Applied Internet of Thing for Smart Hydroponic Farming Ecosystem (HFE)

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***Abstract*—In the present, Thailand is developing to fully apply the Internet of things (IoT) [12] into daily life because IoT is a new trend of the technology and it is very popular today. The IoT helps us link objects and mechanisms to the internet for remote control. In addition, Thailand focuses on agriculture because Thailand is an agricultural country and it is also the main occupation of people in the country, which makes agriculture have many formats in Thailand, but hydroponics [5] [11] is an interesting new format that uses less area than others. Although hydroponics uses less space than conventional planting, it can provide many products for the farmer. In hydroponic farming, it is difficult to plant and manage if you aren't a professional farmer or don't have good knowledge about farming. For some it can be very hard to do hydroponic farming. This paper will propose a Hydroponic Farming Ecosystem (HFE) that uses IoT devices to monitor humidity, nutrient solution temperature, air temperature, PH and Electrical Conductivity (EC). The HFE is made to support non-professional farmers, city people who have limited knowledge in farming and people who are interested in doing vertical planting in very small areas in the city such as building tops, balconies of small rooms in high-rise buildings, and in small office spaces. To make the system easy to control and easy to use, we have an android application to control IoT devices in the HFE and alarm users when their farm is in an abnormal situation.**

Keyword—Internet of Things; Smart Farm; Hydroponic; Automatic Planting; Mobile Applications

I. INTRODUCTION

Hydroponics is the method of growing plants or vegetables without soil, but using mineral nutrient solutions mixed with water. Since this solution will be used as a food source for plants or vegetables, it is necessary to control or manage many factors in this liquid. Some examples of variables we have to control are the PH value or concentration and Electrical Conductivity (EC) of the nutrient solution. There will be many devices involved and interconnected to create such a system. The details will be explained in the following parts of this paper.

To make such a system some main components are needed and one of them would be a microcontroller. The Arduino microcontroller was the most accessible and popular among the developer society, and therefore was chosen for use in this project. It will be used to control and analyze data from all interconnected devices and sensors.

The Hydroponic Farming Ecosystem consists of three parts. The first part is about the detection sensors which include: air temperature, humidity, PH, Electrical Conductivity (EC), water temperature, ultrasonic and water flow sensors.

The second part covers the control system which can be manipulated to regulate the system by monitoring the values form the sensors. The air temperature, humidity and concentration of nutrients can all be controlled so that they are in a specific range or threshold.

The last part will look at the alarms in the application and notifications on a Smart Phone to inform the user of any changes. The user can control the devices in the HFE setup through the android application.

II. SYSTEM ARCHITECTURE

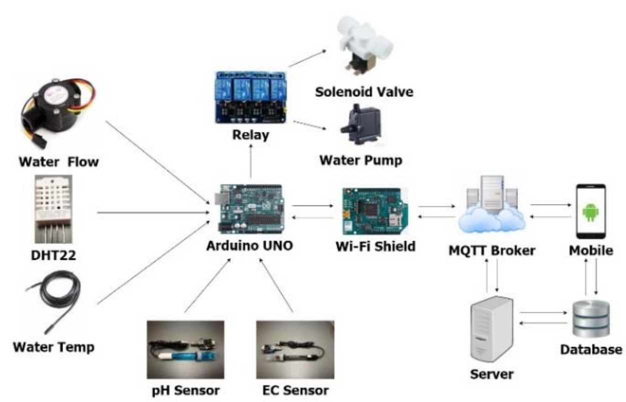

Fig. 1. The system's architecture

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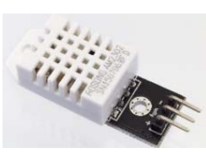
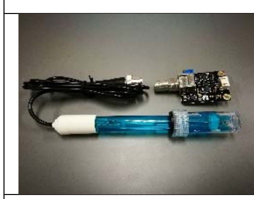
III. SYSTEM OVERVIEW

Figure 1 shows the architecture of the HFE which consists of multiple sensors, an Arduino UNO board, a Wi-Fi Shield, a Relay, an MQTT Broker, a Server, a Database and mobile user. The Arduino UNO is the main microcontroller of the system which receives data from the sensors then passes the data to other parts. The Data from sensors will be combined to one string then converted to JSON. After that, the microcontroller will send that string to the server through the MQTT Broker [10] (A connectivity protocol for the IoT). Although the Arduino Wi-Fi board has a Wi-Fi module, it couldn't be used because the connection was too unstable and unreliable. Therefore, a dedicated Wi-Fi module had to be added, so a Wi-Fi Shield was used. The MQTT Broker is an intermediary that sends and receives data. It has 3 functions. First, the MQTT broker sends data directly to the mobile application. Second, the MQTT Broker will send information to the server. Third, it will receive commands from the mobile app. or server then send them back to the sensors. The server is used for processing and saving all values in the database.

IV. COMPONENTS

TABLE I. TABLE SHOW DEVICE

Device	Description
	This device is the new Arduino Uno board which comes with a Wi-Fi module. The board is based on the ATmega328P processor, and also has an integrated ESP8266 Wi-Fi Module. [2]
	The Arduino Wi-Fi Shield allows a wireless internet connection to the Arduino module. You can connect to your wireless network by following a few instructions to start controlling your work through the internet, as always with Arduino. [3]
	The Relay is an electrically operated switch. The 4 relays support both a Normally Open and a Normally Closed deployment, and each relay has an LED to show the status. [8]
	A digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin. [7]
	This sealed digital temperature probe lets you precisely measure temperatures in wet environments. [17]
	This water flow sensor consists of a plastic valve body, a water rotor, and a hall-effect sensor. When water flows through the rotor, the rotor rolls. Its speed changes with different rates of flow. The hall-effect sensor outputs the corresponding pulse signal. [16]
	The pump that transports water and nutrient solution from the storage buckets to the hydroponic gully and plants.
	A precision device that facilitates dispersion of liquid into a spray for watering the plants and reducing the temperature.
	The EC Sensor is an instrument that measures the electrical conductivity in a solution. It is commonly used in hydroponics, aquaculture and freshwater systems to monitor the amount of nutrients, salts or impurities in the water. [6]
	The PH Sensor is an instrument that measures the hydrogen-ion concentration in a solution, indicating its acidity or alkalinity of water-based solutions, expressed as PH. [18]
	The Solenoid Valve is an electromechanically operated valve. The valve is controlled to switch on or off by an electric current through a solenoid.
	The Ultrasonic Sensor is a device that can measure the distance from an object by using sound waves. It measures distance by sending out a sound wave and listens for that sound wave to bounce back. After the sound wave bounces back, it can calculate the distance between the sensor and the object. [4]

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V. SYSTEM OPERATION

The left flow in Figure 2 shows the process of watering in this system. It starts by reading the temperature and humidity from the DHT22 (Temperature and Humidity Sensor). The temperature value has more importance over the humidity because it has a stronger effect on the plants than humidity. After that, the values will be checked that they are within the threshold. If the values aren't within the threshold, the system will turn on the water pump (by the relay) to water the setup and reduce the temperature. When the value comes into the range of the threshold, the system will turn off the water pump. The Temperature Threshold can be set to suit the season. The data or value read will be shown in the application. The unit of temperature will be in Degrees Celsius (□) and humidity will be shown in a percentage (%), and can also can be set via mobile phone.

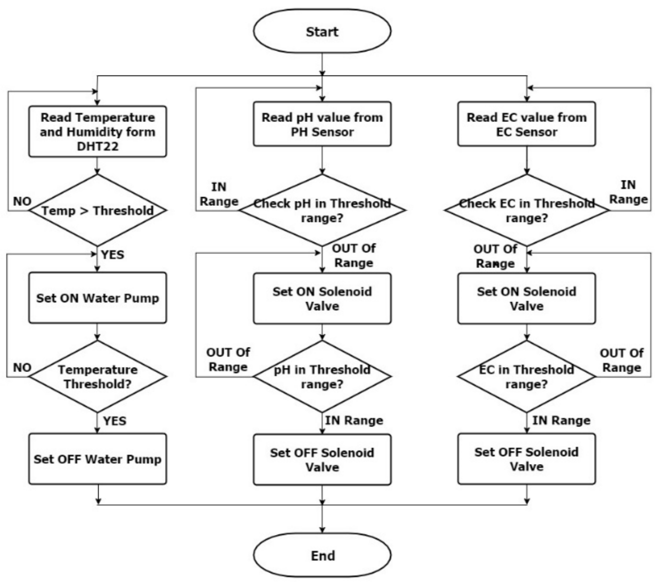

Fig. 2. The process flow of the system

The center flow shows the pH value management which is done by reading the PH Sensor. After receiving data from the sensors, the system will compare it to the threshold range. If the value is not in range, the solenoid valve will be turned on to release a substance, reducing the basicity/alkalinity in the nutrient solution and vice versa. The solenoid valve will adjust the pH value until it reaches the set threshold.

And the rightmost flow shows the process which manages the EC value. It has a similar mechanism to the PH process, but the difference is that the value will be read from the EC Sensor and release different substances. The EC mechanism will add water when the value goes out of the threshold range and will release nutrients if the value is too low. The EC will be measured in millisiemens per centimeter (µS/cm).

All of data in this part will be shown on the smart phone application. In addition, the processes can also be controlled via mobile phone.

VI. EXPERIMENT AND RESULTS

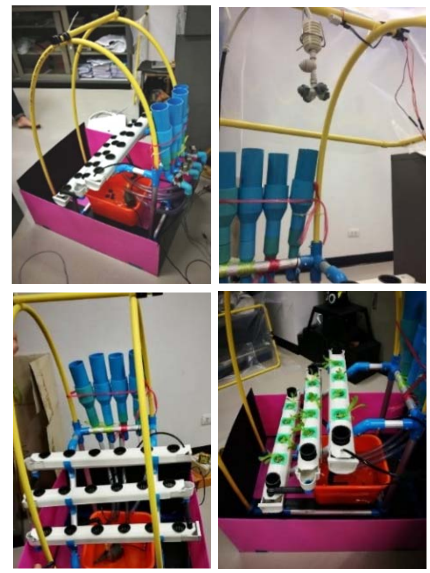

Fig. 3. The Plantation before installed the devices.

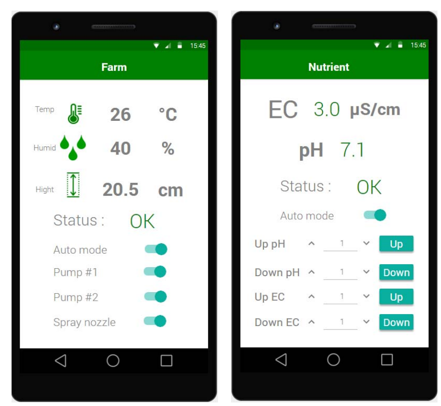

Fig. 4. Mobile monitoring and controlling application.

When we installed all the devices on the plantation as shown in figure 3, the values from the sensors installed in the plantation will be shown on the application shown in figure 4. We split the experiment into 3 phases and each phase has 2 parts, an automatic part and manual part which can be controlled from the mobile application as seen in figure 4.

A. First Experiment

In the first experiment the temperature and humidity were tested. We simulated making the environment hot to test if the process followed the flowchart in figure 2. Then, the water pump was tested to see if it could be controlled via mobile application in which it did.

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B. Second Experiment

The system's pH monitoring device was tested by manually making the solution out of range or have values out of the threshold. The automatic system adjusted the solution as promised. As for the manual pH controls through the application, the automatic system was turned off and the manual adjustment through the app worked as well.

C. Third Experiment

The tests were conducted in the same way the pH monitor was tested and had positive results, functioning both automatically and manually.

D. Fourth Experiment

This tested the accuracy of the sensors. The application was tested to see if it registered the correct values from the sensors. The values sent to the application included the water flow rate, the water levels and the temperature, in which all were sent with a high accuracy.

All of the experiments showed good results to make sure that the system could work correctly after the users installed all devices at their plantation. But sometimes the values shifted too much, making the variables always outside the threshold. This problem was manually solved by user adjustments at the plantation (mainly because of a bad setup) and were fixed easily, in any case this problem should rarely happen.

VII. CONCLUSION AND FURTHER WORK

This paper which applies the Internet of Things for Smart Hydroponic Farming Ecosystem (HFE) can help those who are new farmers or people who want to have a hydroponic farm but do not have time to manage and plant crops. After the experiments were conducted we made sure this system could work whether using it in automatic or manual mode. It will help make life easier no matter how near or far they are from their farm.

Further work is applying the system in a symmetrical plantation to check the accuracy of the HFE across multiple farms in the same area; and verify that controlling via mobile application works correctly.

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