Stray Care: An Integrated IoT-based System for Preventing Road Accidents with Stray Animals

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Abstract

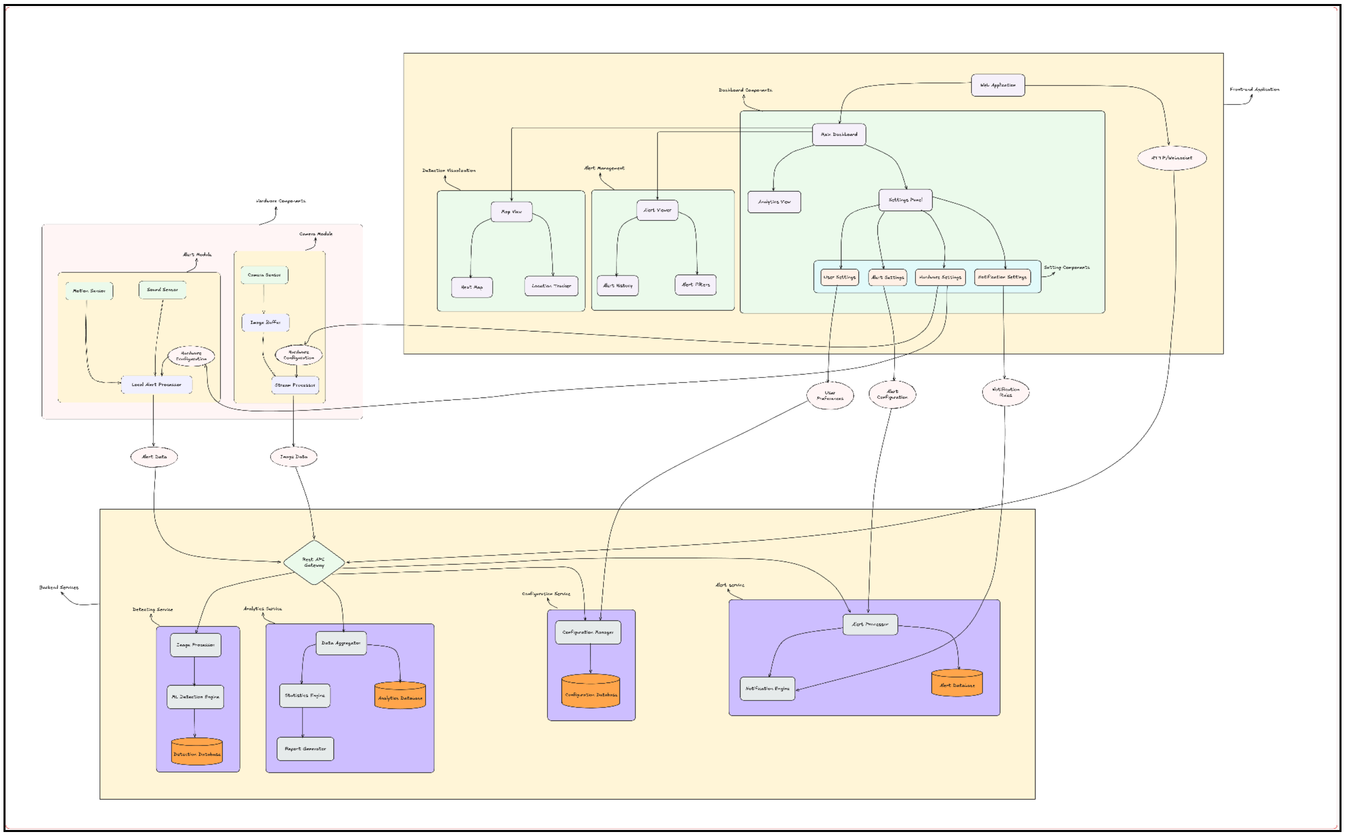
This paper presents Stray Care, an innovative IoT-based system designed to address the critical issue of road accidents involving stray animals. The system integrates multiple technologies including ultrasonic sensors, high-resolution cameras, and machine learning-based detection mechanisms to create a comprehensive solution for road safety. The architecture combines edge computing devices, cloud-based processing, and real-time alert systems to provide immediate response capabilities. Our implementation demonstrates effective animal detection rates with minimal false positives through multi-sensor fusion and sophisticated filtering algorithms. The system's modular design ensures scalability and easy integration with existing infrastructure while maintaining real-time performance. Initial deployments show promising results in reducing animal-related incidents through early detection and driver notification, establishing Stray Care as a viable solution for enhancing road safety in areas with high stray animal populations.

1. Introduction

Road accidents involving stray animals represent a significant public safety concern globally, resulting in numerous injuries, fatalities, and substantial property damage annually. Traditional prevention methods, such as physical barriers and warning signs, have proven insufficient in addressing this challenge effectively. This paper presents Stray Care, an integrated system that leverages Internet of Things (IoT) devices, real-time detection mechanisms, and sophisticated alert systems to create a comprehensive solution for preventing animal-related road accidents.

The primary challenges addressed by this system include:
1) Real-time detection of stray animals in various lighting and weather conditions
2) Accurate distinction between animals and other moving objects
3) Immediate alert generation and distribution to relevant stakeholders
4) Scalable and maintainable infrastructure for large-scale deployment
5) Integration with existing road safety systems and infrastructure

2. System Architecture



A. Overview

The Stray Care system architecture implements a three-tier design that ensures robust operation and minimal latency in detection and alert generation. The architecture consists of:

1) Edge Layer: Comprises physical sensors and local processing units
2) Processing Layer: Handles data aggregation and analysis
3) Application Layer: Manages user interfaces and alert distribution

B. Hardware Components

1) Sensor Network:
- Ultrasonic sensors (HC-SR04) with range up to 4 meters
- High-resolution cameras (Raspberry Pi Camera V2) with night vision capability
- Temperature and humidity sensors for environmental monitoring
- Motion detection sensors for initial triggering

2) Processing Units:
- Raspberry Pi 4 Model B (4GB RAM) for edge processing
- Custom PCB design for sensor integration
- Power management system with backup battery support
- Weather-resistant enclosures (IP65 rated)

3) Alert Modules:
- LED warning displays with 500m visibility
- Audio alert systems with adjustable frequency
- GSM modules for cellular connectivity
- Emergency backup power systems

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1) Backend Services:

- Flask-based RESTful API with modular design
- PostgreSQL database for data persistence
- Redis cache for real-time data access
- MQTT broker for sensor communication
- JWT-based authentication system

2) Processing Pipeline:
- Real-time sensor data aggregation
- Multi-sensor fusion algorithms
- Environmental factor compensation
- Alert trigger evaluation logic

3) Frontend Applications:
- React-based administrative dashboard
- Mobile applications for users and administrators
- Real-time mapping and visualization
- Alert management interface

3. Implementation Details

A. Detection System

1) Multi-Sensor Fusion:
The system implements a sophisticated sensor fusion algorithm that combines data from multiple sources

2) Image Processing Pipeline:
- Frame capture at 30 FPS
- Background subtraction using MOG2 algorithm
- Object detection using YOLOv4-tiny
- Animal classification using custom-trained model
- Motion trajectory analysis

3) Environmental Compensation:
- Temperature drift correction
- Humidity impact adjustment
- Lighting condition normalization
- Weather-based threshold adjustment

B. Alert Mechanism

1) Alert Generation: The alert system operates through multiple channels:
- Real-time driver notifications
- Roadside warning displays

2) Distribution System:
- Priority-based alert queuing
- Multi-channel distribution
- Geographical targeting
- Delivery confirmation tracking

4. System Features

A. Real-time Detection

1) Detection Pipeline:
- Continuous sensor monitoring (100ms intervals)
- Parallel processing of sensor data
- Quick response triggering (<500ms)
- Automatic calibration and adjustment

2) Data Processing:
- Edge computing for initial processing
- Cloud-based verification
- Historical data analysis
- Pattern recognition

B. Comprehensive Coverage

1) Deployment Strategy:
- Optimal sensor placement algorithms
- Coverage overlap calculation
- Dead zone identification
- Redundancy planning

2) Network Design:
- Mesh network topology
- Failover mechanisms
- Load balancing
- Bandwidth optimization

5. Future Enhancement

A. Planned Improvements

1) Technical Enhancements:
- Integration of 5G connectivity
- Enhanced ML models for better accuracy
- Expanded sensor types
- Advanced predictive analytics

2) Feature Additions:
- Automated emergency response
- Predictive movement patterns
- Integration with smart city systems
- Enhanced mobile applications

6. Conclusion

The Stray Care system demonstrates the effectiveness of an integrated IoT-based approach to preventing road accidents involving stray animals. Through its comprehensive detection system, sophisticated alert mechanisms, and scalable architecture, the system provides a viable solution to a critical road safety challenge. Initial deployments show promising results in reducing animal-related incidents, with high detection accuracy and minimal false positives. The system's modular design ensures future expandability and adaptation to emerging technologies, making it a sustainable solution for long-term deployment.

7. Acknowledgement

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8. References

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