THE 3rd INTERNATIONAL CONFERENCE ON AGRICULTURAL TECHNOLOGY, ENGINEERING, AND ENVIRONMENTAL SCIENCES

(The 3rd ICATES 2021)

" Innovative Agricultural and Biosystem Engineering for Sustainable Food, Water, Energy, and Environment "

Banda Aceh, 21 September 2021

Organized by:

Department of Agricultural Engineering

Faculty of Civil Engineering and Earth Resources

POLITEKNIK ACEH SELATAN

Pusat Riset Mekanisasi dan Perbengkelan Pertanian

LPPM Universitas Winaya Mukti

Extended Preface

The ICATES is annual conference organized primary by the Department of Agricultural Engineering, Universitas Syiah Kuala. This year, in the 3rd consecutive year 2021, ICATES conducted the 3rd conference with co-hosted by University Malaysia, Pahang (UMP), Agricultural Mechanization Research Center (PUSMEPTAN) Syiah Kuala University, South Aceh Poly-technique (Poltas Aceh Selatan) and LPPM Winaya Mukti. Surely, we plan to conduct this conference physically just like previous ICATES in August 2019. However, due to the unforseen circumstances of global pandemic COVID-19, the 3rd ICATES 2021 conference was carried out virtually as same as ICATES 2020 by zoom meeting platform. We took this option because this conference was already designated and funded. Keynote and invited speakers were also scheduled for this event. Many delegations and authors requested for this conference to be performed, even virtually, since they need it to cover their publication and sharing knowledge requirements.

The conference itself was run as planned on 21st September 2021 with the support from virtual event organizer started from 8.00 am to 19.00 pm. The ICATES committee members were managed this event in a particular room as a studio along with two appointed MCs. The conference was officially opened by the Rector of Syiah Kuala University, Prof. Samsul Rizal and it is broadcast lively via YouTube platform with recorded participants reach 447 were joined. The main event was started by video presentation from the Keynote speaker Prof. Okke Batelaan from Flinders University, Australia, followed by invited speaker from UMP Malaysia Assoc. Prof. Ramadhansyah Putra Jaya. The discussion session was performed directly once the second speaker was completed his presentation. Then, the second session of keynote speaker was started after 20 minutes break with the speaker from University Technology Mara (UiTM) Dr.rer.nat Shahril Anuar Bahari, followed by the last invited speaker Dr. Joko Pitoyo from Indonesian Center for Agricultural Engineering Research and Development (ICAERD).

Moreover, parallel sessions were started after all keynote speaker session and participants were divided into 8 breakout rooms in zoom platform based on their related sub-topics. The operator acted as virtual Host and Co-host to manage and ensure all presenters and participants were put in the right place. Each participant and presenter was identified by renaming their name to room number and author full name. Presenter was given about 10 minutes for power point presentation via Screen Sharing and 5 minutes for discussion and shifted to next presenter. During the conference, video capabilities were turned on to ensure dynamic conference.

As the conference chair, I firmly believe that the success of a virtual conference like this event can be achieved by arranging a stimulating program. We sincerely hope that next forthcoming ICATES conference will be conducted lively in touch as previously ICATES event in 2019. Thus, everyone finds the conference is stimulating and enjoying.

Cordially yours,
Conference Chair

Dr. Safrizal, ST., M.Si

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KEYNOTE SPEAKER ABSTRACT

WATER-ENERGY-FOOD SECURITY NEXUS

Prof Okke Batelaan

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Abstract

This presentation investigates the global past, current, and future relationship between food production and water use. It is shown that the water use, mainly for agriculture, in the past 60 years has been rising faster than the global population growth. This puts pressure on the sustainability of the global water resources, connected environmental assets and future food security. A positive trend is that the global average of the arable land (in hectares) per person used for our food production in the past 50 years has halved, due to the more efficient agricultural techniques, plant resistance and higher crop productivity. Next, options for meeting the future water-food demand are discussed, including efficiency gains from better quantification of individual and national water footprints and optimizing virtual water. Finally, an example study is presented to investigate how, in an agriculturally dominated area in Southern Vietnam, the profitability and sustainability of water use in groundwater-dependent smallholder farming systems can be improved. It is shown how combining water balance and groundwater models makes it possible to evaluate and rank a range of agricultural development scenarios in terms of sustainability of the groundwater resources for irrigation. It is concluded that global efforts on activating the water-energy-food security nexus are imminent to attain a sustainable future.

KEYNOTE SPEAKER ABSTRACT

WASTE PLASTIC: RECYCLE AND REUSE FOR SUSTAINABLE ROAD CONSTRUCTION

Ramadhansyah Putra Jaya, PhD

Professor (Associate)
College of Engineering, Universiti Malaysia Pahang

Abstract

Plastic disposal is one of the major problems for developing countries especially in South East Asia,at the same time all countries needs a large network of roads for its smooth economic and social development. The limited source of asphalt needs a deep thinking to ensure fast road construction. Therefore, the use of plastic waste in road construction not only can help to protect environment but also able to help the road construction industry. Road construction that uses plastic waste as one of it material is called plastic road. Plastic bag is non-biodegradable but most of it is recyclable. The recycled products are more environmentally harmful than the first time manufactured ones because every time plastic is recycled it is subject to high intensity heat. This can make it to deteriorate and lead to environmental pollution. That is why the use of plastic waste in road construction can be one of the solutions. This type of construction gives benefit to environment because it uses plastics that would otherwise be disposed through environmentally harmful means. In addition, it is not only reducing wasteplastic but also lengthens the road service life.

KEYNOTE SPEAKER ABSTRACT

BAMBOO, A GREAT PLANT FOR GREEN PLAN

Dr.rer.nat. Shahril Anuar Bahari

Senior Lecturer, Faculty of Applied Sciences,
Universiti Teknologi MARA (UiTM), 40450 Shah Alam, Selangor, Malaysia

Abstract

Bamboo is a great plant and important raw material for multiple uses since the earliest epoch. It is a promising material and mainly can be developed to become a supplement raw material in green product manufacturing; e.g.wood-based sector and bio-based industry. Bamboo has been used traditionally in most tropical countries for conventional building construction, housing materials, handicraft items, paper making, foods, and others. Nowadays, bamboo is widely used in modern applications with the great understanding of its characteristics. However, planning to improve the know-how of itsglobal resource handling, processing, manufacturing, as well as green product performance could further boost-up the uses of bamboo in modern green utilization. Industrial players nowadays sareaware about the potential of bamboo in supporting the demand of raw material for a wide variety of green products. Up to the present time, many accomplishments and findings were gained successfully through extensive research on bamboo applications. These findings are very useful in further promoting the potentials of bamboo as a great raw material for green development and consumption planning. Extra information on bamboo resources, processing, manufacturing and product output are necessary for proper utilization of bamboo in modern green industries.The data were widely documented and established; however, bamboo’s contemporary applications are relatively inadequate. In comparison to other green materials, its state-of-the-art in term of operation and products’ green performance, belonging to the most recent stage of technological development are relatively limited. Relationship between the available technology and futuristic potential of bamboo usage should be planned in order to elevate the function of bamboo as a green product in society. It is an important information on bamboo, before it is upgraded for green development and consumption. Understanding of these facts will enable reliable evolution of bamboo products especially for green planning purposes.

KEYNOTE SPEAKER ABSTRACT

REVIEW OF RICE TRANSPLANTER AND DIRECT SEEDER TO BE APPLIED IN INDONESIA PADDY FIELD

Dr. Ir. Joko Pitoyo, M.Si

Specialist Reserach Engineer
Indonesia Center for Agricultural Engineering Research and Development (ICAERD)
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Abstract

The manual labor cost for rice cultivation year by year in some on-going develop country in Asia. The more focus in hand transplanting. There is an option in rice cultivation by direct sowing but still need improvement in order to get yield as same by transplanting method. The challenge to plant one seed or plant per hill by rice ordinary rice transplanter (RT) is still difficult to be achieved due to random in sowing seed by on rice nursery tray. In Japan it was started 1995 by Minoru company as pioneer research and develop the Pot Nursery Rice Transplanter (PNRT) which rice are sow in exact amount in pot tray by special seed sowing machine then later on transplanter by PNRT. Rice Direct Seeding (RDS) method theoretically could be as a solution in order to get precision on rice cultivation. But due to the vigority of seed after sowing in the field and also the unfavorable condition, the more number of seed are still needed and the yield lower compare transplanter method. Recently, the use of rice direct seeding has been increasing rapidly owing to rural labor shortages and continuous increases in agricultural production costs. This article reviews the research and application progress of mechanized rice direct seeding including direct seeding technologies, precision rice seeding, precision rice seed-metering devices. The other important component on succession direct seeding method is also discussed i.e. calcium gypsum coating and iron powder coating. Operating direct seeding machine also need consider about land and water management. Paddy field need to be managed since the seed drooped in order give favor condition of seed and facility the seed with optimum growing condition. In this approach, pre-germinated seeds are uniformly hill-dropped in the expected positions in puddled soil. The both technology PNRT and RDS have prospect and great potential for promoting the development of precession on rice cultivation in Asia

Peer review declaration

All papers published in this volume of IOP Conference Series: Earth and Environmental Science have been peer reviewed through processes administered by the Editors. Reviews were conducted by expert referees to the professional and scientific standards expected of a proceedings journal published by IOP Publishing.

- **Type of peer review:** Double-blind

- **Conference submission management system:**
  For official information, we develop using the University platform: *http://icates.unsyiah.ac.id/* , while for paper submission, We used the EasyChair conference management system: *https://easychair.org/conferences/?conf=3rdicates2021*

- **Number of submissions received:**
  In total, we received 133 submitted papers through submission system

- **Number of submissions sent for review:**
  A total of 121 papers were sent to the reviewers, while remaining 12 submission paper were rejected directly due to irrelevant topics and out of conference scopes.

- **Number of submissions accepted:**
  A total of 74 papers were accepted for presentations on The 3rd ICATES 2021

- **Acceptance Rate (Number of Submissions Accepted / Number of Submissions Received X 100):**
  Acceptance rate = 55.63%

- **Average number of reviews per paper:** *2x for major revisions and 1x for minor revisions*

- **Total number of reviewers involved:** *32 reviewers*

- **Any additional info on review process:** *The review process were carried out by assigning two potential respective reviewers by track editors. The review itself approximately took maximum 3 weeks to complete.*

- **Contact person for queries:**

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Internet-based temperature monitoring system for hydroponic

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Internet-based temperature monitoring system for hydroponic

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Abstract. This study presents a monitoring system to provide real-time measurement data of hydroponic that is accessible from anywhere through internet. Temperatures of nutrient solution and ambient air are of concern in the monitoring system. The system is developed through the following steps: design, implementation, and experimental test. The system is built by applying a NodeMCU ESP-12 as the microcontroller and two temperature sensors DS18B20. The NodeMCU ESP-12 is to collect measurement data of both temperature sensors and send the data to a cloud server through a WiFi internet communication. The Google Sheets is applied as the cloud server to store the measurement data and provide the data to users. Using the Google Sheets, the data is presented in a table as in the Microsoft Excel which is very convenience for processing and analyzing the data. Experimental test results show that the system is able to provide real-time and reliable data of the hydroponics temperatures that can be accessed from anywhere through the internet. The monitoring system has a delay about 3 to 6 seconds in presenting the measurement data. This delay is quite small compare to the temperature change period and therefore is negligible. Moreover, the monitoring system is built at cost USD 6.0 which is quite cheap.

1. Introduction

Measurement is a process to collect data of physical object and compare the data to agreed standards [1]. Some examples of the measurement are measuring mass, length, pressure, temperature, and humidity. The measurement is done by using one or more sensors to collect the physical data. The sensor is a device that converts a physical measure into an electric signal that is read by an observer or by an instrument [2]. The sensor signal can be either analog or digital. The advanced digital technology produces computers that are able to process digital data very fast. Sensor that produces digital signals is readily integrated to the computer for processing the signals. However, the sensor with analog signal out needs an analog to digital converter (ADC) to connect to the computer. The ADC is a device that converts analog signal into digital signal [3]. Integrating the sensor with the computer provides many advantages in the measurement, for examples: data processing, filtering, advanced data presentation, and data distribution.

A monitoring system has been developed to help people in observing an object. The monitoring system is an electronics system that automatically works to measure the object parameters, display the measurement data periodically, and store the measurement data in storage device [4–6]. The monitoring system may also provide a warning signal if any of the measured data is indicated beyond a limit. A traditional monitoring system works only for a local area, where the measurement, display, and data storage are done and located in the same area. This traditional monitoring system is only able to cover a small area.

The advance internet technology provides a high-speed internet connection at quite low prices. It results in fast and cheap communication networks around the globe. The communication through internet is not only done by people to people but also by people to devices, devices to people, and devices to devices. The internet is applied in any parts of life such that dependency to the internet is very high. A term to describe the high internet dependency was defined as the internet of things (IoT) [7]. The IoT describes a system that connects everything to internet including human being, computers and things [8].

The emerging internet technology changes the traditional monitoring-system into a modern monitoring system by integrating to internet. The IoT can be applied in the monitoring system and results in an advance monitoring system, where the measured data is not only presented and stored in a local computer but can be presented and distributed around the world in almost real-time. The term of almost real-time is to emphasized that a small delay should be realized due to the data transmission. This advanced monitoring system is called as the IoT-based monitoring system [9–11]. The IoT-based monitoring systems have been studied to be applied in many fields, for examples: environment [9], agriculture [11], transportation [12], and health [13].

Agriculture is very important in human life as producing foods. The agriculture has many planting methods and one of them is hydroponic. The hydroponic is a planting method without soil but using nutrient solution [14]. Plants in the hydroponic can be mechanically supported using an artificial medium, such as: sand, gravel, vermiculite, rock-wool, perlite, peatmoss, coir, or sawdust [15]. Comparing to traditional agriculture, hydroponic provides some advantages [16], for examples: less space requirement, less maintenance, relatively clean, and high productivity. Considering those advantages, the hydroponic is a suitable implemented in urban life. It will support food sustainability and better life environment.

Nutrient solution is one of the main factors for the growth of hydroponic plants. The nutrient solution is a mix of water and fertilizer that is distributed to the plants through pipelines. Maintenance of the hydroponics needs to periodically observe the quantity and quality of nutrient solution. Quantity of the nutrient solution is represented by a volume, where it can be easily observed by using human eyes. However, monitoring quality of the nutrient solution is more difficult. The quality is represented by several parameters, for examples: temperature, acidity, and concentration [17]. These parameters are observed through measurement process using some sensors. The temperature is measured using a temperature sensor, the acidity is measured by a pH sensor, and the concentration is measured using a total dissolved solids (TDS) sensor. Since observation of the nutrient solution needs to be done frequently, it becomes a tedious job and cumulatively spent a lot of time.

An IoT-based monitoring system is suitably applied in the hydroponic maintenance. The system is able to measure the quantity and quality of nutrient solution every time, while the measured data is stored and accessed from anywhere through internet. Several works on developing the IoT-based monitoring system for hydroponic have been presented. An IoT-based monitoring system presented in [17] was to monitor the volume, temperature, pH, and concentration of the nutrient solution. The monitoring system applied Arduino Uno as the microcontroller, a WiFi module ESP8266 as the connecting bridge to the internet, and a Raspberry Pi 2B as the webserver. The values of monitored parameters were presented in a webpage. Another IoT-based monitoring system was presented in [18] and named the iHydroIoT. The system used Arduino Uno as the microcontroller unit to collect measurement data form sensors, where the sensors communicated to the microcontroller through a Bluetooth Low Energy (BLE) module. A Raspberry Pi 2 was applied as a webserver that received the measurement data from the Arduino Uno and then sent the data to the Plotly cloud service for visualization. This monitoring system was to monitor light intensity, air humidity, and several parameters of the nutrient that include temperature, CO2, acidity, concentration, and volume. An advanced IoT-based monitoring system for hydroponic was presented in [19]. This monitoring system is not only to perform monitoring but also applying the measurement data for advanced data analysis using artificial intelligence. The monitoring system is equipped with a quite complex sensors set that includes temperature, pressure, altitude, humidity, lux, ultraviolet, CO2, water temperature, pH, dissolved oxygen, electricity conductivity (EC), and total dissolved solid (TDS). The monitoring system is also collected vision data using two cameras. An Arduino Mega is applied in the monitoring system to collect the measurement data from the sensors but not the cameras. A Raspberry Pi 3B+ is applied in the monitoring system to collect the vision data from both cameras. The Raspberry Pi 3B+ is also assigned to send the measurement data and the vision data to a database through WiFi communication. The vision data are further analyzed using deep learning for predicting the harvest time.

The previous research works show that the IoT-based monitoring system provides flexibility to monitor the hydroponics. This flexibility means that the condition of hydroponic plant can be monitor anytime from anywhere. The measurement data is not only applied to trigger a warning signal but also to build an artificial-intelligence model. The model can be used to make classification and prediction to improve quality and quantity of the hydroponics production. Applying the artificial intelligent in agriculture is a part of the technology of precision agriculture. Therefore, the monitoring system should be developed to provide data that supports the artificial intelligence.

The temperature is a crucial parameter for determining evapotranspiration of crops, cell metabolism, crops growth, and crops physiological cycles; while, each crops has a specific range of suitable temperature [20–22]. Crop requirement on suitable temperature condition is different at different growth stages and light condition [23–25]. Understanding crop-temperature interaction in precision manner is a one of important keys in managing sustainable greenhouse production.

This study is to develop an IoT-based monitoring system of hydroponic temperatures. This monitoring system will be used to observe nutrient-solution temperature and ambient-air temperature of hydroponic plant. Moreover, the monitoring system will record the temperatures data that is being used in advanced analysis such as finding the optimal temperature for the plant growth and temperature prediction. This monitoring system is built using a NodeMCU ESP-12 and two temperature sensors. Measurement data of the temperature sensors are collected by the NodeMCU and sent to a cloud server via WiFi communication. The data is stored in the cloud server and accessible by authorized users from anywhere through internet. This will provide flexibility in monitoring the hydroponic temperatures. Presentation of this paper is organized as follows. Section I provides background and motivation of the work to develop IoT-based monitoring system with a study case on monitoring hydroponic temperatures. Section II presents the detail of IoT-based monitoring system for hydroponic temperatures. It described the concept, the hardware specification, the hardware design, and the software. Section III describes the experimental test and the result in evaluate the developed monitoring system. Finally, the Section IV concludes the work.

2. Materials and methods

Hydroponic is a planting method by using nutrient solution instead of soil [11]. The nutrient solution is distributed and circulated to all of the plants through lines. Temperature is one of the important parameters for the plant's growth. In the hydroponic, it can be identified at least two types of temperatures: 1) temperature of nutrient solution and 2) ambient temperature. The ambient temperature is the air temperature surrounding the plants. Both temperatures may not be equal due to heat isolation of the pipeline and the different heat capacity of the nutrient solution and the ambient air. The pipelines applied in the hydroponics are commonly made from PVC material. The PVC material is a heat insulator material that prevents heat transfer from the ambient air to the nutrient solution and vice versa. This insulator makes both temperatures may not be equal. Moreover, the nutrient solution has higher heat capacity than the ambient air. The higher heat capacity makes the temperature of nutrient solution more inert than the temperature of ambient air. Temperature change of the nutrient-solution should be slower than the ambient air.

2.2. Concept of Monitoring System

An IoT-based monitoring system to observe the temperatures of nutrient solution and ambient air is developed. A concept of the monitoring system is explained based on a model in Figure 1 as follows. Two temperature sensors are applied in the monitoring system, where one of the sensors is dipped in nutrient solution in the pipeline and another sensor is place above the pipeline and beside the plant. The measured temperature data of the sensors are collected and sent to a could server by a microcontroller. The measurement data is stored in the cloud server and can be accessed by permitted user from anywhere through internet. Realization of the concept needs to specify, design, and implement the required hardware and software.

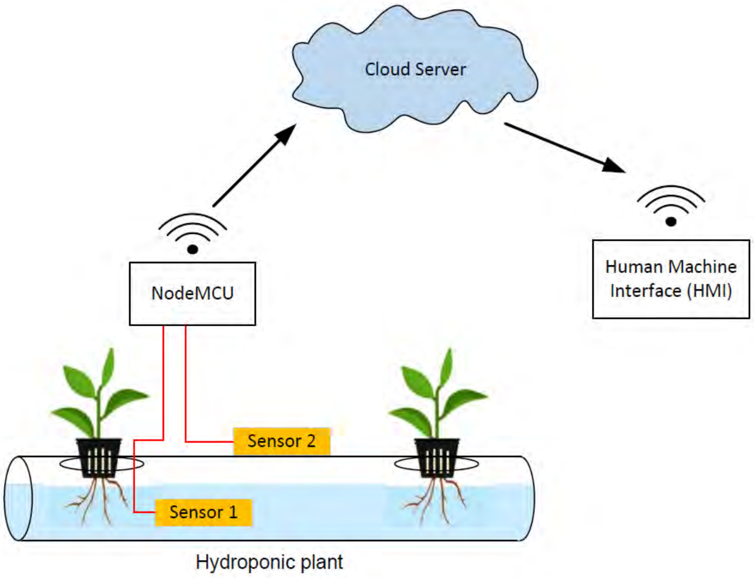


Figure 1. A model of IoT-based temperature monitoring system of hydroponic plant.

2.2. Hardware Specification

According to the concept of monitoring system shown in the Figure 1, the monitoring system consists of four main parts: sensor, microcontroller, cloud server, and HMI. Since the cloud server is a service provided a provider and the HMI is located in the user side, the required hardware for the monitoring system are only the sensor and microcontroller.

This study is concerned in monitoring temperatures of hydroponic that include the nutrient-solution temperature and ambient-air temperature. Therefore, two temperature sensors are required. The first temperature sensor is to measure the nutrient-solution temperature (NST) and called as the NST sensor. The second temperature sensor is to measure the ambient-air temperature (AAT) and called as the AAT sensor. The NST sensor is placed by sinking into the nutrient solution in the hydroponic pipeline. The NST sensor needs to be a waterproof temperature sensor.

For this requirement, the Dallas temperature sensor DS18B20 is applied. The DS18B20 is a water-proof and low-cost temperature sensor that can be used to measure temperature from −10◦C to +85◦C with accuracy ±0.5◦C. Meanwhile, the AAT sensor is not dipped in liquid but for anticipating water contamination on the sensor due to rain and dew, the AAT sensor applies the DS18B20 temperature sensor.The temperature sensor DS18B20 is shown in Figure 2. The sensor has three pins, where the pin 1 is the ground, the pin 2 is the data, and the pin 3 is the VDD [26]. The sensor works by a power supply

3.0 to 5.5 Volts direct current (DC), where the positive voltage is connected to the pin 3 and the negative voltage is connected to the pin 1. The pin 2 is the sensor output that provide the measurement data. For operating the sensor, the pin 2 and the pin 3 have to be connected by using a resistor 4.7 kΩ. More detail specification and operation of the DS18B20 sensor can be found in the datasheet [27].

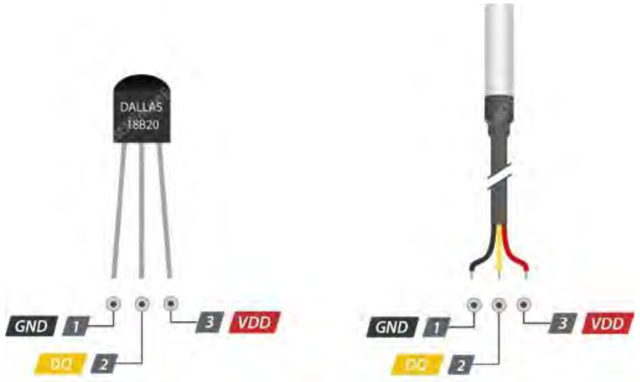


Figure 2. Temperature sensor DS18B20 and the pins wiring [26].

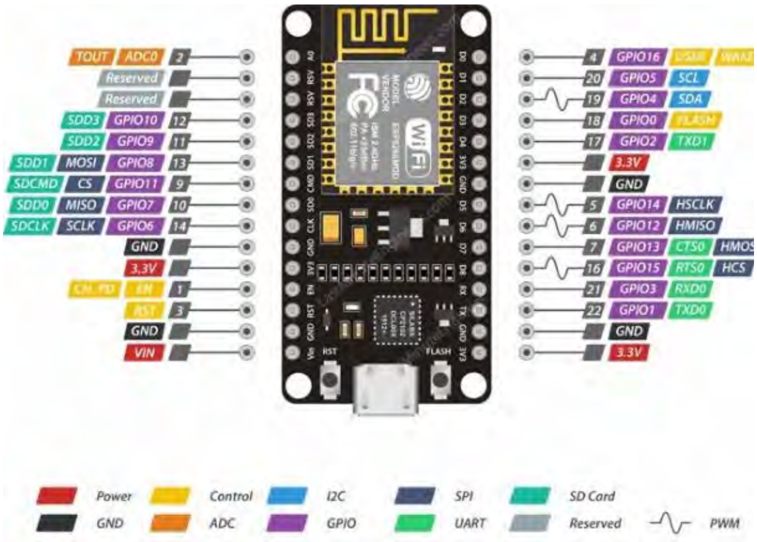


Figure 3. NodeMCU ESP 12 and the pins configuration [26].

Another required hardware in the IoT-based monitoring system is the microcontroller. The microcontroller is used to collect the measurement data resulted by the sensors and sent the data to a web server. Communication between the microcontroller and the web server can be done through wire communication or wireless communication. The wire communication transmits the measurement data to the web server via local area networks (LAN) cable, while the wireless communication does it via WiFi. Compared to the wire communication, the wireless communication provides more advantages, for examples less installation, less cost, but tidier. Developing such kind of the IoT-based monitoring system requires a microcontroller that has an ability to communicate via WiFi. There are several types of microcontrollers that can be applied, for example: Raspberry Pi and NodeMCU ESP-12. Both microcontrollers have facility for WiFi communication. Arduino UNO which is one of most famous microcontrollers does not have facility for the WiFi communication. The Arduino UNO can be applied but requires a WiFi communication module that is available separately. Since the developed monitoring system in this study uses only two sensors, the NodeMCU ESP-12 is best choice by considering the budget. The NodeMCU ESP-12 is a low-cost microcontroller equipped with a WiFi communication module that can be obtained at price less than USD 4.0. Figure 3 shows the NodeMCU ESP-12 and the pin configuration. The NodeMCU ESP-12 has thirteen pins of general-purpose input output (GPIO). It can be used in a monitoring system by handling up to thirteen measurement data. The NodeMCU ESP-12 is a C programmed microcontroller. It can be programmed by using the Arduino integrated development environment (IDE).

2.3. Hardware Design

The specified hardware for the monitoring system needs to be designed and integrated in an electronic-circuit setup. Figure 4 shows a diagram of the electronic-circuit setup. The NodeMCU ESP-12 is powered by a 5 Volt external power supply that is given through the micro-USB port. The NodeMCU ESP-12 is not only consuming the power for operation but also distributing the power. The NodeMCU has a power regulator and power distribution system to distribute the power in two voltages, 5.0 Volts and 3.3 Volts. The 5 Volt power supply is available at the pin Vin, while the 3.3 Volts power supply is available at the pins 3V3. These distributed powers are available at the pin Vin for 5 Volts and the pins 3V3 for the 3.3 Volts.

The distributed power can be used to supply sensors and actuators but for a limited number due to the power capacity. For an application that utilizes several sensors and actuators, it is very recommended to use an external power supply for the sensors and the actuators and not using the distributed power from the NodeMCU ESP-12. The developed IoT-based monitoring system for hydroponic is utilizing only two DS18B20 temperature sensors which are low-power consumption sensors. Therefore, power for both sensors is supplied by the distributed power of NodeMCU ESP12. In this case, both sensors are powered by 3.3 Volts.

Hardware setup of the IoT-based temperature monitoring system for hydroponic is shown in Figure 5. The hardware is built on a PCB and the circuit is quite simple. Both temperature sensors are labeled by numbers 1 and 2. The temperature sensor 1 is connected to the pin D5 of the NodeMCU ESP12, while the temperature sensor 2 to the pin D6. The temperature sensor 1 is the NST sensor that measures temperature of the nutrient solution in the hydroponic pipe, while the temperature sensor 2 is the AAT sensor that measures the air temperature surrounding the plants. This hardware is not ready to operate because the NodeMCU has not been programmed yet. A program that describes an algorithm of the monitoring system need to be embedded into the NodeMCU.

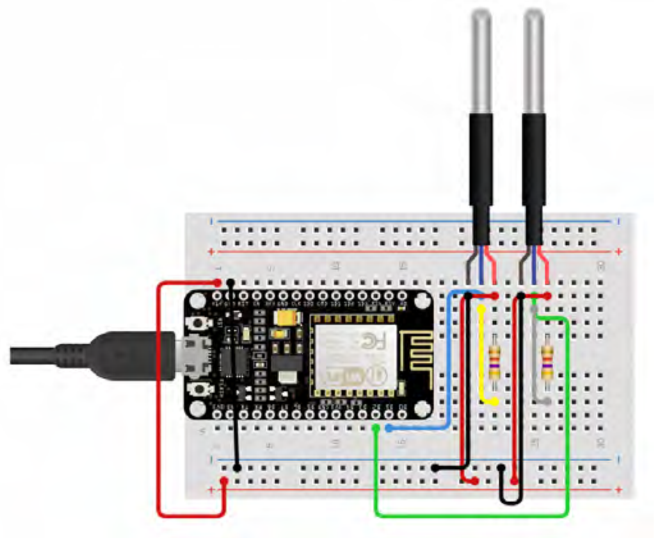


Figure 4. The electronics-circuit diagram of the IoT-based temperature monitoring system.

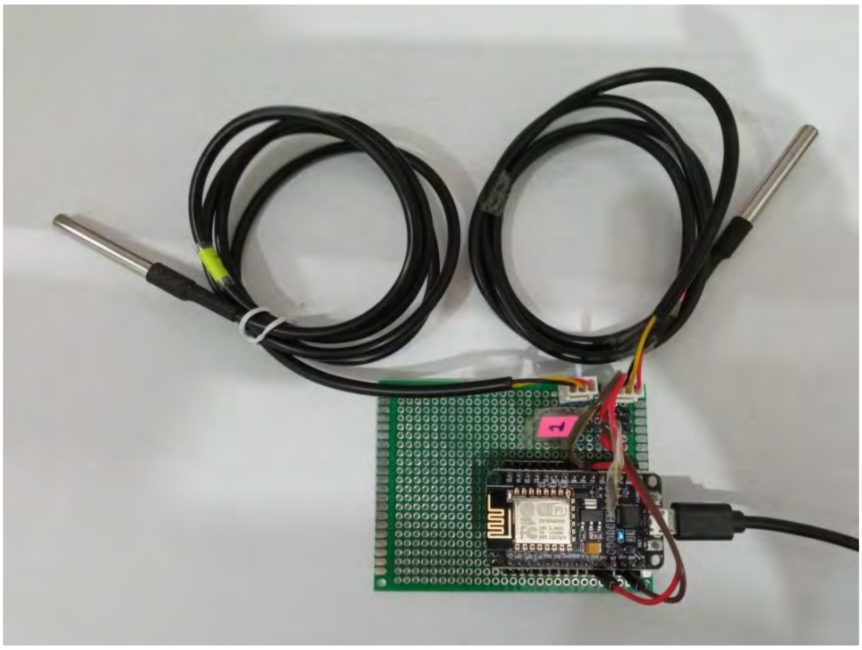


Figure 5. Hardware implementation of the IoT-based temperature monitoring system.

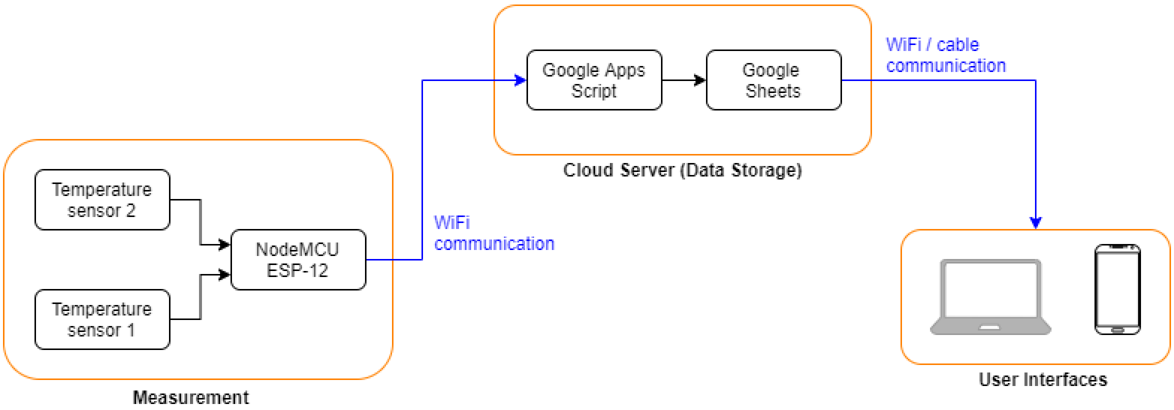


Figure 6. Data flow of the IoT-based hydroponic monitoring system.

2.4. Software

The IoT-based monitoring system consists of three main parts: measurement, cloud server, and user interface. Figure 6 shows a diagram of this monitoring system including the data flow. The measurement is to obtain data using sensors which is done by two temperature sensors and a NodeMCU ESP-12. The NodeMCU is to collect the temperature data and send the data to the cloud server. Communication of the NodeMCU and the cloud server is done through a WiFi communication. The cloud server is to store the data and provide the data to authorized users. The applied cloud server in this study is the Google Sheets. The users do a monitoring of the hydroponic by accessing the Google Sheets on their computer or smartphone.

The NodeMCU is a microcontroller that can be program using the C language. Arduino IDE provides a facility to write a program for the NodeMCU and embed the program into the NodeMCU memory. In this monitoring system, the program declares sequential tasks for the NodeMCU. The tasks include collecting the measurement data of both temperature sensors, connecting to WiFi server, and feeding the measurement data into the Google Sheets [28]. An access of the NodeMCU to the Google Sheets is obtained by defining a code program at the Google Apps Script.

The Google Sheets is a cloud application that can be used to store and process data in cloud. The Google Sheets is very similar to the Microsoft Excel. By storing the temperature measurements data in the Google Sheets, the users can monitor the hydroponic by accessing the Google Sheets on their computer or smartphone. The data can be presented in table as well as in graphs. This provides flexibility in monitoring the hydroponic.

3. Results and Discussion

The IoT-based temperature monitoring system for hydroponic is built and experimentally tested as shown in Figure 7. The hydroponic is placed in open area without sun protector. This is expected to result in a significant temperature different between noon and night. This experiment test is run to observe the nutrient-solution temperature (T_1) and the ambient-air temperature (T_2). The measurement data is logged every 30 seconds and the experimental test is carried out for 3.5 days. Data of the monitoring system is accessed in the Google Sheets using a computer.

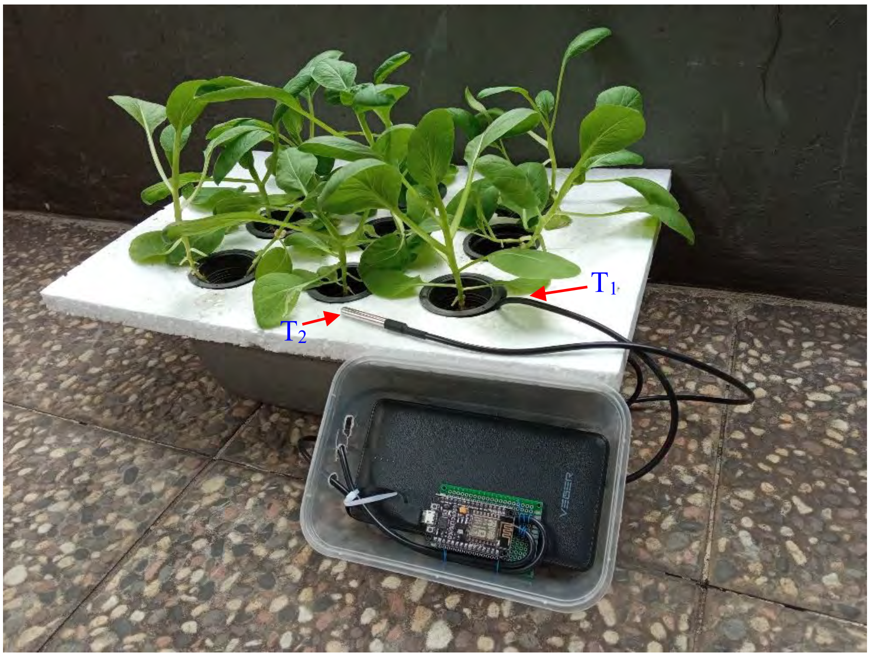


Figure 7. Experimental test setup.

The monitoring results are shown in Figure 8 and Figure 9. The Figure 8 shows a plot of the measured temperatures for the 3.5 days period. The plot was generated in the Google Sheets. The plot shows two temperatures data, the Temperature 1 and Temperature 2. The Temperature 1 is the nutrient solution temperature (NST) measured by the temperature sensor T_1. Meanwhile, the Temperature 2 is the ambient air temperature (AAT) measured by the temperature sensor T_2. The plot shows that both temperatures were change during the time. Maximum temperature of the ambient air every day during the three days period was about 32 to 32.5 °C and occur around 3 PM, while the maximum temperature of the nutrient solution was in the range of 28 to 28.8 °C and occur at 5 to 6 PM. The minimum temperatures of the ambient air were in the range of 24.6 to 25.4 °C at 6 AM, while the minimum temperatures of the nutrient solution were 24.8 to 25.2 °C at 8 AM.

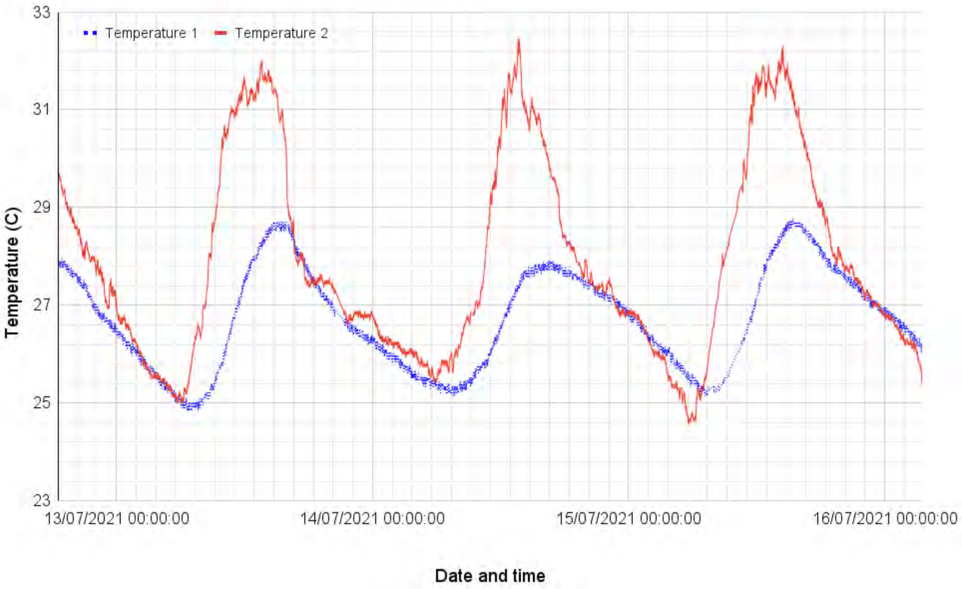
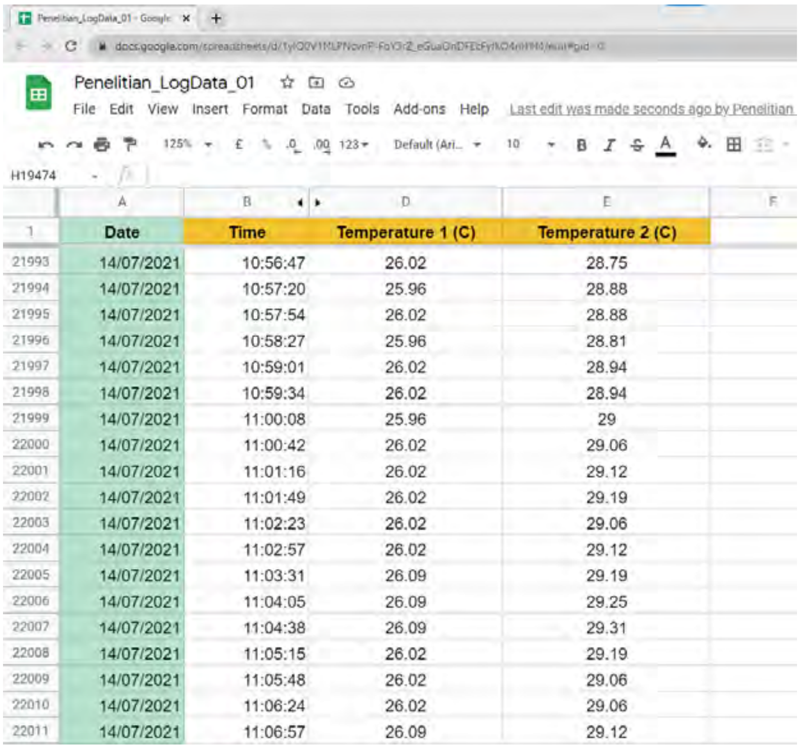


Figure 8. Plot of the hydroponic temperatures.

The Figure 9 presents some measurement data in the Google Sheets table. Time column in the table shows that interval of each data is not exactly 30 seconds but in the range of 33 to 36 seconds. Meanwhile, it was mentioned that the data was logged every 30 seconds. This deviation indicates a delay about 3 to 6 seconds in each transferring data from the NodeMCU to the Google Sheets server. The delay could be caused by the internet connection.



1	Date	Time	Temperature 1 (C)	Temperature 2 (C)
21993	14/07/2021	10:56:47	26.02	28.75
21994	14/07/2021	10:57:20	25.96	28.88
21995	14/07/2021	10:57:54	26.02	28.88
21996	14/07/2021	10:58:27	25.96	28.81
21997	14/07/2021	10:59:01	26.02	28.94
21998	14/07/2021	10:59:34	26.02	28.94
21999	14/07/2021	11:00:08	25.96	29
22000	14/07/2021	11:00:42	26.02	29.06
22001	14/07/2021	11:01:16	26.02	29.12
22002	14/07/2021	11:01:49	26.02	29.19
22003	14/07/2021	11:02:23	26.02	29.06
22004	14/07/2021	11:02:57	26.02	29.12
22005	14/07/2021	11:03:31	26.09	29.19
22006	14/07/2021	11:04:05	26.09	29.25
22007	14/07/2021	11:04:38	26.09	29.31
22008	14/07/2021	11:05:15	26.02	29.19
22009	14/07/2021	11:05:48	26.02	29.06
22010	14/07/2021	11:06:24	26.02	29.06
22011	14/07/2021	11:06:57	26.09	29.12

Figure 9. Presenting the hydroponics temperatures data in the Google Sheets.

This study has resulted in a prototype of IoT-based monitoring system for hydroponic that is intended to monitor the nutrient solution temperature and the ambient air temperature. The system measures the temperatures every 30 seconds. The measured temperatures data are stored and presented in the Google Sheet. This allows the users to monitor the hydroponics by accessing the Google Sheet using computer of smartphone from anywhere through internet.

The experimental test result in Figure 9 shows a delay on the measurement data up to 6 seconds of each measurement. The Figure 8 shows that both temperatures are look like periodical functions with time period about 24 hours. Therefore, the time interval 30 seconds is actually too short compared and can be increased, for an example the measurements are done every 30 minutes. Performing measurements with longer time interval, such as 30 minutes, will make the delays up to 6 seconds to be insignificant values.

4. Conclusion

A temperature monitoring system for hydroponic plant has been developed. The monitoring system is able to provide reliable and real-time measurement data of the hydroponic temperatures. The measurement data can be accessed in Google Sheets by user form anywhere through internet using a computer or mobile device. Presenting the measurement data in the Google Sheets provides a flexibility for further data processing and analysis to the users. The developed monitoring system was concerned on the hydroponic temperatures only. It can be expended to monitor other parameter by adding more sensors, such as pH sensor, TDS sensor, and nutrient volume. This is considered as a further work of this study.

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