International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Real-Time IoT-Based Monitoring and Alert System Using Image Processing for Emergency Vehicles

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Submitted: 02/09/2024 **Revised:** 10/10/2024 **Accepted:** 22/10/2024

ABSTRACT: In countries with dense traffic like India, emergency vehicles (EVs) frequently encounter delays due to civilian drivers trailing them closely to bypass congestion. This illegal tailgating behaviour poses serious safety threats and delays life-saving responses. Despite its prevalence, monitoring and enforcement remain minimal. This paper presents an innovative, real-time detection and penalty system integrated into emergency vehicles. It utilizes RFID (Radio Frequency Identification) tags, distance-measuring sensors, and on board image processing to identify unauthorized followers. By filtering scenarios based on traffic light conditions and congestion levels, the system ensures fair enforcement. Its deployment promises to improve emergency response efficiency and promote disciplined traffic behaviour.

Keywords: *Emergency Vehicle, Emergency Vehicle Assistance, RFID Technology, IoT-Based Traffic Enforcement, Smart Surveillance, E-Challan, Intelligent Transportation System (ITS)*

I. INTRODUCTION

India consistently records among the highest traffic accident rates globally, with over 449,000 accidents reported in 2019 alone, resulting in substantial fatalities and injuries [1]. One underreported yet dangerous contributor is the unauthorized following of emergency vehicles (EVs) by civilian drivers, who exploit their priority movement through traffic. This opportunistic behaviour not only hinders emergency response efforts but also jeopardizes road safety.

Existing traffic enforcement mechanisms largely rely on manual surveillance and static infrastructure, which are neither scalable nor responsive enough to address this issue in real-time. To counteract this, we propose a smart enforcement solution embedded within EVs. This system leverages RFID identification, proximity sensors, and onboard image processing units to autonomously detect, log, and report violations without human intervention.[9]

II. RELATED WORK

Past studies have proposed a variety of smart traffic and surveillance systems. Shobayo et al. implemented a vehicle number plate recognition solution using OpenCV on Raspberry Pi for parking automation [3]. Other research explored mobile apps designed to notify emergency contacts in the event of a crash [4].

IoT-enabled adaptive traffic light systems that adjust signal durations based on vehicle density have been developed to enhance flow efficiency [5]. Optical Character Recognition (OCR) techniques have been successfully used in license plate reading for applications in parking, security, and tolling [6]. Some systems also employed RFID and Zigbee modules to monitor stolen vehicles and streamline VIP vehicle movements [7][8].

Despite these advancements, none specifically focus on detecting and penalizing illegal tailgating behind emergency vehicles from within the EV itself a critical gap this study aims to fill[11].

III. PROPOSED SYSTEM

A. System Architecture

The proposed model comprises:

- Dual cameras (front and rear) for video capture
- Ultrasonic or infrared distance sensors for real-time spacing measurement
- RFID readers capable of reading passive RFID tags installed in civilian vehicles[14]

Fig. 1: Moving Emergency Vehicle when other vehicle trying to chase or overtake

All components are connected to a central microcontroller or single-board computer (e.g., Raspberry Pi), which processes sensor input, evaluates context (traffic conditions, signal states), and triggers enforcement actions [26].

B. Operational Scenarios

1. **Active Movement under Green Signal**:
When the EV is in motion under a green signal and a vehicle intrudes within a predefined unsafe distance, the system issues two sequential warnings:

- Warning 1: Visual alert (e.g., flashing or blinking light)
- Warning2: Audio alert (beeping or vibrant sound)

If the trailing vehicle persists, the system captures an image, scans the RFID tag, and sends an electronic challan (e-fine) to the registered owner's mobile and email.[26]

2. **Idle EV at Red Light** :
While the EV is stop at a red light, the system remains inactive to avoid false positives, acknowledging that vehicles naturally queue close in such conditions.

3. **Congested or Blocked Traffic:**
During dense traffic, the system assesses motion data. If the EV is unable to move freely, enforcement protocols (image capture and e-memo generation) are temporarily suspended to prevent inaccurate violations.[20]

C. Functional Workflow

1. Distance sensors continuously monitor the gap behind the EV.
2. If a violation is detected:
   - A two-stage alert system is activated.
   - Persistent violations trigger RFID scanning.
   - Vehicle details are cross-verified with a centralized database.
   - An e-memo is issued automatically.
3. The system checks real-time traffic light status via on board traffic signal detection or API integration with smart traffic lights.
4. All events, including images and logs, are securely transmitted to the Regional Transport Office (RTO) and stored on a centralized server.[18][19]

Input:

- Distance between EV and following vehicle (d)
- Traffic Signal State (signal_state)
- EV Motion State (ev_motion)
- RFID tag data from nearby vehicles
- Traffic congestion status (is_congested)

Output:

- Alert warnings
- Image capture
- RFID logging
- E-Memo issuance

Steps:

1. **Initialize system components:**
   - Activate front and rear cameras

- Initialize distance sensors, RFID reader, and image processing module
- Connect to traffic signal API (if available)

2. **Continuously monitor EV state:**
   - Read ev_motion
   - Read signal_state
   - Read distance d from distance sensors
   - Check is_congested
3. **If EV is moving AND signal is GREEN:**
   - If d < safe_distance_threshold:
     - Issue **Warning 1** (visual: blinking LED/light)
     - Wait for a short delay (e.g., 2 seconds)
     - Recheck distance d
     - If still d < safe_distance_threshold:
     - Issue **Warning 2** (audio: beep or sound alert)
     - Wait again
     - Recheck d
     - If still tailgating:
     - Capture image of trailing vehicle
     - Read RFID tag of vehicle
     - Fetch vehicle details from database
     - Check signal_state and is_congested
     - If not congested:
     - Generate **e-memo**
     - Send to vehicle owner (via SMS/email)
     - Log image and data on central server
     - Else:
     - Discard detection (false positive prevention)
4. **If EV is idle AND signal is RED:**
   - Disable detection temporarily (avoid false triggers)
5. **If traffic is congested:**
   - Pause enforcement action to avoid penalizing vehicles with no room to move
6. **Loop back to Step 2 continuously**

IV. SYSTEM ADVANTAGES

- The proposed system is designed to identify vehicles that unlawfully follow emergency vehicles at close distances. It can issue alerts through multiple channels, thereby supporting improved traffic flow and promoting safer road conditions.
- Vehicle speed estimation has been effectively achieved using RPM (Revolutions Per Minute) measurements. Additionally, image processing techniques have been employed to detect traffic signals and extract vehicle number plate information. After extensive testing, the system has shown around 70% accuracy under daylight conditions.
- To enhance system capabilities, a GSM module has been incorporated to transmit alerts and warnings to vehicles ahead. This real-time communication proves especially useful in congested traffic situations, contributing to better traffic coordination. The system has exhibited reliable performance in such scenarios.[22]

V. CONCLUSION AND FUTURE ENHANCEMENTS

The system is capable of detecting vehicles that follow emergency vehicles too closely and can issue warnings through various methods. This functionality significantly contributes to enhanced traffic management and improved road safety.

We have successfully measured vehicle speed using RPM (Revolutions Per Minute) counting techniques. Through the use of image processing, the system can identify traffic signals and recognize number plates. After numerous trials, we have achieved approximately 70% accuracy in daylight conditions.

To further enhance functionality, a GSM modem has been integrated into the system to send alerts and notifications to vehicles ahead, thereby improving communication and safety during traffic congestion. The model has demonstrated effective performance in high-traffic environments [23].

Future Scope

In future iterations, the system can be integrated with FASTag technology to automatically capture and verify vehicle details. Expanding the implementation to two-wheelers could further strengthen traffic monitoring and control.

Moreover, the system can be refined to prioritize emergency vehicles, enabling the provision of

timely medical assistance during traffic jams. Incorporating advanced technologies such as radar systems and more sophisticated sensors could further improve detection accuracy and overall system reliability.[24]

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