IoT-based Experimental Aquarium Environment for Observing Crabs

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***Abstract*—There is a need to promote smart aquaculture using information science technologies such as ICT, IoT, and AI. Currently, smart aquaculture has been started in many species, such as oysters, mackerels, and shrimps. It is trying to improve work efficiency and secure appropriate production volume by converting what has been done by experienced and intuition into data. The paper focuses on crabs, especially *Scylla Serrata*, known as mud crab. Note that they have not yet been fully cultivated. To contribute to achieving the intelligent cultivation of these species, we first constructed an IoT-based experimental aquarium environment that can observe the ecology of these species on a laboratory scale. The sensing data and moving images acquired in the environment are displayed on the Web and can be easily checked remotely. The paper also introduces valuable examples through the operation and summarizes the future issues.**

Keywords—IoT, Sensor, Streaming, Monitoring, Crab

I. INTRODUCTION

The introduction and diffusion of information science and technology such as ICT, IoT, and AI are required to transform the fisheries industry into a growth industry, facing a difficult situation of declining fishery production and aging and decreasing fishery workers. Currently, in Japan, the Fisheries Agency aims to realize a next-generation fisheries industry that combines the sustainable use of fishery resources and the transformation of the fisheries industry into a growth industry by 2027 through smart fisheries [1]. The "smart fisheries" scope covers many areas, including resource assessment, fisheries and aquaculture, and processing and distribution.

Smart aquaculture, the focus of this paper, has been initiated in Japan and abroad for many species, including oysters, mackerel, and shrimp [2, 3, 4]. The main approaches include feeding systems, visualization of environmental data, etc., intended to improve work efficiency and ensure appropriate production by converting what has been done mainly by experience and intuition into data.

In order to apply such smart aquaculture, we are currently engaged in research and development of next-generation aquaculture for crabs like mud crabs and blue swimming crabs. The freshly molted ones are called soft-shell crabs, consumed as premium seafood throughout the year. Crabs are widely distributed in Japan, Southeast Asia, and the Indian Ocean, and nursery production is practiced mainly in Indonesia, Thailand, Myanmar, Vietnam, and other Southeast Asian countries. Although some attempts have been made to produce artificial seedlings, most of them depend on natural seedling collection in mangrove areas [5]. Even now, complete aquaculture of mud crabs has not been established.

In order to apply information science and technology to crab aquaculture, we have been working on water quality monitoring [6], molt detection [7], and larval detection [8] using image recognition and LoRa application [9] at an aquaculture farm owned by Hasanuddin University. However, the COVID-19 disaster made it difficult for us to visit these sites. In this paper, we propose the construction of an IoT-based experimental aquarium environment that enables the acquisition of detailed data on a laboratory scale to contribute to the smart development of crab aquaculture. The primary purpose of this project is to observe the ecology of crabs, record and distribute video images, and manage water quality using various liquid sensors.

II. RELATED WORK

As mentioned above, social implementation through smart aquaculture is required. Kura Osakana Farm, established by Kura Sushi, Inc. in November 2021, uses AI-based smart feeding machines for organic young yellowtail [10]. The use of information science and technology will be promoted in the future to solve problems such as human resource shortages and stable supply in the fishery industry.

In recent years, many research and development projects have used ICT, IoT, and AI in aquaculture. Water quality monitoring and feeding systems are the current technological trends. Reference [11] developed a remote feeding function using a smartphone. Reference [12] provides water quality monitoring, automatic tank maintenance, and notification functions. In reference [13], a system using LoRa is developed to realize wide-range water quality monitoring.

On the other hand, research and development for aquaculture with specific target species are also being conducted. In reference [14], a system for counting juvenile shrimp using image processing was developed, and in reference [15], a system for automatic recognition of fish diseases from video images was developed. Although there have been many developments targeting fish and shrimp, to our knowledge, there have not been many research and development projects on smart aquaculture for crabs. The paper addresses the construction of an experimental aquarium environment using IoT on a laboratory scale to contribute to the promotion of smart aquaculture for crabs.

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III. Experimental Aquarium Environment with IoT

A. Overview

In aquaculture, water quality has a significant impact on organisms. Water quality has many items to be observed, including water temperature, pH value, and dissolved oxygen. Analyzing and investigating the effects of these changes on organisms are essential for efficient production. However, numerical data alone are insufficient for data analysis and verification, and a data acquisition environment that includes image data is more efficient. Automatic data acquisition without human intervention as much as possible leads to highly reliable data acquisition without human error.

Therefore, the paper constructs an experimental aquarium environment in the corner of the laboratory (hereafter referred to as the "aquarium area") to acquire sensor data and image data, as shown in Figure 1. The experimental environment targets mud crabs, i.e., *Scylla Serrata*, from Irabu-island, Okinawa Prefecture, Japan. Water quality and image data are obtained from two aquariums, which could be checked remotely (see Figure 2).

Figure 1: Exterior and interior of the aquarium area

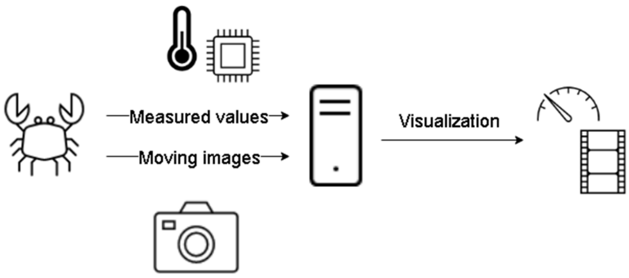

Figure 2: Overview of experimental environment

B. Functions

The environment has the following three functions. The first is a sensing function to obtain environmental information about the aquarium area and the two aquariums. Here, the water quality in the aquariums and the temperature, humidity, and air pressure in the aquarium area are measured. Also, the data measured by the sensors are sent to the server.

The second function is a video recording function for checking the status of the crabs. A nighttime recording is significant because crabs are nocturnal. All of the images are recorded as video files.

The third function is to remotely confirm the sensor and video data acquired by the above two functions. Changes in water quality and the appearance of the crabs can be checked remotely. The following sections describe the implementation of these functions.

C. Implementation of Sensing Functions

Environmental and water quality data in the aquarium area are measured. They are measured using the sensors, shown in Tables 1 and 2, connected with an Arduino and sent to a Raspberry Pi that functions as a server.

The sensors in Table 1 measure the aquarium area's air temperature, humidity, air pressure, and light intensity. The aquarium area, W:3440 mm, D:1730 mm, and H:2310 mm, is small, and the cooler and other equipment will be operated in the area. Hence, it is essential to check the environmental conditions outside the aquarium to determine the cause of equipment problems.

Water temperature, pH, Dissolved Oxygen (DO), Electrical Conductivity (EC), and Oxidation-Reduction Potential (ORP) are measured using the sensors in Table 2. Commonly available reagents for testing seawater quality can measure pH, carbonate hardness, calcium, nitrite, and nitrate. However, as we aim to collect the water quality data automatically, the paper employs the above sensors, which are relatively easy to obtain. In particular, as a first attempt, we focused on water temperature, pH, and DO changes.

Table 1: Sensors in the aquarium area

Measurement item	Sensors
Temperature, Humidity, Atmospheric pressure	Grove– Barometer Sensor (BME280)
Light intensity	Grove – Light Sensor v1.2 – LS06-S phototransistor

Table 2: Sensors in the aquariums

Measurement item	Sensors
Water temperature	DS18B20
pH	Gravity: Analog pH Sensor / Meter Pro Kit V2
EC	Gravity: Analog Electrical Conductivity Sensor / Meter(K=10)
DO	Gravity: Analog Dissolved Oxygen Sensor / Meter Kit For Arduino
ORP	Gravity: Analog ORP Sensor Meter PRO

In addition, a small monitor was installed so that the measured values could be checked on the spot. Figure 3 shows an example of environmental information in the aquarium area. The upper row shows temperature (T) and humidity (H), and then the lower row shows air pressure (P) and light intensity (L, values from 0 to 100).

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Figure 3: Display for measurement data

D. Implementation of Video Streaming and Recording Function

A Raspberry Pi and an infrared camera module (PiNoiR [16]) were used to stream and record aquarium images. The mjpg-streamer [17] is used as the video streaming application, and the FFmpeg [18] is used for recording. Figure 4 shows a streaming video using the mjpg-streamer. The results can be viewed with a web browser.

As mentioned above, nighttime recording is essential because crabs are nocturnal. Therefore, infrared light was installed.

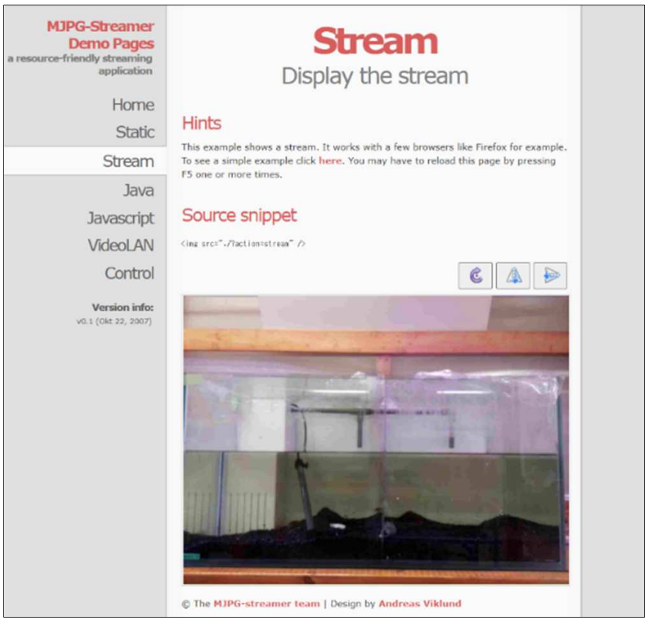

Figure 4: Streaming on a web browser

E. Implementation of Monitoring Functions

A monitoring function was implemented to display the data acquired in Sections 3.3 and 3.4. Node-RED [19] is an IoT flow-based development tool that allows data processing flow to be implemented visually and clearly by combining processes called nodes. By combining processes called nodes, data processing flow can be implemented in an easy-to-understand visual manner.

Figure 5 shows a part of the flow created in this study. In this flow, sensing data received from Arduino is converted to JSON objects for manipulation by nodes and then formatted as a graph to be displayed on a web page and saved as a file in CSV format. Figures 6 and 7 show a web page showing a graph of sensor data and video data of the aquariums by Node-RED.

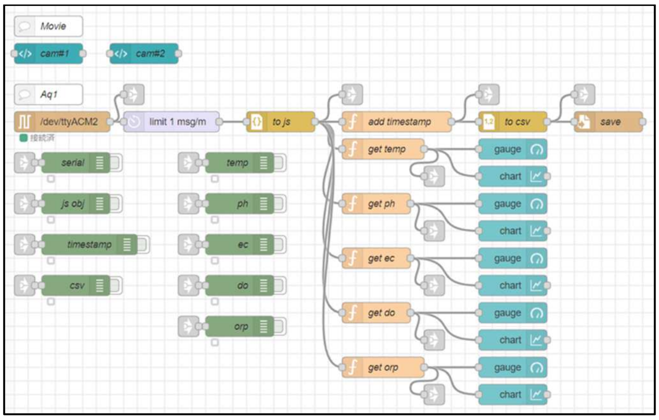

Figure 5: Processing flow for sensor and video data

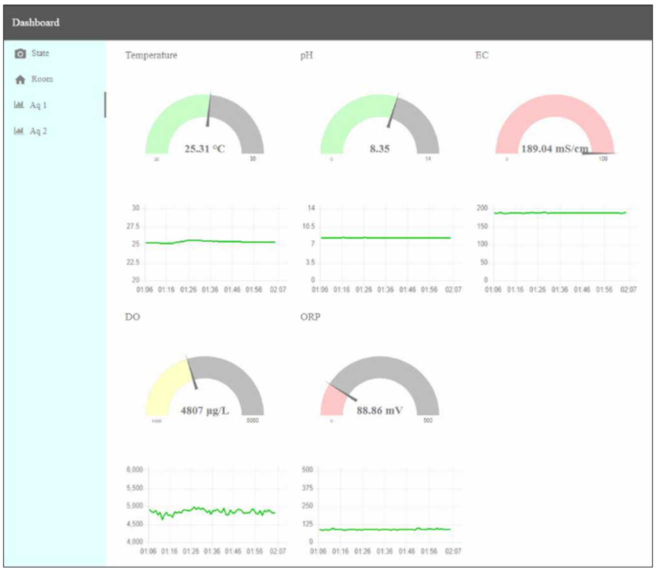

Figure 6: Display of acquired sensing data

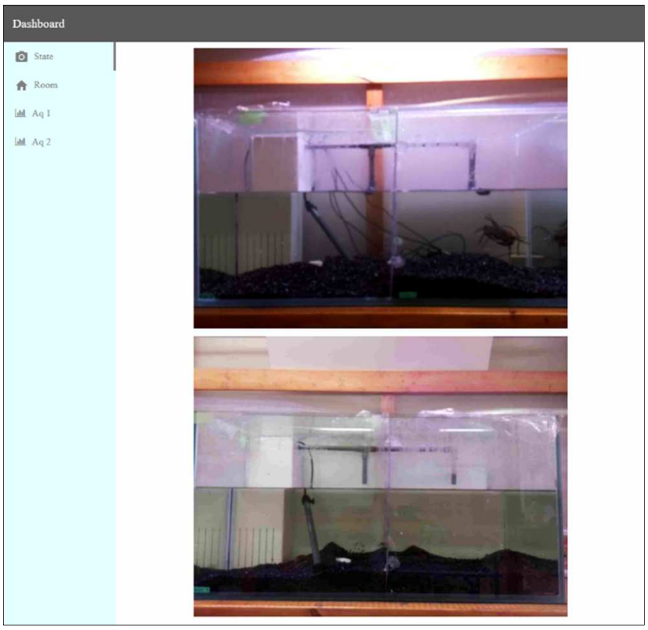

Figure 7: Display of acquired image data

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IV. Operational Status and Issues

A. Status of Operation

The experimental aquarium environment makes it possible to check environmental information and video images on the web inside and outside the aquariums. The monitoring system allows us to know the status of the crabs anytime and anywhere.

The collected data will be recorded on the server and can be used for data analysis at a later date. Since the collected data is recorded on the server, it can be used to estimate the causes of events such as molting or mortality of observed subjects.

The first is the confirmation of signs of molting from video images. As shown in Figure 8, a gap was observed between the carapace and abdomen before molting. The molt was confirmed within half a day after the observation. Since a soft-shell crab is caught immediately after molting, this feature may have the potential as a method for appropriately detecting molting in the future.

Figure 8: Signs of molting by the gap between carapace and abdomen

The second is to confirm the escape route. When feeding on a Monday, we found one dead crab in the corner of the aquarium area. We thought we had set up the aquarium to prevent escape. Reviewing the video recordings, we found that the crab had escaped from an unexpected location late at night on Saturday, two days before the incident. Figure 9 shows the video recording of the escape. We are currently acquiring sensing data, which we plan to utilize in analyzing the relationship between water quality and the activity of the crabs.

Figure 9: Confirmation of escape route by moving images

B. Issues

The environment observes the aquarium area, the aquariums, and the ecology of the crabs. In order to make effective use of the environment, it is essential to solve the problems. The first issue is the measurement values of sensing data. In Figure 6, some measured values, such as EC and ORP, are out of the expected range. It is difficult to determine whether they are due to an abnormality in the sensor or the environment. As described in the literature [15], it is necessary to correctly understand the limitations and performance of water sensors and use sensors that are appropriate for the environment. The cause of the problem should be investigated by comparing the measured values with those obtained by other means, such as reagents.

Next, the current system displays only the last hour's measured values and real-time images at the time of viewing, and data from the past cannot be viewed on the website. In addition, the measured values are displayed in separate graphs for each measurement location, making comparisons difficult. In order to utilize the data by non-expert users, a function to display data for a specified period and a function to display the same type of measured values in a single graph are needed.

Finally, the data is currently used only as a graph or displayed as it is, so we would like to use it as learning data for warning when abnormalities occur and for molt detection by AI.

V. Conclusion

The paper described the construction of a laboratory-scale experimental aquarium environment for the ecological observation of crabs to contribute to the development of smart aquaculture. The environment can acquire various environmental data such as temperature and humidity, aquarium water quality, and aquarium video data. As the current environment has a minimal configuration, we will further expand this environment for next-generation aquaculture for crabs.

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