Automatic Control and Management System for Tropical Hydroponic Cultivation

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***Abstract*—Tropical hydroponic cultivation needs to control humidity, temperature, water level, pH, and EC factors suitable for tropical climate. In order to grow qualified hydroponic plants, nutrient solution has to run through bottom channels constantly, and pH and EC factors in the solution have to control as the plant ages, the varieties of hydroponic plants and also the food safety qualification. In addition, tropical counties have hot climate almost the whole year; therefore, the greenhouse humidity and temperature have to be controlled. The power outage should be detected to avoid shutting off the nutrient solution pump. This paper proposes automatic control and management system for tropical hydroponic cultivation. The system aims to reduce information exchange of multisensor data fusion within the wireless sensor network by grouping the sensors to decide the data fusion results. It can control water level, humidity, and temperature as grower setting automatically. It also sends sensor data and status, collects pH and EC values of individual nutrient solution tank, and sends notification via Android mobile application. The data history is available on web application. This therefore is easily to monitor, manage data, and setting online. The system is tested in northern Thailand hydroponic farm. The evaluated results show that the system can decide the results from multisensor grouping as the setting correctly.**

***Keywords*— Hydroponic vegetable, Internet of Things (IoT), Mobile application.**

I. INTRODUCTION

Healthy eating tends to continue popular due to a number of health-aware customers so that the demand for hydroponic vegetables become growing. In order to increase trade competitiveness of hydroponic market, farmers should grow the hydroponic vegetables in tropical climate smartly to provide high quality and yield.

Most of the vegetables, for example, green oak, butter head, red coral, fillie iceburg, red oak, and cos are planted for salad in farm-to-table restaurants, supermarkets, and hypermarkets that require safe food. Nutrient film technique (NFT) is a popular commercial hydroponic system in tropical countries, especially in Thailand. NFT grows plants by pumping nutrient solution through channels constantly from the main reservoir/tank like a recirculating system. Plants therefore need only water and nutrient to grow. In order to grow qualified vegetables in Thailand, we have to qualify to Good Agricultural Practice (GAP) for food safety.

Accordingly, we need to control factors related to tropical plant growth and GAP qualification. The hydroponic cultivation should control humidity, water level, pH, and EC suitable for tropical climate and control nutrient solution in the tank as safely as possible to GAP qualification. In addition, power outage should be monitored to avoid water pump failure. To improve yield and control factors efficiently, Internet of Things (IoT) are applied for send and receive sensor data online, and analyze the data for precision farming [1].

Nowadays, researchers focus on controlling and managing big data in smart farming [2]. To control and manage the data, we have to concern about raw data and information suitable for analyzing as the purpose and decision making. Some of them develop irrigation management system using wireless sensor networks (WSN) for precision farming [3]-[7]. In hydroponic precision farming, pH and nutrient solution in the main reservoir are automatically controlled throughout 24 hours by calibrating sensors and measuring nutrient solution in order to increase productivity and reduce labor [8] – [9]. However, in tropical countries such as Thailand, weather is normally hot and high humidity for the majority of the country during most of the year. The NFT hydroponic vegetables require suitable temperature and humidity in the greenhouse. Hydroponic system also requires water and air pumps to flow the nutrient solution into the channels almost all the time, therefore it needs reminder when power outage occurs. Moreover, the tropical hydroponic cultivation needs to control nutrient solution temperature suitable for root growth during hot weather. Normally, the tropical cultivation has more disease then other climates; thus, nutrient solution should be separated in different tanks to be available to grow variety vegetable ages, plants, and to control disease easily. In Thailand, the solution has to be controlled pH and EC values as the GAP qualification. Therefore, multisensor data fusion is important to arrange in order to maintain accurately decision results.

This paper proposes an automatic control and management system for tropical hydroponic cultivation. The system can control factors suitable for a various kind of vegetables in different nutrient solution tanks automatically by using Internet of Things (IoT) as wireless sensors. The power status, temperature, humidity, water level, pH, and EC data are sent to database. The system can control water level automatically as the user setting in different tanks by pairing ultrasonic sensor with solenoid valve. For the temperature and humidity control, we pair the SHT31 sensor with foggy solenoid valve. The proposed system is designed to show sensor status, sensor data, and send notification while power outage via Android mobile application. The system is also available to work as automatic and manual modes. The sensors are simply installed. User can connect the sensors with wi-fi and then add them directly via mobile application. It therefore is easily to monitor, control, and set data online as the user requirement, and reduce installation cost. In addition, we can use the data collected in the database to analyze and improve hydroponic vegetable growing in different seasons efficiently.

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II. Overview of Automatic Control and Management System for Tropical Hydroponic Cultivation

This paper presents the automatic control and management system for tropical hydroponic cultivation. The system is divided into 3 processes: sensor node, sensor with data fusion, and data fusion result. In this sensor node process, we get the raw monitoring data from the sensors and then send the data to the sensor with data fusion process. Afterwards, we integrate sensor data from various sources in sensor with data fusion process. This may provide data redundancy due to individual overlapping sensor data. In order to reduce data redundancy, the proposed system allows users to pair or group the sensors that can work together to decide the efficient results in data fusion result process. This provides multisensory data fusion reduction so that we can make decision result accurately. In addition, the users can set sensor data as the condition for data fusion result via mobile application. This is available to apply the sensor to variety hydroponic plants or objectives.

Fig. 1 shows sensor nodes (S_i) in sensor node process. There are 8 sensor nodes, including ultrasonic of tank 1 (S_1), solenoid valve of tank 1 (S_2), ultrasonic of tank 2 (S_3), solenoid valve of tank 2 (S_4), humidity and temperature (S_5), foggy solenoid valve (S_6), wireless transmitter (S_7), wireless receiver (S_8), pH (S_9), and EC (S_{10}). The sensor nodes then send their raw monitoring data to sensor with data fusion process (DF_i). In DF_1, the S_1 sends current water level in real time. Afterwards, S_2 send its status to sensor with data fusion 1 (DF_1). If the S_1 is lower than the setting level in DF_1 condition and the S_2 is online status, the DF_1 will turn the S_2 on. Moreover, the DF_1 can turn the S_2 off automatically when the water level is equal to the DF_1 setting level. The DF_2 is the same as DF_1. It receives monitoring data of S_3 and S_4 which are the ultrasonic and solenoid valve of tank 2. According to data fusion reduction, the system is developed to control nutrient solution level in tank 1 and tank 2 individually due to the proposed grouping sensor. It is convenient to manage the nutrient solution automatically via mobile application, and reduces the labor cost.

For the DF_3, we control the humidity and temperature in the greenhouse by monitor raw sensor data from humidity and temperature sensor SHT31 (S_5) and foggy solenoid valve (S_6). If the S_5 humidity is lower than the user setting or S_5 temperature is higher than the setting, then the S_6 will switch on until the humidity is equal to the setting automatically. The users can also easily adjust the humidity and the temperature via mobile application. It is convenient to adjust the system, and deducts the maintenance cost. In the DF_4, wireless transmitter (S_7) and wireless receiver (S_8) send its status to DF_4. Then, the DF_4 checks whether S_7 and S_8 connect together. If they disconnect to each other, the data fusion result is power outage and the system will send reminder to the mobile application. Both pH (S_9) and EC (S_{10}) sensors can measure the nutrient solution values in each tank to control the solution suitable for GAP standard and hydroponic plants. In order to use the sensors, the users first select the tank number that they need to record. Afterwards, the S_9 and S_{10} sensors send sensor data to DF_5 and DF_6 process, respectively. The data will send directly to the database of each tank, when the user press send button on the sensors. This is available to reduce data concurrency using only one sensor which provide cost reduction.

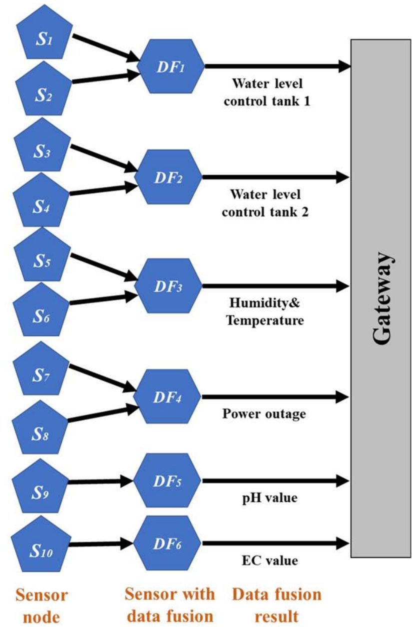
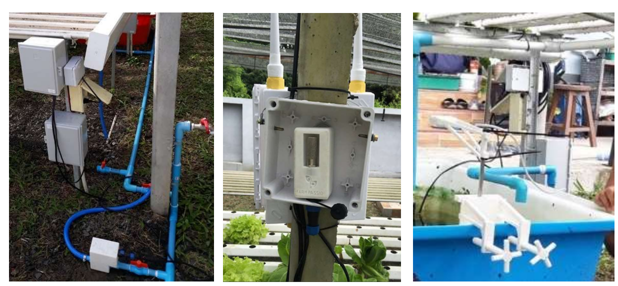


Fig. 1. Overview of data fusion management for automatic control and management system for tropical hydroponic cultivation

The proposed sensors data and history also show on web application so that it is convenient to observe the data in graph or table.

The automatic control and management system for tropical hydroponic cultivation can be access via mobile application and web application. The results of the application are described as follows:

A. Sensors installation



(a) (b) (c)

Fig. 2. Sensor installation (a) foggy solenoid valve (b) humidity and temperature sensor (c) water level sensor

The proposed sensors are installed at northern Thailand hydroponic farm as shown in Fig. 2. There are 6 sets of sensors installed: a set of pH sensor, EC sensor, power outage detection, humidity and temperature sensor, and 2 sets of water level control. The power outage detection sensor is divided into wireless transmitter and wireless receiver. The transmitter plugs in at the power socket and the receiver plugs in at the UPS. The humidity and temperature sensor is paired with foggy solenoid valve. The 2 ultrasonic sensors are grouped with water level solenoid valve in tank 1 and tank 2, respectively. The EC and pH sensors are rechargeable via the built-in lithium polymer batteries. This makes the EC and pH sensors portable. All of the sensors connect to the same internet gateway without data interference because the sensors are grouped to decide the efficient results in data fusion result process.

B. Web Application

The system is available to access to the web application using the same username and password as the mobile application. We can observe sensor data history graph and table online as shown in Fig. 3. In addition, the growers can download the history that helps growers manage and plan the hydroponic cultivation efficiently.

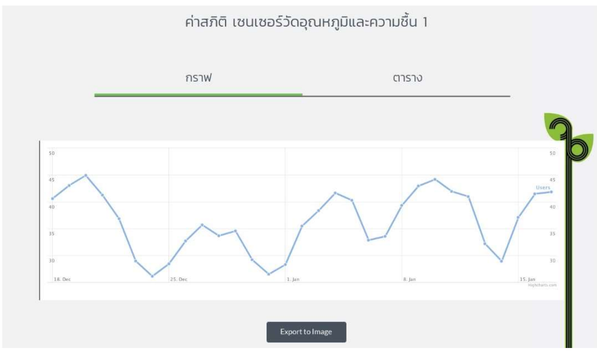


Fig. 3. Sensor data history on web application

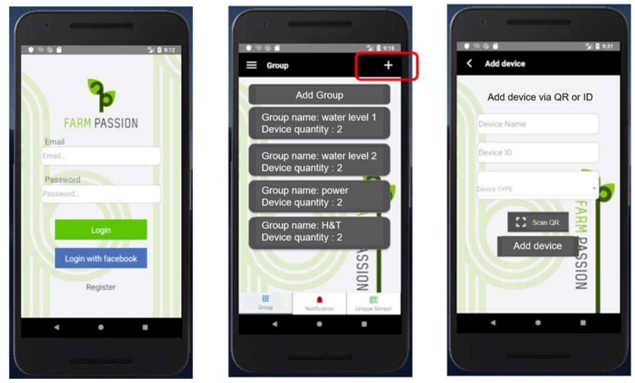
C. Mobile Application

In the Android mobile application, users can log in to the application using Facebook account or register for the new account in Fig. 4 (a). To use the automatic control and management system, we have to add sensor device as the plus icon '+' in Fig. 4 (b). We can match the sensors as group of sensors or add individual sensor by scanning QR code or filling up the sensor ID shown in Fig. 4 (c).

Humidity and temperature sensors can be accessed by clicking on individual tab and then choose the automatic or manual foggy solenoid valve control in Fig. 5 (a). If automatic system is chosen, the valve will switch on when the humidity is less than 25% or the temperature is over 35 Celsius; then the valve will switch off when the humidity is equal 28% automatically. For the EC and pH monitoring, the users can access to individual tab and then they click on the sensor that they need to observe. The EC and pH values of each tank can be displayed sensor history on 'view record' button. We can record the EC and pH values separately of each nutrient solution tank by clicking 'record' button shown in Fig. 5 (b). In this paper, we set the suitable EC and pH values depending on the plant ages are shown in TABLE I.

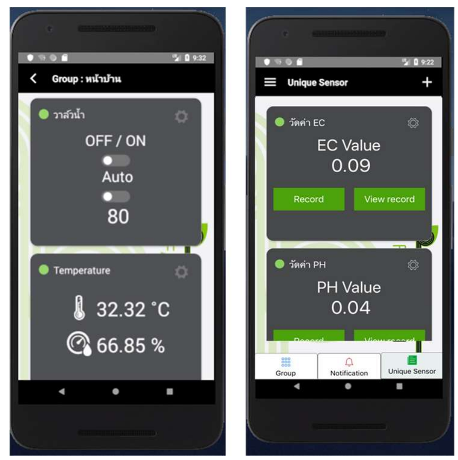
TABLE I. EC AND PH VALUES AS THE PLANT AGES

Plant Age)day(	EC (mS/cm)	pH
1-2	-	-
3-7	-	-
8-14	0.9-1.1	6.0
15-24	1.5 - 1.6	6.0
25-31	1.5 - 1.6	6.0
32-38	1.3 - 1.4	6.0
39-45	1.1 - 1.3	6.0



(a) (b) (c)

Fig. 4. Android application result (a) log in page (b) add device (c) add device using QR code or sensor ID

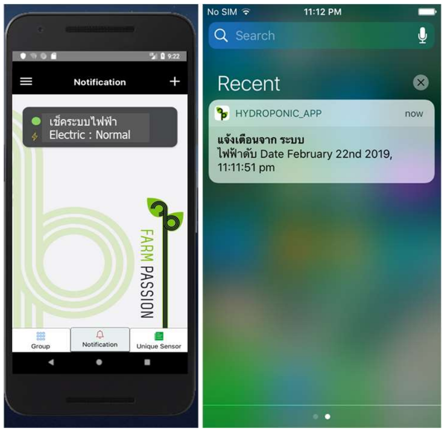


(a) (b)

Fig. 5. Individual sensor page on Android application (a) humidity and temperature monitoring (b) EC and pH monitoring

(a) (b) (c)

Fig. 6. Android application result (a) tank volume estimation (b) water level adjustment (c) water level monitoring



(a) (b)

Fig. 7. Android application result (a) individual sensor page (b) tank volume estimation (c) water level adjustment

To set the water level of each tank, the users have to enter the height, width, and length of the tank so that the system estimate the tank volume shown in Fig. 6 (a). Afterwards, the water level scale can be set the percentage of minimum and maximum water level left in the tank. We can select 'manual adjust' or 'auto adjust' menu. If manual adjust is selected, the users have to adjust the level percentage in Fig. 6 (b). On the other hand, if the auto adjust is chosen, the user just put the water into the tank as the level that they need. Then, the system records this level as the system setting. This paper sets water level manually at the level 30%-80% of the tanks. If the water level is lower than 30% of the tank, solenoid valve will switch on until the water level is equal to 80%. The results of water level monitoring on mobile application is shown in Fig. 6 (c).

Fig. 7 displays the status of power outage detection sensor. To use the sensor, the users have to check whether the wireless transmitter and receiver can connect to each other. If they are connected, the status light will be green and the status will be normal. If the sensors disconnect, the status light will turn red and show status will be disconnected in Fig. 7 (a). If power outage occurs, the system will send the notification immediately to the users on the background reminder shown in Fig. 7 (b).

III. Evaluation Results

This paper evaluates the proposed automatic control and management system efficiency by hydroponic grower in the northern Thailand. The whole system has been installed for 3 months. The system is tested and checked for system usage, stability and accuracy shown in TABLE II.

TABLE II shows evaluated results of the 6 sensors in accuracy, connectivity, and packing to determine user satisfaction in commercial usage. The evaluated results show that the system can send data and decide the results from multisensor grouping as the setting correctly. The sensors can send data correctly and as fast as real time processing. However, the EC and pH sensors is bigger than the conventional offline equipment because they need bigger batteries for wireless sensor and rechargeable batteries. This is results in rarely inconvenient portable equipment.

TABLE II. User Satisfaction Scores From The 24 Users

Sensor	Accuracy	Connectivity	Packaging
pH	O	O	X
EC	O	O	X
power outage	O	O	O
humidity and temperature	O	O	O
water level control tank 1	O	O	O
water level control tank 2	O	O	O

'O' = satisfied and 'X' = unsatisfied

IV. Conclusion

This paper proposes automatic control and management system for tropical hydroponic cultivation to reduce information exchange of multisensor data fusion within the wireless sensor network. The system provides sensor grouping to decide the data fusion results without data interference. The system can control water level, humidity, and temperature as grower setting both automatically or manually. It sends sensor data, sensor status, and notification via Android mobile application meanwhile the sensor data history is available on web application. This therefore is easily to monitor, manage data, and set the system online. The system is tested by hydroponic grower in northern Thailand hydroponic farm. The evaluated results show that the system provides the results as the setting correctly. It presents stable connectivity and durable as the portable equipment.

References

[1] Stepan Ivanov, Kriti Bhargava, William Donnelly, "Precision Farming: Sensor Analytics," IEEE Intelligent Systems, Vol. 30, No. 4, 2015, pp. 76-80.

[2] Sjaak Wolfert, Lan Ge, Cor Verdouw, Marc-Jeroen Bogaardta, "Big Data in Smart Farming – A review," Elsevier, Agricultural Systems, Vol. 153, 2017, pp. 69-80.

[3] Francesco Fabiano Montesanoa, Marc W. van Iersel, Francesca Boari, Vito Cantore, Giulio D'Amato, Angelo Parente, "Sensor-based irrigation management of soilless basil using a new smart irrigation system: Effects of set-point on plant physiological responses and crop performance," Elsevier, Agricultural Water Management, Vol. 203, 2018, pp. 20-29.

[4] Yousef Hamouda, Mohammed Msallam, "Variable sampling interval for energy-efficient heterogeneous precision agriculture using Wireless Sensor Networks," Elsevier, Journal of King Saud University - Computer and Information Sciences, 2018.

[5] Rahim Khan, Ihsan Ali, "Technology-Assisted Decision Support System for Efficient Water Utilization: A Real-Time Testbed for Irrigation Using Wireless Sensor Networks," IEEE Access, Vol. 6, 2018, pp. 25,686-25,695.

[6] Joaquín Gutiérrez Jagüey, Juan Francisco Villa-Medina, Aracely López-Guzmán, Miguel Ángel Porta-Gándara, "Smartphone Irrigation Sensor," IEEE Sensors Journal, Vol. 15, No. 9, 2015, pp. 5,122-5,127.

[7] Federico Viani, Michael Bertolli, Marco Salucci, Alessandro Polo, "Low-Cost Wireless Monitoring and Decision Support for Water Saving in Agriculture," IEEE Sensors Journal, Vol. 17, No. 13, 2017, pp. 4,299-4,309.

[8] Diego S. Domingues, Hideaki W. Takahashi, Carlos A.P. Camara, Suzana L.Nixdorf, "Automated system developed to control pH and concentration of nutrient solution evaluated in hydroponic lettuce production," Elsevier, Computers and Electronics in Agriculture, Vol. 84, 2012, pp. 53-61.

[9] Woo-Jae Cho, Hak-Jin Kim, Dae-Hyun Jung, Dong-Wook Kim, Tae In Ahn, Jung-Eek Son, "On-site ion monitoring system for precision hydroponic nutrient management," Elsevier, Computers and Electronics in Agriculture, Vol. 146, 2018, pp. 51-58.