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SMART AUTOMATED FISH FEEDING BASED ON IOT SYSTEM USING LORA TTGO SX1276 AND CAYENNE PLATFORM

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Abstract

One type of aquaculture that is commonly found in Indonesia is freshwater fisheries in the form of densely stocked fish ponds. An important factor that supports the success of this aquaculture is an appropriate and scheduled feeding system the fish. To address this problem, this paper proposed a smart automation system was designed and implemented to perform feeding management with solar panel as the power. To enhance the productivity of the fish, this paper proposing a new contribution based on Internet of Things (IoT) solution that could control and monitoring the schedule time and amount of feeding and the food behavior of fish. This system is accessed through the Cayenne website and using LoRa TTGO SX1276 to microcontroller and it showed that the schedule and amount of feed was successful with a high accuracy and the panel system also worked well in monitoring and controlling the power system. From the results of testing the entire system, it can be concluded that the feeding automation system can help optimize the productivity of freshwater aquaculture, and provides an innovative solution which user-friendly, secure, scalable, low cost and go green, reliable.

Keywords: automated fish feeding system, scheduling time, LoRa TTGO SX1276, cayenne platform, IoT, smart agriculture.

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1. Introduction

According to the data from Food and Agriculture Organization (FAO), aquaculture activities in the world have increased every year [1–6] and also in Indonesia [7]. This data is in line with the increasing demand for fish consumption [8–15] and on 2030 was predicted 62 percent of all seafood produced for human consumption will come from aquaculture [16].

An aquaculture is the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants [17], and example is freshwater fisheries in the form of densely stocked fish ponds. The problem that is commonly experienced by fish farmers is how to provide fish feed on schedule and maintain the quality of fish pond water. Currently, the provision of feed carried out by fish farmers most is still using the manual sowing method with the amount of feeding that is less than optimal and not in accordance with the nutritional needs of fish [18].

To address this problem, this paper proposed an automated fish feeding that can provide the feed in the right amount and on scheduled. Beside it, the system that we have purposed can monitor the eating habits of fish and if at the time the fish are not eating, the system will stop supplying food. This is very important because if the frequency or the amount of feeding was excessive, it will have a negative impact on both life fish and pond water quality [18–26].

Many studies have been reported related with aquaculture. This shows that this topic is indeed very interesting and challenging to develop. The technology that develop in monitoring and controlling aquaculture systems, are based on the Internet of Thinks (IoT) [14, 27–33], some based on Artificial Intelligence (AI) [34, 35] to collective movement of the fish and their various social behaviors and also both of IoT and Artificial Intelligence (AI) [15].

The results of previous studies have created the fish feeder system using Raspberry Pi but still need developed to make the camera and sensors work [36]. Another fish feeder machine using Arduino Uno with the result can effectively feed the fish but the future work suggests to use the solar cell [37]. The next report was successfully to improve the current automatic fish feeder machine with better materials and low cost. This fish feeder machine which able to distribute 500 grams of pellets within 90 seconds and longest distance of 4.7 meters [38]. The other research was created and devoted to reduce the labor cost as well as develop better pellet dispense system. The machine used a keypad to control the speed of rotation speed of the DC motor [39]. Another study focused on how to make a cheap fish feed machine through its construction design and successfully to increase the efficiency of feeding fish by 5 % compared to the manual method [40]. Then, other research reported that the IoT based smart aquaculture system had been developed. The user can access the system via the Internet (cloud), meanwhile lowering the risk of facing so many uncontrollable/unpredictable situations outdoors. The sensors appeared in this paper also can be utilized to improve the productivity of the aquaculture [41].

Looking at the problems found in the dense stocking fish farming and taking advantage of current technological advances likes IoT and solar panel [42], This paper aims to create a smart automation system for feeding fish. The design we propose has several superior features, including a scheduling-based feeding automation system that can be accessed remotely through an interface, being able to monitor fish feeding behavior so that the amount of food supplied can be adjusted to their needs and the power of the fish feeding system was powered by a solar panel.

2. Materials and methods

2. 1. Solar panel system as a power source

The solar panel provides output in the form of current and voltage that will be flowed to the load from the designed system such as the microcontroller, sensors and actuators needed. Current and voltage will have flowed through the Solar Charge Controller (SCC) type pulse width modulation (PWM), then electric current will be flowed to the load. Excessive temperature and current can cause damage to the components of the system and can also result in increased current in the load in a short time. Therefore, it important to manage the condition of battery. In this paper, the solar panel system has monitoring and control of the condition of the battery.

The following is the block diagram of the solar panel system (**Fig. 1**).

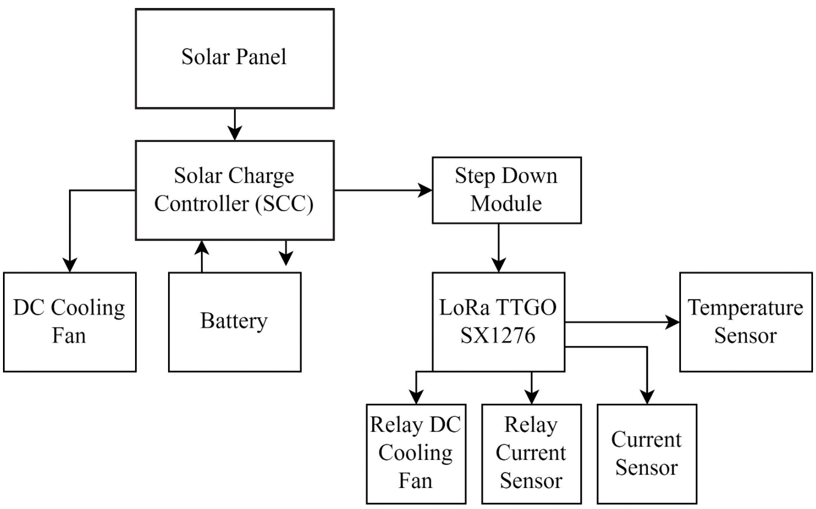

Fig. 1. The block diagram of solar panel system

Fig. 1 shows solar panel subsystem. The voltage and current will be channeled by the solar panel into SCC (Solar Charge Controller) type PWM (Pulse Width Modulation). There is also a Miniature Circuit Breaker (MCB), which functions as a switch while charging and also as a breaker, current when the current given by the solar panel is excessive. Furthermore, the SCC type PWM (Pulse Width Modulation) will control the charging of the battery. The output voltage generated by the SCC will adjust to the battery charging voltage and the SCC will convert excess voltage into additional current when charging. The voltage supplied from the battery will be reduced by LM2596 so that the 12 V voltage can be changed to 3 V according to the input from the LoRa TTGO SX1276 to microcontroller. The microcontroller through TTGO SX1276 LoRa will distribute power to loads such as DC fan relays, current sensor relays, DHT11 sensors and ACS712 current sensors. The power system was designed in two features: monitoring and also controlling battery temperature.

Then, **Fig. 2, 3** show the flowchart of monitoring and controlling the battery flow process.

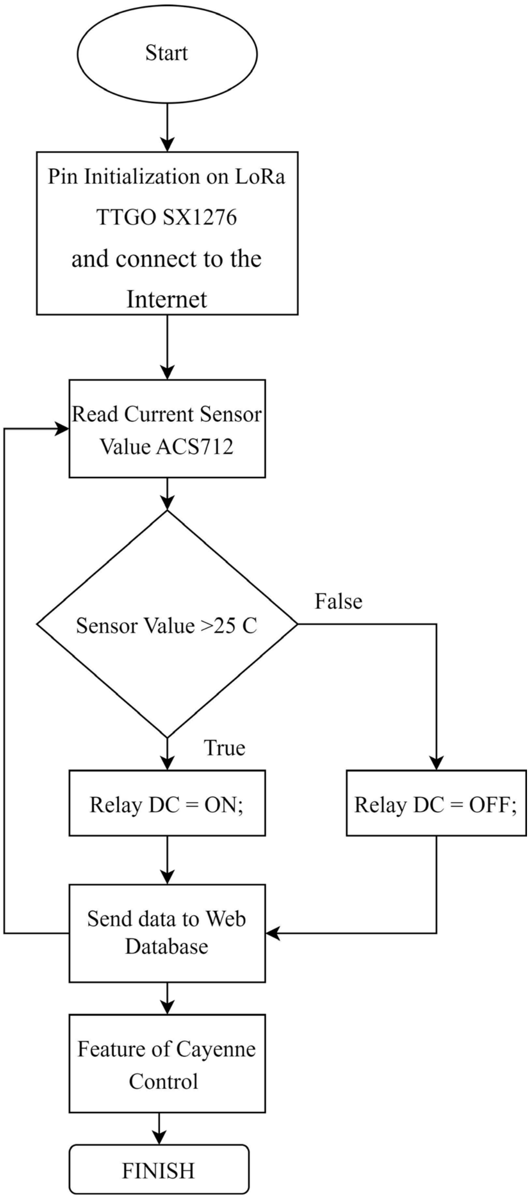

Fig. 2. Battery temperature monitoring and control flowchart

Fig. 2 shows a flowchart of the process of monitoring and controlling the temperature of the battery. When LoRa is connected to the internet, the DHT11 temperature sensor will read the temperature on the battery. The battery temperature value is set at 25 °C and if the sensor measures the battery temperature has exceeded 25 °C then the cooling fan will turn on. However, if it has not exceeded 25 °C, the cooling fan will not turn on. All measured data will be sent to the database and displayed on the Cayenne. This monitoring and control process aims to prevent the battery box from overheating.

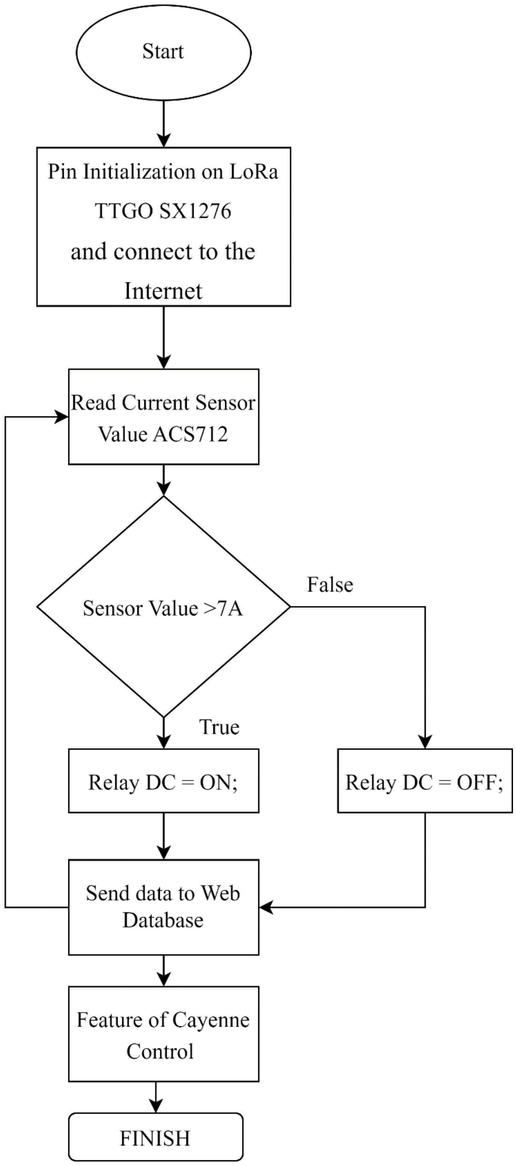

Fig. 3. Load flow monitoring and control flowchart

Fig. 3 shows a flowchart of the process of monitoring and controlling the current of the battery. When LoRa is connected to the internet, the ACS712 current sensor will read the current on the battery. The set value for current is 2 A and maximum limit is 9 A. If the sensor measures the current has exceeded **9A** then the relay DC will turn on. However, if it has not exceeded 9 A, the relay DC will be off. All measured data will be sent to the database and displayed on the Cayenne. ACS712 current sensor is needed to detect the current value and prevent a short circuit in the load by activating a DC relay to break the electrical connection between the load and the SCC [42–44].

2. 2. Smart automation system for fish feeding

The smart automation system for feeding fish is designed with a working mechanism that is, setting the feeding schedule and feed dosage is done remotely via the Cayenne website connected to Wi-Fi. The feed ejector device is designed to consist of an ESP32 microcontroller as the control center, using the LoRa TTGO SX1276 module based on Long Range (LoRa) radio frequencies to carry out the function of sending instructions from the transmitter microcontroller to the receiver microcontroller.

The smart automation system for feeding is designed to be able to automatically feed fish with feeding timings made by user through the Cayenne Internet of Things application (IoT). The process of this system can be seen from the Process Flow Diagram (PFD) in **Fig. 4**.

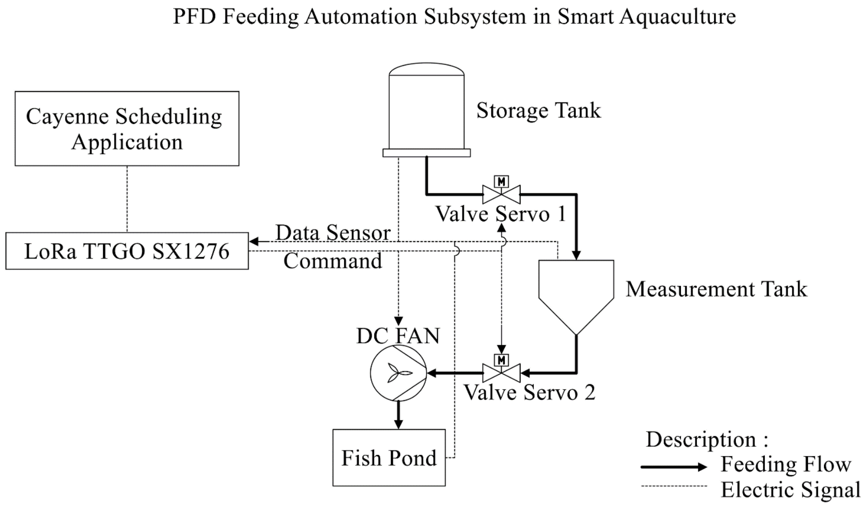

Fig. 4. Process flow diagram of smart automation system for feeding

In the feeding scheduling system, it is necessary to create a widget cayenne that contains parameters such as the time of feeding the fish, the weight of the fish feed to be given, and also the frequency of feeding the fish in a day. If the user wants to change the settings of the parameters on the cayenne, it can be set through the customized settings of the cayenne application.

The state diagram of automation system is presented in **Fig. 5**.

Fig. 5 shows the flow of the control process and the work processes of the intelligent automation subsystem for feeding fish:

1. The Proximity sensor inside the feed storage tube will detect feed availability and provide information on feed conditions back to the ESP32 Microcontroller on the LoRa TTGO SX1276 board.

2. If feed conditions are not available in the storage tube, the proximity sensor will provide feedback to the ESP32 microcontroller so that the Cayenne website displays an alert in the form of a notification to user.

3. If the feed conditions in the storage tube are still available, the cayenne website can accept the data input. The user can manage the input data like the feeding schedule, feed weight, and frequency of each feed every day through the Cayenne Pepper IoT application.

4. The Cayenne website will keep a feeding schedule.

5. The next process Cayenne website will check the feeding schedule in real time.

6. When the scheduling time has arrived, the cayenne application gives commands to the ESP32 microcontroller via Wi-Fi and LoRa communication to open the main tube valve by activating servo motor 1.

7. As a result of the servo motor 1 is working, the valve on the feed storage tube will open and the feed will fall to the bottom, then it will be accommodated in a temporary shelter (weighing tube) to calculate the weight of the feed you want to give.

8. The load cell will work to calculate the weight of the feed in the weighing tube, when the feed weight has been met, the load cell will provide feedback to ESP32 to reactivate the first servo motor to close the feed channel in the feed storage.

9. Next, servo motor 2 will be activated to open the valve in the temporary storage area, then the feed will fall back down. At the same time the ESP32 also activates the feed ejection fan so that the feed is distributed to the pond via the DC eject fan.

10. The DC ejection fan stops working when the load cell has detected that the feed weight in the weighing tube has run out or the feed weight is equal to 0 Kg and the two servo motors close the feed weighing tube valves.

11. This system also has other conditions that can disrupt or stop the ejection process if the accelerometer sensor detects no movement of fish. The sensor will provide feedback to the microcontroller to close the temporary storage valve and deactivate the ejector DC motor due to the condition of the fish. When the fish are eating, the water waves will increase compared to when the fish are not eating. This parameter is measured by the speed sensor and sent to the microcontroller.

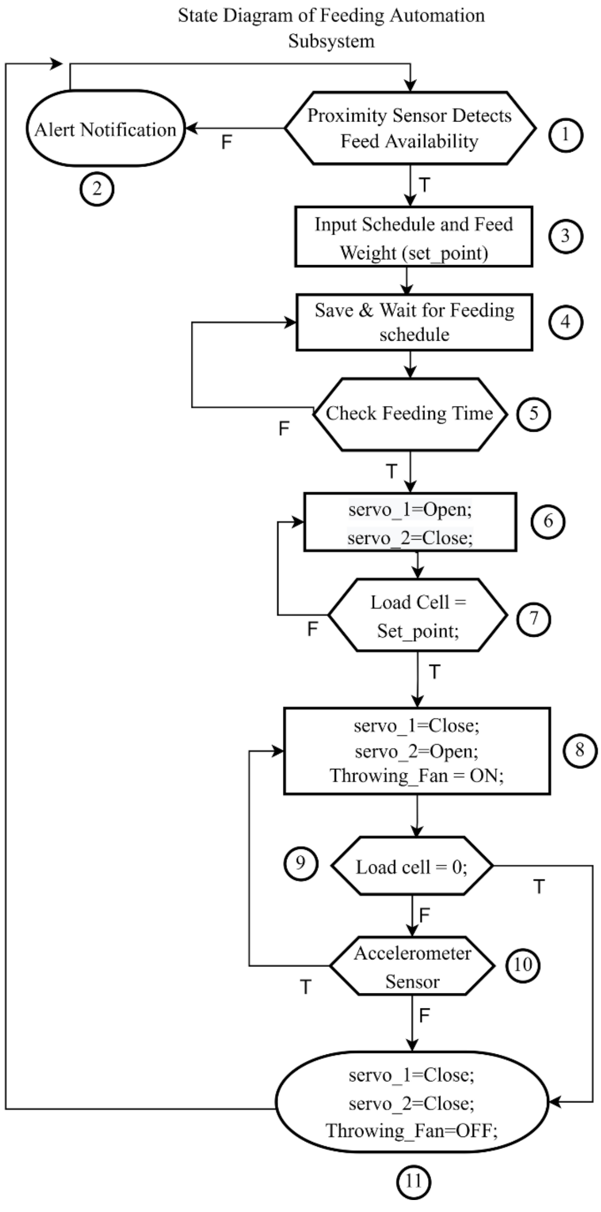

Fig. 5. State diagram of automation system

3. Results and discussion

3. 1. Implementation of solar panel system

Fig. 6 shows that the entire prototype body component of the panel framework has been completed and is able to withstand a solar panel load of 8 kg and a 50 Ah battery with a weight of 15 kg. In the framework of this solar panel, there is also a buffer that functions as a holder and regulator of the direction/angle of the solar panel.

Fig. 6. Overall implementation of solar panel framework

In this system, solar panel voltage, solar panel current, and battery voltage need to be calculated in order to be able to make settings on the SCC from the maximum voltage from the battery when charging and also the minimum battery voltage when used by the system load.

3. 1. 1. Overcurrent circuit breaker relay control test

In the solar panel system, the ACS712 current sensor is used to monitor and control the current on the system load which is placed between the battery output (two output pins from SCC) and the system load. The current given to the load will be cut off using a DC Relay if it exceeds the current of the entire load (microcontroller, sensor, actuator).

From the results of the relay control test in **Table 1**, it can be concluded that the relay works well in accordance with the predetermined program code. When the reading of the current value is equal to or greater than the maximum value that has been determined, the relay will be active.

Table 1

Testing the control of the circuit breaker relay from the SCC to the load

Maximum current value limit	ACS712 Sensor Readout	Relay Condition
1 Ampere	0.9 Ampere	Off
	2 Ampere	On
1.5 Ampere	1.2 Ampere	Off
	1.58 Ampere	On
2 Ampere	1.59 Ampere	Off
	2.6 Ampere	On

3. 1. 2. Battery temperature control test

In the test carried out by taking 5 sample data (**Table 2**), setting the minimum temperature value so that the DC Fan relay is active is 25 °C. When the room temperature reads on the sensor it is above 25 °C then the DC Fan relay will be active. Based on the 98.58 % accuracy value, the DHT11 temperature sensor works well according to the datasheet.

Table 2

DC fan relay control test

Data to	Reference (°C)	DHT11 sensor (°C)	Error (%)	DC Fan Relay
1	23.2	23.54	1.46	OFF
2	24.9	24.10	3.21	OFF
3	27.4	27.00	1.4	ON
4	29.6	29.90	1.01	ON
5	30.3	30.30	0	ON
	Average error percentage		7.08 %	

The DC fan will turn on (ON) when the battery temperature exceeds 25 °C and when the battery temperature has dropped to less than 25 °C the DC fan will turn off (OFF). The temperature and humidity that are received or detected by the temperature sensor are influenced by the temperature of the control panel (box panel) made of plate iron. The temperature and humidity of the control panel will be affected by the weather in the test field. Therefore, the DHT11 temperature sensor will detect a high battery temperature due to the temperature inside the control panel and the high weather in the test field as well.

According to the data from **Tables 1, 2** conduct that the solar panel system work well in monitoring and controlling power system with the average error accuracy is about 7.08 %. This action is very important so that the battery is not damaged quickly.

3. 2. Implementation of pond water quality monitoring and control system

The display of feeding automation system can see in **Fig. 7**.

In **Fig. 7**, feeding automation mechanics are 1 unit with placement locations outside the pond with the ejector position having to be at least 50 cm above the pond surface, this is to ensure that during the feeding process, the maximum distance can be reached.

Fig. 7. Display of feeding automation system

3. 2. 1. Feed weighting test

Feeding in the fish pond where the system is implemented is carried out 2 times a day in the following timeframe: In the morning at 09.00 and in the afternoon at 15.00. The weight of the feed given to one pond is 4 kg. To get an analysis of the load cell test results at the time of weighing the feed, it is presented in **Table 1** using the following formula [45]:

$$\% \, Error = \left| \frac{\text{BP2} - \text{BP1}}{\text{BP1}} \right| \times 100 \, \%.$$

Where, BP1 is the weight of the feed released by the tool, while BP2 is the weight of the expected feed (set point) or the weight of the feed that should be in the weighing tube according to the value given through the cayenne website.

The testing of the feed weighing system was carried out for 6 experimental days, following the daily feeding schedule. The location of system implementation is carried out directly in a densely stocked fish pond with the type of Dumbo Catfish (*Clarias Gariepinus*) as many as 10,000 fish and the size of the pond is 7×7×1.5 m.

The weight of the feed released by the tool is the weight of the feed measured on the feed weighing tube, while the expected feed weight is the weight of the feed that should be in the weighing tube according to the value given through the cayenne website.

Table 3 and the graph in **Fig. 8** show the weight released by the automated feeding system is different from the feed requirement calculated manually through the scales and there is an increase in the average error value. It is because there is an error in reading the *load cell* plus other factors, which are caused by the servo motor which takes time to close completely or completely. So that before the servo closes completely, the feed continues to fall into the temporary shelter, it is seen that the average error of the feeding weighing system is accuracy of 98.975 % with error percentage about 1.025 % during implementation.

Table 3
Feed weighing test

Days to	Expected feed weight (Kg)	Weight of feed removed tool (Kg)	Error (Kg)	Error (%)
1	4	4040	0.040	1
2	4	4041	0.041	1.025
3	4	4.042	0.042	1.050
4	4	4.042	0.042	1.050
5	4	4041	0.041	1.025
6	4	4040	0.040	1
	Average		0.041	1.025

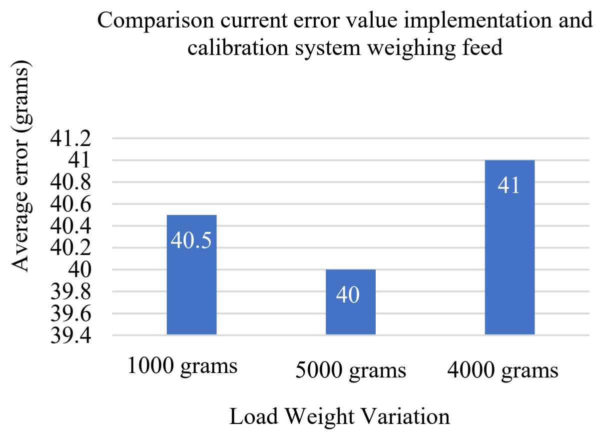

Fig. 8. Comparison of error values during implementation and calibration of feed weighing systems

3. 2. 2. Feed scheduling test

Feed scheduling time for 6 days is presented in **Table 4**.

Table 4
Feed scheduling test results

Days to	Test	Scheduling Time	Feeding on every schedule		Delay (seconds)
			Succeed	Not	
1	1	09:00:00	✔	–	15
	2	15:00:00	✔	–	8
2	1	09:00:00	✔	–	13
	2	15:00:00	✔	–	20
3	1	09.00.00	✔	–	20
	2	15.000.00	✔	–	60
4	1	09.00.00	✔	–	8
	2	15.000.00	✔	–	19
5	1	09:00:00	✔	–	13
	2	15:00:00	✔	–	45
6	1	09:00:00	✔	–	15
	2	15:00:00	✔	–	44

Table 4 shows that the feeding system work very well and on schedule with accuracy is almost 100 % even it still has a delay time in order of several second about 23.33 second. Delay in feed schedule is caused by a delay in reading packets sent from the LoRa receiver (which is connected to the cayenne) to the LoRa transmitter which is connected to the feed eject actuator. This delay occurs because the LoRa TTGO SX1276 module is a radio frequency module with half-duplex performance.

3. 2. 3. Acceleration of water waves test

Based on research that has been reported, it is obtained data that the speed of catfish when swimming is 10 cm/s with an internal 30 cm/s to 120 cm/s [46]. And the time interval for catfish opening and closing its mouth while eating is 176 ms [47]. If it is assumed that a catfish is eating with the maximum speed 120 cm/s with 176 ms, then its acceleration is around 0.68 m/s^2.

According to that data, in this paper was tested the correlation of fish feeding behaviour with acceleration of water waves in **Table 5**.

Table 5
Testing the minimum pool water wave acceleration value for the condition of fish consuming and not consuming feed

Data to	Acceleration of water wave (m/s^2)	Fish behavior
1	11.3	Eating
2	10.1	Eating
3	9.2	Eating
4	9.2	Eating
5	8.7	Eating
6	8.2	Eating
7	8.2	Eating
8	8.1	Eating
9	7.3	Eating
10	7.2	Eating
11	7.0	Eating
12	6.9	Not eating
13	6.0	Not eating
14	5.8	Not eating
15	5.4	Not eating
16	4.9	Not eating
17	4.4	Not eating
18	4.0	Not eating
19	3.9	Not eating
20	3.5	Not eating

Based on **Table 5**, could be concluded that if the acceleration of water wave is less than 0.7 m/s^2 the fish not eat the food and the otherwise if the acceleration of water wave is more than 0.7 m/s^2 means swarm of fish ate their food. This data is accordance to the reference of acceleration one fish about 6.8 m/s^2. In this research, there are limitations and conditions from the application results obtained, namely:

1. The weight of the feed that can be accommodated by the feed storage tube is a maximum of 15 kg.

2. The accelerometer sensor works more effectively in sunny weather, if the weather is rainy or strong winds, it will hinder the accuracy of the accelerometer sensor in detecting fish conditions when consuming feed.

3. Feed weight settings and other access controls can only be made through the cayenne platform interface.

Testing of the entire system has been carried out with several trials and data collection, and the consistent results are obtained with good accuracy value for all parameters. This research has the potential to be further developed not only for freshwater fisheries, but also for brackish water fisheries with high-value aquaculture such as barramundi (*Lates calcarifer*), milkfish (*Chanos chanos*), pearl lobster (*Panulirus ornatus*) cultivation.

To support the further development of this research, several important things that need to be considered are the environment to be controlled such as the condition of water waves at the cultivation site and the conditioning of the LoRa signal with as little obstruction as possible.

Further development of this research is expected to optimize the effectiveness of the system such as smaller waiting times, use of manual interfaces as backups such as keypads and buttons to anticipate if there is trouble on the communication network to the Cayenne platform, and use of more than one sensor for each parameter controlled in order to maximize when there is interference from the environment. This research is also very potential for procuring development in disease outbreak monitoring, water quality and biomass statistics with aquaponic system.

4. Conclusions

The automated feeding system using LoRa based on IoT for smart aquaculture has been successfully created. The feed weighing system is able to weigh the feed with an accuracy of 98.975 % and the accuracy of the scheduling time of the feed is almost 100 %. This system also shows the corelation between the behaviour feed of fish to the acceleration of water waves. While fish ate, the water waves are also increased. The solar panel with the battery management system (BMS) successfully worked very well to power the automated fish feeder. The fan worked according to the set value is 25 °C and the otherwise if the temperature of battery still less than 25 °C, the fan is off or not working. This system also success to monitoring and controlling the current flow to the battery. If the current is more than 9 A, the relay will be active but if still less than 9 A the relay is non-active. This BMS important to prevent the battery be overheating.

Conflict of Interest

The authors declare that there is no conflict of interest in relation to this paper, as well as the published research results, including the financial aspects of conducting the research, obtaining and using its results, as well as any non-financial personal relationships.

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Data availability

Manuscript has no associated data.

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