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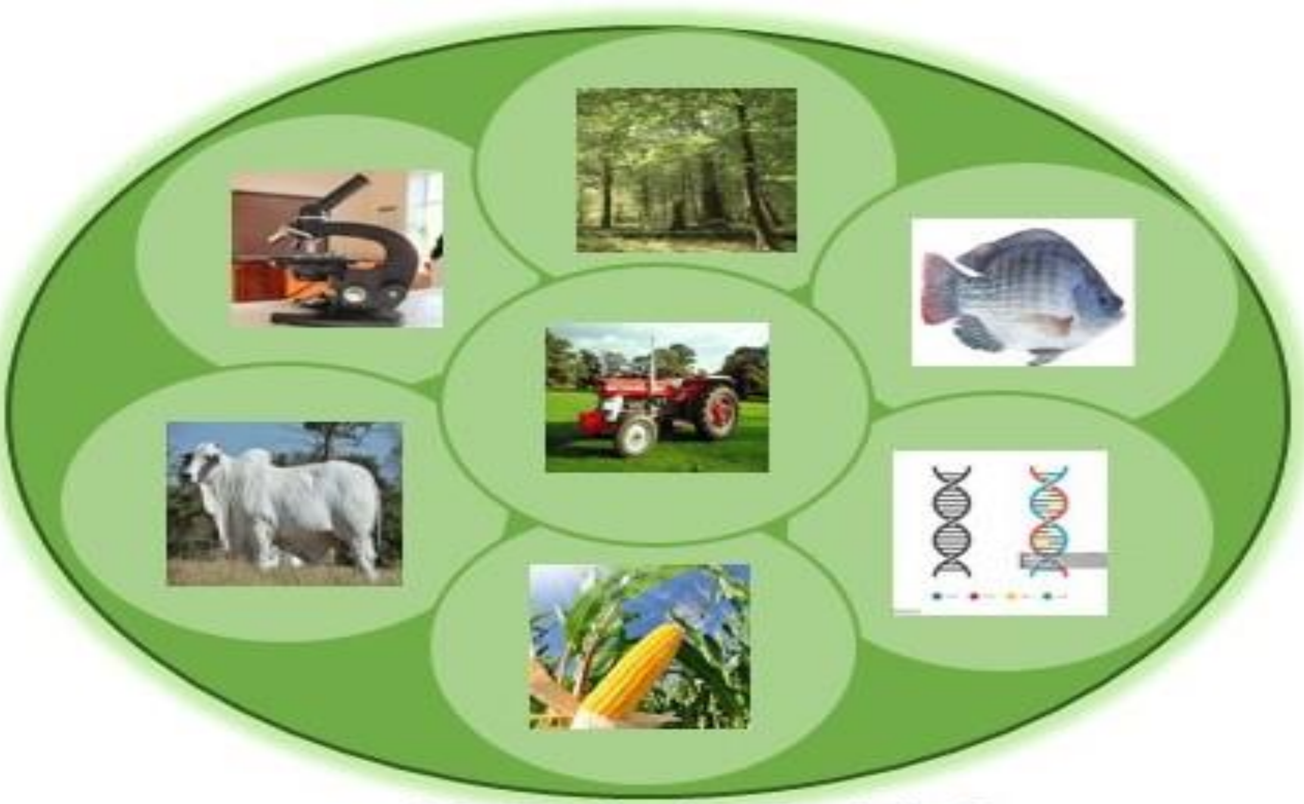

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DEVELOPMENT AND EVALUATION OF AUTOMATIC FISH FEEDING SYSTEM USING MPU6050 ACCELEROMETER/GYROSCOPE SENSOR AND ESP32 MICROCONTROLLER

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ABSTRACT

The automation of aquaculture processes represents a significant step towards increasing efficiency and sustainability in fish farming. The system's objective is to optimize feeding times and quantities, thereby reducing waste and improving fish health and growth rate Fish production can be greatly increased by dispensing the right amount of feed in accordance with the fish's demand, however most mechanical fish feeders still struggle to measure the amount of feed that the fish are actually consuming. Fish feeding according to regulatory frequency results in feed wastage, which degrades the water's quality and causes illnesses and stress on the fish. This research developed an innovative automatic fish feeding system that operates based on the fish movement behavior, utilizing the MPU 6050 accelerometer/gyroscope sensor and ESP32 microcontroller. . The system consists of feed hopper, MPU6050 accelerometer/gyroscope sensor, ESP32 microcontroller, servo motor and Real Time Clock (RTC module). The performance evaluation was carried out by comparing the usual manual feeding method and the developed system based on feed waste. The result of fish growth based on feed consumed in manual and automatic feeding as well as system efficiency in terms of reducing food wastage from 34.48% in manual feeding to 18.92% using the developed system shows a significant control of feed dispensing when compared with the manual feeding. The daily loss per kilogram of feed is found to be ₦54.54 and ₦26.73 for the manual and automatic system respectively. This could significantly improve the future of fish farming, leading to more environmentally friendly and economically viable practice.

Keywords**:** Automatic Feeding, Fish Feeding Behavior, Accelerometer/Gyroscope Sensor, ESP32 Microcontroller, Real Time Clock, Food Waste

Introduction

Fish farming is a profitable industry in most developing countries as it helps them achieve food security and poverty eradication. It is crucial to make sure that the fish are fed regularly in order to accomplish proper growth and development if one hopes to reap a plentiful harvest of fish in this industry. Overfeeding is becoming a major issue in aquaculture. The ineffective management of the feeding process is one of the reasons behind this issue (Mutiu *et al*, 2020). According to Ogunlela *et al*, (2016), ample income intensification requires fish feeding practices that can increase production effectiveness and decrease needless feeding.

About 60% of the feed put into aquariums ends up as particles, whereas the expense of feeding fish accounts for 40–50% of the total aquaculture operating costs (Atoum *et al*, 2015). Water pollution is caused by these deposited particles, which further uses oxygen to break down and produce ammonia-nitrogen and other harmful compounds that can stunt fish growth.

Feeding in fish aquaculture is performed using several methods ranging from extensive to hyper-intensive approaches. All the applied methods have advantages and disadvantages relative to the specific technologies that are used; however, such methods are affected by a common problem, which is the difficulty of achieving accurate feeding decision-making to meet the requirement of the fish in the rearing tank after the scheduled feeding is finished. For example, the feeding inefficiencies associated with intensively cultured prawn systems result in substantial financial cost and environmental impact when some of the water quality parameters are not under control (Smith and Tabrett, 2013; Smith *et al.*, 2002). Furthermore, the feed consumption must be continuously monitored to regulate the food availability according to the demands.

Fish farming, an essential component of aquaculture, requires precise management practices to ensure the health and growth of fish. One of the critical factors in fish farming is the feeding process, which significantly impacts water quality, fish health and resources efficiency. Traditional feeding methods as well as the existing fish feeders, often rely on fixed schedules, which can lead to overfeeding or underfeeding, affecting both the environment and the economic aspects of aquaculture. The development of an automatic fish feeding system based on the real -time behavior of fish presents a solution to these challenges. This paper introduces an innovative automatic fish feeding system that operates based on the analysis of fish movement behavior, utilizing the MPU6050 accelerometer sensor and an ESP32 microcontroller. The system's objective is to optimize feeding times and quantities, thereby reducing waste and improving fish health and growth rates.

Previous studies have highlighted various approaches to automating fish feeding processes including timer-based systems, weight sensors, and video analysis techniques. However, these methods often do not account for the dynamic nature of fish behavior and environmental conditions. The integration of motion sensors to detect fish activity presents a novel approach, offering the potential for more adaptive feeding strategies. The MPU6050 sensor, known for its high sensitivity and low power consumption, alongside the powerful yet cost-effective ESP32 microcontroller, provides a promising foundation for developing such a system.

Automatic Fish Feeder Concept, in essence, a large number of inventions have been created and categorized as "automatic fish feeders." The original design is by David C. Smeltzer which is patented in 4th April 1985. His design has a great degree of accuracy when dispensing feed with different grain sizes across a broad range of dispensing volumes. By using an adjustable counterbalance weight and varying the amount of water needed to make a dispensing action, the gadget was able to distinguish between different amounts of food being given out while also adjusting the vibrating movement made by the fish feeder. Therefore, by counterbalancing the weight, it is possible to adjust both the volume and frequency of feedings.

In 2015, Saahri created and manufactured a "home aquarium automated fish feeding system." For use in a home aquarium, the team created and built an autonomous fish feeding system. In order to regulate the process of fish feeding, it integrated mechanical and electrical/electronic systems. The feeding mechanism and feedback system are operated using an Arduino Uno microcontroller board. The design uses a vertical screw conveyor mechanism to dispense fish food into the water. This mechanism is driven by a unipolar stepper motor, and when the motor is coupled to the screw conveyor, its steps inputs control the amount of food delivered. The design also includes a user interface employing keypad button to choose the amount of dispensed food and infrared sensor as a warning system when the fish food level is low. The system is limited to monitor the amount of feed in the feeder and only for home use not for commercial use.

In 2016, Nasir *et al*. created an automated fish feeder. The apparatus is composed of a PLC (Programmable Logic Circuit), a motor, a stand, fish storage, and a GSM (Global System for Mobile). By releasing the feed from the storage through a hole, the apparatus will feed the fish. A block that is attached to a motor regulates the hole's size. The number of feeding times at different intervals is managed by a timer. Additionally, a feedback mechanism detects the amount of feed that is still in storage. Through SMS (Short Messaging Service), it alerts the user to the need to add a new feed to the storage.

The Smart Fish Feeder developed by Sabari *et al*. (2017) was intended to be a basic system that would react to the quantity of fish, the number of feeds, and the amount of time needed between each feed. When the water gets dirty, a GSM Module alerts the user to clean the tank. A microcontroller, LCD, solenoid valve, and GSM Module make up the design. The design does not take fish behavior or environmental conditions into account when determining how much feed should be supplied.

An automatic fish feeding system based on gasping behavior was produced by Ratna *et al.* (2018). The fish were fed according to daily needs based on their weight (4% body weight), and the eating behaviors were identified by observing changes in the ripples in the water caused by the hungry fish. The autonomous feeding system uses the water ripples produced by gasping as input, and a gyroscope sensor is employed to detect the water ripples. Five fish totaling 1204 grams in weight were employed in the experiment, and the system discharged 46.6 grams of fish feed on average per day, on average openings19 times per day. The system cannot differentiate between the ripples caused by the fish when searching for oxygen and the ripples caused when searching for food.

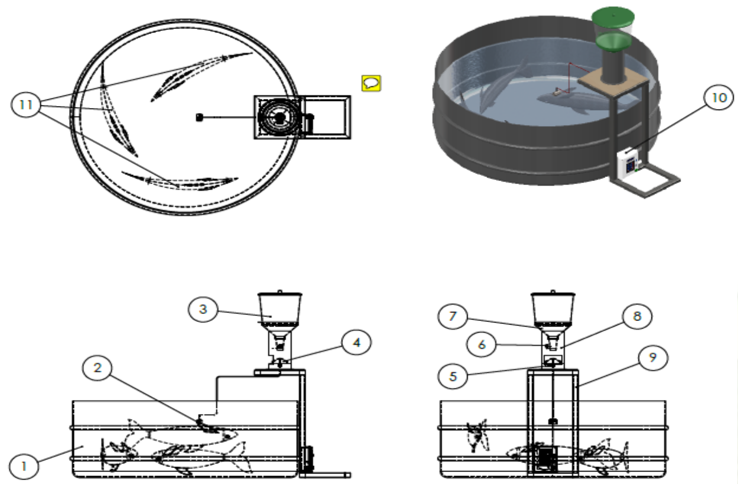
Ojo *et al*. (2018) used an Atmel 8052 microcontroller to develop and build an autonomous fish feeder. The idea uses a fish feeder that combines an electrical and mechanical system to create a device that regulates the feeding behavior of the fish. The feed storage, feed stand, display unit, microprocessor, and DC motor make up this apparatus. The DC motor that controls the feeds is housed beneath the feed storage. The apparatus has a control system attached that let the operator feed the fish at a predetermined period. It also includes a display unit, which is essentially the user interface and is where the system's operation is shown on a screen to provide the user a sense of what's happening within the system. The evaluation of fish feeding intensity in aquaculture using a convolutional neural network and machine vision was the focus of Chao *et al.'s* 2019 work. The study uses an automatic technique based on a Convolutional Neural Network (CNN) and Machine Vision to grade fish feeding intensity in order to assess fish appetite. The images were taken during the feeding process, and noise-invariant data expansion and rotation, scale, and translation (RST) augmentation methods were used to build and expand the dataset. After that, a CNN was trained on the dataset, and the CNN model was used to score the fish's hunger levels. In order to distribute feed based on the intensity of fish feeding, Mutiu et al. (2020) suggested integrating intelligence into the fish feeding regimen. The study developed a model using acceleration and angular velocity data obtained through a data logger that incorporated a triaxial accelerometer, magnetometer, and gyroscope for the purpose of predicting fish behavioral activities. Fish behavioral vibration analysis and artificial neural networks were used in the analysis of an intelligent fish feeding regime system. In order to extract the vectors for the behaviors of swimming, feeding, and escaping, a novel eight-directional chain code was developed. These vectors were then processed using the Discrete Fourier Transform using Fourier Descriptors and input into artificial neural networks.

Materials and Methods

The exploded conceptual sketch of the fish feeding system is shown in Plate 1, the sketch includes the various components that made up the system, such as the feed hopper, dispensing chamber, base frame, fish pond and the electrical control box which houses the microcontroller and other electrical components. The design consists of three sections; the feed hopper where the feed is stored, the dispensing chamber and the control unit. The feed hopper is a cylindrical plastic container with an outlet (funnel) at the bottom of the container. The dispensing chamber is made up of PVC pipe which houses the outlet of the hopper fitted with an open and close valve controlled by a servo motor, while an impeller which is controlled by a DC motor guides the feeds into the pond.

The control unit of the system consists of the MPU6050 accelerometer sensor to detect fish movement, the ESP32 microcontroller for data processing and control, a servo motor to dispense the feed based on the controller’s signal and a spreading mechanism driven by a DC motor to spread the feed within the feeding area. The MPU6050 sensor is placed in a waterproof container and attached to a floating device, allowing it to move freely with the fish. The ESP32 controller collects data from the accelerometer, analyzing patterns that indicate feeding time.

The system collects data on fish movements over a period to establish a baseline of normal activity, using C++ programming codes, the ESP32 microcontroller identifies patterns associated with hunger, such as increased activity or specific movement patterns. Once a feeding pattern is detected, the system calculates the optimal amount of feed, based on their average body weight and age, and triggers the servo motor to release food. The flow chart in Figure 1 describes the working principle of the system.



11.	Model fishes	——	1	——
10.	Electronic control box	Plastic	1	Constructed
9.	Frame stand	Mild steel	1	Constructed
8.	Feed output berrel	Plastic	1	Constructed
7.	Feed control compertment	Plastic	1	Constructed
6.	90 Degrees servo motor	——	1	Standard
5.	Dc motor	——	1	Standard
4.	Feed impeller	Plastic	1	Constructed
3.	Feed hopper	Plastic	1	Constructed
2.	Accelerometer (Sensor)	——	1	Standard
1.	Fish pond (Tank)	Plastic	1	Constructed
SN.	Part description	Material	Qty	Remarks

Figure 1 exploded sketch of the fish feeding system

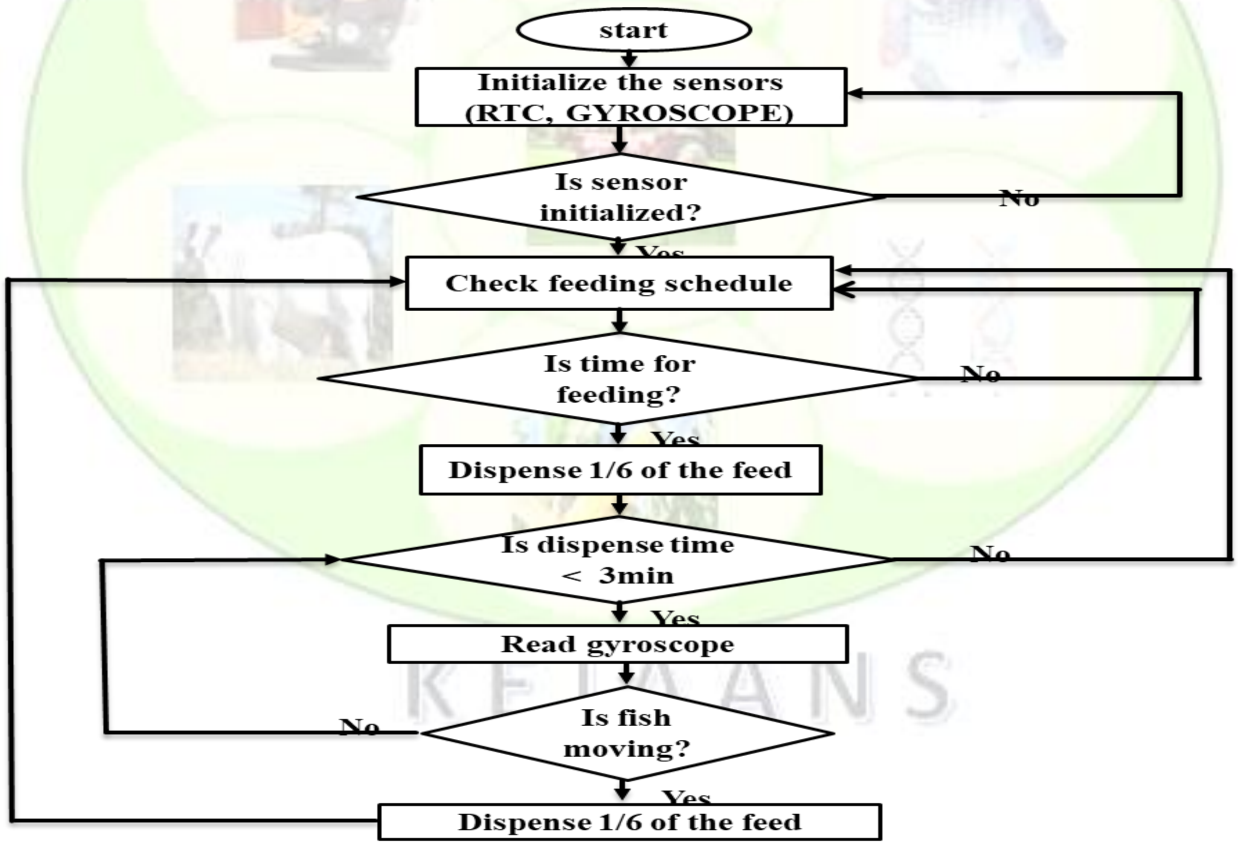


Figure 2: System flow chart

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Table 1 List of Materials/Components

S/N	Component	Selection criteria
1	ESP32 Microcontroller	Low power consumption, WIFI module, high clock speed, wide range of gpios, low cost, ease of interface, good memory
2	RTC module (Real Time Clock)	Low power consumption, low cost, high accuracy
3	MPU6050 accelerometer/gyroscope sensor	Low power consumption, low cost, ease of interface, programmable filters, good sensitivity
4	Servo Motor	Low power consumption, low cost, high torque, low speed, durability, sweep angle 20>x<180
5	Battery (12V, 20Ah)	High mAh rating, light weight, sustainability
6	Jumper wires	Low power consumption, low cost, durability
7	DC motor	Low power consumption, low cost, high torque, low speed, durability
8	Display unit	Low power consumption, low cost, high response speed, clarity and durability
9	Relay	Low power consumption, low cost
10	Plastic container	Low cost, light weight, durability, non-reactive to fish feed

Design Calculations

i. Daily feed needs and feeding frequency are very important to ensure correct amount of feed is given to the fish at the right time, therefore, calculating fish feed requirement is a vital key in designing a fish feeding system. From various literatures it is found that fish are fed based on certain percentage of their body weight coupled with their age or size. Daily feed need of fish is given as in equation 2.1

$$\text{Daily feed need} = \text{Fish biomass(FB)} \times \%\ \text{body weight of fish(\%BW)} \qquad 2.1$$

Also,

$$\text{Amount of feed per feeding} = \frac{daily\ feed\ need(DFN)}{feeding\ frequency\ per\ day(FQ)} \qquad 2.2$$

ii. The feed hopper plays a crucial role as it serves as the container that can hold the needed feed for a period required by the user. To ensure that the specified quantity of feed can be accommodated, it is important to determine the volume of the hopper using the formula provided below:

$$V = \pi r^2 l + \tfrac{1}{3}\pi r^2 h \quad , \qquad 3.3$$

the hopper is a cyndrical container

Where, V= volume of the hopper

r= radius of lower base of the fulcrum

l=length of the cylinder

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h= height of both cylinder and fulcrum respectively

Daily feed need= Fish biomass(FB) x % body weight of fish(%BW)
FB=1205g, %BW=5%
DFN = 1205×5%
=60.2g

$$\text{Amount of feed per feeding} = \frac{daily\ feed\ need(DFN)}{feeding\ frequency\ per\ day(FQ)}$$

Morning: 30%×60.2=18.06g
Afternoon: 40%×60.2=24.08g
Evening: 30%×60.2=18.06g
Volume of the feed hopper
R= 6.75mm
L= 18mm
H= 16.5mm
$V=\pi r^2 l + \frac{1}{3}\pi r^{2h}$
$=3.142\times6.75^2\times18+\frac{1}{3}x3.142\times6.75^2\times16.5$
$V= 3363.75mm^3=3.36m^3$

$$Battery\ life = \frac{battery\ rating\ (Ah)}{total\ current\ drawn\ by\ the\ system\ (Amp)} = \text{Battery life} = \frac{7800}{1458.6} = 5.3 hours,$$

The battery can last for approximately 5hours before recharge.

Results and Discussion

Figure 3 shows the water fluctuations observed during the feeding state, characterized by the movement of fish towards the feed after it has been introduced into the pond. The level of displacement during this feeding activity is notably greater than that observed in the normal state in Figure 4.

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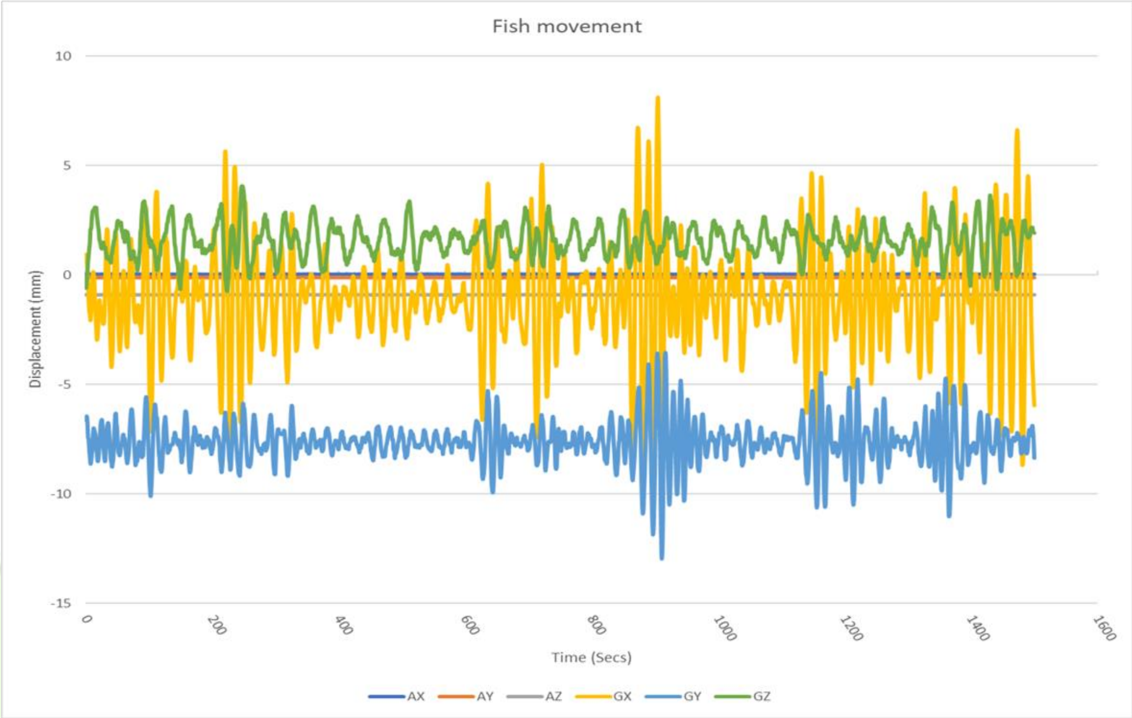

Figure 3. Pond water fluctuation at normal state

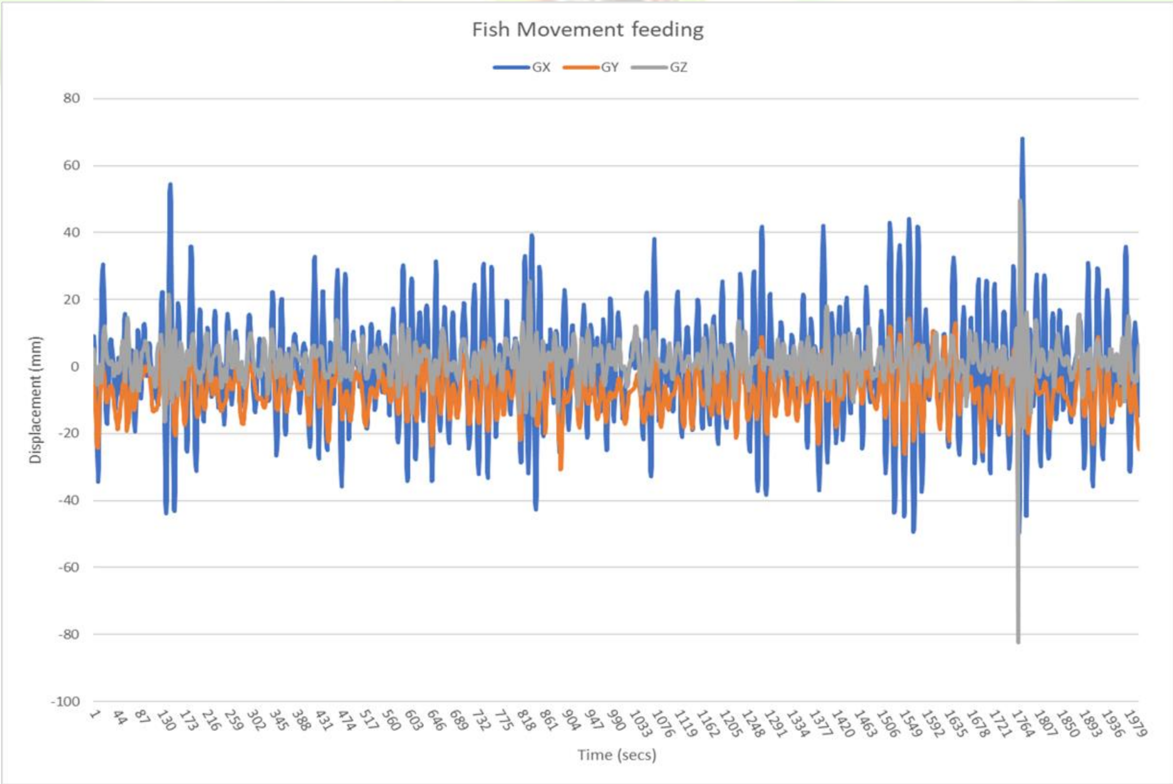

Figure 4. Pond Water Fluctuation at Feeding State

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Table 1 and 2 presents a comparison of the quantities dispensed by the automatic feeding system and the associated percentage of daily waste. The analysis indicates a daily percentage difference of 16%, which is higher than that observed with manual feeding in table 1, thereby contributing to a reduction in food wastage. The percentage of daily waste associated with the automatic feeding system is recorded at 15.56%. These results demonstrate a significant improvement in feed management, as the automatic system reduces food wastage from 34.48% in manual feeding to 18.92%. This indicates that the automatic feeding system is 19% more efficient in minimizing food wastage compared to manual feeding practices.

Table 1. Daily Feed Wastage for Manual Feeding

Day	Period	Quantity by body weight (g)	Quantity dispensed (g)	Difference in quantity (g)	Uneaten feed (waste) g	Percentage daily waste (%)
1	Morning	18.06	18	0.06	8.2	33.0
	Afternoon	24.08	24	0.08	5.4	
	Night	18.06	18	0.06	6.2	
	Total	**60.2**	**60**	**0.2**	**19.8**	
2	Morning	18.06	17.2	0.86	7.8	33.0
	Afternoon	24.08	23.1	0.98	6.3	
	Night	18.06	16.8	1.26	7.1	
	Total	**60.2**	**57.1**	**3.1**	**21.2**	
3	Morning	18.06	16.7	1.36	7.3	
	Afternoon	24.08	22.8	1.28	5.8	
	Night	18.06	17.6	0.46	6.8	34.8
	Total	**60.2**	**57.1**	**3.1**	**19.9**	
4	Morning	18.06	16.2	1.86	6.9	35.0
	Afternoon	24.08	23.4	0.68	6.3	
	Night	18.06	16.9	1.16	6.8	
	Total	**60.2**	**56.5**	**3.7**	**20**	
5	Morning	18.06	15.8	2.26	7.1	36.6
	Afternoon	24.08	22.4	1.68	5.6	
	Night	18.06	16.7	1.36	7.4	
	Total	**60.2**	**54.9**	**5.3**	**20.1**	

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Table 2. Daily Feed Waste for Automatic Feeding

Day	Period	Quantity by body weight (g)	Quantity dispensed (g)	Difference in quantity (g)	Uneaten feed (waste) g	Percentage daily waste (%)
1	Morning	18.06	16.1	1.96	4.1	19.8
	Afternoon	24.08	21.8	2.28	2.8	
	Night	18.06	15.2	2.86	3.6	
	Total	**60.2**	**53.1**	**7.1**	**10.5**	
2	Morning	18.06	15.2	2.86	2.6	17.6
	Afternoon	24.08	22.3	1.78	3.1	
	Night	18.06	14.7	3.36	3.5	
	Total	**60.2**	**52.2**	**8.0**	**9.2**	
3	Morning	18.06	14.3	3.76	2.3	17.6
	Afternoon	24.08	22.8	1.28	2.8	
	Night	18.06	14.1	3.96	3.9	
	Total	**60.2**	**51.2**	**9.0**	**9.0**	
4	Morning	18.06	15.2	2.86	2.6	17.6
	Afternoon	24.08	22.3	1.78	3.1	
	Night	18.06	14.7	3.36	3.5	
	Total	**60.2**	**52.2**	**8.0**	**9.2**	
5	Morning	18.06	16.2	1.86	3.6	22.0
	Afternoon	24.08	21.8	2.28	3.9	
	Night	18.06	14.7	3.36	4.1	
	Total	**60.2**	**52.7**	**7.5**	**11.6**	

Conclusion

The automatic fish feeding system was developed and evaluated using accelerometer/gyroscope sensor. The aim of this work is to provide a simple and easy means of feeding fish for aquaculture management without human intervention, through fish feeding behavior, by utilizing movement sensor. The system was designed, constructed and evaluated. Its main components are; hopper, servo motor, feeding mechanism (feed platform), real time module (RTC), microcontroller and accelerometer/gyroscope sensor. A C++ programming code was successfully developed on an ESP32 to control the feed dispensing process based on feeding parameters and frequencies. The system is programmed to detect feeding schedules and is capable of identifying the amount of feed to be given based on fish age (in weeks), feeding frequency, and temperature. The device was incorporated into a plastic fish pond for four weeks and the performance evaluation was based on feed waste in terms of manual feeding and the developed system using juvenile catfish. The result obtained in terms of reducing food wastage from 34.48% in manual feeding to 18.92% using the developed system shows a significant control of feed dispensing when compared with the manual feeding. Fish feeding behavior can be used for fish feeding management in aquaculture through the use of movement sensors. Feeding fish based on both regular timing and percentage body weight leads to food wastage and therefore requires optimal control in the quantity of feed given during feeding. The integration of feeding schedule with the sensor provides a significant control of food wastage compared to the existing feeders that works based on either only time of feeding or fish movement to dispense the feed.

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