Using IoT for the Smart and Sustainable IBC Aquaponics System

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Abstract— **The International Bulk Container (IBC) Aquaponics system is one of the most popular systems in today's urban-farming for producing foods, such as leafy vegetable and fishes. The term consists of the words 'Hydroponics' and 'Aquaculture' to refer to the use of the IBC as a recycled raising fish tank and a plant grow bed in the way of sustainable circulation system. However, Aquaponics system has been difficult in the way of handling because of variants such as temperature control for general users. Therefore, in this study, the information system and its management were combined: firstly, to collect and transmit values of conditions in the system; and secondly, to design and develop an automated cooling water temperature into the smart and sustainable system. For the economic fish raising, for example, Tor douronensis or Pla Pluang Chomphu, a sensitive river fish in higher temperature was studied. Thus, the water temperature control system became the research focus. Our experiment results showed that the efficiency of the smart system, working more than 90% and the effectiveness of the smart system is 1.15 times higher than the normal aquaponics system from the offsprings values. Thus, it can be concluded that the Smart and Sustainable IBC aquaponics system is considerably improved from the normal IBC aquaponics system.**

***Index Terms*— IoT, Smart, Automated, Aquaponics, Pluang Chomphu, Kelah Fish**

I. INTRODUCTION

THE importance of the research focuses on information technology on the Internet of Things (IoT) applied to the Aquaponics system, to improve the efficiency and effectiveness of the system. The system would add value for farmers or users: the ability to grow economic crops such as organic lettuce (Lactuca sativa) and to raise the high valued fish, such as the Semah Mahseer fish (Tor douronensis) or Pla Pluang Chomphu. The primary aim is to improve the efficiency of the information system of the microcontroller units (MCU) to be used as the water temperature automated cooler. Reaching that aim requires the development of the tools which must be efficient, appropriate, and safe for users. With the efficiency of the developed information system, it could reduce users' concerns about the fish living conditions and provide time resources to monitor and support proper growing processes in the system to a higher level of effectiveness.

This paper proposes a smart system of International Bulk Container (IBC) Aquaponics system using IoT. In monitoring the fish nursing system and controlling the water temperature, the system's effectiveness is optimized by efficiently applying electronics system that consists of IoT-based Microcontroller Unit or NodeMCU, data acquisition and transmission, Wi-Fi signal system, cloud servers, and data visualizations.

II. LITERATURE REVIEW

Ahuja, (2011) discusses the extension of agricultural development with the help of Information and Communication Technologies over Internet or Cyber space called 'Cyber Extension,' the convergence of ICT with sustainable agricultural development. In his model, when education ICT converges with Agriculture, it would become a new age of cultivation: to know weather data such as humidity and temperature; to processes fruitful information to farmers.

Patel, et al (2018) proposes that Aquaponics System should be used in sustainable agriculture, extending it with the Internet of Things with the use of NodeMCU, several environment sensors, a Web Server module and coding software. It is reported that the system uses about 30% less energy per industrial crop yield and brings the economic stability to farmer's better quality of life.

Odema, et al (2018) utilize the system interacted by Graphic User Interface (GUI) , which communicates through Modbus Protocols over TCP/IP networks. These are widely used in standard industries. The system and GUI allow user to operate with remote monitoring and configuration.

Gorli & Yamini, (2017) propose that farming would go smart in the future. It is predicted that the future trend would be Internet of Things (IoT). Thus, the shipment of Agricultural IoT Devices, the amount of Open Source IoT inventions are growing every year.

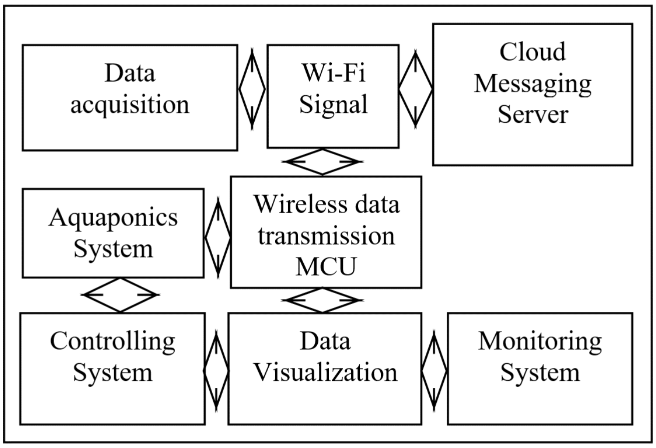

Fig. 1. The Architecture of the system

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III. METHODOLOGY

The study has five steps based on the ADDIE[1] Model.

1) The Analysis

Exploring data: The following resources were explored: related research papers in aquaponics and IoT for agriculture as well as techniques to measure effectiveness of the system and framework in URL or any online paper on internet.

Collecting and categorizing data: In collecting, categorizing and concluding data, we collected the related data and knowledge in both agriculture and agricultural technologies, designing and developing an aquaponics system, measuring tools and an evaluation. Then, they were filtered as specified in the research method.

2) The Design.

Designing the experimental parameters: These served as the sensor parts of the system. There were important parameters for a Smart Aquaponics System, such as light luminance, water temperature, air humidity or moisture, electro-conductivity (E.C.) or fertility, pH, and dissolved Oxygen (D.O.) of water.

Designing the evaluation: This was the evaluation of the results of products from both Smart Aquaponics Systems and Normal Aquaponics System. There were comparable values of survival rate, weight and size from counting, and scaling with standard measurement tools. Then, a result table was constructed for the experiment.

TABLE I
DIFFERENCES IN AQUAPONICS SYSTEMS

Aquaponics System / **Parameter**	***Normal***	***Smart***	***Automatic***
Dissolved Oxygen (D.O.)	Suitable Air Pump	High Power Air Pump	D.O. Probe with Value Detect Module[a]
Light Luminance	-	Wheels	Light Sensor with Artificial light
Temperature	-	Temperature sensor with Visualization	Cooler or Heater
Potential of H^+ (pH)	-	Litmus or pH paper test	pH Probe with Value Detect Module
Electro Conductivity (E.C.)	-	Add-up fertilizer	E.C. Probe with Value Detect Module
Humidity	Watering Pump	Suitable Water Pumping Design	Humidity Sensor with Solenoid Pump

[a]A Module needed for every sensor probe for detection.

Fig. 2. The Smart Aquaponics was based on NodeMCU transmitting to display at least one value and the Automated Aquaponics was based on using an automatic system through NodeMCU controlling at least one variable.

3) The Development

The Aquaponics Systems classification: For the experimental parameters chosen, three different Aquaponics System tables were developed as follows.

Smart and Automated System development: The International Bulk Container (IBC) Aquaponics System was originally designed for the Smart Aquaponics System. The system consists of an electronic box in front, and inside the box, with the Water Temperature sensor DS18b20 combined with NodeMCU. For the water temperature cooling system, liquid coolers were utilized with electric controlling wires to the MCU and a liquid wire to the tank's pump. When water temperature dropped to the degree set by the configuration setting, the liquid coolers would stop working. When the temperature rose up to the configuration setting, the liquid coolers would begin to work again.

Information System development: In order to control the NodeMCU to power the cooling system and to monitor through the water temperature sensor, it was compiled or burned with database in Arduino IDE. With the Firebase Server, the NodeMCU was able to transmit data through TCP/IP or Internet network.

Application development: From the Firebase that collected the data from the NodeMCU, the data was prompted to an application.

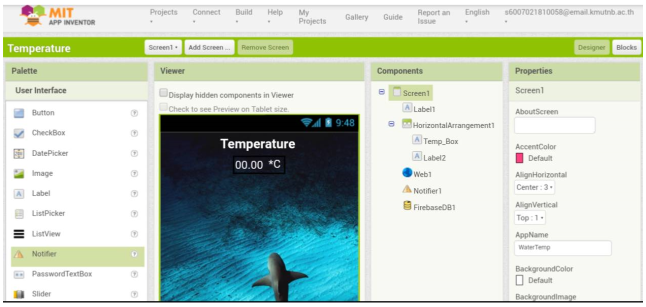

Fig. 3. Creating the Water Temperature Application with MIT's App Inventor, the mobile phone OS app creator by MIT Labs.

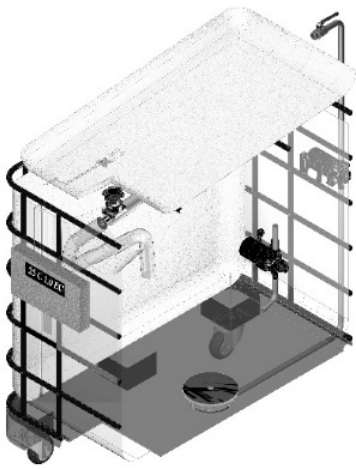

Fig. 4. The 3D print of the developed IBC Smart Aquaponics System model. It consists of a fish tank, a grow bed, suitable aerations, LED and the NodeMCU.

4) The Implementation

The NodeMCU and related sensors were applied to IBC Aquaponics System inside the waterproof box in front of the model. With the coded or compiled NodeMCU, it would be able to transmit with Firebase Cloud Messaging Server that would send data to the application. When the others were in proper position such as the aerations and the camera, the system acquired power resources from either home electricity or solar panel. The system was then checked and recorded.

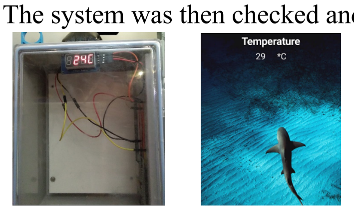

Fig. 5. The LED and Application showing transmitted data from the system.

[1]ADDIE is an instructional systems design framework consisted of five major phases: Analysis, Design, Development, Implement and Evaluation. (Schlegel, 1995)

5) The Evaluations

The electronic system was evaluated on its performance. It should precisely work equal to or over 90 percent.

The Evaluation was conducted on both systems: Normal Aquaponics System and the Smart Aquaponics System. Data on fish survival rate, weights and sizes was calculated with the application of the following equation:

$$E = \frac{A}{O} \tag{1}$$

When E is an effectiveness, A is an average value of the growth kelah fishes and O is an average value of the offspring. With the means and the standard deviations of starting offsprings and full-grown fishes, a table was constructed to record average weight, average size and survival rate. Then, an effectiveness of each value was studied, to compare the different values between the Smart Aquaponics and normal Aquaponics Systems.

The water temperature cooling system and high power air pump eliminated concern about water temperature and, consequently dissolved oxygen. The monthly pH check with pH paper test and filling water was done to maintain the conditions of living in the Smart Aquaponics system, as well as the water temperature at around 24 - 26°C. Because of the 10 Kelah fishes as experimental group, the water temperature should be from 18°C to 26°C according to the Kelah fish research in fishbase.se database website. On the other hand, 10 Kelah fishes in normal aquaponics system were treated as the controlled group. Ten months later with equal feeding, the following is the result of total 20 Kelah fishes in the study.

TABLE II
TEN MONTHS EXPERIMENTAL RESULTS LOG

Value / **No.**	***Length of Kelahs in Normal Aquaponics (c.m.)***	***Length of Kelahs in the Smart Aquaponics (c.m.)***	***Weight of Kelahs in Normal Aquaponics (g.)***	***Weight of Kelahs in the Smart Aquaponics (g.)***
	Oct. 2019	***Oct. 2019***	***Oct. 2019***	***Oct. 2019***
1.	13.7	14.0	23	26
2.	13.5	13.7	22	25
3.	13.2	13.3	22	25
4.	13.0	13.2	21	24
5.	12.7	13.0	21	24
6.	12.7	13.0	20	23
7.	12.4	12.7	18	23
8.	12.0	12.7	16	22
9.	10.7	12.5	13	21
10.	10.7	12.5	12	19

Fig. 6. The experimental log was from January 1st to October 31th, 2019

IV. RESULT

The average of the equation and the data log yields average values in a normal and the Smart Aquaponics as presented in Table III.

TABLE III
OVERALL VALUE OF THE EXPERIMENT

No.	**Values of Kelah Fish**		
	Survival rate (%)	***Avg. weight (g)***	***Avg. size (c.m.)***
1. The Normal System	99.8	18.8	12.5
2. The Smart System	99.9	23.2	13.1
3. The offsprings	-	2.0	5.3

Fig. 7. The average values table represents the higher average values of the Smart System in both weight and size when compared with the normal one.

The green vegetables in the experiment was treated as indistinctive byproduct, whereas E.C. and pH values were varied according to the disposals in the systems. However, the acidity did not harm living things when it exceeded the highest value within the ten months. During that time, water was added to dilute the acidity and to substitute the used and evaporated water. The experiment outcomes reveal that the overall systems worked more than 90 percent efficiently during the experiment and the effectiveness of the Smart System is 1.15 times for the equally selected offsprings than the normal system. However, the development of the full Smart Aquaponics System is still needed to ensure significant value finding in such research because it is not possible with the researchers' fund alone. Thus, the future work of the research could be worth in building an Automated Aquaponics System in luminance, pH and electro-conductivity controls with renewable energy resources.

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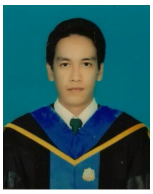

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