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ENSEMBLE DEEP LEARNING FRAMEWORK FOR TRAFFIC ACCIDENT DETECTION IN SMART CITIES

[1]Somireddypalli Maneesh Kumar, MCA Student, Department of MCA

[2] Bushra Tahseen, MCA, (Ph.D), Associate Professor, Department of MCA

[12]Dr KV Subba Reddy Institute of Technology, Dupadu, Kurnool

ABSTRACT

Effective accident detection techniques are essential for improving safety and expediting traffic management in smart cities due to the dynamic and unpredictable nature of road traffic. In addition to providing a thorough overview of various traffic accident types, such as rear-end collisions, T-bone collisions, and frontal impact accidents, this paper provides an in-depth investigation study of popular accident detection techniques, illuminating the subtleties of other cutting-edge approaches. By combining RGB frames with optical flow data, our innovative method presents the I3D-CONVLSTM2D model architecture, a lightweight solution specifically designed for accident detection in smart city traffic surveillance systems. Our experimental study's empirical analysis highlights how effective our model design is. With a remarkable Mean Average Precision (MAP) of 87%, the I3D-CONVLSTM2D RGB + Optical-Flow (trainable) model performed better than its competitors. Our results provide more insight into the difficulties caused by data imbalances, especially when dealing with a small number of datasets, road configurations, and traffic situations. In the end, our study shows the way to an advanced vision-based accident detection system that is ready for immediate incorporation into edge IoT sensors in smart city infrastructures.

I. INTRODUCTION

The detection and prediction of traffic accidents is made more difficult by the interconnectedness of road networks.

The dynamic effect of these incidents, particularly at important crossings, is the complex part of this problem. By improving our capacity to monitor and react to accidents in real-time, the developing discipline of computer vision—which focusses on analysing spatial-temporal patterns—plays a crucial role in tackling these issues. The integration of advanced accident detection and prediction systems into urban infrastructures can greatly improve safety, reduce traffic congestion, lower the frequency of traffic accidents, and improve the general quality of life for city dwellers. This technological advancement is particularly pertinent to the development of smart cities. Every year, 50 million non-fatal injuries and 1.35 million deaths are caused by automobile accidents worldwide [1]. These concerning figures highlight the pressing need for cutting-edge traffic control strategies to enhance urban transport networks' efficiency and safety.

Demand for intelligent transportation systems that can recognise and track a variety of things, including cars, motorbikes, and buses, has increased since the introduction of these systems [2]. The ability to identify and isolate things in individual frames has been significantly improved by object detection in pictures. However, using spatiotemporal data to improve accuracy remains a difficulty for video-based detection systems, which are becoming more and more common in a variety of applications. The use of temporal information for feature extraction in vehicle identification has been studied in the past [3], and other methods have used this information in post-processing phases. The use of sensors for traffic monitoring and accident detection, which may provide useful information for forecasting future traffic conditions, is one of many strategies that have been developed to increase traffic safety and

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lower accident rates [2], [4]. Ultrasonic sensors were suggested by Khalil et al. [4] as a means of automatically detecting traffic accidents. The suggested method uses sound waves to identify impacts with barriers and two ultrasonic sensors to estimate distance. The majority of methods for timely road accident monitoring are still costly and complex in spite of these developments [2]. Modern technologies like GPS, Edge AI, IoT, and security cameras are being used more and more to create and implement deep learning algorithms for the identification of traffic accidents. However, because of intrinsic design restrictions that prevent them from processing sequences from various roadways independently, Recurrent Neural Networks (RNNs), which have historically been employed in these systems, are not very effective at extracting spatial information from traffic data. By combining sequential and geographical data, graph neural networks, on the other hand, provide a viable substitute that makes it possible to analyse traffic patterns in more detail. The study by Le et al. [5] emphasises the significance of road-level accident prediction, recognising that a mix of internal (environment, road type, and road structure) and external (driver behaviour, weather, and traffic volume) factors affect accidents. It is crucial to distinguish between traffic accident detection and traffic anomaly detection in order to connect these cutting-edge technical techniques with real-world traffic management elements. While accident detection is centred on a limited window of traffic accidents defined by occurrences of vehicle crashes and can be categorised as a subset of traffic anomaly, traffic anomaly encompasses a wider range of irregular traffic movements without collisions [6]. The perspective offered by camera angle is crucial in the interpretation and analysis of traffic accidents. This study examines collisions between various vehicle types as well as those in which there is no interaction with another vehicle, omitting motorcycle accidents, and focusses on accidents captured by dash cameras and traffic surveillance. The inherent difficulties in accident detection are highlighted by the diverse character of these accident scenes and the wide range of perspectives that these cameras record. External variables including changing climatic conditions and the dynamic development of accident sites further exacerbate these difficulties.

A. RESEARCH CONTRIBUTIONS

An effective and precise accident detection system is essential in smart city transport systems, where real-time monitoring is essential to maintaining safety. Our research fills important gaps in this field and makes the following innovative contributions:

• Advanced Vision-Based Accident Detection System: Specifically tailored for real-time deployment on edge IoT devices like Raspberry Pi, we present an inventive vision-based accident detection system. Because of its little processing overhead, this system is ideal for traffic monitoring and smart city infrastructures. Its lightweight design effectively combines practical application with computational efficiency, creating an affordable, dependable, and deployable solution for the contemporary smart city.

• Novel Model Architecture: Our study suggests a unique model architecture for video sequences that extracts RGB frames and optical flow information. This model greatly improves accident detection performance by integrating transfer learning methods and the CONVLSTM2D architecture, setting our method apart from other approaches.

The Traffic Camera Dataset and the Dash Camera Dataset are two specialised datasets that we have curated to address the dearth of benchmark datasets in the accident detection space. These datasets are publically accessible at [7] and [8]. These datasets, which are especially designed for accident detection, include a wide variety of situations and road layouts, making them an invaluable tool for further study and advancement in this area.

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The goal of these contributions is to solve current gaps in autonomous transportation systems' scene identification and accident detection. Even though algorithms and modelling of spatiotemporal information in road constructions have advanced [9], [10], [11], and [12], a major obstacle has been the lack of thorough benchmark datasets and assessment criteria. In addition to filling this vacuum, our contributions provide useful methods for identifying traffic incidents in urban environments.

II. LITERATURE SURVEY

"AI on the road: A thorough examination of traffic accidents and smart city accident detection systems,"

M. Ozer, V. Wangia-Anderson, A. Abdelgawad, N. Elsayed, Z. Elsayed, V. Adewopo,

In order to lower the frequency and severity of accidents and enhance traffic management overall, smart city and autonomous transportation systems depend heavily on accident detection and traffic analysis. This study uses data from the National Highway Traffic Safety Administration's (NHTSA) Crash Report Sampling System (CRSS) to provide a thorough examination of traffic accidents in various U.S. areas. This study suggests a framework that makes use of action recognition software and traffic surveillance cameras to automatically identify and react to traffic accidents in order to overcome the difficulties associated with accident detection and traffic analysis. By combining the suggested framework with emergency services, it will be possible to use machine learning algorithms and traffic cameras to react to accidents more quickly and with fewer human mistakes. Traffic management and the severity of traffic accidents will be enhanced by advanced intelligence technologies, such as the suggested accident detection systems in smart cities. All things considered, this research offers insightful information on traffic accidents in the US and offers a workable way to improve the security and effectiveness of transportation networks.

"Examination of action recognition for detecting accidents in smart city transit systems,"

M. Ozer, A. Abdelgawad, Z. ElSayed, N. Elsayed, V. Adewopo, and M. Bayoumi,

One of the most important components of a safer and better community is accident detection and public traffic safety. Using various surveillance cameras to monitor traffic flow in smart cities is essential for identifying accidents and notifying emergency personnel. Digital signal processing, medical imaging, and high-precision video surveillance have all benefited from the use of action recognition (AR) in computer vision tasks. An extensive evaluation of action recognition in accident detection and autonomous transportation systems for smart city applications is presented in this work. This study focused on augmented reality (AR) systems that leverage a variety of traffic video sources, including dash cams, drones, highway monitoring cameras, and static security cameras at crossings. We determined the main methods, classifications, and algorithms used in AR for autonomous driving and accident detection via this research. Additionally, we looked at the datasets used in the AR tasks, determining their main sources and characteristics. In order to reduce human error in accident reporting and enable a prompt response to victims, this paper offers a possible research direction for the development and integration of accident detection systems for autonomous vehicles and public traffic safety systems. These systems notify law enforcement and emergency personnel in the event of traffic accidents.

"Towards video object detection with high performance,"

J. Dai, L. Yuan, X. Zhu, and Y. Wei,

In recent years, there have been notable advancements in visual object identification. Even though video object recognition is more difficult and crucial in real-world situations, it hasn't gotten much attention.This paper, which builds on prior research, suggests a unified method based on the idea of cross-frame motion and multi-frame end-to-end feature learning. With the

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addition of three novel methodologies, our method builds on previous research and gradually advances the performance envelope (speed-accuracy tradeoff) in the direction of high performance video object recognition. "Automatic road accident detection using ultrasonic sensor,"
S. M. Khan, T. Javid, S. A. Raza, A. Siddiqui, U. Khalil, and A. Nasir
Numerous people lose their lives in traffic accidents every day. Deaths often result from injuries sustained by passengers in traffic accidents, but it has also been observed that accident reports often arrive at the emergency room much later than expected, making it impossible for the wounded party to survive. Therefore, every automobile has to have an automated system that can quickly alert the emergency room about a traffic collision in addition to effectively detecting it. Numerous automated techniques for detecting traffic accidents have been developed by researchers. Airbags, smartphones, infrared sensors (IR sensors), and mobile applications are often used in these techniques. For the automated identification of traffic accidents, none of these approaches are ideal. Smartphone filters may make it more difficult to identify low-speed fender benders. The suggested solution makes no indication of the threshold distances at which the infrared sensor will respond. Airbags are not intended for use on motorcycles or bicycles. The program may not function well on all smartphone models if it is used for accident detection since different smartphone models have CPUs with varying speeds. Thus, a new method based on an ultrasonic sensor is suggested in this study. Ultrasonic sensor-based accident detection has the ability to identify collisions in a variety of street scenarios and may also function well in a range of environmental circumstances, such as rain.

III. SYSTEM ANALYSIS & DESIGN

EXISTING SYSTEM

In order to find deviations from typical traffic patterns, Cai et al. [14] investigated the identification of anomalous traffic flow using clustering algorithms. The Hidden Markov Model was used in earlier research, such as that of Morris and Trivedi [15], to describe scenes intelligently utilising spatiotemporal dynamics. With advancements like merging convolution layers with LSTM architectures for enhanced performance [18], [19], and [20], more recent research has moved towards using machine learning and deep learning approaches for extracting spatiotemporal characteristics from video streams [16], [17], and [18]. As shown by Carreira and Zisserman's [21] introduction of the twostream inflated 3D ConvNet (I3D) designs for improved video input categorisation, the investigation of complicated networks in accident detection has also gained prominence. This section explores a number of approaches and models that have made a substantial contribution to the identification and analysis of traffic accidents in the context of smart city frameworks.

According to Le et al. [5], road accidents are a major cause of both economic losses and mortality in modern society. In order to overcome this difficulty, the authors present the Deep Spatio-Temporal Convolutional Network (DSTGCN), a model that predicts traffic accidents by using deep spatial and temporal data. The intricate, non-Euclidean structures present in graph data have been successfully mapped by the emerging science of graph neural networks.

Wang et al.'s study [22] examined the dynamic complexity of road networks and claimed that their impact goes beyond simple proximity analysis. They created the Spatial Temporal Graph Neural Network (STGNN) to efficiently describe long-range global relationships in traffic flow. Three essential parts make up this novel network: a transformer layer, a recurrent neural network layer for processing temporal dynamics, and a positional graph neural network layer for capturing spatial interactions. The design is predicated on the idea that traffic.

Disadvantages

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Yang et al. [9] aim to enhance object detection models by introducing a novel object detection algorithm designed especially to handle video data and lessen the biases of conventional models, taking into account the shortcomings of object detector algorithms in single frames that are emphasised in the research of Wang et al. [22].

PROPOSED SYSTEM

The topic of accident detection has made great progress thanks to the merging of machine learning (ML) and deep learning (DL) approaches. These technologies are especially good at handling big accident data sets, which makes it possible to identify and categorise occurrences according to important factors like vehicle type, speed, and direction. In order to forecast the risk of accidents, Singh et al. [27] suggested a system that uses autoencoders in conjunction with an unsupervised learning model, such as the Support Vector Machine (SVM), to exploit deep representation extraction. This method demonstrates how machine learning models and advanced feature extraction may be used to improve prediction power. Deep learning models provide interesting paths for real-time accident detection in addition to machine learning. These models use sophisticated image recognition and video processing methods to detect possible risks and accident situations by using camera systems to continually watch highways. One of the most important aspects of accident prevention and mitigation is timely accident identification, which is made possible by deep learning models' capacity to evaluate complicated video data in real time. In order to effectively manage traffic and lessen the detrimental effects of congestion and traffic accidents in real-time, Zadobrischi [41] focusses on integrating traffic monitoring systems with intelligent transport systems (ITS) utilising video and image data. A Dynamic-Spatial-Attention (DSA) Recurrent Neural Network (RNN) was suggested by Chan et al. [42] to predict accidents in dashcam footage by using the velocity and trajectory of the vehicle. In order to forecast accidents two seconds before they happen, the proposed method includes an object detector that dynamically gathers tiny clues and the temporal relationships of all cues. A three-step hierarchical system for using surveillance cameras to identify traffic accidents at crossings is presented by Ghahremannezhad et al. [43]. During object tracking, occlusions, overlapping objects, and changes in object form are handled using a special cost function. All things considered, our technique uses a deep learning approach in conjunction with transfer learning to create a thorough, effective, and precise system for detecting traffic accidents.

Advantages

• Advanced Vision-Based Accident Detection System: Specifically tailored for real-time deployment on edge IoT devices like Raspberry Pi, we present an inventive vision-based accident detection system. Because of its little processing overhead, this system is ideal for traffic monitoring and smart city infrastructures. Its lightweight design effectively combines practical application with computational efficiency, creating an affordable, dependable, and deployable solution for the contemporary smart city.

• Novel Model Architecture: Our study suggests a unique model architecture for video sequences that extracts RGB frames and optical flow information. This model greatly improves accident detection performance by integrating transfer learning methods and the CONVLSTM2D architecture, setting our method apart from other approaches.

In order to address the dearth of benchmark datasets in the field of accident detection, we have assembled two specialised datasets: the Dash Camera Dataset and the Traffic Camera Dataset, which are made publically accessible at [7] and [8]. These datasets, which are especially designed for accident detection, include a wide variety of situations and road layouts, making them an invaluable tool for further study and advancement in this area.

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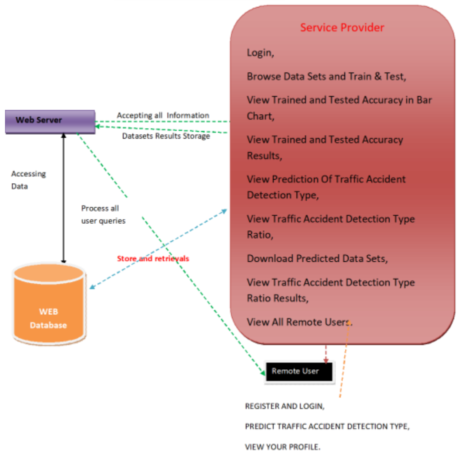
SYSTEM ARCHITECTURE

Architecture Diagram



IV. IMPLEMENTATIONS

Modules

Service Provider

The Service Provider must use a working user name and password to log in to this module. Following a successful login, he may do several tasks including browsing data sets and training and testing. View Results of Trained and Tested Accuracy, View Trained and Tested Accuracy in Bar Chart, Download Predicted Data Sets, View Traffic Accident Detection Type Prediction, View Traffic Accident Detection Type Ratio, View All Remote Users and Traffic Accident Detection Type Ratio Results.

View and Authorize Users

The administrator may see a list of all registered users in this module. Here, the administrator may see the user's information, like name, email, and address, and they can also grant the user permissions.

Remote User

A total of n users are present in this module. Before beginning any actions, the user needs register. Following registration, the user's information will be entered into the database. Following a successful registration, he must use his password and authorised user name to log in. Following a successful login, the user may do tasks including registering and logging in, predicting the kind of traffic accident, and seeing their profile.

ALGORITHMS

Logistic regression Classifiers

The relationship between a collection of independent (explanatory) factors and a categorical dependent variable is examined using logistic regression analysis. When the dependent variable simply has two values, like 0 and 1 or Yes and No, the term logistic regression is used. When the dependent variable contains three or more distinct values, such as married, single, divorced, or widowed, the technique is sometimes referred to as multinomial logistic regression. While the dependent variable's data type differs from multiple regression's, the procedure's practical application is comparable.

When it comes to categorical-response variable analysis, logistic regression and discriminant analysis are competitors. Compared to discriminant analysis, many statisticians believe that logistic regression is more flexible and appropriate for modelling the majority of scenarios. This is due to the fact that, unlike discriminant analysis, logistic regression does not presume that the independent variables are regularly distributed.
Both binary and multinomial logistic regression are calculated by this software for both category and numerical independent variables. Along with the regression equation, it provides information on likelihood, deviance, odds ratios, confidence limits, and quality of fit. It does a thorough residual analysis that includes diagnostic residual plots and reports. In order to find the optimal regression model with the fewest independent variables, it might conduct an independent variable subset selection search. It offers ROC curves and confidence intervals on expected values to assist in identifying the optimal classification cutoff point. By automatically identifying rows that are not utilised throughout the study, it enables you to confirm your findings.

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Naïve Bayes

The supervised learning technique known as the "naive bayes approach" is predicated on the straightforward premise that the existence or lack of a certain class characteristic has no bearing on the existence or nonexistence of any other feature. However, it seems sturdy and effective in spite of this. It performs similarly to other methods of guided learning. Numerous explanations have been put forward in the literature. We emphasise a representation bias-based explanation in this lesson. Along with logistic regression, linear discriminant analysis, and linear SVM (support vector machine), the naive bayes classifier is a linear classifier. The technique used to estimate the classifier's parameters (the learning bias) makes a difference.

Although the Naive Bayes classifier is commonly used in research, practitioners who want to get findings that are useful do not utilise it as often. On the one hand, the researchers discovered that it is very simple to build and apply, that estimating its parameters is simple, that learning occurs quickly even on extremely big datasets, and that, when compared to other methods, its accuracy is rather excellent. The end users, however, do not comprehend the value of such a strategy and do not get a model that is simple to read and implement.

As a consequence, we display the learning process's outcomes in a fresh way. Both the deployment and comprehension of the classifier are simplified. We discuss several theoretical facets of the naive bayes classifier in the first section of this lesson. Next, we use Tanagra to apply the method on a dataset. We contrast the outcomes (the model's parameters) with those from other linear techniques including logistic regression, linear discriminant analysis, and linear support vector machines. We see that the outcomes are quite reliable. This helps to explain why the strategy performs well when compared to others. We employ a variety of tools (Weka 3.6.0, R 2.9.2, Knime 2.1.1, Orange 2.0b, and RapidMiner 4.6.0) on the same dataset in the second section. Above all, we make an effort to comprehend the outcomes.

SVM

The goal of a discriminant machine learning approach in classification problems is to identify a discriminant function that can accurately predict labels for newly acquired instances based on an independent and identically distributed (iid) training dataset. A discriminant classification function takes a data point x and assigns it to one of the several classes that are part of the classification job, in contrast to generative machine learning techniques that call for calculations of conditional probability distributions. Discriminant techniques are less effective than generative approaches, which are mostly used when prediction entails the identification of outliers. However, they need less training data and processing resources, particularly when dealing with a multidimensional feature space and when just posterior probabilities are required. Finding the equation for a multidimensional surface that optimally divides the various classes in the feature space is the geometric equivalent of learning a classifier.

SVM is a discriminant approach that, unlike genetic algorithms (GAs) or perceptrons, which are both often used for classification in machine learning, always returns the same optimum hyperplane value since it solves the convex optimisation issue analytically. The initialisation and termination criteria have a significant impact on the solutions for perceptrons. While the perceptron and GA classifier models are distinct every time training is started, training yields uniquely specified SVM model parameters for a given training set for a certain kernel that converts the data from the input space to the feature space. The only goal of GAs and perceptrons is to reduce training error, which will result in several hyperplanes satisfying this criterion.

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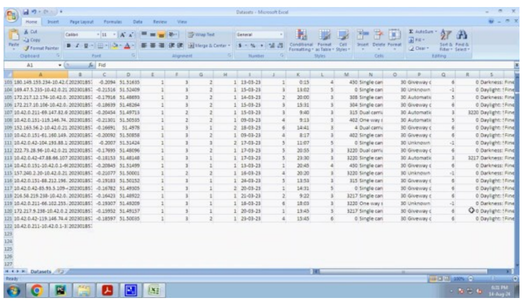
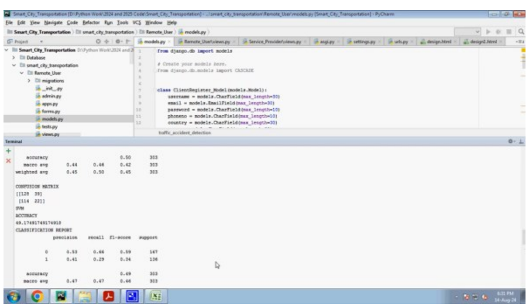
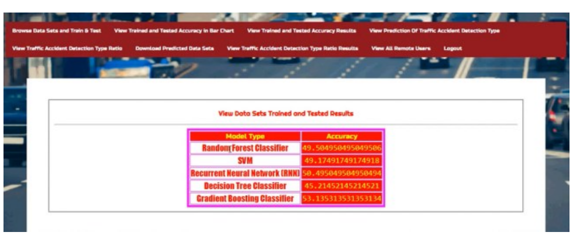
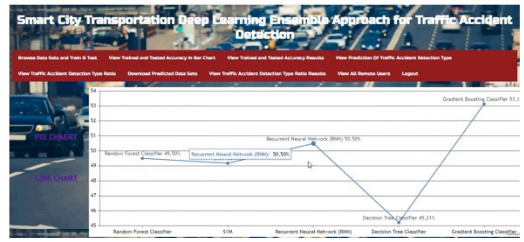
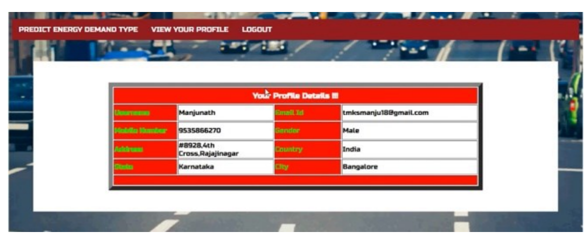
V. SCREEN SHOTS











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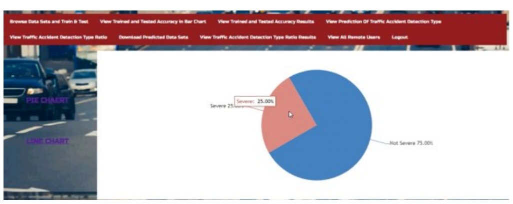

VI. CONCLUSION

Accident detection techniques have changed dramatically over time, moving from manual reporting to automated systems. These state-of-the-art technologies, which use sensors, computer vision, and machine learning algorithms, represent a paradigm leap in accident detection. Computer vision-based systems in particular are notable for their capacity to identify in real time and adapt to a variety of road conditions. These devices have the potential to become essential instruments for improving traffic safety as long as technology keeps improving. The I3DCONVLSTM2D Trainable RGB + Optical Flow model, which was the result of our study, performed very well, with an accuracy of 0.80 and a mean average precision of 87%. The ability of this model to separate traffic accident characteristics from complicated traffic situations is a major advancement in automated accident identification. A significant percentage of deaths are caused by traffic accidents, which remain a serious safety problem, especially in highly populated regions. In order to solve this, our research develops a vision-based accident detection system that can be deployed in real-time on edge IoT devices like Raspberry Pi. We took the initiative to curate a fresh accident dataset after seeing the inherent difficulties of such an approach, particularly the enormous amount of data required. This resource gives researchers the freedom to expand or alter our fundamental framework for accident detection by either complementing already-existing datasets or being used as a stand-alone tool. With 25 million parameters and a lengthy training phase spanning 32 GPU1s for 110k steps, the I3D two-stream network is computationally expensive. On the other hand, our resource-efficient and resource-conscious model was trained on an Ubuntu 20.04.2 LTS system using two 11 GB GPUs.

Our dedication to efficiency is shown by the model specifications, which include 3 million parameters for the RGB model and 9 million parameters for the I3DCONVLSTM2D Trainable RGB+Optical. In conclusion, our research offers a dependable, reasonably priced accident detection system appropriate for smart city infrastructures, bridging the gap between computational efficiency and real-world application. Our research opens the door to more widely available and accessible surveillance systems. Most significantly, our goal of developing lightweight but efficient solutions for important social concerns is shown by the simplicity, effectiveness, and lower computational needs of our approach, particularly when compared to heavyweights like I3D.

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