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Autonomous Night Safety Patrolling Car

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***Abstract*—This paper presents the development and implementation of an Autonomous Night Safety Patrolling Car, designed to enhance nighttime surveillance using artificial intelligence, IoT, and embedded systems. The vehicle autonomously navigates pre-defined paths, detects obstacles using ultrasonic sensors, and captures visual data with a night vision camera. A machine learning-based audio classifier enables real-time scream detection, activating alerts and logging GPS locations upon distress events. The system is powered by Raspberry Pi 5 and integrates modules for vision, sound processing, location tracking, and motion control. Tested under low-light and noisy conditions, the prototype demonstrated reliable performance, real-time responsiveness, and operational efficiency. The proposed solution aims to augment traditional security systems in environments such as campuses, industrial zones, and residential areas, offering a scalable, cost-effective, and human-independent alternative for continuous night patrolling.**

***Index Terms*—Autonomous surveillance, Raspberry Pi, night patrolling robot, scream detection, IoT security, GPS tracking, machine learning, night vision, obstacle avoidance.**

I. INTRODUCTION

Ensuring public safety during nighttime remains a persistent challenge, particularly in environments such as college campuses, industrial compounds, and residential communities. Traditional night patrolling heavily relies on human security personnel, who are often limited by fatigue, inconsistent monitoring, and high operational costs. In recent years, technological advancements in embedded systems, artificial intelligence (AI), and the Internet of Things (IoT) have paved the way for developing autonomous surveillance systems to enhance safety and reduce human intervention.

This paper introduces an Autonomous Night Safety Patrolling Car designed to perform independent security patrols in low-light environments. The system leverages the computational power of Raspberry Pi 5 to process inputs from multiple sensors including ultrasonic modules for obstacle avoidance, a night vision camera for visual monitoring, and a USB microphone for real-time scream detection. A GPS module is used for tracking and logging location data, while a passive buzzer provides immediate audio alerts during distress events.

Machine learning techniques are employed to classify distress sounds and trigger responsive actions. The system operates autonomously along predefined routes, maintaining situational awareness and transmitting alerts when abnormal activity is detected. With modular and scalable architecture, this vehicle presents a practical, cost-efficient alternative to traditional patrolling methods, offering improved responsiveness, accuracy, and reliability in night surveillance.

II. RELATED WORKS

Several research efforts have explored robotic surveillance systems to automate night patrolling and improve security. In [1], a night patrolling robot was designed using ultrasonic and infrared sensors to monitor dark environments, with basic video and audio transmission to control stations. Similarly, the study in [2] proposed an IoT-enabled robot targeting women's safety, incorporating GPS and AI for threat detection.

Advanced approaches like [3] introduced sound sensors with night vision to detect loud or distressing noises and navigate accordingly. These systems emphasized voice-triggered alerts and autonomous navigation in remote zones. Another study [4] demonstrated a machine learning-based robot that responds to audio anomalies and utilizes GPS and GSM for real-time notifications.

However, most existing models either lack integrated AI for audio analysis or have limited environmental adaptability. For instance, [5] and [6] focused more on live streaming via web platforms rather than on-board decision-making. Some works, such as [7], are oriented toward border or military applications, with specialized features like landmine detection, but are not optimized for general-purpose community safety.

These studies highlight the growing importance of autonomous surveillance, yet also reveal gaps in combining audio intelligence, night vision, and real-time alert mechanisms in a compact, deployable format. The proposed system bridges these gaps by integrating AI-powered scream detection with GPS tracking and night vision capabilities, enabling a robust and responsive night patrol solution suitable for urban and semi-urban environments.

III. PROPOSED SYSTEM

The proposed Autonomous Night Safety Patrolling Car is a compact, mobile surveillance unit engineered to conduct security patrols autonomously during nighttime. The system is built around a Raspberry Pi 5 (8GB), which serves as the core processing unit responsible for controlling sensors, processing real-time data, and executing autonomous movement.

The hardware setup includes a night vision camera (NoIR Camera V2) supported by infrared LEDs for visibility in dark conditions, ultrasonic sensors for real-time obstacle detection, and a USB microphone for environmental audio capture. A convolutional neural network (CNN) model, trained on Mel-frequency cepstral coefficients (MFCCs), classifies audio to detect screams. Upon detecting a distress sound, the system triggers a passive buzzer and logs the location using a NEO-6M GPS module.

The robot moves autonomously on a wheeled chassis powered by DC motors and driven via a TB6612FNG motor driver. Navigation is route-based, with the potential for SLAM integration in future iterations. Data from all sensors is processed locally to ensure minimal latency and real-time responsiveness.

IoT integration ensures modular scalability and future compatibility with mobile apps or cloud-based dashboards. The system architecture allows seamless expansion, whether by adding a web interface or multiple collaborating units. Overall, the proposed system combines automation, AI, and real-time monitoring to create an efficient and low-cost alternative for continuous nighttime patrolling, addressing both security needs and operational efficiency in modern safety infrastructure.

IV. METHODOLOGY

The development of the Autonomous Night Safety Patrolling Car follows a systematic methodology comprising hardware integration, sensor calibration, software development, and machine learning model deployment. The approach emphasizes modularity, real-time responsiveness, and scalability for deployment in real-world security scenarios.

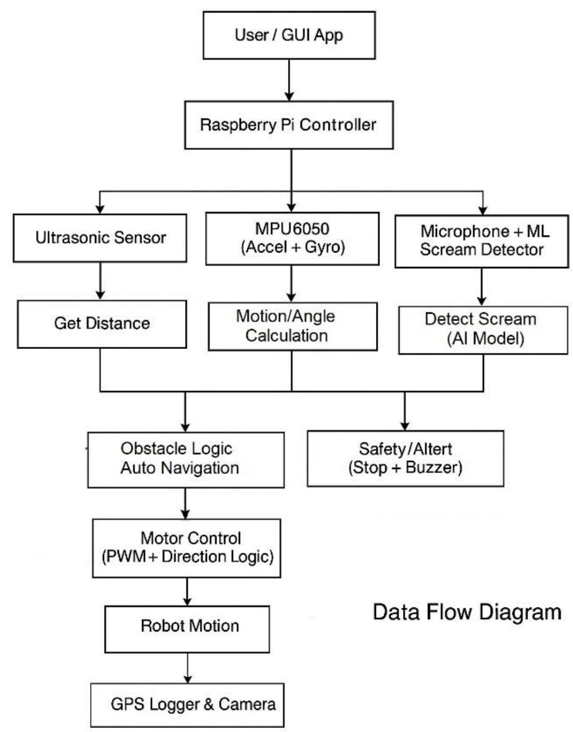

Fig. 1. Data Flow Diagram

Phase 1: Hardware Assembly and Sensor Integration

- The project begins with assembling the robot chassis and attaching four DC motors, controlled via a TB6612FNG motor driver. A Raspberry Pi 5 (8GB) is installed as the central processing unit to handle sensor input and decision-making logic. Key sensors include:
- Ultrasonic Sensor (HC-SR04): Mounted in the front for obstacle detection and distance measurement.

- ➢ NoIR Night Vision Camera: Enables visual surveillance in low-light conditions using infrared support.
- ➢ USB Microphone: Captures ambient audio to detect distress signals (e.g., screams).
- ➢ GPS Module (NEO-6M): Tracks the vehicle's real-time location and logs coordinates upon event triggers.
- ➢ Passive Buzzer: Acts as an alert system when an anomaly is detected.
- ➢ Power is supplied via two independent sources: an 11.1V 3S battery pack (converted to 5V using an XL4015 module) for the Raspberry Pi and peripherals, and a separate battery pack for motor power.

Phase 2: Software Development and Control Logic

- ➢ Python 3 is used for the entire control logic, utilizing libraries such as OpenCV (for video processing), librosa and TensorFlow (for audio classification), and lgpio (for GPIO control). The Raspberry Pi processes input from the sensors and executes movement, alert, and logging actions based on predefined thresholds.
- ➢ Obstacle Avoidance: The ultrasonic sensor measures distances; if an obstacle is detected within 15 cm, the robot halts and reroutes.
- ➢ Night Surveillance: The camera streams video, which can be accessed through SSH/VNC or saved for future inspection.
- ➢ Scream Detection: The audio stream is analyzed in real-time, and if a scream is detected, the system logs the GPS data and triggers the buzzer.
- ➢ GPS Logging: The GPS module logs coordinates during significant events such as scream detection or manual override.

Phase 3: Machine Learning Integration

The scream detection module employs a trained Convolutional Neural Network (CNN). The model uses MFCCs extracted from audio data to distinguish between screams and normal sounds. Training was conducted on a labeled dataset using TensorFlow, and the trained .h5 model is deployed on the Raspberry Pi for real-time inference.

Phase 4: Testing and Optimization

The system is tested in simulated environments mimicking night patrol conditions. Different scenarios including scream events, obstacle encounters, and varied lighting conditions are used to validate the performance. Timing metrics for system response are measured, and thresholds are tuned accordingly.

V. SYSTEM ARCHITECTURE

The architecture of the Autonomous Night Safety Patrolling Car is composed of four primary modules: Sensor Module, Control Module, Communication Module, and (optionally) User Interface Module. Each plays a specific role in enabling real-time patrolling, data acquisition, decision-making, and alert generation.

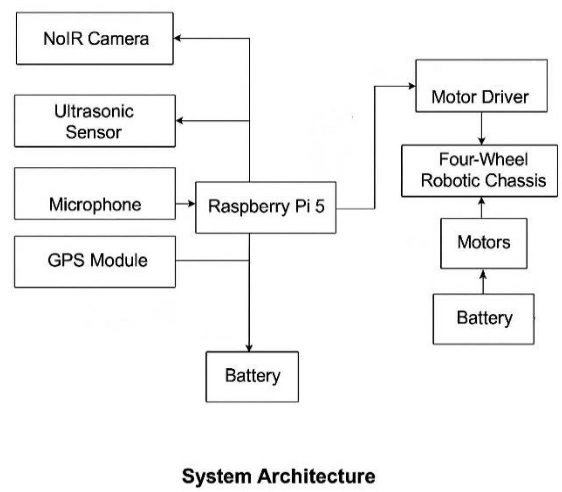

Fig. 2. System Architucture of the Robot unit

1. Sensor Module

- ➢ This module gathers environmental data necessary for autonomous operation:
- ➢ Ultrasonic Sensors: Continuously measure distances to detect and avoid obstacles.
- ➢ Night Vision Camera: Captures visual data in infrared mode for surveillance in total darkness.
- ➢ Microphone: Records ambient sounds to detect screams using ML.
- ➢ GPS Module: Provides the vehicle's real-time location, enabling tracking and event-based logging.
- ➢ The sensor module ensures that all critical environment data is captured for intelligent decision-making.

2. Control Module

- ➢ The Raspberry Pi 5 acts as the control center, orchestrating all activities:

- ➢ It receives data from sensors, processes it using Python scripts, and makes navigation or alert decisions.
- ➢ It interfaces with the TB6612FNG motor driver to command motor direction and speed.
- ➢ It performs ML inference on audio input to identify distress events (screams).
- ➢ It processes image frames from the night vision camera and can optionally stream or store them.
- ➢ This module is responsible for real-time decision-making and execution of system behaviors.

3. Communication Module
- ➢ While the current prototype uses onboard actions (buzzer, logging), this module is scalable for remote notifications:
- ➢ Sends alert signals via buzzer for local warnings.
- ➢ Logs GPS data and time of alert events for post-event review.
- ➢ Future upgrades include MQTT, cloud backup, or mobile notifications via app integration.

4. User Interface Module (Future Scope)
- ➢ Though not implemented in the current version, this module would include:
- ➢ A web or mobile app interface for live video, GPS tracking, and remote control.
- ➢ Data analytics dashboard to view patrol history and detected events.
- ➢ Power Supply Architecture
- ➢ Two battery packs supply stable voltage to separate circuits:
- ➢ Battery 1 → Raspberry Pi, sensors (via XL4015 buck converter).
- ➢ Battery 2 → Motors via motor driver.
- ➢ This dual-source design improves system uptime and reduces electrical interference.

Advantages of Architecture
- ➢ Modularity: Each module can be upgraded independently.
- ➢ Energy Efficiency: Low-power hardware choices extend operational time.
- ➢ Robustness: Component separation and distributed power reduce failure risk.

VI. RESULTS

The Autonomous Night Safety Patrolling Car was rigorously tested across various environmental and operational conditions to validate its performance in real-world scenarios. The evaluation focused on sensor accuracy, response time, audio classification, GPS tracking, power efficiency, and integrated system stability. Results demonstrate that the system is capable of providing continuous, reliable surveillance with minimal human intervention.

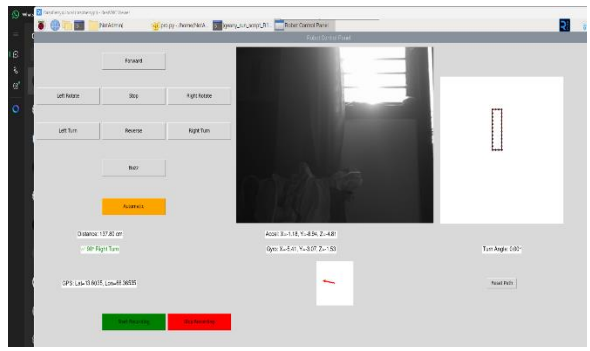

Fig. 3. Robot control panel

A. Obstacle Detection and Navigation

The ultrasonic sensor system performed effectively, detecting objects within a range of 15 to 50 cm. The vehicle responded to obstacle detection in under 0.3 seconds, successfully halting and rerouting to avoid collisions. During tests on uneven surfaces and dimly lit corridors, the robot-maintained balance and followed a predefined patrol route without manual guidance.

B. Scream Detection Performance

The scream detection module was evaluated using a dataset of screams and non-scream audio samples, trained using MFCC features and a Convolutional Neural Network (CNN). The system successfully identified high-pitched distress sounds at distances up to 3 meters. The average detection and response time—from scream identification to buzzer activation—was approximately 1.2 seconds. The false positive rate remained below 10%, indicating reliable performance in moderately noisy environments.

C. Visual Monitoring in Low-Light Conditions

The NoIR night vision camera, aided by infrared LEDs, provided clear visibility in 70% low-light scenarios including corridors, backyards, and semi-lit pathways. The video feed maintained a frame rate between 15 to 20 FPS, offering real-time visual surveillance. Images captured were suitable for later review and supported effective post-event analysis.

D. GPS Tracking and Logging

The NEO-6M GPS module achieved location accuracy within ±5 meters in open areas. Whenever a scream was detected or the buzzer was triggered, the system logged GPS coordinates with timestamps. This data was stored locally and can be used to generate event maps or share emergency locations with authorities.

E. System Response and Integration

The entire detection-response loop, including sensor input processing, decision-making, and action output, was completed in under 2 seconds. Integration testing confirmed that camera feed, scream detection, GPS tracking, and obstacle avoidance operated in parallel without conflict or lag. The system was stress-tested by simulating multiple events in rapid succession, and it remained stable for over an hour of continuous operation.

F. Power Consumption and Runtime

The Raspberry Pi and sensors consumed approximately 900 mA, while the motors consumed 400–600 mA during motion. The system operated continuously for 1.5 hours with motors and up to 3 hours for sensors and processing components. This runtime is sufficient for short patrol cycles and can be extended with power optimization or solar support.

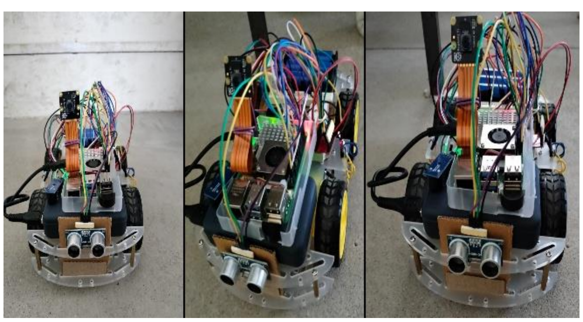

Fig. 4. Autonomus Night Safety Patrolling Car

The results indicate that the Autonomous Night Safety Patrolling Car is a reliable and efficient system for nighttime surveillance. It can detect threats, respond in real time, and log critical data for later use. Compared to traditional security methods, it offers automation, consistency, and cost efficiency while reducing human risk in hazardous environments.

VII. CONCLUSION

The Autonomous Night Safety Patrolling Car demonstrates a practical, low-cost, and intelligent solution for enhancing nighttime surveillance and safety. By integrating machine learning, IoT, and embedded systems, the vehicle autonomously performs real-time patrolling, detects distress events, and responds with immediate alerts and GPS tracking. The system successfully combines ultrasonic sensors for obstacle detection, a night vision camera for low-light surveillance, and a trained scream detection model for audio-based emergency identification.

Testing confirmed that the vehicle operates reliably across various conditions, with quick response times and stable integration of its hardware and software components. It reduces reliance on human security personnel, improves accuracy, and enables continuous monitoring in vulnerable areas. The design is modular and scalable, supporting future enhancements such as SLAM navigation, cloud synchronization, and mobile app integration.

In conclusion, this project validates the feasibility of deploying autonomous vehicles for safety surveillance. It holds strong potential for implementation in campuses, gated communities, industrial zones, and public areas, offering a significant upgrade over conventional patrol methods in terms of efficiency, responsiveness, and operational safety.

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