Smart Pet Care System

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doi.org/10.64643/IJIRTV12I12-206846-459

***Abstract*—The rising need for intelligent, automated, and constant monitoring systems for pets has accelerated the concept and development of IoT wearable technologies. The conventional method for taking care of pets involves observation, regular medical check-ups, and unautomated supervision, leading to a lack of understanding and safety with regard to outside activities. This gap continues to result in delayed medical diagnosis and a greater possibility of pets getting lost and exposed to life- threatening environments. To eliminate these difficulties, we propose a comprehensive Smart Pet Care System incorporating multi-sensor health observation, real-time global positioning, cloud analysis, and online visualization with low-cost wearable technology. The Smart Pet Care System uses an ESP32 microcontroller as a central processing engine, which will be coupled with an MLX90614 infrared temperature sensor, an MX30100 pulse ox sensor, and a NEO-6M GPS engine to constantly acquire vital physiological signals, including body temperature, heart rate, and SpO2, and geospatial data. The extracted sensor values will be processed online and uploaded to the ThingSpeak cloud platform via Wi-Fi connections. The processed data will be saved and analyzed on the cloud and then graphically represented using online visualization tools created with HTML, CSS, JavaScript, Chart.js, and Leaflet.js. It also provides automatic alerts for unusual health readings and geofences entry/exits, thus ensuring pets receive immediate attention from their owners. The device underwent rigorous testing and showed reliable sensor readings, successful location tracking, and efficient wireless communications capable of operating continuously outside. Compared with current market technologies, it should be significantly more affordable, modular, and scalable, thus making it easier for multiple pets and animal shelters or clinics. It clearly shows how a blend of IoT, Biomedical Sensors, and Cloud Analytics will make modern pet life better and more meaningful. It can be expanded in subsequent projects with GSM-LoRa wireless links, data storage, and various intelligent predictive models.**

***Index Terms*—Smart pet care, IoT wearable, ESP32, health monitoring, GPS tracking, cloud analytics, ThingSpeak.**

I. INTRODUCTION

They Pets are increasingly viewed as part of the modern family and, thus, their health, safety, and quality of life. Animals cannot express feelings of pain, discomfort, or even early stages of illness like humans do; therefore, continuous monitoring will permit timely interventions. Traditional care practices for pets involve much manual observation and periodic visits to a veterinarian based on a schedule, The proposed system continuously monitors body temperature, heart rate, and oxygen saturation through non-invasive sensors and concurrently tracks the location of the pet through GPS. Continuous wireless data transmission to a cloud platform enables visualization and further analysis to support real-time alerts for abnormal health conditions and geofence violations. Affordable, easy-to-use, and comprehensive monitoring capability-the proposed system puts forth an integrating approach toward ensuring more safety for pets, supporting early disease diagnosis, and protecting the psyche of the pet owners with intelligent, technology-driven care.

II. LITERATURE REVIEW

Recent Current literature on animal monitoring through the Internet of Things reveals considerable progress made in areas such as health measurements, tracking, and cloud services; however, solutions cover only these areas but not in a comprehensive approach. A number of investigators have also considered wearable collars that incorporate biomedical sensors for health tracking of livestock. Temperature and heart rate biosensors can effectively track health cues of an impending illness, heat stroke, dehydration, or infection. These studies confirm that vital signs play an imperative role in modeling health decline.

Most studies recommend non- invasive health tracking for pet ease, though accuracy of data should be maintained despite variations in environments. The use of tracking systems based on GPS has recently emerged as a popular technique for tracking wild animals, cattle, and domestic pets. Research has indicated that low-cost GPS modules with microcontrollers are quite efficient for geofencing and location information for safety alerts, but most tracking systems are not cloud-enabled for real-time analytics and visualizing information. IoT-based frameworks, including microcontrollers such as ESP32 and Arduino, have demonstrated considerable power in uninterrupted monitoring with the availability of wireless connectivity and multi-sensor interfaces.

The need for low power consumption, wide-range communication, and a modular structure in the design is emphasized in the research. In spite of this progress made, current systems often tend to have shortcomings like being cost-prohibitive, fragmented functionality, poor cloud analytics capabilities, and a lack of combined health and geographical tracking. offering only intermittent glimpses into an animal's physiological status Consequently, sudden development of abnormal vital signs, such as high body temperature, irregular heartbeat, or low oxygen saturation, may remain unnoticed until the condition becomes severe. The absence of continuous health and activity monitoring presents serious risks, especially to older pets or pets with chronic health conditions. Another major challenge faced by pet owners, besides health-related issues, is safety. Pets get lost from home, run away from their enclosures, or enter unauthorized and dangerous environments like busy roads and unknown areas. Without an effective real-time tracking mechanism, locating a lost pet may be challenging and distressing. Despite this challenge, various GPS-based collars are commercially available. However, many of them suffer from one or more shortcomings, including high costs, low accuracy, subscription-based services, or lack of integrated health monitoring features. Most existing solutions focus either on location tracking or basic activity monitoring, failing to provide a comprehensive view of a pet’s health and safety status. Recent developments in IoT, embedded systems, cloud computing, and wearable sensor technologies have provided new avenues for intelligent solutions in pet care. IoT-enabled wearables can perform continuous data acquisition from multiple sensors and send data seamlessly to the cloud platforms for real-time monitoring and analysis. In addition, with the availability of low-power microcontrollers like the ESP32; compact-sized biomedical sensors; and GPS modules, the development of low-cost portable and scalable monitoring systems for pets is now possible. Further, cloud-based dashboards facilitate easy access via web and mobile interfaces by pet owners and veterinarians to vital signs, location data, and long-term trends remotely. The proposed system integrates real-time health monitoring and GPS-based location tracking in one wearable collar motivated by these developments in technology and existing gaps in pet care solutions.

III. PROBLEM STATEMENT

Currently, effective monitoring of health largely relies on manual observation and less frequent visits to the veterinarian, which is generally quite inadequate for the detection of early physiological changes. Vital parameters like body temperature, heart rate, and oxygen saturation can change rapidly due to illness, stress, dehydration, or injury. Since pets cannot communicate discomfort orally, these changes mostly go undetected until the symptoms worsen. The delays in the detection of these conditions increase the risks of complications, which may result in higher costs or life- threatening situations. Another major challenge posed to the owners of the pets is to make sure about the safety and location awareness of their pets. Sometimes, pets wander away from familiar environments and may get lost or enter hazardous areas. This can be tracked only in real time by the owner. With existing GPS-based solutions, there has been evidence of lack in geofencing, timeliness in alerts, or reliability in connectivity, altogether reducing their effectiveness in emergency situations.

IV. EXISTING SYSTEM

The current pet care solutions work to a large extent depending upon human observation and occasional checks by a veterinarian for its health conditions. These solutions give little information regarding the day-by-day health of the pet and do not allow abnormalities to be noticed earlier. Thus, diseases are normally pinpointed when symptoms start to be noticeable. There exist a number of commercial pet tracking devices that provide GPS position tracking. However, most of the existing devices have been known to have a number of drawbacks that include poor position accuracy and the use of cellular subscriptions.

Moreover, most GPS collars for health monitoring purposes do not contain position monitoring functionalities Some of the advanced wearable collars come with basic activity tracking features like steps taken or activity patterns. However, they do not monitor important health aspects that include temperature, heart rate, and oxygen level. The advanced wearable collars that come equipped with health monitoring features tend to be very costly. Additionally, another weakness of current technologies in this area of study is that they lack real-time integration into cloud services. Many of these devices also lack data visualization, making it difficult for analysis to be performed. Another challenge of these technologies is that they lack durability or batteries that can last for sufficiently long periods, even when they are meant to be used outside. Many In a nutshell, pet care needs are currently being met by solutions and plans that are un-integrated, unaffordable, non- scalable, or lack real-time intelligence.

Though there are some systems that deliver data, they lack the capability to provide interpretations in the form of dashboards, graphs, or geofence notifications. Without the real- time alerts provided by the system regarding the unusual health issues or improper movements, the pet owner would not be able to take immediate actions regarding the crises. This reveals the fact that there is a lack of a comprehensive and affordable solution that can monitor pet health and location.

V. PROPOSED SYSTEM

The proposed Smart Pet Care System is an IoT-capable wearable device that seeks to offer constant monitoring of pet health and location in real time. The Smart Pet Care System is realized as a miniaturized smart collar that contains an ESP32 microcontroller, which supports biomedical and location sensing for acquiring pet vital information. The microcontroller is coupled with an MLX90614 IR temperature sensor for tracking the body temperature of the pet and a MAX30100 pulse oximeter for detecting the pet's heart rate and SpO2 values. Furthermore, the pet's location is also tracked via a NEO-6M GPS module to offer accurate pet location tracking information in real time.

The ESP32 microcontroller supports the processing of acquired information and its transmission to a cloud system for constant monitoring without human interaction using its integrated Wi-Fi module. Commercial pet monitoring systems currently available in the market have failed to provide an integrated solution for health and safety together. While most products focus on activity tracking or location monitoring, advanced systems that include health sensing are expensive, with recurring subscription fees. These limitations restrict accessibility and prevent widespread adoption. Most of the existing solutions also lack cloud storage and long-term analytics of data, thus making it tough to analyze trends or even share them with a veterinarian. There is an urgent need for an efficient, reliable, and integrated smart pet care device that continuously monitors health parameters, locates in real time, and provides instant alerts to the owners of the pets.

The solution to this problem can massively help in keeping pets safe, aid in the timely diagnosis of diseases, and upgrade the general quality of pet care. Proprietary systems restrict hardware expansion and the integration with open-source platforms that limit innovation and make it difficult to adapt. Therefore, there is an urgent need for an integrated, low-cost, and reliable Smart Pet Care System that can monitor vital health parameters and real-time location continuously, provide instant alerts in case of abnormal conditions, and allow remote accessibility with cloud-based visualization. Meeting these challenges will lead to great improvements in pet safety, allow for early disease detection, and modernize the conventional way of caring for pets.

VI. METHODOLOGY

The design of the Smart Pet Care System adopts a systematic and modular approach for effective real-time tracking of the health and location of the pet. The design starts with the selection of the most appropriate hardware components, which should have the ability for continuous sensing, low power consumption, and wireless communication capabilities. An ESP32 microcontroller is selected as the central processing unit based on the microcontroller's dual-core architecture, Wi-Fi module, and application suitability for IoT-based wearable technology.

The biomedical sensors MLX90614 infrared temperature sensor and MAX30100 pulse oximeter are utilized for non-invasive health parameters like body temperature, heart rate, and SpO2 levels, respectively. A NEO-6M GPS module is also utilized for real-time location acquisition, ensuring effective tracking of pet movement. The After choosing the hardware components, the next phase involves sensor integration and firmware creation. The ESP32 is connected to all the sensors with proper protocols such as I²C and UART. The code for the firmware is created with the Arduino IDE, where the drivers for each sensor are made to read the data at regular intervals.

This includes signal conditioning to eliminate any kind of noise in the sensor reading values. Threshold values are set for each health parameter, which allows detection of any irregularities such as fever, irregular heartbeat, or low levels of oxygen in the body instantly. By effectively integrating health, GPS tracking, cloud services, and real-time graphical display in a cost-effective, scalable system, the proposed system is able to address existing gaps in technologies available to address pet care.

A. Overall Design

The Smart Pet Care System is developed using an integrated IoT architecture, encompassing wearable sensing technology, wireless communication technology, cloud computing, and web-based graphical representation for real-time health and position tracking of the pet. The heart of this system is the compact wearable collar, designed to include an array of sensors and a GPS module, which is managed by an ESP32 microcontroller. The ESP32 microcontroller acts as the central processing unit of this system, responsible for collecting data related to the body temperature, heart rate, and SpO2 values from the MLX90614 sensor and MAX30100 sensors, as well as position-related values from the NEO-6M GPS module. The whole system comprises a layered structure called the sensing layer, communication layer, cloud layer, and application layer. In the sensing layer, the biomedical and location sensors are mounted on the pet in a non-invasive manner by being embedded in a collar to make the system convenient and practical for prolonged periods of time. In the communication layer, Wi-Fi connectivity in the ESP32 is used to regularly send data from the sensors to the ThingSpeak cloud platform for processing and further actions. Data handling processes are implemented to make the transmission of data secure and consistent.

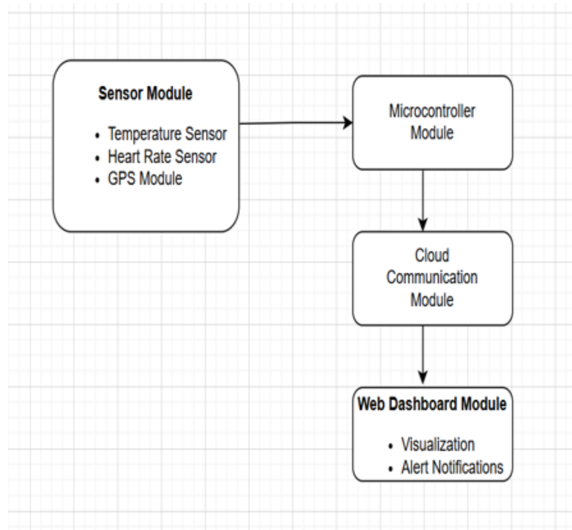

Fig. 1. Module Design

The Smart Pet Care System has been broken down into distinct functional modules to make the system clear, maintainable, and scalable. The modules have specific functionalities that work together effortlessly. The Health Monitoring Module is tasked with acquiring physiological data through the use of the MLX90614 temperature sensor and MAX30100 Pulse Oximeter. This module provides accurate, uninterrupted data and also involves threshold tests for any irregularities. Cloud communication and management of the data mark the third stage of the process.

The resulting data from the sensors and GPS modules are sent wirelessly through Wi-Fi to the cloud IoT platform ThingSpeak. ThingSpeak is utilized for the real-time storage and analysis of the data because of the ease and compatibility that the system provides with IoT technology. Sending each parameter into the respective channel field enables the parameter's constant monitoring and analysis for trends over time. Logic for geofencing is implemented using the GPS location to determine if the pet is still within the predetermined “safe zone.” If the pet has exited the zone or any parameters are indicative of the pet’s ill health by exceeding desirable limits, alert values are attained. The last step in the methodology is the data visualization and user interface. A web-based interface is created utilizing HTML, CSS, and JavaScript. Libraries like Chart.js are used for visual representation of the health data, and Leaflet.js is used for the location mapping. The interface helps the owners as well as the veterinarian to track the condition of the pet from anywhere in the world through the internet.

B. Sensor Data Acquisition and Processing

Health parameter detection is done by continuously sensing the vital parameters using non-invasive biomedical sensors. The purpose of the MLX90614 Infrared Temperature Sensor is to measure the body temperature of the pet without having to touch the skin, which is a safe and convenient method. The MAX30100 Pulse Oximeter is used to read the values of heart rate and SpO_2, which are important indicators of health. The ESP32 receives readings from the sensors at pre-programmed time intervals and performs some basic processing, namely filtering and validation, to remove noise created by motion or variations in the environment. The threshold limits, set depending on safe physiological values, determine when the parameters go out of bounds, and consequently, when abnormalities may arise, such as those that could result in fever, stress, or a lack of oxygen.

C. GPS-Based Loaction Tracking and Geofencing

The movement of the pet is continually tracked using the NEO-6M GPS module that is employed within the pet's collar. The GPS module enables the retrieval of the real-time values of the latitude and longitude coordinates, which are then analyzed by the ESP32 to determine the movement pattern of the pet. The geofencing system is achieved by establishing a virtual boundary around the safe zone, including the pet’s house or yard. If the pet goes beyond the established zone, the system recognizes a breach of the geofence and sends a notification. This aspect of the device is highly important in ensuring the pet does not enter a danger zone, and it is also useful when the pet gets lost.

D. Cloud Communication and Data Storage

In order to achieve remote monitoring, the system sends processed sensor data and GPS data to the ThingSpeak cloud platform via the Wi-Fi module of the ESP32. Data is sent at fixed time intervals to achieve near real-time data updates. ThingSpeak allows for the storage of structured data and facilitates analysis of past sensor readings using specific channels. Past sensor readings on the cloud allow pet owners to monitor trends, detect frequent occurrences of illnesses, and inform their pet care practices accordingly. The cloud-based system allows pet owners to access pet health from any device that is internet capable.

E. Data Visualization and Alert Mechanism

An A user-friendly dashboard system using web technology is developed to display real-time and historical data in a clear manner. Health parameters like temperature, heart rate, and SpO_2 values are represented in graphical forms using Chart.js, making it easier for users to detect anomalies. The pet position is displayed using interactive maps created using the Leaflet.JS system for displaying pet positions and geofence regions for easy tracking of movements and geofence limits. The system also produces notifications when the health metrics go beyond the required limits or when geofence boundaries are crossed. This ensures the pet gets instant attention for necessary medical assistance or actions for increased safety measures.

F. System R`eliability, Power Efficiency, and Wearability

Smart Pet Care System is engineered with a greater focus on durability, power efficacy, and wearability to serve as a viable solution for real-world implementations. Given that this system is required to continuously monitor health and location information of pets, optimizing power management is a highly significant aspect of this project. These requirements are satisfied by the selection of ESP32 microcontrollers because of their significant low-power functionality and the presence of WiFi capabilities onboard, eliminating the need for extra hardware components in the system. Through firmware optimization like managing sensor sampling rates based on health conditions of pets and sleep cycle control, unnecessary hydrogen losses are further prevented in this system by periodically uploading health whenever there is deviation in health and geographical boundaries. The efficiency of power consumption is also improved by optimizing communication with the ThingSpeak cloud service. This is achieved through smaller data packets, less frequent data transmission, and optimal use of Wi-Fi connections. The biomedical sensors, which are composed of both the MLX90614 temperature sensor and MAX30100 pulse sensor, are set to run only when needed, meaning that these sensors are not placed in a constant active state. This will enable a wearable device to run for an extended period without needing to be recharged, which is important for pet wearable devices, considering that these devices cannot use large batteries that would need to fit comfort standards. The reliability of the system is ensured by testing it under various conditions. The testing is done indoor as well as outdoor to check the efficiency of the GPS functionality, sensor performance, wireless connectivity, and data syncing in the cloud. The testing of the system confirms the efficiency of the NEO-6M GPS module in location tracking in open environment, and the health sensors work well in normal movements.

VII. IMPLEMENTATION

We start the implementation of the Smart Pet Care System by assembling its hardware prototype. The ESP32 was prepared on a small board compatible with a collar, and the MLX90614 and MAX30100 sensors were placed in such a way that they would always be in contact to provide precise physiological signals. The NEO-6M GPS module was connected by wires to provide it with a clear view of the satellites. Power supply issues were taken care of by including the rechargeable battery in the housing of the collar for safe and continuous operation. Real-time In the development of firmware, much attention was paid to writing lightweight algorithms that could enable stable sensing and reliable wireless transmission. Data collection was done with optimized intervals of temperature and heart rate for the best balance between responsiveness and battery efficiency. Filtering techniques in data processing were used to reduce noises due to movement of pets or changes in ambient conditions. GPS readings were processed to extract valid latitude and longitude coordinates before cloud transmission. This In parallel, the web dashboard implementation had to be developed, creating user-friendly displays for real-time data analytics. Chart.js was used to build time-series graphs dynamically updated from the cloud, while Leaflet.js allowed for interactive mapping with zoom and updated markers. Other interface components were added, including alerts, geofencing functionality, and multi-pet monitoring, among others. Testing included the assessment of sensor precision, stability of Wi-Fi, speed of cloud updates, and the responsiveness of a dashboard. All the parameters were tested under variable environmental conditions, indoor and outdoor, to make sure consistency would not differ in any scenario.

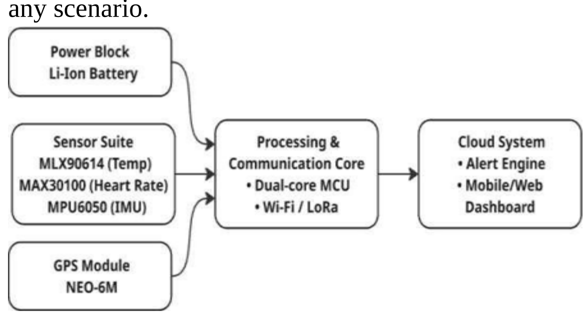

Fig. 2. System Architecture

VIII. RESULTS AND DISCUSSIONS

The proposed Smart Pet Care System has been successfully developed to provide the pet owner with a complete online interface that encompasses pet health monitoring, pet profiles, safety education, and pet care tutorials in one single interface. Figure X below illustrates the developed interface for the proposed system, which serves as the main point where the pet owner interacts with the wearable device. The interface has been developed to provide the pet owner with online real-time information while keeping the interface simple enough to make it visually appealing.

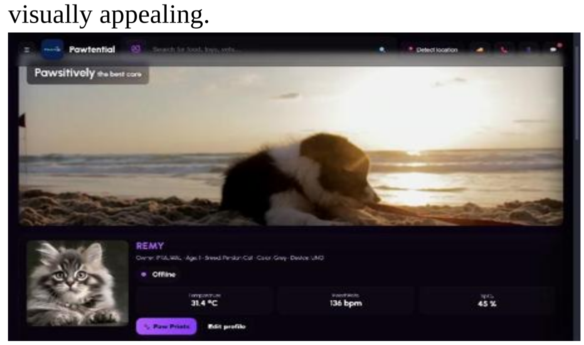

Fig. 3. Smart Pet Care System Web Dashboard

In the dashboard, the customized pet profile page with the pet’s name, age, breed, color, owner details, and the monitoring device connected to the pet is prominently displayed. Through the pet profile page, effective pet management can be accomplished, and the system can be scaled up in case of monitoring multiple pets with the same account. The presence of the device online or offline indicator avoids misunderstandings regarding the pet health metrics when the device is offline. Health metrics, namely temperature, heart rate, and oxygen saturation (SpO2), are also provided through separate metric cards. All these metrics are updated continuously based on data that is received from the IoT module. This numeric representation enables any pet owner to easily evaluate a pet's physiological state without any need for any technical knowledge, as any deviation from normal will stand out immediately. The interface also allows for notification-based awareness using the status updates related to changes in connectivity and irregular readings. If the device is offline or its sensor reading is beyond the safe limits, it is intended to raise an alarm to the user, hence improving the aspect of safety. This aspect seems crucial in preventing the user from losing connectivity when going out. In addition to health observation, the dashboard also encompasses pet care assistance functions that include basic necessities, all-rounded wellness assistance, as well as pet care assistance. The search and navigation functions enable users to conveniently gain access to information relating to food, toys, medical, and general pet wellness. The functions go beyond mere observation to make it a comprehensive pet care system that assists with wellness. The graphical user interface of the dashboard is designed with a dark theme and focus on key metrics, which makes for easier reading and prevents eye strain even with prolonged usage. The functionalities of the dashboard, including user profiles and animal actions, also make for engaging usage. The design is such that it keeps key information visible at all times. In summary, the obtained result has proven that the Smart Pet Care System has all the potential to integrate IoT sensing technologies with a well-designed web interface to provide useful, real-time insights. The integration of health, safety, basic care, and wellness information into a single interface makes the Smart Pet Care System a useful and pet owner-centric solution for pet care. The successful implementation and validation of the dashboard have proven that the proposed solution has all the potential to be successful.

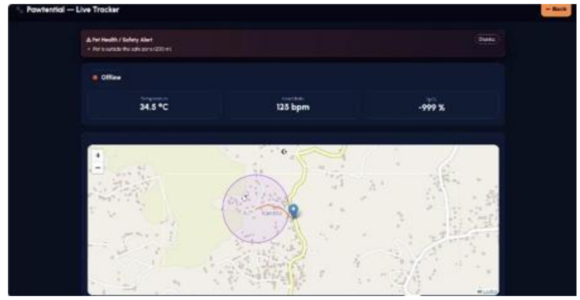

Fig. 4. Live Tracker Interface with Geofence and Safety Alerts

The tracker continually employs the use of GPS information gathered from the wearable collar to project the current position of the pet on an interactive map of the location, with a virtual safety boundary (geofence) established within a safe area such as the home perimeter. As long as the pet remains inside the boundary, no warnings are sent; but as soon as the pet breaches the established limit, the system immediately detects this anomaly and draws a highly visible warning of a pet escape from the safe area into sharp focus, allowing the owner to rapidly act upon the situation. In addition to location tracking and geofencing functionality, the system further incorporates continuous health tracking through the constant update of petSpO2 and heart rate information at preset time intervals based on periodical health observations of the pet’s body temperature and heart beats per minute. Established health threshold limits enable quick health anomaly determination and notification of such conditions as pet fever, irregular heart rate, and low oxygen levels. Through the comprehensive integration of real-time geofencing and health tracking functions into the same graphical interface system, proactive pet care is ensured through speedy emergency response and health management actions taken by the relevant owner and veterinarian.

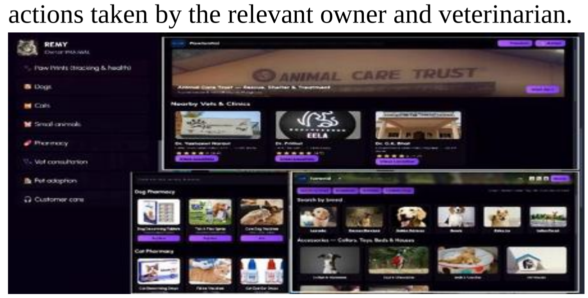

Fig. 5. Additional Pet Care Features and Service Modules

The The website takes off by offering categorized segments pertaining to dog care, cat care, and small animal care, which help users navigate the necessary elements of pet maintenance like food, grooming items, accessories, and activity-based engagement. The presence of pet cafes and pet-related events and celebrities adds to the level of interaction and awareness among the pet maintenance community. Features based on training and activity are combined individually for different types of pets, enabling the pet owner to avail themselves of training information, behavioral advice, and updates related to events for their pets. Such features help the pet owner to be a responsible pet owner, as they promote systematic training, good behavior, and socialization. The pet types are segregated, making the information specific, unlike generalized information that may not apply to all pets. The system also has a veterinary consultation module that helps with preventive and responsive health care. The system also has a list of nearby veterinary clinics and hospitals, which are shown based on the user's location, making it easy to identify reliable health facilities. Available facilities, ratings, and distances are provided to help pet owners make decisions. Booking and scheduling facilities enable pet owners to schedule regular health checks without any delays. Apart from face-to-face consultations, the platform includes online veterinary care services, which facilitate long-distance advice and follow-up consultations regarding minor health issues, as well as nutritional advice.

This component is extremely helpful in situations where immediate personal consultations are impossible. The platform additionally encourages healthy living, as it offers nutritional advice and wellness advice to various groups of pets. The veterinary consultation feature is further supplemented by an integrated pharmacy feature that ensures one-click purchasing for necessary medications, supplements, vaccines, and preventatives. The integrated platform ensures that access to reliable medical products is seamless, which in turn prevents misuse of medications. Additionally, the Smart Pet Care System has a pet adoption functionality that allows users to connect to pet adoption centers, pet shelters, and animal shelters near their location. This component of the Smart Pet Care System promotes responsible pet adoption behavior in the sense that it is equipped with vital pet adoption information, such as available animals, pet adoption centers, and pet adoption procedures. Smart Pet Care System turns it into an integrated digital platform rather than just another pet monitoring system. health monitoring, ensuring safety, essential care on a day-by-day basis, veterinary support, access to pharmaceuticals, and pet adoption assistance, it does have great practical relevance and use. Findings in this study demonstrate that this system has all it takes to provide comprehensive support in all pet care processes throughout a pet's lifetime.

Fig. 6. IoT-Enabled Smart Pet Collar Prototype

The design of the collar incorporates a bright red high-visibility strap for enhanced visibility in the outdoors. This design also facilitates easy identification of the device during tracking. The materials used in manufacturing the strap are flexible and comfortable to wear for an extended period without being too weak to support the installed electronics. All the devices are oriented along the collar to give equal weight distribution to enhance the comfort of the animal as it moves. The unit embedded within the collar consists of an MLX90614 infrared temperature sensor, along with the MAX30100 pulse oximeter sensor. The temperature sensor allows the monitoring of the temperature at a distance while ensuring continuous closeness to the body of the pet.

This feature is ideal since the temperature sensor enables the monitoring of the temperature at an affordable distance. Additionally, the pulse oximeter sensor records the heart rate and the SpO_2 values. The ESP32 microcontroller is used as the main processing unit. The ESP32 microcontroller is responsible for acquiring sensor data, initial processing, and wireless communication of the sensor data to the cloud platform. The ESP32 microcontroller also has Wi-Fi connectivity, which provides seamless connectivity to the web interface for updating health and location information in real time. The connectors between the sensors and the microcontroller are properly secured to avoid disconnection when the pet moves. The collar also contains a GPS module, which allows the real-time tracking of the location.

The module is always receiving satellite information and providing the latitude and longitude data to the controller. This assists in the location-based safety function of the geofence, which allows the user to detect when the pet transitions beyond the boundaries of the predetermined safe area. When testing, it was clear that communication between the collar and the dashboard was strong, and it was also able to provide sensor data. The hardware prototype has proven that it is possible to use its system to translate sensor data gathered from the real world to meaningful insights, which can all be accessed through a web interface. It has been proven that all these components work together to ensure monitoring, safety, and usability. The collar system developed not only proves that there is potential for implementation, and it also ensures that there are capabilities in which the Smart Pet Care System could function effectively as a real-time wearable IoT device.

IX. CONCLUSION AND FUTURE SCOPE

The This study presents the Smart Pet Care System, which has proven effective at integrating the power of the Internet of Things (IoT) in wearable sensors, the capabilities offered by the cloud analytics service, and the functionality enabled by the web platform with the aim of providing the best solution to the contemporary problems associated with the monitoring of pet health/safety. This system effectively integrates the monitoring capabilities associated with the real-time evaluation of the physiological health indicators in the pet, such as body temperature, heart rate, SpO2, GPS location monitoring capabilities, geofencing-based safety alerts, and the web-based graphical interface. This allows the pet owner to have continuous constant monitoring capabilities with respect to the health status as well as the movement status of the pet. This monitoring system, in fact, is centralized as the web platform has the capabilities to provide graphical processing associated with the monitoring indicators, thus enhancing the efficacy of the monitoring capabilities. Besides the monitoring capabilities, additional complementary aspects such as the access service offered by the veterinarian, pharmacy service, health-related guidelines on the day-to-day treatment of the pet, activity guidelines, as well as pet adoption centers have been considered in the system. Results Future upgrades could also allow the system to have enhanced functionalities, usability, and reliability. In terms of hardware components, upgrades could potentially include the use of smaller and more efficient sensor modules, the utilization of flexible printed circuit boards, and the development of durable and waterproof housings suitable for outdoor operations.

Another area of improvement is the upgrading of the wearable collar's ergonomic design with the use of lighter and more ergonomic designs. Connectivity upgrades could also be achieved by implementing the use of other wireless connectivity options like LoRa or even LoRaWAM along with the use of Wi-Fi. In terms of software components, the system could benefit from the integration of more sophisticated functionalities like intelligent scheduling of appointments, automated vaccination reminders, and the management of the pet's health records. The incorporation of artificial intelligence would also make the system capable of handling predictive analytics of the pet's health, disease diagnosis, irregular behavior analysis, and the provision of wellness advice. Via these upgrades, the Smart Pet Care System would also have the high potential to transform into a versatile, intelligent, and industry-ready system capable of supporting not only pet care operations but also other high- end uses like the training of working dogs, search and rescue operations, and even security/surveillance operations. The software aspects can be enhanced with an advanced appointment scheduling system on the platform to enable scheduling of normal health checkups, vaccinations, and follow-up visits directly from the website.

The inclusion of artificial intelligence will be an add-on to the software to provide advanced analytics in healthcare, abnormal activity identification, and personalized healthcare tips. The inclusion of a miniature camera system and voice commands will enable the device to provide advanced monitoring, pet engagement, and behavior identification. In addition to pet care at home, the system can be developed for advanced use cases in training working dogs, search and rescue missions, as well as for use in the military or for security-related tasks. In these cases, improved accuracy in the tracking system, rugged hardware components, real-time communication systems, and the analytics capabilities that come with AI can offer valuable insights into the operations as well as better control. Be it the rapid evolution of the Internet of Things or Artificial Intelligence or wearable technology, the Smart Pet Care System has a bright future in transforming into a flexible and intelligent system for a number of applications.

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