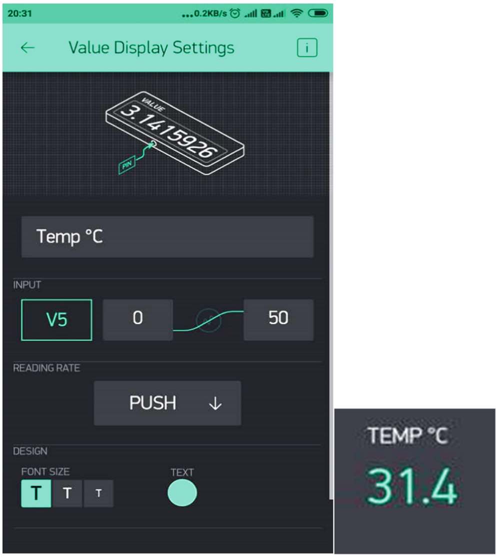

Fig. 9. Temperature setting and output display on app

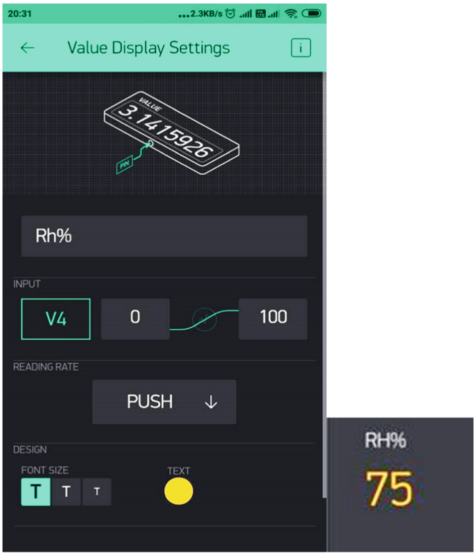

Fig. 10. Humidity setting and output display on app

3.1 Temperature (°C) and Humidity (RH%)

Testing is done to check the effectiveness and working condition of the DHT11 sensor. The data of the surrounding temperature and also relative humidity can be viewed from the graphical user interface in the smartphone (BLYNK) as shown in Fig. 12.

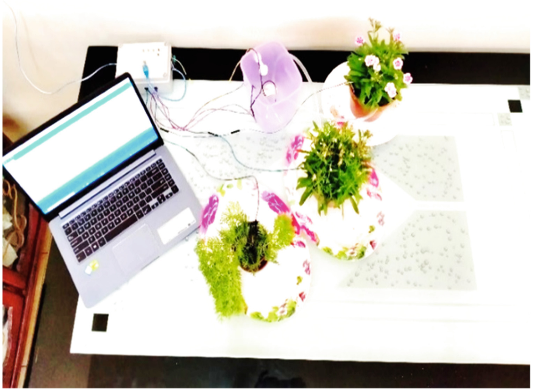

Fig. 11. Experimental prototype

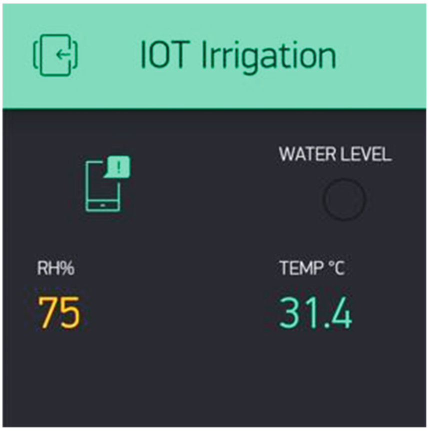

Fig. 12. Display of temperature and humidity on BLYNK App

Each test data in the Table 1 was conducted with 30 min gap. For test 6, 7 and 8 the surrounding temperature were 33.6 °C, 35.2 °C, 34.5 °C and from the results we can say that the surrounding temperature began to increase approximately, by 1 degree Celsius each time and the relative humidity for test 6 was 71% and for test 7 it began to increase to 75% and it remains the same at test 8. These results revealed that the mixture of air-water is more humid which means that the surrounding air was more humid and the evaporation of the water could evaporate more in the area. Other than that, the higher the percentage of relative humidity the higher the saturation of the air and when it reaches 100% the air is fully saturated and it will be at its dew point.

3.2 LDR Sensor Test

Table 2 shows the proper testing of the LDR sensor with sunlight. Since the program set a threshold of 20%, whenever light intensity falls below it and the virtual LED will be

Table 1. Temperature and humidity reading from sensor DHT11

Test Process	Surrounding Temperature (°C)	Relative Humidity (RH%)
Test 1	31.4	75
Test 2	32.4	68
Test 3	32.8	70
Test 4	31.5	65
Test 5	31.8	64
Test 6	33.6	71
Test 7	35.2	75
Test 8	34.5	75

Table 2. LDR testing results

Light Condition (threshold %)	Virtual LED at BLYNK (V6)	Light detection	Observation
< 20	Turn on	Detects The Light	Very Less Sunlight
= 20	Turn off	Detects The Light	Enough Amount of Sunlight
> 20	Turn off	Detects The Light	Very Bright Sunlight

turn on in the BLYNK app (GUI). In addition, when the light intensity is more or equal to 20% the virtual LED will turn off automatically. This actually just to inform the user the sun exposure of the plants.

3.3 Water Level Sensing and Notification

A simple experiment was carried out to test the water level sensor by fully filling up the water and then reducing the water in the storage tank until it reached the low sensing level. The float switch water level sensor is able to detect the water levels perfectly. When the floating ball which is fixed at the pole of the sensor move down thus the switch will be closed and indicating that the water level in the storage tank is low. On the other hand, when the floating ball has reach at the top side of the sensor's pole so the switch will be turned from closed to open which indicate that the water level is full. The observation and findings are tabulated in Table 3.

Besides this, when the sensor detects that the water level is low, the red LED on the prototype casing will blink as shown in Fig. 13. At the same time BLYNK app will send a notification with the message: "Water Level Low!" to the user as shown in Fig. 8. The actual ad virtual red LED will only stop blinking after the water replenish.

Table 3. Water Level and Notification

Water Level Test	Water Level Detection	Switch	Notification Alert System	Red LED Blinking
Test 1	Detected (Full)	Switch Open	No notification is sent	No
Test 2	Detected Low Level	Switch Closed	Notification is sent to the User in the BLYNK APP	Yes

3.4 Moisture Level Sensing

The soil moisture detection test is done by using samples of dry soil, medium wet soil and wet soil. The soil moisture sensor's probes are put inside of the soil to detect the changes of resistance among the 2 probes. The sensor will detect higher level of resistance when the soil is dry.

From the results obtained from Table 4, it clearly shows that all 3 moisture sensors are working well to detect different levels of soil moisture.

When the soil moisture level for each of the flower pots is less than the 20% threshold value, the respective submersible water pumps which are used to irrigate the plant in flower pots will function as required. The response time will only take about a second.

The details of moisture data and observations are illustrated in Table 4.

3.5 Automated Drip Irrigation and Soil Monitoring System

Experiments for running the automated drip irrigation and soil monitoring project was conducted continuously for about 3 days as tabulated in Table 5.

On Day 1, all moisture sensors detected low moisture level hence, all 3 water pumps were initiated irrigation process until the moisture level reached or above 20%. Since the flower pots are small in size so the watering process just about 5s.

On Day 2, only pump 1 activated as the moisture level drop from 94% to 6%. The other 2 pumps remained off as the moisture level all above 20%.

The moisture sensor 2 and 3 had sensed moisture level below 20%, thus both pump 2 and 3 would only be activated for irrigation process on Day 3.

The merit of this project as compare to others [3, 4, 8, 14, 16], is that we have more moisture sensors and each one can be set to different threshold value according to the water requirement of the plant. For example, flower type plant like hydrangea and rose, they need more water than other plants, so the minimum moisture value can be increased.

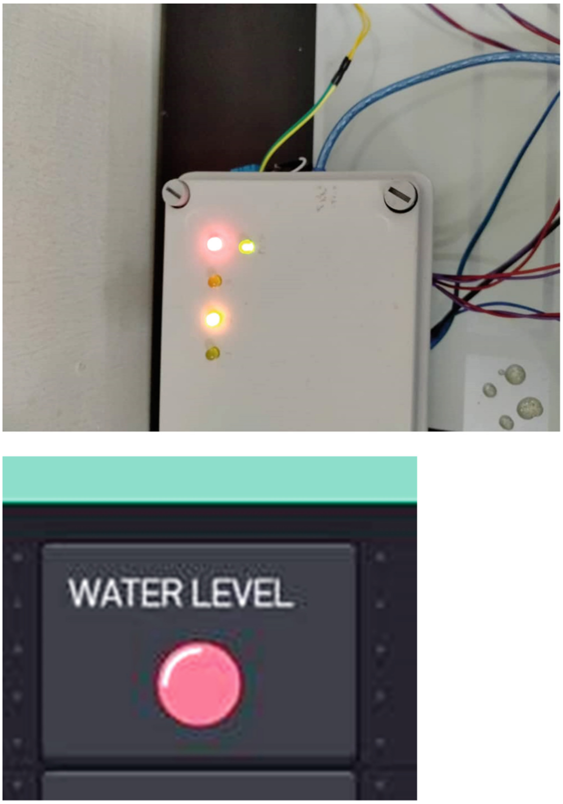

Fig. 13. Red LED Blinking on the prototype and also at the BLYNK App

Table 4. Measuring different moisture level of soil

Soil Moisture Sensor Test	Sensor 1 (%)	Sensor 2 (%)	Sensor 3 (%)	Average Time Response (s)
Test 1 **Dry Soil**	0	0	1	1s
Test 2 Medium Wet Soil	25	36	32	1s
Test 3 Wet Soil	55	64	76	1s

Table 5. Observation of prototype results

System Testing	Flower Pots (Soil Moisture Sensor)	Soil Moisture Level before Irrigation (%)	Submersible Water Pump Status	Soil Moisture Level After Irrigation (%)	Time Taken for Irrigation Process To be completed (s, second)	Submersible Water Pump status when moisture level is > 20%
Day 1	Sensor 1	4	Pump 1 on	94	5	Pump 1 off
	Sensor 2	10	Pump 2 on	46	5	Pump 2 off
	Sensor 3	10	Pump 3 on	27	5	Pump 3 off
Day 2	Sensor 1	6	Pump 1 on	35	6	Pump 1 off
	Sensor 2	64	Pump 2 off	64	-	Remains off
	Sensor 3	70	Pump 3 off	70	-	Remains off
Day 3	Sensor 1	54	Pump 1 off	54	-	Remains off
	Sensor 2	18	Pump 2 on	72	5	Pump 2 off
	Sensor 3	12	Pump 3 on	38	5	Pump 3 off

4 Conclusions

The proposed automated IoT based drip irrigation and soil monitoring system proves to be a useful and precise watering system with the advantage of reduce water wastage, reduce human intervention and time saving. The connectivity of hardware with the Internet of Things (IoT) has bring a lot of conveniences to user. The project can be further improved with the automation of water inlet valve of the storage tank, hence user no need to refill the tank manually.

The main challenge of the IoT system is the live stream monitoring could not be accessed without internet service. However, this will not affect the automate irrigation system.

Authors' Contributions. Wasim conceived of the study, developed both hardware and IoT program. Pang aided in project idea, supervising and paper writing. Chua moderating the project and did the proof reading of the paper.

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