

Enhancing Road Traffic Accident Prediction Using Hybrid Machine Learning Models

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Abstract

In road safety, the ability to forecast traffic accidents correctly is central to the application of proactive responses in terms of accidents. The paper is based on a thorough strategy of improving the accuracy of predicting by a hybrid machine learning model, which is a combination of a Random Forest (RF) machine learning algorithm and Support Vector Machine (SVM). The Kaggle-gathered dataset includes road traffic accidents between 2017 and 2020, which has 32 features and 12,316 accidents. After the preprocessing of data, including Min-Max normalization, the hybrid RF-SVM model is created to take the advantages of both the ensemble learning and the margin based classifiers. The Random Forest aspect is applied to determine the most influential features to consider and the dimensionality of the datasets which can potentially lead to accidents and therefore these are managed well even in large volumes. The step simplifies the model and increases its interpretability. The SVM element then carries out the classification task, which is to optimize the boundaries of decisions by using a narrow range of features. The capability of SVM to work with both non-linear and linear relations as well as the use of kernel tricks makes it possible to guarantee the solid separation of accident-prone and non-accident-prone cases. The RF-SVM model is superior in comparison to other hybrid models like Conv-LSTM, CNN-LSTM, and CNN-GRU, which show a higher level of functionality. The suggested model is tested in Python software, which has an impressive accuracy of 99.13. These measurements highlight the fact that this model is able to make a trustworthy forecast and balance accuracy and recall. The knowledge of the process of feature selection can help the policymaker with the understanding of major elements of accident causes and provide the specific intervention to improve the road safety. The results of the present study indicate the promise of the hybrid machine learning models to the development of the predictive analytics of road traffic accidents and the subsequent creation of smarter, data-driven road safety strategies.

Keywords: Support Vector Machine, Random Forest, Road Traffic, Accident Severity Prediction, Machine Learning

Introduction

Generally, there is anxiety on car crashes across the Indian subcontinent. Car crashes resulted in the death of nearly 151, 000 people in the US in 2019. Traffic accidents lost about three and five percentages of GDP per annum. Only 1 percent of the world autos are present in India, but current statistics in 2013 indicate that this country contributes approximately 6 percent to the total number of traffic accidents. Almost 70 percent of the cases were in younger Indians [1] [2]. Traffic studies indicate that there will be an increase in the number of automobile accidents caused deaths and injuries. Traffic administration and preparation is now being treated through modern methodology because of its importance. Car accidents will be reduced due to the legislation and measures that are based on the concept that there are traffic hazards [3].

The researchers introduced a computer vision-centered method of estimating car accidents [4]. Their ability to follow up on camera recordings at road figures allowed them to discern some situation with an 85 percent accuracy. People who pay importance to the root causes of crashes in roads have conducted additional research in the recent years [5]. The strategy and driver behavior of the entire variable lane structure were researched by the scholars in an attempt to identify the possible dangerous driving behaviours. Both pedestrians and vehicles are at great risk since a high roadway slope exposes them to high risk as per the research conducted to establish the connection between the pavement conditions and auto accidents. Moreover, the threats of climatic changes and the altering demographic of visiting people have never been the focus of any previous research. However, the majority of these studies have simply investigated one of the factors of the environment be they motorists, tourists, highways, or the environment itself in relation to injuries [6].

To ensure the safety of the audience at the database mining equipment event, various data mining plans are utilized by college students [7]. Organizational data mining is often used when obtaining an investigation of the causative factors that result in visitor damage. The hidden networks are revealed by means of strict standards of communication across the risk data [8]. Building the foundations in this manner in that the users are able to live to the worth and the norms of the underpinnings with a dual level of trust and motivation can attract them [9].

The fact that the number of people who are killed in traffic accidents each day amounts to alarming figures of more than 3,000 indicates that road security is a colossal public health problem in the current society. The world economy is also damaged as a result of road accidents. The costs that the developing countries incur because of this [10] [11]. Road communication unit plays a crucial role in terms of creating study on the identification of necessary factors to achieve a better understanding of the sequence of events and making use of related data in key target positions. The regionally accessible mining strategies that can be employed require very little expenditure in case of transmitting Brobdingnagian data.

The officials of only one Asian country had records of the collision. The procedure to consolidate, compile, and document data concerning accidents has a lengthy list of improvements that the channel that focuses only on accidents would prefer to be developed. Currently, analysts only use the most basic of the information and report failure when trying to draw conclusion out of it; data mining software is a commonplace thing. The variety of information mining methodologies is vastly used by scholars. Data mining has been implemented to derive foreseeable information out of extensive knowledge bases and outcomes of the data summary are usually presented in a user-friendly format. Data analysis methods contribute to the discovery of the most important or long-lasting trends.

The Key Contributions of the Article is,

- The paper is a new hybrid ML model that will integrate RF and SVM, which will be able to work together and use the merits of both ensemble learners and margin-based classifiers to achieve a higher level of accuracy in predicting road traffic accidents.
- The study effectively operates on high volumes of data and is able to determine which dimensions are the most important in causing accidents, simplifying the model and making it easier to interpret, as the RF component can be used to select the most important features and reduce the dimensionality of the data set.
- The information obtained during the selection of features in the model gives a wealth of information to the policy makers on important elements that lead to road traffic accidents and thus effective interventions and proactive measures can be taken to enhance road safety and the rate of accidents.

The paper is arranged in the following way section II and III provide the related works and methodology respectively. The results are provided in section IV and the article is concluded in section V.

Related Works

In the real life, road accidents are normally associated with severe loss of life and huge financial costs [12]. The ability to predict crashes in a very efficient and accurate manner can greatly enhance the safety of all and reduce the monetary expenditures. The causation of crashes is rather complex (consisting of multiple variables like time dynamic relations, space connection and outside influence in diverse information that is relevant to the road), thereby making it hard to predict crashes whilst driving. To solve the above issues, this study proposes a distinct Deep Spatio-Temporal Graph Convolutional Network, or DSTGCN, to predict traffic accidents. The proposed model comprises of three components, which are the spatial learning layer, which learns spatial correlations through the application of graph convolutional computations on spatial data. The next layer is the spatio-temporal training layer, which models the dynamic variations on the spatial and temporal perspective with the application of standard and graph convolutions. The third part, which is the incorporation layer, attempts to offer coherent and semantic representations to external data. To evaluate the proposed model, we collect a great deal of factual information in the real world, including the reports of accidents, the speed of automobiles in the cities, and the roads, temperature, and payments of the POI. Tests on real data demonstrate that DSTGCN is more efficient in comparison with contemporary facilities and conventional methods.

Rear-end collision prevention is getting increased attention in order to generate additional protection in the smart communities [13]. Being one of the main causes of crashes, rear-end crashes need to be provided with the means of efficient warning as soon as possible. The objective of the present research is to predict collisions. There is the recommendation to address this difficult issue through the implementation of learning-based strategies, which is beyond the focus of traditional strategies. The back-propagation learning methods are, however, experiencing some problems due to some limitations in locating features, and making predictions about features. This paper has presented a new DL-based RCPM that builds a CNN model. To solve the problem of disparities of the classes, RCPM widens and flatten the data with the help of the evolution theory. The source of data that we use in the model is the prepared dataset and which is divided into training and testing data. The findings of the research prove that RCPM is an effective tool that helps to improve the accuracy of rear-end collision prediction.

Crash detection is essential to providing the public and management centers along the roads with the up-to-date information to reduce its adverse effects [14]. To avoid the occurrence of secondary

collisions and to secure road traffic, crash risk forecasting is necessary. Trying to assist in traffic control of accidents, scholars have devoted numerous years to researching different approaches of correct and timely detection of the collisions. The data on real time traffic can be effectively used due to the recent advancements in data collection systems. Megabig data architecture may use the information to provide appropriate solutions to the highway traffic safety systems. The study examines the ability of DL models in predicting the probability of a crash and determining incidence of the crash. In this investigation, the volume, speed and sensor saturation data were collected using wayside radar detectors on Highway 235 in Des Moines, Iowa. The results show that a deep model has a similar performance to state-of-the-art shallow models in terms of making predictions of accidents and improved performance in crash detection. More so, a sensitivity analysis was conducted to determine the risk of the accidents using the data gathered one, five, and ten minutes prior to the crash occurrence. It was established that the risk of having a traffic situation could not be predicted easily ten minutes before an accident.

To generate the models that approximate the degree of accident damages under the case of a motorbike accident, the study utilizes the categorization methods [15]. The researchers compared the results of their studies to gauge the predicting ability of the MLP, rule induction (PART), and classification and regression trees (SimpleCart) models to establish the severity of motorbike accidents. The data set of motorbike collision statistics that were used to attain this objective was the Building and Road Research Institute in Ghana National Road Traffic Collision Dataset. The data developed was evaluated based on four levels of injury severity, which are deterioration, hospitalized, wounded, and death. Besides allowing the direct comparison and ranking of the data mining models, the data obtained in the framework of this set of data will allow determining the factors that influence significantly the motorbike crash severity. The findings revealed that Simple Cart model outperformed the PART models (73.45%) and the model that was developed by MLP (72.16) out of the studied methods of classification using the 10-fold cross-validation strategy. Simple Cart model was with a mean accuracy of 73.81%. The results indicate that the most significant variables that were associated with the level of injuries incurred during a motorbike accident were the type of the site, the type of settlements, the time of accidents, the type of accidents, and the collision companions.

Proposed RF-SVM Framework

The approach of the article involves the preprocessing of min-max normalization and hybrid RF-SVM accident prediction. It is depicted in Fig 1.

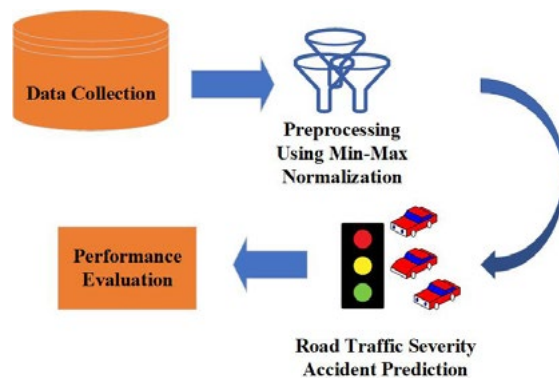


Fig. 1. Proposed Methodology

A. Data Collection

The data on road traffic accident is gathered on Kaggle [16]. This data collection is based on the written reports on the traffic accidents between 2017 and 20. The end product, after all the sensitive data was eliminated during the encoding of data, contains 32 features and 12316 accident occurrences. Subsequently, it is preprocessed and analyzed using different methods of ML to classification to identify the main causes of the incident. RTA Information Base. The csv format dataset is untidied and unprocessed. The processed data is known as csv.

B. Preprocessing using Min-Max Normalization

It is also necessary to preprocess the road site visitors twist of fate data so as to ensure the success of the later system learning models. Min-Max Normalization is one of the most common, and efficient preprocessing methods which make the functions of the data set lie within a specific range, most commonly in [0, 1]. This method is used to convert every function by the help of the subtraction of the smallest value of that feature followed by division by the spread of the characteristic values (most fee- minimum fee). Min-Max Normalization is used to assure that huge scale features will no longer prevail over the learning mechanism so that the performance and convergence rates of most gadget learning algorithms are improved.

$$Y_{norm} = \frac{Y - Y_{minimum}}{Y_{maximum} - Y_{minimum}}$$

Min-Max Normalization would come in handy with our dataset of avenue site visitors accident since there are multiple functions that are exclusive in nature. E.g. one-of-a-kind numbers such as car velocity and time of day will be enormously scaled, which would potentially create a skewed model in the case of unnormalization. Once it is normalized, it can now be subjected to in addition assessment and version schooling with care taken to ensure that each characteristic adds equally to the predictive modeling methodology.

C. Employing RF-SVM for Road Traffic Accident Prediction

The suggestion of a hybrid one such as RF-SVM of road site visitor accident prediction would be an integration of potentials of both ensemble getting to know and margin-based totally classifier which provides a potent method to predictive modelling. The initial part of this hybrid variant is applying RF to select functions and reduce the dimensionality. Random Forest is an ensemble technique of learning that works through constructing a multiplicity of selection trees somewhere in the schooling and giving the mode of the training (class) of the individual timber.

The opportunity that the Random Forest provides to work with the missing facts and to remain accurate without having to preprocess it on a large scale makes it the choice of the initial part of the hybrid version. With the help of Random Forest as a method of selecting the characteristics, we are able to narrow down the list of the most influential factors in the traffic accidents on the street and reduce the list of significant features. This does not only enhance the effectiveness of the version but also makes it easier in expertise the significant factors that desire interest in the prevention of twist of fate. Furthermore, the ensemble characteristic of the Random Forest provides resistance to overfitting to ensure that the chosen features can be applicable to unknown facts.

The second stage of the RF-SVM model involves the utilisation of SVM in the actual type or prediction mission. The popularity of SVM in the excessive-dimensional fields is known, and it is primarily applicable to class tasks. Once dimensionality discounting is done by the aid of Random Forest, SVM is applied with a specific set of functions, which optimizes the selection

barriers between classes of street visitors injury. The intermediate idea of SVM is that of finding the hyperplane that is delightful to divide the distinct categories within the feature space. The latter is what renders SVM incredibly efficient in the separability of coincidences-prone and non-twist of fate-prone times, and thus enhancing predictive accuracy.

Practically, the RF-SVM hybrid model is experienced in different steps. In the first step, the Random Forest model is trained on the data to identify the ranking of the importance of each of the functions. Characteristics that have the highest scores of significance are then chosen in the second stage one, whereby the SVM model is trained on the use of this pruned set of characteristics. Such a staged approach is no longer the simplest, simplifying the process of the computations, but also increases the readability of the version, through the emphasis on the most impactful features. The model parameters of the two Random Forest and SVM are optimized in the training part (tuning), whereby move-validation mechanisms are adopted to prevent overfitting and ensure that overall performance is at the top of the line on the validation statistics.

RF-SVM application in coincidence predicting of traffic on the street can significantly enhance the efficiency and performance of prediction techniques. Consequently, it will become an effective instrument of the foretelling of accidents on the road, which will enable the authorities to implement proactive steps to avert coincidence and enhance the safety of ordinary avenues. The information derived during the function choice process may also inform the manual policymakers to work on the most significant factors that lead to the injuries of the street site visitors and thus derive the statistics-driven selections of improvements in public protection.

Results and Discussion

The results section contains the performance evaluation of the proposed model, which is written in Python.

A. Accident Severity

The Fig 2 provides a comparison of traffic density to the severity of accidents, which provides the number of injuries identified by their degree of the threat High Risk, Low Risk and Moderate risk under particular traffic densities (High, Low, and Moderate). The density of excessive-danger injuries and low-risk injuries are 500 and 2500 respectively in the region containing overly many visitors of the sites, but there are no moderate-chance injuries. When the density of site visitors is low, all the 3500 injuries are less than the low-chances category, and there are no excessive-threat or slight-hazard accidents. In the density events of mild visitors, 500 injuries are termed as mild risk, simultaneously as 3000 are low danger.

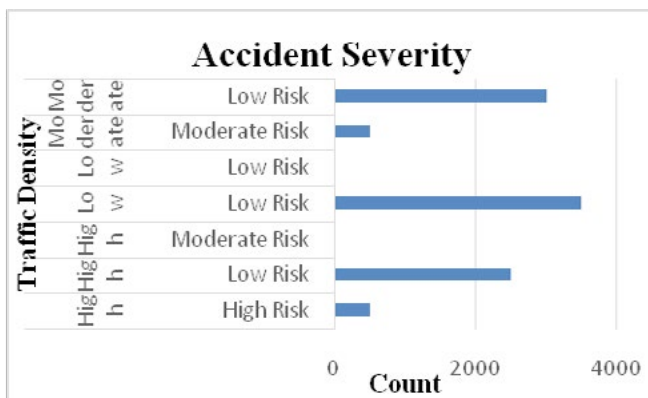


Fig. 2. Accident Severity

B. Accident Severity due to Road Structure

In Fig 3, the relationship between the severity of accidents and road structure is demonstrated. It shows that injury along curved roads or on ill-kept surfaces is more likely to result in additional extreme outcomes than the injuries on well-kept directly roads. The facts presented within the parent supports that road structure is a significant factor with regards to the severity of coincidence as complex or dilapidated avenue conditions tend to result in more levels of damage and more severe extreme crashes.

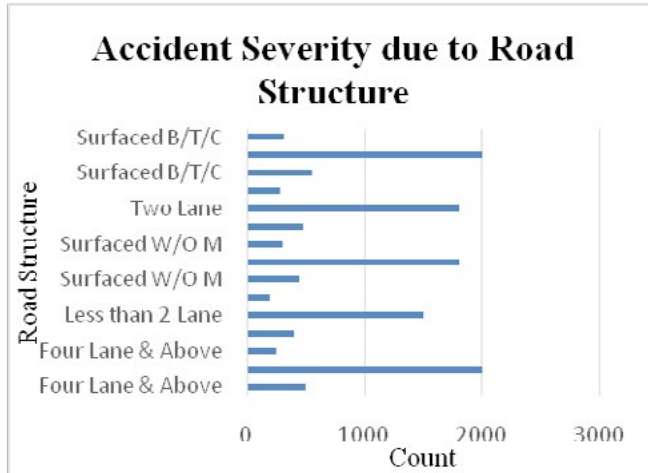


Fig. 3. Accident Severity due to Road Structure

C. Performance Metrics

Conv-LSTM model has achieved high scores with 98.12 percent accuracy, 94.77 percent precision, 96.98 percent recall, and 92.83 percent F1-Score, which shows that it performs well in all the measures. CNN-LSTM model comes next with an accuracy of 97.97, however, with a significant decrease in precision (89.55) and recall (92.45), the F1-Score is also a bit lower (91.67). The CNN-GRU model with an acceptable accuracy of 96.89 also has a high precision (94.56), F1-Score (94.32), but slightly low recall (92.77). RF-SVM has an impressive accuracy of 99.13, a precision of 96.32, a recall of 97.13, and F1-Score of 95.47 which shows that the proposed RF-SVM model is better placed to predict road traffic accidents and balance the precision and recall inaccuracies that other models have. Table I provides the comparison of the performance metrics.

Table I. Performance Metrics Comparison

Methods	Performance Metrics			
	Accuracy (%)	Precision (%)	Recall (%)	F1-Score (%)
Conv-LSTM [17]	98.12	94.77	96.98	92.83
CNN -LSTM [18]	97.97	89.55	92.45	91.67
CNN-GRU [19]	96.89	94.56	92.77	94.32
Proposed RF-SVM	99.13	96.32	97.13	95.47

D. Discussion

The RF-SVM version with the accuracy of 99.13 is better than other hybrid models that include Conv-LSTM, CNN-LSTM, and CNN-GRU. The high accuracy (96.32%), remember (97.13%),

and F1-Score (97.47) scores also emphasize the strength of the version and the possibility to make stable predictions. The fact that the RF-SVM version can cover both linear and non-linear association between the information ensures that it would be capable of differentiating between coincidence-prone and non-twist of fate-prone times and provide a complex and distinct predictor.

Moreover, the selection of the features with the help of Random Forest is not only not the easiest one but also enhances the efficiency of the version but also provides invaluable information about the causes of road visitors accidents. This way identified major attributes that could be most effective predictors of twist of fate phenomena, that could guide policy-makers and visitors control agencies of critical areas that they should take into account. Indicatively, factors that encompass avenue shape, traffic congestion and environmental factors had been demonstrated as enormous predictors. Its ability to perform well in reality on the global software in visitors management systems is highlighted by the overall performance of the RF-SVM version compared to the various hybrid strategies.

V. Conclusion and Future Works

With an excellent accuracy of 99.13 and robust precision, bear in mind, and F1-Score scores, the RF-SVM model outperforms the various hybrid methods alongside Conv-LSTM, CNN-LSTM, and CNN-GRU. Future research might wish to be addressed on the expansion of the data to include additional recent information and a more diverse group of features, consisting of climate scenarios, real-time visitor updates, and driving force behavior indicators, to also embellish the version with predictive electricity. There is also a possibility of incorporating higher levels of ML of processes such as DL and reinforcement learning to get additional complex patterns and interactions within the information. Moreover, the real-time application of the model to visitors control structures and its connection to the infrastructure of a smart city should provide the dynamic and real-time predictions and warnings, which will significantly enhance the protection of the avenues.

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