Automatic Feeding System for Ornamental Fish Farming

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Abstrak — **Penelitian ini mengembangkan sistem pemberian pakan otomatis untuk budidaya ikan hias guna meningkatkan efisiensi dan mengatasi tantangan pemeliharaan manual. Sistem ini memungkinkan penjadwalan pakan melalui aplikasi Telegram dan mendeteksi sisa pakan di kolam untuk mencegah overfeeding, serta memantau tingkat pakan di tempat penyimpanan. Implementasi perangkat keras mencakup mikrokontroler ESP32-DevKitC V4, motor DC dengan driver untuk pengeluaran pakan spiral, sensor ultrasonik HC-SR04 untuk deteksi tingkat pakan, dan ESP32CAM untuk verifikasi pakan di kolam. Pengujian menunjukkan sistem berhasil memberi pakan secara otomatis ke dua kolam dengan tingkat akurasi dan konsistensi yang dapat diterima, serta memberikan notifikasi real-time kepada pengguna. Solusi ini secara signifikan meningkatkan efektivitas pengelolaan pakan, memastikan nutrisi optimal, dan meminimalkan pemborosan pakan.**

Kata kunci— IoT, budidaya ikan hias, pemberian pakan otomatis, skema pemberian pakan, deteksi pakan

I. PENDAHULUAN

Budidaya ikan hias bernilai ekonomi tinggi, namun membutuhkan perawatan intensif. Indonesia menyumbang ±75% pasokan ikan hias air tawar dunia, tetapi keterbatasan waktu dan pengetahuan peternak dapat menghambat keberhasilan.

Pemberi pakan otomatis berbasis Internet of Things (IoT) menjadi solusi efektif, menggabungkan kontrol perangkat keras dan perangkat lunak untuk pemberian pakan jarak jauh, pemantauan sisa pakan, serta pengaturan jadwal. Sistem ini mengurangi risiko overfeeding/underfeeding dan meningkatkan efisiensi tenaga kerja..

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II. KAJIAN TEORI

A. Pentingnya Pakan dalam Budidaya Ikan

Feed is a crucial factor in fish cultivation, directly impacting growth and health. Fish generally require 20-60% protein in their feed, with 30-36% being optimal for growth. Insufficient protein (below 30%) can hinder fish growth. Conversely, overfeeding can lead to problems like murky pond water due to uneaten food, diseases such as hepatic lipidosis, fish stress, and decreased water quality. Underfeeding can also impede fish growth due to nutritional deficiencies.

Manual feeding, though common, often results in scheduling errors, leading to overfeeding or uneven distribution. Automatic feeding systems with interval timing offer an effective solution, enabling more precise control over feed quantity and schedule, thereby increasing efficiency and minimizing negative environmental impacts. This ensures fish receive adequate feed for optimal growth while maintaining good water quality.

For this system, two types of ornamental fish were selected:

- Koki Fish: Known for their rounded bodies and slow movements, Koki fish require small-sized feed (2 mm) for optimal growth.
- Koi Fish: With larger bodies and faster growth rates, Koi fish require larger feed sizes (approximately 5 mm) to meet their nutritional needs.

B. Internet of Things (IoT)

IoT is a concept aimed at extending the benefits of continuous internet connectivity. The proposed ornamental fish farming system is built on an IoT framework, adhering to ISO 30141:2016 standards. This includes functional and management capability separation, allowing IoT devices to perform management without disrupting other device functionalities. The system also supports real-time operations, ensuring no significant latency in any operation.

III. METODE

The design and implementation of the automatic feeding system involved careful selection of hardware and software components to ensure optimal operation.

A. Selected Hardware Components for Automatic Feeding

The core hardware components for the automatic feeding system include:

- Microcontroller: ESP32-DevKitC V4 The ESP32-DevKitC V4 is a reliable and versatile development board ideal for IoT applications, known for its integrated Wi-Fi and Bluetooth connectivity. This allows direct connection to networks and other devices without additional components. Its multitasking capabilities are rated highly compared to alternatives.

- Feed Dispensing Mechanism: Spiral Conveyor driven by Motor DC + Driver Motor A spiral conveyor is chosen for its ability to dispense feed slowly and uniformly, ensuring precise distribution. The Motor DC + Driver Motor combination is selected as the actuator. While a simple DC motor can control feed release, adding a motor driver allows for flexible speed adjustment, which is crucial for optimizing feed quantity and rate. The driver also serves as an additional power supply for other sensors and actuators, simplifying circuit design and enhancing overall power efficiency.

- Feed Storage Container: Funnel-Shaped Tube (Tabung Bercorong) This design combines a large cylindrical top for maximum storage capacity with a funnel-shaped bottom to facilitate smooth feed flow by gravity, preventing blockages and spoilage. This design is considered the most effective for efficient feed storage and distribution.

- Feed Level Detection in Storage: HC-SR04 Ultrasonic Sensor The HC-SR04 ultrasonic sensor is used to detect the amount of feed remaining in the storage box. It measures the distance from the sensor to the feed surface by emitting ultrasonic waves and calculating the time it takes for the waves to return. This distance is then used to estimate the feed quantity. Its affordability also made it a preferred choice.

  Perhitungan Sisa Pakan menggunakan Sensor HC-SR04:

  $$1. Jarak\ Terukur = \frac{(Waktu\ Echo\ \times\ Kecepatan\ Suara)}{2}$$

  $$2. Tinggi\ pakan = Tinggi\ Kotak\ -\ Jarak\ Terukur$$

  $$3.\ Persentase\ pakan = (Tinggi\_Pakan\ /\ Tinggi\_Kotak\_Total) \times 100\%$$

  Dimana:

  -Waktu Echo = waktu pantulan gelombang ultrasonik (µs)

  - Kecepatan Suara = 343 m/s (pada suhu ruang)

  -Tinggi Kotak = 19 cm (tinggi total kotak penyimpanan)

- Feed Presence Detection in Pond: ESP32CAM OV2640 Camera The ESP32CAM OV2640 Camera is integrated into the system for visual verification of feed presence on the pond surface. It features a 2MP camera, Wi-Fi, and Bluetooth, allowing it to capture and analyze images. The camera is mounted on a two-axis servo bracket, enabling it to move and point in the required directions, serving multiple functions with a single camera.

B. Software Components for Automatic Feeding

- User Interface: Telegram Application Telegram is utilized as the user interface due to its robust bot API, which facilitates direct communication between IoT devices and users. Its widespread popularity means users do not need to install additional applications. Telegram bots enable real-time notifications (e.g., feed status, warnings) and interactive control via inline buttons and commands. This choice also reduces development costs as it leverages Telegram's existing infrastructure.

- Database: Firebase Realtime Database Firebase, a Backend as a Service (BaaS) by Google, provides a NoSQL database with real-time data synchronization capabilities. This is crucial for rapid communication between the ESP32 and the backend, storing user schedules, sensor readings, and actuator commands. Firebase offers a free tier suitable for initial development and scales automatically.

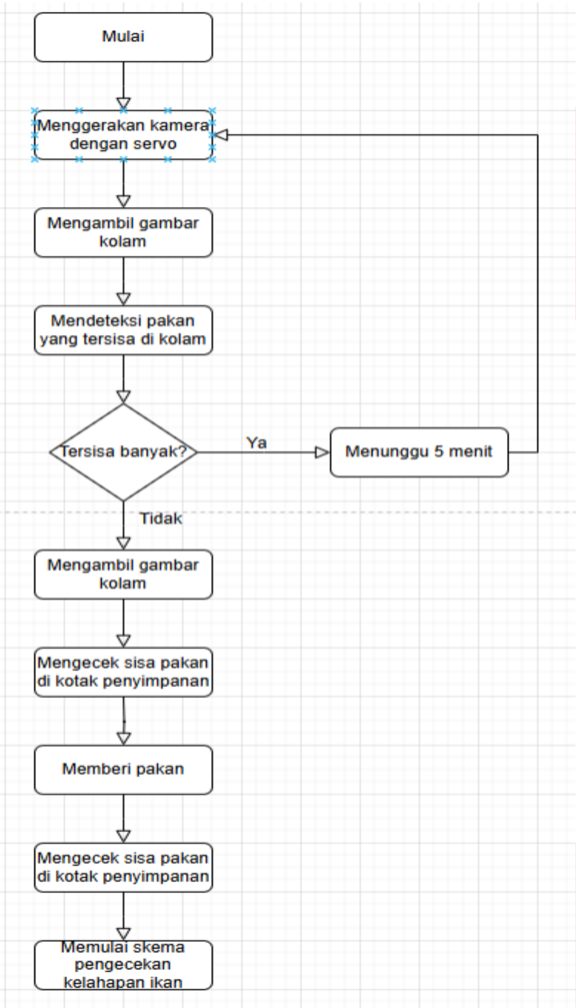
- Backend Server: Express.js Express.js, a minimalist and flexible Node.js framework, serves as the backend server. It connects the Telegram Bot user interface with Firebase Realtime Database and the ESP32 devices. Its primary roles include providing API endpoints for data communication, managing HTTP requests from users, processing user input before forwarding to Firebase or IoT devices, and temporarily storing user session data for notifications.

C. Feeding Scheme and Process The automatic feeding scheme is designed to optimize feed delivery and prevent overfeeding or underfeeding:

1. Schedule Input: Users input desired feeding schedules for each pond via the Telegram application. Each pond can have multiple, distinct schedules per day. If a schedule is modified, the system updates the existing one. Users can also delete schedules for purposes like fish fasting, which helps control growth.

2. Schedule Check: The system continuously compares the real-time clock with stored schedules (hour and minute) every minute. Once a match is found, the feeding execution function for the specific pond and schedule is triggered.

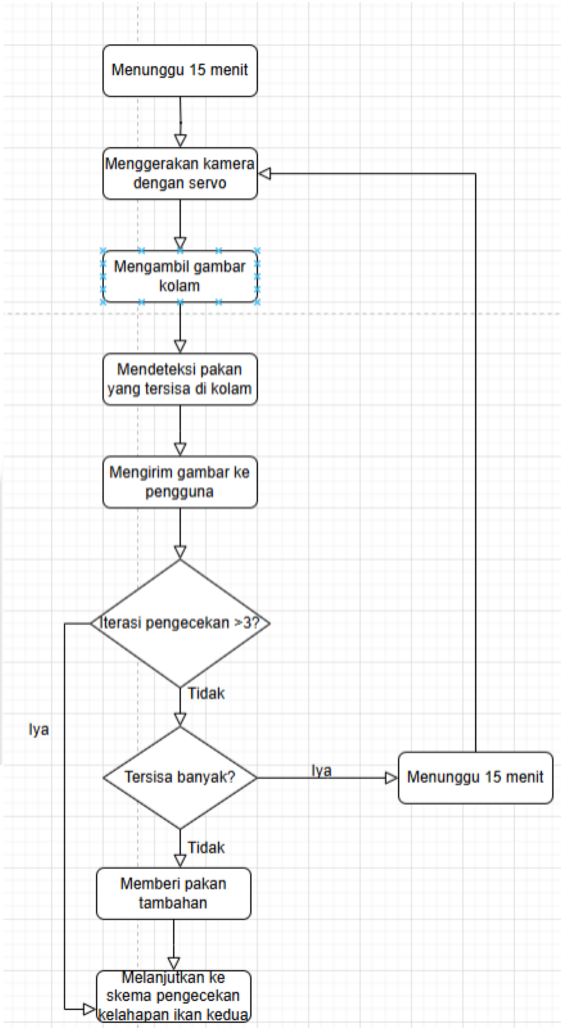
3. Feeding Execution:



GAMBAR 1
Flowchart eksekusi pemberian pakan

- Initial Feed Level Check (Storage): Before dispensing, the system queries the HC-SR04 sensor to check the remaining feed in the storage box of the target pond. This helps monitor feed availability and inform users for refilling.
- Initial Feed Presence Check (Pond Surface): The ESP32CAM takes a picture of the pond surface and sends it to a machine learning algorithm (YOLOv11 model) to detect leftover feed. This is a crucial step to prevent overfeeding. If a significant amount of feed is detected, the system delays feeding for 5 minutes and rechecks. If the feed is still present when the next scheduled feeding time arrives, the current schedule is skipped, assuming the fish are still consuming the previous feed.
- Feed Dispensing: If little or no feed is detected on the pond surface, the Motor DC is activated for the specified pond to dispense feed. The motor driver regulates the motor's rotation speed to control the feed amount.
- Post-Feeding Verification & Notification: After feeding, the system takes another picture of the pond as proof of completion and sends it to the user. It also re-checks the feed level in the storage box and notifies the user.

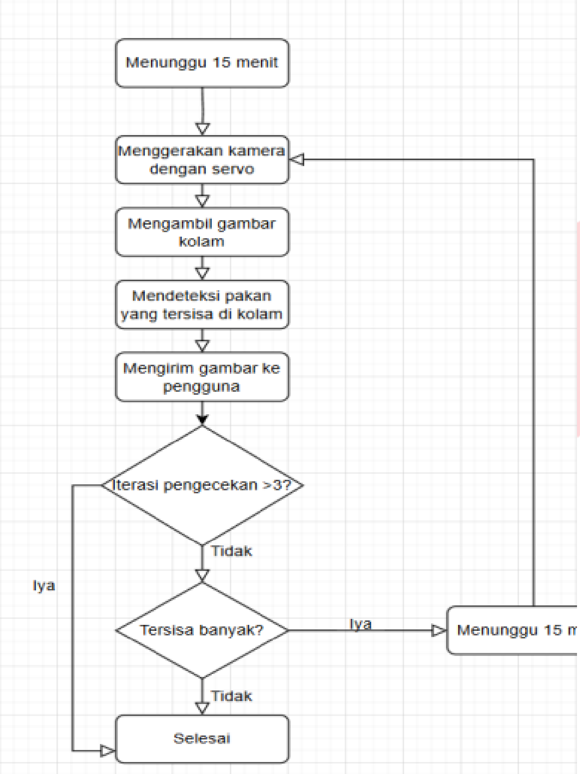
4. Fish Appetite Monitoring (Phase 1):



GAMBAR 2
Flowchart pengecekan kelahapan ikan pertama

After the initial feeding, the system initiates a two-phase fish appetite monitoring. In phase one, it waits for 15 minutes, then moves the camera (using servos) to the pond to take a picture. This image is sent to the web server for detection and then to the user. This check repeats every 15 minutes, up to three times, if a large amount of feed remains on the surface. If little feed is detected in any iteration, additional feed is dispensed to prevent underfeeding.

5. Fish Appetite Monitoring (Phase 2):



GAMBAR 3
Flowchart pengecekan kelahapan ikan kedua

Following phase one, phase two continuously takes pictures of the pond at regular intervals, sending the detection results to the user without dispensing additional feed. This helps users assess fish appetite and decide on necessary actions if fish exhibit low appetite.

IV. HASIL DAN PEMBAHASAN

The implementation and testing of the automatic feeding system focused on its core functionalities, ensuring accurate and reliable feed delivery.

A. Automatic Feed Dispensing and Schedule Management (SR 1.1 & SR 1.2) The system was tested for its ability to automatically dispense feed to two separate ponds, accommodating different feed sizes: 2mm for Koki fish and 5mm for Koi fish. The Motor DC, controlled by duration, was used for dispensing.

Based on discussions with users, ideal feed weights per feeding cycle are approximately 3 grams for Koki fish and 25 grams for Koi fish. Preliminary tests determined optimal dispensing durations: 1 second for 2mm feed (Koki) and 20 seconds for 5mm feed (Koi). Extensive testing was then conducted: 100 trials for 2mm feed (1-second duration) and 60 trials for 5mm feed (20-second duration).

TABEL 1
(A) HASIL PENGUJIAN PEMBERIAN PAKAN OTOMATIS

Jenis Ikan	Ukuran Pakan	Durasi (detik)	Rata-rata (gram)	Std Dev	CV (%)	Target (gram)
Koki	2mm	1	3.45	0.67	19.42	3
Koi	5mm	20	25.10	2.30	9.16	25

Results for 2mm Feed (Koki fish, 1-second duration, 100 trials):

- Average: 3.45 grams (close to ideal 3 grams)
- Standard Deviation: 0.67 grams
- Minimum: 2.00 grams
- Maximum: 5.00 grams
- Coefficient of Variation (CV): 19.42% The CV indicates a relatively high variation, but the range of dispensed feed (2.00-5.00 grams) is still within acceptable limits for small feed sizes, thus not significantly affecting system performance.

Results for 5mm Feed (Koi fish, 20-second duration, 60 trials):

- Average: 25.10 grams (very close to ideal 25 grams)
- Standard Deviation: 2.30 grams
- Minimum: 21.00 grams
- Maximum: 29.00 grams
- Coefficient of Variation (CV): 9.16% This lower CV demonstrates better consistency compared to the 2mm feed, confirming the system's reliability for dispensing larger feed sizes.

The scheduling function (SR 1.2) was tested by sending commands via the Telegram bot to set and delete schedules for both ponds. The system successfully stored schedules in the Firebase database and executed them automatically at the set times. Deleting schedules also functioned as intended.

B. Feed Detection and Notifications (SR 1.3, SR 1.4, & SR 1.5)

This test verified the system's ability to automatically check for leftover feed in the pond using machine learning (SR 1.3), detect the remaining feed quantity in the storage box (SR 1.4), and send Telegram notifications about feed levels (SR 1.5).
As shown in Figure 5.9:

- When a scheduled feeding time arrived (e.g., 09:34 for pond 2), the system first checked for leftover feed in the pond.

- If a large amount of feed was detected, the feeding was delayed by 5 minutes, and the check was repeated. If little or no feed was detected, the process continued.
- Next, the system checked the feed level in the storage box.
- Feed dispensing then occurred, followed by a final check of the feed level in the storage box and a notification to the user.

For feed level detection in the storage box (SR 1.4), the HC-SR04 sensor was used. The storage box is 19 cm high and holds 550 grams of feed. Feed levels were categorized based on the distance from the sensor to the feed:

- Little: Distance ≥ 15 cm
- Medium: 10 cm ≤ Distance < 15 cm
- Much: Distance < 10 cm

TABEL 2

(B) HASIL PENGUJIAN AKURASI SENSOR HC-SR04

Jarak Aktual (cm)	Rata-rata Pembacaan (cm)	Error (%)	Kategori Pakan
5	4.30	14.0	Banyak
10	9.56	4.4	Sedang
15	14.61	2.6	Sedikit

To assess the reliability of the HC-SR04 sensor, tests were performed by measuring objects at actual distances of 5cm, 10cm, and 15cm from the sensor.

- 5cm actual distance (representing "much" feed): The average reading was 4.30 cm, with a 14% error.
- 10cm actual distance (representing "medium" feed): The average reading was 9.56 cm, with a 4.4% error.
- 15cm actual distance (representing "little" feed): The average reading was 14.61 cm, with a 2.6% error. The sensor performed better at longer distances within the 5cm-15cm range. Adjustments were made to use the average of sensor readings to determine the remaining feed quantity more accurately.

After the main feeding, additional checks for leftover feed in the pond were performed every 15 minutes, up to three times (SR 1.3). As shown in Figure 5.13 and 5.14, if feed remained, no additional feeding occurred. If the feed was consumed, a second feeding was triggered. Subsequent checks merely reported the feed status to the user without further dispensing.

Notifications (SR 1.5) were consistently sent via Telegram to inform users about the feed status before and after dispensing, proving the system's effectiveness in keeping users informed.

C. System Utility and Monitoring (SR 1.6, SR 1.7, SR 3.1, & SR 3.2) The system's utility features were also successfully implemented and tested:

- Schedule Listing (SR 1.6) and Deletion (SR 1.7): Users could easily view a list of all set schedules and their completion status for each pond via the Telegram bot, and delete existing schedules as needed.
- Menu Display (SR 3.1): The Telegram bot could display a comprehensive menu of available commands and their parameters, simplifying user interaction with the system.
- Device Uptime Monitoring (SR 3.2): The ESP32 continuously sent its uptime to the backend. If no update was received within 30 seconds, the ESP32 was considered inactive, and a notification was sent to the user. This feature successfully detected device disconnection during testing.

Overall, the comprehensive testing confirmed that all specified features related to automatic feeding and its supporting elements functioned as designed, indicating a high level of success for the solution.

V. KESIMPULAN

The developed ornamental fish farming management system successfully addresses the challenges of automatic feeding, demonstrating a 100% success rate in meeting its design specifications. Key aspects successfully implemented include:

The automatic feeding system reliably dispenses feed to two separate ponds, achieving an average dispensing rate of 2.08 grams per second using DC motors. It accurately executes schedules set via Telegram, ensuring precise timing and dosage. The integration of the ESP32CAM allows for automatic detection of leftover feed in the pond, preventing overfeeding and maintaining water quality. The detection of feed levels in the storage box using the HC-SR04 sensor provides users with estimated quantities (little, medium, much) with an accuracy of ±1-2 cm, which is acceptable for practical use. Real-time Telegram notifications keep users informed about feeding status and feed levels.

While the system successfully achieved its objectives, some limitations exist. The feed storage capacity of 550 grams still requires periodic manual refilling. The system's functionality is dependent on a stable internet connection for communication with Telegram and Firebase. The budgetary constraints during development influenced component selection, leading to the use of relatively affordable, standard-quality components. Despite these limitations, the system significantly enhances the efficiency and effectiveness of ornamental fish feed management, ensuring optimal nutrition and minimizing waste.

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