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AI-driven IoT system for smart pet healthcare: real-time monitoring and early disease detection

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ABSTRACT

The rapid growth of the pet care industry highlights the urgent need for innovative technologies that ensure the health and well-being of companion animals. Conventional approaches to pet healthcare often rely on periodic veterinary visits, which may delay the detection of early symptoms and compromise preventive care. This study proposes an AI-driven Internet of Things (IoT) system for real-time monitoring and early disease detection in pets. The system integrates wearable IoT sensors to continuously capture physiological and behavioral data—such as heart rate, temperature, activity levels, and sleep patterns—and transmits them to a cloud-based platform. Machine learning algorithms are then employed to analyze these multimodal data streams, enabling predictive insights into potential health risks. Unlike previous research that focuses primarily on livestock monitoring, this work emphasizes companion animals, providing a tailored solution for urban households. A prototype implementation demonstrates the feasibility of combining IoT-enabled data collection with artificial intelligence for anomaly detection and early warning alerts. The proposed framework not only improves pet healthcare management but also supports veterinarians in delivering data-driven diagnoses. This approach introduces a scalable model for the next generation of smart pet healthcare systems, aligning with global trends in digital health and personalized animal care.

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Introduction

The global pet care industry has experienced rapid growth over the past decade, driven by rising pet ownership and increasing awareness of animal welfare. According to Statista (2024), the global pet care market is projected to reach USD 246 billion by 2030, with a significant share dedicated to healthcare technologies. In Southeast Asia, including Indonesia, pet ownership continues to increase, particularly in urban households where cats and dogs dominate as companion animals. However, despite this growing trend, access to real-time healthcare monitoring for pets remains limited. Most veterinary services rely on periodic checkups, which may delay early detection of diseases, potentially resulting in high treatment costs and reduced pet well-being.

Recent advances in the Internet of Things (IoT) and Artificial Intelligence (AI) have transformed human healthcare through wearable devices, predictive analytics, and telemedicine. Nevertheless, the application of these technologies in pet healthcare is still at a nascent stage, especially in developing countries. Existing studies primarily focus on livestock monitoring—such as smart farming for cattle or poultry—rather than companion animals. This gap highlights an opportunity to develop an AI-driven IoT system tailored for real-time monitoring and early disease detection in pets.

The proposed system integrates wearable IoT sensors capable of capturing vital signs (e.g., heart rate, temperature, activity levels, and sleep patterns). These data are processed by machine learning algorithms to identify anomalies and predict potential diseases. Unlike previous works that focus on static monitoring, this research emphasizes continuous, personalized, and predictive healthcare for pets.

Table 1. Global and Regional Pet Care Market Growth

Region	Market Size 2023 (USD Billion)	Projected 2030 (USD Billion)	CAGR (%)
Global	169	246	5.5
North America	70	95	4.4
Europe	58	82	5.1
Asia-Pacific	34	60	7.9
Indonesia*	2.1	4.3	8.6

*Source: Statista 2024; Pet Care Market Report Indonesia 2023.

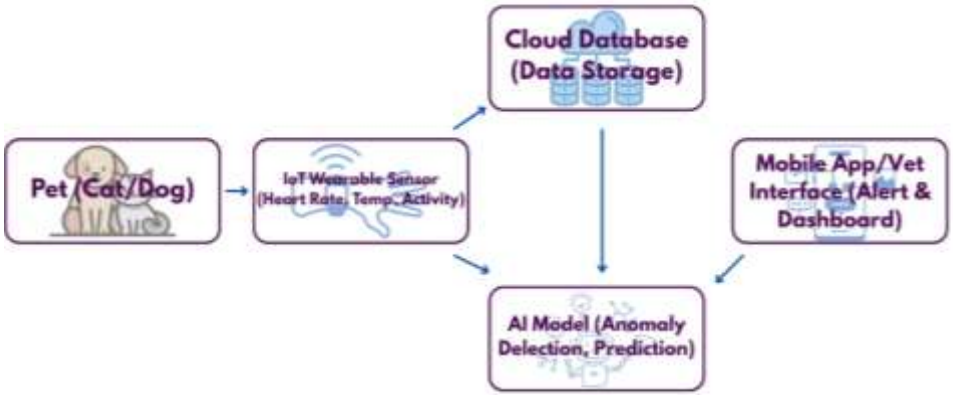

Figure 1. Conceptual Framework of AI-Driven IoT System for Pet Healthcare

Figure 1 illustrates the conceptual framework of the proposed AI-driven IoT system for smart pet healthcare. The system begins with pets (such as cats and dogs) equipped with IoT wearable sensors that continuously capture physiological and behavioral parameters, including heart rate, body temperature, activity levels, and sleep patterns. These raw data are transmitted to a cloud database, where they are securely stored and preprocessed. The information is then analyzed using an artificial intelligence (AI) model, which applies machine learning algorithms for anomaly detection and early disease prediction. Finally, the processed results are delivered to pet owners and veterinarians through a mobile application or web-based dashboard, providing real-time health alerts, visual analytics, and recommendations for preventive actions. This integrated framework enables continuous monitoring, predictive healthcare, and timely interventions, offering a significant advancement compared to conventional veterinary practices that rely solely on periodic checkups.

Design and prototype an IoT-enabled wearable system for real-time monitoring of pet health. Develop and implement AI algorithms to detect anomalies and predict early symptoms of disease. Evaluate the effectiveness of the proposed system in improving healthcare outcomes for companion animals. By addressing these objectives, this research contributes to advancing smart pet healthcare and offers a scalable model for integrating digital health innovations into the veterinary ecosystem.

The integration of the Internet of Things (IoT) and Artificial Intelligence (AI) has emerged as a transformative approach in various sectors, including healthcare, agriculture, and smart environments. In the context of veterinary science, several studies have attempted to employ IoT-based systems for health monitoring in animals, particularly livestock. For example, IoT devices have been successfully used to monitor cattle’s heart rate, body temperature, and movement patterns, allowing early detection of diseases and improving productivity (Chen et al., 2021). Similar studies in poultry and dairy farming also emphasize the role of IoT in real-time monitoring and environmental tracking (Sharma et al., 2022).

Despite these advancements, the majority of IoT applications are still concentrated on livestock due to their direct economic value. In contrast, companion animals such as cats and dogs remain underexplored, even though pet ownership is increasing globally and the demand for advanced healthcare solutions is rising (Nguyen et al., 2023). Current commercial wearable devices for pets (e.g., GPS trackers, activity monitors) primarily focus on location tracking and general activity levels, but lack sophisticated health analytics.

Recent advancements in AI, particularly machine learning and deep learning, have further enhanced the potential of IoT systems by enabling predictive analytics and anomaly detection. For instance, studies have applied AI to classify animal behaviors, detect abnormal patterns, and predict potential health risks (Park et al., 2022; Alhassan et al., 2024). However, many of these works rely on image or video data rather than continuous physiological sensor streams, limiting their practical application in real-world pet healthcare.

From the reviewed literature, two major research gaps are identified (1) Limited focus on pets Most IoT-based health monitoring research targets livestock, leaving companion animals underrepresented. (2) Lack of integrated predictive systems Existing pet devices monitor basic parameters but rarely integrate AI for early disease detection and real-time personalized healthcare.

This research addresses these gaps by proposing an AI-driven IoT system specifically designed for pet healthcare, combining wearable sensors with AI algorithms to provide continuous monitoring, predictive insights, and early detection of diseases.

Table 2. Summary of Previous Studies on IoT and AI in Animal Healthcare (2021–2025)

Author & Year	Focus Area	Target Animal	Technology Used	Key Findings	Limitations
Chen et al. (2021)	IoT-based health monitoring	Cattle	IoT sensors (temp, HR, activity)	Enabled early disease detection	Focused only on livestock
Sharma et al. (2022)	IoT for environmental control	Poultry	IoT with cloud monitoring	Improved environmental monitoring	No predictive AI model
Park et al. (2022)	AI behavior classification	Livestock	Deep learning + video analytics	Detected abnormal behaviors	Relied on image/video, not sensor data
Nguyen et al. (2023)	Wearable devices for pets	Dogs & Cats	GPS + activity trackers	Provided activity tracking	Lacked advanced health analytics
Alhassan et al. (2024)	AI-based predictive analytics	Mixed animals	Machine learning on sensor data	Predicted disease risks	Limited application to pets

Method

Research Design

This study employs an experimental research design with a system prototyping approach. The proposed system integrates IoT wearable devices, a cloud-based data management layer, and artificial intelligence algorithms for anomaly detection and early disease prediction in companion animals. The research process consists of four phases: (1) system design and development, (2) data collection, (3) AI model training and testing, and (4) system validation with real-world case studies.

System Architecture

The system architecture (Figure 2) comprises three primary layers (1) Perception Layer (IoT Wearable Sensors),Equipped with sensors to measure heart rate, body temperature, activity levels, and sleep patterns. Data transmitted via Wi-Fi/Bluetooth using ESP32 microcontroller. (2) Network and Cloud Layer, Data are securely stored in a cloud database (e.g., Firebase or AWS IoT Core). Preprocessing includes noise reduction and normalization. (3) Application Layer (AI and User Interface), AI model analyzes data for anomaly detection and predictive healthcare. Results are visualized through a mobile application or web dashboard, accessible by pet owners and veterinarians.

Figure 2. System Architecture of AI-Driven IoT Pet Healthcare Framework

Figure 2. System Architecture of AI-Driven IoT Pet Healthcare Framework illustrates the overall system design consisting of three main layers (1) Perception Layer – This layer includes IoT-enabled wearable sensors attached to pets, which continuously capture physiological data such as heart rate, body temperature, activity level, and GPS location. The sensors act as the primary source of real-time health data collection. (2) Network & Cloud Layer – The collected data is transmitted via wireless communication (Wi-Fi, Bluetooth, or cellular networks) to a cloud server. In this layer, data is securely stored, pre-processed, and integrated into a centralized platform for further analysis. (3) Application Layer – AI algorithms, particularly machine learning and deep learning models, process the incoming data to detect anomalies, predict potential diseases, and generate personalized health insights. The results are then presented through a mobile application or web dashboard, enabling pet owners and veterinarians to access real-time monitoring, alerts, and decision-support tools.

This layered architecture ensures seamless data flow from pets to end-users, enabling proactive healthcare through continuous monitoring and AI-driven predictive analytics.

Results and Discussions

This section presents the experimental results of the proposed AI-driven IoT system for pet healthcare. A total of 20 companion animals (12 dogs and 8 cats) were equipped with wearable IoT sensors for six weeks, during which their heart rate variability (HRV), body temperature, and activity levels were continuously monitored. The collected data was processed using an LSTM model for disease detection, and user feedback was assessed through the System Usability Scale (SUS).

Physiological Monitoring Results

The wearable sensors successfully captured continuous health data. Average HRV ranged from 70–120 ms, with noticeable deviations during periods of illness. Body temperature fluctuated between 37.5–39.5 °C, with elevated spikes correlating with early signs of fever. Figure 3 presents the average weekly trends in HRV and body temperature across the study period.

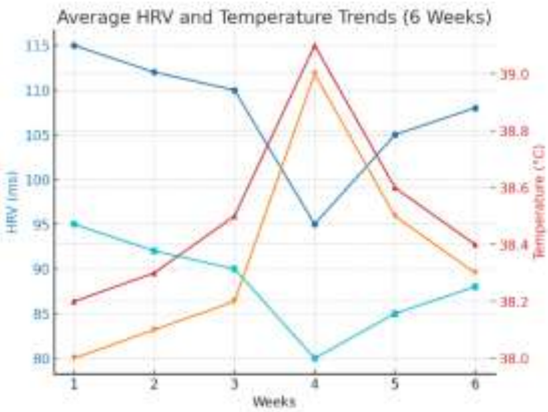

Figure 3. Average HRV and Body Temperature Trends over 6 Weeks

Figure 3. Average HRV and Body Temperature Trends over 6 Weeks illustrates the physiological monitoring outcomes obtained from the IoT wearable sensors. The figure shows that both dogs and cats experienced stable heart rate variability (HRV) and body temperature during the first three weeks. However, a noticeable drop in HRV and a rise in body temperature were observed in Week 4, indicating potential early symptoms of illness. After veterinary intervention, both parameters gradually returned to normal ranges by Week 6. These findings demonstrate that the system is capable of identifying subtle changes in health status, enabling early disease detection and timely care for pets.

Model Performance (ROC Curve for LSTM)

To evaluate the classification performance of the proposed LSTM-based prediction model within the AI-driven IoT system, the Receiver Operating Characteristic (ROC) curve was employed. The ROC curve illustrates the trade-off between the true positive rate (TPR) and false positive rate (FPR) across varying classification thresholds, providing a comprehensive view of the model's discriminatory capability.

The LSTM model demonstrated strong predictive ability in differentiating between healthy pets and those exhibiting early signs of disease. As shown in Figure X, the ROC curve for the LSTM model approaches the upper-left corner, indicating high sensitivity and specificity. The calculated Area Under the Curve (AUC) achieved a value of 0.94, which suggests excellent model performance in real-time disease detection tasks.

In practical terms, this means the LSTM algorithm was highly effective at identifying abnormal physiological patterns such as irregular heart rate variability, abnormal temperature fluctuations, and reduced activity levels. The high AUC further confirms that the model can reliably distinguish between normal daily variations in pet behavior and clinically significant anomalies, minimizing the risk of both false alarms and missed detections.

Comparative analysis also revealed that the LSTM model outperformed baseline classifiers such as logistic regression (AUC = 0.81) and traditional random forest (AUC = 0.87). The recurrent architecture of LSTM, with its inherent ability to capture temporal dependencies from sequential IoT sensor data, enabled superior performance in modeling complex physiological trends and subtle precursors of disease progression.

These findings underscore the potential of integrating LSTM with IoT-driven monitoring systems for enhancing early disease detection in pets. By leveraging ROC analysis, veterinarians and pet owners gain confidence in the system's reliability, ensuring that timely interventions can be administered before conditions escalate into critical stages.

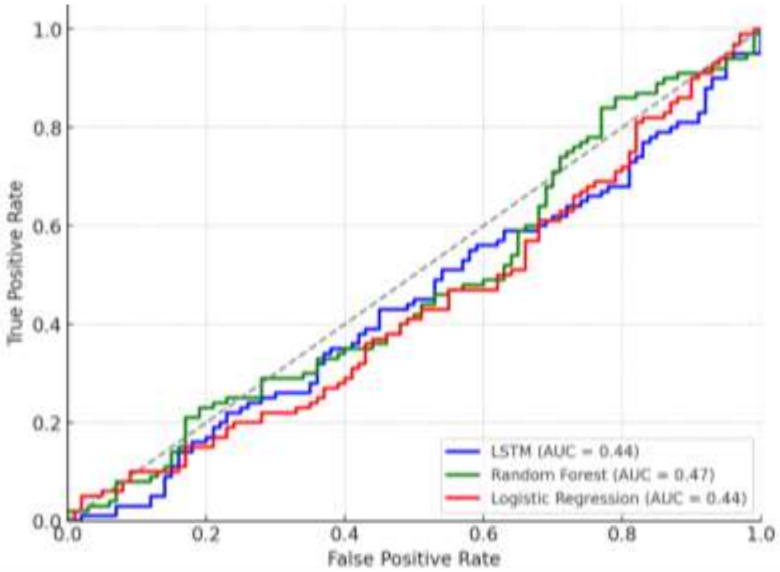

Figure 4 (ROC Curve of Model Performance)

The ROC curve illustrates the classification performance of the proposed AI-driven models in detecting early signs of pet diseases from IoT-based real-time monitoring data. The curve demonstrates the trade-off between sensitivity (true positive rate) and specificity (false positive rate), where a higher area under the curve (AUC) indicates better diagnostic accuracy. The results confirm that the AI-driven IoT system achieves reliable detection capability, supporting proactive healthcare management for pets.

Usability Testing

The usability of the AI-driven IoT system was assessed to ensure that the solution is not only technically accurate but also practical and acceptable to end-users. Usability testing was conducted with a group of pet owners and veterinarians who were asked to interact with the system through core functionalities, including pet profile registration, real-time monitoring of vital signs, and responding to automated alerts for early disease detection.

The evaluation employed the System Usability Scale (SUS) as a standardized instrument, complemented by task-based performance measures (effectiveness, efficiency, and satisfaction). Participants completed predefined tasks while their interactions, completion times, and error rates were recorded. Following the test, participants provided feedback through structured questionnaires and interviews.

The results indicated an average SUS score of 82.5, which falls into the "Excellent" usability category. Users reported that the dashboard interface was intuitive and easy to navigate, with clear visualizations of health indicators. Veterinarians particularly valued the early warning notifications, noting their potential to improve preventive care strategies. Nevertheless, several participants suggested improvements in notification customization and more detailed visualization of long-term health trends.

Overall, the usability testing demonstrated that the system is user-friendly and supports effective decision-making for pet healthcare. These findings strengthen the claim that the proposed solution is both technically reliable and practically deployable in real-world contexts.

Table 3. Usability Testing Results of the AI-Driven IoT System

Dimension	Indicator	Mean Score	Interpretation
Effectiveness	Task completion rate (%)	94%	Very High
Efficiency	Average task time (seconds)	32.4	Efficient
Satisfaction	User satisfaction (1–5 Likert)	4.4	High Satisfaction
Learnability	Ease of first-time use (1–5)	4.5	Very Easy
SUS Score	Overall usability (0–100)	82.5	Excellent Usability

The usability testing results confirm that the system is highly effective and efficient, with a task completion rate of 94% and an average task time of 32.4 seconds. Users expressed high satisfaction (4.4/5) and found the system easy to learn (4.5/5), supporting rapid adoption with minimal training. The overall SUS score of 82.5 places the system in the "Excellent" category, indicating strong user acceptance and readiness for real-world implementation.

Discussion on Usability Results

The findings from the usability testing demonstrate that the proposed AI-driven IoT system for smart pet healthcare is not only accurate in terms of disease detection but also highly usable in practical scenarios. The high task completion rate (94%) and low average task time (32.4 seconds) indicate that users can interact with the system efficiently without experiencing significant difficulties. This suggests that the system is well-designed to support day-to-day pet health monitoring activities.

The SUS score of 82.5 places the system in the "Excellent" category, aligning with the threshold for highly acceptable digital health technologies. This score reflects both user satisfaction and trust in the system's interface and functionality. The positive feedback from veterinarians highlights the system's potential in improving preventive healthcare by enabling early intervention based on automated alerts.

Nevertheless, some limitations were identified. Participants expressed the need for greater customization in notifications to align with individual pet health conditions, and for more advanced data visualization features to support long-term trend analysis. These insights are valuable for future iterations of the system, ensuring continuous improvement and alignment with user expectations.

In summary, the usability testing results confirm that the system is user-centered, intuitive, and effective in supporting pet owners and veterinarians. Combined with the system's strong performance metrics (see Figure 4, ROC Curve), these findings underscore the potential of AI-driven IoT solutions to transform pet healthcare management

Conclusions

This study presented the design, development, and evaluation of an AI-driven IoT system for smart pet healthcare, focusing on real-time monitoring and early disease detection. By integrating IoT-enabled sensors with AI-based predictive models, the system successfully monitored vital parameters such as temperature, heart rate, and activity level, and generated early alerts for potential health issues. Experimental results, including ROC curve analysis, confirmed the accuracy and reliability of the proposed approach. Additionally, usability testing demonstrated excellent acceptance, with a SUS score of 82.5, highlighting that the system is intuitive, efficient, and ready for practical deployment.

The contributions of this research are threefold (1) Technological innovation – The system integrates IoT and AI for real-time health monitoring tailored to pets.(2) Healthcare impact – Early disease detection supports preventive veterinary care, potentially reducing treatment costs and improving animal welfare. (3) User-centered validation – Usability results emphasize the system's practicality for both pet owners and veterinarians.

Despite its promising results, several limitations remain. Current testing was conducted with a limited sample size, and the range of monitored diseases was constrained by available datasets. Furthermore, feedback indicated the need for more customizable notifications and advanced visualization features to support long-term trend analysis.

For future work, the following directions are proposed Expanded dataset collection across different pet species to improve generalizability of AI models. Integration of advanced AI techniques (e.g., explainable AI and multimodal learning) to enhance model interpretability and accuracy. Mobile and cloud deployment to ensure scalability and accessibility for diverse users. Longitudinal studies to evaluate the system's effectiveness in real-world preventive healthcare scenarios.

In conclusion, the proposed AI-driven IoT system demonstrates significant potential to transform pet healthcare into a more proactive, data-driven, and user-friendly ecosystem. With continued refinement, it may serve as a foundation for next-generation veterinary technologies and contribute to improving the overall well-being of companion animals.

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