Indoor Hydroponic System Using IoT-Based LED

Wiedjaja Atmadja, Ivan Alexander*, Satrio Dewanto, Adela Cahya Nugraha, Stefan Gokparulian

Computer Engineering Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia, 11480

*Corresponding author: ialexander@binus.edu

Abstract. The goal of this research is to design a hydroponic automation system for germination until generative growth based on ESP32 microcontroller, and BLYNK called LOTUS. ESP32 acts as main controller for all sensors and actuators. LOTUS able to control temperature, humidity, irrigation, and automatic lighting. LOTUS uses automatic irrigation with ebb-and-flow method. LOTUS included with LED Drivers that able to regulate the amount of light intensity on LED and provide more power efficient usage level. System successfully manages to reduce temperature, humidity, automatic lighting, and irrigation on time. Results from this research show that reading accuracy of the sensors temperature and humidity are, 99.11% for temperature, 97.275% for humidity, power usage for whole system is 49.6 watt, and adjustable irrigation system.

Keywords: Hydroponic, ESP32, LOTUS V.1, ebb-and-flow, BLYNK

1. Introduction

Hydroponic planting technique is an environmentally friendly plant cultivation technique. Cultivation of plants using this hydroponic system has many advantages compared to other planting methods. The hydroponic method is starting to be widely used by farmers because it has a much higher yield increase. Not only farmers, but many people also nowadays in urban areas are now using this hydroponic method to grow vegetables on their land which is now called Urban Farming [1]. In its cultivation, the hydroponic method does not require a large area of land. According to the Central Statistics Agency (2018), vegetable crop production increased to 44,090,074 tons, which in the previous year (2018) production of vegetable crops reached 42,888,024 tons.

However, this hydroponic method has a shortcoming, it requires a controlled environment to avoid a decrease in plant quality to plant development. Seeing some people in urban areas who have started using this hydroponic method, of course there are obstacles in controlling the hydroponic plants they plant both in terms of time and the determinant variables for plant growth using the hydroponic method. Seeing these shortcomings, this research conducted aims to help urban people and hydroponic farmers in increasing the yield of quality crops, both vegetables and flower plants. The most appropriate way to overcome the impact of the shortcomings of this hydroponic method is to monitor the determinant variables, namely water pH, water level, nutrients, temperature, oxygen circulation and lighting. Previous research that has been done is to control the determining variables, namely temperature control in the nutrition box container and the nutrient pH for plants [2]. According to Roidah the advantages of hydroponic cultivation include the success of plants to grow and produce more secure, higher crop production, continuous harvests, reduced pest and disease attacks, and free from flooding [3].
By referring to previous research, we seek how hydroponic cultivation can be done indoors where the use of sunlight is replaced by light and heat intensity from artificial LEDs. The University of Wisconsin first suggested the use of LEDs for growing crops. The lighting used uses LEDs with a variety of colors that can be controlled, later the LED color changes will affect the intensity of the heat generated. The research conducted under the title "Light-Emitting Diodes (LEDs) for Miniature Hydroponic" shows the effect of red, blue and fluorescent LED colors as determinants of plant growth [4]. So that the determinants of the growth of the hydroponic method can be controlled properly, the researcher makes a microcontroller that is connected to the internet that will send data about the conditions from the determinant variables of hydroponic plants to monitoring the physical condition of the plant using a camera, which later all the data will be sent to the android smartphone application in real time. Research has been done by Shatadru Bipasha shows that, microcontroller ESP32 can be operated with a remote system by sending results to a web server that can be operated into a remote irrigation system with just a click of a smartphone [5]. The research has been done by Yingchao Xu shows that Artificial light sources using LEDs can be used to make vegetables and plants grow in a growth system without direct sunlight. Increasing the rate of plant growth using an LED light source, using a certain design and ratio in the red and blue lighting system (Spectral Distribution), namely the wave peaks for red 650 nm and blue 460 nm with a relative spectral distributive ratio of 4:1 [6]. The research has been done by Ullas S Patel, shows that and Android application can be developed as a form of monitoring and controlling the microclimate in the greenhouse. Measurement of planting media, humidity and temperature sensors in accordance with the settings and thresholds that have been set for each sensor. The use of each compositing function such as water spray, nutrient spray, cooling fan and lighting can be set in real time through the android application [7]. Every plant needs different Photosynthetic Active Radiation (PAR) [8] and Photosynthetic Photon Flux Density (PPFD) [9]. A Farmer need a lot of things to do about plant, first is the plant lifecycles itself [10], second is the grow light positioning [11], third is the heat [12], fourth is the light spectrum [13], fifth is the space [14] and last is the market for selling the plant [15] [16]. PAR stands for Photosynthetic Active Radiation; it describes the wavelength of light between visible range 400 – 700 nm. PAR itself doesn’t measure light, it is used for farmer to determine the volume and type of light needed for a plant, when the PAR fits, the plant will be healthy [17]. The next one is PPFD, it stands for Photosynthetic Photon Flux Density it defines how much PAR are landing on a specific area. PPFD is measured in micromoles per square meter per second (µMol/m²/S) [18] [19]. In this research we combine all the previous research.

2. Research Method

In this research, a system is made for farming using an indoor hydroponic system with Artificial LED Grow Light. Artificial LED Grow Light uses 3 types of LEDs, namely Blue, Red, and NFF, each of which consists of 10 LEDs. Each type of LED is connected to the LED Driver so that the intensity can be adjusted according to the needs of the plant. This system has 2 chambers at the top and bottom, the top chamber has 8 holes on the top for seeding plants, where in each hole there is a netpot for placing rockwool and plant seeds. The lower chamber functions as a water reservoir to carry out the Ebb and Flow irrigation system, where nutrient water will be channelled to the upper chamber using a water pump and then there is a pipe that has a filter to channel water in the upper chamber back down so as not to overflow the water in the chamber. The top, the pump will continue to run for a certain number of minutes, then the nutrient water will flow back into the lower chamber. To keep rockwool moist, researchers used Hydrogel media which is useful for temporarily storing nutrient water. This system is also equipped with a fan on the upper side of the Chamber to reduce humidity around the leaves of the plant.

The hardware design in this research using an Artificial LED Grow Light in hydroponic plant growth which serves to provide a certain spectrum for plants. By using an application that is connected to the device, it allows the user to schedule the active period of the system to monitor Ebb and Flow activities as well as humidity and temperature sensors around the plant.
Figure 1. Block Diagram

Figure 1 is the block diagram of the system; the whole system uses ESP32 as a microcontroller and a Wi-Fi module. In this system there is 1 sensor input, namely DHT11 which functions to monitor the humidity and temperature around the plant. In addition, there are two relay outputs, the first relay is used to regulate the DC fan which will activate when the ambient humidity has exceeded the specified limit to reduce the humidity. The second relay is used to regulate the Water Pump in carrying out the Ebb and Flow irrigation system. Then there is an output to the LED Driver module to set the LED Grow Light. In this study using 2 power supplies, the first is 12V which will activate the Water Pump and will also enter the 7V Buck Converter regulator to be safe to activate the ESP32. In addition, there is a 36V power supply to activate the LED Driver in providing power to the LED Grow Light. To make the device controllable via Smartphone, the Wi-Fi module on the ESP32 must be connected to Wi-Fi with the specified SSID and Password to connect to the Cloud Server from Blynk.

Figure 2. System Initial Preparation Process Flowchart

Figure 3. Process of Running Scheduler and Sensor Reading Flowchart
Figure 2 is the system initial preparation process flowchart. In the initial process of the system, the first thing is to initialize the device that will be used. There are several libraries used in ESP32, first is the Blynk library which is useful for connecting between ESP32 to the Blynk Cloud Server, secondly there is a DHT library for the use of DHT11 components, thirdly there is a library for using the EEPROM function on ESP32, fourth using the NTP (Network Time Protocol) library.) which is useful for getting clock data on the internet, and finally using the Scheduler library to schedule tool functions so that they can work on time. The next flowchart flow is to get the data stored in the EEPROM. If at this stage the system does not get the data stored by the previous user or has never been used, the system will write the Default data to the EEMPRM. The next stage is processing the specified schedule to activate the tool, for Default the tool will be active from 6 am to 10 pm (16 hours). Then the system will activate the Timer function from Blynk in running a program function at specified intervals, including the DHT11 sensor reading, which is done every 0.5 seconds, then running the Scheduler checking function every 1 second, and activating the Water Pump for the Ebb and Flow system for Once an hour for Default, then turn off Ebb and Flow function after 3 minutes active. In the next process, the system will connect the device to the Blynk Cloud Server via Wi-Fi with the specified SSID and Password.

Figure 3 is a process of running scheduler and sensor reading flowchart. At this initial stage is to get clock data from NTP (Network Time Protocol) which is then matched with the Scheduler function, if there is a task that must be activated on the LED Grow Light and Ebb and Flow then the Timer for Water Pump will be active periodically depending on the interval determined by users. If the system schedule has ended, the LED Grow Light and Ebb and Flow will turn off and the Timer for the Water Pump will also stop. The next stage is reading the DHT11 sensor to get temperature and humidity data which will then be sent to the application. From the sensor readings, if the ambient humidity exceeds a predetermined limit of 70 in Default, the DC fan will turn on to reduce humidity around the plant, if it has dropped from the predetermined limit, the DC fan will turn off.
and EEPROM storage Flowchart

Figure 4 is the Blynk command, water pump timer and EEPROM storage flowchart. For this stage, the first is to read the data sent by the user through the application. Then run the Water Pump Timer function, if the Water Pump Timer is active then the Ebb and Flow system will be active during the specified Interval, in Default is 1 Hour. Then there is a timer to turn off Ebb and Flow after turning it on for 3 minutes. This will continue to be done during the active period of the system. If it is time for the scheduler to turn off the system, the Water Pump timer also stops. The next process is in terms of saving data to the EEPROM, if the user has given the command to save data via the application, then the PWM LED variable, the system schedule is on and off, the Ebb and Flow interval and the humidity limit that has been set will be saved to the EEPROM.

Figure 5 is a user command from Blynk flowchart. This process is carried out to obtain data retrieved from the Blynk Cloud Server. There are several variables taken, namely the intensity for the LED Grow Light, if there is a command to change this variable, the system will immediately change the PWM value for the selected LED Grow Light. Then there is the interval variable for the Ebb and Flow system and the scheduling for the scheduler function to set the clock for the system on and off.

3. Result and Analysis

Several experiments has been conducted in this research. The first experiment is the DHT11 temperature and humidity sensor test which is compared to the Digital Elitech Sensor.

![Figure 6. DHT11 Temperature Sensor Test Results Compared to Digital Elitech Sensor](image1)
![Figure 7. DHT11 Humidity Sensor Test Results Compared to Digital Elitech Sensor](image2)

Figure 6 and 7 is the test result for temperature and humidity comparing test. Based on the data collection test, the accuracy of temperature and humidity readings in room 1 and 2 are 98,82% dan 99,41% for temperature, 95,88% and 98,67% for humidity. The temperature and humidity reading accuracy on the DHT-11 sensor is 99,11% and 97,27%. Besides testing we also display the results of temperature and humidity on the Blynk application, Figure 8 and 9 below are the results interface for temperature and humidity on the Blynk Application.

![Figure 8. Blynk Interface for Monitoring Temperature](image3)
The next experiment is to test power efficiency of the LED Driver for driving red, blue, and white LEDs. The power input from Led Driver (Power Output PSU) is compared to output power of Led Driver when connected to 10 of Red, Blue and White LED. The test was carried out 5 times by changing the voltage on the power supply, 19.2V, 22.5V, 26V, 30V, 31V of the LED drivers.

Figure 10 shows that Led Driver driving to 10 Red Led produces the best efficiency value of 5.54/5.72=97% at a voltage 22.5V and produces efficiency value of 90% at a voltage 30–31V. For the Blue Led, experiment in Figure 11 shows efficiency value of 5.71/5.54=95% at 22.5V. In Figure 11 show Led Driver input and output power when driving 10 White Led, the efficiency result is 5.57/5.92=94%.

The next experiment is testing the power usage on the whole system by comparing the 3 power usage conditions. The conditions used for comparison are idle, the water pump and fan are on, and the entire system is on. The following figure 13 is the experiment results.
Based on the power consumption measurement using digital kWh meter, the system only uses 7.4W in idle mode, and when all system is active, the system requires 49.6W.

The next experiment is Light spectrum testing. The light spectrum test is carried out by adjusting the light intensity on the LED by assigning a PWM (Pulse with Modulation) input value to the BLYNK application. The experimental method was carried out by testing the combination of PWM values through the BLYNK application and measured using a PAR meter.

**Table 1.** Experiment with 3 Colour LED PWM Combinations to get the PPFD value.

| No  | White | Red | Blue | PPFD  |
|-----|-------|-----|------|-------|
| 1   | 0     | 0   | 0    | 1.900764 |
| 2   | 300   | 0   | 0    | 15.56134  |
| 3   | 500   | 0   | 0    | 24.63612  |
| 4   | 800   | 0   | 0    | 38.59685  |
| 5   | 1023  | 0   | 0    | 49.03081  |
| 6   | 0     | 500 | 0    | 24.52961  |
| 7   | 0     | 0   | 500  | 38.43652  |
| 8   | 1023  | 300 | 0    | 59.70068  |
| 9   | 1023  | 500 | 0    | 72.20696  |
| 10  | 1023  | 800 | 0    | 89.30342  |
| 11  | 1023  | 1023| 0    | 94.69482  |
| 12  | 1023  | 500 | 250  | 88.98913  |
| 13  | 1023  | 500 | 300  | 101.56133 |
| 14  | 1023  | 500 | 500  | 107.96227 |
| 15  | 1023  | 500 | 400  | 101.32305 |
| 16  | 1023  | 500 | 600  | 116.22315 |
| 17  | 1023  | 0   | 1023 | 126.51269 |
| 18  | 1023  | 1023| 0    | 101.71031 |
| 19  | 1023  | 1023| 1023 | 181.2577  |

The experimental results in Table 1, shows that the PPFD (Photosynthetic Photon Flux Density) value can be found by measuring the combination of PWM values for each LED colour. The combination of PWM values set through the BLYNK platform shows a change in the PPFD value from each experiment with different combinations. Light spectrum experiment. The following Figure 14 is a picture of the experimental light spectrum.

**Figure 14.** The results of measuring the intensity of light in the visible spectrum
The experimental results above show that the combination of PWM values of 1023 white, 500 red and 500 blue is 107.962 PPFD where this value is the appropriate limit value for the plant growth process, which is > 100. The combination of 3 LED colors gives the right spectrum for the absorption of chlorophyll a, where in the spectrum the process of chlorophyll a in plants is very maximal. Figure 15, 16, 17 and 18 below is the view of the hydroponic system that has been made.

Figure 15. Hydroponic System View 1

Figure 16. Hydroponic System View 2

Figure 17. Hydroponic System View 3

Figure 18. Hydroponic System View 4

4. Conclusions
The hydroponic system works well which is indicated by the accuracy level of the DHT-11 sensor used to obtain temperature and humidity data around system is 99.11% for temperature readings and 97.275% for the DHT-11 humidity sensor. The level of power usage used in the system, precisely on the LED driver, is lower than the power output from the Power Supply with a setting of 250mA. The power consumption required by the entire LOTUS system is 49.6 Watts where the entire system is on simultaneously. The system can influence plant growth by adjusting the light intensity of each spectrum using a combination of PWM on each LED and the Blynk application makes it easy for users to automatically maintain plants and monitor equipment performance.
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