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Innovation IoT Solutions for Economic Animal Propagation Using Raspberry Pi Boards

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ABSTRACT

With the expansion of IoT platforms for smart livestock farming applications and their application to agriculture, farmers are becoming more interested. This research paper presents innovative IoT solutions for the economic propagation of animals using Raspberry Pi boards. This research has two main objectives (1) design and build a cooling system that continuously controls the temperature between 8-20 degrees Celsius and controls the oxygen content in the water between 4-8 mg/L. This control uses IOT technology to control the sending and receiving of data with the Raspberry Pi board. (2) The experimental cultivation of Chinese mitten crab in a traditional cold pond was compared to that of a new type of culture pond. The design and creation of the Chinese mitten crab culture pond and the use of IOT technology to control data transmission with Raspberry Pi boards together with temperature and oxygen sensor devices. Culture ponds have been found to cause eddy water and cause sewage and suspensions to be collected in the center of the pond and removed for their intended purpose. The design of the cooling system showed that the temperature and oxygen in the culture pond can be controlled according to its purpose. Similarly, the use of IOT technology to control the operation of temperature and oxygen sensor devices can be controlled with Raspberry Pi boards, which are ready to send and receive data via a Web server in RaspPi, and alarms can be displayed on computers and LINE applications with satisfactory results. Evaluation and experimental cultivation of Chinese mitten crab in a traditional cold pond compared to a new type of culture pond designed and created. Eighty male and 80 female Chinese mitten crabs that were one week old in a culture pond with a 1- to 6-week cycle of traditional culture had an average survival rate of 79.17%, and those in the new type of pond culture had an average survival rate of 89.58%. The evaluation also revealed that male crabs have a higher survival rate than female crabs and have a satisfactory, reliable, and objective growth rate.

1. INTRODUCTION

IoT solutions for economic animal propagation using Raspberry Pi boards are a subject that has been comprehensively researched and is an urgent research topic [1, 2]. Breeding work is one of the most important tasks on farms and determines the quantity and quality of animal products; therefore, over the years, many breeding technologies have been developed and applied [3-5]. As a fantastic multiple agent system, IoT technology brings science and technology to breeding work. Breeding work is more intelligent, digital and information intensive, so researchers in animal breeding and genetics are shifting research from breeding methodology development to breeding information system development [6, 7]. With the rapid popularization of IoT technology, an increasing amount of breeding information system hardware will be used to construct the infrastructure of the breeding IoT world. With advances in information technology, breeding experts will have the chance to observe the behaviors and survival of each animal; therefore, breeding work will step into a new and modern world [8, 9]. Despite these challenges, the future of the IoT breeding world is promising for scientists and, most importantly, for animal welfare. It is well known that in traditional methods of animal monitoring, the observer must look at the animals for a long time, or the observer may use the CCTV to help the observation, but this moves the problem to the monitor [10-12]. However, some species, such as rabbits, have the habit and behavior of hiding away, which makes head counting difficult. We are thankful for the modern GPS technology. RFID chips, which are embedded underneath animal skins, can provide information on the exact location, time and date of the animal [13, 14]. As the data will be captured by the readers who are distributed everywhere on the farm, the time series data for each animal can be collected, and the habit and health can be monitored throughout the day. This is definitely a great help for animal survival, especially for sick animals. It is well established that environmental factors and gene types play a very important role in animal development and health. Researchers are trying to identify the most efficient methods for monitoring and analyzing these factors to reduce the mortality rate of newborn animals. The most common and effective way is to record the locations and changes in environmental factors, such as temperature, humidity and weather [15, 16]. However, these records could be time consuming and less accurate, so there is a rising demand for the development of automatic environmental monitoring systems. Using IoT technology, environmental monitoring data can be wirelessly transmitted to a database, and researchers can simply query the data for analysis by using a computer. Additionally, with the advancement of the cloud computing system and big data analysis technology, researchers can use the molecular information of each animal to provide superior and critical genetic analysis [17-19]. With a cost of approximately 35 euros each, the deployment of boards is cost effective and hence brings no financial barriers to any farms, whether small or large. According to the research, commercial farms and animal research centers have adopted single board computers for animal monitoring [20, 21]. This is quite certain that we are at a very early stage of these technologies, but their long-term prospects are clear [22, 23]. These works will provide not only a more cost-efficient and effective animal monitoring solution, but also a completely modern working environment for breeders and geneticists. The small size and zero electrical noise of a single -board computer are advantages for field work.

The relevant literature describes the use of IoTs for animal tracking and observation of animal growth life cycles to analyze animal genetics, inside those animals. The research paper presented here introduces a new Internet of Things (IoT) solution for the Raspberry Pi board based on the economic propagation of animals. The economic animal used for this research was an aquatic animal named a Chinese mitten crab or a Shanghai crab whose scientific name is Eriocheir sinensis. This animal has a life cycle and lives in lakes with clean water and extremely cold water temperatures below 10 degrees Celsius. During the mating season, they migrate to breed and lay eggs in lakes or sand lands at the end of each year because they have the right temperature for breeding. For Thailand, the Doi Inthanon Royal Project Foundation brought crab breeders to Shanghai City, The People's Republic of China, for experimental farming. Experiments carried out in cold ponds at temperatures below 10 degrees Celsius showed that the growth rate did not achieve the desired purpose. The following year, it was assigned to the Bangpakong Centre of the Department of Fisheries, Chachoengsao Province. They were reared in areas with a mixture of seawater and freshwater, which is brackish water, and the temperature in open ponds was controlled to be cold enough to grow, but it was found that the survival rate of crabs in nursery ponds was not successful. Therefore, the research team has developed and designed a crab culture pond, which appropriately controls the temperature and oxygen in the pond, to monitor and control the operation of the cooling system through IOT. Therefore, the principles and methodologies of the research team have developed and designed a Chinese mitten crab pond by maintaining a stable and appropriate temperature and oxygen in the pond to monitor and control the operation of the cooling system through IoT technology. However, the next section explains the principles and methodologies for further research.

2. METHODOLOGY

Modern technological advances in the form of the Internet of Things (IoT) are being used worldwide to create animal propagation facilities. With so many solutions, beginner-friendly tutorials, and commercials available, it can be daunting to navigate these options and make informed decisions. The purpose of this research paper is (1) to design and create a cooling system that keeps the temperature constant at 8-20°C and controls the oxygen content in the water with sensors at 4-8 mg/L using IOT technology controlled by a Raspberry Pi board. (2) Experiments with cultivation of Chinese mitten crabs were carried out in an open cold pond with a traditional pond layout compared to a new type of culture pond. The next subsection describes the implementation of IoT technology that controls the use of Raspberry Pi boards, the design of new culture ponds, and the installation of temperature and oxygen sensors in the culture ponds as follows.

2.1 IoT solutions for breeding Chinese mitten crabs

Thai government policies and modernization support to modernize the animal propagation industry using IoT solutions. Therefore, it is worth studying how the IoT can be adapted and applied in the context of Thai economic animal propagation. Currently, there are five national research stations, excluding the research stations of various royal projects that exist throughout the country, specializing in the study of animal genetics and breeding to enhance the propagation of different economic species. In addition to these research stations, there are several large-scale privately owned animal breeding farms. The innovative IoT solution presented in this research uses water and oxygen control technology in a closed pond designed with Raspberry Pi boards and aimed at breeding Chinese mitten crabs, an economic animal in Thailand and around the world. This research also explains the continuous use of real-time data from wireless sensors integrated into the animal propagation process with a pattern of using IoT solutions in conjunction with Raspberry Pi boards, as shown in Figure 1.

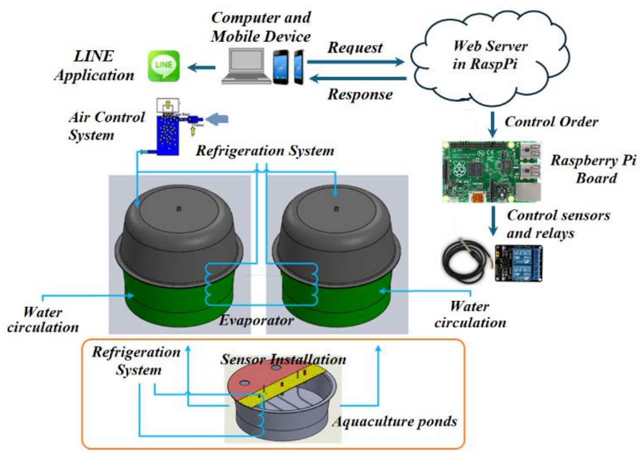


Figure 1. Overview of the working process of IoT technology

As shown in Figure 1, an overview of the IoT process will display the working status through the LIEN application with computer and smartphones devices, connect the Big Data request and response through the Raspberry Pi web server, and send signal communication to control the measurement order of the sensor, temperature, and oxygen through the Raspberry Pi control board. This data communication signal controls the operation of the water pump and the water circulation in the newly designed closed culture pond, as shown in Figure 2 (a), where the original culture pond has an open form, as shown in Figure 2 (b). However, in Figure 2 (b), temperature and oxygen cannot be stabilized, and only water circulation can be controlled. likewise, Figure 2 (a) shows that the design of the new culture pond will be a closed pond, which will allow the temperature and oxygen in the pond to be controlled for the intended purpose and can also control the operation of the water pump and water circulation.

(a) (b)

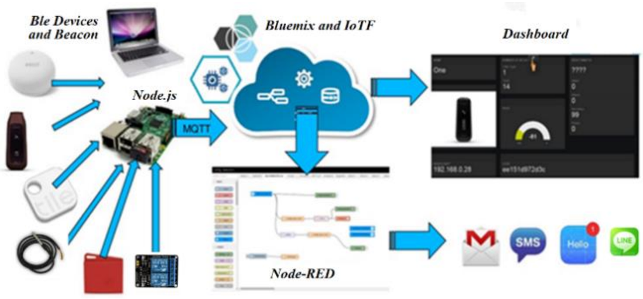
Figure 2. Old and new Chinese mitten crab aquaculture ponds

2.2 Raspberry Pi board technology

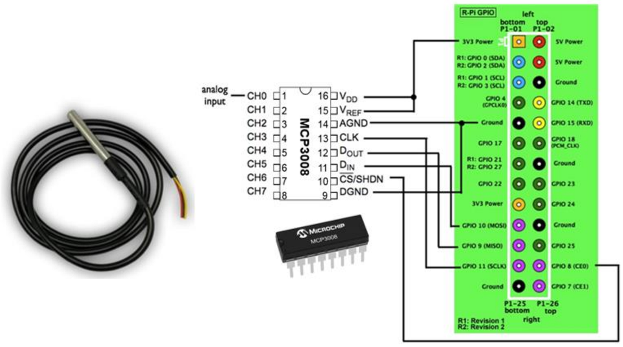
The Raspberry Pi is similar to a small computer that can write simple programs. Instant control. Raspberry Pi is a bare integrated circuit board that clearly sees all the parts that are computer components. Raspberry Pi board technology can support Linux, Android, and Windows10 IOT operating systems installed on SD cards. This Raspberry Pi board is designed to have a CPU, GPU, and RAM within the same chip. This research will be used in conjunction with temperature sensor equipment and oxygen sensor devices. The technical characteristics of the Raspberry Pi board are currently available in several models, all of which have similar technical characteristics and may differ only partially. However, for Raspberry Pi boards, as shown in Figure 3 (a), the arrangement of the GPIO's legs is free; the function can be selected as input or output. To control the logic emitted externally, the mode is selected as the output. To read the incoming logic value, the input is selected. Similarly, for the modes on Raspberry Pi, a voltage of 0 V is used instead of a Logic 0, and a voltage of 3.3 V is used instead of a Logic 1. This Raspberry Pi has a maximum GPIO input voltage of 3.3 V. If the input voltage is exceeded, it may damage the Raspberry Pi. For this research, it will be used in conjunction with temperature sensor devices and oxygen sensor devices selected as input modes. Figure 3 (b) For the water temperature sensor device, this research uses the DS18B20 model to measure water temperature and oxygen using the HI9147 model by analog-to-digital signal conversion and provides large amounts of water and oxygen temperature data within the Chinese mitten crab breeding pond.

2.3 MQTT message queuing telemetry transport

MQTT is a protocol designed for machine-to-machine connections. Similarly, it is designed to support the IoT, a technology in which the internet connects to different devices, including smartphones and Raspberry Pi, among others. It makes it possible to connect devices together over the internet and is also designed for use with small electronic devices and small network traffic. The design in this research uses the Publisher/Subscriber principle and has an intermediary called Broker, which is an intermediary for managing data from Publisher and Subscriber by configuring the MQTT Protocol, as shown in Table 1.



(a)



(b)

Figure 3. Node-RED runs on node.js

Table 1. Configuration of the MQTT protocol

MQTT Protocol Constituents	Main Functions
Broker	It is an intermediary to manage quotes from Topic using the following links: 1. Iot.eclipse.org Port 1883 2. broker.hivemq.com Port 1883 3. test.mosquitto.org Port 1883
Publisher	Send data to Topic
Subscribe	Change message information that references Topic
QoS	Data Transmission QoS0 = Single data transmission QoS1 = Sending data only once and remembering the last submitted data QoS2 = Sending data to the destination can receive the data

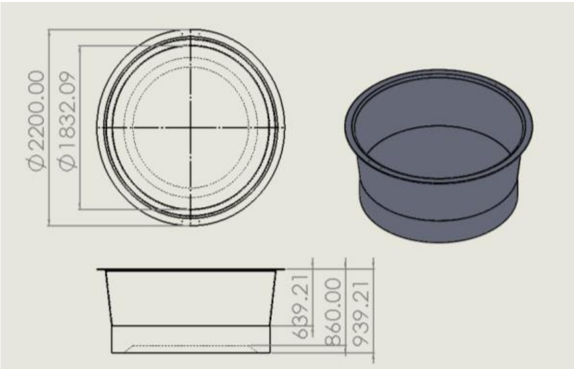
2.4 Node-RED server configuration

With the use of IoT technology, the establishment of MQTT servers has become essential to facilitate communication between devices of the IoT. Many IoT devices require Internet monitoring and control. However, without adequate protection, these devices are still vulnerable to attacks from individuals around the world. However, devices can communicate through different channels. In addition, the Node-RED server allows data to be exchanged in several ways. In this research, Node-RED servers are defined as recipients and transmit and retrieve data from the Web and the LINE applications. However, there are several limitations to its configuration and settings, so this research uses MQTT servers through the Secure Sockets Layer (SSL), which is a secure means of communication over the Internet. To configure the data function, the SSL encrypted client connection is accepted, and the mosquitoto.conf line is added to those files.

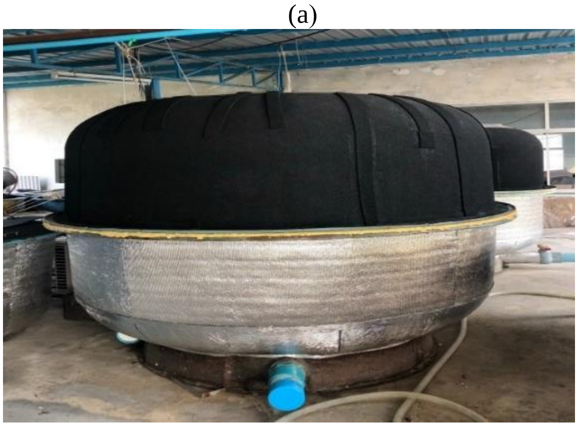
2.5 Design of breeding ponds for Chinese mitten crabs

The design of the lobster breeding pond of this research is based on the principle of circulating water in the culture pond with the pressure of water flowing into the breeding pond. Therefore, the design is cylindrical in shape to achieve good water circulation, as shown in Figure 4 (a) and (b).

It also causes suspension and an organic matter phenomenon that occurs because the sewage contained in the water is concentrated at the midpoint at the bottom of the well to discharge as much as possible and as quickly as possible. The diagram and structure of the prototype pond for this research are shown in Figures 4 (a), (b) and (c).



(a)



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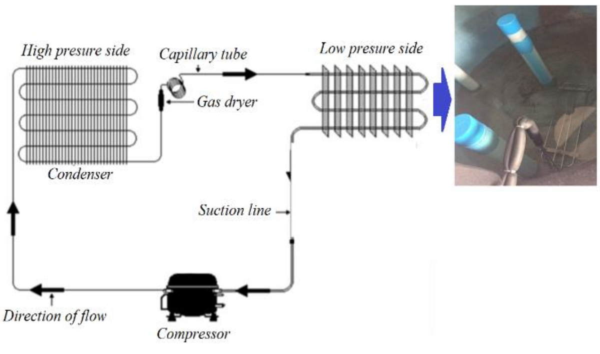


(c)

Figure 4. Design of a prototype pond for Chinese mitten crab culture

Based on the data presented in Figure 4, this constructed culture pond is designed to cultivate Chinese mitten crabs. The structure inside the pond is equipped with two types of sensors, consisting of a temperature sensor and an oxygen control sensor in the water. It has been strategically laid out to be consistent with the objectives and standards given. Similarly, the arrangement of sensors used to maintain the temperature in the culture pond to the optimum level, as shown in Figure 4 (c), shows the cooling system design of the prototype culture pond. However, this master pond was a closed culture pond, as shown in Figure 4 (b). The upper cover is covered with insulation to maintain a constant and consistent temperature. However, this research focused on the application of innovative IoT technology to enhance the cultivation of Chinese mitten crabs through the use of Raspberry Pi boards. As a result, diagrams of the design and creation of IoT connectivity applications, including LINE applications, are discussed.

Figure 5 shows the compatibility diagram of the Raspberry Pi board with various sensor devices. The diagram consists of several components, the first of which is a Raspberry Pi board that is used to control the temperature and oxygen level in the culture pond. The second part uses an MCP3008 microchip, which is an 8-channel analog-to-digital signal conversion IC with a resolution of 10 bits. This second part serves to obtain analog temperature and oxygen data and convert them into digital data. These digital signals are fed into the Raspberry Pi board GPIO to be stored as data, after which the results are displayed.

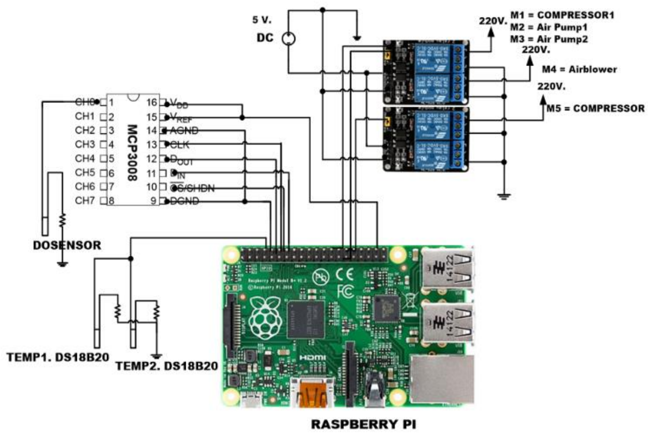
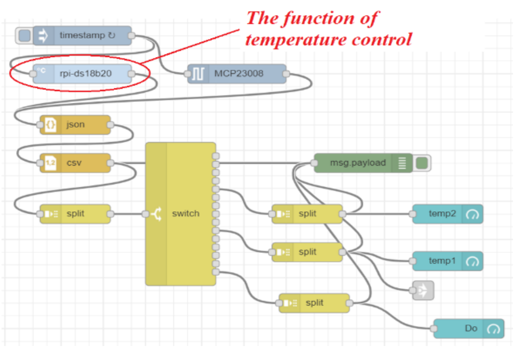


Figure 5. The synchronization process with aid of sensors and microcontroller boards

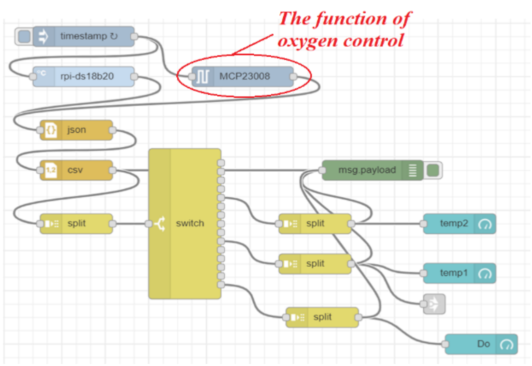
The control function can be divided into two functions, consisting of a temperature control function and an oxygen control function, as shown in Figures 6 (a) and (b).

Figures 6 (a) and (b) show the temperature and oxygen control functions. The function in this section takes commands from the user, which receives commands from the web browser to NETPIE, as the management component. This management section is programming created with the language Node jp. and Node RED of the raspberry board to enable the control function to work according to the configured conditions.

However, the Raspberry Pi temperature and oxygen control provides flexibility to modify the temperature and oxygen according to the user's needs, as shown in Figures 7 (a) and (b).

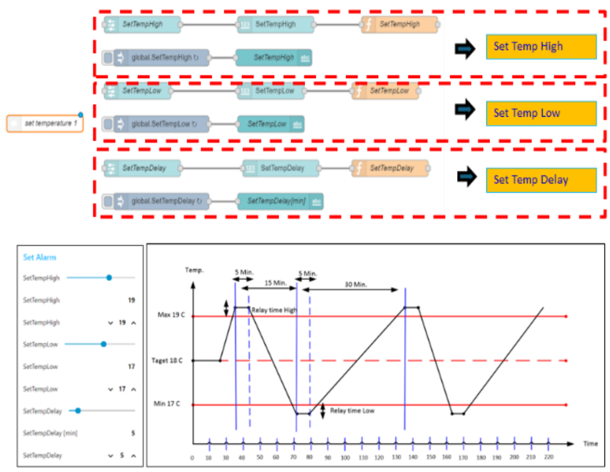


(a)

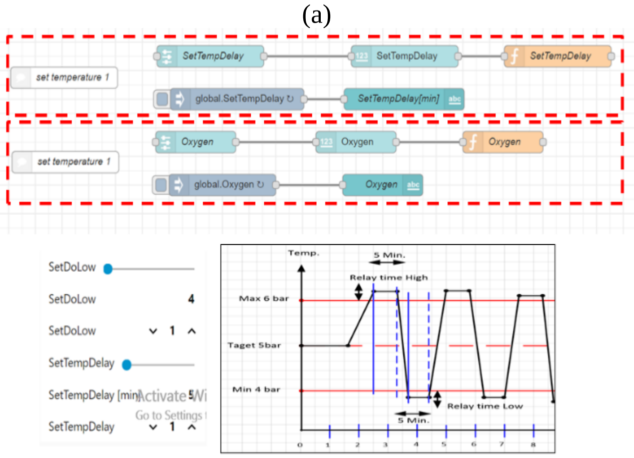


(b)

Figure 6. Creating temperature and oxygen regulation capabilities utilizing Raspberry Pi



(a)



(b)

Figure 7. Altering the temperature and oxygen value as per the requirements

Figure 7 shows the temperature and oxygen change range, which can be configured according to the needs. This configuration uses programming developed with Node jp. and Node RED language. This program update uses relay control methods to work according to the user requirements. However, the relay will start working according to the actuation of the defined function, which will cause the current flow in the electrical circuit for the chiller to work and result in a temperature control system. The oxygen content sensor can control the temperature of the water and oxygen according to the user's needs. However, if the user wants to enable or disable it manually, the user can do so. The output control status can be displayed as shown in Figure 8.

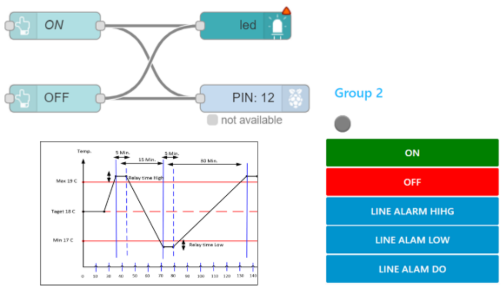
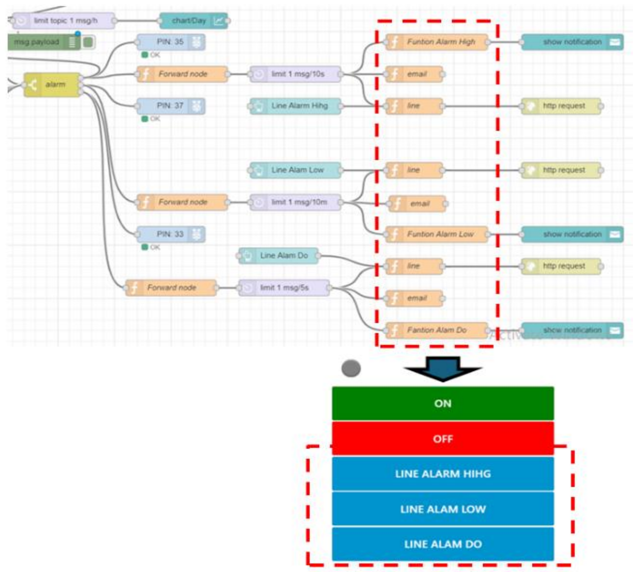
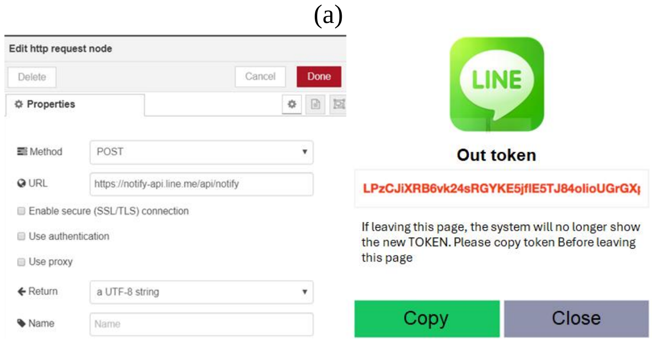


Figure 8. Manually enable or disable control



(a)



(b)

Figure 9. The LINE application interface

Similarly, Figures 9 (a) and (b) show the mechanism to modify the visualization on the screen of the LINE application. However, the protocol used to connect devices from the user to the Raspberry Pi board is not the same. It can be divided into main parts, consisting of water temperature measuring devices and water oxygen machines, a Raspberry Pi, water temperature measuring devices and water temperature measuring devices. Devices that can support website opening and smartphones, which are interoperable with sensor devices in breeding ponds, are used to measure water temperature and oxygen and are displayed through the LINE application.

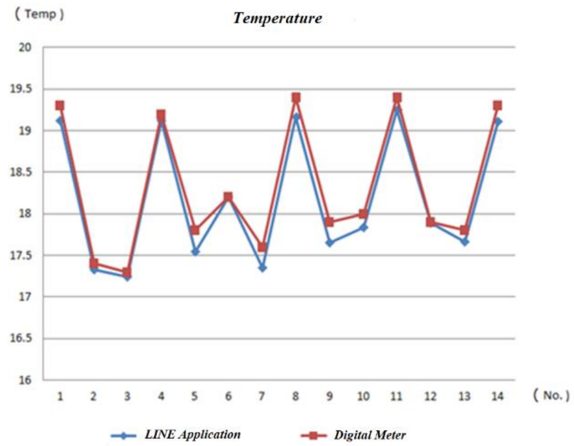
However, the next section presents the discovery and analysis of temperature and oxygen settings performed on the Raspberry Pi, providing a more comprehensive explanation.

3. RESULTS AND DISCUSSION

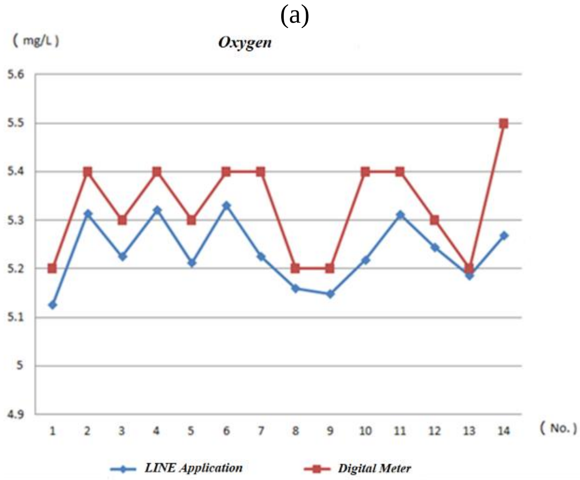
The objectives of this research paper are (1) to design and create a cooling system that keeps the temperature constant at 8-20 degrees Celsius and controls the oxygen content in the water with sensors at 4-8 mg/L using Raspberry Pi board controlled IOT technology. (2) The experimental cultivation of Chinese mitten crabs in an open cold pond with a traditional pond layout was compared with that in a new type of culture pond. Based on this research, the experimental operations and research results were divided into two phases: (1) evaluation and testing of the control of temperature and oxygen in water with sensor devices and (2) analysis of the evaluation results using basic statistics to determine the average of the data from the display of the sensor devices. Details of the results and discussion are shown below.

Figure 10. Temperature and oxygen control system prototype

Figure 10 shows the results of a Chinese mitten crab culture pond design and cooling system in which the temperature was kept constant at 8-20℃ and the oxygen content in the water was controlled with sensors to 4-8 mg/L using Raspberry Pi board controlled IOT technology. The design of the Chinese mitten crab pond showed that the sensor device installed in the pond can control the temperature through LINE application at an average of 17.67 degrees Celsius. Similarly, compared to the display through the screen, a digital measuring instrument mounted to the culture pond showed an average of 17.82 degrees Celsius. However, if the difference between the two sets of data was considered, an error of 0.163% was found. The temperature control results are satisfactory and objective. Likewise, oxygen control in water with the sensor devices showed that temperature control via the LINE application averaged 5.23 mg/L. Compared to the screen display, the digital measuring instrument installed in the culture pond was found to be average. 5.31 mg/L. If the difference between the two data points is considered, an error is found. 0.072%. The results are satisfactory and within the range defined in the objectives. However, according to this research, the water capacity of the culture pond is 500 liters. Based on the evaluation of the experimental results, a comparison of the temperature and oxygen content is shown in Figure 11 (a) and (b).



(a)



(b)

Figure 11. The comparison of the temperature and oxygen reporting

Similarly, based on the evaluation of the operation of the MQTT, the Raspberry Pi and application LINE servers are connected and displayed between hardware and software. Displays the user's TOKEN name settings as specified with notification message display on computer and mobile devices.

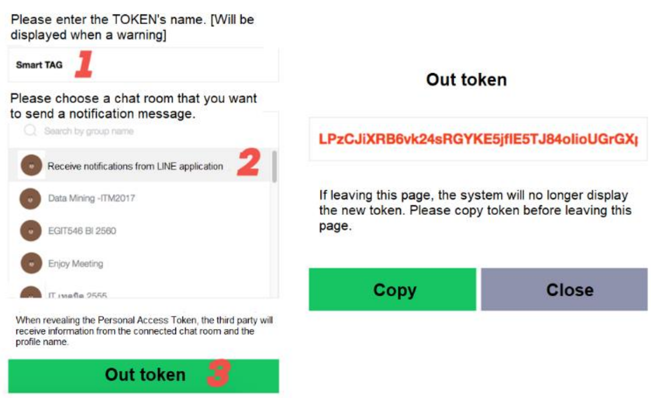


Figure 12. Recipient settings for notifications

Figure 12 shows that the experimental interaction between hardware and software devices through MQTT servers, along with the display on the user's smartphone screen that had configured the settings, yielded results according to the programming configuration. These results are consistent with the defined goals and assumptions. Figure 13 shows the results produced by controlling the temperature of the Raspberry Pi board according to the configured conditions. The temperature configuration can be configured according to the intended purpose of meeting the needs of Chinese mitten crab culture.

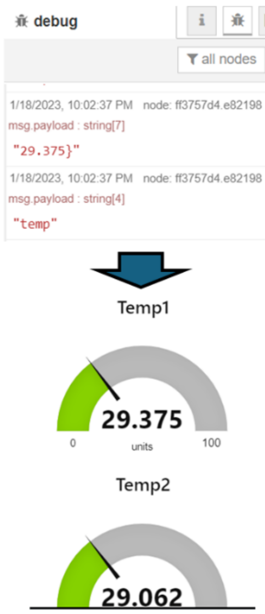


Figure 13. LINE application interface of temperature

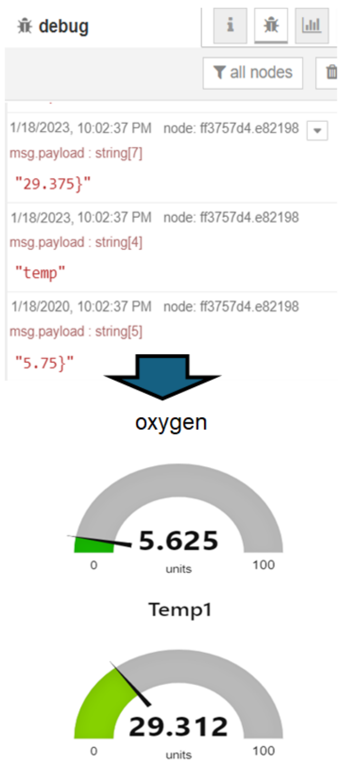


Figure 14. LINE application interface for oxygen

Similarly, using the oxygen control function of the Raspberry Pi board, the oxygen content in the Chinese mitten crab culture pond is shown in Figure 14, in which, a higher level of precision is required to monitor oxygen levels in a culture pond, which can be achieved by installing sensors in the area of more cultured ponds.

However, from programming functions to control operations and displays, specific text details can be defined within these functions. Figure 15 shows that the configuration can display recurring notifications. Each notification can display the data of each sensor installed based on the number of installations.

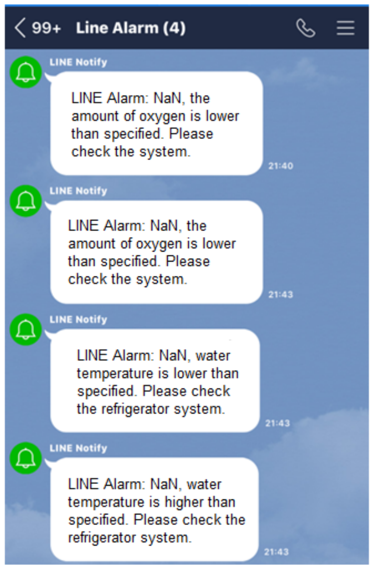


Figure 15. Notifications on LINE application

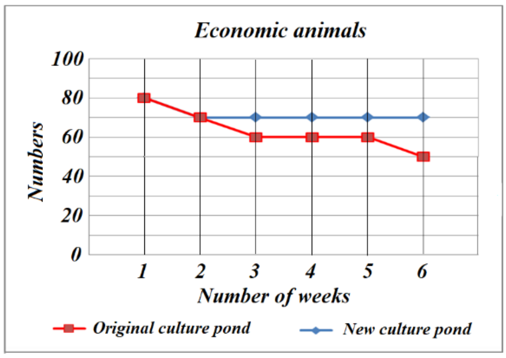


Figure 16. Comparison of Chinese mitten crab farming in a culture pond

Based on objective (2), Chinese mitten crabs cultivated in traditional culture ponds were compared to those cultivated in newly designed culture ponds. This experiment used 1-week-old Chinese mitten crabs cultured in traditional ponds with new culture ponds. This assessment method used a method to assess the survival rate of Chinese mitten crabs according to their 6-week life cycle using 80 male and female Chinese mitten crabs. Figure 16 shows that male and female Chinese mitten crabs cultured in traditional ponds for 1-6 weeks had an average survival rate of 79.17%. Similarly, the average survival rate of the new type of pond culture in weeks 1-6 was 89.58%. According to the evaluation of Chinese mitten crabs, male crabs have a greater survival rate than female crabs and a greater growth rate. However, in this research, the design should consider the effects resulting from suspensions and reactions that occur in ponds. If there is a large amount of waste inside the pond and it is not removed from the pond, the amount of dissolved oxygen in the water, which is inversely proportional to the temperature and concentration of dissolved minerals, may cause the amount of oxygen in the water to decrease. Therefore, controlling the temperature and oxygen availability in culture ponds can decrease the survival rate of female hair claw crabs compared with that of male crabs, as show Figure 16.

Figure 17 shows the growth of Chinese glove crabs in a pond designed and created for this research. This research is confirmatory and reliable for economic animal husbandry in a well-designed pond. However, Chinese glove crabs can thrive in water that is adequately controlled in temperature and oxygen for their intended purpose.

Figure 17. Growth of Chinese mitten crab in a new breeding pond

However, future research directions and how to expand IoT platforms for smart agriculture applications other than culture and breeding are challenges and obstacles for those interested. Therefore, the expansion of IoT platforms for other smart farming applications should be considered in all aspects of these pets. Factors that should be considered especially important are the life cycle and living behavior of those animals. These are some of the experimental and discussion opinions from this research.

4. CONCLUSIONS

This research paper has two main objectives and goals: (1) design and create a cooling system that keeps the temperature constant at 8-20 degrees Celsius and controls the oxygen content in the water with sensors to 4-8 mg/L using IoT technology. The design and construction of animal culture ponds and the results of the experimental cultivation of Chinese mitten crabs shown and discussed above can be summarized as follows. The design of the pond can circulate water and cause sewage and suspensions to be collected at the center of the pond and removed with satisfactory results. If the cooling system is considered, the temperature and oxygen in the culture pond can be controlled according to the intended purpose. Similarly, the use of IOT technology to control the operation of temperature and oxygen sensors is considered. Control order with a Raspberry Pi board. The data transmitted through the Web server in Raspi can display the alarm on the computer and the LINE application at the specified time if the IOT network is stable. However, point (2) of the experimental cultivation of Chinese mitten crabs in traditional cold ponds compared to the new type of culture pond designed and created for this research can be summarized as follows: 1 week old Chinese mitten crabs were isolated from traditional culture ponds with new culture ponds. The survival rate of Chinese mitten crabs was evaluated based on the 6-week life cycle of 80 male and female Chinese mitten crabs. According to the results, male and female Chinese mitten crabs cultured in traditional ponds for weeks 1-6 had an average survival rate of 79.17%, while those cultured in new-type ponds for weeks 1-6 had an average survival rate of 89.58%. However, the assessment also revealed that male crabs have a higher survival rate than female crabs and have a higher growth rate. The future direction of research for those interested in culture and breeding is also a challenge and an obstacle for those interested. Similarly, if one wants to use IoT platforms for smart agriculture applications, interested parties should study the life cycle and livelihood behaviour of these animals as a priority.

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