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AI-Based Real-Time Vehicle Crash Detection and Automated Emergency Alert System Using Deep Learning

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ABSTRACT

Road accidents are one of the leading causes of fatalities worldwide, especially in developing countries where timely medical assistance is often delayed. Immediate detection of vehicle crashes and rapid communication with emergency services can significantly reduce mortality rates. This project proposes an **AI-based real-time vehicle crash detection and automated alert system** that leverages deep learning and computer vision techniques to identify accidents from live video streams or recorded footage. The system utilizes a pre-trained deep learning model built using **Tensor Flow Object Detection API** to analyze video frames and detect crash-related patterns. Video input can be sourced from CCTV cameras, dash cams, or stored video files. Each frame is processed and passed through the trained model, which identifies objects and predicts whether a crash event has occurred based on confidence thresholds. The system continuously monitors detection scores and triggers an alert only when consistent crash detection is observed over multiple frames, ensuring reliability and reducing false positives. Once a crash is detected, the system captures relevant frames, enhances image quality, and stores them for further analysis. Simultaneously, it activates an automated alert mechanism that sends notifications via email and SMS to nearby emergency services such as hospitals, police stations, and regional transport offices (RTOs). This dual-alert system ensures redundancy and increases the likelihood of a timely response.

A user-friendly graphical interface is developed using **Tkinter**, allowing users to load video sources, monitor detection results in real time, and visualize system outputs. The interface also displays detection progress and system status updates, improving usability for non-technical users. The proposed system integrates multiple technologies including **Open CV** for video processing, **Tensor Flow** for deep learning inference, and threading for concurrent execution of detection and alert modules. The architecture ensures efficient processing and minimal latency, making it suitable for real-time deployment. Experimental results demonstrate that the system can effectively detect vehicle crashes with high accuracy under varying lighting and environmental conditions. The use of a high confidence threshold and multi-frame validation reduces false alarms

significantly.In conclusion, this system provides an intelligent, automated solution to enhance road safety by enabling rapid accident detection and emergency response. It has the potential to be deployed in smart cities, highways, and traffic surveillance systems to save lives and improve emergency management.

Keywords: Vehicle Crash Detection, Deep Learning, Tensor Flow, Object Detection, Computer Vision, Emergency Alert System, Real-Time Monitoring, Smart Surveillance, Road Safety, Accident Detection

I. INTRODUCTION

Road safety is a critical concern globally, with millions of accidents occurring each year, leading to severe injuries and fatalities. One of the primary challenges in accident management is the delay in detecting crashes and notifying emergency services. Traditional systems rely heavily on human intervention, such as witnesses reporting accidents, which can result in significant delays. To address this issue, there is a growing need for automated systems that can detect accidents in real time and initiate immediate response actions. Advancements in **Artificial Intelligence (AI)** and **Computer Vision** have opened new possibilities for intelligent surveillance systems capable of analyzing visual data and making decisions. Deep learning models, particularly convolution neural networks (CNNs), have shown remarkable performance in object detection and image classification tasks. These technologies can be leveraged to build systems that automatically detect unusual events, such as vehicle crashes, from video streams. This project presents a real-time vehicle crash detection system that uses deep learning techniques to monitor video feeds and identify accident scenarios. The system is designed to process video input frame by frame, extracting relevant features and detecting objects associated with crashes. By using a trained object detection model, the system can distinguish between normal traffic conditions and crash events. A key feature of the proposed system is its ability to reduce false positives by analyzing multiple consecutive frames before confirming a crash. This ensures that temporary anomalies or non-critical events do not trigger false alarms. Once a crash is confirmed, the system captures images of the incident and initiates an alert mechanism.

The alert system is an essential component that enhances the practical applicability of the solution. Upon detecting a crash, the system automatically sends notifications via email and SMS to emergency responders, including hospitals, police, and transport authorities. This ensures that help is dispatched quickly, potentially saving lives. The system is implemented using Python and integrates several powerful libraries such as OpenCV for

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video processing, Tensor Flow for deep learning inference, and Tkinter for graphical user interface development. The use of threading allows simultaneous execution of detection and alert processes, ensuring real-time performance. Additionally, the system provides a user-friendly interface where users can select video sources, view live detection results, and monitor system status. This makes the system accessible to users without technical expertise. In summary, this project aims to bridge the gap between accident occurrence and emergency response by providing an automated, intelligent solution for real-time crash detection and alert generation. It contributes to the development of smart transportation systems and enhances road safety through the use of advanced AI technologies.

II. LITERATURE SURVEY (WITH EXISTING METHODS)

Several research efforts have been made in the field of accident detection using machine learning and computer vision techniques. Early approaches primarily relied on sensor-based systems, such as accelerometers and GPS modules, installed in vehicles. These systems detect sudden changes in motion or impact and send alerts. While effective, they require additional hardware and are not scalable for large areas. With the advancement of computer vision, researchers began exploring video-based accident detection systems. These systems analyze CCTV footage to detect abnormal events. Traditional methods used handcrafted features such as motion vectors, optical flow, and edge detection to identify collisions. However, these approaches were limited in accuracy and struggled in complex environments. Recent studies have focused on deep learning-based methods, particularly convolution neural networks (CNNs), for accident detection. Models such as Faster R-CNN, YOLO (You Only Look Once), and SSD (Single Shot Detector) have been widely used for real-time object detection tasks. These models can detect vehicles, pedestrians, and crash events with high accuracy. For instance, YOLO-based systems have demonstrated excellent performance in detecting accidents in real-time due to their speed and efficiency. Similarly, Faster R-CNN provides higher accuracy but at the cost of increased computational complexity. Researchers have also explored hybrid models that combine object detection with temporal analysis to improve reliability.

Another area of research involves integrating alert systems with detection models. Some studies have implemented automated notification systems that send alerts via GSM modules or internet-based services. These systems aim to reduce response time and improve emergency handling. Despite these advancements, existing solutions face challenges such as false positives, high computational requirements, and limited scalability. Many systems also lack a user-friendly interface and real-time alert capabilities. The proposed system addresses these limitations by combining deep

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learning-based detection with multi-frame validation and an integrated alert mechanism. It also provides a graphical interface for ease of use and supports multiple video sources. Overall, the literature indicates a strong trend towards AI-based solutions for accident detection, highlighting the potential of deep learning in improving road safety and emergency response systems.

III. EXISTING SYSTEM

Existing vehicle crash detection systems can be broadly categorized into sensor-based systems and video-based systems. Sensor-based systems use hardware components such as accelerometers, gyroscopes, and GPS modules installed in vehicles to detect sudden impacts or abnormal motion. When a crash is detected, these systems send alerts to predefined contacts or emergency services. While effective, they require installation in every vehicle, making them costly and difficult to scale. Video-based systems, on the other hand, use surveillance cameras to monitor traffic conditions. Traditional video-based approaches rely on image processing techniques such as motion detection, background subtraction, and optical flow analysis to identify abnormal events. However, these methods often fail in complex scenarios involving occlusions, varying lighting conditions, and dense traffic. Recent advancements have introduced deep learning-based approaches that use neural networks for object detection and event recognition. Although these systems offer improved accuracy, many of them are computationally intensive and require high-end hardware. Additionally, some systems generate false alarms due to lack of proper validation mechanisms. Another limitation of existing systems is the absence of integrated alert mechanisms. Many solutions focus only on detection and do not provide automated communication with emergency services. This reduces their effectiveness in real-world applications.

Furthermore, most existing systems lack user-friendly interfaces, making them difficult to operate and monitor. They also do not support real-time processing efficiently, leading to delays in detection and response. In summary, current systems face challenges related to scalability, accuracy, cost, and usability. These limitations highlight the need for an improved solution that combines accurate detection, real-time processing, and automated alert generation in a single integrated system.

IV. PROPOSED METHOD

The proposed system is an **AI-based real-time vehicle crash detection and automated emergency alert system** designed to overcome the limitations of traditional accident detection methods. It leverages deep learning and computer vision techniques to detect crash events from video streams and initiate immediate alert mechanisms.

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The system uses a pre-trained deep learning model built on object detection frameworks such as **Region-Based Convolution Neural Networks (R-CNN)** and **Tensor Flow Object Detection API**. The model processes video frames captured from CCTV cameras, dash cams, or stored video files. Each frame is analyzed to detect objects and identify crash-related patterns using bounding boxes, class labels, and confidence scores.

To improve accuracy and reduce false positives, the system implements a **multi-frame validation mechanism**, where crash detection is confirmed only after consistent detection across multiple consecutive frames. This approach ensures that temporary disturbances or non-critical events are not misclassified as crashes. Once a crash is detected, the system captures the relevant frames, enhances the image quality, and stores them for evidence and further analysis. Simultaneously, an automated alert system is triggered. This system sends notifications via email and SMS to emergency services such as hospitals, police stations, and transport authorities, ensuring a rapid response.

The system also includes a **Graphical User Interface (GUI)** developed using Tkinter, enabling users to monitor real-time detection, select video sources, and view system updates. The use of threading allows concurrent execution of detection and alert modules, ensuring efficient performance. Overall, the proposed system integrates detection, validation, and alert mechanisms into a single framework, making it a scalable and effective solution for smart traffic monitoring and road safety enhancement.

V. IMPLEMENTATION

The implementation of the vehicle crash detection system is carried out using Python, integrating multiple libraries and frameworks such as Tensor Flow, OpenCV, NumPy, and Tkinter. The system is divided into several modules, including video processing, model loading, object detection, visualization, and alert generation. The first step involves loading the pre-trained deep learning model using Tensor Flow. The model is stored in a saved model format and loaded using tf.saved_model.load(). A progress bar is displayed using Tkinter to indicate the loading status, enhancing user experience. Once the model is loaded, the system captures video input using OpenCV's cv2.VideoCapture() function. The input can be a live camera feed or a pre-recorded video file. Each frame is read, flipped if necessary, and converted into RGB format for processing. The frame is then converted into a tensor and passed to the detection model. The model outputs detection results, including bounding boxes, class labels, and confidence scores. These outputs are filtered based on a predefined threshold to ensure only high-confidence detections are considered.

The detected objects are visualized on the frame using OpenCV functions such as cv2.rectangle() and cv2.putText(). The system continuously monitors detection results

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and increments a counter when crash-related objects are detected. If the detection persists for a specified number of frames, the system confirms the occurrence of a crash. Upon confirmation, the system captures the region of interest (ROI) and enhances the image using resizing and sharpening filters. The processed images are saved for documentation purposes. Simultaneously, a separate thread is initiated to handle alert generation. The system sends email notifications using SMTP protocols and SMS alerts using integrated APIs. These alerts contain information about the detected crash and the source of the video. The GUI, developed using Tkinter, displays the video feed, detection results, and system status. A canvas is used to render frames in real time, and labels are updated dynamically to inform the user about system operations. The system also records the processed video with detection overlays using OpenCV's VideoWriter, enabling post-analysis. Overall, the implementation ensures real-time performance, modularity, and scalability by combining deep learning, computer vision, and user interface technologies.

VI. ALGORITHMS

The proposed system utilizes a combination of deep learning and computer vision algorithms for accurate crash detection. The primary algorithm used is a **Convolution Neural Network (CNN)-based object detection model**, implemented through Tensor Flow's Object Detection API. The detection process begins with frame extraction from the video stream. Each frame is passed through the CNN model, which performs feature extraction using multiple convolution layers. These layers identify spatial features such as edges, shapes, and object structures. The system employs object detection algorithms such as **R-CNN or SSD**, which generate bounding boxes and classify objects within the frame. Each detected object is assigned a confidence score, representing the probability of correct detection. To enhance detection reliability, a **thresholding algorithm** is applied. Only detections with confidence scores above a predefined threshold (e.g., 0.92) are considered valid. This reduces noise and improves precision. A **multi-frame confirmation algorithm** is implemented to minimize false positives. The system maintains a counter that increments when a crash is detected in consecutive frames. If the counter reaches a specific threshold (e.g., 20 frames), the system confirms a crash event.

Additionally, image processing techniques such as resizing and filtering are applied to improve image quality. A sharpening filter enhances important features within the detected region. Recent research suggests that combining deep learning with temporal models such as Hidden Markov Models and Kalman Filters can further improve crash detection accuracy by analyzing motion patterns over time. Overall, the algorithm integrates spatial feature extraction, object detection, thresholding, and temporal validation to achieve robust and reliable crash detection.

VII. SYSTEM DESIGN

The system architecture is designed as a modular and scalable framework that integrates video processing, deep learning-based detection, and alert mechanisms. The system consists of five major components: input module, processing module, detection module, alert module, and user interface. The **input module** is responsible for acquiring video data from various sources such as CCTV cameras, webcams, or stored video files. OpenCV is used to capture and preprocess video frames. The **processing module** handles frame conversion, resizing, and transformation into tensor format. This module ensures that the input data is compatible with the deep learning model. The **detection module** is the core component of the system. It uses a pre-trained Tensor Flow model to perform object detection on each frame. The model identifies vehicles and detects crash events based on learned patterns. The module also includes a validation mechanism that analyzes multiple frames before confirming a crash. The **alert module** is activated when a crash is detected. It consists of two subcomponents: email alert and SMS alert systems. The email alert system uses SMTP protocols to send notifications, while the SMS system uses APIs to send messages. These alerts are sent to predefined emergency contacts, ensuring rapid response.

The **user interface module** is developed using Tkinter. It provides a dashboard for users to interact with the system, select video sources, and monitor detection results. The interface displays real-time video, detection labels, and system status updates. The system also includes a **data storage component**, where detected images and videos are stored for future analysis. This helps in documentation and evidence collection. To ensure real-time performance, the system uses **multithreading**, allowing simultaneous execution of detection and alert processes. This reduces latency and improves efficiency. Modern research emphasizes the importance of integrating temporal and spatial features for improved crash detection accuracy, highlighting the effectiveness of hybrid architectures in intelligent transportation systems. Overall, the system design focuses on modularity, scalability, and real-time performance, making it suitable for deployment in smart cities and traffic monitoring systems.

SYSTEM DESIGN IMAGES

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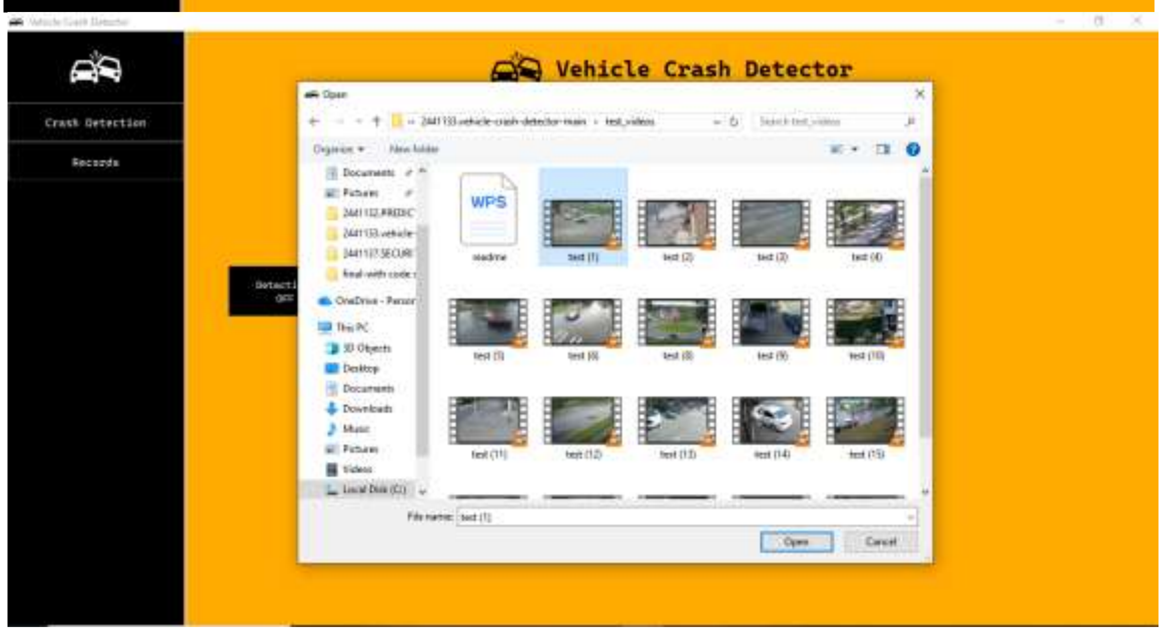

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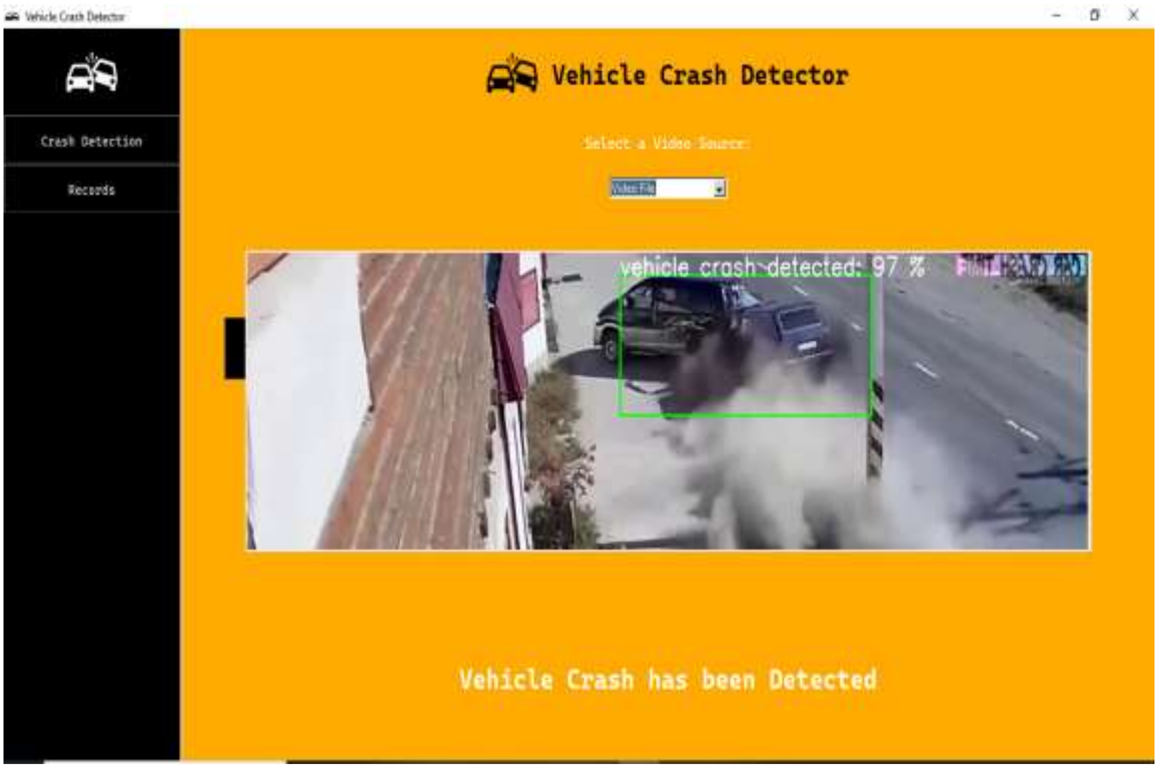

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VIII. CONCLUSION

The proposed AI-based vehicle crash detection and alert system provides an effective solution to enhance road safety and emergency response. By leveraging deep learning and computer vision techniques, the system can accurately detect crash events in real time and initiate immediate alert mechanisms. The integration of Tensor Flow-based object detection models with OpenCV enables efficient processing of video streams and accurate identification of crash-related patterns. The use of multi-frame validation significantly reduces false positives, ensuring reliable detection. One of the key strengths of the system is its automated alert mechanism, which sends notifications via email and SMS to emergency services. This feature ensures timely response and has the potential to save lives by reducing delays in accident reporting. The system's modular architecture and user-friendly interface make it easy to deploy and operate. The use of threading enhances performance by enabling concurrent execution of detection and alert processes.

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Despite its advantages, the system has some limitations. It relies heavily on the quality of video input and may face challenges in low-light or highly congested environments. Future improvements can include the integration of advanced models such as Vision Transformers and temporal analysis techniques to enhance accuracy. Recent advancements in deep learning and intelligent transportation systems indicate a strong potential for further improvements in crash detection accuracy and scalability. In conclusion, the proposed system demonstrates the potential of AI in improving road safety and emergency response systems. It provides a foundation for future research and development in intelligent traffic monitoring and accident management systems.

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