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IOT BASED HYDROPONIC PLANT IRRIGATION SYSTEM USING FUZZY LOGIC

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ABSTRACT: This paper focused on the development of an IoT-based hydroponic plant irrigation system using fuzzy logic and employing hardware modules to obtain temperature, humidity and water level readings, and a web application, that aimed to display the obtained temperature, humidity and water level readings from the sensor modules in the hydroponic system. DHT22 and HCSR04 ultrasonic sensor were used to measure the temperature and humidity of the environment and the water level inside the reservoir, respectively. The readings acquired from these sensors and using Fuzzy Logic algorithm were recorded and plotted every 10 minutes to the web server of ThingSpeak.com. SMS notifications were sent whenever the sensor produced an output to keep the user on track, particularly if there were critical values. The plants were irrigated according to the conditions set inside the prototype. To test its reliability, the difference of temperature and humidity readings were compared using a hygrometer and the plant irrigation device. Mean Average Percentage Errors (MAPE) of 2.25% for temperature, 0.45% for humidity and 1.85% for water level reading were determined; these were good, because they are considered low. Cross-browser testing was done on the web application to guarantee the behaviour of the system, reliability and device testing. Lastly the IoT based hydroponic plant irrigation system was implemented to remotely monitor the temperature and humidity of the environment and irrigate the plants with less human intervention through the help of Fuzzy Logic algorithm and existing advanced technology.

KEYWORDS: ***Internet of Things, hydroponics, Nutrient Film Technique, Fuzzy Logic, plant irrigation***

1.0 INTRODUCTION

The term "Hydroponic" is derived from two Greek words hydro and ponos which means "water" and "labor", respectively. It is also known as aquaculture, nutriculture, soil-less culture or tank farming. It was a method of growing plants [1] which uses other kinds of medium like perlite, coir, gravel and vermiculite, instead of soil. The nutrients needed for the plants are just added to the water, wherein the roots are submerged. According to Barbosa et al. [2], this farming method is very versatile and can be adapted from rudimentary backyard setups to commercial setups. However, like the conventional farming method, it also has its drawbacks asmonitoring needs to be done to make it more effective and efficient. PH level, water level, nutrient level, soil moisture and weather conditions are some of the factors that must be noted every day because these things have great significance to the growth of the plant. This is the part where advanced technology can be applied. Through the use of the algorithm called Fuzzy Logic and the concept of Internet of Things, monitoring and irrigating the plants in a hydroponic method were simplified.

Fuzzy Logic is a logical system and, at the same time, a theory related to classes of objects with unsharp boundaries in which membership is a matter of degree ("What is Fuzzy Logic", n.d.). In 1965, it was first introduced by Prof. Lofti A. Zadeh in his seminal work "Fuzzy sets", which describes the mathematics of the Fuzzy Set Theory [3]. At first, it is just as simple as "true" or "false" but when ideas sparked from the researchers, Fuzzy sets next represented common sense linguistic labels like slow, fast, small, large, heavy, low, medium, high, tall, etc. Today, it is used to design an intelligence system that deals with issues such as forming impressions and reasoning on a semantic or linguistic level [4]. The most common fuzzy inference method and one of the first systems out of the Fuzzy Set Theory is the Mamdani-Type Fuzzy Inference [5], which is used for this irrigation system. Together with the concept of Internet of Things, a system according to a British technology pioneer, Kevin Ashton, in which objects in the physical world could be connected to the Internet by sensors [6], an alternative for such tasks can now be lessened into simpler and more coherent tasks. With its benefits, it is making more impact in industries, especially in agriculture [7].

Hydroponics as a farming method is a good choice especially in urban areas. The plants would not be prone to human and chemical wastes in a way that the environment can now be controlled. Another good advantage in implementing the system is that it can be assembled even with a limited space, making it accessible and convenient. The objective of the study was to integrate hardware and software technologies to create a system that innovated hydroponics and made it more feasible in households. With the help of this study, such possibilities for the improvements of Nutrient Film Technique in hydroponics may be realized. The automation of the irrigation process as introduced, will ease the burden of the urban farmers, gardeners and hobbyists in monitoring and irrigating the hydroponics-grown plants. Through the concept of Internet of Things and Fuzzy Logic, hydroponics can be widely known and adapted as an alternative in growing plants.

2.0 METHODOLOGY

Figure 1 shows the design concept that explains how the system must work and what should be expected of the system being divided into three parts: the input, process and output.

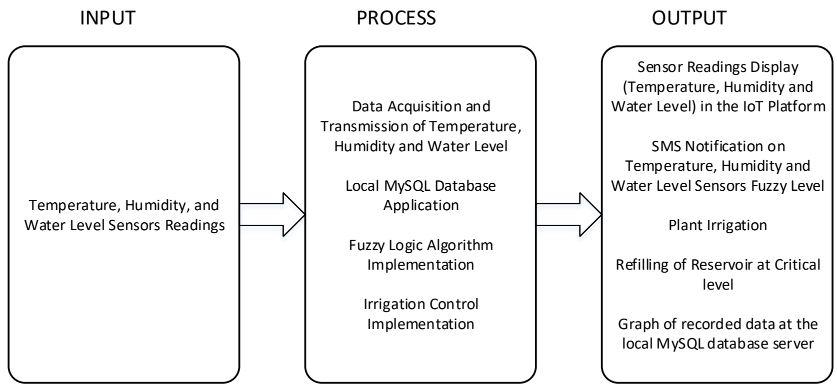

Figure 1: Design Concept

The sensor readings served as the input for the hardware device then certain conditions need to be met in order to do the things on the process block. The process block includes the data acquisition and transmission of sensor readings, fuzzy logic algorithm implementation and irrigation control. After that, expected output as shown on the last block is produced as part of the main objectives of the study to include sensor readings display, SMS notification, refilling of reservoir and recorded data graph at the local database server. With this framework, the methods were subdivided into four parts: algorithm development, hardware development, web development and hydroponic system prototyping.

2.1 Algorithm Development

Mamdani Fuzzy Inference method was used for algorithm development, wherein four main parts of the Fuzzy Logic System are needed: fuzzifier, determining the fuzzy linguistic variables, setting the fuzzy rules and defuzzification. The fuzzifier partincludes the sensor readings of temperature, humidity and water level on the reservoir entering the system Nextpart focuses ondetermining its respective fuzzy linguistic variables namely, temperature, humidity, and water level. The readings are recorded under its respective variable. If it has a unit of degrees celsius, it is under temperature. If it is in percent, it is humidity. Moreover, if it is in centimeters, it means it is under water level. After grouping the values, fuzzy rules are set according to the result of data mining, which was done for calibration of the system. Fuzzy rules were set for the readings using IF-ELSE statements. Inferences from the results of the rules were then made. The processed data were then evaluated in the last step called defuzzification. This is the part wherein the final fuzzy values, also called membership functions, for the system were determined and became the basis for the action to be done by the system. For temperature membership functions, the readings were determined if they were cold, normal, and hot; for humidity, dry, normal and damp were used and lastly, there were labels for critical points, such as low, normal, and high for the water level. This whole algorithm is shown in Figure 2 which were the basis on how the plants are irrigated and when the water reservoir is refilled.

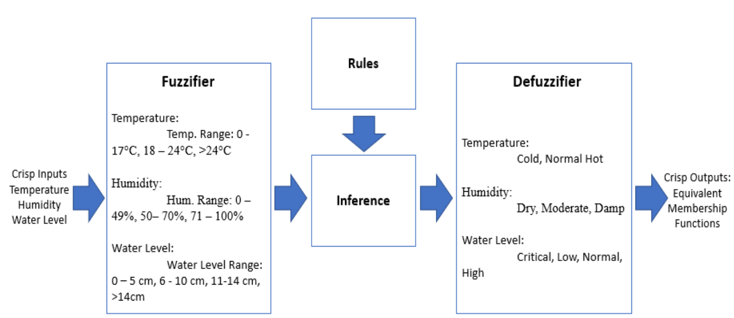

Figure 2: Fuzzy Logic System Algorithm

2.2 Hardware Development

The IoT system is composed of sensors, microcontroller, server and a network. The sensor system was composed of ultrasonic sensor, temperature and humidity modules to record data parameters affecting plant growth. The DHT22 Sensor determines the temperature and humidity, while HC-SR04 ultrasonic sensor is used for the determining the water level inside the reservoir. Together with the relay module that controls the flow of electricity to the solenoid valve and water pump, these sensors are controlled by WEMOS D1 R2 Microcontroller. The readings are processed according to the algorithm that has been developed and recorded to the web server of the ThingSpeak, a website that is specialized in recording and displaying the values that have been acquired by the sensors. After recording the values, notifications are sent to the owner through a Sim800l GSM module.

The water on the reservoir was manually supplied with nutrients and the nutrient-rich water flowed through the submerged roots with the use of the water pump. A solenoid valve worked when certain situations happened in the water tank. The functions were already set through the embedded program of the hardware. The network part was composed of a wireless router and a module used for mobile communications. The wireless router handled the interconnections between the devices used while the global system for mobile communications module sent SMS notifications to the user through cellular network. A personal computer connected to the router acted as the server of the system; handled the processed data of the server and the web-based application used. Figure 3 shows how the devices were connected in developing the hardware part of the system.

This keeps the user on track even without accessing the web application. The last step was to display the readings using a web application. From the web server of the ThingSpeak, the recorded data are extracted on the web application to display the readings in the form of table and graph for easier analysis. In this part, software applications such as Xampp and Sublime Text are used to develop the web application that allows the data to be accessed remotely by a certain user. A user account management is present in this application, where an admin can see the numeric values and fuzzy values in the form of table aside from the graph that is displayed on the dashboard.

Overall, to make the whole system work, these parts must be integrated successfully into the hydroponic system. A hardware with an embedded algorithm responsible for monitoring and irrigating the plants, and a web application that allows easy access to data should work together to make the IoT based irrigation system for hydroponic system feasible.

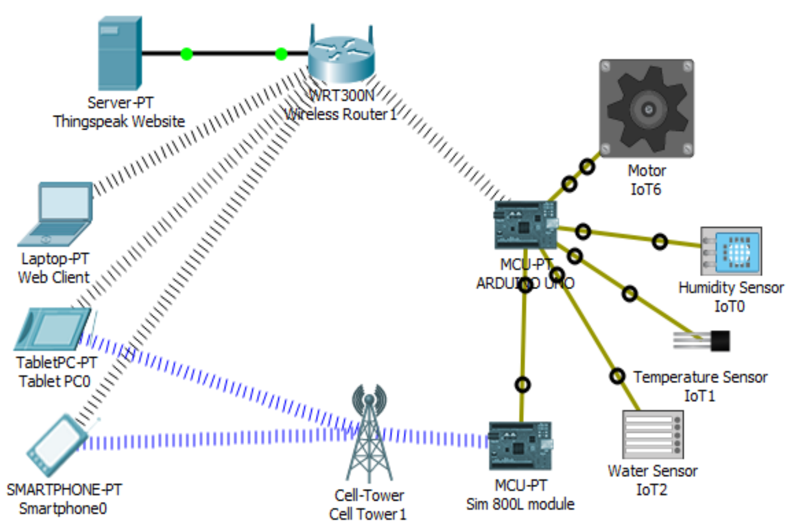

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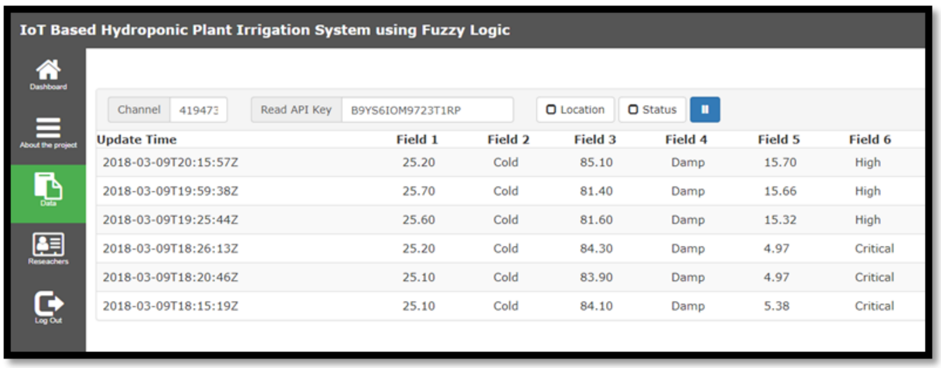
Figure 3: IoT Network System Topology

2.3 Web Development

The web-based application for the irrigation system was developed using different languages for creating online websites. These were the Personal Home Page: Hypertext Preprocessor (PHP), which is for server-side scripting that lets the developer do certain tasks like generating dynamic page contents, and sending and receiving cookies; Hypertext Markup Language (HTML), which is used to provide the set of general rules that give structure to the content of the web page being developed; Cascading Style Sheets (CSS), which is used for designing and making the web page more interactive and lastly, JavaScript, which is used for creating interfaces that enhance the functionality of the client-side events. Through a software called Sublime text, a text editor for code, markup and prose, can all be programmed because it has all the features to support these web programming languages. For the database of the system, ThingSpeak was used because it was the most reliable and easy-to-use option for this part of project as shown in Figure 4. A software called Xampp was used to make these things work within the local server; it helped transfer data with the use of Internet connection. In combining these essential softwares and features, creating the web-based application for the hydroponic irrigation system became feasible.



Update Time	Field 1	Field 2	Field 3	Field 4	Field 5	Field 6
2018-03-09T20:15:57Z	25.20	Cold	85.10	Damp	15.70	High
2018-03-09T19:59:38Z	25.70	Cold	81.40	Damp	15.66	High
2018-03-09T19:25:44Z	25.60	Cold	81.60	Damp	15.32	High
2018-03-09T18:26:13Z	25.20	Cold	84.30	Damp	4.97	Critical
2018-03-09T18:20:46Z	25.10	Cold	83.90	Damp	4.97	Critical
2018-03-09T18:15:19Z	25.10	Cold	84.10	Damp	5.38	Critical

Figure 4: IoT Platform Web Display

2.4 Hydroponic System

Figure 5shows the prototype of the hydroponic system. It was fixed and rearranged into a 30-hole NFT ladder type system and was still vertically arranged to utilize small space.

Figure 5 Hydroponic System Prototype

3.0 RESULTS

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The final prototype of the system is composed of primary components to meet the objectives of the study. It has ladder type Nutrient Film Technique system, which utilizes the power of water pump. It is composed of 30 holes to support 30 net pots of Romaine Lettuce plants. The developed device was installed at the top of reservoir and implemented to automate the irrigation process of the system and the refilling process of the reservoir. The device was calibrated according to the results from existing devices as shown in tables 1, 2 and 3.

TABLE 1: COMPARISON OF TEMPERATURE READINGS FROM HYGROMETER AND THE PLANT IRRIGATION DEVICE AFTER 2 HOURS OF DATA HARVESTING

Temperature (°C) based on the hygrometer (Actual)	**Temperature (°C) based on the device (Forecast)**	**|Actual - Forecast| (°C)**	**| (Actual - Forecast)/Actual|**
26.00	25.20	0.80	0.030769231
26.00	25.10	0.90	0.034615385
27.50	27.00	0.50	0.018181818
27.50	26.90	0.60	0.021818182
27.30	26.50	0.80	0.029304029
27.00	26.30	0.70	0.025925926
26.80	26.65	0.15	0.005597015
26.80	25.90	0.90	0.033582090
27.00	26.50	0.50	0.018518519
26.90	26.20	0.70	0.026022305
27.00	26.50	0.50	0.018518519
27.00	26.80	0.20	0.007407407

TABLE 2: COMPARISON OF HUMIDITY READINGS FROM HYGROMETER AND THE PLANT IRRIGATION DEVICE AFTER 2 HOURS OF DATA HARVESTING

Humidity (%) based on the hygrometer (Actual)	**Humidity (%) based on the device (Forecast)**	**|Actual - Forecast| (%)**	**| (Actual - Forecast) /Actual|**
84.0	83.2	0.8	0.009523810
84.0	84.1	0.1	0.001190476
85.0	84.5	0.5	0.005882353
82.0	81.4	0.6	0.007317073
81.5	80.9	0.6	0.007361963
86.0	85.1	0.9	0.010465116
84.0	84.0	0.0	0
84.0	83.5	0.5	0.005952381
84.0	84.2	0.2	0.002380952
84.0	84.0	0.0	0
84.0	83.8	0.2	0.002380952
84.0	84.2	0.2	0.002380952

TABLE 3 : COMPARISON OF WATER LEVEL READINGS FROM RULER AND PLANT IRRIGATION DEVICE AFTER 2 HOURS OF DATA HARVESTING

Water level (cm)	**Water level (cm)**	**|Actual - Forecast|**	**| (Actual - Forecast)**

based on the ruler (Actual)	based on the device (Forecast)	(cm)	/Actual|
16.0	15.61	0.39	0.024375000
16.0	15.75	0.25	0.015625000
16.0	15.37	0.63	0.039375000
16.0	15.66	0.34	0.021250000
16.5	16.16	0.34	0.020606061
16.0	15.70	0.30	0.018750000
16.0	15.70	0.30	0.018750000
16.0	15.70	0.30	0.018750000
15.5	15.30	0.20	0.012903226
15.5	15.30	0.20	0.012903226
15.5	15.20	0.30	0.019354839
15.0	15.00	0	0

Mean Average Percentage Error (MAPE) was used to analyze the data between the readings of the device and other devices. Using the formula of Equation 1, the MAPE of temperature was 2.25%, 0.45% for the humidity while for the water level reading was 1.85%. This simply means that the results are acceptable since it has a low MAPE, indicates that the system is reliable (Singh, 2015).

$$MAPE = \left(\frac{1}{n}\right) \times \left(\frac{\sum|Actual - Forecast|}{Actual}\right) \times 100\% \qquad (1)$$

After implementing the protoype successfully, the user was able to receive notification as expected. Sensor readings were also shown on the web application on real time basis. The solenoid valve and water pump also worked when certain conditions according to the embedded algorithm were met. It means that the irrigation system works according to the desired output and were successfully implemented.

4.0 CONCLUSIONS

An IoT-based hydroponic plant irrigation system using Fuzzy Logic was designed and implemented to monitor the temperature and humidity of the environment with less human intervention. Aside from that, growing of plants were remotely maintained due to the control of the water pump and solenoid valve that let the water flow, depending only on the readings acquired by the sensor system. With the development of the web application, monitoring of the hydroponic system is easier since the status of the system can be easily determined based on the sensor readings displayed. In addition, the sending of SMS notifications added to the efficiency of the system. This lets the user track the status of the system and gives information on problems that will affect the growth of the plants. Faster response can also be done to solve the problem immediately with the application of this system. The hardware part of the system which consisted of the microcontroller, sensors and relays made the implementation of this system possible. With these components, the data acquired by the sensors were sent to the database system wirelessly and were processed according to the Mamdani-Type Fuzzy Inference method, which made the interpretations a lot easier. After the recording and processing of data, the gathered data became the basis for the relays to control the solenoid valve for automatic refill of the reservoir and water pump that let the water with nutrient solution flow throughout the system. With these outputs, irrigation of the plants became possible. In summary, with the integration of the hardware and web application, IoT Based Hydroponic Plant Irrigation System using Fuzzy Logic became feasible. Future work on this study will include image processing.

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