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The development of smart flowerpot based on internet of things and mobile and web application technology

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ABSTRACT

Cultivation of ornamental plants in the office is popular among office workers and the general public because it can create a good environment in the area, but the plant growers must pay attention to watering the plants, because it may cause the plant to die. With the advancement of internet of things (IoT) technology, used to control devices wirelessly, this research developed the smart flowerpot system that works through mobile and web applications, using a microcontroller to control the system and connect to users via mobile and web application that can monitor the system, and control the operation both directly and automatically. When soil moisture is reduced to a predetermined value, the system will order the plants to be watered automatically, and when the water level is almost completely reduced, the ultrasonic sensor will send a notification to the mobile application to let the user know, after testing the system, it was found that the smart plant pot can work efficiently and can automatically water the plants.

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1. INTRODUCTION

Ornamental plants are important to the life and well-being of human beings, in addition to the four necessary factors, providing a shady, beautiful and livable environment is also important to make residents mentally happy, and to have good health for people who like to plant trees for beauty because it helps to relax the body because of the different colors of trees. It makes the atmosphere look calm and also helps to concentrate, stimulates the release of adrenaline or the substance of happiness that will help relax the body, clear the brain, increase energy in the body, make oxygen flow better, and also can purify the air, without the need to rely on air purifiers alone, because plants can help filter the air and absorb formaldehyde toxins well. Some ornamental plants also have properties that help to treat eye fatigue, because the green color of the tree can help relieve eye strain and increase the visual distance after staring at a computer screen for a long time. Along with helping to prevent glaucoma and cataracts, it also stimulates creativity. In addition, ornamental plants can also be used as souvenirs in various festivals [1], some people also use them to enhance the horoscope, to enhance the birth zodiac to have good fortune, money flows in [2], adding creative decorative value, including the trend of global warming campaigns, by planting more ornamental plants, and some ornamental plants are also meaningful and enhance feng shui on the desk for the comfort of the grower and

not too hard to plant. Moreover, the ornamental plants are small or small enough to be planted to decorate various corners of the room or to be on the desk [3], [4].

Cultivation of ornamental plants on the desk or at work has the problem of plants dying from lack of water, due to work holidays on Saturdays and Sundays, or other holidays, not watering the plant causes the plants to die of dehydration, and there is also the problem of watering and overflowing, or spilling onto the workbench, as well as the problem of over and under watering, affecting the growth of the plant [5]. Based on the above problems, the researcher proposes the Smart Flowerpot that can grow plants and can automatically water, using the soil moisture sensor with a microcontroller as a control, taking values from the sensor then decides to control the water pump, that works to automatically water the plants according to the specified soil moisture value, and there is a water level sensor in the pot that is stored for watering the plants, the sensor will tell you that the water is still full or out of the water, and has an app to allow users to connect to the plant online, to control or view the values from the various sensors of the pot in real-time.

2. LITERATURE REVIEW

According to Boonchieng *et al*. [6] presented research on smart farm: Applying the use of NodeMCU, internet of things (IoT), NETPIE and LINE application programming interface (API) for a Lingzhi mushroom farm in Thailand. This research aims to find the best practices for building a smart Lingzhi mushroom farm prototype in Thailand, this research applied the NodeMCU together with the humidity sensor and IoT platform to measure and monitor the humidity in Lingzhi Mushroom Farm, moisture data is carried out through NETPIE developed and provided by NECTEC, Thailand. It is a free service for IoT, moisture data is stored in NET FEED (sub-service from NETPIE) and displayed on mobile devices and computers via NET FREEBOARD (another sub-service of NETPIE).

This technology also controls sprinklers, misting pumps and operating status (Switch state from on and off) will automatically alert via LINE API on LINE application. Research devices and tools are NodeMCU, humidity sensor, real-time clock (RTC), relay module, sprinkler and misting pump. For programming languages use C++ and Node.JS. It uses the services and protocols of network platform for the IoT (NETPIE) with sub-services such as NETPIE FEED, NETPIE FREEBOARD, and NETPIE REST API, and also uses the LINE API. NodeMCU with humidity sensors, and an IoT platform, demonstrates smart farming best practices.

According to Janpla and Jewpanich [7] presented a study in the architecture of the smart flowerpot by using the IoT, presented the smart flowerpot, it helps to facilitate the planters, to reduce the time of care, and watering the planted trees, because the flowerpots presented by the researcher have a Soil humidity sensor that measures soil moisture and sends the soil moisture level to the processor unit, which uses the NodeMCU ESP8266, if the soil moisture level falls below a preset value, the NodeMCU sends a signal to the Relay module to allow the water pump to pump water up to the plants, and an Ultrasonic sensor module measures the water level for watering the plants, if the water level is almost exhausted to a preset value, NodeMCU will send a notification message to the smart plant owner's Line Notify to add water, and in addition, the smart pot is equipped with a red green blue light-emitting diode (RGB LED) module to Indicates soil moisture status, if LED is green means soil is high humidity, yellow soil is moderate moisture, red soil moisture is low, and users can use Mobile application for management and show the value of the sensor to let users know the different status of the smart flowerpot. The researcher has designed the architecture of smart flowerpot using the IoT and then brought it to the experts to evaluate the suitability. The overall assessment results were at the most appropriate level.

According to Tan and Chen [8] presented a research paper titled the system design of solar maglev smart home flowerpot, based on the disadvantages of artificial culture and growing potted plants in a traditional home, designed a magnetic levitation and solar-powered smart home flowerpot system, which this system uses STC89C52, a single-chip microcomputer as the core hardware, and a temperature and humidity sensor, light sensor to be used for automatic watering and lighting regularly. In addition, there will be a magnetic levitation device to control the inner of the flowerpot, so that the inner pot can float. According to the experiment, a simulation of a smart home flowerpot system using a single chip microcomputer STC89C52, the single-chip microcomputer works well, and the smart home flowerpot can realize the effect of adding water, lighting, and magnetic levitation through the system settings.

In presented Fan *et al*. [9] their research on the flower "Dock"-single-chip microcomputer-based smart flowerpot, which designed a smart flowerpot using a single chip microcomputer, named STC89C52, and uses the temperature and humidity sensors often used in environmental sensors, to be used with the storage, temperature, and soil humidity system, to perform real-time monitoring of flower growth, to maintain a suitable environment for flower growth inside the pot, guaranteeing the environment, stable

livelihood, good health for the plants, and assessing the health status of the flower. The entire system adopts a modular design and the soil temperature and humidity sensor module is used for the design of the system. The smart flowerpot has the advantages of simple operation, stable performance, and convenient debugging. In conclusion, the smart flowerpot can detect and control the temperature, humidity, light, and other environmental parameters of the flower growing environment effectively.

In presented of Zhang *et al*. [10] research on a novel and smart automatic light-seeking flowerpot for monitoring flower growth environment. This study aims to design a smart flowerpot that uses a microcontroller. It all consists of three parts: information collection layer, automatic control layer, and data transmission layer. The first layer is the data collection process and uses algorithms to improve the accuracy of data collection. The second Layer for precise control decisions to automate on-demand watering, and the third layer is a comparative analysis of local light intensity, being used to achieve light-seeking and light-supplementing. The results showed that the smart flowerpot has high anti-interference efficiency for data collection, suitable soil relative humidity for flowers should be kept at 65% and the flower should receive a well-diffused light on the flower. The error angle of light-supplementing is between -3 degrees and 3 degrees.

According to Prangchumpol [11] a model of mobile application for automatic fish feeder aquariums system, development of an automatic fish feeding system that works through a mobile application, the system consists of the microcontroller Raspberry pi operates the entire system and has a pH sensor used for a water change, which researchers use pH for a water change, the optimal pH is 6.5 to 9.0 and has a feeding system developed using Raspberry pi to control fish feeding automatically, where users can set the amount of food and time. A lighting system is a module for controlling lights on-off. In an aquarium, based on the current time, and designed a mobile application by designing a database and images on a mobile phone screen linked to a Raspberry pi, using a wireless connection. From the system validation test, this app can be executed according to user commands and set the time without shutting down or unplugging the system. The system can feed the fish on time and can also accurately control the pH of the water. The system can alert the user when the water pH is below a certain value, as well as automatically turn the lights on and off. This study shows that automatic aquariums can be used and adjusted according to the size of the aquarium.

3. PROPOSED SYSTEM

The proposed system is an IoT based smart flowerpot system that works with both hardware and software, which automatically works by reading the values from the sensors, to control the variations of soil moisture without human control, this system provides the following functionality: i) The device will connect to the Internet using a wireless fidelity (Wi-Fi) signal. The connection will be checked regularly so that users can contact the device via mobile application and web application at all times. ii) The heart of this device is microcontroller based on the NodeMCU ESP826 that connects all the components, including a Wi-Fi access point to connect to the internet. iii) The signal received from the sensor connected to microcontroller will be used for executing the specified value. iv) Programs written to provide the microcontroller receives information, to be used for controlling the entire system, and can also send and receive information (sensor status and send control information and system settings) to the user via mobile application, and web application as well.

- NodeMCU ESP8266 is a microcontroller used for controlling the operation of the entire system, it accepts values from the soil moisture sensor and ultrasonic sensor, and serves to turn on-off the relay module and LED module serves to connect. Connect to the internet, by connecting to a Wi-Fi access point because NodeMCU has built-in Wi-Fi that can be used to connect to the internet wirelessly.
- Soil moisture sensor, this module sends the soil moisture value in the pot to the NodeMCU to compare it with the specified value whether the plant needs watering or not, the low humidity value must be turned on the water pump to Pre-watering if the readings are as set, NodeMCU will command to relay module to turn on the water pump when watering until the humidity reaches the set level, it will turn off the relay to make the water pump stop working. This works automatically according to changes in soil moisture.
- Ultrasonic level sensor serves to measure the level of water in the pot, which is the part of the pot used to collect water for watering plants, when water is used for watering plants, the water level is almost completely reduced, NodeMCU sends information to the app. The application of the owner of the flowerpot to fill the pot with water.
- Relay module receives commands from NodeMCU to turn on and off the water pump to water the plants.
- The water pump is a small device used for watering plants, turns on-off from the operation of the relay module.
- LED module is a decorative pot light, used to turn on-off to illuminate the pot and for beauty, which the owner of the pot can order on-off from the application.

- Power supply module is a circuit that converts AC220 V power to DC5 V to power all devices, including NodeMCU and all sensors.
- Wi-Fi access point is a wireless Internet connection, which must support connection with service set identifier (SSID) and password. In this section, you need to write code for NodeMCU board to connect to the access point with IEEE 802.11b connection. /g/n, once connected, the board can connect to the Internet.
- Cloud network is a platform that provides services for controlling or connecting IoT devices with mobile apps or web applications, by acting as an intermediary between IoT devices and smart phones or web sites, which will provide various facilities. To allow IoT devices to work, including: i) Server: Which is an intermediary that provides cloud service for IoT devices to communicate with Smart Phone or web site. ii) Library: It is a support for writing code to support communication or communication between IoT devices and servers and mobile apps or websites. iii) Application: It is an application that is used on smart phone both Android and iOS systems that are used to control various devices. iv) mobile application and web application: It is a part of the user interface with the owner of the smart flowerpot, to display data from the sensor and control the operation of the equipment IoT. All details are described in the section of mobile application and web application, as shown in Figure 1.

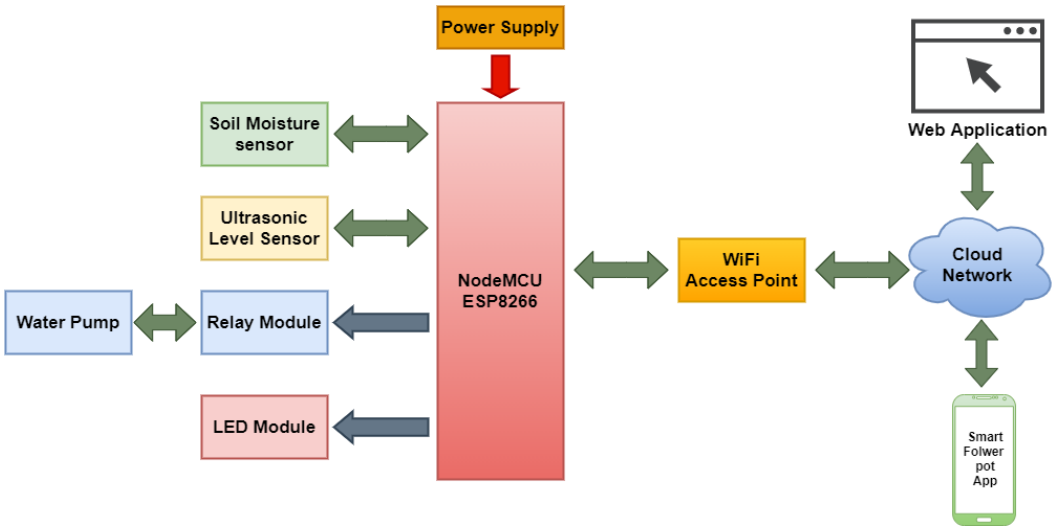

Figure 1. Block-diagram of smart flowerpot using IoT

4. HARDWARE REQUIREMENTS

4.1. NodeMCU microcontroller

NodeMCU: An open-source firmware and development kit that helps build IoT products, NodeMCU was developed to simplify using advanced APIs for input-output (IO) hardware and uses APIs to reduce redundantly. For hardware configuration and management, the NodeMCU is designed like an Arduino IO hardware. The NodeMCU uses Wi-Fi at the lowest cost.

ESP8266: It is the most used integrated Wi-Fi chip, the chip size is 5 mm x 5 mm. ESP8266 requires minimal external circuitry and integrates a 32-bit Tensilica micro controller unit (MCU), integrated with other modules. All in one small package [12], [13].

The NodeMCU features Arduino such as analog (for example A0) and Digital (D0-D8), with pins on the board, it supports most commonly used communication formats, for example, UART, SPI, I2C, and others. This allows NodeMCUs to be implemented in a variety of applications [14]. NodeMCUs are often chosen for their low cost and community support if help is needed [15], [16]. Characteristics of NodeMCU as shown in Figure 2.

4.2. Soil humidity sensor

Soil humidity sensor can be used to measure soil moisture, it can be connected to a microcontroller using an analog input to read the humidity, or choose to use a digital signal sent from the module, the sensitivity can be adjusted by adjusting the Trimpot [17]. The measurement PCB must be plugged into the

ground so that the voltage divider circuit works fully, and then a voltage comparator circuit using the LM393 OP- Amp I.c to measure the voltage comparison between the voltage**.** measured from the soil density, with the voltage measured by the voltage divider adjusted using Trimpot, if the voltage measured from the soil thickness is greater, the circuit will release logic 1 to pin D0, but if the soil thickness is less then logic 0 will be released to pin D0. Pin A0 is directly connected to the circuit used to measure soil moisture. Which provides a voltage from 0-5 V **(**ideally**)**, if the soil moisture is high. The pressure released will also be less, in the form of a reversal [18], [19]. Characteristics of soil humidity sensor as shown in Figure 3.

4.3. Waterproof ultrasonic sensor module

Soil Humidity Sensor can be used to measure soil moisture, it can be connected to a microcontroller using this is an ultrasonic distance sensor that measures the distance from a target by measuring the time it takes between transmitting a signal and receiving a reflected signal [20], [21]. A02YYUW is a waterproof ultrasonic sensor module. It can measure distances up to 4.5 meters, supports a voltage range of 3.3 ~ 5 V, and works with 3.3 V or 5 V devices such as Arduino and Raspberry Pi. The A02YYUW's average current is only 8 mA, so it can be powered from the IO port. The ultrasonic sensor uses a closed probe making it waterproof and dustproof, which is suitable for harsh and moist measurement environments. All signal processors are integrated into the module, therefore, users can obtain distance values directly through the Asynchronous Serial Interface with a transmission rate of 9600 bits/s, the sensor can communicate with the microcontroller easily, which greatly shortens the user's development time. Characteristics of ultrasonic sensor module as shown in Figure 4 [22], [23].

Figure. 2 NodeMCU version 2 (ESP8266-12E) [16]

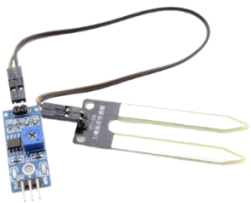

Figure 3. Soil humidity sensor [17]

Figure 4. Ultrasonic sensor module [22]

4.4. Relay module and water pump

Relay module is a digital switch to allow the microcontroller to work with high-voltage devices. The relay module can accept current up to 10 A, can be used for both direct current and alternating current, receives a voltage of 5 V directly from the NodeMCU. It is designed to protect the control circuit from the power side, by using Opto couplers transmission, on all relays widely used to create smart home projects [24]-[26] in this research, it is used for turning on and off the water pump for watering plants, relay module as shown in Figure 5. A water pump is a small submersible water pump and operates on a voltage between 3 and 5 V, has a motor inside which pumps water in through the bottom holes and pumps out water from the side. Typical applications such as watering plants, it is easy with this water pump, just place it in a bucket of water and turn it on to spray water through the spout [27], [28] water pump as shown in Figure 6.

Figure 5. Relay module [26]

Figure 6. Water pump [27]

4.5. LED strip module

There are several LED Strips available, selected for this project has 30 RGB LEDs per meter, that can control each LED individually, this is a digitally positioned LED strip, color can be set as well. Defining red, green, and blue elements. Each LED has an 8-bit PWM resolution (24-bit color per pixel).

This LED uses a maximum power of 9.5 W per meter (~2 Amps @5 V), rated power consumption: assuming all LEDs are displayed in full white, the design for colorful LED applications should be designed to be able to supply power at 1/3 to 1/2 of the maximum output current, a good power supply such as 5 V 2 A or 10 A power supply, the control chip inside the LED is cool type, and use one pin for input and one pin for output. The protocol used is very time-specific and can only be controlled by the microcontroller, which is reproducible within 100 nS. Therefore, it should be used with microcontrollers with operating speeds of 8 MHz or more. Pixel control by the microcontroller configures all control of pixels into a memory buffer, so the microcontroller must have enough random access memory (RAM) to store all the control programs, and for the LED pixels according to the number of active pixels. Must choose a microcontroller with enough RAM for use [29]-[31]. Characteristics of LED strip module as shown in Figure 7.

Figure 7. RGB LED module [29]

4.6. Power supply module

HLK-10M05 Hi-Link 5V 10W AC to DC Power Supply Module**:** It is a step-down power supply module, Modular mounted on the PCB, plastic-type, capable of supplying 5V DC from 100V AC - 240V AC and has a power output of 10W. This makes it ideal for smaller projects that require 5V from the mains, there are many advantages for these modules such as low-temperature rise, low power consumption, high efficiency, High reliability, high security, and are widely used in smart home, automation control, communication equipment, instruments, and other industries [32], [33]. As shown in Figure 8.

Figure 8. Power supply module [33]

5. CIRCUIT DIAGRAM

Circuit design for NodeMCU, to use for Smart Flowerpot will connect sensors in the input, 2 sensors are soil moisture sensor and ultrasonic sensor, to use for reading soil moisture of flowerpots and reading water level in pots, respectively. On the output side, it is connected to relay module and led module, all connections are as shown in.

- Soil moisture sensor module connected at pin A0 and voltage common collector (VCC),
- Soil moisture sensor must be connected to Soil moisture sensor probe with 2 wires, a + and - cable.
- Ultrasonic sensor module connected at Pin D5, D6, and VCC, ground (GND)
- 5 V 1 channel relay module connected at pin D1 and VCC, GND
- The water pump must be connected to the Relay Module and connected to the pin of the 5 V power supply.

- LED strip module connected at pin D2, and VCC, GND
- Power Supply Module connected to pin VCC, GND and the other side connected to household power 220 V AC

All connections as shown in Figure 9.

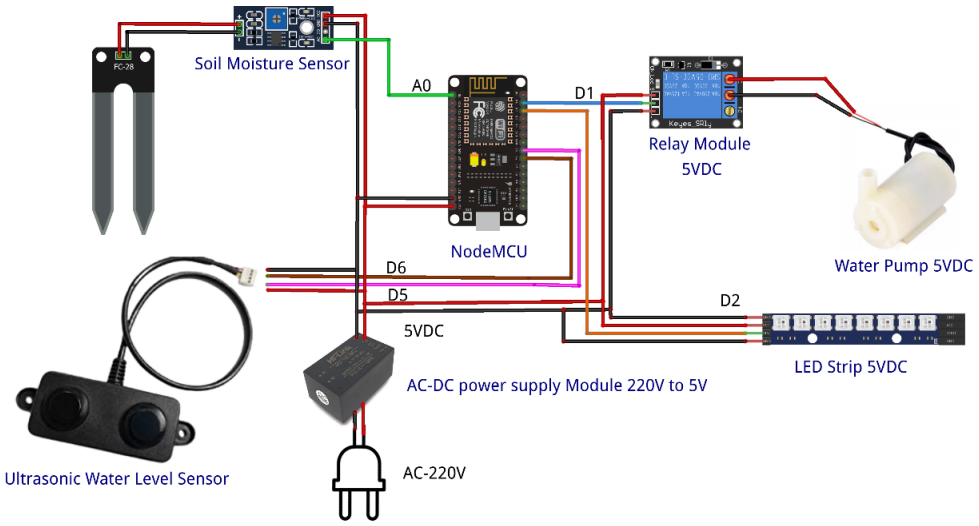

Figure 9. Circuit design of smart flowerpot

6. RESULTS

This research divided the research results into two parts, the smart flowerpot system part and the mobile and web application part. The smart flowerpots were 2-layer pots, the outer was large pots, closed, no holes to contain water, the inner pots had holes, to drain when watering the plants, if more water then water would flow down go to the bottom, to collect water to continue watering the plants. The mobile and web application was a tool that allowed the smart flowerpot owners to manage planted trees such as login, installing a watering program, displaying system status.

6.1. Smart flowerpot system

The flowerpot is a 2-part pot, the bottom part can contain water, the upper part is the planting part, and there will be holes to drain water when watering the plant. If there is a lot of water, the water will flow down to the bottom to store water for further watering the plants. To make it a smart flowerpot, put a microcontroller as a controller and have a Soil Humidity Sensor, and then send the soil moisture value to the control using NodeMCU ESP8266, if low soil moisture (read value from sensor 500-600) NodeMCU will command to relay module to make the water pump work, pump water up to water the plants, when watering the plants will increase the humidity to the set value. (Sensor reading < 200), the NodeMCU commands the relay module to turn it off, causing the water pump to stop working. The readable value from the soil humidity sensor is between 0-1023, so the soil moisture test has been tested until the soil moisture level can be divided into 4 levels: if the readable value from the sensor < 200 means high humidity, 200-500 moderate humidity, 500-600 low humidity, and >600 very low humidity, as shown in Table 1.

Table 1. Readable value from the soil humidity sensor

Readable value	Meaning
< 200	High humidity
– 200500	Moderate humidity
600 -500	Low humidity
> 600	Very low humidity

The water level measurement part uses the ultrasonic sensor to measure the water level, which will send the value for a distance. (The sensor is mounted on top of the plant pot. The readable value, if small distance means high water level if reading distances high means the low water level in the pot) to NodeMCU,

if the water level drops too low, NodeMCU sends a warning message to the mobile app and web application to inform the owner of the smart flowerpot to continue adding water. And in addition, the flowerpot has an LED Strip Module installed as a light bulb to show the soil moisture status, if the lamp is green, the soil is high humidity, the lamp is yellow, the soil is moderately moist, the lamp is red, the soil is low humidity, the installation of various equipment as shown in Figure 10.

Figure 10. Smart flowerpot

6.2. Mobile and web application technology

Mobile and web applications have the same functionality as shown in: i) Serves to connect to the IoT cloud network, which is a system designed to control IoT devices, which can remotely control over the Internet network. ii) Home: serves to display the sensor value from the smart flowerpot system, display the value from the soil moisture sensor. Display the value from the Ultrasonic sensor to measure the level of water in the pot, the water intended for watering the plants. iii) Control: Controls on-off Output Devices, serves to control the on-off Relay Module to order the Water pump to work. It is watering the plants and serves to turn on-off the LED Module, to turn on-off the LED light of the plant pot on. iv) Alert: Alert is the setting of the water level in the flowerpot, it will alert when the water level in the potted plant reaches the set value, it will send an alert message to the mobile and web application of the plant owner. v) Settings: Settings for automatic control, to set the system to work automatically by the configuration of the soil moisture sensor, set the soil moisture value is low, it will turn on the Relay Module to run the water pump for watering the plants, set the high soil moisture value to turn off the Relay Module so that the water pump stops working. Some images of the web application are shown in Figure 11. Some images of the mobile application are shown in Figure 12.

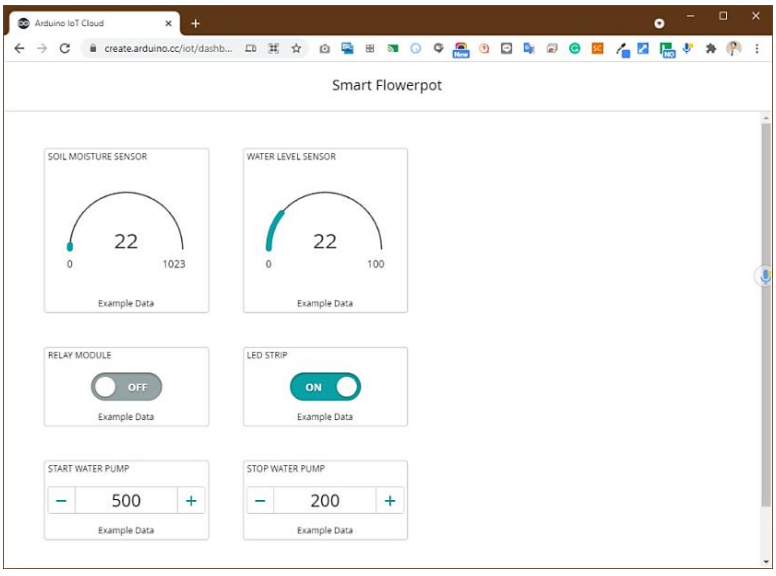

Figure 11. Web application

Figure 12. Mobile application

7. CONCLUSION

This research has developed a smart flowerpot that used IoT technology to be able to control via the Internet, using mobile and web applications, the developed smart flowerpot system could automatically water the plants. From testing the accuracy of the system, it was found that mobile and web applications could work according to the user's command and the sensor could be configured to run automatically. The system could read the soil moisture value to compare with the set value, the system would start the pump when the reading from the soil moisture sensor reached the preset value. (Low soil moisture), and would stop when the soil moisture value reached a preset value, and the system could alert the user when the water level was lower than the specified value, as well as automatically turn on and off the light. This study showed that the smart flowerpot operation could be controlled and the sensor data could be viewed from the mobile and web application.

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