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FUZZY LOGIC CONTROLLER IMPLEMENTATION TO AN ARDUINO-BASED SOLAR-POWERED AQUAPONICS SYSTEM PROTOTYPE

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ABSTRACT

A fuzzy-logic control based controller is implemented to a solar-powered aquaponics system prototype using Arduino microcontroller. The system automates the process of maintaining the levels of the temperature, pH and level of the water in two basins where fish and plants are grown. Fuzzy-logic membership functions are designed to produce fast reaction time for the control.

***Keywords**: Aquaponics, hydroponics, aquaculture, arduino, fuzzy logic, pH*

INTRODUCTION

Aquaponics is a combination of aquaculture & hydroponics. This means that fish and plants are grown in an integrated system, creating a symbiotic relationship between the two. An Aquaponic system uses the water from the fish tank to circulate through a grow bed where the plants are grown. The effluent is treated by nitrogen-fixing bacteria (nitrification) transforming ammonia via nitrites into nitrates, which are utilized by the plants as nutrients. The water is then re-circulated back to the aquaculture system [1]. The plants use these nutrients as their main nutrient supply. The fish also benefit from this process, as the water is filtered by the plants, giving the fish clean water to live in. This integrated system of Aquaponics has benefits not achievable when Aquaculture and Hydroponics are done separately [2]. Aquaculture has the problem of build-up of wastes in the water, requiring filtering systems to clean the water as well as periodic releasing of waste water into the environment. Hydroponics uses chemical nutrients that eventually build up in the water and create toxic water. This water can no longer be used in the irrigation of the plants and is disposed of into the environment. Aquaponics takes both of these problems and turns them into solutions, as the waste in the water is used to feed the plants, therefore not requiring any chemical nutrients to be added to the system, and can have no pollution of the environment by either fish wastes or chemical pollutants [3].

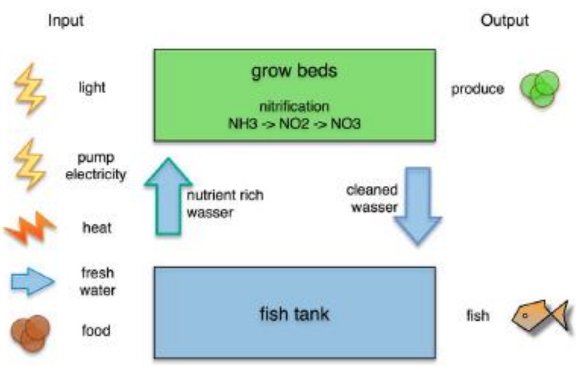

Figure 1 Aquaponics system [1]

Figure 1 shows the aquaponic system components. The system needs electricity for lighting and pumps as well as heat for the fish tanks and plants. In addition, fishes need to be fed and fresh water is needed to make up for evaporation. The outputs are fish and produce [4].

Objectives of the Study

The general objective of the study is to develop an Arduino-based automation of an aquaponics system capable of sustaining the symbiotic cycle between aquaculture basin and hydroponics basin.

The specific objectives are as follow:

1. Develop an algorithm for the water pump and valve control;
2. Integrate electronic sensors (i.e. pH, water level and temperature) that monitor the defined parameters in optimizing the condition of the water based on the species requirement.

METHODOLOGY

A. Process

Fig. 2 shows the methodology used for this study that includes the design, implementation both in software and hardware, implementation, data gathering, interpretation of results and conclusion.

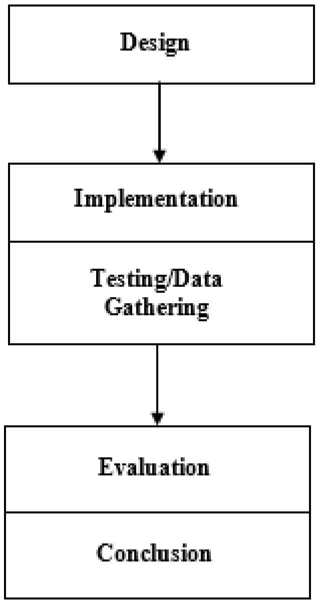

Figure 2 Methodology

CONCEPTUAL FRAMEWORK

The conceptual framework of the system is shown in Fig. 3.

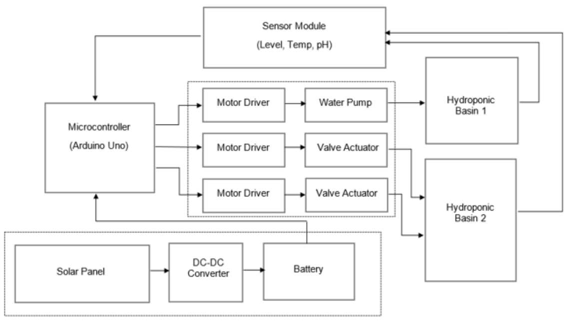

Figure 3 Conceptual Framework

The system is mainly composed of two basins; the upper, and the lower basin. The upper basin serves as the hydroponic area where plants are nourished and cultivated. The lower basin serves as the aquaculture area where fishes are grown.

The initial set-up includes filling-up the basins with fresh water. The components needed for each basin is discussed in the hardware implementation. After the plants and the fishes are being deployed in the basins, monitoring of water level, pH and temperature is automatically done by the system.

The data gathered is fed to the microcontroller that activates the actuators. Actuators include the water pump, valve control and base fluid dispenser.

The nutrient-rich water in the lower basin is continuously pumped to the upper basin. Water level sensors in the upper basin are activated once the water reaches specific levels. Once the highest water level is reached, the water pump stops. The microcontroller will now start the timer with the set interval. Simultaneously, the pH level of water in the lower basin is monitored. When the water reaches above the pH setting, the microcontroller activates the motor that dispenses basic compound to lower the pH level until it reaches the requirement. The system maintains the pH level through this continued pH level control process. The temperature is also maintained through by-passing the time interval and forcing the water pump and valve. Thus, there is a continuous cycle of water that cools it.

After the time interval that enables the plants to filter the nutrients and nitrogen from the water, the microcontroller activates the valve to drain the upper basin. The clean water then goes down to the fishes.

The cycle is repeated until the fish and plants are ready for harvest. The water in the system can be totally replaced by draining it through the manual valves installed in both basins.

IMPLEMENTATION

A. Organic Elements

1.) Plant

Almost any variety of plant can be cultivated in the aquaponics system based on studies. The pandan plant is used in this set-up to be tested. Coconut husks are used to cover the roots of the plants and make them stay in their positions. The husks have water-absorption capabilities to provide the plants the moisture needed during the process.

2.) Fish

Tilapia was chosen to be the fish for testing since it is locally available and known to be one of the major fish variety in the market supply.

B. Hardware

The hardware mainly includes Arduino Uno microcontroller, motor drivers, motors/actuators, water level/pH/temperature sensors. Solar panel is used to charge the battery that supplies power to the system. The voltage from the solar panel is regulated by the charge controller/DC-DC converter.

Fig. 4 shows the relay circuit that will be used to drive the water pump through the microcontroller pin outs.

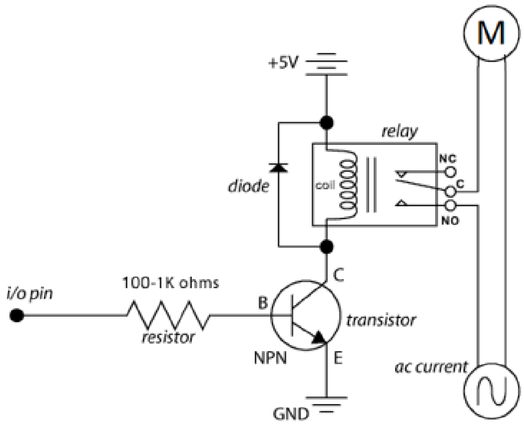

Figure 4 Relay Circuit

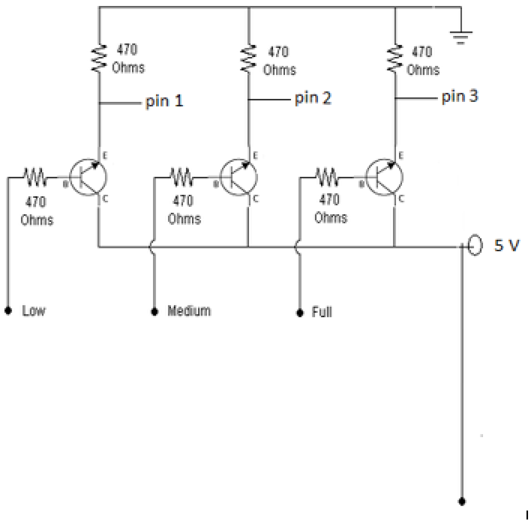

Figure 6 Water-level indicator schematic

Figure 5 Fluid valve set-up

Figure 7 Basin 1

Fig. 5 shows the set-up for fluid-valve. This is primarily composed of a servo motor, water valve and rubber tubing. The arduino is programmed to drive the servo motor that turns its shaft to close or open the valve where the water from the upper basin flows through towards the lower basin.

Fig. 6 shows the schematic diagram of the water-level indicator. The three npn transistors are switched on when the water reaches their respective input terminals that correspond to the water levels (i.e. low, medium and full). Once activated, the circuit gives 5 volt output from each output terminal for the arduino.

Fig. 7 shows the Basin 1 with the water-level indicator and water-shower system. Water is pumped from the larger basin (i.e. Basin 2) to irrigate the plants in the Basin 1. The water-level detector continuously monitors the level of the water.

The signal is sent down to the microcontroller set-up. The solar panel set-up is also seen in this figure. Basin 1 set-up also includes the pH sensor that monitors the level of pH of the water.

Figure 8 Basin 2

Basin 2 set-up is shown is Fig. 8. The water-pump, aerator and temperature sensor are installed here. Water shower tube provides the corrected water from the Basin 1. pH correction is done before water is given back to the Basin 2 for the fish.

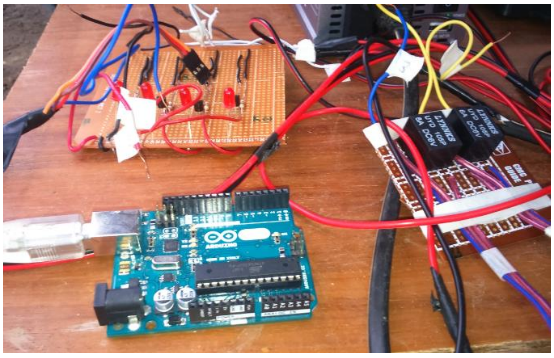

Figure 9 Microcontroller set-up

The control panel is composed of the microcontroller set-up, relay circuit, water level indicator system, solar-panel set-up, dc-dc converter and the battery. Fig. 9 shows the set-up of the controller used.

C. ***Software***

Fuzzy-logic algorithm is used in the control of temperature, pH and water level. This algorithm is implemented in Arduino Uno microcontroller [5].

1) Pseudo-Code

Start

Check for the pH, water level, temperature

If the pH is lower than 7, add basic compound until pH = 7

If water level = high,

Timer starts

pinch valve = on

Else pinch valve = off

Motor pump = on

If water temperature > set point,

motor pump on

pinch valve = on

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2) Fuzzy Logic

The input parameters are temperature level, water level and pH level. The membership functions for the inpunts are lowpH, normalpH, highpH, lowwater, normalwater, highwater, lowtemp, normaltemp and hightemp.

The output parameters consist of the time duration to open the valve for each corrective action set-ups (i.e. pH, water level and temperature). Membership functions for the outputs are lowdispense, mediumdispense and highdispense. Sample membership functions for the input and output are shown in Fig. 10 and 11 respectively.

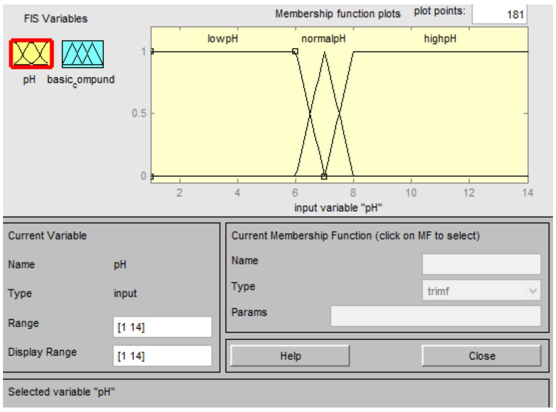

Figure 10 Input membership functions

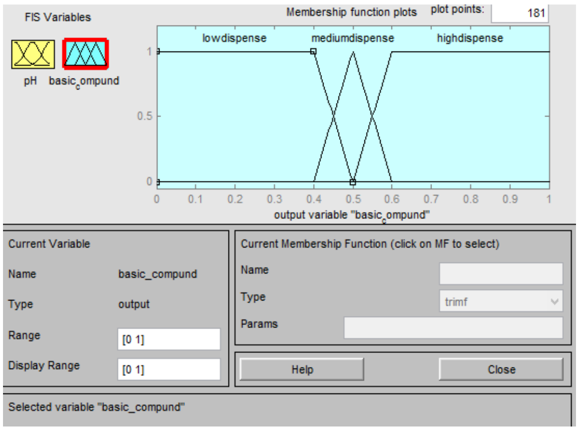

Figure 11 Output membership functions

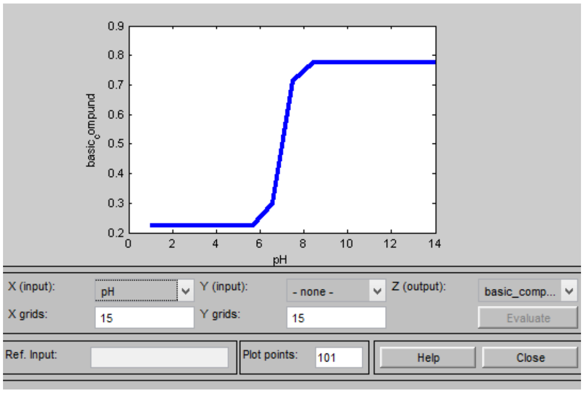

Figure 12 Output surface plot

The surface plot of the input-output relationship is shown in Fig. 12. It is noticed that when the input levels are low, the output levels are also low and then vice versa.

TEST AND RESULTS

The system prototype is tested with the fish and the plants for 1 hour. The sensors are activated and the control mechanisms are enabled. The temperature of the water is maintained at 28ºC. The pH of the water is maintained at 7 and the water level of the system is constantly changing based on the flushing requirement.

The battery is observed to be charging through the solar-panel set-up. The microcontroller that houses the intelligence of the system is working well with the sensors and the relays. Fig. 13 shows the actual system prototype under test.

Figure 13 Actual system prototype

CONCLUSION

Fuzzy logic algorithm is successfully implemented and tested with the developed aquaponics system prototype. The controller smoothly automates the process of maintaining the required temperature, pH and water levels of the water in the basins. Fast response time can be observed in the system because of the ruggedness of the Arduino microcontroller and the simplicity of the FLC codes.

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