Design and Implementation of an Automated Fish Feeder Robot for the Philippine Aquaculture Industry: Feeding Mechanism and Float Design Module

Maria Cizel U. Deroy*, Aeus Joshua Espaldon, Johanna Ericka F. Osa, Gian Paulo B. Macalla and Diogenes Armando D. Pascua
College of Engineering and Architecture
University of Science and Technology of Southern Philippines
Cagayan de Oro City, 9000 Philippines
**deroymariacizel2194@gmail.com*

Date received: May 24, 2017
Revision accepted: August 1, 2017

Abstract

The researchers developed an automated fish feeder robot's feeding mechanism and floater mechanical assembly to be used in aquaculture farming that aims to aid in the distribution of feeds. Data such as the conveyor's feeding capacity per unit time, the density of pellets dispensed in the cage and per quadrant were calculated and critical load check and stability tests were completed. Visual tests for the prototype were also conducted. The Aslong 12v JGB37-550 direct current (DC) motor was used to drive the bucket conveyor which is responsible for the transport of pellets to be dispensed to the outlet. On the other hand, the 3-blade commercial remote-controlled (RC) boat propeller driven by the Graupner 12V brushed motor was used to propel the floater while navigating and dispensing feeds throughout the fish cage. After assembling and building the whole prototype and combining the feeding system and the floater design, the researchers have tested its effectiveness, stability, and operation. With those parameters tested and calculated, it is concluded that the design of the feeding mechanism and floater is operational and suitable for automation of fish feeding in fish cages.

Keywords: aquaculture, bucket conveyor, DC motor, RC boat propeller, brushed motor

1. Introduction

In 2013, the Philippines ranked 7th among the top fish producing countries in the world with its total production of 4.7 million metric tons of aquatic resources.The production constitutes 2.46% of the total world production of 191 million metric tons. Moreover, the fishing industry's contribution to the country's Gross Domestic Products (GDP) was 1.6 % and 1.8% at current and constant prices, respectively. Because of the significant contribution of the fishing industry to our economy, it evolved into various forms to optimize fish production, one of which is aquaculture. (Department of Agriculture - Bureau of Fisheries and Aquatic Resources, 2014)

Aquaculture is the process of breeding, growing and harvesting of some water species in both marine and freshwater environments under controlled conditions. Aquaculture is an important sector in Philippine fisheries and the most dynamic since the decline of marine fisheries starting 1976. The future of aquaculture industry is bright, particularly in Mindanao where water quality is not heavily affected by pollution (Aypa, 1995).

In any aquaculture operation, feeding is the most important daily activity (de Silva and Anderson, 1994), but many fish cage caretakers are spending an enormous amount of time and effort manually feeding the fishes. The manual feeding is also the most common practice among farmers in the Philippines (FAO, 2010). Manual feeding technique, also called as hand feeding, is a technique that refers to scooping by feed out of bag or tube and flinging into the pond. (Ayub *et al*., 2015). Because of that, feeds being thrown manually are concentrated to a particular part of the course leaving some areas barren and some overly fed. Furthermore, during harvest time, fishes come with varying sizes due to the concentration of feeds to areas of the fish cage.To address these problems in the Philippines, a smart robotic fish feeding system is designed to carry the feeds and automatically navigate itself through the entire course of the fish cage while dispensing a certain amount of feeds necessary for the fishes. It comes with an android-based application for real-time monitoring of device parameters such as the feed levels of both the main and dispensing tank, the percentage level of the battery, and the level of inclination of the device and a solar-powered charging station for an independent and efficient source of power.

The study focuses on the manner of distributing the feeds into the fish cages. It mainly aims to introduce an automated fish feeder robot to automatically dispense pellets that aids the distribution of feeds in fish cages. Specifically, it designs the mechanical assembly and develop the propulsion of an automated fish feeder robot, and to create a prototype of the study.

2. Methodology

The following procedures were done in developing the design of the feeding system and floater that can address the problem and disadvantages of manual feeding.

2.1 Design of the Feeding System

For the feeding system design, the following were considered: (a) the type of feeds, (b) the size of the storage or hopper, and (c) the manner of feeding. Materials/hardware used, processes and steps conducted, and the results of implementation are discussed further in the following:

2.1.1 Material/Hardware Used

For the fabrication of the conveyor, the materials were the following; (a) standard bike chain with a length of 12in and width of 12.70 mm, the (b) sprockets 47-mm diameter, 17 teeth, (c) bearings, (d) brushed motor, (e) 4-ply marine board for commercially available elevator cups to shove the feeds out from the container to the outlet, (f) 30mm and 20mm diameter-engineering plastics, and a (g) O-ring.

For the hopper design, a galvanized sheet # 26 was used for the body of the hopper and its cover.

2.1.2 Process

With the materials specified, the 4-ply marine board was cut in the form shown in Figure 1, and then the bucket was mounted on the chain with screws and placed the chain around the sprocket.

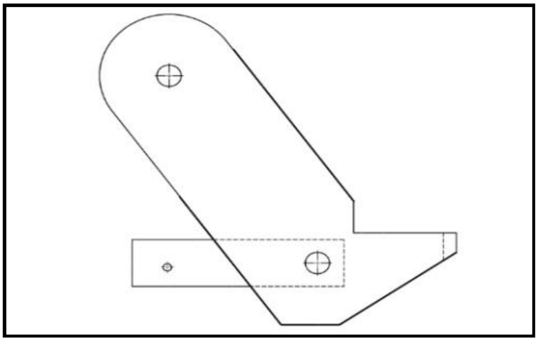

Figure 1. Body of the conveyor cut from the marine board

After which, the bearings and sprockets were assembled and placed right upon the cut out of the marine board. Upon computations, a requirement of 2.8 kg·cm torque was calculated, and a 3.0 kg·cm-torque was chosen. Due to the excess torque, engineering plastics were turned and was then attached to the motor and conveyor in such a way the researchers can achieve a mechanical pulley type system to reduce the speed of feeding. For the hopper, the galvanized sheet was cut and shaped with a dimension of 395.73mm x 395.70mm for the cover and 300.79 mm x 302.04 mm for the body. It was used as a container for the fish pellets with a maximum weight of 5 kg. For the overall construction of the feeder system, the hopper was placed at the back of the bucket elevator conveyor, and the outlet of the hopper was connected to the inlet of the conveyor.

2.1.3 Design Results

The final design was able to execute its operation properly to dispense fish pellets. The design is shown in Figure 2.

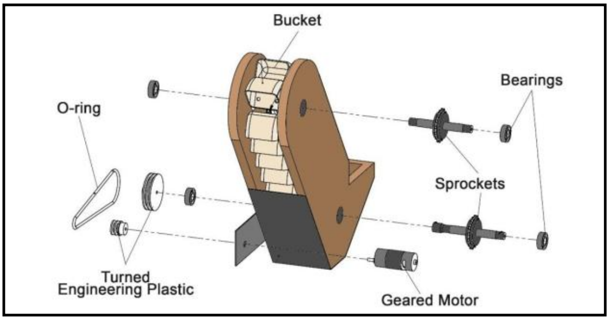

Figure 2. Final design of the feeding system

2.2 Design of the Floater

For the mechanical assembly and propulsion, the (a) total capacity the floater can carry and (b) the size and weight of prototype were the design considerations. Designs including the materials/hardware used, processes and steps conducted and the results of implementation are discussed further in the following:

2.2.1 Materials/Hardware Used

For the hull design, the materials chosen were:

(a) A 4-ply marine board was chosen to be the material for the whole body of the floater, and (b) acrylic panel to serve as the cover for the compartments for the components of the feeding system.

For the propulsion, the researchers used the following: A commercially available (a) 3-blade RC boat propeller, to drive the floater forward, a (b) no. 16 and no. 10 steel shaft to connect the propeller to the motor, a (c) brushed motor to turn the propeller, a (d) 1-ply marine board for the rudder which was responsible for steering the floater left and right and a (e) servo motor which turns the rudder.

2.2.2 Process

With the materials specified, the researchers came up with the design of the new floater and propulsion placement which is inspired by a ship's design and operation. Accordingly, incorporating parts of the ship like bulbous bow helps it to move more effectively in the water based on ship designs.

The boat was designed to be a meter in length and roughly 300 mm in width. Calculations were made for the buoyancy and critical load which is the maximum load the floater can carry. The total weight of the feeding system and the components used for the whole module was identified and was verified that it is below the critical load of the floater.

Marine board plywood was chosen because it is the material used by fishermen and boat enthusiasts in making their boats. Also, it is a type of board that is widely used for marine applications. It was cut and formed into a small ship-like floater as shown in Figure 3. Compartments were made for the small components of the feeding system, motors, and microcontrollers. The floater was also made to adequately house the final design of the feeding system.

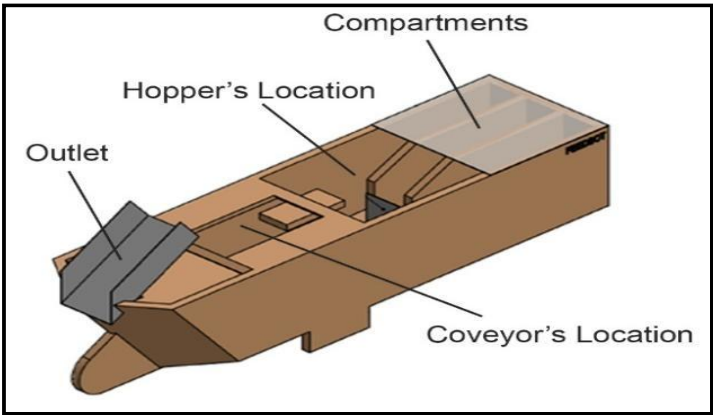

Figure 3. Final design of the floater

The assembled piece of the brushed motor, shaft, and propeller from the initial design was just adopted by the final design except that the inclination was eliminated and was placed horizontally on its compartment at the bottom rear end part of the floater, secured, sealed and completely submerged in water.

The rudder, with the shaft and servo motor, was placed and held on the face of the back side of the floater perpendicular to the position of the propeller to effectively turn the floater left or right.

The final design was fully secured and was tested on both ideal and actual scenarios as shown in Figure 4.

Figure 4. Final Design of the module on actual scenario

2.2.3 Design Results

The floater was successful in moving forward, turning and carrying the whole module although it was not that fast. Figure 5 shows the overall system design and functionality of the fish feeder robot.

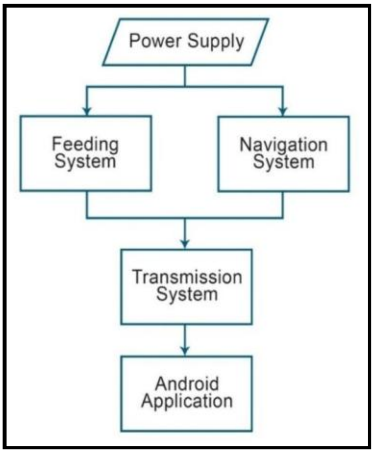

Figure 5. System overview

2.3 Power Supply

The power supply was the input point that was responsible for the procedure in which the solar panel absorbs the solar radiation from the sun and converts that light to electrical impulses as DC voltage. The converted energy which is a DC voltage will then be delivered to the charge of the LiPo battery. Power source from this module was fed into the feeding system and navigation system for the operation.

2.4 Feeding, Navigation, and Transmission Systems

The feeding system was responsible for the dispensing the pellets through the entire operation. This was done during the process when the fish feeder robot is navigating through a sinusoidal pattern on the fish cages.

The navigation system ensured the speed and motion of the fish feeder robot. These two will be the one to maintain the mobility of the feeder robot during its navigation at the fish cage to feed the fishes.

The transmission system provided the output view of the fish feeder robot using real-time data monitoring using android platform. The parameters that were observed were the feed level of the dispensing tank (hopper) and the main tank, the voltage level of the Li-Po battery, and the inclination angle of the feeder robot. These signals were being conditioned and to the android application. The output then includes the Android application where the transmitted data are displayed.

2.5 Materials and Components in the System

Figure 6 shows the materials used in the system which is involved in the block diagram of the module as demonstrated in Figure 7. The selection of the solar panel depended upon the system requirements, its current, voltage, and power ratings. The 50W solar panel was used to absorb solar radiation from the sun and converts that light energy to DC voltage as the power source of the system. The compatibility of the LiPo charger and the LiPo battery was utmost considered due to its sensitivity and must be handled properly. The capacity of the lead acid battery used was calculated based on the system requirements to complete the whole process of feeding the fishes. Microcontroller board was used to program the data logging feature of the solar powered charging station and to calibrate current and voltage sensors for this module. It is responsible for the overall control of the feeding system. Bucket elevator conveyor important part of the feeding system containing bucket elevators which were responsible for the transport of pellets. This was used to scoop up pellets from the lower level and dispense through the outlet to the entire fish cage. Brushed motor was used to drive the propeller for the entire navigation operation of the fish feeder robot in its straight and snake-like pattern. Geared motor was chosen from the calculated design requirement. Used for the operation of the bucket conveyor that is used in the feeding system of the fish feeder robot. Servo motor allowed for precise control of angular or linear position, velocity and acceleration in driving the rudder. Rudder was important in the operation of the navigation system of the feeder robot to control and redirect the water that may pass through the feeder and thus, imparting a turning motion to the fish feeder. Propeller was also significant to the design to convert the rotary motion from the fish feeder power source to provide propulsive force, creating force leading to the movement for the feeder's navigation process.

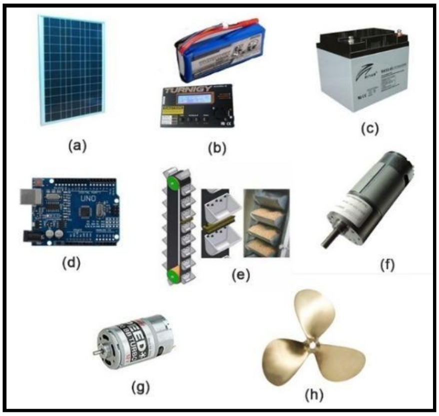

Figure 6. Materials and components used in the System: (a) 50W Solar Panel, (b) 5000mAh Lipo battery, LiPo Charger, (c) 40Ah Lead Acid Battery, (d) Rev V3. Arduino UNO board (Microcontroller), (e) Bucket Elevator Conveyor, (f) Aslong 12v JGB37-550 12v dc motor, (g) Graupner 12 Brushed Motor, and (h) 3-blade Commercial RC Boat Propeller

For the overall process, the microcontroller was responsible for the overall control of the feeding system and propulsion as shown in Figure 7. The switch turns on the microcontroller that triggered the motors of the rudder and the propeller to start navigating through the fish cage. It also triggered the geared motor of the bucket conveyor to start working to deliver the feeds or fish pellets from the hopper through the slope going to the outlet. An ultrasonic sensor was used as a level sensor to monitor the level of the feeds inside the hopper for real-time monitoring.

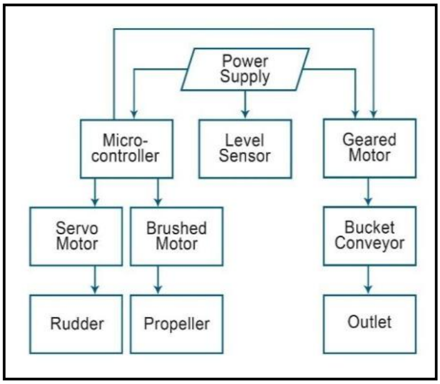

Figure 7. Block diagram

3. Results and Discussion

Data were gathered to test the automated fish feeder robot's effectiveness, stability, and operation. In obtaining the feeding capacity or feeding rate, ten trials were conducted to measure the average time per revolution and average weight of the pellets dispensed per revolution as shown in Table 1. The feeding capacity or feeding rate was then calculated using the average time and weight of the pellets dispensed in every revolution with a value of 23.426 g/sec.

Table 1. Trial results in getting the weight of pellets per revolution

Trials	Measured Values	
	Time consumed in a revolution (sec)	Weight of pellets per revolution (g/rev)
1	3.34	81
2	3.02	64
3	3.46	91
4	3.23	71
5	3.27	74
6	3.30	75
7	3.32	80
8	3.30	75
9	3.32	74
10	3.31	85
Average	3.287	77

The researchers conducted another trial of the feeding system operating while navigating throughout the fish cage. The weight of pellets consumed was measured by getting the difference of the weight of feeds in the hopper before and after of every run. After every session of feeding, the weight of the remaining pellets in the hopper was measured to identify the weight of pellets dispensed giving the researchers the average pellets consumed in every round which was 1770 g as demonstrated in Table 2.

Table 2. Trial results of actual feeding on the fish cage.

Trials	Measured Values		
	Time Consumed in Navigation (sec)	Weight of pellets Left in the Hopper (g)	Weight of Pellets Dispensed (g)
1	66	2400	1600
2	74	2300	1700
3	87	1800	2200
4	69	2300	1700
5	71	2300	1700
6	65	2400	1600
7	79	2200	1800
8	72	2400	1600
9	69	2400	1600
10	93	1800	2200
Average	74.5		1770

Figure 8 shows the comparison of the average weight of pellets dispensed from the actual feeding on fish cage which was 1770 g. The average actual measured pellets were close enough to the calculated expected average weight of pellets which is 1745.237 g which showed an average difference of only 24.763 g.

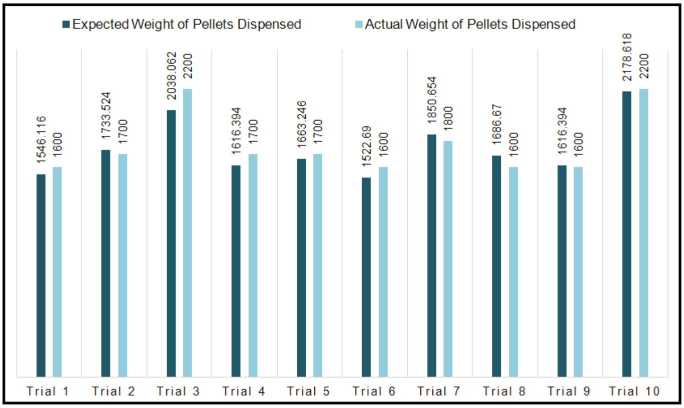

Figure 8. Comparison of calculated and measured weight of feeds

Using the area of the fish cage which is 530.929 ft^2 and the average dispensed pellets in one round of feeding, we got the average density of feeds dispensed which is equal to 3.3337 g/ft^2. The density of feeds dispensed for every quadrant was also calculated and showed a difference of 0.81 g/ft^2, thus ascertaining that the feeding system effectively aids in the distribution of feeds. Results are shown in Table 3.

Table 3. Comparison of Feeds Dispensed

Quadrant	Average Density of Pellets Dispensed (x) (g/ft^2)	Actual Measured Density of Pellets (y) (g/ft^2)	Difference $\lvert y - x \rvert$ (g/ft^2)
1		3.7670	0.4333
2		4.5204	1.1867
3	3.3337	4.5204	1.1867
4		3.7670	0.4333
Average		4.1437	0.81

It was calculated that the critical load or the total load the floater can carry to be stable is 23,400 g. The measured total load carried by the floater was 12,850 g as presented in Table 4 which is less than the critical load. Thus, the floater is considered stable.

Table 4. Summation of the load

Materials	Weight
Hopper	750
Conveyor	4,800
Battery	200
Pellets	5,000
Ballast tank	2,000
Circuit board	100
Total	12,850

Time was extracted with the trials conducted. With the average consumed time of 74.5 sec and approximate total distance of 81.5 ft, the motor was able to propel the module with a speed of 1.11 ft/sec which effectively aid in the distribution of feeds.

For the implementation as shown in Figure 9, a total of 40 trials were conducted to test the actual operation of the prototype. The tests were done on an actual scenario located at Cugman Bay, Cagayan de Oro City. The automated fish feeder robot was tested through a straight path of 26 ft. Out of 40 trials, 33 (82.5%) showed that the prototype was successful in doing its operation. There was no instance that the prototype failed, capsized, or sank.

Figure 9. Implementation of final prototype of the study

4. Conclusions and Recommendations

The outcome of the study showed that there was only a difference of 0.81 g/ft^2 dispensed pellets for every quadrant from the average density of feeds dispensed, thus ascertaining that the feeding system effectively aids in the distribution of feeds.

The center of gravity and buoyancy were calculated, and the total weight of materials or load carried by the floater was less than the calculated critical load thus, the floater was considered stable.

The prototype underwent several trials to test its operability and showed that the prototype was 82.5% operational and there was no instance that the boat capsized or sank proving reliability.

Therefore, the entire feeding system and floater design of the automated fish feeder robot is recommended in the aquaculture industry as a contributor to the automation of fish feeding because of its effectiveness, stability, and reliability.

Upon 40 trials conducted to test the actual operation of the prototype, 17.5% of which was considered unsuccessful due to the inclined orientation of the automated fish feeder robot. For the additional stability of the floater and the automated fish feeder robot as a whole, ballast bags must properly be installed to counterbalance the height and load of the robot. Ballast must be used to add weight and lower the center of gravity of the robot to provide the stability that will help the feeder in eliminating the probability of capsizing the feeder and lessen the chance of failing to do its operation.

5. Acknowledgement

The completion of this study could not have been possible without the participation and assistance of people whose names may not all be enumerated. Their endless support and significant contributions from the very beginning until the completion of this study are sincerely appreciated.

6. References

Aypa, S.M., (1995). Aquaculture in the Philippines. In: Bagarinao T.U., Flores, E.E.C. (Eds.), Towards Sustainable Aquaculture in Southeast Asia and Japan: Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia, Iloilo City, Philippines, 137-147.

Ayub, M. A., Kushairi, S., and Latif, A.A., (2015). A new mobile robotic system for intensive aquaculture industries., Journal of Applied Science and Agriculture., 10(8), 1-7.

de Silva, S.S., and Anderson, A.A., (1994). Fish Nutrition in Aquaculture, 1st Ed. Springer & Business Media, 227.

Department of Agriculture - Bureau of Fisheries and Aquatic Resources, (2014). Philippine Fisheries Profile 2014, from https://www.bfar.da.gov.ph publication.jsp?id=2338#post.

FAO, (2010). Report of the FAO Expert Workshop on On-farm Feeding and Feed Management in Aquaculture. Manila, the Philippines, 13–15 September 2010. FAO Fisheries and Aquaculture Report No. 949. Rome, FAO. 37 pp. (also available at www.fao.org/docrep/013/i1915e/i1915e00.pdf).