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Safepath: Protecting Wildlife with Smart Streetlight

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Abstract -With the increased number of roads passing through the forest and rural areas, the chances of animal-vehicle collisions are also on the rise, which is a major threat to the lives of humans as well as the wildlife. The existing safety measures such as the display of warning boards and the usage of reflecting signs are not effective as they cannot send immediate alerts. Keeping this issue in view, this paper proposes a smart streetlight system known as SafePath that can detect the presence of animals near the road and alert the driver immediately.

The proposed system includes the usage of Passive Infrared (PIR) and thermal camera sensors to detect the presence of animals based on the motion and heat of the bodies of the animals, especially at night. An LDR sensor is also used to operate the system at night only. As soon as the system detects the presence of an animal, the color of the streetlight changes from white to red, which is enough to alert the approaching vehicles. The system also includes the usage of wireless communication modules to trigger the streetlights near the road, which creates a chain reaction to alert the approaching vehicles.

The power source for the system is solar power, hence suitable for use in remote areas and environmentally friendly. The design of the entire system allows for automation, efficiency, and responsiveness. The focus of this project is on enhancing road safety, wildlife protection, and creating a viable option for the development of smart transportation systems.

***Key Words*:** Animal detection, Smart streetlight, Wildlife protection, PIR sensor, LDR, IoT, Road safety, Solar-powered system

1.INTRODUCTION

The growing expansion of the road network in forest and rural regions has resulted in a substantial increase in animal-vehicle accidents, which pose a serious threat to the lives of animals as well as humans. These accidents generally take place during nighttime when the driver cannot see the animals crossing the road. The conventional method of providing safety involves the use of warning boards and reflective signs. These are not very effective as the driver does not get timely alerts, and the chances of the driver being careless are always high.

In addition, with the development of smart technologies and IoT, there is an increased possibility of developing smart systems that could actively monitor and respond to situations. Smart street light systems equipped with sensors and communication devices could play an important role in enhancing road safety and preserving wildlife. The smart system could detect environmental changes and respond accordingly without human intervention.

In this work, an intelligent animal detection system, namely SafePath, is proposed. The system is equipped with sensors such as Passive Infrared (PIR) and thermal cameras for detecting animals based on movement and body temperature. The system also includes an LDR (Light Dependent Resistor) for ensuring operation during nighttime. When an animal is detected, the street light changes color from white to red for alerting drivers. In addition, wireless communication devices are also used for alerting other streetlights, creating a chain of alerting drivers. The proposed system is implemented as a mini project with an emphasis on implementation and enhancing road safety.

2. OBJECTIVES

- Analyze the road conditions in forest areas that are prone to animal-vehicle collisions.
- Identify animal movement using PIR and temperature sensors based on animal movement and heat detection.
- Allow the system to function in low-light conditions using an LDR.
- Design smart streetlights that change color from white to red as a warning signal.

- Integrate wireless communication in streetlights using NRF24L01.
- Make it energy-efficient using solar power.
- Assess the effectiveness of the system in improving road safety.

3. LITERATURE REVIEW

Recent research has focused on the importance of smart streetlights and IoT in ensuring road safety and efficiency in terms of power consumption. Fouad Agramelal et al. (2023) emphasized the advancements in the control of automated streetlights, while Merina Susan Cherian et al. (2024) emphasized the importance of intelligent power management systems in the field of streetlights. Zhang et al. (2018) demonstrated the effectiveness of PIR sensors in detecting wildlife, while Kumar et al. (2019) emphasized the importance of energy efficiency using Arduino technology in the field of streetlights. Singh et al. (2020) emphasized the importance of wireless communication in the field of streetlights, where data sharing is possible.

Recent research has also emphasized the importance of computer vision, deep learning, and thermal imaging in the detection of animals, ensuring accurate detection even in low-light environments. The proposed SafePath concept relies on the concepts of animal detection, adaptive lighting, wireless communication, and solar power, ensuring the safety of the road and wildlife in the environment.

4.SYSTEM ARCHITECTURE AND COMPONENTS

The system begins by detecting the environment through the use of sensors that are installed around the road. An LDR sensor detects whether it is night or not, ensuring that the system functions only when necessary. Next, PIR sensors and thermal sensors detect the animals depending on the movement and body temperature, respectively. The ESP32 microcontroller receives the information from the sensors and determines whether an animal is present or not, acting as the brain of the entire system. If an animal is detected, the streetlight changes its color from white to red to warn the driver.

At the same time, the NRF24L01 wireless communication module sends signals to the streetlights, ensuring that they also turn red, acting as a chain of warnings along the road. As the animal moves away, the streetlight returns to its normal condition automatically. The entire system uses solar power and batteries, ensuring that it functions in the environment without harming it in any way. Therefore, the entire system functions as an efficient solution to the problem of animal safety on the road.

5.METHODOLOGIES

5.1 Data Collection

The process starts with collecting data on the environment concerning animal movement around roads. The system collects real-time data from various sensors, such as PIR sensors and heat cameras, that sense animal movement and heat. Other relevant information, such as intensity of light, is collected using an LDR sensor to determine whether it is day or night.

5.2 Data Preprocessing

The collected data is then preprocessed to eliminate noise and irrelevant signals. The system is designed to ensure that irrelevant movements are filtered out, such as wind or other irrelevant movements. The intensity of light is used to ensure that the system operates at night.

5.3 Feature Extraction

Key features are extracted from the collected data. The system uses various sensors, such as PIR sensors that sense animal movement, as well as heat cameras that sense heat, thereby improving accuracy, especially during night or when it is foggy.

5.4 Detection and Decision Making

The processed data is then sent to the ESP32 microcontroller. The microcontroller then analyzes all the inputs and determines whether an animal is present or not. This is based on certain conditions that have been previously defined.

5.5 System Implementation

Once an animal has been detected, the system will then be implemented. This is done by implementing the response mechanism. The RGB street light will then turn red from white, alerting drivers. At the same time, the NRF24L01 wireless module will be used to alert other street lights.

5.6 Result and Performance Analysis

The performance of the system is based on how well it detects animals and responds accordingly. The performance of the system is also based on certain parameters. The system has been implemented in such a way that it will always work. This is due to the ability of the system to reset itself when an animal leaves.

6. IMPLEMENTATION

The implementation of the system is a smart hardware-based system that automatically detects animals near the road using intelligent streetlights. The system is implemented using various techniques that ensure smooth operation. The main modules that are part of this system are as follows:

The major modules include:

1. Setup of Smart Streetlight Unit.
2. Development of Animal Detection System.
3. Implementation of Alert and Communication Mechanism.

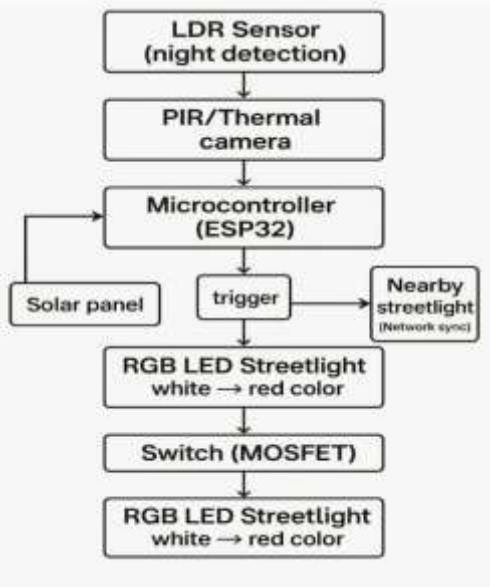
6.1 Setup of Smart Streetlight Unit

The smart streetlight unit is part of this system that performs all functions required by this system. The smart streetlight unit is equipped with various components such as ESP32, LDR sensor, PIR sensor/thermal camera, RGB LED streetlight, NRF24L01, MOSFET switches, solar power unit, etc. The LDR sensor is used to ensure that this system operates during night hours. The ESP32 is used to control all operations within this system. The RGB LED streetlight is normally white color but turns red when detecting an animal. The solar power unit is used to ensure that this system is always on with power through a rechargeable battery.

6.2 Development of Animal Detection System

The animal detection system is developed in such a way that it can identify the animal by tracking the movements of the animal and the heat produced by the animal's body. The PIR sensors help track the movements of the animal, while the heat sensors help improve the accuracy of the detection by tracking the body heat of the animal, especially when the environment is dark or when it is foggy. The data obtained from the sensors is constantly monitored, sending the data to the ESP32 microcontroller.

6.2.1 Block Diagram



6.3 Implementation of Alert and Communication Mechanism

When the animal is detected by the system, the system alerts the drivers by changing the color of the streetlight from white to red, cautioning the drivers who are approaching the spot. At the same time, the system sends signals to the other streetlights in the road through the NRF24L01 wireless module, which helps the other streetlights change their colors to red, creating a chain alerting the drivers of the presence of an animal on the road. The system returns to normal when the animal moves away.

7. RESULT AND FEATURES

The SafePath smart streetlight system works by monitoring and detecting road conditions and animal movement. The accuracy of animal detection is enhanced by proper calibration and efficient filtering. The smart streetlight system responds instantly when an animal is detected by changing the color of the streetlight from white to red and turning other streetlights using wireless communication. This shows that the smart streetlight system has an instant response mechanism and effectively covers a wider area. The smart streetlight system also works automatically without any human intervention. The sensors detect environmental conditions and alert users, providing clear visual warnings. The smart streetlight system is also energy-efficient, as it operates during nighttime using an LDR and provides continuous operation using solar power.

8. CONCLUSION

The SafePath: Protecting Wildlife with Smart Streetlight project was successful in developing a system that was scalable and efficient enough to detect the movement of animals and alert the driver using smart technology. The workflow was strictly adhered to by the project, which involved sensing, processing, system design, and implementation. As such, the system was effective in detecting the presence of animals near the road and responding accordingly in real-time. The system employed the use of PIR sensors and thermal cameras to effectively detect the presence of animals near the road. Various components such as LDR, ESP32, and wireless modules were integrated into the system to make it operate effectively.

The system was made effective by the integration of solar power, which made the system energy efficient. The system was made more effective by the integration of multiple streetlights, which enabled the development of a chain alert system to make the driver more aware of the road.

The reliability and scalability of the system were ensured through system testing and validation. The system is then ready to be used in actual forest and rural road scenarios. The project, therefore, shows that smart and IoT-based systems can help prevent animal-vehicle accidents, but also that improvements are always necessary as conditions change.

9.APPLICATIONS

The system can be applied across banking, e-commerce, and payment gateways to detect suspicious transactions in real time. Its ability to handle large-scale fraud monitoring ensures that institutions can process high transaction volumes without compromising accuracy. By reducing false positives and negatives, it helps improve customer trust and confidence in digital payments. The system also plays a crucial role in minimizing financial losses, safeguarding both businesses and users. With its scalable architecture, it can be seamlessly integrated into existing financial platforms, making it suitable for deployment in diverse real-world environments. This adaptability ensures that the solution remains effective as transaction patterns and fraud techniques evolve.

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