SYSTEM DESIGN AND IMPLEMENTATION AUTOMATION SYSTEM OF EXPERT SYSTEM ON HYDROPONICS NUTRIENTS CONTROL USING FORWARD CHAINING METHOD

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***Abstract*—In this paper, presented the design of an embedded system that used to controlling nutrients content for hydroponics. The embedded system implanted artificial intelligence using Forward Chaining method to take the conclusion of nutrient condition. Embedded system also help users in measuring parameters needed by plant, calculate nutrient needs and the right conditions of nutrients, and determine the conclusion using forward chaining method. The embedded system developed by potential of hydrogen sensor, electrical conductivity sensor, temperature sensor and cooling fan, water pump.**

Keywords— hydroponics, embedded system, automation system, expert system, forward chaining.

I. INTRODUCTION

In this modern era is very rarely found supportable planting area in big city, especially for urban communities living in dense settlements and minimalist house. Even until its impossible to provide some area for yard. Its becomes a problem for people to able to gardening in the yard. In other words, the increasing population causes the availability of agricultural area to be reduced, because it is used for housing and urban expansion[1].

Hydroponics is an alternative for people who want to gardening, but don't have enough place to do. Hydroponics is a method of cultivating plant by utilizing water medium, without soil medium[1]. By optimizing the nutrients needs for the plant using water nutrients solution. Hydroponics can be used to grow vegetables and fruits. However, farming in this hydroponic way needs more handling, maintenance and monitoring than conventional farming with soil media. So the owner needs to pay more attention to the plant. As we know that urban communities are mostly workers who can not at all time monitor their hydroponics conditions.

From these problems, we need an intelligent system tool that can be used as a maintenance tool works automatically to determine condition of solutions to problem in hydroponics system. In addition, this intelligence system can also be used to fabricate the habitat culture according to the characteristics and needs of the hydroponics plant. Implementing several types of sensors that attached to the hydroponics system installation, they are potential of hydrogen (pH) sensor, electrical conductivity (EC) sensor, temperature sensor, its will measure and get the required data, then will be processed by the system and will get the appropriate output. The data obtained will the be stored to the Cloud. Do that hydroponics owners can access through internet. Utilizing internet of things technology. Intelligent system are expected to assist hydroponics owners in monitoring the state and automatic maintenance of the crop being cultivated wherever and whenever.

II. DESIGN SYSTEM

The system have three kind of actuator for output system they are water pump for each adjustment solutions, Cooling fan for cooling down solution temperature.

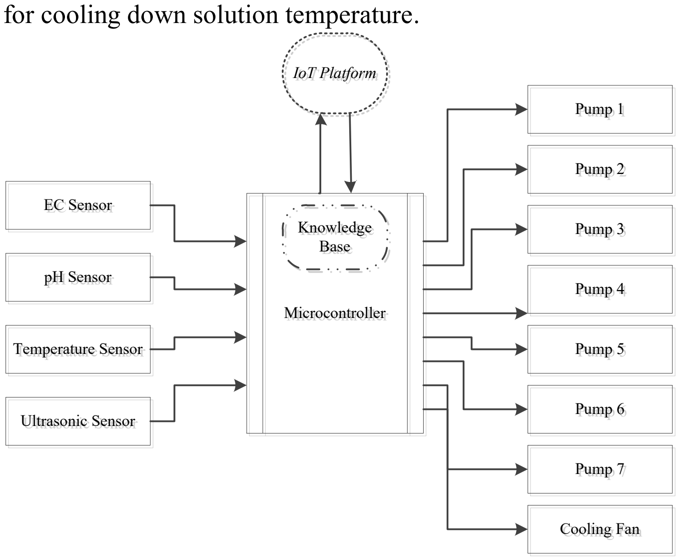

fig 1 Blok Diagram System

Figure 1 shows this system implanted an expert system using forward chaining method to determine the solution of the nutrient condition. Microcontroller using Arduino Mega 2560 in which will implemented the forward chaining method. In sensor system has four kind of sensor, they are pH sensor, EC sensor, temperature sensor, ultrasonic sensor. Then the actuator has 7 water pump (to drain pH up solution, pH down solution, water, nutrient A solution, nutrient B solution, to sprinkling and to drain water tank. And Cooling Fan (to reduce water temperature). Integrated with cloud web service and mobile application. The system will implemented connect to the internet using ESP8266 module.

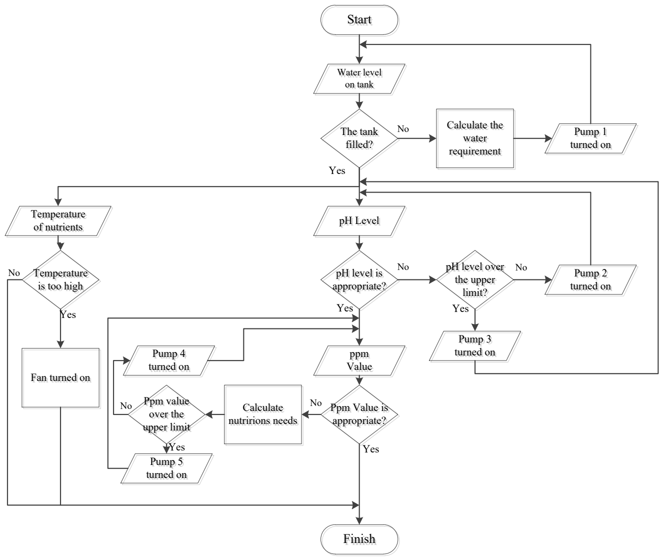

fig 2 Flow chart of system

Figure 2 shows the flow charts diagram that occurs in embedded systems. Data input taken from ultrasonic sensor, pH sensor, EC sensor, and temperature sensor. After get the conclusion from forward chaining then the microcontroller will command the actuator cooling fan and water pump to execute to neutralize the nutrient.

A. *Knowledge Base Design*

Table 1 List of Nutrient Condition

Condition ID	Nutrient Condition	Solution
K001	Nutrient normal	The system works normally
K002	Nutrient temperature is not right	Cooling Fan turned on
K003	Excess ppm levels	Added water
K004	Lack of ppm levels	Added ABMix solution
K005	Excess ppm levels and temperature is not right	Added water and fan turned on
K006	Lack of ppm level and temperature in not right	Added ABMix and fan turned on
K007	pH levels is too high	Added pH Down solution
K008	pH levels is too low	Added pH Up solution
K009	pH levels is too high and temperature is not right	Added pH Down solution and fan turned on
K010	pH levels is too low and temperature is not right	Added pH Up solution and fan turned on
K011	pH levels is too high and excess ppm levels	Added pH Down solution and water
K012	pH levels is too high and lack of ppm levels	Added pH Down solution and ABMix
K013	pH levels is too low and excess ppm levels	Added pH Up solution and water
K014	pH levels is too low and lack of ppm levels	Added pH Up solution and ABMix
K015	pH levels is too high, excess ppm levels and temperature is not right	Added pH Down solution, water and fan turned on
K016	pH levels is too high, lack of ppm levels and temperature is not right	Added pH Down solution, ABMix and fan turned on
K017	pH levels is too low, excess ppm levels and temperature is not right	Added pH Up solution, water and fan turned on
K018	pH levels is too low, lack of ppm levels and temperature is not right	Added pH Up solution, ABMix and fan turned on

Table 1 shows the list of nutrient condition based on measurment result on system, nutrients condition as conclusions that accur in the state of nutrient solution.

B. *Symptoms List*

Table 2 List of Measurement Indication

Symptom ID	Measurement Symptoms
G001	Ppm level within limits
G002	Ppm level above the limits
G003	Ppm level below the lmits

G004	pH level within limits
G005	pH level above the limits
G006	pH level below the lmits
G007	temperature within limits
G008	temperature above the limits

Table 2 shows the list of mesurement indication on nutrient. The indication as result measurements from the sensor.

C. *List of Decisions*

Table 3 List of decisions based on symptoms

	Nutrient Conditions (K001=1, K002=2 . . ., K0018=18)																	
ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
G001	√	√					√	√	√	√								
G002			√		√						√		√		√		√	
G003				√		√						√		√		√		√
G004	√	√	√	√	√	√												
G005							√		√		√	√			√	√		
G006								√		√			√	√			√	√
G007	√		√	√			√	√			√	√	√	√				
G008		√			√	√			√	√					√	√	√	√

Inf √ : relations

Table 3 show the table decision nutrient conditions based on relationship symptoms of measurement result and conclusions nutrient conditions of the built system

D. *Forward Chaining Decision making tree*

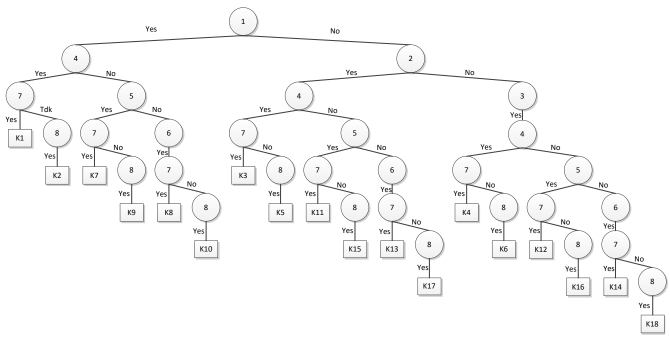

fig 3 Decision-making Tree

Based on the knowledge base that has been collected it can be made a decision tree with forward chaining method. Shows in Figure 3, show that the search is performed for each condition. The decision tree will be used to assist in the process of creating the rule base which will eventually be used to determine the conclusions and solutions to the existing condition. The number in the tree representing state of Nutrient condition, if the conditions is correct then the searching will continue by following the 'yes' to the next state, instead if the state is not correct the search will continue by following the 'no' to the next state. Searching will end when the searching process is up to the root of the tree, the last state. So, it will be conclude in last state with 'K' ID means Conditions ID.

III. EXPERIMENT RESULT

Implementation of a system that has been designed previously need to know the process and the result. Therefore, in the experiment section will explain how the system process and the result of each sensor, actuator and forward chaining that has been designed previously.

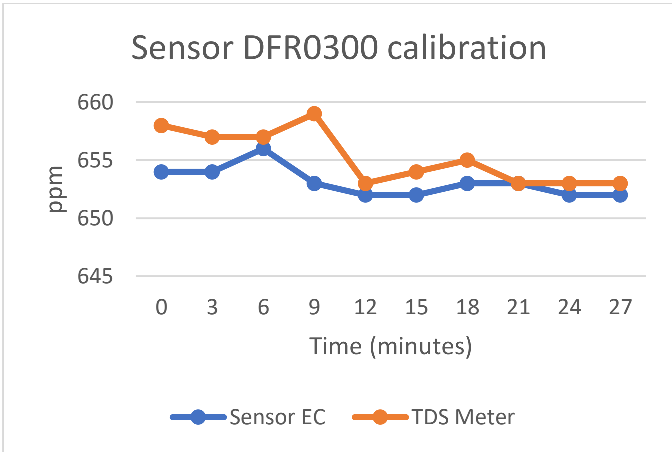

fig 4 DFR0300 Calibration

The EC sensor calibration is performed by comparing between measurement result of DFR0300 sensor with measurement result of TDS Meter. In the Figure 4, obtained result of comparison two result have the different result. The biggest difference value of 6 ppm. While the smallest difference value is 0 ppm. Can be calculated the average difference measurement DFR0300 sensor with TDS meter is 2.1 ppm. The difference is still within the tolerance limit of the sensor that is <10% of the measurement result. So it can be conclude that the DFR0300 sensor can be used properly and correctly to measure nutrient levels.

Table 4 pH sensor calibration

No	pH Level	pH Sensor measurement	pH Meter measurement	Difference measurement
1	9.18	9.06	8.9	0.16
2	9.18	9.05	8.9	0.15
3	9.18	9.07	9.0	0.07
4	6.86	7.13	7.1	0.03
5	6.86	7.12	7.1	0.02
6	6.86	7.14	7.1	0.03
7	4.01	4.44	4.5	0.06
8	4.01	4.42	4.5	0.08
9	4.01	4.41	4.5	0.09
Average pH level difference between pH sensor and pH meter				0.0766

The pH sensor calibration was performed using three types of pH buffer solution, they are pH buffer 4.00, pH buffer 6.86 and pH buffer 9.18. in the Table 4 show that calibration by comparison between pH SEN0169 sensor with pH meter PH-009(I). using three types of pH buffer solution aims to determine the ability of sensor to measure acid level at 4.00 pH level, alkaline at 9.18 pH level and neutral level at 6.86 pH level. The experiment obtained the average of measurement difference. And with average value is 0.0766. the difference is still within normal limits, because pH SEN0169 sensor has a measurement accuracy of 0.1 pH value. So, it can be concluded that pH SEN0169 sensor can be used properly and correctly to measure pH level.

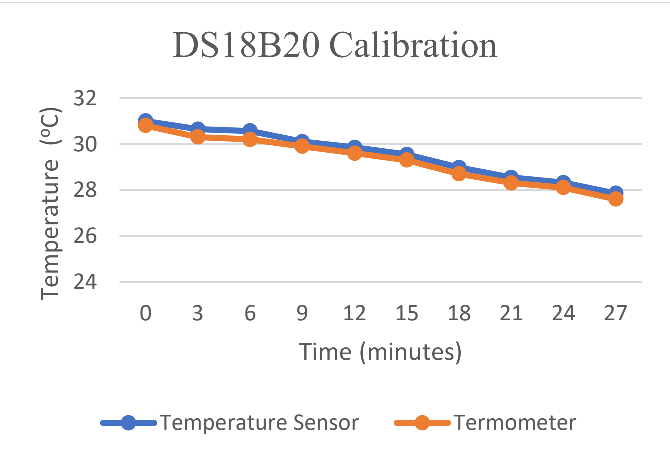

fig 5 Temperature Sensor Calibration

Figure 5 shows the calibration result of comparison measurement between DS18B20 sensor and thermometer obtained difference between two result. The maximum difference is 0.37°C and the minimum difference is 0.2C. within an average difference is 0.258°C. in the tolerance of 0.5°C accuracy. So, it can be conclude that the DS18B20 sensor can be used properly to measuring water temperature

Table 5 Distance test result ultrasonic sensor

No	Ruler (cm)	Ultrasonic Sensor (cm)	Difference Measurement
1	2	2.19	0.19
2	7	7.04	0.04
3	12	11.99	0.01
4	17	17.16	0.16
5	22	22.02	0.02
6	27	26.79	0.21
7	32	31.98	0.02
8	37	37.01	0.01
9	42	42.10	0.10
10	47	46.82	0.18
Average distance difference between ultrasonic sensor and ruler			0.094

Based on sensor calibration result as shown in Table 5 above, obtained a comparation between ultrasonic and ruler. The difference maximum is 0.21 cm and the minimum difference is 0.01 cm, with an average difference is 0.094 cm in tolerance of 0.1 accuracy. So, it can be conclude that ultrasonic sensor are good for measuring distance.

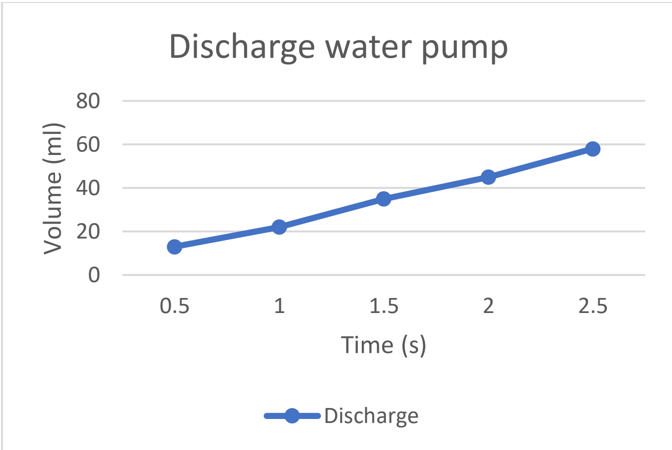

fig 6 Discharge Water Pump

Figure 6 show the graph of DC pump test that is done with difference duration of the pump, with the different of duration is 0.5 seconds. The test is performed 5 times starting from the duration of 0.5 second to 2.5 second. The first test duration of 0.5 seconds has a debit of 26 ml/s, the second test duration of 1 second has a debit of 22ml/s, the third test duration of 1.5 seconds has a debit of 23.33 ml/s, the fourth test duration of 2 seconds has a debit of 22.5 ml/s and the fifth test duration 2.5 Sec has a debit of 23.2 ml/s. The average discharge from this test is 23.4 ml/s or 84.26 L/H. So the DC pump can flow water with a discharge of 23.4 ml/s.

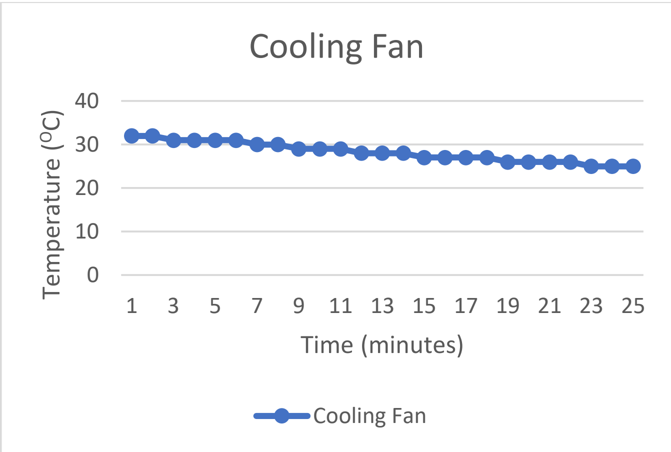

fig 7 Cooling Fan

in Figure 7 shows that there is temperature reduction to the optimum temperature need by the plant suggested by the expert. To get the optimum temperature the cooling fan takes 23 minutes to lower the temperature from 32ºC to 25ºC. So, cooling fan can be used to reduce the temperature of nutrient solution.

Table 6 Forward Chaining

No	Observation Time	Sensor Measurement	Actuator Action	Forward Chaining conclusion	Inf
1	7 July 2017	• pH = 6.1 • ppm = 629 • temp = 25	• Pump 1 = Off • Pump 2 = Off • Pump 3 = Off • Pump 4 = Off • Pump 5 = Off • Fan = Off	(Rule 1) Normal Nutrition	equal
2	9 July 2017	• pH = 6.1 • ppm = 569 • temp = 26	• Pump 1 = Off • Pump 2 = Off • Pump 3 = Off • Pump 4 = Off • Pump 5 = Off • Fan = On	(Rule 2) Nutririon temperature is not right	equal
3	11 July 2017	• pH = 6.2 • ppm = 539 • temp = 27	• Pump 1 = Off • Pump 2 = On • Pump 3 = On • Pump 4 = Off • Pump 5 = Off • Fan = On	(Rule 6) Lack of ppm level and temperature is not right	equal
4	13 July 2017	• pH = 6.2 • ppm = 690 • temp = 27	• Pump 1 = Off • Pump 2 = Off • Pump 3 = Off • Pump 4 = Off • Pump 5 = Off • Fan = On	(Rule 2) Nutririon temperature is not right	equal
5	15 July 2017	• pH = 6.5 • ppm = 714 • temp = 28	• Pump 1 = Off • Pump 2 = Off • Pump 3 = Off • Pump 4 = Off • Pump 5 = Off • Fan = On	(Rule 2) Nutririon temperature is not right	equal
6	17 July 2017	• pH = 6.4 • ppm = 700 • temp = 28	• Pump 1 = Off • Pump 2 = Off • Pump 3 = Off • Pump 4 = Off • Pump 5 = Off • Fan = On	(Rule 2) Nutririon temperature is not right	equal
7	19 July 2017	• pH = 6.0 • ppm = 695 • temp = 26	• Pump 1 = Off • Pump 2 = Off • Pump 3 = Off • Pump 4 = Off • Pump 5 = Off • Fan = On	(Rule 2) Nutririon temperature is not right	equal
8	21 July 2017	• pH = 6.1 • ppm = 685 • temp = 27	• Pump 1 = Off • Pump 2 = Off • Pump 3 = Off • Pump 4 = Off • Pump 5 = Off • Fan = On	(Rule 2) Nutririon temperature is not right	equal
9	23 July 2017	• pH = 5.9 • ppm = 680 • temp = 25	• Pump 1 = Off • Pump 2 = Off • Pump 3 = Off • Pump 4 = Off • Pump 5 = Off • Fan = Off	(Rule 1) Normal Nutrition	equal
10	25 July 2017	• pH = 6.0 • ppm = 662 • temp = 25	• Pump 1 = Off • Pump 2 = Off • Pump 3 = Off • Pump 4 = Off • Pump 5 = Off • Fan = Off	(Rule 1) Normal Nutrition	equal

Forward chaining experiment to test the system is working in accordance with the rules of Forward Chaining method. The test is performed by monitoring the measurement of sensor and the action of the actuators compared to the expert system concept that have been prepared with the truth status approved by an expert.

The result of forward chaining test on the hydroponics nutrition control automation system is show in Tabel 6. Sensor measurement is taking data of pH, ppm, and temperature. After going through a process with forward chaining method will produce output that will activate the actuator according to the conclusion.

Pump 1 is used to drain the water, pump 2 as a pH Up solution flow drainer, pump 3 as a pH Down flow drainer, pump 4 to drain the A solution, pump 5 to drain B solution, then pump

6 as the nutrient drain from nutrient tank to the hydroponics system, 7 as a discharge pump, and a cooling fan is used as a cooling nutrient solution.

The action output of the system through the actuator is equal to the conclusion of the knowledge base forward chaining designed for the nutritional control system. From the 10 times of sampling result, the result is 100% match. So it can be concluded the automation system work well.

IV. CONCLUSION

Based on the result of the experiments, it can be concluded that the nutrient control automation system in hydroponics using forward chaining method can run well as desired and the forward chaining as the decision making. And also can perform data retrieval functions, send data to the cloud, and run actuators for nutrient control.

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