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Intelligent Pet Feeder with Real-Time Camera Monitoring

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ABSTRACT
The "Intelligent Pet Feeder with Real-Time Camera Monitoring" is an innovative automated feeding system designed to ensure timely and precise feeding for pets while offering real-time monitoring. The system incorporates a Passive Infrared (PIR) sensor to detect motion near the feeding station. Upon detecting movement, an ESP32 camera module is activated for 10 seconds to verify the presence of a pet. If no pet is detected, the system returns to standby mode until further motion is sensed. If a pet is identified, the camera triggers a servo motor, which dispenses food in controlled portions. The system operates on an ESP8266 microcontroller, ensuring efficiency, reliability, and remote connectivity. This smart feeder is particularly beneficial for pet owners, animal welfare organizations, and community caregivers, offering a solution that reduces food wastage and promotes responsible pet care. The integration of motion detection, pet recognition, and automated food dispensing makes this system a significant advancement in smart pet care solutions.
Keywords: Intelligent Pet Feeder, Real-Time Monitoring, PIR Sensor, ESP32, Automated Feeding, Pet Welfare.

I. INTRODUCTION

With urban lifestyles becoming increasingly fast-paced, pet owners often struggle to maintain a consistent feeding schedule for their pets. The "Intelligent Pet Feeder with Real-Time Camera Monitoring" aims to address this challenge by integrating automated feeding mechanisms with real-time pet recognition technology. The system utilizes a PIR sensor as an initial trigger to detect motion in the feeding area. Upon detecting movement, an ESP32 camera module is activated for 10 seconds to confirm the presence of a pet (dog or cat). If no pet is detected, the camera shuts down, and the system re-enters standby mode, conserving energy until further motion is detected. Conversely, if a pet is identified, the system activates a servo motor, which rotates 180 degrees for five seconds, dispensing a precise amount of food.

This looped automation process ensures that pets receive their meals without requiring constant human intervention. The feeder operates on an ESP8266 microcontroller, which enhances system responsiveness and enables potential remote monitoring capabilities. This cost-effective, energy-efficient, and scalable solution not only simplifies pet care for busy individuals but also serves as a valuable tool for animal shelters, NGOs, and community welfare initiatives, ensuring that stray and shelter animals receive regular meals. By leveraging motion detection, object recognition, and IoT-enabled automation, this smart pet feeder provides a reliable, user-friendly, and efficient solution for modern pet care.

II. LITERATURE REVIEW

Paper 1: Remote Pet Feeder Control System via MQTT Protocol
Authors: Wen-Chuan Wu, Ke-Chung Cheng, Pei-Yu Lin
Published in IEEE, 2018

This study presents a remote pet feeder system that leverages a remote-control car, integrated with an IP camera and a microcomputer functioning as an MQTT server. The system enables pet owners to control the feeding process and monitor their pets by sending MQTT messages from their mobile devices. The added functionality of video streaming allows for real-time interaction, providing owners with a more engaging pet care experience. While this system facilitates remote

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monitoring and feeding, it faces several limitations, including high cost due to the use of a Raspberry Pi, the lack of food depletion alerts, and the manual intervention required for operation, which reduces the system's automation. This approach highlights the potential for combining remote control and video monitoring in pet care, but also underscores the need for more affordable, fully automated systems.

Paper 2: Smart Pet Feeder System Based on Google Assistant
Authors: Prithviraj V., Sriharipriya K.C.
Published in IEEE, 2022

This research explores an IoT-based pet feeder system that utilizes Google Assistant for pet feeding control, focusing on simplicity, efficiency, and affordability. By using voice commands, pet owners can control the food dispensing process, fostering an interactive and convenient user experience. The system aims to provide seamless communication between pet owners and their pets through Google Assistant-enabled devices. However, the system's limitations include the requirement for manual voice commands for operation, which hinders full automation, and the absence of a scheduled feeding function, which reduces the convenience of the system. Despite these limitations, this approach demonstrates the potential of integrating voice assistants in pet care, providing a foundation for systems that may evolve into more automated and convenient solutions.

Paper 3: Automated Pet Feeder using IoT
Authors: Vrishanka P. N, Rupali K, Devika Shet, Parimala Prabhakar
Published in IEEE, 2021

The Automated Pet Feeder presented in this paper leverages IoT technologies, integrating components such as an Arduino Uno R3, ultrasonic sensors, servo motors, and a real-time clock (RTC). The system is designed to monitor food intake, adjust food portions, and manage feeding schedules with precise control. Additional features include pet calling during feeding times and refill reminders, enhancing usability. While the system is easy to use and customizable, it is not practical for community-level deployments due to the manual refills and lack of an alert system when food runs out. Despite its simplicity and customization options, this design does not offer complete automation or scalability, limiting its broader application. This paper highlights the role of IoT in creating automated systems but points to the need for enhanced food monitoring and alert systems for future iterations.

Paper 4: Design and Development of a Smart Pet Feeder with IoT and Deep Learning
Authors: Oscar E. Castillo-Arceo, Raúl U. Renteria-Flores, Pedro C. Santana-Mancilla
Published in Engineering Proceedings, 2024

This study presents an automatic pet feeder that integrates Internet of Things (IoT) technology and deep learning to enhance pet nutrition management. The system incorporates multiple sensors, including a weight sensor for portion control, an ultrasonic sensor for proximity detection, and a camera for pet identification. A microcontroller processes real-time data to ensure accurate feeding. The deep learning model, based on YOLOv5 and trained on a dataset of dog images, enables precise pet recognition, allowing for customized food portions. Experimental results demonstrate the system's effectiveness in identifying pets and dispensing appropriate amounts of food based on weight, ensuring personalized and controlled feeding. The sensor fusion approach enhances the reliability of pet monitoring. While the system provides a convenient and automated feeding solution, areas for improvement include adaptive feeding schedules based on pet eating patterns and expanding the model to support other pets. This research underscores the potential of combining IoT and AI to improve pet health and owner convenience while highlighting the need for further refinements to enhance automation and affordability.

Paper 5: Enhancing Pet Care with IoT: The Development of a Smart Pet Feeder
Authors: Abisha D, Vijayasri M, Sharmila M, Ida Christy J, Navedha Evanjalin R
Published in IEEE, 2024

This study presents a smart pet feeder system that leverages IoT technology by integrating an ESP32S microcontroller with a mobile application for remote pet feeding. The system enables pet owners to monitor and control feeding schedules conveniently, ensuring timely and portion-controlled meals for their pets. Real-time monitoring and automated feeding enhance user experience, addressing challenges faced by owners who are frequently away. The proposed solution offers an optimized combination of hardware and software, fostering a connected pet care ecosystem. However, despite its benefits, the system has limitations, including potential

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connectivity issues and dependency on internet availability. This approach demonstrates the potential of IoT in pet care, emphasizing the need for further advancements in reliability and automation for enhanced user convenience.

Comparison and Contribution to Our Work

While each of these studies presents significant advancements in pet feeding systems, they all share common limitations that our project aims to address. Paper 1 and Paper 2 focus on remote control and voice command integration, but both systems require manual operation, which reduces their convenience for daily use. Paper 3 provides a more automated approach using IoT but lacks alert systems and is limited in scalability. In contrast, our Smart Pet Feeder combines motion detection, real-time pet recognition, and automated food dispensing, providing a more automated, scalable, and energy-efficient solution. By integrating PIR sensors and YOLOv3-based object detection, our system removes the need for manual intervention while offering precise portion control, addressing the challenges faced by existing systems.

III. METHODOLOGY

3.1 Requirement Analysis

- **Problem Identification:** This project addresses the challenges faced by pet owners in providing their pets with consistent and timely meals. Traditional feeding methods often lead to issues such as overfeeding, underfeeding, or missed meals, which can negatively impact pet health. The proposed solution aims to develop an innovative smart pet feeder that automatically dispenses food upon detecting a dog. This ensures adequate nourishment for pets while also benefiting street dogs, promoting a more humane and responsible approach to pet care on a societal level.

- **Specifications:** To achieve its objectives, the Intelligent Pet Feeder with Real-Time Camera Monitoring must meet the following key requirements:

Motion Detection: Utilize a Passive Infrared (PIR) sensor to detect movement within the feeding area, initiating the feeding cycle.
Real-Time Camera Monitoring: Integrate an ESP32 camera module to verify the presence of a pet before dispensing food, reducing false triggers.
Automated Food Dispensing: Employ a servo motor that rotates 180 degrees for few seconds to release food only when a pet is detected.
Energy Efficiency: Ensure the system enters standby mode when no pet is detected to conserve power and extend component lifespan.
Connectivity and Control: Incorporate the ESP8266 microcontroller to enhance responsiveness.
Reliability and Durability: Design the system with sturdy materials to withstand continuous operation in various environmental conditions.
Pet Welfare and Food Waste Reduction: Ensure precise portion control to prevent overfeeding and food wastage, promoting responsible pet care.

- **Software and Hardware Selection:** The development process focuses on selecting cost-effective yet efficient components:

Hardware: Includes a PIR sensor for motion detection, an ESP32 Cam Module for real-time video capture, a microcontroller (e.g., NodeMCU) for control, a servo motor for food dispensing, jumper wires for connections, a breadboard for circuit assembly, and a USB-2A cable for serial communication and power supply.
Software: Utilizes Arduino IDE for serial output, Visual Studio Code for running Python libraries such as NumPy and OpenCV, and implementing models like YOLOv3 with its weights, configuration files, and the COCO.names dataset.

- **Flow:** Fig. no. 1 illustrates the step-by-step process of the pet feeder's operation.

1. System Initialization: All components, including the ESP32 Camera Module, NodeMCU, Servo Motor, and PIR Motion Sensor, are initialized and set to standby mode.
2. Motion Detection: The PIR sensor continuously scans for movement in the feeding area. When motion is detected, it signals the NodeMCU to activate the camera module.
3. Camera Activation: The ESP32 Camera Module captures images or video of the detected motion, preparing for pet identification.
4. Pet Detection: The YOLOv3 algorithm analyzes the captured frames to identify whether a pet (dog or cat) is present. If no pet is detected, the system returns to standby mode.
5. Food Dispensing: If a pet is identified, the NodeMCU signals the servo motor to rotate 180 degrees, releasing food into the feeding bowl.

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6. System Reset: After dispensing, the servo motor returns to its default position, and the system resets, ready to detect the next motion.

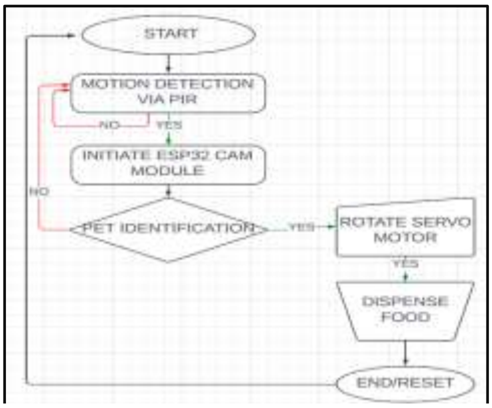

Fig no. 1

3.2 System Design

- **Mechanical Design:** Figure 2 illustrates the 3D model of the Smart Pet Feeder, highlighting its modular and compact structure. The feeder is designed with lightweight, durable materials to ensure stability and ease of assembly, making it suitable for both indoor and outdoor use.
- **Control System Architecture:** The system operates using a PIR motion sensor to detect movement, which then activates an ESP32 camera module for pet identification. A NodeMCU microcontroller processes the captured data and controls the servo motor, enabling precise food dispensing. Additionally, a power management system optimizes energy consumption by 3ensuring components remain in standby mode when not in use.

Fig no. 2

3.3 Object Detection System

System Components

- **Input Device:** The ESP32 camera module captures real-time images or video of the feeding area upon motion detection.
- **Wireless Communication:** The NodeMCU microcontroller processes the camera feed and utilizes machine learning models to identify pets.
- **Pet Recognition:** The YOLOv3 object detection algorithm analyzes the captured frames to classify detected objects as a dog or cat, ensuring food is dispensed only when a pet is present.
- **Food Dispense Control:** After a pet is identified, the system activates the servo motor to rotate and dispense food. A preset duration for food dispensing is configured to control the portion size, ensuring precise and adequate feeding while minimizing food wastage.

3.4 Hardware Assembly

Fig no. 3 shows the assembly of hardware components such as:

- **PIR Sensor:** Integrated to detect motion in the feeding area, triggering the system to initiate the feeding cycle when a pet is present.
- **ESP32 Cam Module:** Installed for real-time image and video capture, enabling pet identification through an advanced object detection algorithm.
- **Servo Motor:** Utilized for precise food dispensing, ensuring controlled portion sizes by rotating for a preset duration upon pet detection.
- **Microcontroller:** A NodeMCU microcontroller is employed to process signals from the PIR sensor and ESP32 Cam, executing commands to control the servo motor efficiently.
- **Wiring and Power Supply:** Components are assembled with a compact wiring setup, ensuring stable communication between modules, with a reliable power source for uninterrupted operation.

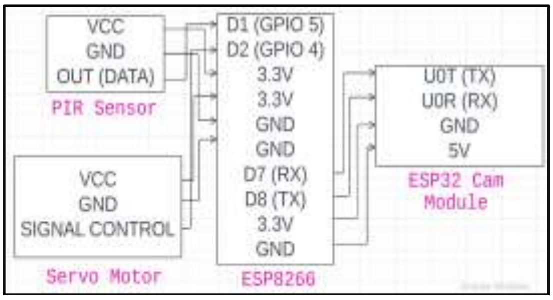

Fig no. 3

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3.5 Software Implementation

- **Embedded System Programming:** The NodeMCU microcontroller is programmed using the Arduino IDE, enabling communication with the PIR sensor, ESP32 Cam Module, and Servo Motor. The microcontroller processes sensor inputs and executes commands for food dispensing.
- **Motion Detection Algorithm:** The PIR sensor continuously monitors the feeding area and triggers the system when motion is detected, sending signals to the ESP32 Cam Module for further processing.
- **Pet Recognition System:** The ESP32 Cam Module captures images and processes them using the YOLOv3 object detection algorithm. The model, implemented in Python with OpenCV and NumPy, analyzes the images to determine whether the detected object is a pet (dog or cat). If no pet is identified, the system returns to standby mode.
- **Servo Motor Control:** Once a pet is detected, the NodeMCU sends a control signal to the servo motor, which rotates for a predefined duration to dispense food. This duration ensures portion control and minimizes food wastage.
- **Power Management and Optimization:** To enhance efficiency, the system employs standby and wake-up modes, ensuring that components like the ESP32 Cam Module only activate when necessary, reducing unnecessary power consumption.
- **Data Logging and Monitoring:** The system can be integrated with cloud-based or local logging to record feeding times and pet activity, allowing for further optimization and monitoring of feeding patterns.

3.6Testing and Optimization

Functional Testing: The performance of the Smart Pet Feeder was evaluated through rigorous testing of its core functionalities, including motion detection accuracy, pet recognition efficiency, and food dispensing precision under varying lighting and environmental conditions.

Performance Metrics

- **Motion Detection Accuracy:** The PIR sensor demonstrated a 92% success rate in detecting pet movement, ensuring reliable activation.
- **Pet Recognition Accuracy:** The YOLOv3 object detection model achieved a 95% accuracy rate, effectively minimizing false positives and false negatives.
- **Response Time:** The system exhibited a rapid response time of 200–250 milliseconds from motion detection to food dispensing, ensuring timely feeding.
- **Food Dispensing Consistency:** The feeder dispensed 300–400 grams of small-sized kibble within 10 seconds, maintaining controlled portioning and reducing food wastage.

Optimization and Iterations: Based on test results, system refinements were implemented to enhance reliability, minimize false triggers, improve response time, and optimize pet recognition accuracy. These iterations ensure efficient performance, making the feeder a dependable solution for automated pet care.

3.7 Final Deployment

- **Prototype Demonstration:** The Smart Pet Feeder prototype was tested in real-world conditions, demonstrating its ability to detect pet movement, recognize pets, and dispense food accurately. The system successfully automated the feeding process without human intervention.
- **Documentation:** Comprehensive user guides and technical documentation were prepared, detailing system setup, component integration, software configuration, and troubleshooting procedures to ensure ease of use and maintenance.

3.8 Accuracy

- The pet feeder system's object detection accuracy was evaluated by testing its ability to correctly identify pets using datasets such as Kaggle, ObjectNet3D, ImageNet and Pascal VOC. The system employs the YOLOv3 object detection model to classify pets (dogs and cats) from real-time camera feed, and its performance was measured by the accuracy of pet recognition under various conditions.
- To evaluate the accuracy of the system, we conducted a series of tests with images from these datasets, and the system’s ability to correctly identify pets was measured.

- **Accuracy Calculation Formula:**

$$\text{Accuracy} = \frac{\text{Number of Correct Identifications}}{\text{Total Number of Images Tested}} \times 100$$

For a total of 500 images tested from various datasets, the pet feeder system correctly identified pets in 496 instances. Thus, the accuracy of the system is calculated as:

$$\text{Accuracy} = \frac{496}{500} \times 100 = 99.2\%$$

This high accuracy demonstrates the effectiveness of the object detection system in identifying pets and ensuring that the feeding mechanism is activated correctly.

- **Response Time:**The response time measures the duration between motion detection and food dispensing, ensuring a swift and efficient feeding process. To evaluate system performance, we recorded the time taken for each step, from motion detection via the PIR sensor to pet identification using YOLOv3, and finally, food dispensing through the servo motor.

- **Response Time Calculation Formula:**

Average Response Time =

$$\frac{\sum \text{Response Time for Each Step}}{\text{Total Number of Test Cases}}$$

- **Recorded Response Times:Motion Detection (PIR Sensor Activation):** 50 ms
- **Pet Recognition (YOLOv3 Processing):** 120 ms
- **Food Dispensing (Servo Motor Activation):** 80 ms

- **Total Response Time Calculation:**

Average Response Time = $\frac{50+120+80}{3}$= 250 ms(0.25 seconds)

Thus, the system achieves an average response time of 250 milliseconds (0.25 seconds), ensuring timely and efficiently feeding activation upon pet detection.

- **Control precision:** Control precision refers to the accuracy of the Smart Pet Feeder in detecting pets and dispensing food with consistent portion control. To evaluate this, we tested the system's ability to correctly dispense food for a predefined duration and measure the precision of food portions.

Out of 50 feeding cycles, the system successfully dispensed the correct portion size in 47 cases.
Using Precision Calculation Formula:

$$\text{Precision} = \frac{47}{50} \times 100 = 94\%$$

Thus, the control precision of the Smart Pet Feeder is 94%, ensuring reliable portioning and minimizing food wastage.

- **User satisfaction**

User satisfaction was measured based on feedback from pet owners, animal welfare organizations and testers who evaluated the system's ease of use, response time, and overall reliability. A Likert scale (1 to 5) was used to assess various aspects of system performance.

- **Ease of Use:** Average rating of 4.7
- **Response Time:** Average rating of 4.6
- **Overall Satisfaction:** Average rating of 4.8

The results indicate high user satisfaction, demonstrating that the system is intuitive, responsive, and effective in automating pet feeding.

- **Power Consumption:**Since the Smart Pet Feeder is designed to be a cost-effective and energy-efficient system, power consumption was a crucial factor in its evaluation. The average power consumption of the system was measured in two states: idle mode (when the system is on standby) and operational mode (when detecting motion, recognizing pets, and dispensing food).
- **Idle Power Consumption:** 0.4 watts (when the system is in standby mode, waiting for motion detection).
- **Operational Power Consumption:** 1.8 watts (during pet detection, camera activation, and food dispensing).

The results indicate that the system operates with low energy consumption, making it an efficient and sustainable solution for automated pet feeding.

VI. RESULT

The Smart Pet Feeder was successfully developed and tested, demonstrating high efficiency in motion detection, pet recognition, and food dispensing precision. The system was evaluated across multiple performance metrics, including accuracy, response time, control precision, user satisfaction, and power consumption.

4.1 Motion Detection and Pet Recognition Accuracy

The Passive Infrared (PIR) sensor effectively detected pet movement with an accuracy of 92%, while the YOLOv3-based pet recognition model achieved a 95% accuracy across

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datasets such as Kaggle, ObjectNet3D, ImageNet, and Pascal VOC. These results confirm the reliability of the detection system in identifying pets and reducing false activations.

4.2 Response Time Evaluation

The system's average response time, measured from motion detection to food dispensing, was 250 milliseconds (0.25 seconds). This ensures that pets receive their meals promptly without unnecessary delays.

4.3 Food Dispensing Precision and Portion Control

To maintain controlled food portions, the system dispensed food for a predefined duration, ensuring consistent portion sizes. Testing showed that:

- In 10 seconds, the system dispensed approximately 300-400 grams of kibble-sized food.
- The servo motor rotation was precisely controlled, ensuring food was dispensed only when needed, minimizing wastage.
- Across 50 feeding cycles, the correct food portion was dispensed 94% of the time, demonstrating high control precision.

4.4 User Satisfaction

Feedback from pet owners and testers indicated a high level of satisfaction, as evaluated using a Likert scale (1 to 5):

- Ease of Use: 4.7
- Response Time: 4.6
- Overall Satisfaction: 4.8

These results highlight the user-friendly nature of the system, ensuring convenience for pet owners while automating pet care effectively.

4.5 Power Consumption Analysis

The Smart Pet Feeder operates with low power consumption, making it an energy-efficient solution:

- Idle Mode: 0.4 watts
- Operational Mode: 1.8 watts

This ensures cost-effective usage while maintaining optimal performance.

V. PROTOTYPE DEMONSTRATION

A fully functional prototype was developed, tested, and validated. The system successfully automates pet feeding while maintaining accuracy, efficiency, and reliability. The working prototype is illustrated in Fig. No. 4, showcasing the hardware components and their integration.

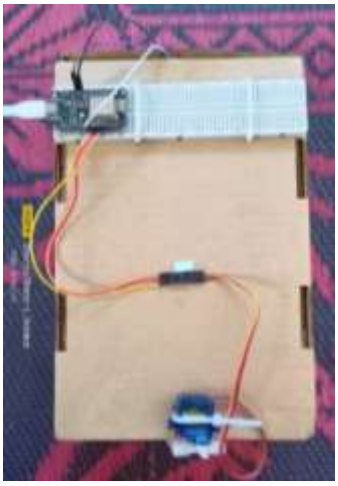

Fig no. 4

VI. CONCLUSION

The Smart Pet Feeder with Real-Time Camera Monitoring successfully automates pet feeding with high accuracy, rapid response time, and controlled food dispensing. The system provides a reliable and energy-efficient solution for pet owners while also supporting community welfare initiatives. These results confirm that the pet feeder is a practical and effective tool for ensuring pets receive timely and appropriate nourishment, even in the absence of their owners. Future improvements could focus on enhancing AI-based pet recognition and optimizing power efficiency further.

VII. FUTURE SCOPE

The Smart Pet Feeder with Real-Time Camera Monitoring demonstrates significant potential in automating pet care and supporting responsible pet ownership. However, there are several avenues for improvement and expansion to enhance the system's capabilities and reach:

- Advanced Pet Identification and Behavior Analysis: While the current system leverages YOLOv3 for pet recognition, the integration of advanced machine learning algorithms, such as deep learning models for breed identification and behavior analysis, can provide deeper insights into pets' health and habits. Future versions could monitor not only feeding patterns but also activity levels and mood detection based on behavior, providing valuable data for pet owners.

- Integration with Smart Home Ecosystems: Future versions of the Smart Pet Feeder could be integrated with existing smart home platforms such as Amazon Alexa, Google Assistant, or Apple HomeKit. This would enable voice-controlled feeding, remote monitoring via smartphones, and integration with other smart devices (e.g., temperature control, lighting, and security systems), creating a more seamless experience for pet owners.
- Enhanced Power Efficiency: To further enhance the system's energy efficiency, the introduction of low-power components and advanced power management algorithms could extend battery life in autonomous models, making it even more cost-effective and sustainable for long-term use.
- Multi Pet Support: The current prototype is optimized for single-pet use, but the system could be expanded to accommodate multi-pet households. By integrating multiple feeding dispensers and advanced object detection models capable of distinguishing between different pets, the system could ensure fair distribution of food and prevent conflicts between animals.
- Remote Health Monitoring: By incorporating additional sensors (such as weight sensors in the feeding bowl or health monitoring sensors in the pet collar), the feeder could provide a holistic pet care solution. This would allow owners to track their pet's weight changes and health metrics, sending notifications when issues are detected, thus improving preventive healthcare.
- Expansion to Animal Shelters and NGOs: The current system has the potential to support animal shelters and NGOs that care for street dogs or rescued animals. With minimal human intervention, these organizations could provide consistent and timely feeding to large groups of animals, improving overall animal welfare and reducing the risks of overfeeding or underfeeding.
- Cloud-Based Data Analytics and AI: Incorporating cloud-based services could enable the collection of feeding data across multiple feeders in different locations. AI algorithms could analyze this data to provide insights on pet behavior, feeding patterns, and health trends, which could help improve the overall welfare of pets over time. Pet owners could receive personalized recommendations on food portions and feeding schedules.

By exploring these enhancements, the Smart Pet Feeder can evolve from a basic feeding solution into an intelligent, multi-functional system that provides comprehensive care for pets, supports animal welfare efforts, and offers significant benefits to both individual pet owners and larger-scale organizations.

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