

ABSTRACT

The Autonomous Smart Rover is an integrated IoT and AI/ML-based intelligent vehicle designed to enhance campus automation, safety, and visitor interaction. The system incorporates autonomous navigation, real-time obstacle classification, uniform detection for students, and voice-based guest reception features, making it a multipurpose robotic solution suitable for modern educational institutions.

The rover uses an ESP32-based control architecture combined with an ESP32-S3 AI camera module to perform onboard machine learning inference for visual recognition tasks. For navigation, the vehicle continuously collects data from ultrasonic sensors, a camera, and a mmWave radar human presence sensor. These sensors together enable the rover to detect obstacles such as walls, objects, insects, and people with high accuracy. A decision-making algorithm determines the rover's behavior based on the detected obstacle: it reroutes itself when a non-human obstacle appears, but immediately stops and performs additional analysis when a person is identified. This ensures a safe, environment-aware autonomous movement system suitable for real-world campus conditions.

A major component of the rover's intelligence is the student uniform detection system. Using the AI camera and a trained deep-learning model, the rover captures a student's frame and classifies whether the student is fully uniformed, partially uniformed, or not wearing the required uniform. Based on the classification, the system provides verbal feedback using a DFPlayer-based audio output module. Fully uniformed students receive positive reinforcement such as "Super — fully uniformed!", whereas violations trigger the response "You are not in full college uniform. Get out from the college." This automated uniform-checking mechanism reduces manual monitoring effort and supports institutional discipline.

In addition to its surveillance and navigation capabilities, the rover serves as an intelligent guest reception assistant during special events. It can greet visitors with pre-programmed voice messages such as "Welcome, Sir!" or "Please follow me," and guide them to designated locations on campus. The combination of high-torque Johnson motors, a heavy-duty metal chassis, precise servo-based pan-tilt camera movement, and long-range Wi-Fi amplification ensures smooth, stable operation across varying environments.

This project demonstrates the powerful integration of IoT hardware, embedded systems, computer vision, sensor fusion, and machine learning on edge devices. By combining autonomous driving, intelligent human detection, interactive audio

feedback, and AI-powered uniform recognition, the Smart Rover represents a complete cyber-physical system capable of real-time decision making and autonomous service delivery. Its modular design and scalable architecture make it suitable for future extensions such as facial recognition, RFID-based student logging, security patrolling, or campus delivery tasks. Overall, the Autonomous Smart Rover showcases how AI and IoT can transform traditional campus operations and contribute toward smarter, safer, and more automated educational ecosystems.