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Location Tracking Device to Monitor Real-Time Movement of Animals

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ABSTRACT
This paper presents an IoT-enabled animal tracking and monitoring system designed to enhance real-time location tracking, geofencing, and community-driven lost animal recovery. The system utilizes a compact device worn by the animal, equipped with a NodeMCU module and GPS technology. This device transmits location data to a web-based platform where caretakers can monitor the animal's whereabouts, set virtual boundaries (geofences), and receive alerts if the animal strays outside the designated area. The platform also offers innovative features to facilitate lost animal recovery, including social media integration for "lost animal" alerts and a dedicated website for reporting found animals. This system prioritizes animal safety, responsible pet ownership, and fosters a collaborative community approach to animal welfare.

KEYWORDS
Animal tracking, Collaborative systems, Geolocation, GPS, Internet of Things (IoT), Microcontrollers, Real-time monitoring, social media

1. INTRODUCTION

There is a growing need for reliable animal tracking solutions to ensure the safety and well-being of animals, whether they are livestock, pets, or wildlife. Traditional methods like physical fences have limitations, and this paper proposes an IoT-based animal tracking system to address these concerns. The proposed system employs a compact and wearable device equipped with a NodeMCU ESP8266 module and GPS technology. This device continuously transmits the animal's location data to a web-based monitoring platform. Caretakers can utilize this platform for real-time location tracking, visualizing the animal's current location on a map, and setting up geofences to receive alerts if the animal enters or leaves the designated area. The animal's path history is stored on the cloud for further references.

One of the key features of this system is its focus on lost animal recovery. By enabling social media integration for "lost animal" alerts and facilitating found animal reporting through a website, the system mobilizes the community to aid in recovery efforts. This approach aligns with the growing need for reliable animal tracking solutions to prevent wildlife trafficking and poaching, mitigate human-wildlife conflict, monitor endangered species, study animal behaviour and ecology, and locate lost or escaped livestock.

Several studies explore animal tracking and monitoring technologies, each with its own strengths and limitations. Saputra et al. [1] and Ramesh G. et al [4] utilize GPS for location tracking, similar to our proposed system. However, our system offers additional functionalities like real-time tracking on a web platform and geofencing for out-of-bounds alerts.

Saputra et al. focuses on temperature monitoring with SMS alerts, while Ramesh et al. doesn't elaborate on real-time tracking or lost animal recovery.

Sharma S. et al [5] also uses GPS for pet tracking with SMS alerts, but lacks a real-time web platform and community collaboration aspect, which are key strengths of our proposed system. L. Nóbrega et al. [8] explores location using RSSI technology, but its limited range and susceptibility to environmental factors make it unsuitable for our outdoor tracking application. S. Verma et al. [10] focuses on indoor pet location tracking with RFID technology, which is not ideal for our outdoor scenario and can potentially have negative health impacts on animals.

Hassan, M. et al [2] emphasizes the role of IoT in animal monitoring, particularly for livestock management with health sensors. While our system also leverages IoT, it targets companion animals (pets) with a focus on lost animal recovery through social media integration, a feature not explored in Hassan et al. Roland Kays et al. [13] proposes a tracking environment with telemetry receivers for wildlife monitoring. This approach is not suitable for pet tracking due to cost and limitations in real-time data acquisition.

Kim G. et al [6] introduces an AI-based pet care robot using voice recognition for pet management at home. This differs from our outdoor tracking system with a focus on location and lost animal recovery. Hart et al. [12] designed a GPS tracker for large animals, but it may not be compact enough for smaller pets.
The proposed IoT-enabled animal tracking and monitoring system offers several advantages over existing works in the field of animal location tracking and management. One key

advantage is the comprehensive approach of the proposed system, which combines real-time location tracking, geofencing, and community-driven lost animal recovery features [1, 4, 5, 8, 9]. This is in contrast to the location-only or RSSI-based approaches discussed in the literature, which lack the geofencing and community engagement aspects [1, 4, 8].

The integration of social media and found animal reporting features in the proposed system leverages the power of the community to aid in lost animal recovery, a unique aspect not present in the existing works [1, 4, 5, 8, 9, 10]. This collaborative approach significantly increases the chances of reuniting missing pets with their owners [1, 4, 5].

The proposed system has also demonstrated its versatility in various animal management domains, including wildlife conservation, livestock management, and pet ownership [2, 6, 12, 13]. This makes it a more adaptable solution compared to the domain-specific approaches mentioned in the literature [2, 6, 12, 13].

Furthermore, the use of the point-in-polygon algorithm for geofencing and the AJAX-based web server architecture in the proposed system represent technological advancements that enhance the system's efficiency and responsiveness compared to the reviewed works [9]. These features provide more accurate and real-time monitoring capabilities [9].

The continuous tracking of animal movements and locations in the proposed system has the potential to provide valuable insights into animal behavior and ecology. This capability is not explicitly explored in the existing works, making the proposed system a significant advancement in the field [2, 3, 11].

In comparison to the existing works, the proposed IoT-enabled animal tracking and monitoring system stands out in its comprehensive approach to animal management. By integrating real-time location tracking, geofencing, and community-driven lost animal recovery features, the system provides a holistic solution that addresses the growing needs of various animal-related domains. The versatility, potential for behavioral insights, and the use of advanced algorithms and web server architecture further enhance the system's capabilities and effectiveness.

2. PROPOSED WORK

The goal is to create a GPS tracking device that not only tracks the animal's whereabouts in real-time but also leverages the power of community for enhanced animal safety. To monitor location, a GPS module with an integrated antenna is interfaced with the NodeMCU. A web platform is developed to display the latitude and longitude data, allowing for visualization of the animal's location. Additionally, the platform incorporates geofencing to determine if the animal is within its designated territory. This system takes a step further by integrating social media and community features for lost animal recovery. Caretakers can activate "lost animal" alerts on social media platforms through the webpage, and users can report finding an animal with the tracking device through a website. This collaborative approach mobilizes the community to assist in reuniting lost animals with their owners.

The most important task in Geo-fence utilizing ESP8266 is detecting if the target is inside or outside the barrier. The fence may have any design. As a result, we must address this problem by assuming the barrier is an n-dimensional polygon. The complexity of the algorithm also plays an important impact in tracking efficiency. Taking these concerns into consideration, the following algorithm is chosen in this paper.

2.1 Point-in-polygon Algorithm:

Assume the user's fence is an n-dimensional polygon and the coordinates of all the polygon's vertices are in $P_n (x_n, y_n)$ format. A (x_a, y_a) denotes the tracking point's current position. Fig.1 gives an idea of how the algorithm works.

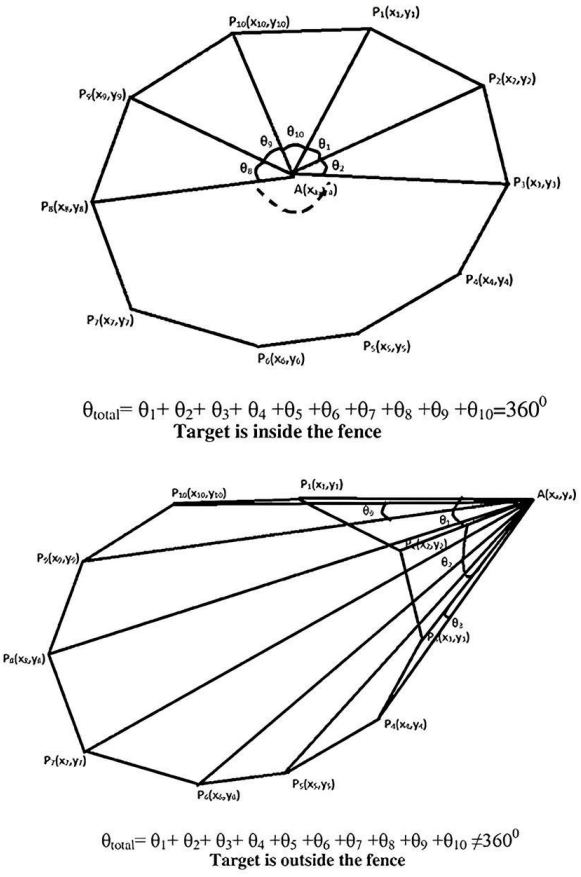

Fig. 1 Visualization of Point-in-polygon Algorithm

The total of the angles formed by the successive lines drawn from the tracking point to the vertices determines whether the target is inside or outside the fence. The summation can be done clockwise or counter clockwise. If the sum of all central angles of the polygon is equal to 360°, then the target is inside the polygon i.e., geofence. If the sum of all central angles of the

polygon is not equal to 360°, then the target is outside the polygon i.e., geofence.

The dot product of two vectors ($|m.n| = |m|.|n|.\cos(\theta)$). Let 'm' represent the vector from the tracking point to vertex 1 and 'n' represent the vector from the tracking point to vertex 2.

$$m=(x_1-x_a)\,\hat{\imath}+(y_1-y_a)\,\hat{\jmath}$$
$$n=(x_2-x_a)\,\hat{\imath}+(y_2-y_a)\,\hat{\jmath}$$

From dot product:

$$\theta = \cos^{-1}\left[(m\cdot n) / (|m|\,|n|)\right]$$

So,

$$\theta_1= \cos^{-1}\left(\sqrt{(((x_1-x_a)\,(x_2-x_a))^2+ ((y_1-y_a)\,(y_2-y_a))^2)}\right) / \left((\sqrt{(x_1-x_a)^2+ (x_2-x_a)^2})\,(\sqrt{(y_1-y_a)^2+ (y_2-y_a)^2})\right)$$

Similar computation can be done for the other angles.

2.2 Creating the Geo-fence:

Open Google Maps, pin the spot where you intend to build the fence's vertex, label the vertex, and take note of the coordinates. Repeat the same for the remaining spots as well. Fig.2 shows the fence that we built and used in this paper.

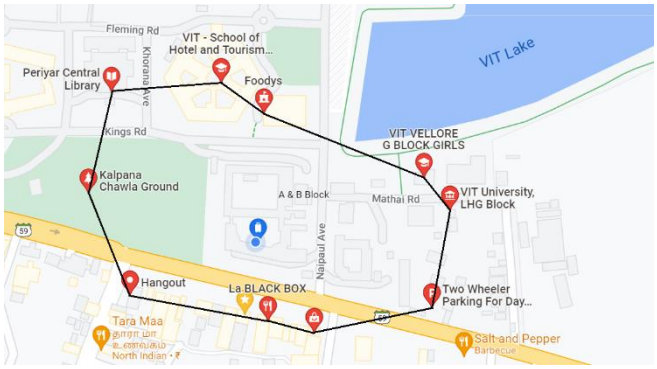

Fig.2 Geo-fence used in this paper

The fence's latitude and longitude are hardcoded to the variable fence, that is a three-dimensional array. The third dimension is used to save the coordinates of different Geo-fence.

2.3 AJAX based Webserver:

Our system utilizes an AJAX-based web server to dynamically monitor the target in real-time, offering more than just location updates. It facilitates lost animal recovery through the power of community collaboration.

Traditional web servers require the entire page to be reloaded whenever new information is needed. AJAX-based web servers, on the other hand, only update the specific portion that has changed. This makes them ideal for real-time applications like ours, where both location tracking and social media integration are crucial.
The web platform displays the animal's real-time location on a map. However, we recognize that GPS tracking has limitations. For instance, the signal can be lost if the animal wanders too far, or weakens in areas with dense foliage or buildings. A dead battery on the tracking device would also render location tracking useless.

This is where community collaboration comes in. Caretakers can activate "lost animal" alerts on social media platforms through the web platform, significantly broadening the search area compared to relying solely on GPS data. Social media alerts can reach a wider audience, potentially leading more people to search for the lost animal near its last known location. Additionally, community members searching for the animal can provide real-time updates or sightings, offering valuable information beyond the GPS data. This broader search effort, facilitated by social media, can lead to a quicker reunion between the lost animal and its owner.

In essence, the GPS tracker provides a general area like a red dot on a map. The community acts as a search party, combing the actual area and potentially finding the animal even if the GPS signal is weak or unavailable. This collaborative approach significantly increases the chances of a successful reunion.

3. RESULTS AND DISCUSSION

The experiment was carried out in Vellore Institute of Technology with a human carrying the proposed device (as shown in Fig.3). The outcome achieved from the experiment can be seen in Fig.4 and Fig.5. The dashboard shows the real-time location (latitude & longitude) of the test subject, and if the test subject is present inside or outside of the geo-fence. The experimentally obtained information was verified using Google Maps. The empirically confirmed location information of the in terms of longitude & latitude of the test subject was precisely matched with the manual location information.

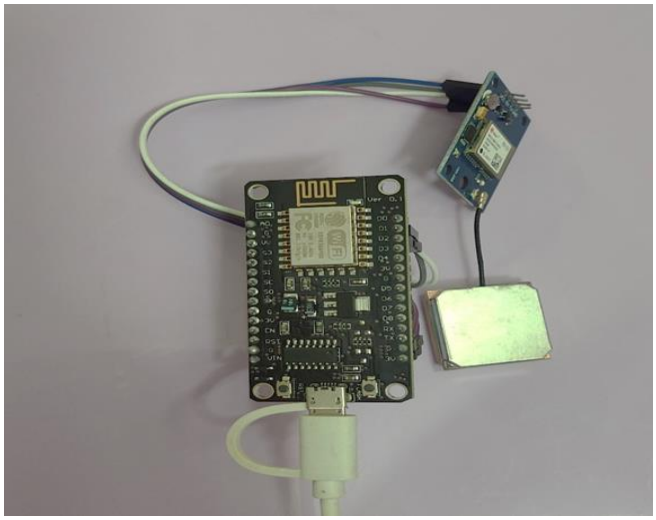

Fig.3 The Location Tracking Device that Monitors Real Time Movement of Animals

If the animal is out of the geo-fence and its location is lost then the caretaker can select the 'report lost animal' button on the

dashboard as shown in Fig.4 and Fig.5. A new web page opens where they can provide the required details of the lost animal as shown in Fig.6. Once they press the submit button, the details will be posted on social media platforms linked to it.

If a community member encounters the lost animal, then they can access the ‘Report found animal’ (as shown in Fig.7) web page that is linked to the social media handle of the caretaker or organization.

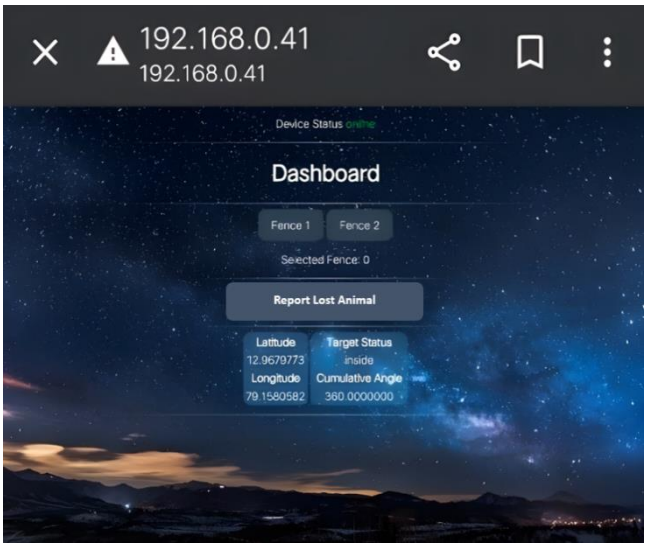

Fig.4 Target is inside the geo-fence

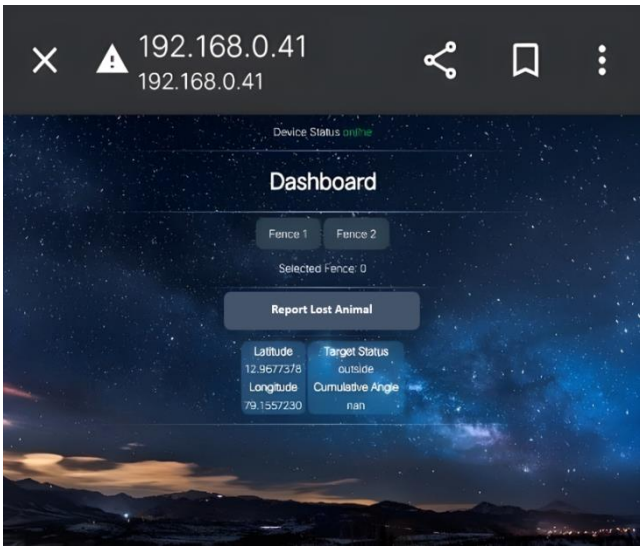

Fig.5 Target is outside the geo-fence

The social media integration and found animal reporting features have demonstrated the system's ability to leverage the broader community in aiding lost animal recovery efforts. By activating "lost animal" alerts on social media and facilitating the reporting of found animals, the system has increased the chances of reuniting missing pets with their owners.

The versatility of the system has been highlighted through its applications in various domains, including wildlife conservation, livestock management, and pet ownership. The ability to track and monitor animals in real-time has proven valuable for preventing wildlife trafficking, mitigating human-wildlife conflict, and locating lost or escaped livestock.

The continuous tracking of animal movements and locations has the potential to provide valuable insights into animal behavior and ecology. By analyzing the data collected by the system, researchers and wildlife managers can gain a deeper understanding of animal movement patterns, habitat usage, and other behavioral characteristics.

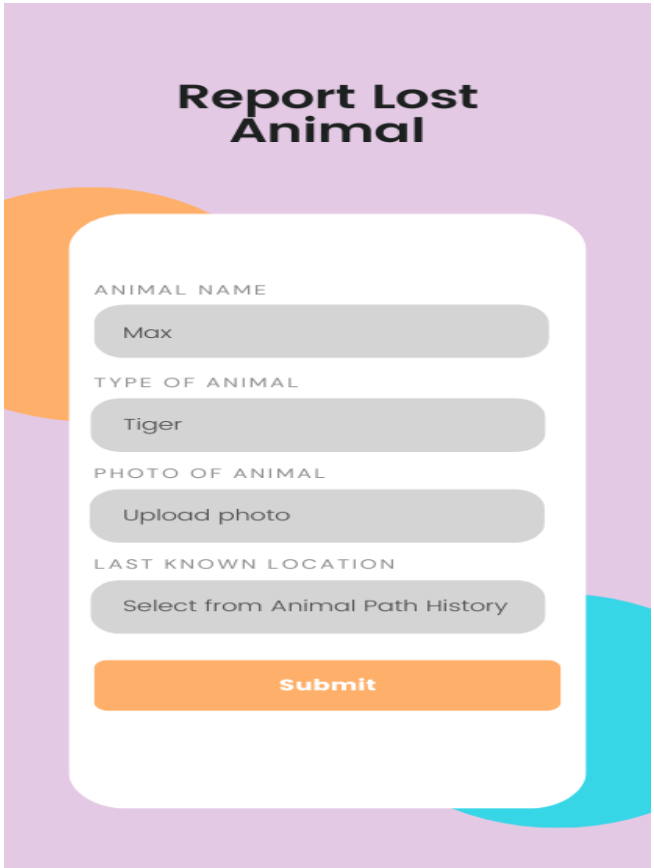

Fig.6 Web page for reporting lost animal

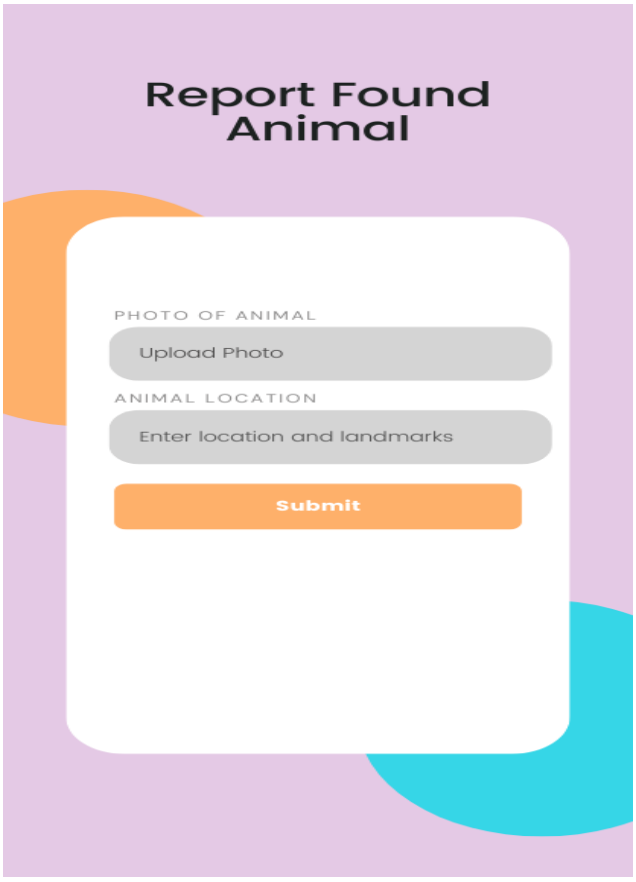

Fig.7 Web page for reporting animals that the people find

The proposed work provides alerts for lost animals straying from safe areas. It also leverages community power to expand search area and increase recovery chances. Offers user-friendly interface for location monitoring. The proposed device can be used with any animal and has very sustainable lost animal recovery feature.

Table. 1 Proposed work's qualitative analysis

Feature	**Proposed Work**	**Saputra et al. [1]**	**Sharma et al. [5]**
Geofencing	Alerts for out-of-bounds zones (Point-in-Polygon Algorithm)	Not included	Not included
Social Media Integration	Alerts and community reporting for lost animals	Not included	Not included
Data Display	Web platform for visualization	SMS alerts	SMS alerts
Animal Management Focus	All animals	Livestock	Companion animals (pets)
Lost animal recovery	Sustainable and is community led. Very reliable.	Not included	Not included

The proposed IoT-enabled animal tracking system goes beyond simple location tracking. By combining real-time data, social media integration, and a versatile approach, it offers a comprehensive solution for various animal management needs, promoting animal safety, responsible ownership, and improved understanding of animal behavior.

4. CONCLUSION

The IoT-enabled animal tracking and monitoring system presented in this paper offers a comprehensive solution to address the growing need for reliable animal tracking and recovery. By integrating GPS technology and geofencing capabilities, the system provides real-time location tracking and virtual boundary monitoring for caretakers.

A key strength of this system is its focus on lost animal recovery. The social media integration for "lost animal" alerts and the found animal reporting feature mobilize the community to assist in recovery efforts, aligning with the principles of responsible pet ownership and animal welfare.

The system's versatility extends to preventing wildlife trafficking, mitigating human-wildlife conflict, monitoring endangered species, studying animal behaviour, and locating lost or escaped livestock. As the world grapples with challenges posed by human-animal interactions, innovative technologies like this become increasingly crucial.

Future advancements could explore integrating additional sensors for health monitoring and machine learning for behaviour analysis. This system's potential extends to wildlife monitoring, offering valuable data for research and conservation efforts. By continuously innovating, we can create a safer and more secure environment for both animals and humans.

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