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IoT-Based Smart Feed Management System Using Load Cell Sensors for Catfish Farming

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Abstract

Feed management is one of the key factors influencing the growth performance and production efficiency of catfish farming. However, in many small-scale and medium-scale aquaculture operations, feeding activities are still carried out manually, which often results in inconsistent feed portions, irregular feeding schedules, and limited control over feed stock availability. These conditions can affect fish growth and increase production costs. This study presents the development of an Internet of Things (IoT)-based smart feed management system designed to support accurate feed distribution and feed stock monitoring. The proposed system uses a NodeMCU ESP32 microcontroller, a load cell sensor to measure feed weight for accurate feed portion control, and an ultrasonic sensor for monitoring feed stock levels. Feed is released according to a predefined feeding requirement, while sensor data are transmitted through an IoT network for real-time monitoring. Telegram integration is implemented to provide notifications regarding feed stock status, daily feed usage, and estimated feed requirements. System testing demonstrated that the proposed solution was capable of automatically dispensing feed according to the calculated feed portions, monitoring feed stock conditions remotely, and providing notifications to users via Telegram. The developed system can assist fish farmers in improving feeding accuracy, reducing feed waste, enhancing operational efficiency, and supporting sustainable aquaculture management.

Keywords: *Internet of Things (IoT), ESP32, Load Cell Sensor, Smart Feed Management, Catfish Farming, Telegram.*

1. Introduction

Effective feed management is one of the most important factors influencing fish growth performance, feed utilization efficiency, and the overall productivity of aquaculture operations. Appropriate feeding strategies are essential to support fish growth and survival while maintaining sustainable aquaculture systems. Feeding practices in small-scale catfish farming are still commonly performed manually based on farmers' estimations.

Such practices may result in feed portions that do not accurately correspond to the nutritional requirements of the fish. Excessive feeding can increase operational costs and deteriorate water quality due to the accumulation of uneaten feed and organic waste, whereas insufficient feeding may reduce fish growth performance because the nutritional requirements of the fish are not adequately fulfilled. Therefore, accurate feed management is required to maintain a balance between fish growth, environmental quality, and farming efficiency [1] [2].

In addition to determining appropriate feed portions, farmers also face challenges in monitoring feed availability and maintaining feeding consistency. Feed stock monitoring is often conducted manually, making it difficult to accurately determine the remaining feed inventory and evaluate daily feed consumption. Furthermore, feeding schedules frequently depend on farmers' availability, which may result in delayed or missed feeding sessions. These limitations can reduce feeding efficiency and negatively affect fish growth performance. Therefore, the implementation of automated monitoring and feeding systems has become increasingly important to support more effective feed management in aquaculture operations [3].

Previous research by Ayon et al. proposed an IoT-based smart aquarium system for real-time water quality monitoring and automated fish feeding. The system utilized an ESP32 microcontroller integrated with pH, temperature, turbidity, and TDS sensors, as well as a servo feeder and water pump for automatic control.

Experimental results showed high sensor accuracy and reliable system performance, demonstrating the effectiveness of IoT technology in reducing manual intervention and maintaining stable aquatic conditions [4].

Vishnu Priya et al. developed an IoT-based smart pet feeding system using an ESP32 microcontroller to automate and monitor feeding activities remotely. The system integrated a load cell with an HX711 amplifier for accurate food measurement, a servo motor for food dispensing, and an RTC module for scheduled feeding operations. Through mobile application connectivity, users could monitor and manage feeding processes in real time, improving convenience and feeding consistency [5].

Saipul et al. developed a green energy-powered autonomous IoT catfish feeder using an Arduino Mega, ESP8266, solar panel, servo motor, and RTC module to automate feeding operations in catfish farming. The system provided scheduled feeding three times per day and was evaluated under different feeding scenarios to assess fish growth and feed utilization. Experimental results showed that the automated feeding schedule improved fish growth by 33.3% compared to limited feeding while using significantly less feed than excessive feeding practices [6].

Risma et al. designed a smart fish feeding system for aquaponic farming by integrating a load cell sensor and a Real-Time Clock (RTC) to automate and optimize feed delivery. The system was evaluated using Nile Tilapia over a 12-week period and demonstrated high feeding precision, with an average feed weight deviation of only 0.34 g, while supporting significant fish growth. In addition, the implementation of the ARIMA forecasting model enabled prediction of future feed requirements based on fish growth trends, helping to reduce overfeeding and improve feed management [7].

Table 1. Summary of Previous Research

No	Reference	Year	Strengths	Limitation
1	Ayon et al. [4]	2026	Provides real-time IoT monitoring and automatic fish feeding with multiple water quality sensors.	Doesn't calculate feed requirements based on fish age and population.
2	Vishnu Priya et al. [5]	2024	Implements accurate feed measurement using a load cell and remote monitoring via a mobile application.	Designed for pet feeding and does not support fish farming feed management.
3	Saipul et al. [6]	2023	Applies an IoT-based automatic feeder for catfish farming and demonstrates improved fish growth.	Uses fixed feeding schedules without feed calculation based on fish growth factors.
4	Risma et al. [7]	2025	Integrates a load cell and predictive model to improve feeding precision.	Doesn't provide real-time feed stock monitoring and focuses on aquaponic systems.

As shown in Table I, previous studies have successfully implemented automatic feeding systems for aquaculture applications. However, most existing systems focus only on feeding automation and do not calculate feed requirements based on the age and number of fish. In addition, feed stock monitoring and feed usage tracking are rarely integrated into a single system. As a result, farmers may face difficulties in managing feed consumption and replenishment. Therefore, this study proposes an IoT-based automatic feeder for catfish cultivation that calculates feed requirements according to fish age and population while monitoring the remaining feed stock in real time.

This study proposes an IoT-based automatic feeder for catfish farming that calculates feed amounts based on fish age and population. The system also monitors feed usage and remaining stock in real time to support better feeding management. This approach is expected to reduce manual work and improve feeding efficiency, and the system is limited to catfish cultivation and focuses only on feeding management aspects.

2. Research Methods

This study uses a quantitative approach with experimental methods combined with research and development (R&D) methods to design and evaluate an Internet of Things (IoT)-based automatic fish feeding and using telegram for set parameters or notification.

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2.1. System Architecture

2.1.1. System Design

The proposed system is an IoT-based automatic fish feeder developed for catfish cultivation. The system calculates feed requirements based on fish age and population and automatically dispenses feed according to the calculated amount. To improve feed management, the system also monitors the remaining feed stock in the feeder. An ESP32 microcontroller is used as the main controller, while a load cell, ultrasonic sensor, and servo motor support the feeding process. Monitoring information and system notifications are delivered through a Telegram Bot, allowing users to check feed stock conditions and feeding activities remotely. Figure 1 shows the overall architecture of the proposed system.

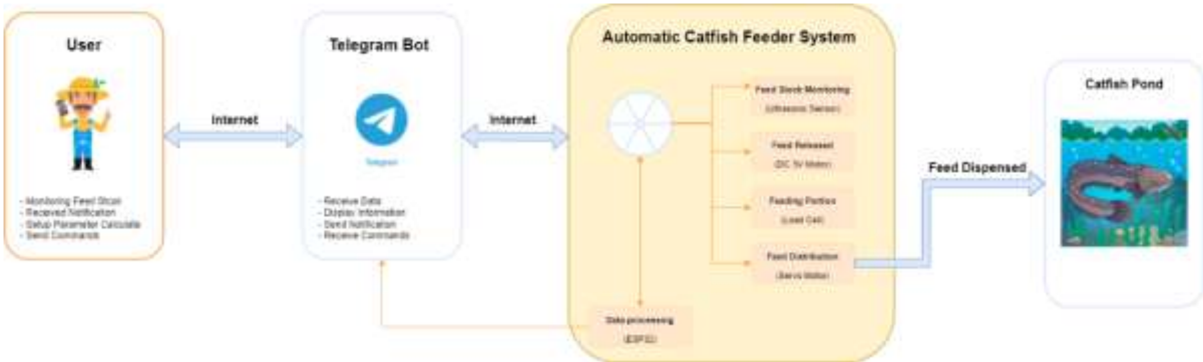

Figure 1. System Design

Figure 1 illustrates the overall concept of the proposed system. Users interact with the automatic feeder through a Telegram Bot to receive notifications and monitor feeding activities. The feeder system automatically calculates feed requirements and dispenses feed to the catfish pond according to predefined parameters.

2.1.2. Block Diagram System

To facilitate the design and manufacture of the tool, a block diagram of the system as a whole is made. The following block diagram show in figure 2.

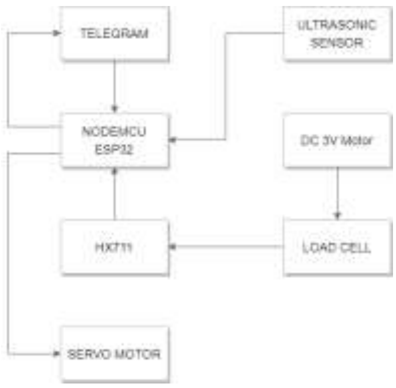

Figure 2 Block Diagram System

Figure 2 illustrates the block diagram of the proposed automatic fish feeding and monitoring system. The ESP32 acts as the main controller that processes sensor data and controls the feeding mechanism. The ultrasonic sensor is used to monitor the remaining feed level inside the storage container, while the load cell combined with the HX711 module measures the weight of the feed released using servo motor. Through the Telegram application, users can remotely monitor feed stock, and feeding status. The ESP32 also sends notifications and measurement results back to Telegram through an internet connection.

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Table 2. System Components and Functions

No	Component	Function
1	ESP32	Main controller for processing data and controlling system operations.
2	Load Cell + HX711	Measures the portions of feed released.
3	Ultrasonic Sensor	Monitors the remaining feed stock in the container.
4	DC 3V Motor	Controls the feed release to load cell tank.
5	Servo Motor	Controls the feed distribution mechanism.
6	Telegram	Provides notifications and monitoring information to users

Table 2 presents the hardware and software components used in the proposed system. The ESP32 functions as the main controller for processing sensor data and managing feeding operations. The load cell and HX711 module are utilized to measure feed weight, while the ultrasonic sensor monitors feed stock levels. A servo motor controls feed dispensing, and a Telegram Bot provides users with real-time notifications and monitoring information.

2.1.3. System Flowchart

The proposed system operates by first receiving fish age and population data entered by the user. These parameters are used to calculate the required feed amount according to predefined feeding recommendations. The calculated value is stored and associated with the feeding schedule. When the scheduled time is reached, the ESP32 activates the servo motor to dispense feed automatically. During the feeding process, the load cell measures the released feed weight, while the ultrasonic sensor continuously estimates the remaining feed stock. The resulting information is then sent to the Telegram Bot to provide users with real-time updates regarding feeding activities and feed availability.

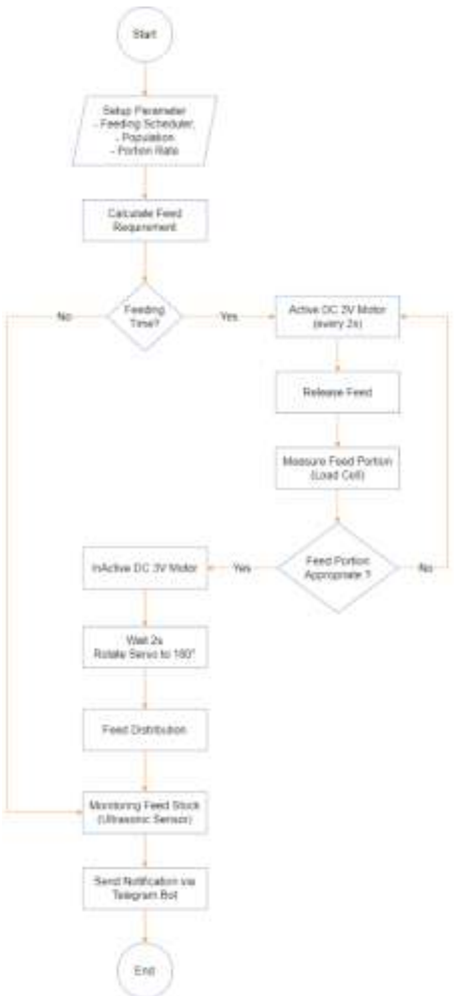

Figure 3. Workflow of the proposed IoT-based automatic catfish feeder system

Figure 2 illustrates the sequence of operations performed by the proposed system, from feed requirement calculation to feed dispensing and stock monitoring. The workflow also highlights the integration of sensor measurements and Telegram-based notifications for remote monitoring.

2.2. Hardware Design

2.2.1. Wiring Diagram

Figure 4 illustrates the wiring diagram of the proposed automatic fish feeding system. The ESP32 functions as the central controller that receives input data from the ultrasonic sensor, load cell, servo motor, DC 3V motor.

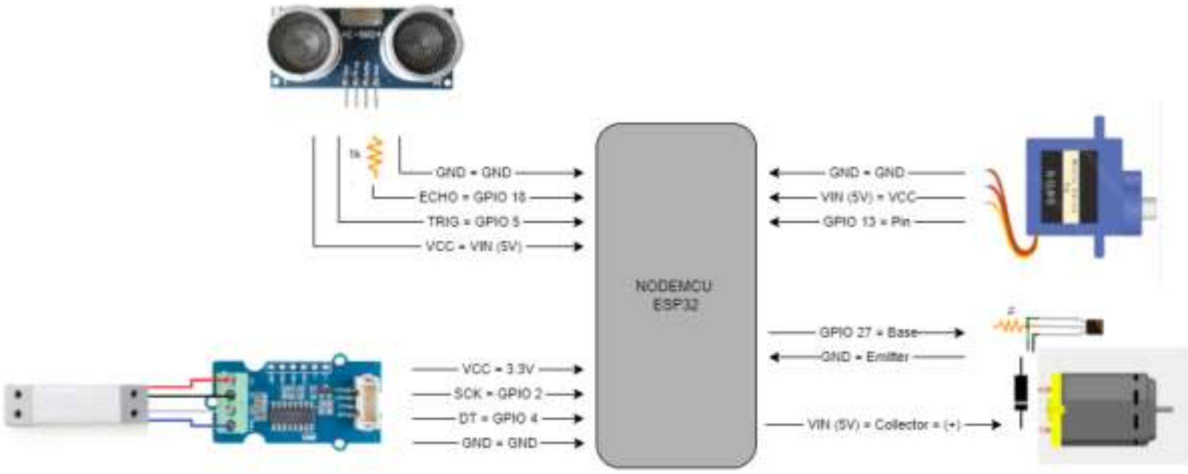

Figure 4 Wiring Diagram

The HC-SR04 ultrasonic sensor is connected through GPIO 5 (TRIG) and GPIO 18 (ECHO) to measure the distance between the sensor and the feed surface. The HX711 module communicates with the ESP32 through GPIO 4 (DT) and GPIO 2 (SCK) to transfer feed weight measurement data obtained from the load cell sensor. The SG90 servo motor is connected to GPIO 13 and is responsible for controlling the feed outlet mechanism. Meanwhile, GPIO 27 is utilized to drive the DC motor

Table 3 presents the pin configuration used to connect the ESP32 with all hardware components.

Table 3 ESP32 Wiring Configurations

ESP32 Pin	Device Pin	Device
VIN (5V)	VCC	HC-SR04
	VCC	SG90
	+	DC 3V Motor
3.3V	VCC	HX711
GND	GND	All Component
GPIO 5	TRIG	HC-SR04
GPIO 18	ECHO	HC-SR04
GPIO 4	DT	HX711
GPIO 2	SCK	HX711
GPIO 13	Signal	SG90
GPIO 27	Base Transistor	DC 3V Motor

A voltage divider consisting of a 1K resistor and a 2K resistor was connected to the ECHO pin of the HC-SR04 sensor to reduce the output voltage from 5V to approximately 3.3V before entering the ESP32 GPIO pin. This configuration protects the microcontroller from overvoltage conditions and ensures reliable distance measurements. And for DC 3V Motor needs diode, resistor 1K and transistor for control DC 3V Motor and

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protected ESP32 GPIO. All components share a common ground reference to ensure stable signal transmission and proper operation of the control system.

2.2.2. Specification Components

The proposed automatic feeding system consists of five main hardware components as show in table 3.

Table 4 Specification Components

No	Component	Specification
1	ESP32	NodeMCU ESP32, Dual-Core 240 MHz, Wi-Fi and Bluetooth integrated, Operating Voltage 3.3V.
2	Load Cell + HX711	Capacity 1–5 kg, 24-bit ADC, Operating Voltage 2.6–5.5V.
3	Ultrasonic Sensor	HC-SR04, Measuring Range 2–400 cm, Accuracy ±3 mm, Operating Voltage 5V.
4	Servo Motor	SG90 Servo Motor, Operating Voltage 4.8–6V, Rotation Angle 0–180°.
5	DC 3V Motor	Operating Voltage 3V uses with diode, resistor 1K and transistor

2.3. Feed Requirement

Feed requirements were automatically calculated based on fish population. The system estimates the total feed amount by considering the number of fish and the feeding rate recommended for each growth stage. The calculated value is then used as the feeding reference for the automatic feeder system [8] [9]. This method enables more controlled feed management and helps minimize overfeeding in catfish cultivation.

$$Biomass = Population\ x\ Average\ Fish\ Weight \quad (1)$$

$$Feed\ Requirement = Biomass\ x\ Feeding\ Rate \quad (2)$$

3. Results and Discussions

Figure 4 is the result, components of the tool will be describe with the following numbering: 1. Ultrasonic Sensor HC-SR04, 2. DC 3V Motor, 3. Servo Motor, 4. NodeMCU ESP32, 5. Adding Breadboard.

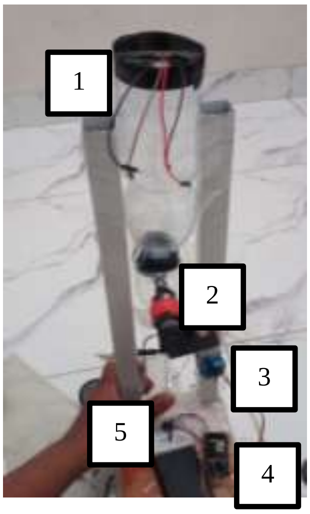

Figure 5 Result

Discussion is the basic explanation, relationship, and generalization shown by the results. The description answers a research question. If there are any dubious results then show them objectively.

3.1. NodeMCU ESP32 Testing

ESP32 is a WiFi module that is used to communicate between sensor data and users or servers. This protocol has the advantage of accessing the internet which allows users to access devices virtually or remotely and allows data delivery in real-time. The ESP32 supports WiFi connectivity, which is used to send data to the monitoring application [10].

The test results show that the data transmission process was performed smoothly with minimal delay. The ESP32 also demonstrated good performance in handling simultaneous tasks, including reading data from sensors and sending data through WiFi communication.

3.2. Ultrasonic Sensor Testing

The ultrasonic sensor (HC-SR04) was used to monitor feed stock level inside the container. The sensor measures distance from the top of the container to the surface of the feed.

Figure 6 HC-SR04 Ultrasonic Sensor Used for Feed Stock Level Measurement

The HC-SR04 ultrasonic sensor is utilized to measure the distance between the top of the feed container and the surface of the feed. This measurement is used to estimate the remaining feed stock level inside the storage container. The sensor works by transmitting ultrasonic waves and receiving the reflected signal, where the time difference is converted into distance [11].

The calculation of the percentage of remaining fish feed is carried out based on the distance of the ultrasonic results divided by the length of the tube and multiplied by 100 [12].

$$Feed\ Stock\ Level = \left(\frac{Distance\ (cm)}{Tube\ Length\ (cm)}\right)\ x\ 100 \qquad (1)$$

Table 5 Result Ultrasonic Sensor Testing

No	Actual Distance (cm)	Measured Distance (cm)	Error (%)	Feed Stock Level (%)
1	10	10.2	2	40.8
2	15	14.8	1.3	59.2
3	20	20.4	2	81.6
4	25	24.7	1.2	98.8

The average error of the ultrasonic sensor is approximately **1.6%**, which indicates that the sensor is accurate enough for feed level monitoring in real conditions. The conversion of distance into percentage provides a more intuitive representation of feed availability. When the measured distance approaches the full tube height (25 cm), the system indicates nearly full capacity (98.8%), while lower distances correspond to reduced feed levels

3.3. Load Cell Testing

The load cell sensor integrated with the HX711 amplifier module was tested to evaluate its capability in measuring feed weight accurately. The sensor was installed beneath the feed container as shown in Figure 6. The testing procedure involved placing known weights on the container and comparing the measured values obtained from the load cell system with those from a calibrated digital weighing scale.

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Figure 7 Load Cell sensor for Measure Feed

Prior to measurement, a calibration process was conducted using a reference weight of 500 g. The calibration factor was adjusted until the reading from the load cell matched the actual weight measured by the digital scale. After calibration, several feed samples with different weights were tested to determine the sensor accuracy.

Table 6 Load Cell Sensor Calibration

Reference Weight (g)	Load Cell Before (g)	Load Cell After (g)
500	472	500
500	475	501
500	478	500

After calibration, several feed were weighed and compared with a digital scale.

Table 7 Compared Load Cell sensor with a Digital Scale

No	Digital Scale (g)	Load Cell (g)	Error (g)	Error (%)
1	100	102	2	2
2	200	199	1	0.5
3	300	301	1	0.3
4	400	398	2	0.5
5	500	503	3	0.6

The experimental results indicate that the load cell sensor combined with the HX711 module is capable of measuring feed weight with good accuracy. The maximum error observed during testing was 2%, while the minimum error was 0.3%. These results demonstrate that the sensor is suitable for feed monitoring applications in aquaculture systems.

3.4. Servo Motor Testing

The servo motor is controlled when the feed weight is at the target, the servo moves a maximum of 180, fast response (<1 second) No problems such as jamming or wrong position were found. The servo motor was installed as shown in Figure 7.

Figure 8 Servo Motor SG90

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3.5. Telegram

Telegram bot can receive commands given by the user [13]. Here is a list of telegram bot commands in this system.

Table 8 Telegram Bot Commands

No	Command	Action	Information
1	/start	Check status connection bot with ESP32	Success
2	/status	Check feed stock level and time previous feed catfish	Success
3	/schedule *hours*	Set Scheduler of feeder	Success
4	/population *number*	Set population in the catfish pond	Success
5	/info	Check the current list schedule and population	Success

4. Conclusion

In conclusion, an Internet of Things (IoT)-based smart feed management system for catfish farming was successfully developed. The system is capable of dispensing feed using a load cell sensor to measure feed weight. Once the target feed weight is reached, the dispensing process is automatically stopped. A servo motor then rotates the container to distribute the feed, and the system transmits data through an IoT network integrated with Telegram notifications. Experimental results show that the system can operate reliably in measuring feed weight, controlling feed portions, and providing real-time monitoring information to users. The implementation of this system improves feeding efficiency and accuracy, and enhances aquaculture operational management. Future work may focus on improving automation algorithms and integrating predictive feeding models based on fish growth patterns.

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