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IoT-ENABLED ACTIVITY TRACKING COLLAR FOR CATS WITH GPS LOCALIZATION

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Abstract

Pet tracking and health monitoring are a must to maintain pet safety and health, especially in those pets that like to stray and get lost. This project proposes an IoT-based smart collar that integrates GPS, Wi-Fi, and various health sensors to provide real-time tracking of the location and health monitoring. The system consists of an ESP32-based collar equipped with Wi-Fi for indoor tracking, an MPU6050 accelerometer for activity tracking, and an MLX90614 infrared sensor for temperature monitoring. Data collected from the sensors is transmitted to Firebase, where it is processed and displayed through a mobile application, enabling pet owners to monitor their cat's activity, health parameters, and location in real time. In addition, integration of Google Maps API for geolocation provides more accurate tracking, enables geofencing to alert owners in the event their pet gets out of a specified boundary, and enables the use of animal clinics nearby from one's location. The system offers an end-to-end solution for pet owners with better monitoring, early response to any potential health issues, and better pet safety.

Keywords: IoT, GPS, Wi-Fi, tracking, health Monitoring, ESP32, Firebase, Arduino IDE, Android Studio, Google Map API, mobile application, geofencing

INTRODUCTION

According to recent statistics, pet ownership in Malaysia has grown significantly, with 53% of respondents in a 2022 survey reporting pet ownership, and cats being the most popular choice (Statista, 2022). In 2023, research showed that 77.7% of pet owners in Malaysia owned at least one cat, while 14.9% owned dogs (Standard Insights, 2023). This growing attachment to pets has increased concerns about pet safety and health, particularly for cat owners. Cats

often roam freely, making them susceptible to getting lost or stolen, and traditional tracking methods such as ID tags or microchips have limitations, as they do not provide real-time location tracking (Saputra et al., 2021). Additionally, monitoring a cat's health in real time remains a challenge for pet owners, as subtle changes in activity levels or body temperature can be early indicators of illness but are often overlooked (Almazan et al., 2020). Without an efficient monitoring system, veterinarians may struggle to diagnose health conditions accurately due to the lack of comprehensive historical health data.

To address these concerns, this project proposes the development of a portable IoT-based cat collar equipped with Wi-Fi-based tracking and real-time health monitoring features. The system integrates sensors such as the MPU6050 to track activity levels and step count, the MLX90614 to measure body temperature, and Neo-6M GPS is for tracking. The collar transmits data via Wi-Fi to a mobile application, allowing pet owners to monitor their cat's location and health status remotely through Firebase cloud services. Additionally, the mobile app includes a vet clinic locator based on the pet owner's current location, enhancing accessibility to veterinary care. By leveraging IoT and wireless connectivity, this system provides real-time updates, proactive alerts, and historical health data, ensuring better care and safety for pets. Designed for use in homes, pet daycares, and veterinary clinics with stable Wi-Fi connectivity, this project aims to enhance the safety, tracking, and well-being of cats while providing owners with greater peace of mind.

LITERATURE REVIEW

This part describes a literature review on article and information collected to develop this cat-tracking collar and health monitoring. The data and information were gathered from research articles, clinical websites and other resources. To explain and elaborate the details of the system is the main objective on collecting this data.

Cat Tracking and Health Monitoring

In recent years, there has been a lot of interest in using technology to track and monitor cats' health. Currently, technology can help fix the situation. The Internet of Things (IoT) may offer cat care services through automation and integration. All the cat's needs can be met automatically with a customized arrangement. IoT can also provide remote monitoring,

configuration, and execution of all cat-care technology. (Wicaksono et al., 2019). Technological advancements have significantly enhanced health monitoring for humans and animals alike. This animal health monitoring and tracking system is extremely effective for detecting disease early on and preventing it from spreading to other animals. Over the years, several studies have been conducted in this field to monitor animal health, however the methods used require either the removal of an animal's fur or the insertion of a small chip into the animal's body. There are proven health monitoring devices used for human health monitoring, such as wearable hand gears or blood pressure monitors, but the same system cannot be used to monitor any animal. Additionally, as the number of pet owners grows, the need for the same system becomes a necessity in daily life. (Mhapne et al., 2020)

Tracking Technologies

Tracking technologies include a variety of methods used to monitor and find objects or animals in real time. These include GPS, which uses satellite signals for precise outdoor navigation, VHF and Bluetooth beacons for short-range locating, and Wi-Fi for precise indoor localization. Hybrid systems apply multiple technologies to ensure continuous, dependable tracking across various environments. The Global Positioning System (GPS) is a dictionary-based satellite, device, and receiver system that calculates the time difference between satellite and receiver signals to determine the receiver's latitude and longitude on Earth. GPS is normally determined using triangulation, with a satellite system and an earth receiver defining each receiver's latitude and longitude. GPS is typically calculated by triangulation as a satellite system coupled with an earth receiver, which defines the latitude and longitude of each receiver. (Sivaraman et al., 2021). GPS remains the best navigation and tracking innovation to date, with accuracy dimensions of within 4-20 m of the true position of the object being traced. (Sirish Kumar & Srilatha Indira Dutt, 2020)

Mobile Application

The integration of a mobile application is essential for providing pet owners with real-time tracking and health monitoring of their cats. By leveraging Firebase Realtime Database, the mobile app retrieves and displays live data from the IoT-enabled cat collar, ensuring seamless communication between the hardware and software components. Users can access critical information such as the cat’s location, activity level, and body temperature, allowing them to

take immediate action when necessary. Additionally, the application features geofencing capabilities, notifying users if their pet moves beyond a predefined safe zone. In case of abnormal health readings, the app also facilitates finding nearby veterinary clinics based on the user's current GPS location, enhancing the overall pet care experience (Saputra et al., 2021). The use of IoT and cloud-based databases in mobile applications ensures reliable data transmission, real-time alerts, and a user-friendly interface for efficient pet monitoring (Almazan et al., 2020).

Comparison of Related Works

Table 1 shows the comparison of related works of this project, which is Outdoor Pet Tracking and Health Monitoring System, CAHM: Companion Animal Health Monitoring System, Integration of animal tracking and health monitoring systems,

Table 1: Comparison of Existing Project

Comparison	Outdoor Pet Tracking and Health Monitoring System	CAHM: Companion Animal Health Monitoring System	Integration of animal tracking and health monitoring systems
Focus	Pet tracking and health monitoring using IoT	Pet adoption and related services with location-based technology	Pet health monitoring & location tracking
Hardware Components	ESP32 microcontroller, Neo-6M GPS module, MPU6050 sensor (step activity), DHT11 sensor (temperature)	None specified (software-focused)	Arduino Pro Mini, MLX 90614 temperature sensor, NEO 6M GPS module, SIM 800L GSM module
Software	Arduino IDE Blynk application	React Native framework	Custom software integrated with SMS-based alerts
Communication Method	Blynk platform	Mobile app (iOS & Android)	GSM (SMS-based)

Tracking Technology	GPS	Location-based services using mobile technology	GPS
Geofencing Feature	No	No	No
Targeted Animals	For all type of pets	Primarily for dogs (specific breeds: Labrador, Siberian Husky, German Shepherd, Golden Retriever, Dachshund)	For all type of pets

METHODOLOGY

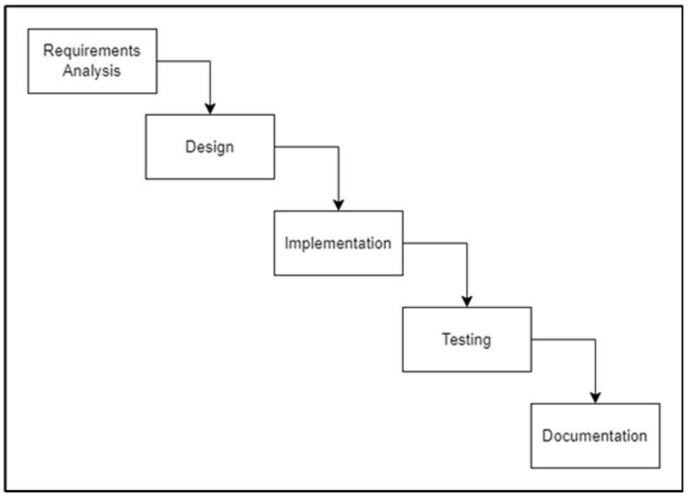

Figure 1 Methodology Framework

The Waterfall methodology takes a sequential and linear approach, as it will ensure one step will be completed first before proceeding to the next step. This structured approach makes the development process is predictable and can do accurate planning, listing well milestones, and simple project timelines. Waterfall methodology emphasizes extensive documentation at every stage of development. This documentation provides a clear understanding of project requirements, design specifications, and implementation proposals. Waterfall projects are easier for project managers to handle because of their established criteria and well-defined phases, which allow for effective resource allocation, task assignment, and progress tracking. The Waterfall methodology emphasizes the development of measurable and well-defined deliverables at the conclusion of each phase. Providing clear expectations for stakeholders and

clients promotes transparency and successful communication. Waterfall is ideal for small projects with clear and steady requirements. Its basic method is useful for less frequent adjustments during development. (Pargaonkar, 2023).

System Design

In this project, the design phase will have a use case, flowchart of the system, Entity relationships diagram (ERD), system architecture, and interface design. For the flowchart will have two types of flowcharts which is: tracking flowchart and health monitoring flowchart as shows below.

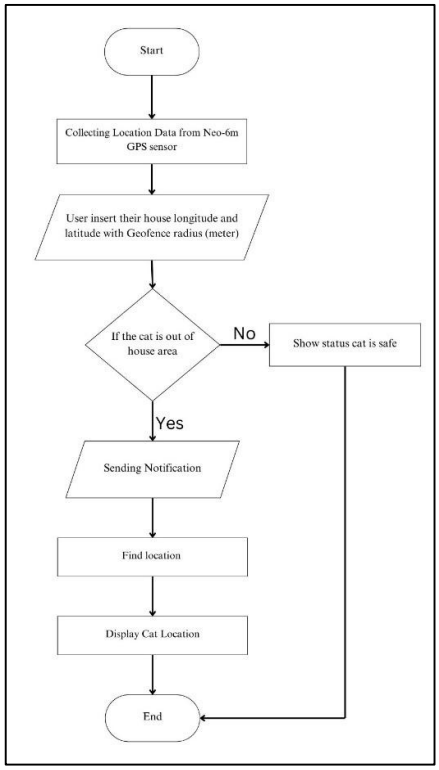

Figure 2 Tracking Flowchart

The Tracking Page Flow starts by reading the current GPS location in longitude and latitude from the NEO-6M GPS module. This is to be sent to Firebase Realtime Database over Wi-Fi from ESP32 continuously, while the mobile application fetches this information and displays the location of the cat on the tracking page. The user can set a geofence by defining a safe zone with a specific radius. If the cat moves out of the geofenced area, the system triggers an instant notification to alert the user and updates the location in real time. If the cat remains within the defined safe zone, the app will display a status indicating that the cat is safe. Such

smooth connectivity ensures real-time location tracking, automatic monitoring of geofences, and instant alerts that will definitely help users in keeping their pets safe for not getting too far away.

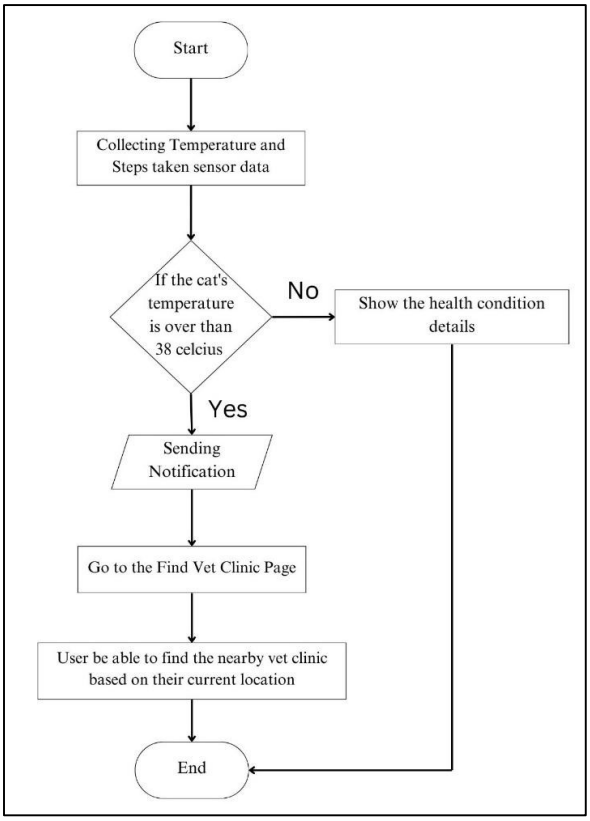

Figure 3 Health Monitoring Flowchart

The flow would base itself on the Health Monitoring Page, pulling in real-time data from the temperature sensor MLX90614 and accelerometer MPU6050 for computation in calculating the body temperature and step count. This will involve the constant transmit of these information across the board to Firebase Realtime Database using ESP32-WIFI. The data are fetched from the Firebase by the mobile app to show on the Health Monitoring Page. If the temperature of the cat is above 38°C, the system will immediately send notification to the user about a possible health hazard. At the same time, the application will auto-forward the user to the Find Vet Clinic Page, where he can find the nearest veterinary clinics from his current GPS position. If the temperature is less than this value, no action is taken, and the normal process of monitoring proceeds. It ensures smooth functioning: real-time tracking, instant alerting in conditions of abnormal health state, easily accessible vet service to help a user in time to respond against any health concern regarding their pets.

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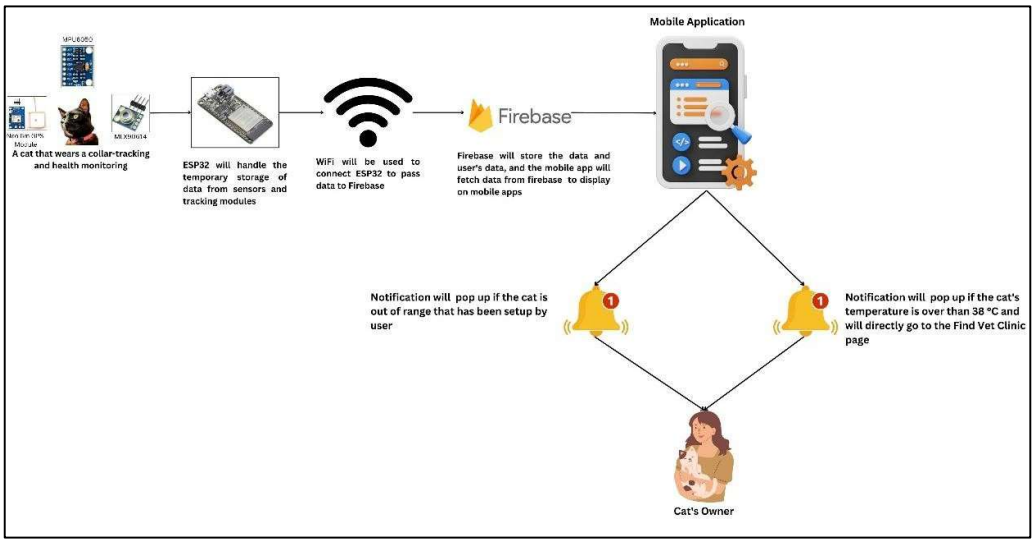

Figure 4 System Architecture

It provides the essential architecture of a GPS Localization-based IoT-Enabled Activity Tracking Collar for cats that should, in turn, perform the task of collecting real-time data with processing, storing, and presenting it to its users while indicating any important event. The feline is anticipated to wear the smart collar equipped with an ESP32 microcontroller and several sensors: NEO-6M GPS module for providing location tracking; MPU6050 accelerometer for steps detection; and MLX90614 temperature sensor capable of body temperature reading from the animal itself. These sensors continuously collect real-time data, which is then processed and stored temporarily on the ESP32. The ESP32 then transfers this data over a Wi-Fi network to Firebase Realtime Database, where it is securely stored and dynamically updated.

Accordingly, the mobile app fetches updated data from Firebase to display a cat's real-time location, step count, and temperature on the mobile. The user would also be able to set up the geofence boundary by determining his home longitude and latitude and a radius of safety over which the device will alert one in case this geofencing is breached by the cat's movement. If the temperature is above 38°C, an alert will appear in the application, which then automatically routes users to the Find Vet Clinic page so users can look for the closest veterinary clinic nearby for help. This architecture is designed for the purpose of continual monitoring, synchronization of real-time data, notification in time, and efficient users' experience while keeping pets healthy and safe.

RESULT AND DISCUSSION

Testing of this project will be very much valuable to ascertain whether the IoT-Enabled Activity Tracking Collar with GPS Localization for Cats functions with reliability, precision, and timeliness. It is presumed that the end clients of the designed system would primarily be all those pet owners whose intention is to monitor the whereabouts and the state of their cats effectively. Testing consists of sensor accuracy, data transmission to Firebase, real-time updates on the mobile app, and geofencing alerts, as well as responsiveness of notifications. The mobile applications shall be tested with Android-based smartphones, starting from Android 12 upwards, to be able to assure the state-of-the-art update in security and system-wise. Also, network performance tests are conducted with regard to Wi-Fi connectivity, data synchronization speed, and the speed of notification delivery to make sure that in real-life conditions, the system will work flawlessly. With such comprehensive testing, the whole process of user experience in pet tracking and health monitoring becomes seamless, reliable, and effective.

Functional Testing

This test is performed for the functional testing of hardware and the mobile application to ensure that all the functionalities work appropriately and effectively. A test on a small group of five users was performed to prevent exceeding hardware and Firebase capacity, as both have limitations in terms of data collection and storage. It ranges from several key functionalities: GPS tracking, step detection, temperature monitoring, geofencing alerts, and real-time Firebase synchronization. The performance and reliability of the system have also been reviewed by the supervisor lecturer, Sir Mohd Ali Bin Mohd Saad. The mobile application works on devices with Android 12 and above versions for flawless operation. Regarding the hardware, it's been tested in various aspects regarding Wi-Fi connectivity, sensor accuracy, and data transmission. In general, here, the design ensures that the system provides desired performances without compromising on stability and accuracy, being user-friendly for any pet owner.

Table 2: Functionality Testing

No	Functionality	Description	Expected Result	Pass/Fail
1	Sign-Up Page	User registers by email, and password.	Registration data is stored in Firebase, and the user receives a success message.	**Pass**

2	Login with Email	User logs in using their registered email and password.	User is authenticated and directed to the Tracking Page.	**Pass**
3	Login with Third-Party Email	User logs in using email-based sign-in (e.g., Google).	User is authenticated via third-party service and directed to the Tracking Page.	**Pass**
4	Tracking Current Location	Displays the cat's real-time location on the map.	The GPS coordinates from Firebase are shown on the map in the mobile app.	**Pass**
5	Geofencing Setup	User sets a geofence longitude, latitude and radius around the cat's location.	Notification pops up if the cat moves outside the geofenced area.	**Pass**
6	Geofencing Status	Display cat safe or not safe	Show cat status based on geofencing situation	**Pass**
7	Google Maps Integration	Fragments for google maps directs the user to Google Maps for detailed address view.	User can go to Google Maps showing the exact location of the cat.	**Pass**
8	Temperature Monitoring	Displays the cat's temperature and checks if it exceeds 38°C.	Notification pops up if temperature is above 38°C; data is displayed correctly.	**Pass**
9	Steps Monitoring	Displays the total steps taken by the cat.	Steps data from Firebase is displayed correctly in the mobile app.	**Pass**
10	Save Health Monitoring Data	User saves the temperature and step count data.	Data is successfully stored in the table for future reference.	**Pass**
11	Delete Health Monitoring Data	User deletes saved health monitoring data.	Data is successfully removed from the table.	**Pass**
12	Find Vet Clinic Page: User can find nearby vet clinic	User can find nearby vet clinic and can access location (GPS) on device to find nearby vet clinic	Successfully find nearby vet clinic and can open google maps for address details	**Pass**
13	Navigation Buttons	Allows user to navigate between Tracking Page, Health Monitoring Page, and Logout.	Navigation works smoothly, and pages update without issues.	**Pass**
14	Logout	Logs the user out of the mobile app.	User is successfully logged out and redirected to the Login Page.	**Pass**
15	Wi-Fi Connection for Hardware	Hardware (sensors, GPS) connects to Firebase via Wi-Fi.	Data from GPS, temperature, and step counter is sent to Firebase in real time.	**Pass**
16	Real-Time Data Fetching in Mobile App	Mobile app fetches data from Firebase for tracking, temperature, and step monitoring.	Data in Firebase is fetched correctly and updates in real time in the mobile app.	**Pass**

17	Neo-6m GPS collecting data	Collecting location data:longitude and latitude	Successfully data collected	**Pass**
18	MPU6050 collecting data	Collecting steps taken data	Successfully data collected	**Pass**
19	MLX90164 collecting data	Collecting temperature data	Successfully data collected	**Pass**
20	Notification for Unsafe Geofence Condition	Sends notification when cat moves outside the geofenced area.	User receives a pop-up notification when the geofencing condition is not met.	**Pass**
21	Notification for High Temperature	Sends notification when the cat's temperature exceeds 38°C.	User receives a pop-up notification when temperature is above the threshold.	**Pass**

Accuracy Testing

The geofencing accuracy for detecting the user's current location is also considered, finding the nearest veterinary clinic, and the real-time update from Firebase. This geofencing shall be tested by the movement of a cat's location within and outside a defined boundary to see if notifications are rightly pushed. This integration with Google Maps will be assessed to check that the app properly detects the real-time location of the user and shows it accurately on the map. Further assessed will be the Find Vet Clinic feature, that this indeed would prompt the right nearest veterinary clinic as per GPS coordinates. Testing involves testing of real-time synchronization of ESP32, Firebase, and mobile regarding temperature and steps taken at the moment without lag or latencies. Tests of this kind assure reliability of the system and hence accurate tracking for seamless experiences in real-time monitoring by any owner.

Table 2: Accuracy Testing

Test Case	Description	Expected Outcome	Result
Geofencing Accuracy	Verify if the system correctly detects when the cat moves in and out of the geofence boundary.	Notification is triggered when the cat leaves the geofenced area, and status updates correctly.	**Pass**
User Location Detection	Check if Google Maps accurately detects the user's current location.	The app correctly displays the user's real-time location on the map.	**Pass**
Vet Clinic Location Accuracy	Verify if the app correctly identifies nearby veterinary clinics based on the user's GPS location.	Nearby vet clinics are displayed accurately within the expected range.	**Pass**
Real-Time Data Sync	Check if the mobile app displays real-time data from Firebase without delays.	Data updates instantly in the app when ESP32 sends new readings to Firebase.	**Pass**

Network Testing

Network testing is required to assure the efficiency and reliability of the whole cat collar tracking system since it relies on a steady Wi-Fi connection to transmit data in real-time. This testing aims at assessing the major areas in relation to Wi-Fi connectivity, network latency, packet loss, integrity in the transmission of data, and network range. Since the system relies on ESP32 to send sensor data to Firebase and the mobile application to fetch and display this data, it is crucial to verify that the network performs well under different conditions. Additionally, testing the maximum Wi-Fi range helps determine how far the collar can still transmit location data and alerts before losing connection, ensuring that pet owners receive accurate and timely updates about their cat's status.

Table 2: Network Testing

Test Case	Description	Expected Outcome	Result
Wi-Fi Connectivity	Verify if the ESP32 successfully connects to Wi-Fi and maintains a stable connection.	The ESP32 connects and stays connected without frequent disconnections.	**Pass**
Latency and Packet Loss	Use ping tests to measure response time and detect packet loss between ESP32 and Firebase.	Low latency (fast response times) and minimal or no packet loss.	**Pass**
Data Transmission Integrity	Check if data from ESP32 is correctly transmitted to Firebase and displayed on the mobile app in real-time.	The mobile app shows accurate, real-time data with no missing values.	**Pass**
Network Range	Determine the maximum Wi-Fi range in which the ESP32 can still transmit data and send notifications.	The ESP32 can send data as long as it remains within Wi-Fi coverage. Once out of range, data transmission stops.	**Pass**

CONCLUSION

This project really succeeded in achieving its aims by developing a portable IoT-based cat collar integrated with sensors and GPS for real-time tracking. Location, movement, and temperature data are effectively collected from the collar, transmitted by it over Wi-Fi to Firebase Realtime Database. A mobile application displaying tracking and health monitoring data was developed in order to enable users to check their pets remotely. Further network range tests were conducted for estimating the furthest distance on which the device on the collar can

provide information and send messages. This includes real-time access to data with geofence alerts and a health monitoring service that will promote pet safety. Several testing, such as functionality, accuracy test, and Network test, substantiated that it is reliable, efficient, and can be reliably applied by citizens with pets in their homes or places of rearing.

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