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Wildlife Observation Robot

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Abstract: The Wildlife Observation Robot represents an innovative solution for automated forest surveillance and protection. This autonomous system integrates advanced computer vision capabilities with robust hardware components, all controlled by a Raspberry Pi microcomputer. The robot continuously patrols forest areas, utilizing a rotating camera system and Ultrasonic sensors for comprehensive environmental monitoring. Through OpenCV-based image processing, it can detect both wildlife presence and potential fire outbreaks in real-time. Upon detection, the system immediately alerts relevant authorities via Telegram messaging, providing crucial information including precise location coordinates and photographic evidence. This implementation significantly enhances forest management capabilities while reducing human intervention in potentially dangerous situations.

Index Terms - Autonomous Wildlife Monitoring, Smart Surveillance System, Automated Alert System

I. Introduction

In recent years, human-animal conflicts and forest fires have become serious issues, especially in areas where forests are close to farms, villages, or protected regions. Animals unknowingly enter agricultural lands in search of food or water, often damaging crops and causing panic. At the same time, forest fires—whether natural or accidental—can spread rapidly, destroying wildlife, vegetation, and even nearby human settlements. Traditional methods like guard patrols, fixed CCTV cameras, or manual alerts are not always reliable, as they depend heavily on human presence and cannot provide continuous, wide-area monitoring. To address these challenges, this project introduces an automated monitoring system that can detect both animal boundary crossings and fire incidents without the need for manual intervention. It is designed to work in remote forest areas where resources and manpower are limited. The system uses sensors and a camera to monitor surroundings, and if an animal is detected crossing a set boundary or a fire is spotted, it instantly sends an alert to the concerned authorities. The alert includes the name of the detected object (animal or fire), its image, and the exact GPS location where it was found. The proposed system is a surveillance vehicle designed for real-time detection of animals and fire in restricted areas. . It uses a camera module integrated with OpenCV and YoloV5 algorithms to identify animals and fire, capturing images and sending alerts via Telegram with the detected object's name, image, and location. An ultrasonic sensor aids in obstacle avoidance, ensuring smooth navigation. The system is equipped with motor drivers and DC motors for controlled movement. This IoT-based solution enhances safety by providing instant notifications to authorities, helping in wildlife conservation and fire prevention. What makes this project useful is its ability to work on its own. It can move through rough forest paths, avoid obstacles using sensors, and keep checking its environment. All these features make it a smart solution for wildlife protection and early fire warning.

Its scope includes:

1. Autonomous Monitoring: Enabling 24/7 fire detection, wildlife tracking, and environmental condition assessment using advanced sensors and computer vision.
2. Coverage Expansion: Developing adaptable navigation for various terrains, scalable zones, customizable patrol routes, and multi-robot coordination.
3. Environmental Assessment: Conducting evaluation of environmental conditions to enhance forest management and protection efforts.
4. Scalability: Creating a framework that can be adapted to wide range of forest.
5. Technological Enhancement: Expanding sensor capabilities for enhanced surveillance.

II. Literature Survey

B. VS, M. AR, A. Ganapathy PS, and M. Manju discuss a Scarecrow Monitoring System that employs MobileNet SSD for real-time animal classification. This system helps in minimizing crop damage by deterring wildlife and promoting precision farming. The continuous monitoring mechanism ensures accurate wildlife detection and provides a cost-effective solution for agricultural and wildlife applications. However, the system requires technical expertise for proper implementation. [1]

P. Kaur, S. Kansal, and V. P. Singh propose PAW, a system designed to predict wildlife movement using image dehazing techniques and the ROS framework. A Tortoise Bot mobile robot autonomously navigates near railway tracks to prevent animal-vehicle collisions. The project ensures high visibility in adverse weather conditions, improving road safety. However, deployment in diverse environmental conditions presents a challenge. [2]

B. Bhagabati, K. K. Sarma, and K. C. Bora present a YOLOv5-based animal detection system integrated with SENet attention for monitoring wildlife around Kaziranga National Park. The project aims to reduce human-animal conflicts by sending real-time alerts, ensuring a high detection accuracy of 96%. This system plays a significant role in conservation efforts, but regular monitoring and maintenance are essential for optimal performance. [3]

S. Kumar and R. Patel introduce an IoT-based forest fire detection system that uses thermal imaging and the YOLOv4 algorithm. The system integrates GSM and GPS modules with a Raspberry Pi control unit to provide real-time alerts and location tracking. This early warning mechanism helps mitigate forest fire damage, making the system cost-effective and energy-efficient. However, the complexity of setup and implementation remains a challenge. [4]

L. Zhang et al. propose an autonomous forest surveillance robot with animal detection capabilities. The system utilizes MobileNetV2 for accurate detection and a rotating camera for 360° surveillance. Ultrasonic sensors enable obstacle avoidance, while real-time monitoring is facilitated via cloud storage. Although the system achieves a 91% detection accuracy, managing power for continuous operations is a limitation. [5]

X. Chen and P. Williams develop a smart forest monitoring system that employs CNNs for fire and animal detection. The system integrates PIR sensors for motion detection and LoRaWAN for long-range communication. Edge computing minimizes false positives and enhances real-time response. While the system optimizes power consumption for extended field operations, limited connectivity in remote areas remains a challenge. [6]

A. Patel and J. Lee propose a multi-spectral imaging and smoke detection system for early fire detection. The project integrates environmental sensors to monitor temperature, humidity, and air quality. Cloud-based platforms ensure scalable monitoring and rapid alerts, reducing false alarms. However, the system is heavily dependent on internet connectivity for efficient cloud access. [7]

H. Kim and T. Brown combine YOLOv5 and thermal imaging for high-accuracy animal detection under all weather conditions. The system features Edge AI processing for real-time detection and reduced false positives. Automated tracking ensures continuous animal movement monitoring. This energy-efficient, low-cost system requires regular algorithm updates for maintaining detection accuracy. [8]

L. Wang and S. Miller present a hybrid machine learning model that integrates sensor fusion for enhanced fire and animal detection. The system predicts maintenance needs, ensuring reliability and cost-effectiveness. Advanced alert mechanisms enable immediate notifications, reducing downtime. However, sensor malfunctions can impact overall accuracy and performance. [9]

M. Rodriguez and K. Singh design an OpenCV-based image processing system combined with MQTT protocol for forest monitoring. The project ensures 24/7 surveillance with real-time fire and animal detection alerts. Powered by solar energy, the system is sustainable for remote areas. While the architecture is scalable and weather-resistant, a reliable IoT network is necessary for continuous operation. [10]

R. Thompson et al. apply transfer learning for multi-species recognition and integrate blockchain for secure data transmission. The system enables autonomous navigation with adaptive path planning for efficient monitoring. Night vision is incorporated to enhance low-light detection. While this project improves 24/7 wildlife monitoring, night operations still require enhancements for better visibility. [11]

M. Garcia et al. develop an autonomous forest surveillance robot using a ROS-based control system and LiDAR for mapping forest terrain. Wireless mesh networking enhances communication between sensors, while AI-powered decision-making improves navigation. The system is expandable for multi-robot coordination, but the initial setup complexity due to ROS poses a challenge. [12]

K. Anderson et al. introduce an IoT-enabled forest monitoring robot equipped with a web-based control interface for remote operations. The system integrates multiple sensors for environmental monitoring and real-time video streaming. Automated patrol routes optimize surveillance efficiency. However, a stable high-speed internet connection is required for uninterrupted remote access. [13]

P. Sharma and V. Rao implement an IoT-based smart surveillance system utilizing Support Vector Machine (SVM) algorithms for fire and animal detection. A cloud-based alert mechanism ensures real-time notifications for quick response. The system is scalable across various forest environments, improving conservation efforts. However, its high dependency on internet connectivity poses a limitation. [14]

III. Problem Identification

In the existing systems, forest monitoring is hindered by limited coverage, delayed response to forest fires and wildlife intrusions, high manpower requirements, inconsistent surveillance, weather-dependent monitoring, inadequate early fire detection, insufficient wildlife tracking, and the lack of cost-effective, autonomous, and real-time alert mechanisms.

IV. Objectives

1.To Develop a 24/7 autonomous robot for animal detection and fire using advanced navigation and image processing.
2.To Create a GPS-based alert system to ensure instant notifications via Telegram for detected events.
3.To Implement reliable detection algorithms with minimal false positives for enhanced monitoring.
4.To Design a cost-effective, adaptable system that integrates with existing forest management practices.

V. Methodology

The system is powered by a Raspberry Pi, which serves as the central processing unit, managing data flow and processing inputs from multiple sensors. It continuously collects and analyzes data from the camera, ultrasonic sensor, GPS module, and fire detection sensor. The camera module captures real-time images of the surrounding area, which are processed using the YOLOv5 algorithm and OpenCV to detect animals or fire. If an animal crosses the boundary or a fire is detected, the system triggers an alert containing the captured image and GPS location. This alert is sent to authorities via the Telegram mobile application for immediate response. The ultrasonic sensor detects obstacles in the robot's path, helping it navigates safely and monitor movement near the boundary. The GPS module provides real-time tracking, ensuring precise location details are included in the alert. Motor drivers and DC motors enable the robot to move autonomously along the boundary, patrolling the area efficiently. If an obstacle is detected, the Raspberry Pi commands the motor driver to adjust movement, avoiding collisions. The system operates on rechargeable batteries, ensuring continuous functionality in remote areas. The power supply maintains stable operation preventing disruptions. operation, preventing disruptions. The mobile application allows authorities to receive real-time alerts remotely, improving response time. The robot continuously scans the environment, capturing images and processing them for object detection. If no threats are found, it resumes patrolling. When an animal or fire is detected, the Raspberry Pi retrieves GPS coordinates and sends an instant alert. The system autonomously navigates, ensuring large-area surveillance. The alert messages contain critical details to help authorities take immediate action. The system operates in a loop, ensuring 24/7 monitoring and real-time threat detection.

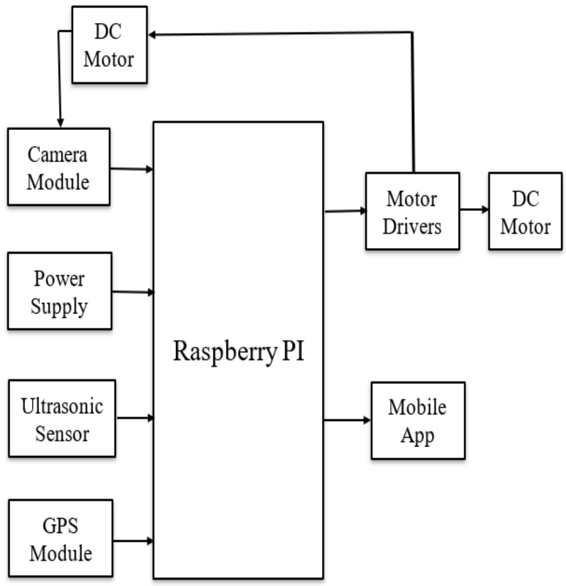

Fig.1: Block Diagram of Proposed System

Figure 1 describes about the components used in the proposed system.

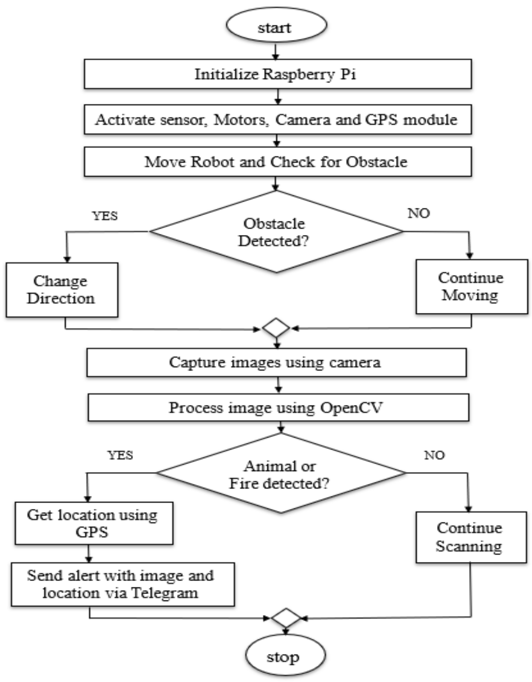

Fig 2: Flow Chart of the Proposed System

VI. Results

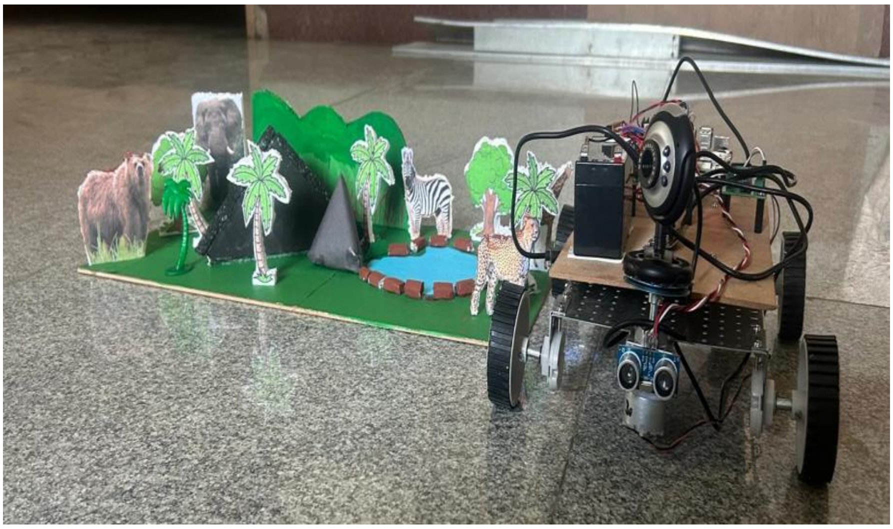

Fig. 3: Proposed System

The figure showcases the proposed system, which is an autonomous robotic surveillance vehicle designed for animal boundary monitoring and fire detection. The robot is equipped with essential components, including a camera module, ultrasonic sensor, GPS module, and motorized wheels, all mounted on a sturdy chassis. The Raspberry Pi serves as the central processing unit, controlling the movement and processing data from the sensors. The system operates by continuously patrolling a predefined boundary and capturing real-time images of its surroundings. The camera module, mounted on the front, is responsible for detecting both animals and fire incidents. If an animal crosses the boundary or fire is detected, the system sends an alert message with the captured image and GPS location to authorities via a mobile application. The ultrasonic sensor positioned at the front helps in obstacle detection, ensuring smooth navigation by preventing collisions with objects. The system is powered by a rechargeable battery, making it suitable for remote locations where a conventional power supply is unavailable. The vehicle moves autonomously with the help of DC motors and motor drivers, allowing it to cover a large monitoring area efficiently. The surrounding setup in the image represents a simulated environment with animal cutouts and landscape models, providing a clear demonstration of how the system functions in real-world scenarios. By integrating advanced image processing techniques with real-time communication, this robotic system enhances the safety of restricted areas by preventing animal intrusions and quickly identifying fire hazards.

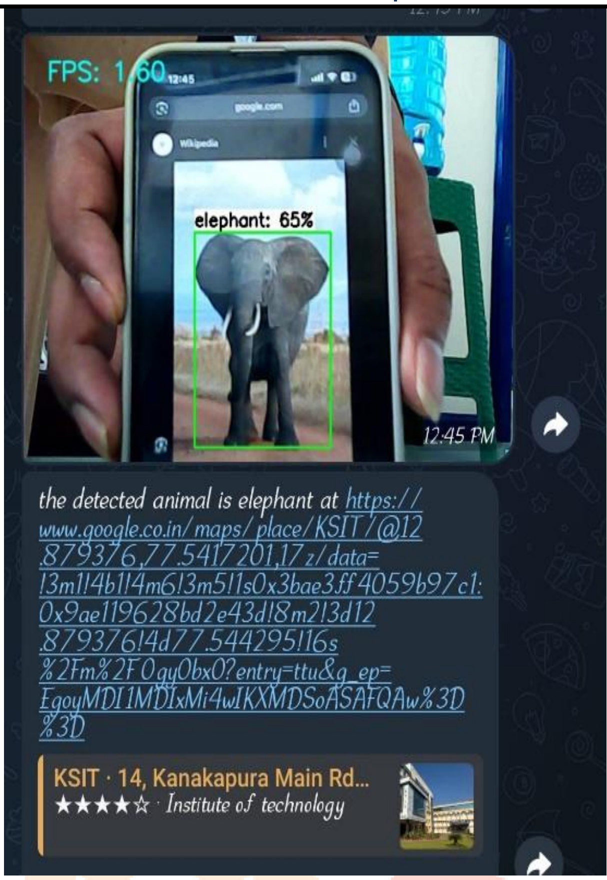

Fig. 4: Alert Received for elephant detection along with image and location through Telegram

The figure represents an alert message received via Telegram for an elephant detection event. The system has successfully identified an elephant with a confidence level of 65%, as indicated by the green bounding box around the detected animal. This detection is performed using the YOLOv5 object detection algorithm, which processes images captured by the camera module in real time. Once the system identifies an animal crossing the boundary, it generates an alert containing the detected animal's name, confidence level, captured image, and GPS location. In the message, a Google Maps link is provided, allowing authorities to view the exact location where the detection occurred. This feature helps forest officials take immediate action to prevent potential human-wildlife conflicts or safeguard restricted areas.

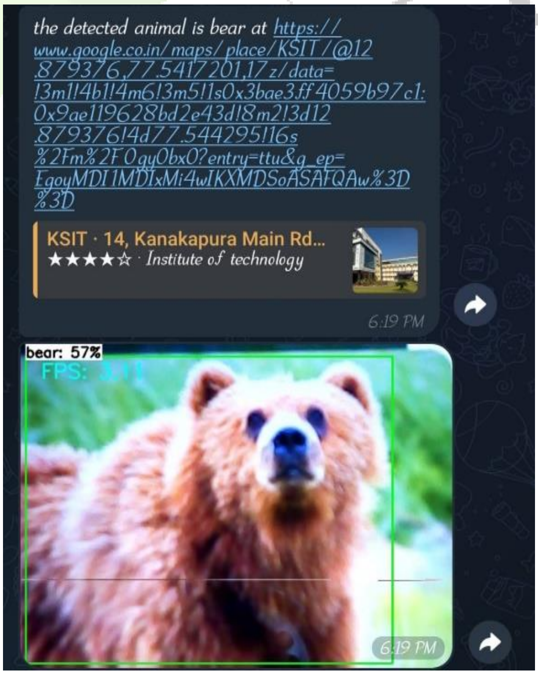

Fig. 5: Alert Received for Bear detection along with image and location through Telegram

The figure represents an alert received via Telegram for the detection of a bear. The system has successfully identified a bear with a confidence level of 57%, as shown in the bounding box around the detected animal. The detection process is carried out using the YOLOv5 object detection algorithm, which analyzes images captured by the camera module. Once the system confirms the presence of an animal within a restricted area, it generates an alert containing details such as the animal's name, confidence level, an image of the detected animal, and the GPS location. The message includes a Google Maps link, which helps authorities pinpoint the exact location of the detection event. This feature is particularly useful for wildlife conservation efforts, as it allows forest officials to take necessary actions to prevent conflicts between animals and human settlements. The real-time alert system ensures quick responses, enabling authorities to monitor and control animal movements effectively.

Fig. 6: Alert received for Fire detection along with location through Telegram

The figure represents an alert message received via Telegram for fire detection. The system has successfully identified the presence of fire and immediately generated an alert message, including the detected location. This fire detection feature is implemented using image processing techniques, where the camera module captures real-time images of the monitored area. These images are analyzed using deep learning models trained to recognize fire patterns based on color, texture, and shape characteristics. Once the system detects fire, it sends an automatic alert containing a Google Maps link to pinpoint the exact location of the incident.

VII. Applications

1. wildlife monitoring:
    - identifies and tracks various animal species for ecological research and conservation.
    - helps in preventing human-wildlife conflicts by detecting animal movement near human settlements.
2. forest fire detection:
    - uses image processing to detect early signs of smoke or fire in dense forests.
    - sends real-time alerts to authorities, allowing quick response and minimizing damage.
3. agricultural protection:
    - prevents animals from crossing boundaries and damaging crops near forested areas.
    - Reduces the risk of human-wildlife conflicts by keeping wildlife away from farmland.

4. Environmental Monitoring:

- Monitors temperature and humidity levels to analyze climatic changes in forest ecosystems.
- Helps in detecting abnormal weather conditions that may indicate potential hazards like droughts or forest fires.

VIII. Conclusions

Forest surveillance is essential for monitoring wildlife activity, preventing fire, and ensuring environmental conservation. This project addresses these needs by developing an automated wildlife observation robot equipped with Raspberry Pi, sensors, and a camera module for real-time monitoring. The system enables accurate animal detection using YOLOv5 and OpenCV, providing valuable data for researchers and conservationists. GPS tracking and ultrasonic sensors enhance navigation, ensuring smooth movement in forest environments. The integration of a mobile app allows remote access and control, making monitoring more efficient. This project serves as a reliable and effective solution for improving forest surveillance and wildlife protection.

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