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Proceeding Paper

Design and Development of a Smart Pet Feeder with IoT and Deep Learning †

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Abstract: The well-being of pets is essential for owners. This project developed an automatic pet feeder that leverages Internet of Things technology and deep learning to address feeding challenges. The feeder integrates sensors, including a weight sensor for portion control, a camera for pet identification, an ultrasonic sensor for proximity detection, and a servo motor for dispensing food. A microcontroller for real-time monitoring and processing controls these components. Based on YOLOv5 and trained on a dataset of dog images, the DL model ensures accurate pet recognition and customized feeding. Results show that the system effectively identifies pets and dispenses appropriate portions based on weight, ensuring precise and personalized feeding. The sensor data fusion provides reliable information about pet characteristics. Overall, the smart feeder offers a convenient and efficient solution for managing pet nutrition, improving pet health, and increasing owner convenience.

Keywords: smart pet feeder; Internet of Things; deep learning; sensor fusion; pet health and well-being

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1. Introduction

Proper nutrition and care for pets are critical for their health and well-being. Some pets, like dogs and cats, are considered family members [1,2]; ensuring they receive the correct food in appropriate quantities is essential [3]. However, busy schedules often lead to inconsistent feeding practices, resulting in issues such as underfeeding or overfeeding [4]. Overfeeding can cause obesity, while underfeeding can lead to malnutrition, both of which have significant health implications. Pet food costs are significant for many families, making efficient and controlled feeding practices even more important [5].

To address these challenges, we aim to develop an automatic pet feeder that uses Internet of Things (IoT) technology and deep learning (DL) techniques. The device is designed to dispense appropriate food portions, enhancing pet nutrition management and overall health. By automating the feeding process, the system ensures that pets receive the right amount of food, regardless of the owner's availability. This approach contributes to improving pets' health and well-being and offers pet owners convenience and peace of mind.

The development of smart devices for pet feeding has been a growing area of interest due to the need to improve efficiency and effectiveness in pet feeding. For example, the automatic feeder proposed by Birha et al. [6] uses IoT technology to enable remote control via a web page, incorporating ultrasonic sensors, a real-time clock, and a weight sensor for precise dispensing.

Similarly, Vrishanka et al. [7] developed an automated feeder that uses IoT to adjust feeding times and food quantity and monitor food levels, providing a solution to overfeeding and underfeeding small pets.

Additionally, integrating deep learning techniques has proven effective in enhancing monitoring and control systems, as demonstrated by the work of Jain et al. [8], who developed an IoT-based food dispensing system to train pets to eat at scheduled times, monitoring their feeding patterns.

This project aims to design and develop a smart pet feeder that combines IoT and deep learning technologies to automatically and accurately dispense food. This project addresses common issues such as overfeeding and underfeeding and enhances convenience for pet owners, ensuring their pets receive the necessary care even in their absence.

The contributions of this paper are twofold:

It contributes to improving the health and well-being of pets by ensuring they receive the appropriate amount of food every time, using sensors to customize feeding quantities based on the specific size of each pet.

It provides convenience to pet owners by enabling the feeding process in their absence.

2. Materials and Methods

The methodology employed in this project was the SCRUM framework [9,10], an agile approach for developing systems involving both software and hardware components. SCRUM is characterized by rapid iterations, known as sprints, each with specific objectives, allowing for continuous improvement and adaptation. This methodology was chosen for its inherent flexibility, allowing the delivery of functional prototypes within short periods and fostering constant feedback and iteration. Our group has previously used it successfully [11].

2.1. System Design

The system design integrates multiple sensors to ensure accurate and efficient food dispensing. The core components include the Tecneu HX711 weight sensor, an HEJO camera for pet identification, the Tecneu HC-SR04 ultrasonic sensor, and a Tecneu servo motor. All components were purchased from Colima, Mexico, via the Mexican Mercado Libre website.

Figure 1 illustrates the IoT system architecture for the system.

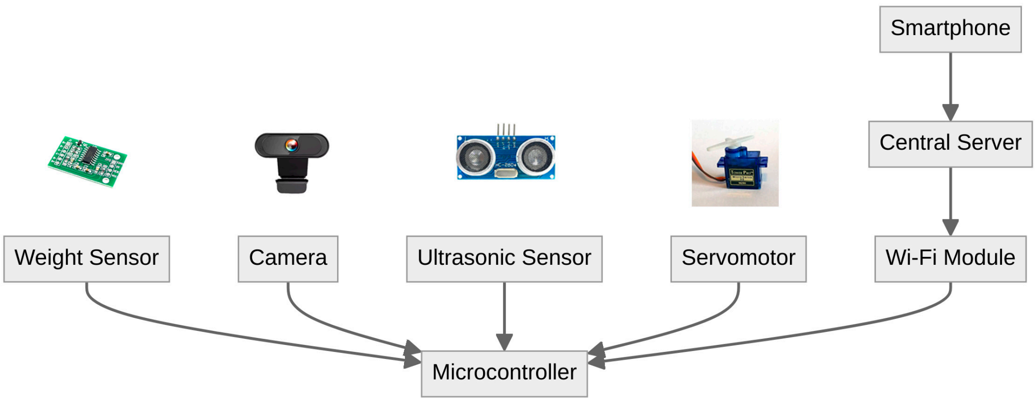

Figure 1. The IoT system architecture for the smart pet feeder.

The HX711 is a highly precise, low-cost integrated weight measurement sensor commonly used in applications requiring weight measurement, such as electronic scales, inventory control systems, and automatic dispensers [12]. In this project, the HX711 sensor is crucial for determining the pet's weight to determine the size and amount of food to be dispensed, as well as the weight of the food in the container to ensure accurate portion control.

The camera's role in our smart feeder is to detect whether the approaching pet is a dog. Through image processing, the system can identify the distinctive features of a dog to perform classification. It helps in providing specific feeding to this species.

The HC-SR04 ultrasonic sensor is widely used for measuring distances using ultrasonic waves [13]. This sensor detects the pet's proximity to the feeder, ensuring that food is only dispensed when a dog is near, preventing wastage.

A servo motor is an electromechanical device that controls and generates movement in specific applications [14]. In our project, the servo motor controls the dispensing mechanism to release the appropriate amount of food based on the dog's weight.

The Arduino.CC Arduino Mega 2560, Colima, Mexico, was selected as the microcontroller for the system due to its versatility and extensive input/output capabilities [15]. The Mega 2560 is based on the ATmega2560 microcontroller, providing 54 digital I/O pins, 16 analog inputs, and four hardware serial ports, making it ideal for handling multiple sensors and actuators simultaneously. In this project, the Mega 2560 managed the integration of the HX711 weight sensor, the HC-SR04 ultrasonic sensor, the camera module, and the servo motor, coordinating the food dispensing mechanism efficiently.

In addition to the integration of sensors for weight and proximity measurement, the camera plays a crucial role in identifying whether the approaching animal is a dog. The camera utilizes a dataset for training a deep learning model capable of recognizing dog breeds through image processing. By leveraging this training, the system can accurately classify the animal based on its visual features, ensuring that the food dispenser is activated only for dogs. This capability is critical for providing targeted feeding and preventing misidentification. Combining all the sensors and machine vision enables the smart pet feeder to operate efficiently and deliver species-specific food.

2.2. Data Acquisition

We utilized the Stanford Dogs Dataset [16] to train and evaluate the model. This dataset, publicly available on Kaggle, contains over 20,000 images of 120 dog breeds. It provides a diverse and extensive dataset for breed recognition and classification tasks. The availability and well-documented structure of the dataset make it ideal for computer vision projects. It allows for the accurate training of deep neural networks to identify breed-specific characteristics.

2.3. Dataset Annotation

As the next step, the dataset was annotated using labelImg [17], a widely used open-source tool for creating bounding boxes in image datasets. The annotation process involved manually labeling the images and ensuring accurate bounding box placement for each dog in the dataset. The annotated data were then organized into a structured format with separate directories for training and validation.

2.4. Model Training

The project uses a pet identification model based on YOLOv5, a cutting-edge deep learning model known for its speed and accuracy in object detection [18,19]. YOLOv5 was chosen for its real-time image processing efficiency, making it perfect for applications requiring quick vision identification. The model was trained using the pre-annotated dataset, resulting in high accuracy in recognizing dogs of various breeds.

3. Results

Figure 2 shows the prototype developed.

Testing demonstrated that the system effectively identified pets, dispensed appropriate food portions based on weight, and provided real-time monitoring. The YOLOv5 model consistently identified dogs with high precision, as seen in Figure 3.

The integration and fusion of sensors provided reliable data on food consumption and pet weight, optimizing feeding. The weight sensor accurately measured the dispensed food portions, ensuring consistency in feeding. The ultrasonic sensor effectively detected the presence of pets, preventing unauthorized access to the food. This combination of sensors ensured that the system operated efficiently and minimized food wastage.

Figure 2. Smart pet feeder prototype.

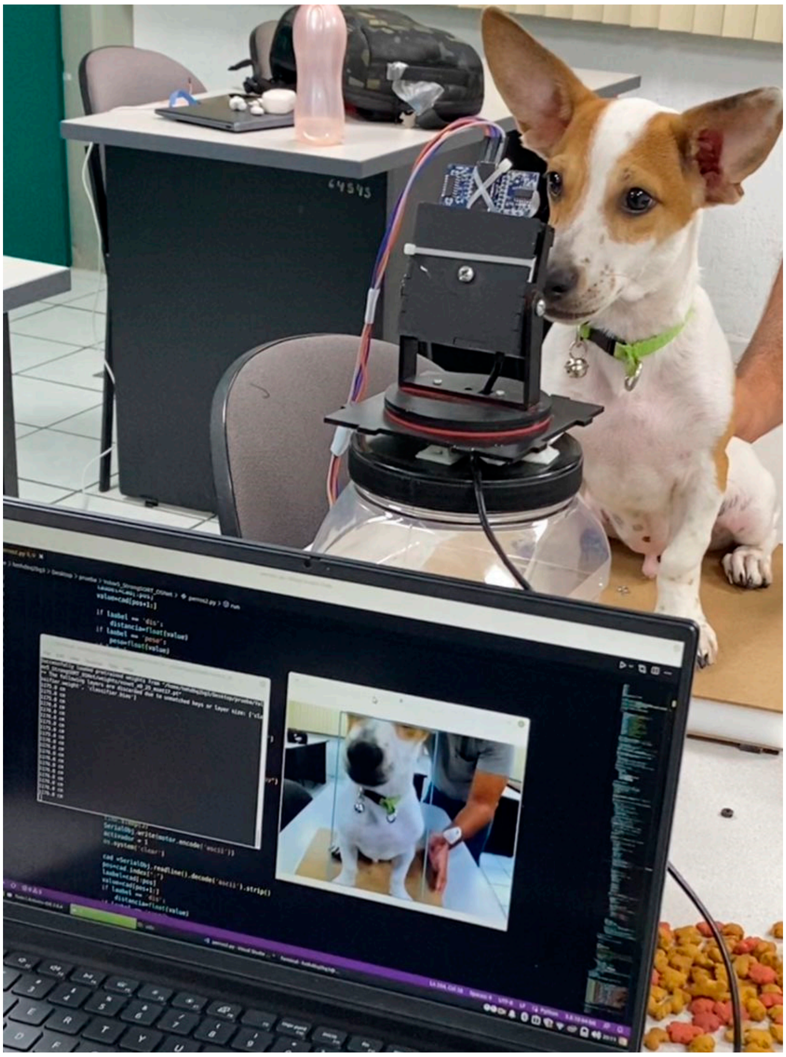

Figure 3. Smart pet feeder vision capabilities.

4. Discussion

The automatic pet feeder's capability for precise measurement and real-time data processing ensures that pets receive the correct amount of food, preventing issues related to overfeeding or underfeeding. This system addresses common problems of inconsistent feeding practices and offers a reliable solution for busy pet owners.

However, there are areas for improvement and future development. For instance, the system could learn from the pets' eating patterns and adjust feeding schedules and portion sizes over time. The project also opens opportunities for expanding functionalities, such as adding different pet identifications like cats.

5. Conclusions

The automatic pet feeder successfully achieved its objectives by providing a convenient, reliable, and adaptable solution for pet nutrition management.

The synergy between the computer vision system and sensor fusion significantly enhanced the smart pet feeder's overall efficiency, demonstrating the feasibility of integrating IoT and deep learning technologies in real-world applications, like promoting pet well-being through precise and automated feed management.

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