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Servo Motor and Ultrasonic Sensor Application in Aquaponic System

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Abstract

Aquaponic is one of the excellent systems that enable agricultural practices and fish farming to be carried out simultaneously. The same water cycle is used to irrigate plants and provide fish with food. The natural evaporation process that happens results in an inadequate amount of water in this system. Also, excessive feeding of fish allows excess food to pollute the quality of the water and clog the system. The development of a Water Evaporation Indicator (WEI) for an aquaponic system using Ultrasonic Sensor HC-SR04 as the main component, along with Arduino UNO, LEDs, and the buzzer is explained in this paper. Furthermore, a Servo Motor Fish Feeder (SMFF) to control fish feeding activities was also created by using DXW90 9G servo motor and Arduino UNO. The outcome of the experiment determines that the application of Ultrasonic Sensor in WEI and Servo Motor in SMFF for the aquaponics system has been able to work effectively.

Key-word: Aquaponic System; Servo motor; Ultrasonic Sensor

1. Introduction

Aquaponics is the combination of aquaculture and hydroponic technology to grow fish and plants together (Filep, 2016). Fish, plants and bacteria are three essential elements in the aqueous system that will form a mutually beneficial relationship or symbiotic mutualism. A grow tray and a reservoir for fish breeding constitute the aquaponic architecture. To irrigate the grow tray and provide nutrients to the plants, a water pump was required. Furthermore, a filter is used to clear the water from solids and biological waste from the reservoir. The aquaponic system design is shown in Fig.1.

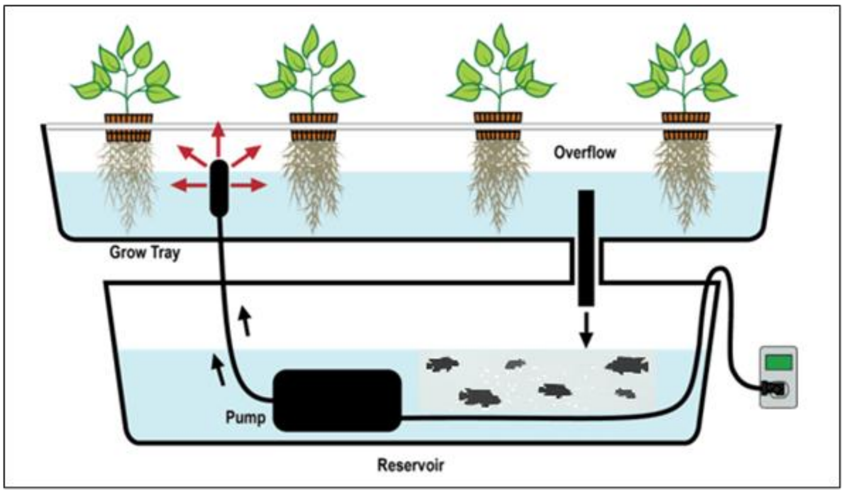


Fig. 1. Aquaponic system design

In an aquaponic system, mineral transfers from aquaculture to hydroponics support efficient nutrient recycling, while water recirculation reduces the water use (Goddek, 2015). Generally, it takes 2000 to 5000 liters of water to produce one person's daily food. In such a situation, a method like aquaponics can contribute effectively to the problem by lowering the amount of water usage for cultivation by 75% to 80% of the area requirement (Khot, 2017). However, water evaporation from the aquaponic system resulted in an increased concentration of substances in the water. Concentration changes in the reservoir environment would harm the fish since they are accustomed to nature, wherein they live. In order to bring about a corresponding constancy of the environmental conditions in the reservoir, it would be necessary to replace the evaporated quantities of water continuously. Therefore, an indicator has to be developed to notify consumers if the water decreased below the specified level due to the water evaporation process.

Excessive fish foods in aquaculture will contaminate or pollute water (Y.Lin, 2019). The fish appear to produce 0.25 kilograms of solids in the water for the absorption of feed per kilogram. The accumulation of fish excreta will create a toxic environment for the growth of fish in a short time, which will eventually lead to the blockage of the system and disturb the flow rate of water, resulting in an unstable system (Y.Wei,2019). In order to maintain water quality and prevent clogging in the aquaponic system, automatic fish feeders which can set the period and quantity of the food are therefore created.

The purpose of this study is to create and evaluate a Water Evaporation Indicator (WEI) by using an aquaponic system's HC-SR04 Ultrasonic Sensor to detect the critical water level caused by the process of water evaporation and then notify the owner via an alert mechanism to add water. Servo Motor Fish Feeder (SMFF) will also be established and evaluate in this study to control fish feeding activities based on the required quantity of fish food and specify the duration to prevent excessive that could cause water pollution and clog in the aquaponic system.

2. Problem Statement

i. Difficulties in the detection of critical water levels caused by the natural water evaporation process in the aquaponic system.

ii. Excessive fish food may create a toxic environment for the growth of fish, lead to blockages and interrupt the flow of water in the aquaponic system.

3. Objective

i. To create and evaluate a Water Evaporation Indicator (WEI) by using HC-SR04 Ultrasonic Sensor to detect the critical water level and then notify the owner via an alert mechanism.

ii. To monitor the fish feeding activities on the basis of the necessary quantity of fish food and specify the duration to avoid excess by developing a servo motor operated fish feeder.

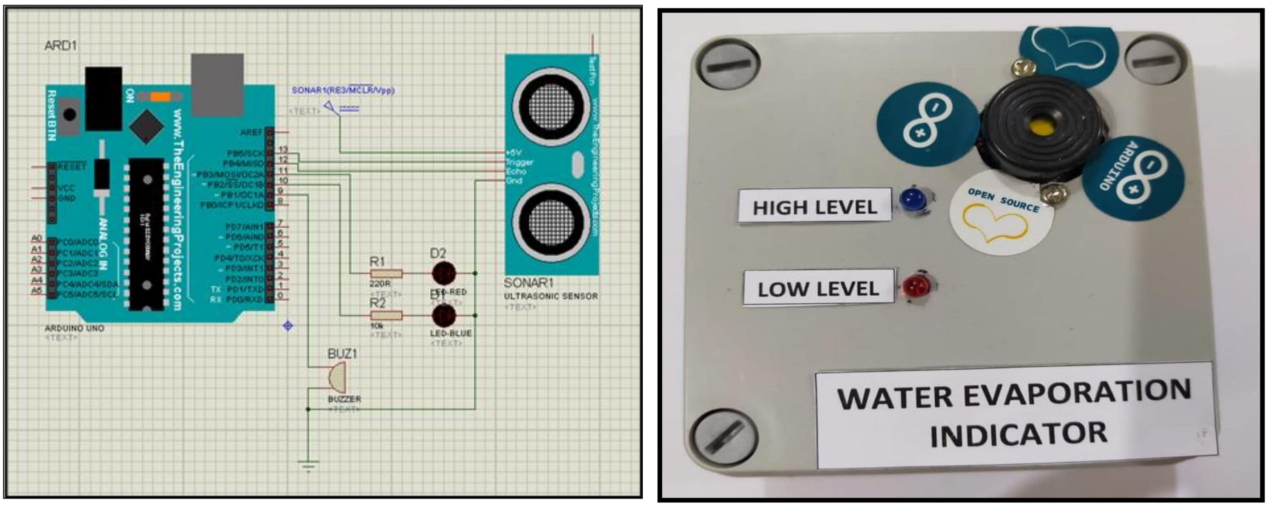
4. Methodology

The developed aquaponic system consists of two main parts which are Water Evaporation Indicator (WEI) and Servo Motor Fish Feeder (SMFF).

4.1 Water Evaporation Indicator (WEI).

The WEI was constructed by using an Arduino, HC-SR04 Ultrasonic sensor, LEDs and a buzzer. Fig. 2a and Fig. 2b displays, respectively the circuit and the design of WEI. According to the aquaponic model developed in Fig. 3, it is possible to change the distance between the ultrasonic sensor and the water surface between 3 cm and 19 cm. The distances were described in the Arduino command sketch. For example, when the distance between the ultrasonic sensor and the water surface is smaller or equal to 3 cm, the blue LED will light up and the buzzer will sound off. However the red LED will turn on and the buzzer will sound when the distance is greater than 3 cm.It will then inform the user to add the water via an alert mechanism as guided by the command below :

```
 if (distance <= 3)
{                                          // This is where the LED On/Off happens
 digitalWrite(blueLed,HIGH);       // Led blue ON
 digitalWrite(redLed,LOW);                 // Led red OFF
 digitalWrite(buzzer,LOW);                 // buzzer OFF
}
 else
{
   digitalWrite(blueLed,LOW);      //LED blue OFF
   digitalWrite(redLed,HIGH);      //LED red ON
   digitalWrite(buzzer,HIGH);      // buzzer ON
 }
```



a b

Fig.2. Water Evaporation Indicator (a) circuit (b) design

By facing the water surface at a 90 ° angle, the ultrasonic sensor emits acoustic waves at a high frequency (20-200kHz). The emitted waves strike the liquid to be measured, and reflected back to the sensor. The level of water is determined from the time difference between the emission and the acoustic waves' reflection. To assess the efficacy of the WEI in the aquaponic system, different distances were measured.

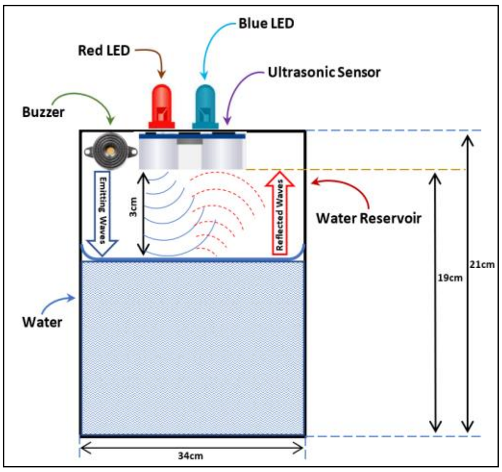
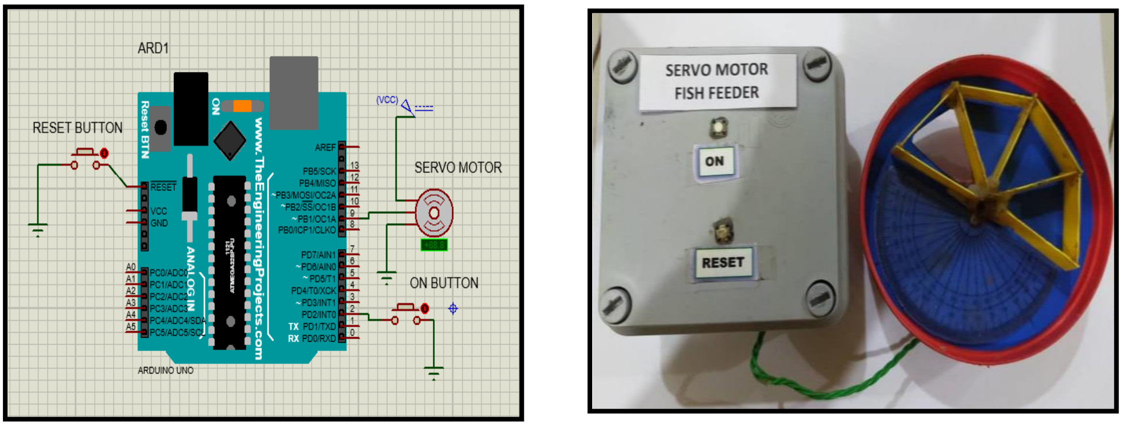


Fig.3. Water Evaporation Indicator position in the aquaponic system.

4.2 Servo Motor Fish Feeder (SMFF).

Arduino UNO and DXW90 9G servo motors were used to create the SMFF. A servo motor is defined as an actuator with the ability to be precisely controlled in terms of rotational and angular position (Sadun, 2015). To rotate the feeder tray, the servo motor output shaft can be operated to rotate in the angular range of 0 to 180 degrees. The angle and delay are based on the sketch of the Arduino that was developed. Fig. 4a indicates the circuit and Fig. 4b indicates the SMFF design.



a b

Fig. 4. Servo Motor Fish Feeder (a) circuit (b) design

5. Result

5.1 Design Consideration.

The aquaponic system structure, which combines aquaculture and hydroponic elements, is shown in Fig.5. The aquaculture components consist of a 34 cm (L) x 16 cm (W) x 21 cm (H) water reservoir, resulting in a total volume of 11,424 cm3. The hydroponic components consist of a 28 cm(L) x 23 cm(W) x 8 cm(H) growth tray, resulting in a total volume of 5,152 cm^3. To irrigate the growth tray and provide nutrients to the plants, the 35 Watt, 240 Vac water pump was used. Water was transferred via an overflow tube from the grow tray into the water reservoir.

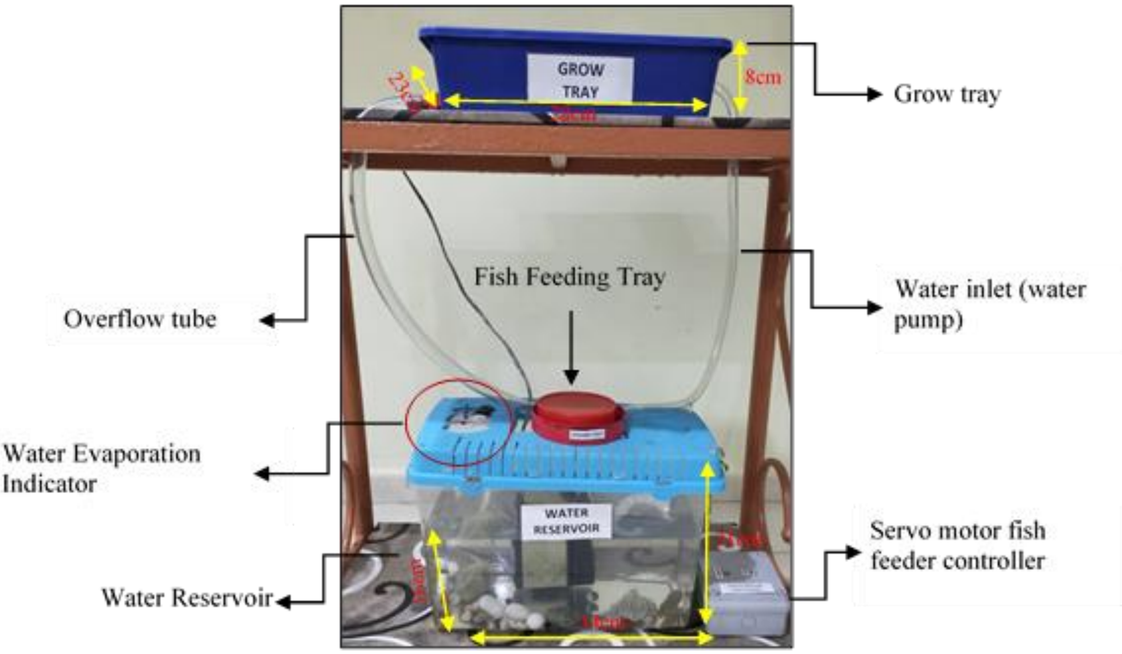


Fig. 5. Aquaponic system construction

5.2 The Water Evaporation Indicator (WEI) result.

The chart in Fig.6 demonstrates the outcome of distance testing for the WEI. The x-axis refers to the diagram showing the theoretical and experimental distances between the ultrasonic sensor and the water surface, measured using various distances in the 3 cm to 19 cm range, while The y-axis refers to the diagram showing the distances between the ultrasonic sensor and the water surface, both theoretical and experimental. In the experiment, a 0 to 6.67 percent error occurred and it can be measured using the equation Eq.1

$$Error\ (\%) = \frac{|Experimental\ value - Theoretical\ value|}{Theoretical\ value} \tag{1}$$

The accuracy of the ultrasonic sensor in WEI is influenced by several factors such as ambient temperature, the propagation path of the signal, the angle of incidence wave and the shape or the size of the object (Zhmud, 2018). Referring to Koval (2016), the speed of sound in the ultrasonic sensor is dependent on the type of environment in which it moves and the current temperature. However, small errors due to these factors still allow the WEI to work properly.

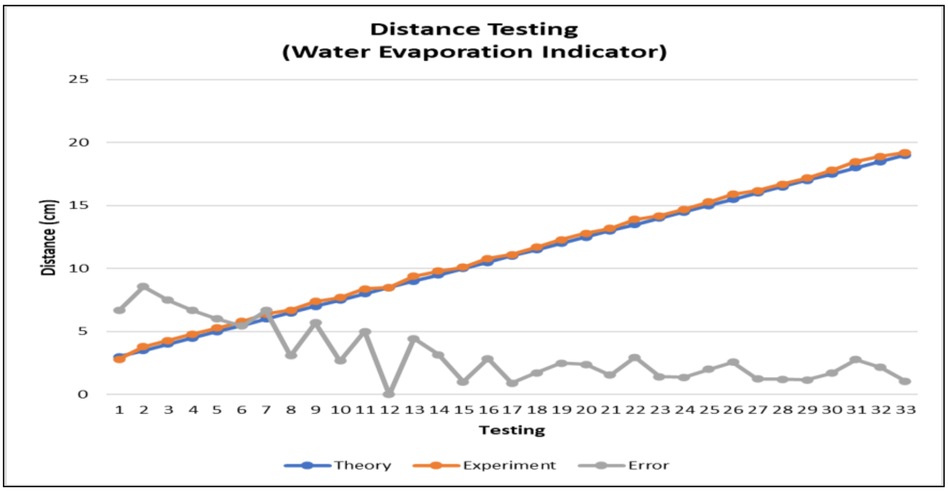


Fig. 6. Distance testing result for Water Evaluation Indicator

5.3 The Servo Motor Fish Feeder (SMFF) results.

In order to verify the servo motor feature at each of the rotation angles, the SMFF testing was performed. The x-axis represents the 1st to 5th rotation, while the theoretical and experimental angle value is expressed by the y-axis. It can be observed that the servo motor operates successfully by generating five angles of rotation. However, as shown in Fig.7, the angle of the experiment is significantly greater relative to the theoretical angle. Despite the outcome in Table1, the percentage error in the 0-4.44 percent range is seen.

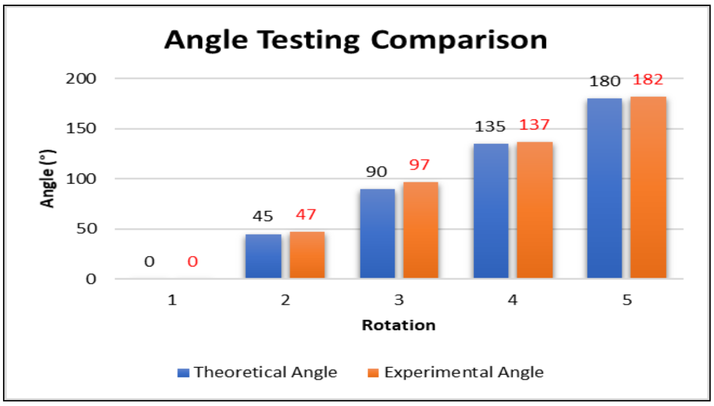


Fig. 7. Angle Testing Comparison Chart

Table 1. Angle Testing Comparison Result

No	Angle (°)		Error	
	Theory	**Experiment**	**Degree (°)**	**Percentage (%)**
1	0	0	0	0
2	45	47	2	4.44
3	90	97	7	2.22
4	135	137	2	1.48
5	180	182	2	1.11

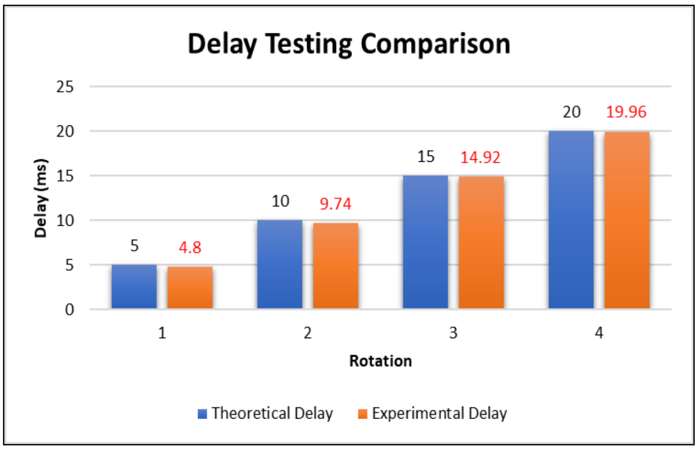


Fig. 8. Delay Testing Comparison Chart

Table 2. Delay Testing Comparison Result

No	Delay(ms)		Error	
	Theory	**Experiment**	**Delay (ms)**	**Percentage (%)**
1	5	4.80	0.2	4
2	10	9.74	0.26	2.6
3	15	14.92	0.08	5.3
4	20	19.96	0.04	0.2

To track the dosage of the feed as required, delay testing is performed. The delay value is directly proportional to the feed's weight coming out. The bigger amount of food will released by the higher delay value. In aquaculture, as described in the introduction section, excessive fish food can contaminate the water. The SMFF delay research relation between the theoretical value and the experimental outcome is shown in Fig.8 and Table 2. The x-axis represents the rotation from 1st to 5th, while the y-axis represents theoretical and practical delay measurement. Referring to the outcome, it shown that the delay time taken in the experiment to reach the desired angles is nearly similar to the theory. The small percentage of 0.2 percent to 4 percent errors is still acceptable.

6. Conclusion

The application of the Ultrasonic Sensor in the Aquaponic system can be demonstrated by the creation of WEI, which is seen as the ability to indicate water loss due to the natural evaporation process, thus effectively warning the consumer to add water to the reservoir. In addition, through the production of MSFF, which can monitor water quality by effectively restricting and scheduling food feeding activities, the application of the servo motor can be clearly seen. Ultrasonic Sensor application in the Aquaponic system can be shown through the development of WEI, which is seen as the ability to indicate the water loss due to the natural evaporation process, thus successfully warning the user to add water into the reservoir.

The MSFF rotary angle and delay must be set by the user in this study by editing the Arduino sketch. It is ideal if the device has its own external part for editing, such as using a keyboard as an additional technique. In addition, to optimize and improve the MSFF output in the next project, the use of a 360 ° continuous rotation servo motor is suggested.

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