Real-time Nutrient Film Technique Management and Monitoring System Using Internet of Thing

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Abstract
Nutrient Film Technique (NFT) is a modern cultivation system that introduced under a hydroponic system that suitable to apply in a small or large unit area. However, conventional NFT system requires plenty of time and workforce to manage and monitor the fertilizer solution. Therefore, there is a need to improve the existing conventional NFT management and monitoring technique in order to save time and reduce workforce. Thus, we built the NFT management and monitoring system that can be monitored and get the real-time data of the several fertilizers' parameters based on the Internet of Thing (IoT) technology. The parameters such as electrical conductivity (EC), pH, temperature and water level were measured using sensors that connected to the Generic NanoFI microcontroller and Wi-Fi module ESP8266. Next, this system was calibrated to ensure the accuracy of data retrieved and sensitiveness of alarm systems. The result shows that this system was able to retrieve the real-time data of the fertilizer solution' parameters and sending the early alarm notification if any data is exceeded the range setting. Thus, based on the calibration results, it is a reliable system to manage and monitor the NFT fertilizer solution remotely.

Keywords: NFT management and monitoring system , Internet of Thing, microcontrollers, real-time data

Introduction

Nutrient Film Technique (NFT) is one type of closed hydroponic system that only producing crops by recirculating the nutrient solution which allows it to has high efficiency in utilizing water and nutrient usage (Burrage, 1993). In Malaysia, the NFT system has been giving good impacts on food security as well as high yield production. However, there are some problems arise from the system include the shortage of labor, difficulty in controlling the external factors of the natural environment and the lack of time for busy people to care the system (Changmai, Gertphol, & Chulak, 2018; Romadloni, 2015).

Although NFT only used a small area of land and growing plants in the absence of soil, it requires special care in terms of water temperature, water level, water acidity (pH) and the concentration of nutrient (EC/ppm) in water (Crisnapati, Wardana, Aryanto, & Hermawan, 2017). Due to the external factor of natural environment such as water temperature, the acidity of water, nutrient content in water can give big impacts on making sure the plant grows in very well condition and it is difficult to control all of them (Changmai et al., 2018).

Previous studies conducted by Changmai (2018), Romadloni (2015), and Ruenittinun (2017) show that introduction of the Internet of Things (IoT) technology in managing and monitoring agriculture make both processes become more easier and practical.

According to Anderson & Lee Rainie (2014), IoT can be defined as a global, invisible networked computing environment that built via the continued proliferation of smart sensors, cameras, software, databases and big data centers in a world-spanning information fabric. IoT is a network system that connected with small electronic devices equipped with sensors that functioning in detecting the operating environment of the system. There is a various IoT that functioning in detecting the operating environment of the system. One of them is the Plant Link system that made up from Link sensor and the base station. The base station responsible to handle all the analysis and connects to the router. The link informed the user the time for watering plants and can be programmed with sprinklers associated with specific plant types (Doknić, 2014).

Therefore, a new method is created and integrated with the conventional NFT system in order to allow farmers to manage and monitor the water temperature (℃), water level, the water acidity (pH) and the concentration of nutrient or electrical conductivity (EC). It involves the used of related sensors that can be connected to the microcontroller and displayed the appropriate data via the IoT. The system allow the user to obtain a real-time data and being notify if any data is exceeded the specific ranges remotely.

This paper focused on developing the real-time NFT management and monitoring system which involve the use of the IoT technology, and also calibration of the system to ensure the reliability and accuracy of the data retrieved and sensitiveness of alarm notification systems.

Materials and methods

Hardware and Software Development

Figure 1 illustrated the schematic diagram of the Internet of Things (IoT) system developed to manage and monitor the Nutrient Film Technique's (NFT) fertilizer solution. This system consists of power supply unit, microcontroller, sensors and actuators, and cloud storage. For the power supply unit, a single unit of 20,000 mAh power bank was found enough to operate this system for atleast one week before needs to be replaced with a power bank standby unit.

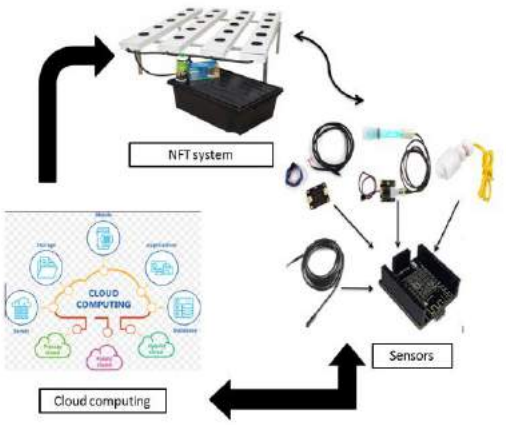

Figure 1: Schematic diagram of real-time NFT management and monitoring system

There are four different sensors installed in the system to monitor the level of water, acidity (pH), electrical conductivity (EC) and temperature. Each sensor has different specifications and level of accuracy depending on parameters that need to be measured.

For water level monitoring, a Horizontal Float Switch was used. This type of switch is widely used in in electronic, electrical, chemical, water treatment, drainage and other walks of life level control and alarm. It does not have a complex circuit, thus, can be easily installed in the fertilizer tank to monitor the level of water.

Analog pH sensor was installed in this system to measure the pH level in the water tank. This useful pH sensor kit comes with a pH probe that allows the user to dip it into the water tank and it also comes with a circuit board that can be connected directly to the microcontroller. It has the capability to measure the pH level from 0 to 14 with the accuracy of ±0.1pH at specific temperature of 25°C.

The level of EC was measured using SEN0244 Analog TDS (Total Dissolved Solids) sensor. The TDS measurement range is between 0 to 1,000 ppm with the accuracy of ±10% F.S (25°C). Both EC and TDS values can be used to measure the concentration of nutrient. However, the concentration of nutrient is commonly measure in EC unit (mS/cm). Thus, a specific mathematical equation was included in the programming code to convert the retrieve data from TDS units to EC units.

DS18B20 Digital Temperature sensor was used to measure the variation of temperature inside the water tank. This waterproof sensor is able to measure temperature variation between -55°C to +125°C ±0.5°C accuracy from -10°C to +85°C. It also can notify the user when the temperature is out of accepted range. The sensor is widely use in thermostatic controls, industrial systems, consumers products, thermometers, or any thermally sensitive system.

All four sensors were connected to the Generic NanoFi microcontroller that equipped with ESP8266 module as a communication medium through a wireless network to the internet. The use of wireless communication media provides the system with advantages that can be integrated with other tools and can be controlled via the Internet. In addition, the system connected to the network can be accessed using the browser based on the server address via the webpage. The next step is the authentication page where login is required before the main page can be accessed. Webserver can submit a request or receiving a response from the module objects. Requests sent will be processed in accordance with the specific function. Whenever there is a response, the server will received and stored the data in the cloud storage and then displayed it on a webpage.

For this real-time NFT management and monitoring system development, an open source software was used to write the arduino programming language. The programming language is very important to ensure the sensors and microcontroller are able to run the specific command properly. Entering an incorrect command will cause the system fail to run. Furthermore, if the system is running with incorrect command, it will collect the wrong data. To make worse, if the user did not realize that situation.

A webserver was used to collect, store and viewing the data online. This web tool is allowing the users to send data privately to the cloud, analyze and visualize the data, and trigger a reaction to the collected data.

Calibration of the System

The real-time NFT management and monitoring system was calibrated to identify the accuracy of the sensors and measure the sensitivity of alarm system developed.

The water level, acidity water (pH) value, electrical conductivity (EC) value and temperature value were taken three times using the real-time system. Next, those data were used to calculate the average data for each parameter. The accuracy of these sensors were calibrated by comparing those average data retreived from real-time system with the average data taken using existing measuring tools.

The water level sensor effectiveness was examined at different level of water available. For example, if the level of water is enough, the signal received should be '0', however, when the water level is below the specific limit, the signal received should be '1' and the Green LED at breadboard will be lighted up. Beside that, the alarm notification also will be send to the webpage.

For the acidity water (pH), the accuracy of the sensor was determined by comparing the average data taken using real-time system with recorded data from HI-98107 pHEP pH Tester. 0.0 to 14.0 pH is the range for this measuring equipment, while the accuray of it is around ±0.1 pH. The range for pH level was set up between 5.50 to 6.30 as stated in Table 1. If the pH level is out of range, the Yellow LED will be lighted up and the user will be noticed via online system.

Table 1: Specific range set up for each parameters

Parameters	Range Set up
pH	5.50 – 6.30
EC (mS/cm)	1.15 – 6.30
Temp (℃)	15.00 – 25.00

The electrical conductivity (EC) of fertilizer is measured using TDS sensor. This sensor was calibrated by comparing the average data obtained by real-time system with the average data recorded using HI-98331 Gro Line EC Tester. This measuring tool is able to record the conductivity values ranging from 0.00 to 4.00 mS/cm. Beside that, it also can be used to measure the temperature values between 0.0 to 50.0℃. The accuracy of this device is ±0.05 mS/cm and ±1℃ for EC and temperature values respectively. The alarm notification was set up to make sure that the range of EC values is between 1.15 and 6.30 mS/cm as mentioned in Table 1. The Blue LED will be lighted up and the notification will be sent out to the user spontaneously when the EC value is not in range.

Water temperature sensor was calibrated by comparing the average data retrieved using real-time system with the average data obtained from the measuring tool. The measuring tool use to measure the temperature value is the same tool used to measure EC level. The range set up for temperatures of the fertilizer is between 15.00 and 25.00 ℃. Like previous sensors, if the data obtained is out of range, the LED (Red) will be lighted up and the user will also get the notification via the internet.

Results and discussion

Data Acquasition

Table 2 shows the data acquisition of water level obtained during calibration process in the laboratory. As mentioned before in the calibration procedure, if the water level is below the specific limit, the signal received should be '1'. In contrast, when the water level above the specific limit, the signal received should be '0'. From three tests conducted for both conditions, the system was able to send a correct signal with zero percentage error.

Table 2: Data acquisition of water level

Below specific water level		
R1	R2	**R3**
1	1	1
Above specific water level		
R1	**R2**	**R3**
0	0	0

Mean values of pH, EC and temperature recorded using measuring tools and real-time system were shown in Table 3. From the result, it was found that there was no signifcant difference between methods use to measure all three parameters. Thus, it shows that the developed system is able to read data accurately.

Table 3: Data acquisition of pH, EC and temperature

Measuring tools			**Real-time system**		
pH	**EC**	**Temp**	**pH**	**EC**	**Temp**
5.5^a	0.21^b	27.0^c	5.4^a	0.21^b	27.0^c

*mean values with same superscript did not show any significant different (p>0.05)

Notification system

Table 4 shows the alarm notification reaction when the parameter levels are below, between and above the specific limit or ranges. The water level, pH, EC and temperature alarm notifications were represented by Green LED, Yellow LED, Blue LED and Red LED respectively. For the water level, we concern more on the lacking of water compare to excessive water level. Hence, the notification system was design only to turn ON the LED light when the water level is below the specific limit. While, for other parameters, they have their own range of level setting. The Yellow LED was light up when the pH levels are below or above the allowable range and turn OFF when the pH levels are within the acceptable range. Based on the calibration test conducted also, the alarm notification systems for EC and temperature also work accordingly. Besides notify the users through the LED light, this developed system was also sent the notification to the webserver, thus allow the users to monitor the condition of their fertilizer solution remotely.

Table 4: Notification system using different LED light colour

Parameters	LED	Specific limit / Range		
		Below	Between	Above
Water level	Green		OFF	
pH	Yellow	OFF	ON	
EC	Blue	OFF	ON	
Temp	Red	OFF	ON	

Conclusions

The real-time NFT management and monitoring system developed was calibrated. The result shows that the deloped system was able to retrieve the data such as level of water, pH, EC and temperature of the fertilizer solution accurately. Besides that, the system was also able to notify the users on any changes of those parameter level remotely.

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