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IOT BASED SMART CAGE WITH WATER FILTERING MONITORING SYSTEM FOR CATS AND DOGS

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Abstract

Domestic animals are often left unattended by pet owners today due to the nature of their profession. This unavoidable phenomena of unsupervised access to clean food and water may result in substantial psychological and physical harm to their overall well-being, such as dehydration, anxiety, and potential infections. The researchers consider in light of how the issues caused by modernity can be a tool to gain from it as well. An innovative solution is presented: The Smart Cage, consisting of an integrated watering monitoring system, ESP-WROOM-32 and the ESP-CAM as the primary microcontroller, Wi-Fi module, and camera. The IOT-based system aids the owners' concerns of catering their pets' basic necessities only with a few taps from the Blynk IoT mobile application and website. It is attached with several sensors to collect data to monitor in the Blynk dashboard for accessibility and monitoring. Particularly, ISO 25010:2023 was used to evaluate the general performance of the system to ensure that it meets the quality standards, focusing on the following, functional suitability, performance efficiency, interaction capability, reliability and security. The assessment of the study received a general mean rating of 4.80%, interpreted as excellent signifying the effectiveness and safeness.

Keywords: Esp32, Automated Smart Cage, Blynk Application, Internet of Things, Water Quality Monitoring.

Introduction

Companionship of a dog or cat improves the ability of the pet owner's social interaction, and it also reduces loneliness (Hemendinger, 2024). However, pet ownership comes with several challenges, especially when owners have to balance their responsibilities with daily life. One of the most common challenges is leaving pets unattended for extended periods, which can cause separation anxiety, boredom, or destructive behaviors. Additionally, ensuring proper nutrition, hydration, and healthcare is essential for a pet's well-being. Failure to meet these needs can lead to malnutrition, dehydration, and other health issues. Providing a clean and safe environment is another concern, as pets can be exposed to harmful bacteria or parasites, especially when drinking from unclean water sources. The ethical concerns of pet ownership include exploitation, abuse, neglect, and abandonment, which may arise due to a lack of knowledge or resources. To safeguard the welfare of animals, legislation and organizations like PETA (Briggs, 2020) advocate for better care standards and stricter laws.

Water, a crucial substance for all living beings, is a key factor in pet care. The demand for clean and safe water is increasing rapidly, expected to rise by 60% by 2030 (Kılıç, 2020). Pets, like humans, require safe drinking water, as the loss of 10-15% of water in their body can lead to fatal dehydration. Stagnant bodies of water such as puddles, ponds, and ditches often harbor harmful bacteria (Leptospirosis), parasites (Giardia), and toxic blue-green algae, which are poisonous to both dogs and cats. Blue-green algae poisoning, in particular, is fatal for pets and can result in symptoms such as vomiting, diarrhea, and internal damage (Vetster, 2023). Most pet owners rely on municipal or tap water, which is generally safe if it meets regulatory standards (Beal, 2024).

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Furthermore, with modern lifestyles, pet owners face additional challenges, particularly when they are away from home. Pets are often left alone without sufficient supervision or care. The increasing availability of technological innovations, such as IoT-based smart cages, offers a potential solution. These systems allow pet owners to monitor and manage their pets' needs remotely. A study by Pulainthran and Lias (2022) emphasized the importance of adapting to current technology trends to improve pet management, making it easier for owners to ensure their pets' well-being, even when they are not physically present.

In response to these problems addressed, the study aims to develop an IoT based smart cage system by using the ESP-WROOM-32 as the main microcontroller, the smart cage system features a pet feeder, water fountain with pH level reading, sanitation, and environmental conditioning. The smart cage is an IoT based system using the Blynk IoT mobile and website application as the platform. The monitoring of the pH level, temperature, humidity shows a real-time graphical representation and a real-time streaming video focus on the pet's area reflecting on the Blynk Dashboard. There are controls for some of the features in the system that can be accessed through the dashboard. This in sync oversight of the control and monitoring panel allows owners to effectively manage their pet's needs and reduce the risk of neglect and ensure a healthier environment.

The smart cage system is designed to promote convenience and enhanced monitoring setup as compared to the conventional methods that are commonly practiced by many. The integration of the new technology using an IOT based system, an innovative solution simplifying the daily tasks and also fosters a more active approach that will set a higher standard of pet care and management. The study shows utmost importance to the mass pet owners, pet shops, and veterinarians ensuring the safeness of the pets and allowing the users to accommodate the pet needs remotely especially when the pets are left unattended due to various circumstances such as going to work and living alone.

Conceptual Framework

Figure 1: Conceptual Framework of the System

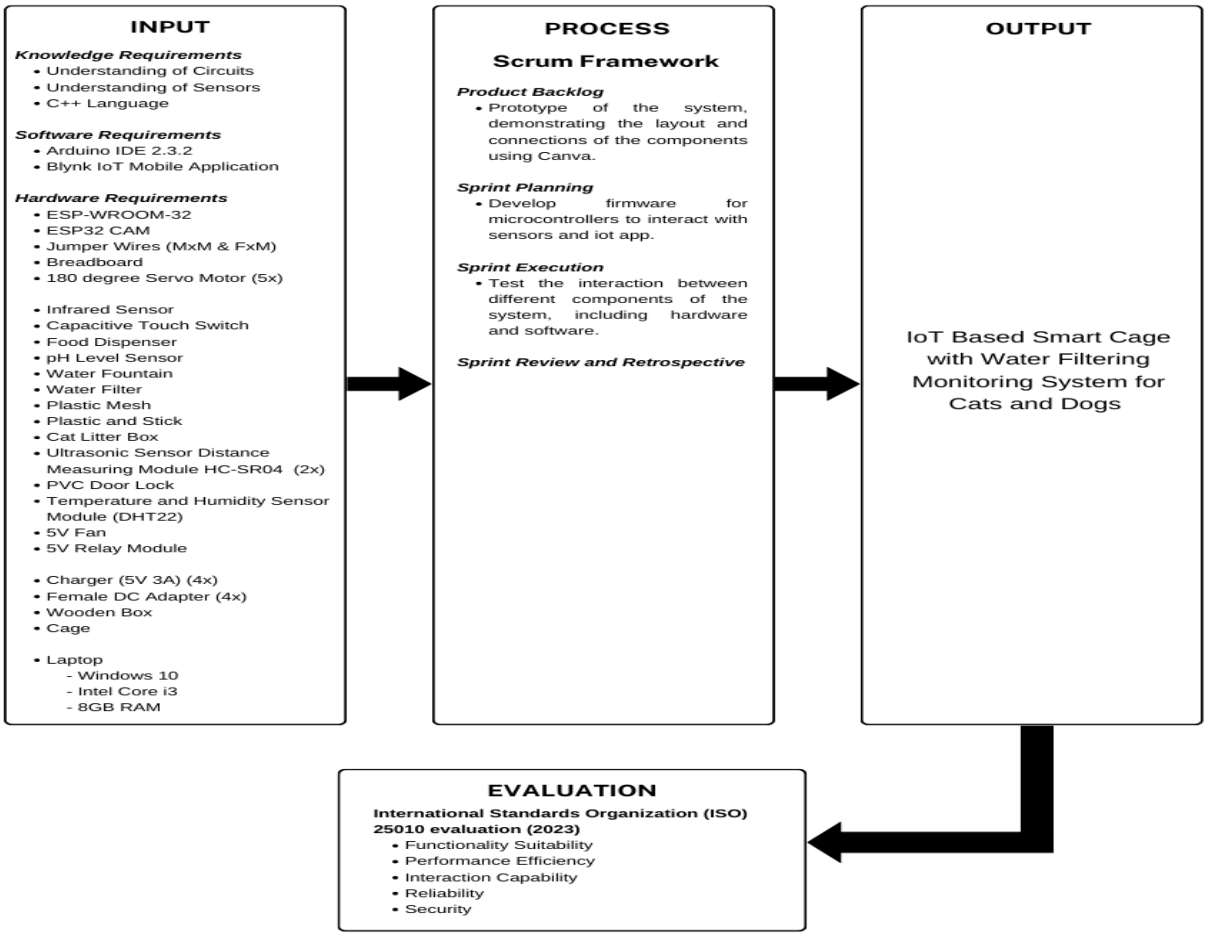


Figure 1 illustrates the conceptual study of the proposed system, which primarily focuses on creating a smart cage with a water-filtering monitoring system for cats and dogs. The inputs for this system include knowledge requirements, software requirements, and hardware requirements. The system will encompass an understanding of circuits, sensors, and the C++ programming language. Software requirements such as the Arduino IDE (Integrated Development Environment) and Blynk IoT mobile application will provide service and assistance in developing the system and provide an interface for the control system of the IoT system. As for the hardware materials, it requires the following: ESP-WROOM-32, ESP32 CAM, jumper wires (MxF and MxM), breadboard, 180 degree Servo Motor (5x), Infrared Sensor, Capacitive Touch Switch, food dispenser, pH Level Sensor, and more. The process will follow the Scrum framework, starting with hardware design in Canva, followed by integrating the ESP-WROOM-32 with sensors and testing for improvements. System quality will be evaluated using ISO 25010 standards.

Statement of the Problem

1. What preventive methods and technologies can be developed to alert pet owners when their pets' food and water supplies are low, ensuring their safety and well-being by maintaining proper nutrition and water quality level?
2. How does new technology help prevent pets from unintentionally escaping by controlling the door and monitoring the pet, and if they do escape, what impact does this have on their overall safety and security?
3. How does this study contribute to improving the sanitation of pets' living environments, and how does it enhance the owners' ability to maintain cleanliness, promoting better health for their pets?

Scope and Delimitation

This project aims to develop a smart IoT-based pet care system for small dogs and cats. The smart cage integrates Arduino technology for automated feeding, temperature and humidity regulation, water monitoring with a pH sensor, and an automatic PVC door with servo motors and ultrasonic sensors to detect pet presence. Key components include an ESP-WROOM-32 for Blynk app control, an ESP32-CAM for live streaming, an automated food dispenser, water fountain, and fan.

The proposed study excludes the following features: Water capacity is fixed, with manual refilling of water, food, and litter. The system focuses on small-scale prototypes and excludes sanitation cameras. Environmental factors, sensor accuracy, and complex pet behavior may affect data reliability. Scaling for commercial use and regulatory compliance are beyond this study's scope.

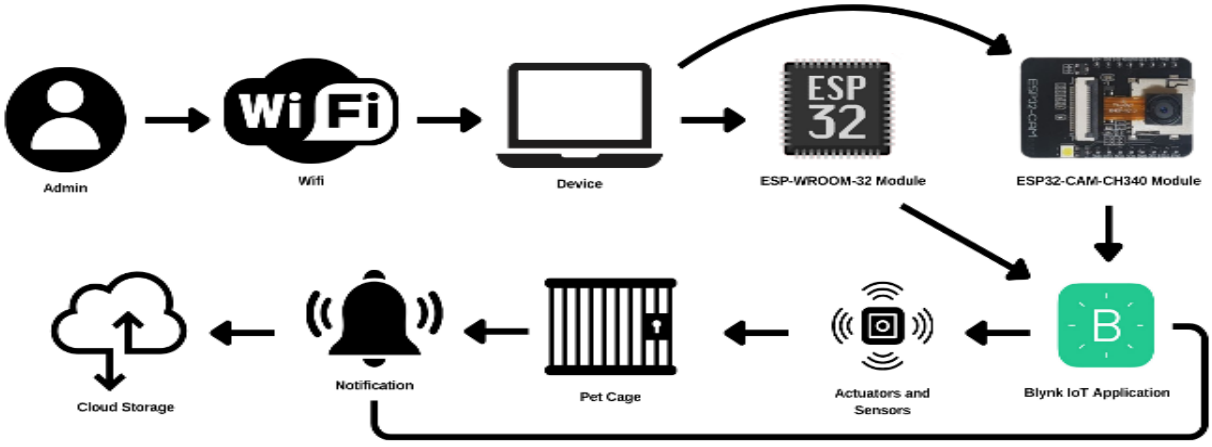
Methodology

In this part, the researchers provide a detailed overview of the System Design, covering aspects such as System Architecture, Block Diagrams, and Initial Design Prototype. Following this, the researchers discuss the Research Development Process, Data Collection, Population and Sample, and the Instruments Used methodologies used in the system.

System Design

a. System architecture

Figure 2: System Architecture

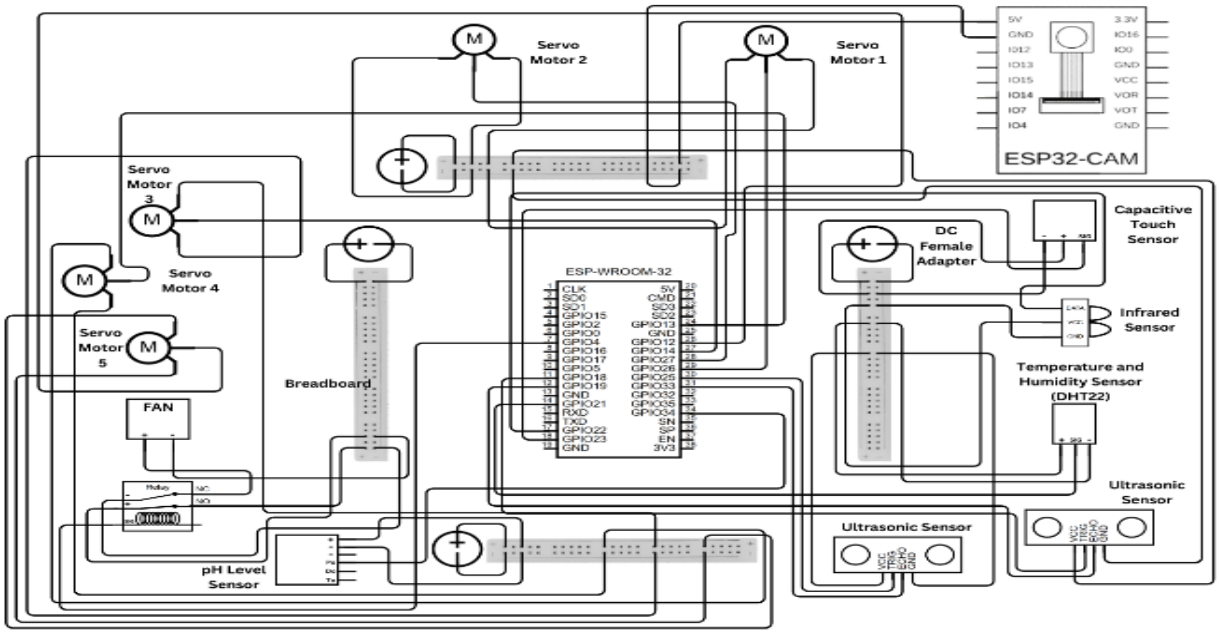


This model defines the structure, behavior, and interaction of integrated components to work seamlessly. Using the ESP-WROOM-32, users can control sensors and actuators via the Blynk IoT app, while the ESP32-CAM-CH340 enables pet live streaming. The Blynk app offers an intuitive interface to manage actions and monitor data. Key features include automated food and water

dispensers, waste management, an automatic door lock, and environmental controls, enhancing pet well-being and owner convenience with notifications and cloud storage.

b. Block diagram

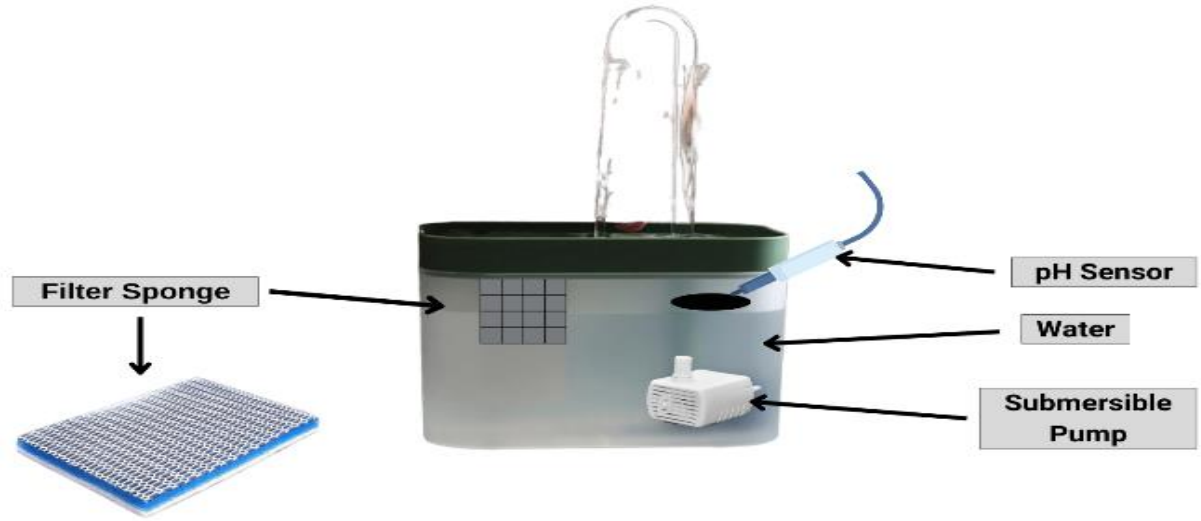
Figure 3: Block Diagram of the System



The block diagram shows the system's connections. The ESP-WROOM-32 controls sensors and actuators. When the ultrasonic sensor detects the pet, the door servo opens or closes, and the lock servo secures the door. A pH sensor monitors water quality, while a food servo controls the dispenser with a capacitive touch switch and infrared sensor to detect food levels. The DHT22 sensor tracks temperature and humidity, triggering the door to open if it gets too hot. Two servos manage the litter tray for waste cleanup, and a 5V fan is controlled via a relay. The ESP32-CAM connects to a power supply for live streaming. The ESP-WROOM-32 links everything to the IoT cloud via Blynk.

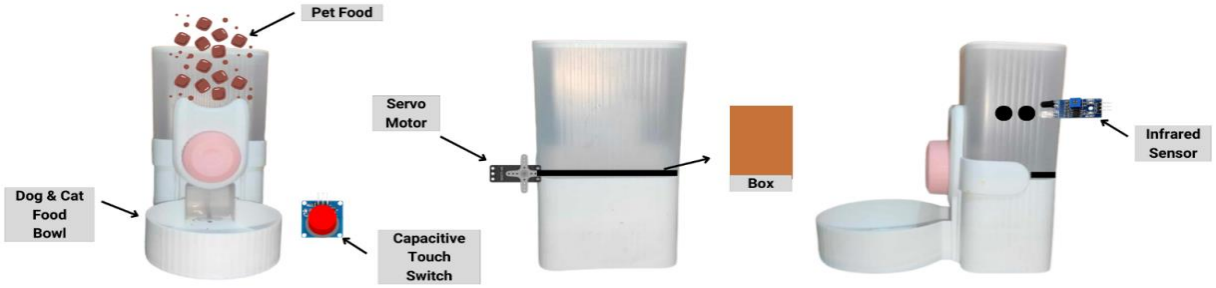
Initial Design Prototype

Figure 4: Water Fountain Dispenser



This water fountain dispenser holds the water quality monitoring system. The figure displays its different parts, such as the submersible pump, which is responsible for pumping water to the surface of the fountain, a water filter sponge, and a pH sensor that will put into the water to determine if the water is alkaline, neutral, or acidic.

Figure 5: Automated Food Dispenser



The food dispenser has a storage compartment that holds the food, with the bottom section releasing food into the pet's bowl. A servo motor on the exterior controls the release into the bowl. The amount of food, measured in grams or ounces, is based on the owner's knowledge of their pet's dietary needs. The food is automatically released through a widget in the Blynk app, allowing the user to adjust the portion. An infrared sensor monitors whether the dispenser is empty or full. The device can be controlled remotely via the IoT app or operated manually using a capacitive touch switch.

Figure 6: Pet Waste Disposal Box

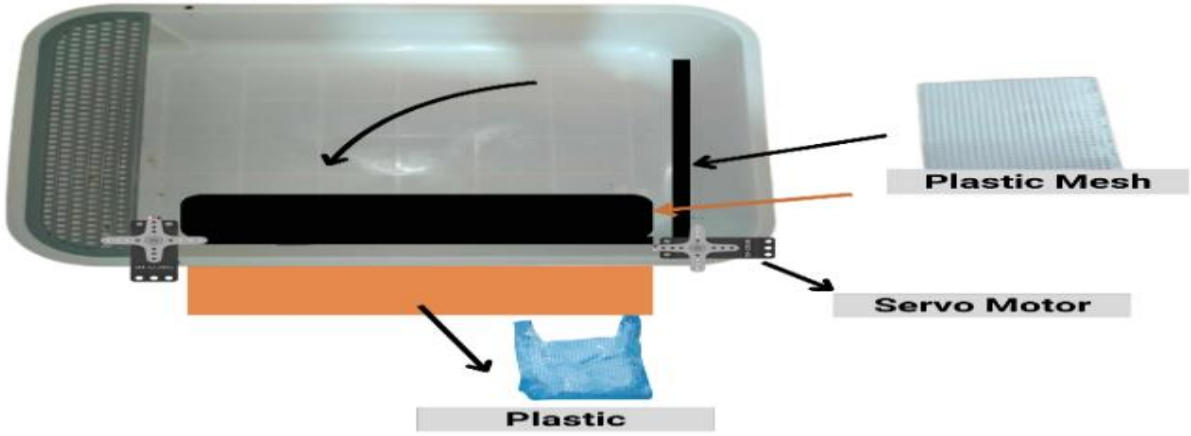
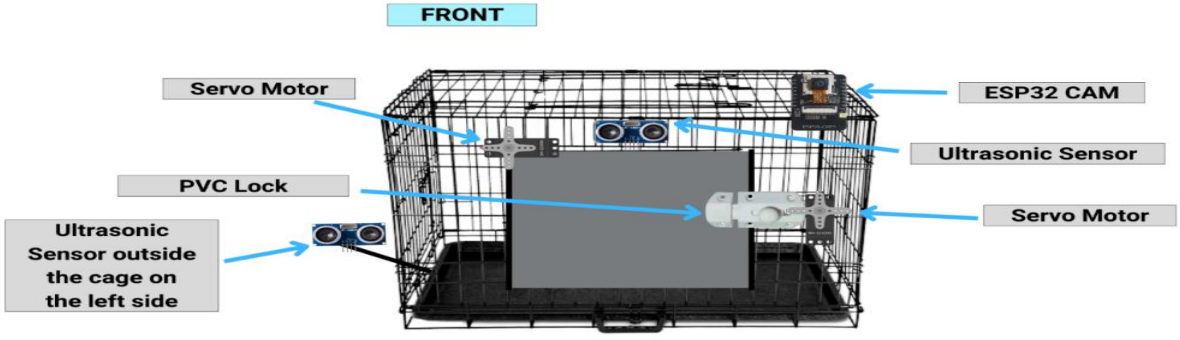


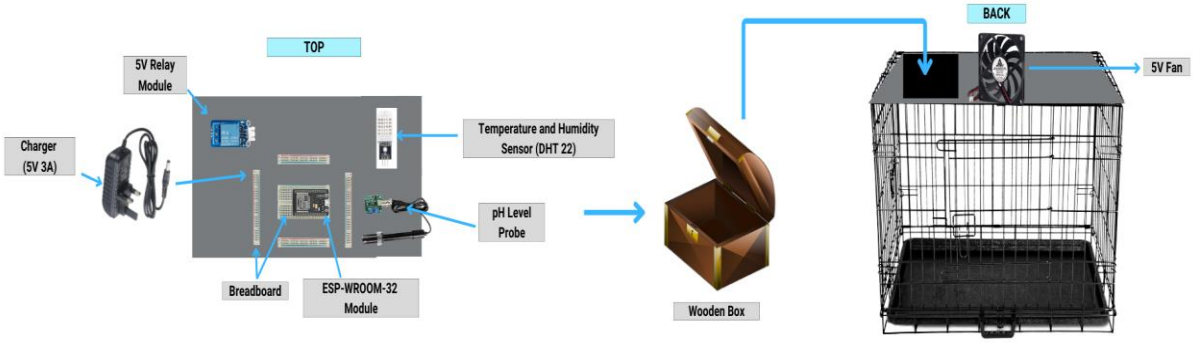
Figure 6 illustrates the Waste Management Prototype of the Smart Cage. The cat and dog waste will be collected in the litter tray. On the left side of the tray, a servo motor enables the mesh to wipe down. Another servo at the bottom of the tray flips or ejects the waste, which is first filtered through the mesh and then directed into a plastic bag.

Figure 7: Automated Door



The visual model for the Automated Door of the smart cage includes an Ultrasonic Sensor that detects the presence of the pet. Once the pet is detected, the PVC Lock will unlock, and Servo Motors will move to open the cage door. After the pet is inside, the cage door will shut. Additionally, there will be another Ultrasonic Sensor to detect the pet and notify the owner if the pet is inside or not. An ESP32 camera will also be included, allowing the owner to live stream their pets. Furthermore, the locking and opening or closing of the cage door depend on the owner, as the lock and door can be remotely controlled through the IoT app.

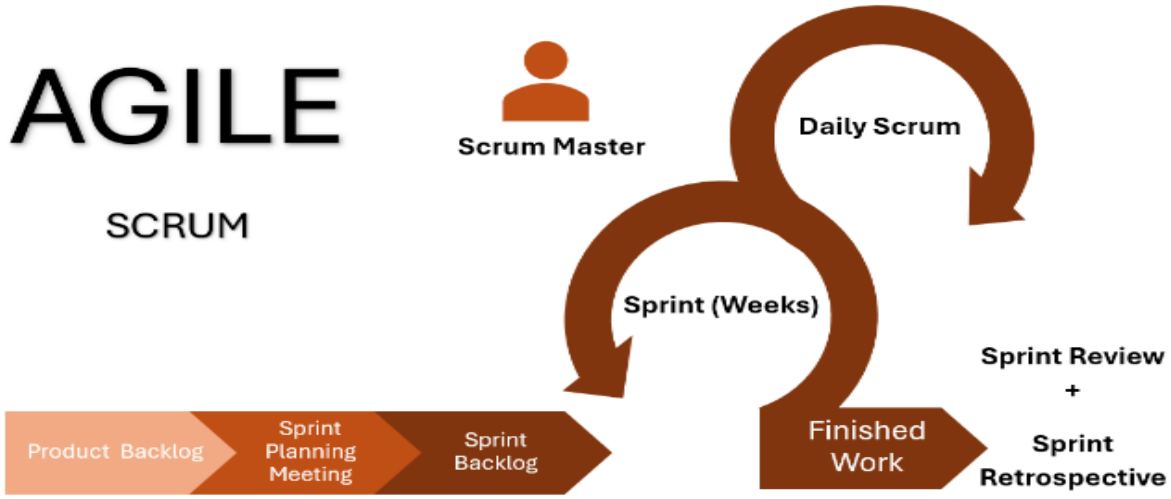
Figure 8: Environmental Control in Cage



The power system uses a 5V 3A charger connected to a Female DC Adapter to power the breadboard and ESP-WROOM-32, which also connects to a laptop. The fan is powered through a 5V relay module to regulate power. The ESP32 board is linked to a DHT22 sensor and water monitoring system. If the temperature rises, the cage door opens automatically, and the fan, mounted on top, enhances ventilation.

Research Development

Figure 9: Scrum Agile Methodology



The development of the IoT based smart cage system applies the scrum agile framework, focusing on an iterative process with regular feedback. This involves phases such as product backlog, sprint planning, sprint execution, daily scrum, sprint review, and sprint retrospective. The product backlog prioritizes creating a list of main features and updates necessary for the system project. Followed by the first sprint, the team conversed regarding the system proposal and gathered the clients feedback, specifically on the challenges related to unmonitored water and pet monitoring. After finalizing, the team presented the system proposal to receive feedback. For the second sprint, the focus of the team shifts to refining the problem statement and specific objective. The team finalizes Chapter 2 of the proposal after receiving the feedback. The team conceptualizes the system

framework for the third sprint, including a schematic diagram, and architecture. Canva is mainly used in diagramming and gathering resources for literature and review. In the fourth sprint, the team continuously works on physical assembling of the system, calibrating sensors, and attaching devices to the cage. The calibration process is done but still encountering minor issues in the system. As for the last sprint, the whole system is further refined to meet specific objectives, however there are still some bugs that need to be addressed. The team collaborates to troubleshoot issues and enhance the overall performance of the system.

Each phase involves meetings, collaboration, and review with the whole team to improve the system constantly based on the feedback from the panelists, clients, and internal discussions.

Participants/Respondents of the Study

Table 1: Population and Sample

Target Respondents	Population Size	Percentage	Sampling Method
Canine and Feline Owners	100	100%	Random Sampling

The target respondents for the topic "IOT Based Smart Cage with Water Filtering Monitoring System for Cats and Dogs" would be canine or feline owners who are willing to provide their time to give information about the needs of their pets, as well as giving any relevant information for the smart cage. It is recommended to get a minimum sample of 100 respondents to get sufficient data for the study. The random sampling method is employed for the best data gathering method for this particular type of study, where in majority of the sample population would have a current or at least had an experience with canine and feline pets.

Instrument/s of the Study

The survey instrument is meticulously structured around ISO certifications, aiming to assess various aspects of these standards. By adopting this approach, the study ensures that the collected data reflects a broad and unbiased sample of participants, enhancing the reliability and validity of the findings.

Participants are asked to rate their perceptions and experiences using a Likert scale, where 5 signifies the highest level of agreement or satisfaction and 1 denotes the lowest. This scale allows for a nuanced capture of respondent attitudes and opinions, providing a comprehensive overview of the data. The quantitative nature of this method facilitates a detailed analysis, enabling the identification of significant trends and patterns related to ISO certification adherence and its perceived impacts on organizational performance and quality standards.

Data Collection and Analysis

The researchers first collected data by testing the Smart Cage with their own pets. After thoroughly testing all the features, the researchers demonstrated how the device operates to the users/pet owners, who then allowed their cats and dogs to use it. Afterward, pet owners received questionnaires and were asked for their evaluations based on their observations of the system in action.

System Evaluation

To assess the IoT Based Smart Cage with Water Filtering Monitoring System for small breed cats and dogs, developers utilize the ISO/IEC 25010 standard, ensuring the system meets key quality attributes such as functionality, performance efficiency, interaction capability, and reliability based on user feedback. This widely accepted model evaluates software products by focusing on these core characteristics (ISO/IEC 25010, 2023), ensuring the system functions as intended. Further ISO/IEC 25010 characteristics will be assessed after the system is deployed and used.

This study aims to evaluate the system based on the following characteristics:

1. Functional Suitability - Determines if the system provides functions that meet both stated and implied needs under specified conditions.

2. Performance Efficiency - Assesses how effectively tasks or processes are executed given the allocated resources and context. This is crucial for evaluating performance, identifying areas for improvement, and optimizing resource allocation across various fields such as operations management, economics, and performance evaluation.

3. Interaction Capability - Examines whether the IoT Based Smart Cage with Water Filtering Monitoring System for Cats and Dogs system is user-friendly, allowing users to accomplish their tasks effectively, efficiently, and satisfactorily. Essentially, it measures if users can easily navigate and use the system to achieve their goals.

4. Reliability - Evaluates the system's ability to perform its intended functions under predetermined conditions for a specified period. It assesses how well the system or product meets desired performance standards and operates as expected.

5. Security - Evaluates the measures in place to protect the system from unauthorized access, data breaches, and other security threats. It assesses the effectiveness of encryption, authentication, and other security protocols in safeguarding engine data and tracking information.

Table 2: The five-point Likert Scale

Criteria	Numerical Value
Excellent	4.21 – 5.00
Very Good	3.41 – 4.20
Good	2.61 – 3.40
Fair	1.81 – 2.60
Poor	1.00 – 1.80

A Likert scale is a rating tool that aids in understanding users' perceptions of the system. Table 3 analyzes the evaluation using a five-point Likert scale to gather user feedback on system quality. This scale, ranging from excellent to poor with a neutral option, helps developers assess user perceptions and identify areas for improvement (VOXCO, 2022). Its simplicity and moderate granularity allow respondents to express opinions effectively, ensuring accurate data collection and easy analysis for the predictive scheduling system's development.

Ethical Considerations

The study was carefully conducted by following the ethical guidelines to ensure the proper study practices were implemented, protecting the privacy of the research respondents, and no pets were harmed during the process. Participants of the study were introduced to the objectives, scope and limitations of the smart cage. Rest assured that the pets used to utilize the cage were under surveillance by the researchers to prevent any unforeseen circumstances that may occur.

Results and Discussion

The survey form utilized by the proponents is comprised of questions that were categorized based on the respondents' experience with the "IoT Based Smart Cage with Water Filtering Monitoring System for Cats and Dogs" system. The proponents used a Google Form to conduct the survey and disseminated to random respondents. 100 respondents participated in the survey and provided feedback through the evaluation form. The questionnaire was designed to assess the system's functionality, interaction capability, and overall user experience. The responses were assessed with a Likert Scale, ranging from 1 to 5 to gauge the respondent's perception on functionality, reliability, interaction capability, and overall satisfaction.

Table 3: Reliability Metric

IoT Smart Cage with Water Filtering and Monitoring for Cats and Dogs						
Reliability Metric						
MTTR	3.29	hrs	Date	Operating	Down Time	No Failure
MTBR	8.57		10/05/2024	4	2	1
MTTF	5.29		10/06/2024	7	1	0
$\text{MTTR} = \frac{\text{Total Downtime}}{\text{Number of Failures}}$			10/07/2024	10	3	1
			10/08/2024	3	4	1
			10/09/2024	4	2	1
$\text{MTBR} = \frac{\text{Total Operating Time}}{\text{Number of Failures}}$			10/10/2024	6	1	0
			10/11/2024	5	3	1
$\text{MTTF} = \text{MTBR} - \text{MTTR}$			10/12/2024	5	1	0
			10/13/2024	5	2	1
			10/14/2024	8	0	0
			10/15/2024	3	4	1
TOTAL				60	23	7

The IoT Smart Cage shows a MTTR of 3.29 hours, meaning repairs take about 3 hours on average after a failure. Its MTBR is 8.57 hours, indicating the system runs for around 9 hours between failures. The MTTF of 5.29 hours suggests the system operates for about 5 hours before failing. Over the monitored period (October 5-15, 2024), the system had 60 hours of operation and 23 hours of downtime, with 7 instances of no. failure. While the system runs reliably, reducing downtime and increasing the time between failures would improve overall performance.

Table 4: Overall Mean for Characteristics in ISO 25010 Evaluation

Criteria	Criteria	Interpretation
Functional Suitability	4.82	Excellent
Performance Efficiency	4.75	Excellent
Interaction Capability	4.84	Excellent
Reliability	4.84	Excellent
Security	4.74	Excellent
Overall Mean	**4.80**	**Excellent**

IoT Based Smart Cage with Water Filtering Monitoring System for Cats and Dogs has achieved an Excellent rating on different criteria. The system scored 4.82 for Functional Suitability, 4.75 for Performance Efficiency, 4.84 for Interaction Capability, 4.84 for Reliability and 4.74 for Security. All scores are interpreted as Excellent based on the Likert Scale and show that the system is effective in meeting the user's needs. The overall mean of the scores is 4.80 which signifies that the system's functions, efficiency, interaction capability, and reliability are excellent. This result shows that the system is successful in meeting the objectives of the study.

Using this 5-point Likert scale, the respondents were able to answer the following questions:

Table 5: The five-point Likert Scale

Response Categories	Numerical Value
Very Satisfied	5
Satisfied	4
Neutral	3
Unsatisfied	2
Very Unsatisfied	1

Conclusion

The IOT-based Smart Cage with Water Filtering and Monitoring System successfully integrates various sensors and devices to help pet owners remotely care for their pets. By automating key features like water quality, food dispensing, door locking, live streaming and sanitation, the system enhances efficiency in pet care. Thorough testing confirmed the functionality of the sensors and servos, ensuring accurate monitoring and automation. The system was evaluated using the ISO 25010:2023 tool, showing that it meets standards for Functionality, Performance Efficiency, Interaction Capability, and Reliability. Continuous feedback and technological advancements offer opportunities for future improvements.

Recommendations

The study recommends several improvements for future researchers of the IOT-based Smart Cage. First, 3D printing should be used to create components like the food dispenser, sanitation system, and door lock, ensuring precise fits with minimal adjustments. Adding an automatic water disposal and refill feature is suggested to ensure pets always have access to clean water. A larger cage should be designed to accommodate bigger breeds of cats and dogs. Exploring different IoT applications and microcontroller boards, like the ESP-WROOM-32 with built-in Wi-Fi, is advised to find the most suitable setup. Lastly, a long-term impact assessment should be conducted to evaluate the system's sustainability and identify areas for further improvement based on ongoing data and feedback.

Conflict of Interest

The authors declare that there are no significant competing financial, professional, or personal interests that might have influenced the performance or presentation of the work described in this manuscript.

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