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Smart City Traffic Management and Vigilante Detection using IoT and Open CV

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***Abstract*— Traffic congestion and public safety remain two of the most pressing concerns in today's fast-growing cities. Long queues at traffic signals waste time and fuel, increase pollution, and frustrate commuters, while security threats demand quicker and more reliable law enforcement responses. This paper introduces a practical, low-cost solution that tackles both problems together—an IoT and OpenCV-based Smart City Traffic Management and Vigilante Detection System.**

Our system uses infrared (IR) sensors to continuously monitor traffic density on each lane. Instead of relying on rigid signal timers, it adjusts green light durations in real time—5 seconds for moderate traffic and 8 seconds for heavier congestion—guided by a priority-based algorithm. If traffic builds up on multiple lanes, predefined rules decide the sequence, and in the event of prolonged jams, the system automatically issues rerouting alerts to ease the bottleneck.

On the security front, a facial recognition module built with OpenCV, Haar-Cascade classifiers, and the Face Recognition library scans live video from surveillance cameras, comparing detected faces against a stored criminal database. If a match is found, the system instantly retrieves the person's details, pinpoints their GPS location via the GEOPY library, and emails an alert—with photo and information—to law enforcement.

Developed using an Arduino Uno, Python-based processing, and a wireless camera, the system demonstrated perfect accuracy in IR-based vehicle detection, reduced average wait times by 14% over fixed-timing signals, and reliably triggered criminal alerts during testing.

By combining smart traffic control with real-time criminal detection in a single platform, this approach offers a scalable blueprint for safer, more efficient cities. Future upgrades aim to incorporate AI-driven traffic prediction, deep learning-based face recognition, and cloud-based analytics for seamless, city-wide operation.

***Keywords*— Intelligent Traffic Management, OpenCV, IoT, IR, Density-Based Traffic Control, Facial Recognition, Criminal Detection, Smart City.**

I. INTRODUCTION

Traffic congestion is a growing concern in Indian cities, where inefficient traffic management leads to de-lays, fuel wastage, and increased pollution.

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Traditional traffic signal systems operate on fixed timers, often failing to adapt to real-time traffic conditions. This not only causes unnecessary waiting times but also re-sults in traffic bottlenecks, especially during peak hours. A more intelligent and adaptive approach is need-ed to enhance urban mobility and reduce congestion. Urban security and traffic inefficiencies challenge law enforcement. Integrating computer vision and IoT can automate traffic control and enhance surveil-lance, improving safety and efficiency. This paper presents a Smart City Traffic Management and Criminal Detection System that utilizes Infrared (IR) sensors for real-time traffic density analysis and OpenCV-based facial recognition for criminal detection. The system is built on a web camera, which captures live video feeds and processes them using OpenCV & Haar-Cascade Algorithm. If a recognized criminal is de-tected, the system automatically sends their GPS location and identification details to the relevant authori-ties, enabling quick response actions. By integrating IoT, artificial intelligence (AI), and intelligent traffic control, this system aims to make urban areas more efficient and secure. The proposed solution is cost-effective, scalable, and adaptable to different city infrastructures, making it a viable approach for modern smart cities.

II. Literature Review

S. Duraipandi et al. [1] proposed a real-time traffic management system using various IoT devices and techniques to address the challenges posed by outdated traffic systems. The system utilizes IR sensors placed on either side of the road to detect and monitor traffic density, relaying this information to an Ar-duino controller for processing, which then determines when to change the traffic lights. I. N. Mahmood et al. [2], aim to solve traffic jams and inefficient traffic management with their work which uses IR sensors, magnetometer sensor and cameras to gauge traffic density and assign traffic lights accordingly. Their demonstration has all lights red initially and when the designated threshold for density is reached at a spe-cific side the Arduino prompts to that respective side to change to green. If two or more sides relay thresh-old reached signal then the system changes lights on the basis of (FIFO) First In First Out Model. M Ven-katesh et al. [3], proposes an automated face recognition system to enhance criminal detection and preven-tion in response to rising crime rates in public and private places. The system leverages a combination of advanced technologies like the Local Binary Patterns Histogram (LBPH) classifier, the Fisher face algo-rithm and HAAR Cascade classifier is used to detect faces. The system is implemented using Python and OpenCV. The system is fed with criminal database and algorithms are performed on it. The system can then be used to detect criminal faces in real-time and match them against the database. By utilizing these two approaches, he improved the accuracy, precision, recall, and F1 score of his facial recognition system yielding a high accuracy of 98 percent. S. Salunke and S. Bang [4] propose a smart traffic management sys-tem with data acquisition, processing, and control modules that utilize advanced computational algorithms to manage traffic light timings. The system showcases the use of Artificial Intelligence (AI) and the Internet of Things (IoT) in urban traffic management. The Integrated Traffic Management System (ITMS), based on AI and IoT technologies, emerges as a comprehensive solution for enhancing traffic safety and efficiency.

Yusuf Patanwala et al. [5] developed a Smart Traffic Management System using various hardware compo-nents in IoT. Traffic optimization is achieved through an IoT platform by dynamically allocating varying signal durations based on the vehicle count on the road. The system is designed to efficiently address con-gestion and facilitate re-routing at intersections. S. Javaid et al. [6] highlight that with increasing population growth and urban mobility in metropolitan cities, traffic congestion is a common issue. To address various challenges in traffic management and assist authorities in effective planning, this paper proposes an IoT-based smart traffic management system. A hybrid strategy, combining centralized and decentralized ap-proaches, is employed to optimize traffic patterns, and an algorithm is developed to efficiently manage dif-ferent traffic scenarios.

P. Thakre et al. [7] present a novel dynamic traffic signal system that utilizes an array of sensors and an IoT-based emergency override feature to adjust signal timings based on traffic density while ensuring the safety of emergency vehicles. The paper also provides a detailed description of the digital circuit design and Verilog implementation, enabling efficient multi-lane management. The findings demonstrate that the system can significantly enhance traffic management efficiency. V. Sreevani et al. [8] propose a criminal identification method using image recognition, which holds significant importance in law enforcement and public safety. Key benefits of this approach include enhanced crime detection, improved accuracy and re-liability, real-time monitoring and alerts, and increased public safety and deterrence. S. Usmonovir et al. [9] propose an intelligent and connected system utilizing smart cameras at road intersections to enhance traffic management in urban areas. The system improves safety for emergency vehicles by enabling onboard units (OBUs) to communicate with signal controllers as an emergency vehicle approaches an in-tersection. A secure and reliable gateway is responsible for receiving data from sensors and forwarding it to the traffic management system for efficient decision-making.

L. A. Elrefaei et al. [10] present a study on criminal face detection, achieving real-time performance by computing integral images for cascaded windows. The proposed face detection and tracking system is eval-uated using two feature extraction methods: Fast Corner Features and Regular Features with the Optical Flow algorithm. Additionally, the paper focuses on a side-face detection and tracking system during the capturing process, allowing users to preview face tracking functionality in real-time conditions. A. K. Sirivarshitha et al. [11] discuss the use of the OpenCV library as a popular and straightforward method for facial recognition in Python. OpenCV utilizes a collection of XML files, known as cascades, to identify objects. Once configured with the desired cascade, the program automatically performs face detection. The appearance-based method, which relies on a set of trained face images, is used for face recognition. This approach demonstrates superior performance compared to other recognition techniques.

III. Methodology

We developed our system by first implementing "Vigilante Detection" and "Traffic Management" separate-ly before integrating them. To demonstrate the system, we utilized the components configured as shown in Fig. 1, with the block diagram represented by Fig. 2 and circuit diagrams presented by Fig. 3 and Fig. 4.

A. Components Required

- IR Sensors: We used IR sensors for object detection in our system.
  - IR1 & IR2 - Lane 1 IR
  - IR3 & IR4 - Lane 2 IR
  - IR5 & IR6 – Lane 3 IR
- Led Lights: We used LEDs to simulate traffic lights, 3 on each intersection, totaling 9.
- Arduino Uno: We used Arduino uno as our microcontroller.

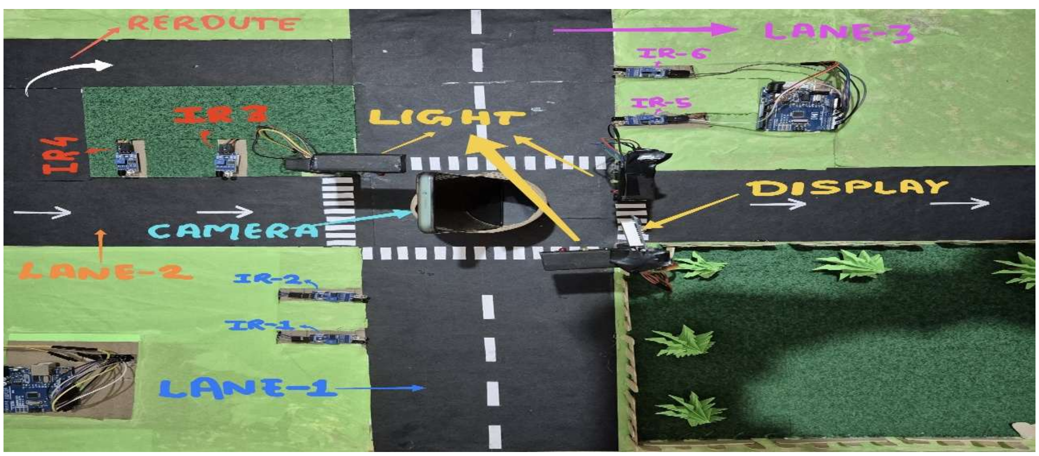

Fig. 1. Our Model and Configuration.

- 7 Segment Display: We used seven segment display for emergency rerouting signaling.
- Web Cam (Wireless): For Criminal detection part we used Web Cam (Phone camera) to simulate CCTVs.
- Open – CV: For video capture & face detection.
- Face Recognition: For biometric comparison.
- Pandas: For managing the vigilante data stored in excel.
- SMTP: For sending email alerts.
- GEOPY: For live location data.

B. Circuit Diagram

We use a model with 3 road intersection of which two are two lane and the other one is single lane. Two IR sensors are placed on each lane one after another with the one near footpath acting as first density level and the farther one as second. Traffic lights are also there for each lane. The system is connected with Ar-duino for operation.

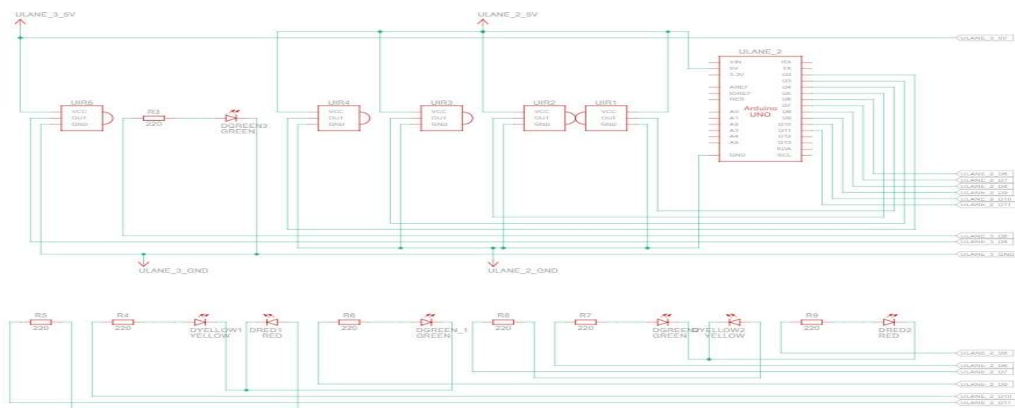

Fig. 2. Lane 1 and Lane 2 Circuit diagram

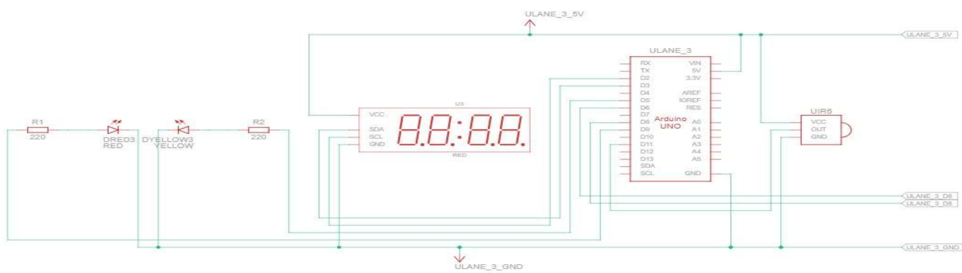

Fig. 3. Lane 3 Circuit diagram.

Implementation of Traffic Management
Priority System
By default, all signals remain red. Lane 3 operates independently to demonstrate rerouting in case of accidents. When a first-level infrared sensor (IR1 for Lane 1, IR3 for Lane 2, IR5 for Lane 3) detects a vehicle, that lane turns green for 5 seconds while others stay red. If both first- and second-level sensors (IR2, IR4, IR6) detect vehicles, the lane turns green for 8 sec-onds, indicating heavier traffic. In simultaneous detections, priority goes first to the lane with both sensors active over one with a single sensor; if both have full detection, Lane 1 is priori-tized, then Lane 2. The complete algorithm is shown in Fig. 4.

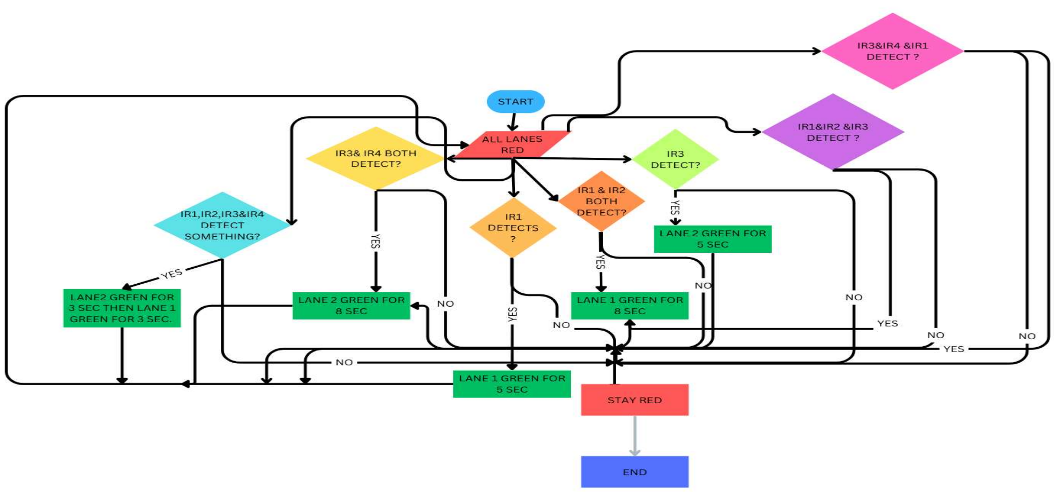

Fig. 4. Algorithm of LANE1 & LANE2.

Rerouting

If all levels of IRs of all sides are detecting vehicles for more than 10 seconds then we assume that accident has happened and the traffic has jammed so we keep all sides red and display “left” for the 2nd lane to let the vehicles know that they have to diverge so that the vehicles on it can reroute and avoid the traffic on the intersection as shown in Fig. 5.

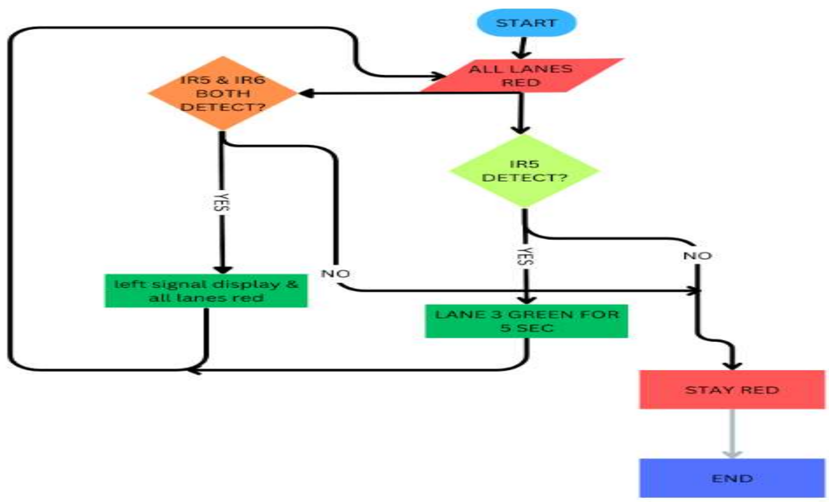

Fig. 5. Algorithm LANE 3

Implementation of Vigilante Detection

For vigilante detection, we use OPEN—CV (Computer Vision) with Haar—Cascade Classifiers and a Face Recognition library algorithm for which is shown in Fig. 6.

- Face Detection: The system captures video frames using OpenCV and detects faces using the Haar Cascade classifier.
- Feature Extraction: The detected face is converted into feature vectors using the Face Recognition library.
- Face Matching: The extracted features are compared with the preloaded criminal database.
- Database Lookup: If a match is found, the system retrieves the suspect’s details from an Excel-based database.
- Geolocation Retrieval: The GEOPY library is used to fetch the suspect’s real-time location (lati-tude and longitude).
- Automated Alert Generation: The system compiles the criminal’s details, location, and captured image into an email alert.
- Email Notification: The system sends the email to law enforcement agencies, enabling quick re-sponse.
- Continuous Monitoring: The system continues real-time surveillance, processing new video frames dynamically.

IV. Results and Discussions

The system was tested on a dataset containing multiple known faces. The face recognition accuracy was found to be dependent on the quality of the images and prevailing lighting conditions; although not perfect-ly accurate, the recognition module functioned effectively under most conditions. Email alerts were suc-cessfully triggered upon detecting a stored criminal, and the geolocation information was accurately re-trieved, as illustrated in Fig. 7. A limitation of the current system is the requirement for manual updates to the criminal database.

The traffic management module was evaluated under various traffic conditions, where the infrared sensors achieved 100% detection accuracy, as summarized in Table I. On average, the proposed system reduced waiting times by approximately 14% when compared to conventional fixed-timing traffic signal systems. The priority-based control logic operated as intended. However, the present system does not yet incorpo-rate priority handling for emergency response vehicles such as law enforcement or ambulances, nor does it address climate-related emergencies such as earthquakes.

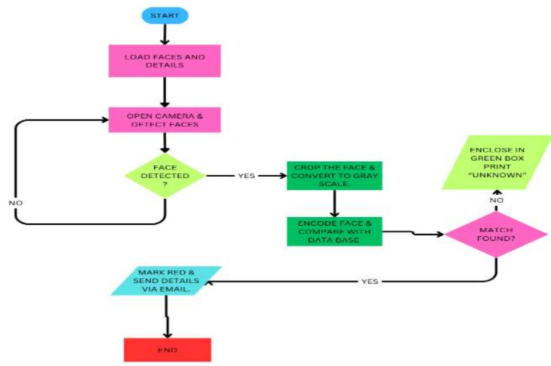

Fig. 6. Algorithm of Vigilante Detection System

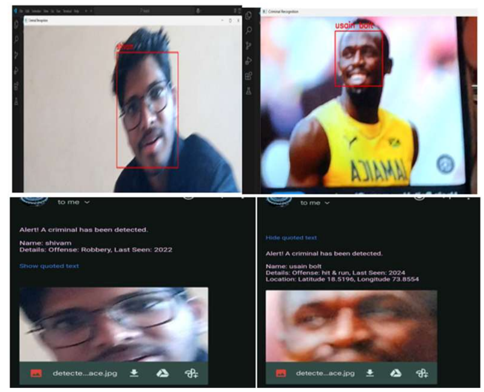

Fig. 7. Successful detection and alert sent

TABLE I: TEST RESULTS

Test Case	Condition	Expected System Response	Actual Response	Pass/Fail
1	No vehicle detected on any lane	All signals remain red.	All signals remain red	PASS
2	IR1(LANE1) detects a vehicle.	Only Lane 1 turns green for 5s.	Only Lane 1 turns green for 5s.	PASS
3	IR1 & IR2 detect vehicles.	Only Lane 1 turns green for 8s.	Only Lane 1 turns green for 8s.	PASS
4	IR1 (Lane 1) & IR3 (Lane 2) detect vehicles simulta-neously	Priority to Lane 1, Lane 1 turns green for 5s, Lane 2 waits.	Lane 1 turned green for 5s, Lane 2 remained red	PASS
5	IR1 & IR2 (Lane 1) and IR3 & IR4 (Lane 2) detect vehicles simultaneously	Lane 1 gets priority (8s), then Lane 2 (8s)	Lane 1 turned green for 8s, followed by Lane 2 8s	PASS
6	IR5 & IR6 (Lane 3) detect vehicles	Lane 3 turns green for 8s	Lane 3 turned green for 8s	PASS
7	All sensors detect vehicles continuously for 10+ sec-onds	Assume accident, all lights red, "Left" displayed for Lane 2	All lights turned red, "Left" displayed for Lane 2	PASS

V. FUTURE SCOPE

Technological advancements will significantly enhance the efficiency and accuracy of our systems. AI models will analyze traffic trends by considering factors such as weather, public events, and live incidents. The integration of big data and cloud connectivity will optimize congestion management, while AI-driven violation detection will improve road safety. Vehicle-to-Infrastructure (V2I) communication will facilitate real-time interactions between vehicles and traffic systems, enabling more intelligent management of an urban environment. Sensors for prioritizing law enforcement and ambulances, as well as sensors for detect-ing earthquakes and fires, can be integrated into this system to enhance smart traffic management.

In the realm of facial recognition, utilizing diverse datasets that encompass various ethnicities, ages, and lighting conditions will ensure greater accuracy. Deep learning methods, particularly Convolutional Neural Networks (CNNs), will enhance facial feature detection, and transfer learning will improve recognition with minimal data requirements. Real-time processing will allow for immediate recognition from live video streams, increasing responsiveness. By connecting surveillance networks and smart cameras, we can boost the efficiency of public monitoring. Ultimately, these technologies will lead to smarter and more reliable traffic management and security systems. The system proposed in [10] can be used for dynamically updat-ing criminal data.

VI. CONCLUSION

This research presents an IoT and OpenCV-based Smart City Traffic Management and Criminal Detection System to enhance urban mobility and security. The system effectively optimizes traffic signals using IR sensors for real-time traffic density analysis, reducing congestion, fuel wastage, and emissions. Additional-ly, the Open-CV recognition module accurately identifies preloaded criminal profiles, ensuring enhanced law enforcement support. The integration of computer vision and IoT demonstrated high efficiency in adaptive traffic control and real-time criminal detection, making it a scalable and cost-effective solution for smart cities. Experimental results highlight significant enhancement in traffic flow and enhanced law enforcement official's response time.

Future enhancements could include cloud-based analytics, machine learning-driven facial recognition improvements, and AI-based predictive traffic management. This study establishes a strong foundation for future innovations in automated urban infrastructure, contributing to safer, more efficient, and intelligent cities.

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