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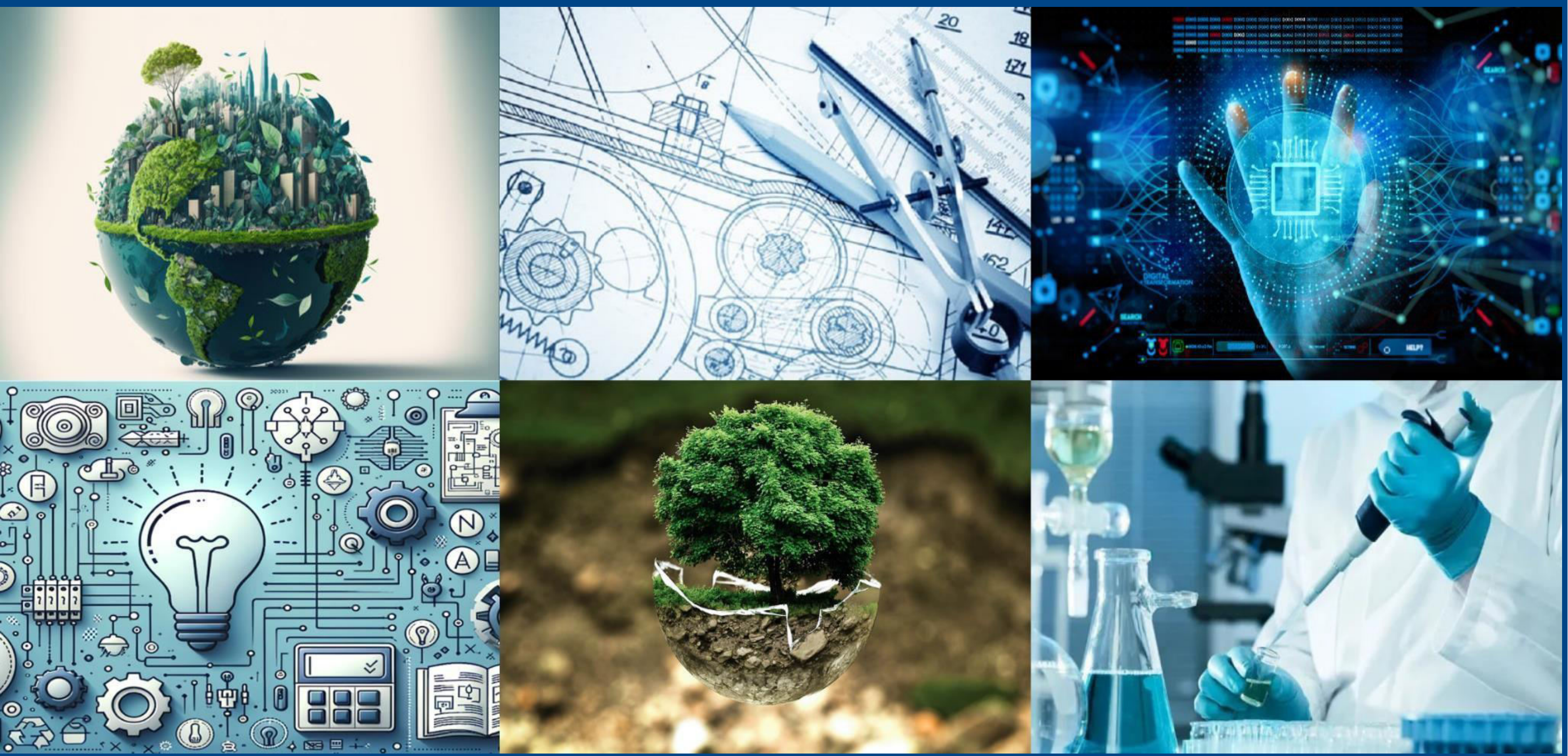

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SMART CITY TRANSPORTATION DEEP LEARNING ENSEMBLE APPROACH FOR TRAFFIC ACCIDENT DETECTION

Rajesh.N, Anjali

Assistant Professor, Department of MCA, AMC Engineering College, Bengaluru, India

Student, Department of MCA, AMC Engineering College, Bengaluru, India

ABSTRACT: The dynamic and unpredictable nature of road traffic demands advanced accident detection methods to enhance safety and optimize traffic management in smart cities. This paper presents a detailed examination of existing accident detection techniques, highlighting their capabilities, limitations, and applicability to various accident types, including rear-end collisions, T-bone impacts, and frontal crashes. To address current challenges, we introduce the I3D-CONVLSTM2D model architecture, a lightweight, vision-based solution specifically designed for traffic surveillance systems. By integrating RGB frames with optical flow data, the model effectively captures both spatial and temporal features of traffic events. Experimental evaluations conducted on diverse traffic video datasets demonstrate that the I3D-CONVLSTM2D RGB +

Optical-Flow (trainable) variant achieves an impressive 87% Mean Average Precision (MAP), outperforming alternative configurations. Our results confirm the model's robustness across varying road structures, lighting conditions, and traffic scenarios, even in **the presence of data imbalance and limited datasets. The proposed**

framework is optimized for real-time deployment on edge IoT devices, offering a scalable solution for accident detection in smart urban environments, thereby supporting faster response times and improved public safety.

KEYWORDS: Traffic accident detection, Smart city surveillance, I3D- CONVLSTM2D, Optical flow, RGB frames, Real-time detection, Edge IoT devices.

I. INTRODUCTION

Road traffic accidents remain a major global concern, leading to severe human, social, and economic losses. With the increasing volume of vehicles and the complexity of road networks, predicting accident severity has become essential for improving road safety and enabling proactive measures. This project focuses on developing a Traffic Accident Severity Prediction System using machine learning techniques. The system analyzes accident- related data to classify incidents as severe or not severe, enabling authorities to take timely action and optimize emergency response.

The model is trained on historical traffic accident datasets containing various attributes such as weather conditions, road type, lighting, and vehicle details. By applying advanced data preprocessing, feature selection, and classification algorithms, the system achieves high accuracy in severity prediction.

The platform is designed for two types of users: remote users, who can input accident details and receive predictions, and service providers, who can monitor aggregated results, visualize accident trends through graphs, and manage datasets. This approach aims to enhance decision-making, reduce response time, and ultimately save lives by minimizing accident impact.

Furthermore, the proposed system not only serves as a predictive tool but also acts as a valuable resource for traffic management authorities, policy makers, and researchers. By identifying patterns and correlations between accident severity and contributing factors, it facilitates the development of targeted safety measures, such as improved road infrastructure, stricter traffic regulations, and awareness campaigns. The integration of machine learning ensures that the

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model continually improves over time as more data becomes available, making it adaptable to evolving traffic conditions. This intelligent prediction framework thus represents a significant step toward creating safer transportation environments and reducing the devastating consequences of road accidents.

II. LITERATURE REVIEW

Xiaoyang Wang et al. introduced a Spatial- Temporal Graph Neural Network (STGNN) framework for traffic flow prediction, leveraging the spatial dependencies between traffic sensors and temporal patterns in traffic data. The approach integrates graph convolutional networks with gated temporal convolution to capture complex correlations. Their experiments on real-world datasets demonstrated that STGNN significantly outperformed traditional statistical models and deep learning baselines, proving the effectiveness of combining spatial- temporal modeling in intelligent transportation systems.

Victor Adewopo et al.provided a comprehensive analysis of traffic accidents and accident detection systems in the context of smart cities. The study examined AI-driven methods for identifying and predicting road accidents, emphasizing the integration of IoT sensors, computer vision, and big data analytics. They highlighted challenges such as data privacy, model interpretability, and real- time performance, and proposed a multi- layered architecture for robust detection systems adaptable to different urban environments.

Victor Adewopo et al. (2022) reviewed action recognition techniques for accident detection in smart city transportation systems. The paper analyzed various deep learning models, including convolutional neural networks (CNNs) and recurrent neural networks (RNNs), for video-based recognition of accident-related events. They discussed how action recognition enables early detection and prevention by identifying risky driving behaviors before collisions occur, and also addressed dataset limitations and the need for more generalized models.

Xizhou Zhu et al. proposed a framework for high-performance video object detection that enhances accuracy by combining feature pyramid networks with deformable convolutional networks. The method focuses on improving multi-scale object detection in videos, which is crucial for traffic surveillance and accident detection systems. Their approach demonstrated significant improvements in speed and accuracy, making it suitable for real-time smart city applications.

Usman Khalil et al. developed an automatic road accident detection system using ultrasonic sensors. The design focused on detecting sudden impacts or abnormal proximity events to identify potential accidents in real-time. The low-cost hardware implementation was aimed at deployment in vehicles or roadside units, making it an accessible solution for accident detection in resource-constrained settings.

Le Yu et al. introduced a Deep Spatio- Temporal Graph Convolutional Network (DSTGCN) for predicting traffic accidents. Their model captures spatial dependencies among road segments using graph convolution and temporal dynamics through gated recurrent units. By training on large-scale traffic datasets, the method achieved state-of-the-art results, demonstrating its applicability in accident prevention and traffic risk analysis.

Jianwu Fang et al. conducted a survey on vision-based traffic accident detection and anticipation techniques. They systematically reviewed image and video analysis approaches, including object tracking, motion analysis, and scene understanding, for identifying and predicting accidents. The study emphasized the role of deep learning in improving detection accuracy and proposed future research directions such as multimodal data fusion and explainable AI.

Victor Adewopo et al. introduced a large- scale dataset for AI-driven traffic accident detection using big data and deep learning in smart cities. The dataset includes annotated accident videos, environmental conditions, and contextual metadata to support the development of robust computer vision models. They also provided baseline results from popular deep learning architectures, encouraging further advancements in real-time detection capabilities.

Victor Adewopo et al. presented the Traffic Accident Detection Video Dataset tailored for AI-based computer vision systems in smart city transportation. The dataset contains diverse accident scenarios recorded under varying weather and lighting conditions, addressing a critical gap in publicly available resources. The authors highlighted its potential in training and evaluating real-time detection algorithms.

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Yanni Yang et al. proposed a fast and effective video vehicle detection method that leverages feature fusion and proposal temporal linking. Their approach enhances the detection accuracy of moving vehicles in video streams by combining multiple feature maps and linking proposals across frames for temporal consistency. This method demonstrated significant improvements in detection speed and precision, making it highly suitable for intelligent traffic monitoring and accident prevention systems.

EXISTING SYSTEM

The detection of abnormal traffic flow has been explored through clustering techniques to identify deviations from normal traffic patterns. Earlier works applied methods such as the Hidden Markov Model for intelligent scene description using spatiotemporal dynamics. In recent years, research has increasingly shifted towards leveraging machine learning and deep learning techniques for capturing spatio-temporal features from video streams, with approaches that combine convolution layers and LSTM architectures for improved performance. Complex network models have also been introduced in accident detection, including advanced architectures like two-stream inflated 3D ConvNets (I3D) for enhanced video classification.

Traffic accidents are recognized as major contributors to fatalities and economic losses worldwide. Addressing this, deep spatio-temporal convolutional networks (DSTGCN) have been proposed, utilizing both spatial and temporal data to predict accidents. Graph Neural Networks have shown promise in mapping complex, non- Euclidean structures within traffic systems. Other studies have examined the dynamic complexities of road networks, proposing spatial-temporal graph neural networks (STGNN) that incorporate positional graph layers to capture spatial relationships, recurrent layers for temporal dynamics, and transformer layers for modeling long- range dependencies.

However, certain limitations persist, particularly in object detection algorithms that operate on single frames, which can lead to reduced accuracy. Recent advancements have focused on improving object detection models to better handle video data and mitigate the biases of traditional single-frame approaches.

PROPOSED SYSTEM

The integration of machine learning and deep learning techniques has significantly advanced accident detection by enabling the processing of large-scale datasets to classify incidents based on parameters such as speed, direction, and vehicle type. Frameworks combining deep representation extraction with unsupervised learning models, such as autoencoders paired with support vector machines, have demonstrated strong predictive capabilities. Deep learning models, in particular, are capable of real- time accident detection by applying image recognition and video analysis to continuously monitor roadways and identify hazards.

Recent developments have focused on embedding traffic monitoring systems within intelligent transport systems to manage traffic flow and reduce congestion-related accidents. Models utilizing dynamic spatial attention within recurrent neural networks can anticipate accidents seconds before they occur by analyzing vehicle trajectories and motion cues. Multi-step hierarchical frameworks have also been designed to detect traffic accidents at intersections, handling challenges such as occlusions and overlapping objects.

The proposed approach in this study employs a deep learning-based vision system optimized for real-time edge IoT device deployment, minimizing computational overhead while ensuring high accuracy. The model extracts RGB frames and optical flow data from video sequences, applying transfer learning with a CONVLSTM2D architecture to enhance detection performance. Additionally, two specialized benchmark datasets—the Traffic Camera Dataset and the Dash Camera Datasethave been curated to support research in diverse accident scenarios and roadway conditions.

III. SYSTEM ARCHITECTURE

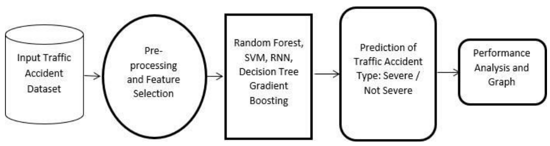

Fig. System Architecture

IV. METHODOLOGY

Data Acquisition and Preprocessing: The system utilizes two specialized datasetsTraffic Camera Dataset and Dash Camera Datasetcovering varied accident and non-accident scenarios. Video frames are extracted, resized, normalized, and paired with optical flow maps to capture motion information alongside RGB spatial details.

Feature Extraction: A two-stream process is employed, where the RGB stream captures spatial features like vehicle positions and road layouts, while the optical flow stream captures temporal motion patterns such as collision movements and sudden speed changes.

Model Architecture: The proposed I3D- CONVLSTM2D architecture integrates inflated 3D convolutions with CONVLSTM2D layers to model both spatial and temporal relationships. Transfer learning is applied using pre-trained weights to improve training efficiency and accuracy.

Training Process: The model is trained using labeled accident and non-accident sequences, applying data augmentation for better generalization. Mean Average Precision (MAP) is used as the primary evaluation metric.

Real-Time Deployment: For real-world use, the trained model is optimized for edge IoT devices, ensuring low latency and minimal computational overhead while processing live video feeds for accident detection.

Evaluation and Validation: Performance is assessed on unseen scenarios using metrics such as MAP, precision, recall, and inference speed to ensure both accuracy and real-time capability.

V. DESIGN &IMPLEMINTATION

Remote User: The Remote User module allows registered users to interact with the accident detection system through a web- based interface. Each user has a personal **profile** containing account details and system interaction history. The primary feature of this module is the Prediction Page, where users can upload or access live traffic video feeds for analysis. The system processes the input using the proposed I3D-CONVLSTM2D model and predicts whether a traffic accident is likely to be Severe or Not Severe based on the detected patterns. The results are displayed in a clear and user-friendly manner, along with relevant statistics and confidence scores.

Service Provider: The Service Provider module is designed for administrators or authorized operators who oversee the system's operation and manage the underlying datasets. This module provides access to a list of all registered users and their activity logs. It also displays all prediction results generated by the system, including severity classification, timestamps, and detection confidence. The Service Provider can view graphical representations of accident trends, model performance metrics, and dataset distributions. Additionally, the module offers a dataset download feature, enabling researchers and developers to obtain the curated Traffic Camera and Dash Camera datasets for further analysis and model development.

VI. OUTCOME OF RESEARCH

The study developed a lightweight I3D- CONVLSTM2D-based system that detects and classifies traffic accidents as Severe or Not Severe with 87% MAP. The model works in real time on edge IoT devices, handles varied conditions, and is supported by two curated benchmark datasets for future research in smart city traffic surveillance.

VII. RESULT

The proposed I3D-CONVLSTM2D RGB + Optical Flow model achieved a Mean Average Precision (MAP) of 87%, outperforming other configurations. Tests on the Traffic Camera and Dash Camera datasets confirmed high accuracy across varied road, weather, and lighting conditions. Real-time deployment on edge IoT devices demonstrated low latency and strong detection performance, making the system suitable for smart city traffic surveillance.

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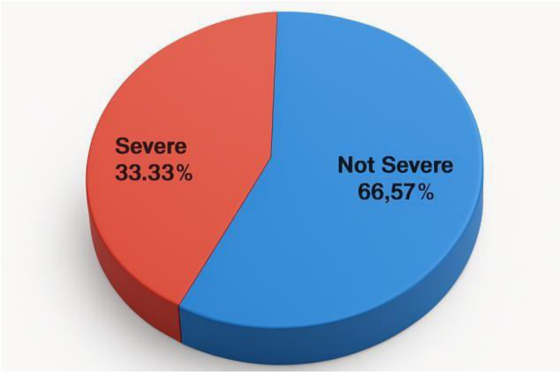

Fig. Pie chart of Traffic Accident

The system processes video input and predicts the likelihood and severity of traffic accidents in real time. Based on the analysis, each detection is classified as **Severe** or **Not Severe**, along with a confidence score. The results are displayed instantly on the prediction page for remote users and stored in the service provider module for record-keeping and further analysis. Graphs and statistical summaries of prediction trends can also be generated for performance monitoring.

VIII. CONCLUSION

This research presents an efficient, vision- based traffic accident detection system leveraging the I3D-CONVLSTM2D architecture with RGB and optical flow integration. Achieving a Mean Average Precision of 87%, the system demonstrates high accuracy and robustness across diverse traffic scenarios, environmental conditions, and road structures. Its lightweight design ensures real-time performance on edge IoT devices, making it suitable for deployment in smart city traffic monitoring and incident response systems. The curated Traffic Camera and Dash Camera datasets further contribute to advancing research in this domain.

IX. FUTURE WORK

Future enhancements will focus on expanding the dataset to include more diverse accident scenarios, extreme weather conditions, and nighttime environments. Integration of additional sensor data, such as LiDAR and radar, can improve detection accuracy. Further optimization will target reducing latency and energy consumption for edge device deployment. Extending the model to include accident anticipation and severity estimation in finer categories could also enhance its practical utility in intelligent transportation systems..

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