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Designing an Automated Control of a Portable Hydrophonic Plantation Facility based on Fuzzy Logic Algorithm.

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Abstract

The paper discusses the design of an apparatus for hydrophonic plants to grow effectively in a limited growth area, using a plastic square tank with a size of 60 cm by 80 cm, which is filled using a pump with water and the growth media, so that it can be easily move from one place to another, and moreover can be stacked on top of another. The required acidity and nutrient, as well as the intensity of sunlight, are controlled using a microcomputer, based on the pre-set values to the standard requirements for specific vegetables. These values are set preliminary in to the microcomputer and use as references for the control algorithms. To release the system from the non-linearity conditions, the fuzzy logic control algorithm is applied to each of the control loop such that the growth environtment required for the vegetables can be achieved. A stirrer is used to speed-up the mixing time to reach homogeneous condition.
The Takagi–Sugeno type Fuzzy Logic Controller was used, with only three membership functions at the input and the inference results are then weighted averaged at the output. The results shows that the apparatus works well under closed loop control, although there is still a small problem due to slow response and the insentitivity nature of the pH sensor that should be clean very often for better results.

(Abstract should be approximately 200-250 words in length)

Keywords
portable growth media, fuzzy logic Control, plant nutrition, pH sensor, acidity

1. Introduction

The current trend on hydroponics technology in farming is heading towards a promising growth with applications mainly in the green vegetable industry[1]. Several Hydroponic methods can be applied according to resource availabilities and needs, and nowadays it is not only done by farmers, but also by hobbyist in regular households [2][3]. Although the technology is fairly easy to be implemented, it is occasionally found difficult to get good results due to the improper handling to maintain the constant nutrition value, growth media acidity, as well as lighting, which are important aspects in the farming [4]. For this reason, a technology to support the maintenance of hydroponic plants automatically, is developed so that farmers can achieve the highest quality with

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minimum effort. The system aims to broaden the scope of farmers so hydroponics can be done by anyone, anywhere and anytime. In this paper, an automation system that can simplify hydroponic farming in monitoring, maintaining, and optimizing the growth of hydroponic plants is designed. The system is based on microcontrollers, sensors, and actuators that adjusts pH value, nutrition concentration, and lighting with user friendly operation and affordable price. Each unit is also made portable, can be arrange easily into stainless steel racks which ae staggered in a large room.

2. The System Design

In this research, we use the Flood & Drain method, which is a hydroponic growing system where plants get the water, nutrition, and oxygen through a reservoir that is pumped in to the media in the grow tray. In a certain time, the water together with the nutrition will be drained back to the reservoir through an overflow channel. And after a certain predetermined time passed the the solution liquid is pumped back in to the grow tray, such that the roots of the vegetables will not be dried up, which may cause it to die of drought. The cycles of flood and drain is repeated during the grow period until the vegetables are harvested. The flood and drain period can be adjusted using a timer eliminating the risk of plant dehydration or overwatered. Fig. 1 shows the detailed diagram of the Flood & Drain grow tank. [5][6].

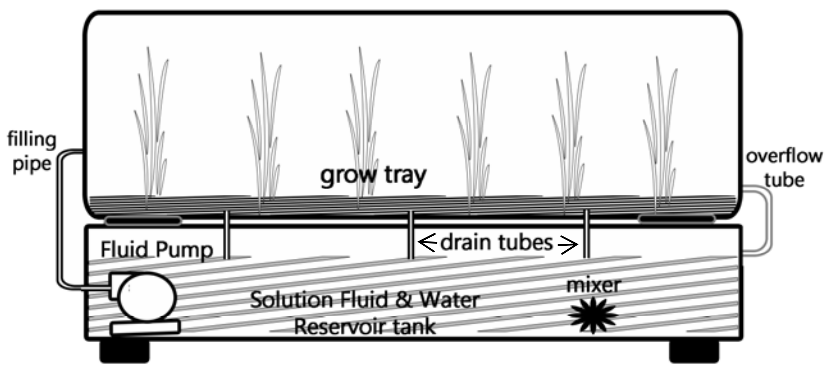


Figure 1. The Ebb & Flow system for portable hydrophonic.

The height of the roof is in the range of 30 to 50 cm, depending on the type of vegetables to be grown, and the roof is designed to be detachedable, to ease the farmer when harvesting.

The system involves the control of pH, nutrition, and lighting to support the plant growth effectively. All facilities are provided and controlled by using an Arduino-Uno single-board microcontroller, which is reasonably cheap and has the capability to support all necessary functions in the system. The system controls water flow using a water pump that runs under the control of a timer, air concentration in the water reservoir using an aerator, a stirring motor to mix the pH regulating solution and nutrition in the reservoir. The system is equipped with an LCD display and Keypad for users to input a required set point for the pH level, while other aspects are controlled automatically in a certain amount of time using the microcontroller internal timer. Keypad, LCD Display, and pH sensors are connected directly with the microcontroller while the micro gear pumps are powered by an external 12V DC source and the aerator is powered by an external 220V AC power source.

2.1. The User Interface

The user interfaces consist of a numeric keypad and an LCD Alphanumeric Display, which are connected to the microcontrolle via I2C serial interface lines with analog pin A4 and A5 connected, as shown in figure 2 below. The keypad is used to set the necessary data for setpoints, while the LCD is used to display the necessary information to the user.

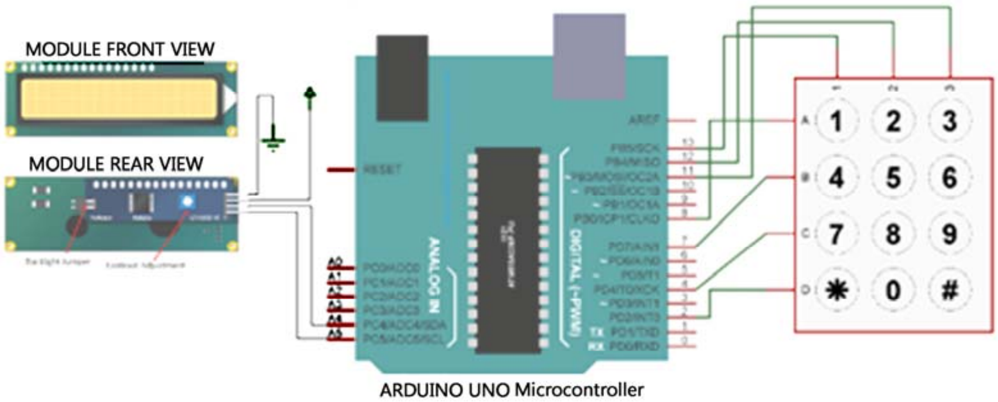


Figure 2. the user interface electronics

2.2. The controller

The acidity of the liquid and its nutrition content, are infact the most important to be managed carefully but both are also the most difficult to be controlled. This is due to the non-linear characteristics of the titration process of controlling the pH values of the liquid solution, and the non-linear characteristics of the nutrition sensor. And it is due to the same reason, the Fuzzy Logic controllers are used in both cases.

The data of pH of the growth liquid is acquired by using a pH sensor, and the nutrition content is read using a conductivity sensor as the nearest indicator to be used for th nutrition content. The closed loop Fuzzy logic control block diagram for pH control is shown in figure 3 below. The pH value is read using a pH probe, and sent to the micro controller, and then compared to the setpoint, the error and change of error are calculated as :

CurrentError= pH set – actual pH, (1)

ChangeOfError = CurrentError – pastError (2)

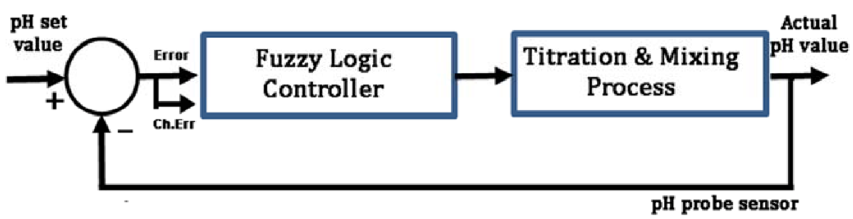
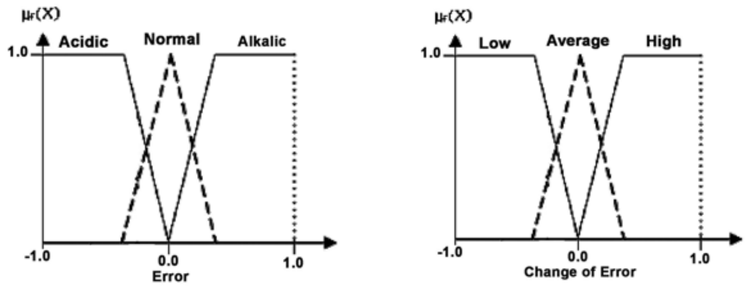


Figure 3 the Fuzzy logic Controller set-up

These two information is then fed in to the Fuzzy logic controller, to be fuzzified, using the membership function defined in the FLC for the Error and the Change of Error as shown in figure 4 below, each contained only three triangular shaped membership functions. Using the Takagi-Sugeno Type Inferences, the rule base is defined in the form of IF- THEN rule as follows:

IF *Error* **IS** *A* **AND** C*hangeOfError* **IS** *B* THEN *Out=ax + b*

The *A* is one of the three conditions for *error*, ie., *Acidic*, *Normal* or *Alkalic*. While *B* is one of the the other three conditions for the *changeOfError*, ie., *Low*, *Average*, or *High*. The function *out=a x +b*, are straight line approximation of the titration curve, which can be divided into 7(seven) segments of straight lines, but be aware that the value of the output is zero, indicate the pH has reached the value of 7, ie. reach the normal condition, while a positive value indicates alkalic condition, and while a negative value indicate the acidic condition.



(a) (b)

Figure 4. Triangular shape membership function, (a).for Error, and (b) for ChangeofError

At the defuzzification stage, the output of the inference engine, will be averaged, using the same weight of =1.0 which means both acidic and alkalic conditions are equally important for the system. When the defuzzification output indicate "alkalic condition, and the pump which releases the Phosphoric Acid (H3PO4) 10% solution should be set to "ON", and when it indicates the acidic condition, and the pump which releases Sodium Hydroxide (NaOH) 10% solution should be set to "ON". And the absolute values of the defuzzification will determine the length of the "Pump ON" condition. The sensor reads the pH in 20ms interval and the LCD display is updated in 800ms interval [8]. One of the recording of the response of the pH value when changed from 10.5 down to 5.75 is shown in figure 5, it is seen that the settling time is around 175 secods and the time constant is 30seconds. Which is still very resonably fast for this type of system.

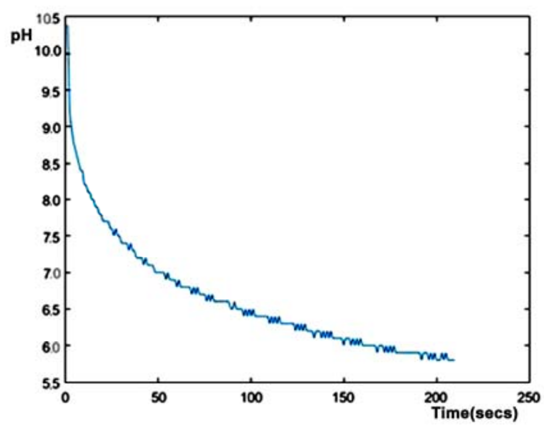


Figure 5. the control of pH to reach 5.75

2.3. *The control of Nutrition.*

The closed loop Fuzzy logic control block diagram for nutrition control is the same shown in figure 3 above. The nutrition value is read using a conductivity probe, and sent to the micro controller, and then compared to the setpoint, the error and change of error are calculated as :

CurrentError= pH set – actual pH, (3)

ChangeOfError = CurrentError – pastError (4)

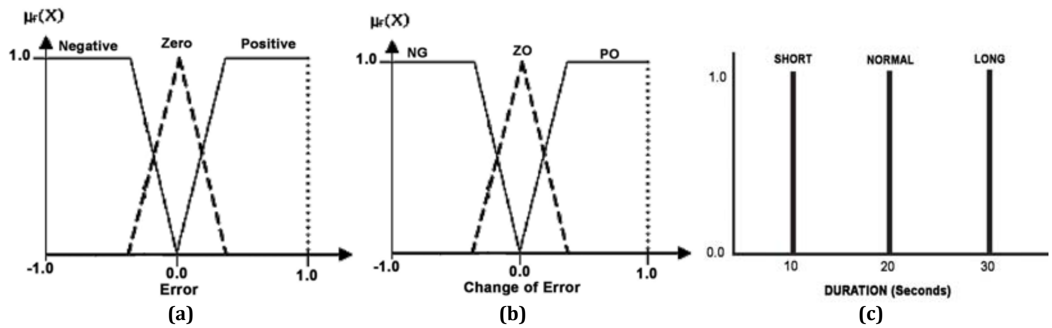


Figure 7. The membership functions, (a) at input Error, (b) at Change of Error, (c) at output

The membership function at the input stage is shown in figure 6., using triangular shape membership function, and the output is using three singleton memberhip functions. Using the Takagi-Sugeno Type Inferences, the rule base is defined in the form of IF- THEN rule as follows:

IF *Error* **IS** *A* **AND** C*hangeOfError* **IS** *B* THEN *C*

The *A* is one of the three conditions of *error*, ie., *Negative, Zero and Positive*. While *B* is one of the the other three conditions of the *changeOfError*, ie., *Negative, Zero and Positive*, and the output is the duration of pumping in *Short*, *Normal*, or *Long*.

At the defuzzification stage the outputs are averaged by using the same weight equal to 1.0, and the value is used as the time duration to activate the nutrition solution pumping.

2.4. The control of Lighting.

In order to let the hydrophonic grow tanks be placed indoors, the it is necessary to provide appropriate lighting to replace the sun-light. According to Resh(1987) and Djaffri(2016) the best color spectrum during the vegetation grows, in general is as follows,

- During Vegetative Period : the blue color spectrum for10 days.
- During The generative Period : the red color spectrum for10 days.
- During the Period of flowering : the purple color spectrum for10 days.

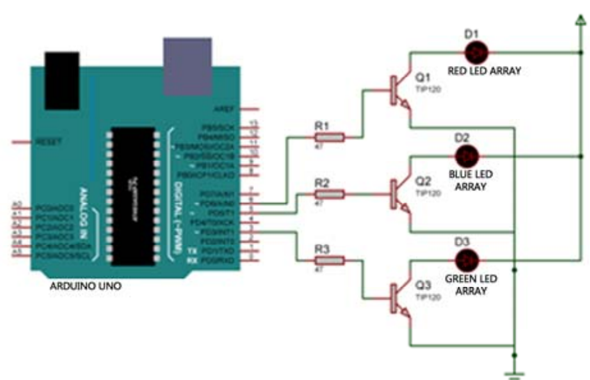


Figure 8. the driver electronics for the RGB Stripes to the microcontroller.

In the hydrophonic system, the lighting uses the combination of red-green-blue(RGB) LED Stripes, and then it is programmed in the microcontroller to turn on a switch for each colour-stripe in every 30(thirty) days period, so that RGB LED Strip can change the color spectrum every 10 days with stages of change red -> blue -> purple. The purple colour is the results of having the red and the blue colours together and the green color is not used, can be ignored. The driver electronic for th RGB Led stripes to the microprocessor is shown in figure 8. above. The sequence of switching on and off is given in the table1.

Switch	0-10	10-20	20-30	30-40	40-50	50-60	...
Red Light	OFF	ON	ON	OFF	ON	ON	
Blue Light	ON	OFF	ON	ON	OFF	ON	
Green Light	OFF	OFF	OFF	OFF	OFF	OFF	
Results:	BLUE	RED	PURPLE	BLUE	RED	PURPLE	

2.5. The Flood and Drain Sequence.

The Flood and Drain of the water so;ution in to the grow tank is arranged by only the on/off period of the pump using a timer generated inside the microcontroller. The power source of the pump is a 12V DC connected through a relay, driven by a seried transistor to be controlled by the low powered signal from the microcontroller. The period and the length of pumping is predeterminde by the operator , by keying the time period in to the system using the keypad provided.

3. Conclusions

In this paper, Automation System for Hydroponic Plantation Based on Flood and Drain Method has been designed and built. The system shows promising automated control of the aspects necessary in hydroponics farming using the method by having most those aspect of pH, nutrition, lighting, and water flow under good controlled, providing the simplification hydroponics farming process. We had tried to apply the Fuzzy logic control to manage two of those important parameter for vegatable growing wil a success.There is still yet many room for improvements in the system such as using Neural Network or others algorithms in closed loop control of other aspects beside the pH, which may be developed in the future.

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