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The development, application, and improvement of pet locators

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Abstract. This thesis aims to explore the technological development, current application status, and future improvement directions of pet trackers. With the continuous advancement of science and technology, various innovative technologies are constantly being transformed into practical forces for optimizing pet care. As a practical representative of these, pet tracker technology has shown great potential in diverse scenarios such as pet safety protection, daily activity monitoring, and rapid recovery of lost pets. It points out challenges in aspects like battery life, signal coverage, and user experience while suggesting corresponding improvements. From the development perspective, evolving from the initial handwritten sticker technology to modern GPS and Bluetooth positioning technologies, it has home management and health monitoring applications. The emergence of pet positioning devices has reshaped the pet positioning model with their high precision and long battery life. They bring significant peace of mind to pet owners and play a crucial role in promoting the development of intelligent pet products toward precision and humanization. This thesis points out the challenges of these devices in terms of battery life, signal coverage, and user experience, and puts forward corresponding improvement suggestions. Finally, regarding the future development of pet trackers, this thesis emphasizes the importance of artificial intelligence and big data in enhancing the functions of pet trackers.

Keywords: Pet Tracker; Positioning Technology; Health Monitoring; Signal Coverage; Intelligentize.

1. Introduction

Various intelligent products have also appeared on the market with the rapid development of contemporary science and technology. These products further emancipate the labor force and make people's lives more convenient. Through the survey of China's big data, the number of pet-raising households is increasing, reaching 5.912 million this year, and there is still a large room for growth; in 2017, the proportion of pet-raising households in China increased by 2% compared with the previous year, reaching 17%; in 2017, the number of pet-raising households in China reached approximately 5.912 million [1]. Moreover, 91.1% of people choose to raise cats and dogs among these pet choices.

According to the data from the Pet Market Consumption White Paper, by the end of 2023, the number of pet-raising households in China had increased to 105.65 million, exceeding 100 million in scale, and the number of people keeping pets will continue to grow.

With such a large population, tricky problems will emerge—the universality of the pet loss problem. In recent years, the importance of pets as family members has become increasingly prominent, and the continuous growth of the global pet population has made the problem of pet loss more prominent. Big data monitoring and statistics show that about 10% of pets experience yearly loss. This not only causes huge physical and psychological pressure on pet owners but also poses a threat to the safety of pets and a certain threat to social security. There are many reasons for pet loss, including accidental escape, natural disasters, traffic accidents, etc. However, lost pets often face the risks of hunger, disease, and injury from harsh environments. To solve this problem, many pet owners have begun to seek effective solutions, among which pet trackers, as an emerging technical tool, have gradually attracted public attention. Through real-time tracking and positioning functions, pet trackers can help owners quickly find lost pets, thereby reducing the risks and losses caused by pet loss.

Looking back at the entire development history of pet trackers, early trackers mainly relied on simple RFID technology. They had limited functions, while modern devices combine GPS, Bluetooth,

and Internet of Things technologies to provide multiple functions such as real-time positioning, health monitoring, and activity tracking. This part of the research will lay a foundation for understanding the current market situation and future development of pet trackers. From the manual tracking methods in the past to the current intelligent positioning devices, it clearly shows how technological progress has changed pet safety management. From the technological changes in different stages, we can also understand how consumers' needs and market trends promote and improve the design and functions of trackers.

2. Modern Positioning Technology

2.1 GPS

The application of GPS technology has not only improved the accuracy of positioning but also expanded the functions of pet trackers, making them an important tool for monitoring the location of pets in modern times [2]. Modern pet trackers usually have a built-in GPS module, which can transmit location information to a smartphone application via a mobile network or Bluetooth. Users can check the pet's location in real time through the mobile application, enabling pet owners to take quick action when searching for their pets and preventing pets from getting lost.

2.2 RFID

RFID microchips are encoded according to international animal coding rules and are unique. It serves as the "electronic ID card" of the pet dog for its entire life. The microchip ID number corresponds to the electronic information registered for the pet dog, including the dog's basic information, the dog owner’s information, epidemic prevention information, pedigree information, daily feeding and management, etc. A special chip reader can read this ID number, and the encoded information in the ID can also be read from a distance of 1 meter. The collaborative management between the microchip and the background database realizes the informatization of pet management and enables traceability and dynamic management. It is an important technology for the modern management of pet dogs in the new era [3].

2.3 Bluetooth Positioning and WIFI

For Bluetooth positioning, the realization of localized positioning usually relies on the measurement and analysis of a series of radio frequency signals. For example, it captures the Received Signal Strength (RSS) of the WiFi network and then combines these signal data with the pre-constructed signal fingerprint spatial distribution map to complete the positioning process. However, with the gradual popularization of 4G LTE telecom small base stations in practical scenarios, a new positioning technology is ushering in a development opportunity: although hardware characteristics limit small base stations and have a relatively limited coverage range, they can output richer and more accurate signal strength information, such as Reference Signal Received Power (RSRP), by virtue of their technical advantages. This provides key data support for the improvement of positioning accuracy and the optimization of positioning technology and also lays a more solid foundation for the implementation of new positioning solutions [4].

Wi-Fi positioning technology is mainly divided into two types: the ranging method, which uses multi-sensor measurement of the strength difference between signal transmission and reception to obtain position coordinates; and the technique that first acquires spatial position data through data collection to form a location fingerprint database and then uses an analysis algorithm to parse the data when read by a mobile device to obtain the location information required by the user [5, 6]. Wi-Fi positioning technology is mainly suitable for indoor environments and can provide accurate pet location tracking in homes or commercial places.

2.4 STM32 Microcontroller

Based on the STM32 platform, a fully functional pet health monitoring and positioning system is developed. The system needs to include functional modules such as temperature detection, heart rate detection, positioning, communication, alarm, power detection, and WiFi. The temperature detection module is used to detect the pet's body temperature; the heart rate detection module is used to detect the pet's heart rate and blood oxygen; the positioning module uses GPS positioning technology to locate the pet's position and update the longitude and latitude; The communication module sends data information such as the pet's body temperature, blood oxygen, heart rate, and positioning to the mobile phone terminal, and the mobile phone can be used to set thresholds and input relevant information. The power detection module detects the battery power in the device and will remind the user when the power is too low; the alarm module will make the buzzer sound an alarm when the heart rate, blood oxygen, temperature, or power is lower or higher than the set thresholds [7].

For the pet health monitoring and positioning system developed based on the STM32 platform, the integration and implementation of its functional modules can be achieved by relying on the product form of the "Smart Collar," which is lightweight and highly adaptable. For example, the smart collar is a universal pet tracker, featuring a compact design and extreme comfort, suitable for various pets to wear. It adopts GPS technology for positioning, enabling users to track the pet's location in real time through a smartphone application. This application can set device parameters and allow users to view the pet's location map and travel history. The device mainly transmits data through the Long-Range Wide-Area Network (LoRaWAN), which has extremely low power consumption and can be used continuously for several days at a single charge. In addition, the smart collar does not charge a monthly service fee, providing pet owners with a simple and convenient way to ensure they never lose their beloved pets [9].

3. Application of Pet Locators

3.1 Real-time location and tracking for family pet management

Pet trackers have various application scenarios, covering multiple aspects such as real-time location tracking, geofencing setup, health monitoring, social collaboration, and travel and outdoor activities. These functions not only enhance the safety of pets but also provide pet owners with a more convenient management method. Based on GPS positioning, a high-sensitivity GPS receiver operates autonomously and uses enhanced signal processing hardware and special algorithms for satellite code phase data collection and propagation of error corrections forward in time. Enhanced sensitivity receivers make measurements in signal conditions where conventional sensitivity receivers falter [8].

Pet trackers can also play an important role in travel or outdoor activities. Many pet owners equip their pets with trackers when engaging in activities such as camping and hiking to ensure their safety.

3.2 Pet Health Monitoring

With the research and development of pet trackers with increasingly comprehensive performance, the latest pet trackers can now provide pet health monitoring functions. In existing studies, testing of some updated functions has begun. This design project consists of two parts: an Android mobile application and a vest for dogs to wear. The vest integrates a microcontroller (NodeMCU), a Wi-Fi module, GPS, GSM, a Bluetooth module, and sensors. All components are connected via the microcontroller, which is responsible for data collection and storing the data in a database server. The Android mobile application will use the sensors and Google Maps to obtain the dog's vital signs and location information and display all data on the smartphone screen. Another function of this application is that the owner can create a circular geofence at a specific location; if the dog enters or exits this area, the system will notify the owner in a timely manner. In addition, the vest is also equipped with an alarm system—once the lock is removed, the sensor combined with GSM will automatically send a text message to the pet owner. To help the owner monitor the dog's health status,

the application provides a dedicated list of medical records that can store data files from daily to annual records, which will greatly assist veterinarians in conducting physical examinations for the dog [10]. With the continuous advancement of technology, future pet trackers are highly likely to integrate more intelligent functions and will further improve the efficiency and convenience of pet safety management.

4. Limitations

Although many modern pet trackers use low-power technology, battery life remains an issue when features like GPS are used frequently. Users need to charge the device often, which can be inconvenient. For active pets, frequent charging can negatively impact the user experience, especially during long trips or outdoor activities—running out of battery may cause the GPS to stop working.

Regarding positioning services, there are signal coverage limitations and environmental dependencies. GPS signals can be interfered with indoors or in enclosed spaces, such as basements and high-rise buildings, which can lead to inaccurate positioning or failure. Additionally, Bluetooth and Wi-Fi trackers are limited by their signal range and cannot operate in areas without signals. Severe signal interference may also occur, especially in environments with strong interference, like crowded places, affecting the tracker's accuracy and making it difficult for users to find their pets quickly.

5. Future Directions

5.1 Improve battery life

For pet trackers, the most important issues are battery life and power. To extend their service life, improvements to the battery are necessary, and a combination of methods should be used to significantly enhance battery life. The reliability and cost of energy storage systems are two crucial parameters in uninterruptible power supplies (UPS) and other battery applications. Therefore, extending battery life and predicting battery failures are two core features of a Battery Management System (BMS). In addition, the BMS can also integrate some other useful functions. For advanced batteries, specific functions such as thermal management (for high-temperature batteries) or safety management (for lithium batteries) are particularly required. Therefore, the BMS must be optimized for the battery type and application. In small-scale systems, the BMS is closely integrated with the battery and may even be built into the battery itself; the system cannot operate normally without the BMS [11]. Optimization combined with the latest BMS can enable pet trackers to have longer battery life and longer service lives, making consumers more inclined to purchase such durable devices.

5.2 Enhance Signal Coverage

Location positioning is a key feature of pet trackers. To ensure accurate and real-time location updates, integrating globally used positioning systems is essential. When these systems are effectively utilized, signal coverage improves. The Global Positioning System (GPS) and the Bei Dou Navigation Satellite System (BDS) are currently popular satellite navigation systems known for their high precision, each offering unique advantages. Combining these two systems can enhance both the accuracy and stability of positioning. First, higher positioning accuracy increases the number of satellites that can be observed, optimizes the receiver's observation geometry, and reduces errors caused by signal blockage and reflection. Second, stronger signal coverage the overlap in satellite coverage from both systems ensures better signal reception, especially in challenging environments like canyons and jungles. Third, improved system reliability if one system fails or experiences unstable signals, the other can be activated immediately to maintain positioning services [12]. Integrating these systems can significantly enhance the performance of pet trackers. It will enable more precise, real-time tracking of pets' movements and locations. This allows pet owners to quickly find their pets and prevent them from getting lost [13].

5.3 AI-based Innovations

The combination of artificial intelligence (AI) and machine learning will enable pet trackers to possess stronger intelligent analysis capabilities. By analyzing pets' activity data, AI can identify pets' behavioral patterns and provide personalized health management suggestions. This kind of intelligent analysis not only improves the efficiency of pet health management but also helps owners detect potential health problems promptly, thereby taking necessary measures.

Big data analysis will provide support for the expansion of the function of pet trackers. Manufacturers can identify trends in pet health and behavior by collecting and analyzing a large amount of pet data, thereby providing users with more scientific care suggestions. The introduction of artificial intelligence (AI) technology will enable pet trackers to analyze pets' behavioral patterns and provide personalized health management suggestions. For instance, by analyzing pets' activity data, AI can identify abnormal behaviors and notify owners in a timely manner, helping owners better monitor their pets' health conditions and seek medical treatment promptly to avoid irreversible losses.

6. Conclusion

When studying the development, application, and improvement of pet trackers, it is obvious to us that this field is in a stage of rapid growth. Continuous technological progress and increasing market demand make the future of pet trackers full of possibilities. From the perspective of the product itself, today's pet trackers are no longer the simple tracking tools they were in the early days. They integrate multiple technologies such as GPS, Bluetooth, and Wi-Fi, evolving into highly intelligent devices. They can track pets' locations in real time, monitor health conditions, and set up geofences. These functions enhance the trackers' accuracy and make them more user-friendly for owners. In terms of market demand, as more and more people keep pets, owners pay greater attention to their pets' safety and health, which naturally gives the pet tracker market strong growth potential. In addition, the integration of artificial intelligence and big data technologies will lay the foundation for intelligent upgrading of trackers, making pet health management more efficient and providing owners with more thoughtful personalized services.

Future research shall focus on user needs, technological innovation, and health management, can promote the continuous development of this industry. It is believed that through in-depth research and innovation, pet trackers can better serve pets and their owners, making pets' lives safer and of higher quality. With the continuous advancement of technology, future pet trackers may integrate more intelligent functions, further improving the efficiency and convenience of pet safety management.

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