An intelligent applied Fuzzy Logic to prediction the Parts per Million (PPM) as hydroponic nutrition on the based Internet of Things (IoT)

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***Abstract*—Hydroponic plants require regular monitoring of plants that grow well and can even cause plants to die. Because too late in providing nutrition or getting too little or too little food or routine monitoring in the hydroponic system. The innovation proposed in the agricultural sector that we suggest is the process of monitoring hydroponic plants in real-time. This study aims to predict the excess or lack of nutrient content based on the results of routine monitoring and has the analytical ability to determine the prediction of the value of Parts per Million (PPM) to find the nutritional value of plant media. Measurement of nutritional value using Electrical Conductivity (EC) and the potential of Hydrogen (pH) in hydroponic plant media. In this research, using the NFT hydroponic system as the application of fuzzy logic with the Mamdani method to determine the predictions of PPM values in providing nutrients at plants to adjusting the nutritional at each plant (e.g., for water spinach plants are need 1050 until 1400 PPM). The implemented is method Internet of Things (IoT) to remote sensing on measure using a smartphone as the representation of the measurement results on the hydroponic system.**

***Index Terms*—Electrical Conductivity (EC), Fuzzy Logic, Internet of Things (IoT), Nutrition for Hydroponic, Parts per Million (PPM)**

I. Introduction

One of the main areas of intelligence is the management and dissemination of the latest information in assuming data clearly shows many uncertainties that cannot exist quantified in information content. Conventional logic cannot explain difficulty and inaccuracy in observing and measuring the propositions used. Fuzzy assemblies and fuzzy logic provide a logical framework for the description of various values of ambiguity, uncertainty, and inaccuracies shown in the data as real consideration to complement the strength of the structure in the design of a reliable and safe real-life system [1]–[4].

The research conducted by Nisa Hanum Harani et al. [5] is to implement a remote control application for controlling lights. The control system based Arduino that has an infrared device as a remote control. The app uses an artificial intelligence method that is fuzzy logic by using two parameters, namely temperature and light intensity level to adjust the luminance of the lamp.

Drinking water companies keep water in a storage tank with a specific volume, where the arrangement manage do not to exceed the capacity as a source of water supply to the public. The purpose of the study was monitoring the results of testing of water filling adjusted to the tank volume using a water level control with fuzzy logic. The fuzzy will reasoning was desired setpoint to improve water level response results. Fuzzy logic control method will identify the plant using the first-order system. The use of Arduino Uno as a control center implanted a fuzzy logic function and set the stability of the water plant level by reading the condition of the water level [6].

The research Achmad Mahdiyatul Tajrie et al., they proposed two processes in the greenhouse. The first is the watering system will be made automatically by using a water-efficient drip watering system to watering plants. The second one is lighting control is also arrangement automatically. The method of watering and lighting of plants is regulated automatically by comparing three factors temperature, light intensity, and soil moisture [7].

The purpose research [8], [9] is to design the control system of tomato cultivation based on absolute reference was simulated with scale 1:1440 for cultivation time for a nutrient solution using Arduino. The fuzzy logic function was used with EC (due to nutrient uptake) value error and number of nutrient solution as inputs. The result of observation showed that system could reach setpoint after 130 seconds when the setpoint changes from 1.7 mS/cm to 1.6 mS/cm and 207 seconds from 1.6 mS/cm to 1.9 mS/cm. During the observation, the RSME value of the system while the steady-state was 0.005 mS/cm. They are using the ebb and flow hydroponics system with fuzzy logic to control a pump to distribute the nutrient to the growth of media [10]. The researchers implemented a control system a temperature sensor and soil moisture sensor and channeling nutrients to the planting media. There are several operating schemes obtained during testing at the temperature of 30C. (1) fast-rotating of pump upon reaching moisture of 0.1% RH, (2) medium-rotating of a pump at humidity is 30%

RH, (3) slow-rotating of a pump at a thickness of 50% RH, and (4) pump-off at the moisture of 74.2% RH. The actual testing performed by growing green bean plants resulting in 22 cm height of plants with 14 leaves after 28 days.

The internet is a means of communication that is very popular with the people, and it cannot reject that the development of digital technology is increasing over time, specifically in terms of communication. The twenty-first century is the culmination of the development of communication in the digital field, one of which is internet technology that is increasingly increasing the need for networks, connecting the whole world, the general purpose of using the internet, relating the world as a whole with its network access. In addition to the rapid development of internet technology, the use of internet technology in the development of the 4.0 industrial revolution by utilizing the integration of the Internet of Things (IoT) [11].

The development of computer science and information technology is increasingly rapid at this time, thus affecting various activities of daily life. One of the techniques in information technology that is currently developing is the Internet of Things or commonly abbreviated as IoT. The Internet of Things is a concept where an object can transfer data over a network without requiring human to human or human interaction to a computer. By using IoT activities that should be done directly can be done remotely via the internet. As a claim by Engel [12], the increasing application of Internet of Things (IoT) based systems and devices from every aspect of life, for example, health, home automation, automotive and logistics, smart city, and IoT industries. The use of the internet and automation, providing the application of innovation in agriculture crucially increases many aspects of agricultural practice.

One application of the Internet of Things that can do performed is the monitoring and control of hydroponic systems. A new method related to how to plant plants without using soil as a medium of plants is called hydroponics. This method is a technique of changing the planting using water via paragon as a place to plant by flowing nutrients [13], [14]. The hydroponic plan is currently moving used more in agriculture to grow products as an increase received by farmers [15].
Problems in the process of planting a plant using hydroponic media require routine monitoring. When nutritional plants are organized, according to the composition of plants needed by plants to stay alive With the development of Industry 4.0 and digital transformation [16] [17], conventional farmers move regarded as industries that rely on the sky. Now, innovative IoT technology can give farmers not only predict prices more accurately but more stable production and sale.

II. THEORETICAL BASIS

A. Fuzzy Logic

The fuzzy set was first introduced by Prof. Lotfi Zadeh, 1965, in Zadeh's monumental paper, "Fuzzy Sets," Information and Control, 8, 1965, h. 338-353. In the article, the basic ideas of fuzzy sets are presented, which include inclusion, union, intersection, complement, relation, and convexity [18]–[20]. Fuzzy set applications are almost unlimited, for example, process control, production processes, robotics, large-scale management, civil engineering, chemistry, transportation, medicine, and economics. The pioneer of fuzzy set applications in the field of control is Prof. Ebrahim Mamdani et al. from Queen Mary College London. Mamdani applied results of Fuzzy sets are mixing tanks, and steam engines. The application of fuzzy logic control is used to the industry proposed by Prof. Sugeno from the Tokyo Institute of Technology. Also, Prof. Yamakawa from the Kyusu Institute of Technology researched fuzzy computers, while Togai and Watanabe from Bell Telephone Labs created a fuzzy logic chip.

*1) **Fuzzy Set Operation**:* Logical operations are operations that combine and modify 2 or more fuzzy sets. The value of new members as a result of the two set operations is called firing strength or alpha predicate.

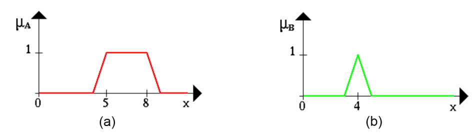

Fig. 1. Fuzzy sets (a) Fuzzy set A and (b) Fuzzy set B

Basic fuzzy set operations for fuzzy sets are:

1) Union (OR) of 2 fuzzy sets is the maximum of each pair of elements in the two sets (in figure 2.a).

$$\mu_{(A \cup B)}(u) = \mathbf{max}\ \{\mu_A(u),\ \mu_B(u)\}, u\ \varepsilon\ U \quad (1)$$

2) Intersection (AND) of 2 fuzzy sets, is the minimum of each couple of items in the two sets (in figure 2.b).

$$\mu_{(A \cap B)}(u) = \mathbf{min}\ \{\mu_A(u),\ \mu_B(u)\}, u\ \varepsilon\ U \quad (2)$$

3) Complement (NOT) Complement of the fuzzy set consists of all elements complement (in figure 2.c).

$$\mu_{\bar{A}}(u) = 1 - \mu_A(u),\ u\ \varepsilon U \quad (3)$$

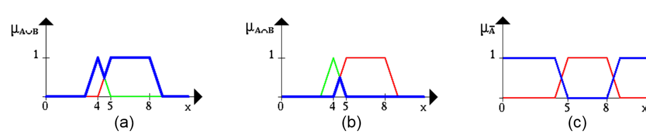

Fig. 2. The Result of the fuzzy set operation

*2) **Fuzzification**:* The process of fuzzification is a process for converting non-fuzzy variables (numerical variables) into fuzzy variables (linguistic variables). Input values that are still in the form of binary variables that have to quantize before being processed by fuzzy logic controllers must be changed first into fuzzy variables. Through the membership function that has a compiler, the input values become fuzzy information which is useful later for fuzzy processing

*3) **Control Rule**:* In general, fuzzy rules expressed in the form of 'IF-THEN,' which is the core of fuzzy relations. Fuzzy relations, represented by R, are also called fuzzy implications. Fuzzy relations in basic knowledge can define as a set of fuzzy connections.

$$IF\ x\ is\ A3 \quad OR\ \ y\ is\ B1\ THEN\ z\ is\ C1 \tag{4}$$

$$IF\ x\ is\ A2\ AND\ y\ is\ B2\ THEN\ z\ is\ C2 \tag{5}$$

$$IF\ x\ is\ A1 \qquad\qquad\qquad THEN\ z\ is\ C3 \tag{6}$$

*4) **Defuzzification**:* In the control system, in general, there is a specific causal relationship between the input and output of the system. It is this relationship characteristic that distinguishes one system from another

B. Internet of Things (IoT)

The general definition of Intenet of Things is a network of several physical objects. The internet is not only communication and sharing information in the system of computer network but has developed into a network of devices of all types and sizes, vehicles, smartphones, household appliances, toys, cameras, medical instruments, and industrial systems. The IoT for plants, animals, humans, buildings, all connected, and also communicate and share information based on established protocols to achieve reorganization, determine positions, manage tight control and personal monitoring in real-time online, update data, control processes and administration [21] [22].

*1) **Internet of Things Architecture**:* The IoT architecture consists of various layers of technology (see Figure 3) that support IoT. The serves to illustrate how multiple technologies relate to each other and communicate scalability, modularity, and configuration of IoT deployments in various scenarios. IoT has four layers, which sensor layer, communication and Network layer, service and application layer, and the last presentation layer [23].

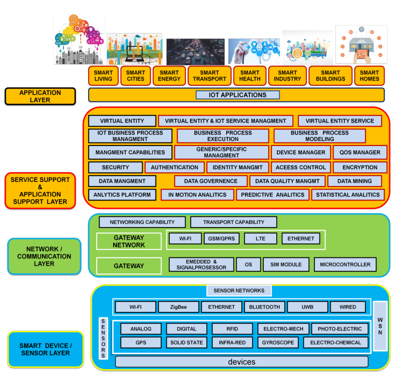

Fig. 3. Architecture of IoT

Internet of Things (IoT) is an idea and model that considers a full performance of things into wireless and wired connections using unique addressing. That can connect and work with other things to create applications or new services and achieve common goals.

In this context, research and development for the imaginative world are extensive. A world where it is challenging, digital, and virtual to create smarter environments that make energy, transportation, cities, and many other regions [24].

*2) **Benefits of Internet of Things (IoT) in Agriculture**:*

1) Collected Data intelligent agricultural sensors, such as weather conditions, soil quality, progress in plant growth, or livestock health. This data can be used to track the state of your business in general, as well as staff performance, equipment efficiency, etc.
2) Better control of processes and results, the ability to estimate output from farmer production allows farmers to plan for better product distribution.
3) With increased power, overproduction cost management, waste reduction, and in-plant growth, the farmers will be able to reduce the risk of losing crop yields.
4) Increasing business efficiency through process automation and smart devices, farmers can automate many processes throughout the production cycle, such as irrigation, fertilization, or pest control.
5) Increased product quality and volume of the production process and maintain higher plant quality standards and growth capacity through automation.

C. Hydroponic System

Hydroponics comes from Greek, Hydroponic. Divided into two syllables, hydro, which means water and porous means work. By these meanings, planting hydroponic is a farming technology that uses water, nutrients, and oxygen.

The most noticeable difference between hydroponics and the conventional way of cultivation is that the supply of plant nutrients is very dependent on the ability of the soil to provide sufficient amounts of nutrients in [15].

Hydroponics is commonly used to grow vegetables and fruit. Even some vegetable and fruit plants have been widely planting hydroponically. Call it water spinach, salad, pakchoi, tomatoes, and others. All is possible with a good relationship between plants and the place of growth.

The essential elements needed by plants are not land, but the water reserves contained in the soil absorbed by the roots and also the support provided between the soil and growth. It knows that the roots of plants that grow on the ground absorb water and vital substances from the soil. The means that without soil, a plant can grow as long as there is enough water and salts of food substances.In figure 4 are shown the Hydroponic System

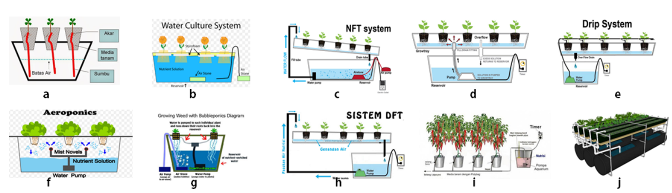

Fig. 4. Illustration of the type of Hydroponic System (a) Wick, (b) Water Culture, (c) Nutrient Film Technique (NFT), (d) Ebb and flow, (e) Drip, (f) Aeroponyc, (g) Bubbleponics, (h) Deep Flow Technique (DFT), (i) Fertigation, and (j) Bioponic

D. Nutrition

In general, plants also need food for life, where the way plants get food for life is called nutrients. Nutrients are nutrients that are required (essential) plants and cannot replace by other nutrients.

The process of extracting nutrients can also be obtained from plants from the soil through roots. In [25], generally, plants can live needed food intake in plants consisting of 16 types of elements the three types of items (oxygen, hydrogen, and carbon dioxide) obtained through the air. And the plant foods require 13 types of nutrients carried out by absorbing by plants through soil or water.

*1) **Macronutrients**:* Macronutrients are nutrients needed by plants in large quantities. Table I shows macronutrients based on chemical names and symbols. Macronutrients have a result on plant growth, and then only these macronutrients can not replace macronutrients.

TABLE I
THE LISTING OF MACRONUTRIENTS

Number	Name of nutrition	Chemical symbol
1	Carbon	C
2	Hydrogen	H
3	Oxygen	O
4	Nitrogen	N
5	Phosphor	P
6	Potassium	K
7	Calcium	Ca
8	Magnesium	Mg
9	Sulfur	S

*2) **Micronutrients**:* Micronutrients were showing in Table 2. The use of micronutrients in a plant is determined in small quantities and is very important as a source of food for plants in plants.

TABLE II
THE LISTING OF MICRONUTRIENTS

Number	Name of nutrition	Chemical symbol
1	Iron	Fe
2	Manganese	Mn
3	Boron	B
4	Molibden	Mo
5	Copper	Cu
6	Zinc	Zn
7	Cl	Cl

III. METHOD AND IMPLEMENTATION

The design of our study uses the NFT type hydroponic system, where there are EC sensors and pH. The next step is to read the EC and pH values that will be converting to digital values, and then the numeric values will be sent to the cloud system. Through the cloud system, an Android-based application will download any data changes. Then it will calculate the predictive value using fuzzy logic with the Mamdani method to get the results of the estimated PPM value. The following is a block diagram design in figure 5.

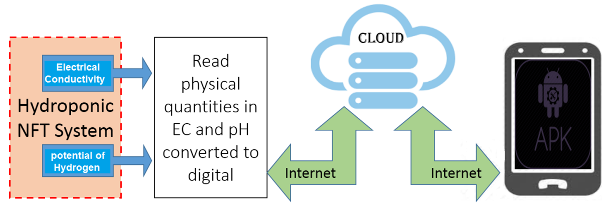

Fig. 5. The block diagram of the architecture in our research

Figure 5 is a diagram block of a hydroponic monitoring and control system using the Internet of Things. In the diagram, it consists of 3 main blocks, namely the application of monitoring and control of the hydroponic system on an Android smartphone, Cloud service (ThingSpeak) and the Control System including Provider of information from the greenhouse using Raspberry PI.

Applications on Android smartphones function to read and send data on the Cloud service. Utilization of Cloud service serves to receive and store data as well as a liaison between the application of monitoring and control of hydroponic systems with control systems and information providers. Control systems and information providers function to send sensor data and read data on the Cloud service for commands on pumps, lights, and fans.

A. Design system

*1) **Hydroponic type NFT system**:* Figure 6 is a hydroponic system that used for planting. Where the author uses a hydroponic type NFT which has a total of 12 pots. Material for hydroponic systems for container plants and flow of nutrient solutions using PVC paralog which has uses holes (12 holes). Also, there is a nutrient solution container with plastic material and a rectangular box.

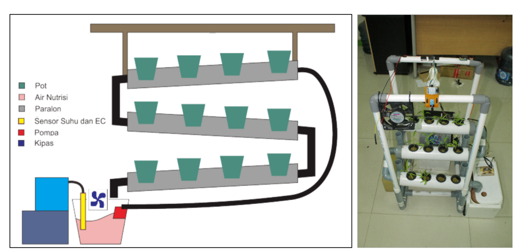

Fig. 6. Design installation and realization general of the NFT system

*2) **The Sensors and Actuator systems**:* Sensor modules can be applied, such as aquaponics, environmental water testing, hydroponics, and others. In electronic circuits as sensor data readers shown in Figure 8, the relationship between EC Sensor and pH with the Arduino system as data reading the conductance and Hydrogen.

First, to get the EC value. A conductivity sensor is an electronic component or sensor which measures the value of a solution in conducting electricity. Measurements made using

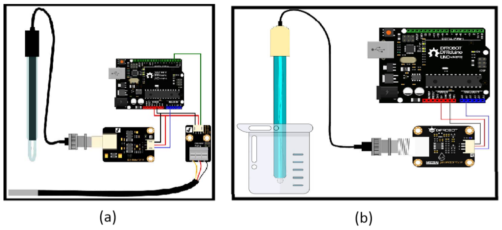

Fig. 7. Design Electronics of the sensor systems

the Electrical Conductivity method connect two probes to the solution to be measured. Then the signal processing circuit that has implanted in the EC module will produce an output that shows the conductivity of the solution.
In this sensor, there are two types of conductivity electrodes, namely the kind of shiny electrode and black platinum electrode. Black-coated platinum aims to increase the active area of the electrode sheet and be free of polarization.

In a metal, conductance decreases with increasing temperature, but in a semiconductor, conductance will be greater with higher temperatures. So the conductance can be affected by temperature. Therefore, to get the conductance supported by a temperature sensor. Temperature Sensor is a component that can change the amount of heat into electrical quantities so that it can detect the symptoms of temperature changes in particular objects (figure 8.a).

The second requires a pH meter sensor module (Type SEN0161-V2) which shown in the image 8.b. In a sense, pH is a value used to measure the level of acidity or alkalinity in a solution. The range of PH values is between the numbers from 0 to 14 with the provisions as in the table III.

TABLE III
THE LISTING OF MACRONUTRIENTS

Number	pH Value	pH Level
1	pH ¡ 7	acid
2	pH = 7	Neutral
3	pH¿ 7	bases

The figure 8.a and 8.b, this application monitors other sensor data such as detection of temperature, light intensity, and control of pumps, lights, and expos fan on hydroponic systems We utilize cloud systems available on the internet, called name application is thingspeak so that all parts of the system can integrate and communicate.

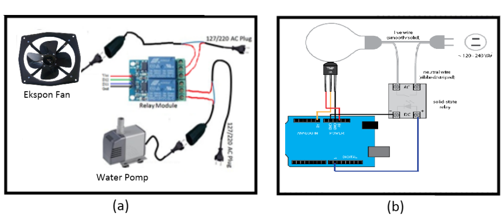

Fig. 8. Design Electronics of the actuator systems

*3) **ThingSpeak Cloud for Data Storage system**:* In this study, the ThingSpeak service functions as a Cloud-based data storage; the results of input readings to stored at the ThingSpeak service. Then it will be read by the Android smartphone application to calculate PPM predictions. Also, ThingSpeak functions as a store of value for other sensor monitors and accepts changes in control sent from the Android smartphone application. Changes as a control value will forward to a hydroponic system. And a microcontroller will control pumps, lights, and fans.

*4) **Monitoring and Control systems on Hydroponic Systems using the Internet of Things**:* Our research proposes that the design block of a hydroponic monitoring and control system using the Internet of Things is carried out on a software subsystem. Software subsystem, programmed so that each module in the system communicates with each other. The following is a flowchart design of the EC sensor and pH sensor monitoring application via a smartphone. And also, the controlling pumps, lamps, and fans on an IoT-based hydroponic system.

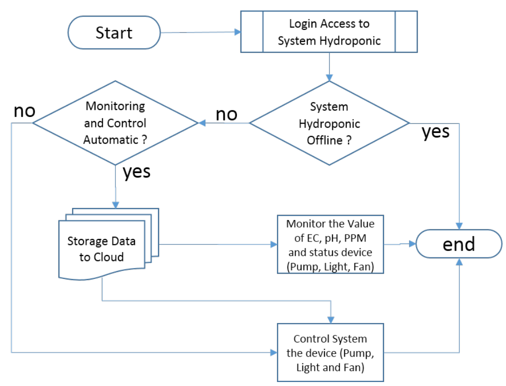

Fig. 9. Flowhcart the monitoring and Control based IoT System

Smartphone applications must log into the system. If successfully logged in, first ensure that the hydroponic system is online. Besides, the hydroponic system can be configured automatically based on predetermined rules. For example, monitoring the PPM value is it still within the specified range or not? If outside the adjusted range, then nutrition will be added if the PPM value is detected to be less. For manual system conditions, control fixed to the last configure applied to the hydroponic system.

*5) **Predict the PPM value on an Android system**:* This stage will design a conceptual design based on all inputs (EC and pH data) that enter this stage. At this stage to develop tools based on the fuzzy method as parameters that are input in the fuzzy approach. Fuzzy logic techniques/methods used to overcome uncertainty in problems that have many answers. Fuzzy logic is a multivalued logic that can define values between current conditions such as true or false, yes or no, white or black, and others.

Before the PPM calculation, smartphone as the android system first downloaded EC data and pH data from the Cloud System. The results of input obtained (i.e., EC and pH) will be processed by fuzzification on each input value in the fuzzy set. Fuzzification results together with predetermined rules to get the fuzzy inference. Then the defuzzification process will be carried out by using the results of fuzzy inference with the output value on the fuzzy set. The result of this defuzzification will provide predictions for the PPM value (see figure 10).

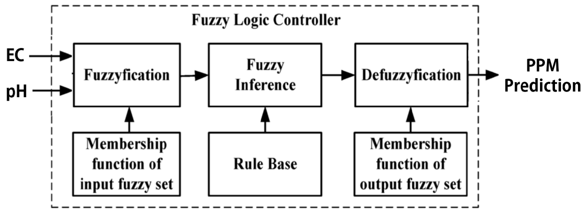

Fig. 10. Block Diagram in Fuzzy Logic for Predicting PPM value

The stages of Fuzzy logic are:

a) Formation of fuzzy sets

In the Mamdani method, both input variables and output variables are divided into one or more fuzzy sets.

b) Application function implications

In the Mamdani method, the implication function used is minimum. So from the value in the form of the fuzzy set. The amount used as the implication is the MIN value or the lowest value.

c) Composition of rules

What is meant by the formation of the provisions in the fuzzy method is in the form of methods used to determine the evaluation of the fuzzy set? Among the several techniques that can be used in the composition of rules, namely the max (maximum), additive, and probabilistic OR methods . **d) Defuzzification**

This is the final step or stage in fuzzy Mamdani. Affirmation or often known as defuzzification is the process of processing a fuzzy set obtained from the composition of fuzzy rules to produce output in the form of a number in the fuzzy set domain.

B. Analys and Result

*1) **An Application based IoT system**:* IoT systems test results that are declared valid or accurate data, where data from the hydroponic system received by Cloud ThingSpeak will be stored. Then the data will appear on applications that have to install on an Android smartphone. And the application IoT can control systems some device on a water pump, light, and fan (figure 11.b). The application of this section utilizes the microcontroller as a sensor data reader, data processor and control on some automatically controlled actuator components such as pumps,light and fans.

The application will display the sensor values obtained will be presented each sensor value through the User Interface (UI). The process of taking it regularly every 15 seconds. Figure 11.a shows the UI from Activity Monitor. The data displayed consisted of water temperature, air temperature, Parts per Million, Electrical Conductivity, water humidity (pH), battery capacity, light detection, motion detection, lighting systems,

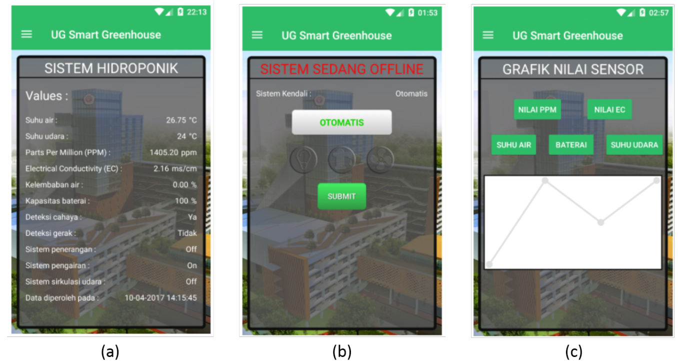

Fig. 11. The User Interface to Monitoring and Control at NFT system

irrigation systems, air circulation systems and time of the hydroponic system.

Figure 11.b shows the control of lights, pumps, or fans either manually or automatically based on the system regulator by the user.

To see the graph of the sensor value displayed as a graph (figure 11.c), namely the PPM value, EC value, water temperature, battery, and air temperature.

*2) **Analys the predict with Fuzzy logic**:* The results of the analysis of our researchers, where sampling of pH and EC data on nutrient testing for hydroponic plants as much as 60 random data. Furthermore, the data obtained will be processed using fuzzy logic with the Mamdani method. The test results show that the higher the pH value will not affect the PPM value significantly. Conversely, the EC value has a significant influence on PPM, if the EC value changes the amount that is not large.

From the results of the PPM changes, the nutrients produced can affect hydroponic plants.

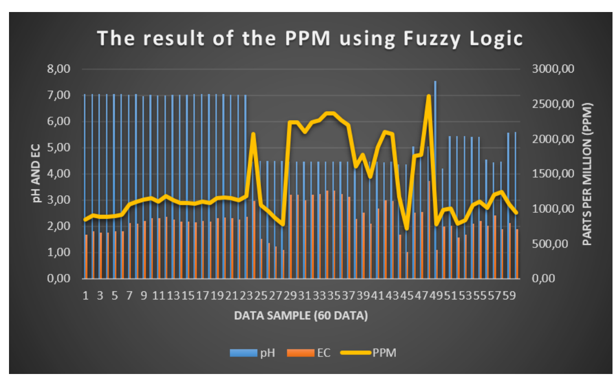

Fig. 12. The curve of the signal output (pH, EC, and PPM)

IV. CONCLUSION AND FUTURE WORK

The application by using Fuzzy logic can find out the results of Part Per Millions that obtain are highly dependent on EC results that are read by the sensor. Because in this study only using water spinach as a test plant, it needs testing on other types of plants in hydroponic systems.

The use of the Internet of Things has been successful in testing and realized by connecting the Android-based UG Smart Greenhouse application. Monitoring and control at a smartphone for hydroponic systems bridged by Cloud services like data storage. Problems found in cloud services at Thingspeak have a response time of 15 seconds or more.

V. ACKNOWLEDGEMENT

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