Artificial Intelligence for Customer Relationship Management Report

Topic: IoT based Smart Pet Caring System

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1. Project Overview

1.1 Background

Nowadays, more and more families are starting to raise a pet at their home, meant to be less boring and to have more companions. However, when the host is not at home with the pet, whether they are studying in school, working at office or travelling, it is really hard to control the behaviour of pets and feeding them, taking care of them properly. Sometimes we will ask family members or neighbours for a hand but not all of us want to do this. Under this situation, the idea for the IoT-based Smart Pet Caring System(SPCS) emerged from a growing need to address the challenges faced by modern pet owners in providing constant care and monitoring for their beloved pets.

After recognising this problem, our team is willing to provide a design to solve this problem - building a bridge to link the gap between busy pet owners and their animals. The IoT-based SPCS proposed in this report is a great solution at this stage, combining with the technologies and enthusiasm, we believe this will be a perfect design to benefit all pet lovers.

1.2 Introduction

This system combines IoT technology, automation and webcam-based monitoring to provide personalised care for pets. It offers autonomous feeding, watering and waste management, while predicting pets' behaviour and well-being. The system aims to enhance pet owners' ability to care for their furry companions, even when they are away, fostering a happier and healthier life for pets.

1.2.1 Technologies

The SPCS utilises the power of Artificial Intelligence (AI), Internet of Things (IoT), image processing, and video processing technologies. The SPCS will be equipped with a series of IoT sensors and devices, including cameras for image and video capture, automatic feeders, waste cleaning systems, and health monitoring devices. The core of the system will be powered by AI algorithms, which will process the data collected from these devices to understand the pet's behaviour, health status, and needs.

The image and video processing algorithms will analyse the pet's movements, behaviours, and physical condition. The web-cam in the room will continually monitor the pet and predict its needs according to their behaviours. If the cat keeps sleeping, it probably means that they are full and they need rest; if they are furry and keep walking to the feeding or watering pot, it means that they might be hungry or thirsty.

On the other side, the feeding and watering machines are relatively easier to work, all we need is to apply a chip as the microcontroller board, and a Wi-Fi module for accessing to the Wi-Fi network, into the sensor (motherboard) that controls the devices. In this case, mainly three devices: food feeder, water dispenser and litter box.

With all these technologies, this system will recognize when the pet is ready to eat or has excreted waste, triggering the automatic feeder or waste cleaning system. (Yixing Chen, Maher Elshakankiri, 2020)

1.2.2 Devices

1. Cameras: Cameras will be strategically placed to monitor the pet's activities and behaviours. They will capture images and videos that will be processed by AI algorithms. The cameras will be equipped with motion detection capabilities to identify significant movements or changes in the pet's behaviour.

2. Automatic Feeder: The automatic feeder will be programmed to dispense food at specific times and in specific quantities. It will be equipped with sensors to detect when the pet is ready to eat and when the food needs to be refilled.

3. Automatic Watering: The same logic as automatic feeder, automatic watering system is built to provide pets with appropriate amounts of water without human‘s control.

4. Waste Cleaning System: The waste cleaning system will be designed to automatically clean the pet's litter box. It will have sensors to detect when the pet has excreted waste and when the litter box needs to be cleaned.

5. Wi-Fi Modules and Arduino Uno Boards: These components will be used to connect the IoT devices to the local network and enable communication between the devices and the central processing unit.

6. Smart Mobile Application: Each user could download an application on their smartphones that can connect to the SPCS. They can access the web-camera - to watch the current life of pets; receive the history of feeding, watering or replacement of pooping pad and also do some manual manipulation of the devices at home.

1.2.3 Methods

The system in this report can be divided into three main parts: the sensor-based feeding machines , the behaviours detection webcam and the user-friendly mobile application.

First, the food feeder, the water dispenser and litter box can be deemed as a complete system. There are sensors inside these machines which control the working of machines. There is also a Wi-Fi module inside of the machine, it helps those appliances to connect to the network at home, then the users can access them on the application remotely through the server.

Second is the webcam, it contains an algorithm to detect the behaviour or the pets and predict its status. According to the prediction, it can send instructions to the machines and give actions to the pets' behaviour (for instance, to serve food when they are hungry and water when they are thirsty automatically).

The feeding and cleaning machines' connection principle is shown in Fig.1.

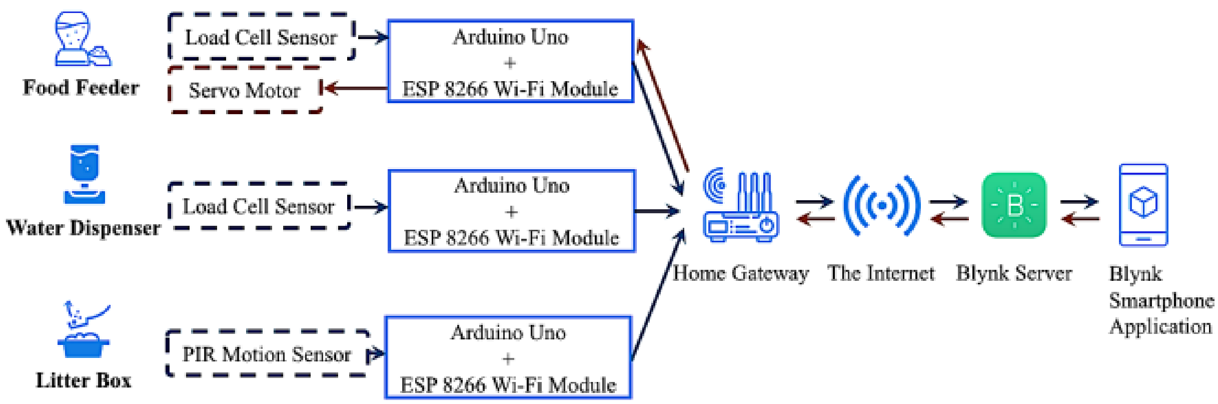

Fig.1 The Block Diagram of Pet Care System

1.2.4 Research Questions

1. What specific AI algorithms can be effectively employed for image and video processing to understand and predict pet behaviour and health status?

2. How can we integrate IoT devices with AI algorithms to automate pet care tasks such as feeding, waste cleaning, and health monitoring?

3. How can we ensure the accuracy and reliability of the AI algorithms in different scenarios and with different types of pets?

4. How can we design the UI of an application on the phone to enhance the usage performance (easy use)?

1.3 Hypothesis

With this system, we have an anticipation to integrate it to significantly improve pet care and well-being. The primary objective of this system is to understand and monitor pet behaviour, automate feeding, watering and waste cleaning processes, assist in pest control and room cleaning. The operation of this system is mainly based on sensor applied devices and webcam monitoring which is supported by computer vision (Machine Learning) algorithms. Then it is for pet owners to assure that their pets are living happily in the room from a distance.

Moreover, we anticipate that the system's user-friendly mobile application will empower pet owners with remote access and control, allowing them to stay connected with their pets throughout the day.

In terms of the data privacy and AI ethical problem considerations, we anticipate that the SPCS will mitigate any potential risks during operation of the system, including the records from the Web-cam, personal information from the users and histories of the pet feedings etc..

All in all, our anticipation of this project is to aid pet owners to strengthen the bond between them and their pets by providing them with personalised service while protecting all of their personal information.

In the rest parts of this report, we will continue illustrating the design of this system with the following structure:

1. Firstly, we will present a list of data that might exist or be produced during the operation of the system and how they are produced;

2. Assumed and related projects that has been done in previous studies;

3. Chosen AI algorithms, why to chose them and how to implement them with a certain structure;

4. KPIs and metrics to measure the performance of this system.

2. Real-life Examples

2.1 List of data

In this project, different kinds of data will appear in the whole procedure, some are for training the systems and to learn how the pet behaves when living and charging themselves; some are for collecting the using history of machines and webcam; in terms of the application, it also contains the user profile information and other personal settings information; finally, user's feedback and suggestions should also be recorded. Here are 10 types of data that might exist in this system:

1. Pet Behaviour Data:
    a. Feeding behaviour (frequency, quantity consumed);
    b. Drinking behaviour (frequency, water consumption);
    c. Litter box usage (frequency, waste elimination patterns);
    d. Playtime activities and duration;
    e. Resting or sleeping patterns.
2. Webcam Data:

   a. Real-time video feed of the pet's activities (only record pets when they are moving around);
   b. Images or snapshots for behaviour analysis;
   c. Timestamps for activity tracking.
3. Environmental Data:
   a. Ambient temperature and humidity in the pet's living area
   b. Light levels and changes in lighting conditions
4. Machine Operation Data:
   a. Feeding machine activation and dispensing logs
   b. Watering machine activation and water level monitoring
   c. Pooping machine activation and cleaning logs
5. System Logs:
   a. User interactions and commands from the web interface
   b. System status and error messages
   c. Timestamps for device operation and user actions
6. Predictive Behavior Patterns:
   a. Predictions about feeding and drinking routines based on historical data
   b. Anticipated litter box usage based on previous behaviour
7. Health and Well-being Indicators:
   a. Abnormal behaviours or signs of distress
   b. Potential health concerns inferred from behaviour data
8. Web Interface Usage Data:
   a. User login and session information
   b. Feeding/watering schedule settings
   c. Automated tasks and schedules
9. Alerts and Notifications:
   a. Low food or water levels triggering notifications
   b. Critical health alerts for immediate attention
10. User Feedback and Preferences:
   a. User surveys and feedback regarding system performance
   b. User-defined preferences for feeding times, portions, etc.

2.2 Related Research

Scenario Assumptions:

Scenario 1: A pet owner is at work and their dog is at home. The system monitors the dog's activity and alerts the owner if the dog is unusually inactive. The owner checks the dog's heart rate and temperature through the wearable device and sees that they are abnormal. The owner then calls a vet.

Scenario 2: A pet owner is away from home for a few days. The system automatically feeds the pet and cleans the litter box. The owner monitors the pet's food and water consumption and defecation patterns through the smartphone application and interacts with the pet through connected entertainment devices.

Scenario 3: The system detects that the pet's fur condition has changed, indicating a possible pest infestation. The owner is alerted and takes the pet to a vet, who confirms the infestation and prescribes medication. The owner then uses the system to schedule the medication administration, ensuring that the pet receives the correct doses at the correct times.

Real Related Projects:

In Seungcheon's work, he proposed a SPCS which has remote feeding, remote controlled automatic defecation, CCTV service and Smart phone APP. In his project, the application can control all the devices at home to serve food and clean the litter box etc,. Besides, on the application, users can monitor the situation at home in real-time through the camera. It was a very good trial and he achieved it. (Kim, Smart Pet Care System using Internet of Things, 2016)

Besides, Hansika and her co-workers proposed a "Smart Dog Caring System" (a smart phone application) that can not only feed dogs through the IoT-based automated pet feeder, it can also detect the potential skin disease through image processing with the help of the application, what they need to do is just to input an image taken by user of dogs and it will detect automatically and provide with reliable results. What is more, this application can generate growth plans for dogs individually by providing some information from the start of their lives. (Krishnarajan.L, Kulathunga H.M.W.B, Jayawardhana K.H.M.I.N, et al., 2020)

Also there are some products that only provide part of the functions mentioned in this report but they did good. For example, the Petsafe only provides a food feeder application, instead of establishing an ecosystem. (Petsafe, n.d.) The OurPets only designed a water fountain that can satisfy the needs of drinking for pets. (Cosmic Pet, n.d.)

3. Questions about AI algorithms

3.1 Algorithms and Choosing Reason

In general:

1. Image Processing Algorithms: These algorithms will analyse the images captured by the cameras to detect changes in the pet's weight, fur condition, or behaviour. Techniques such as edge detection, pattern recognition, and object detection may be used.

2. Video Processing Algorithms: These algorithms will analyse the videos captured by the cameras to understand the pet's movements and behaviours. Techniques such as motion tracking, behaviour recognition, and anomaly detection may be used.

3. Data Analysis Algorithms: These algorithms will analyse the data collected from the IoT devices to make predictions and automate tasks. Techniques such as regression analysis, time series analysis, and machine learning may be used.

4. Decision Making Algorithms: These algorithms will make decisions based on the analysed data. They will determine when to activate the automatic feeder or waste cleaning system, when to alert the pet owner, and when to adjust the pet's care routine. Techniques such as rule-based systems, decision trees, and reinforcement learning may be used.

Image and Video Processing Algorithm:

1. **Convolutional Neural Networks (CNNs):** CNNs are a type of deep learning algorithm that are excellent for image and video processing tasks. In our system, we can use CNNs to analyse the images and videos captured by the cameras. For instance, a CNN can be trained to recognize different behaviours of the pet, such as eating, sleeping, playing, or showing signs of distress. The CNN works by automatically and adaptively learning spatial hierarchies of features from the raw input data. This makes it highly effective for tasks like object detection and recognition in images and videos.

2. **Principal Component Analysis (PCA):** PCA is a dimensionality reduction technique that can be used to simplify the data collected from the IoT devices. For example, the health monitoring device might collect a large amount of data about the pet's heart rate, temperature, and activity levels. PCA can be used to identify the most important features in this data, reducing its complexity without losing important information. This makes the data easier to analyze and interpret.

3. **Generative Adversarial Networks (GANs):** GANs are a type of deep learning algorithm that can generate new data similar to the input data. In our system, we could use a GAN to predict future behaviours of the pet based on past behaviours. The GAN works by training two neural networks, a generator and a discriminator, in a competitive setting. The generator tries to create data that is similar to the input data, while the discriminator tries to distinguish between the real input data and the data created by the generator. Over time, the generator becomes better at creating data that is similar to the input data, allowing it to make accurate predictions.

For example, if the pet has a regular feeding schedule, the GAN can learn this schedule and predict when the pet will be ready to eat. This can then trigger the automatic feeder to dispense food at the right time. Similarly, if the pet has a regular pattern of activity and rest, the GAN can learn this pattern and predict when the pet will be active or resting. This can help the pet owner to plan their pet's care routine.

4. **Image Matrix Differentiation**: this is an easy method to realise the detection of pets' movements. The webcam will take photos of the video being recorded every second, and subtract image matrixes currently and previously. If the numbers on some pixels changed significantly, the webcam will judge that the pet is moving and the behaviour detection algorithm will start working to predict the status of pets.

For instance, if the subtraction result of two continuous images is 0 or it has only a small area is not 0, it means that the pet is not moving or they are maybe scratching or yawning, at this time we cannot judge them moving around. But when the result is a huge area that is not 0, then it will judge the pet is moving.

Decision Making Algorithm:

1. **Decision Tree:** Decision Tree is a machine learning algorithm that is used for making different decisions according to the criteria being made. We define decisions based on pet behaviour data including feeding, water and litter box usage. Then we select key features for doing division-making (feeding frequency, water consumption, etc.). One decision tree is always designed to make only a few decisions and they are usually related.

2. **Random Forest:** Random Forest is a machine learning algorithm that can be used for decision making tasks. In our system, we can use a Random Forest algorithm to decide when to activate the automatic feeder or waste cleaning system. The algorithm works by creating a 'forest' of decision trees, each of which votes on the decision. The majority vote is then chosen as the final decision. This makes the Random Forest algorithm robust and accurate, as it averages the results of many different decision trees.

3.2 Pipeline and structures

The structure of the SPCS is a network of interconnected IoT devices and AI algorithms. The IoT devices collect data, which is then sent to a central processing unit. This unit runs the AI algorithms, which analyse the data and make decisions based on it. The decisions are then sent back to the IoT devices, which carry out the necessary actions.

The pipeline of the system is as follows:

1. **Data collection**: The IoT devices collect data about the pet's behaviour, health, and needs.

2. **Data processing**: The data is sent to the central processing unit, where it is analysed by the AI algorithms.

3. **Decision making**: The AI algorithms make decisions based on the analysed data.

4. **Action**: The decisions are sent back to the IoT devices, which carry out the necessary actions.

4. KPI and Metrics

4.1 Accuracy of Behavior Recognition

This metric measures how accurately the system can recognize and classify the pet's behaviours using the image and video processing algorithms. It can be calculated as the number of correctly recognized behaviours divided by the total number of behaviours. Further information is listed in the following Table.1.

Table.1 Information of Accuracy of Behaviour Recognition

Goal	Accurate recognition and classification of pet's behaviours
Measurement	Percentage of correctly recognized behaviours
Calculation	(Number of correctly recognized behaviours / Total number of behaviours) * 100

Determine whether a behaviour has been correctly recognized:

1. **Expert Annotation**: We can have pet behaviour experts annotate our training data. This means that they'll watch videos of the pet and label different behaviours. This labelled data can then be used to train and validate our machine learning models. The accuracy of behaviour recognition can then be measured by comparing the model's predictions to the expert annotations.

2. Owner Feedback: Pet owners know their pets better than anyone. We can use a system where pet owners correct the system's behaviour recognition in real-time. For example, if the system misclassifies a behaviour, the owner can correct it. This feedback can be used to continuously improve the system's accuracy.

3. Behavioural Baselines: Certain pet behaviours are universally recognized, such as eating, drinking, sleeping, or using the litter box. We can establish behavioural baselines for these actions and use them to train our model. The system's accuracy can then be measured by its ability to correctly identify these baseline behaviours.

4. Veterinary Consultation: Veterinarians and animal behaviourists can provide valuable insights into pet behaviour. We can consult with these experts to help design our behaviour recognition system and validate its accuracy.

4.2 Reliability of Automatic Feeder and Waste Cleaning System

This metric measures how reliably the automatic feeder and waste cleaning system perform their tasks. It can be calculated as the number of successful operations divided by the total number of operations. Further information is listed in the following Table.2.

Table.2 Information of Reliability of Automatic Feeder and Waste Cleaning System

Goal	Reliable operation of automatic feeder and waste cleaning system
Measurement	Percentage of successful operations
Calculation	(Number of successful operations / Total number of operations) * 100

4.3 User Satisfaction:

This is a qualitative metric that measures how satisfied the pet owners are with the system. It can be assessed through user surveys and feedback. Further information is listed in the following Table.3.

Table.3 Information of User Satisfaction

Goal	High user satisfaction with the system
Measurement	User satisfaction score
Calculation	Average score from user surveys and feedback

4.4 Pet Well-being

This is a qualitative metric that measures the impact of the system on the pet's well-being. It can be assessed through observations of the pet's behaviour, health, and interactions with the system. Further information is listed in the following Table.4.

Table.4 Information of Pet Well-being

Goal	Positive impact on pet's well-being
Measurement	Observations of pet's behaviour, health, and interactions with the system

Calculation	Qualitative assessment based on observations and expert opinion

5. Conclusion

In this report, we proposed an IoT-based Smart Pet Caring System. It presents a cutting-edge and innovative solution to address the challenges faced by busy pet owners in providing constant care and monitoring for their beloved pets. By leveraging the power of IoT technology, automation and webcam-based behaviour detection, the system offers a seamless and personalised pet care experience.

The three main parts of this project construct the whole system. The implementation of autonomous feeding, watering and waste management machines are controlled by the embedded sensor and they could be controlled by the application when users need, and can also be controlled automatically with the help of webcam-based pets behaviour detection algorithm. Those machines ensure that pets receive timely access to food, water and a clean living environment, promoting their overall health and well-being.

The webcam can detect the movements of pets and analyse them in time. It has the ability to predict pet status through machine learning and deep learning algorithms, then providing valuable insights for pet owners to make informed decisions regarding their pets' well-being.

Finally, the user-friendly app enables remote access and control, empowering pet owners to stay connected with their pets and manage the SPCS from anywhere, enhancing convenience and peace of mind.

As the IoT-based SPCS continues to evolve through user feedback and improvements, it promises to revolutionise the way pets are cared for, setting new standards in pet care that embrace technology while maintaining a compassionate and loving approach. With the development of technology, we can more easily connect ourselves with our beloved pets closer by creating a harmonious environment where pets can thrive, ensuring a happier and healthier life for our cherished animal companions.

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