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Original Article

Accident Severity Prediction and Real-Time Alert System Using Environmental and Temporal Factors

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Abstract

Road accidents are among the leading causes of injuries and fatalities worldwide. Early assessment of accident severity is crucial for prompt action and effective traffic man¬agement. Conventional accident analysis techniques rely mostly on manual reporting and historical data, resulting in delayed and inaccurate responses. This paper proposes a machine learning-based system to predict accident severity using temporal param¬eters such as time of day, day of the week, and season, along with environmental parameters such as weather, traffic, visibility, and road conditions. The system classifies accident severity into three levels: low, medium, and high. In addition, a real-time alert mechanism is integrated to automatically notify local hospitals, traffic authorities, and emergency services. The proposed system aims to improve road safety, accelerate emergency response, and assist traffic control authorities in decision-making.

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Keywords

Accident severity prediction, machine learning, random forest, logistic regression, real-time alert system, envi¬ronmental factors, temporal factors, road safety.

Introduction

Traffic accidents pose a serious threat to public safety and human life. As the number of vehicles and the degree of traffic congestion continue to increase, both the frequency of accidents and their severity have also risen. Traditional accident management systems focus mainly on post-accident analysis rather than predictive and preventive measures.

Machine learning (ML) enables the analysis of large vol-umes of accident data to discover hidden patterns and predict the severity of accidents. Temporal and environmental factors play a significant role in determining accident outcomes. The goal of this work is to develop a predictive system that uses these factors to estimate accident severity and notify the relevant authorities in real time.

Problem Statement

Road accidents continue to account for a large number of injuries and fatalities worldwide. The severity of an accident is influenced by multiple factors, including weather conditions, road surface conditions, traffic volume, visibility, and time of day. Existing accident management tools are primarily reactive and focus on reporting and analysis after an accident has already occurred. There remains a gap in intelligent systems that can predict accident severity in advance and immediately notify the concerned authorities. Without such a system, inter-vention is delayed and response measures are less effective. Therefore, there is a clear need for a machine learning-based framework capable of predicting accident severity and generating compliant real-time alerts using historical and contextual accident data.

Objectives

The main objectives of the proposed work are as follows:

1. Collect and clean historical road accident data.
2. Analyze environmental, temporal, and traffic-related factors affecting accident severity.
3. Predict accident severity using machine learning techniques.
4. Classify severity into three levels: Low, Medium, and High.
5. Generate real-time alerts for serious and high-risk situations.
6. Provide safety recommendations to drivers.
7. Reduce emergency response time and improve overall road safety.

Literature Review

Most of the existing literature on road accident analysis has focused on statistical and machine learning techniques to identify the factors that influence accident severity. Environmental variables such as weather, visibility, road condition, and traffic density have been widely studied. Temporal variables such as day of the week, time of day, and seasonal variation have also been found to be important.

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Machine learning approaches such as Random Forest and Logistic Regression have been used to improve prediction accuracy. However, many existing techniques rely mainly on offline analysis and historical data. Although machine learning models have shown promising results, many currently available systems do not provide real-time alerting capability integrated with severity prediction.

Proposed System

The proposed system is a machine learning-based frame-work for accident severity prediction integrated with a realtime alert mechanism. The objective is to estimate the potential severity of a traffic accident and send immediate alerts to appropriate authorities whenever the risk is high. The system uses historical accident data together with real-time environmental, temporal, and traffic-related inputs.

The process begins with data cleaning, which includes handling missing values, reducing noise, and converting categorical data into numerical form. Relevant features that significantly influence accident severity are then selected and supplied to the learning model. In this work, Random Forest is considered the primary prediction model, while Logistic Regression is used for comparison.

After training, the model classifies an incident into one of three categories: Low, Medium, or High severity. If the predicted severity is high, the system immediately notifies emergency services, traffic authorities, and nearby hospitals. At the same time, it can issue safety recommendations to road users, such as advising speed reduction under risky conditions. The overall aim is to support proactive accident management, improve road safety, reduce emergency response time, and contribute to intelligent transportation systems.

Methodology

The proposed Accident Severity Prediction and Real-Time Alert System follows a structured and intelligent workflow. First, historical road accident data are collected, along with information related to weather, road conditions, visibility, traffic, time of day, day of the week, and seasonal variation. These inputs are used to build a comprehensive dataset for analysis.

Once the data are collected, they undergo preprocessing. Missing values are handled, irrelevant records are removed, and categorical attributes are transformed into numerical representations suitable for machine learning algorithms. This ensures data consistency and improves the quality of model training.

Next, the system identifies the features that significantly affect accident severity. Feature selection reduces computational complexity and helps improve prediction accuracy. The selected features are then used to train machine learning models such as Random Forest and Logistic Regression. These models learn the relationships among environmental, temporal, and traffic-related factors and classify severity into three levels: Low, Medium, and High.

After prediction, the system compares the predicted severity against predefined risk thresholds. If the predicted severity exceeds the threshold, the real-time alert subsystem is triggered. Emergency services, traffic authorities, and nearby hospitals are notified immediately, and safety recommendations are issued to drivers. The system can also be improved continuously by retraining the models using newly available accident data.

Rule-Based Methodology

This methodology employs predefined traffic safety rules such as severity levels, weather risk conditions, and high-risk time intervals. After the severity prediction is generated, the system uses these rules to make alert decisions. This rule-based verification improves correctness and supports more reliable alert generation.

Constraint-Based Methodology

This method introduces safety constraints such as severity thresholds, alert confidence, and response priority. Alerts are issued only when the relevant conditions are satisfied. This approach reduces false alarms and ensures controlled and dependable decision-making.

Optimization Methodology

The optimization component aims to improve both prediction accuracy and response speed. It uses feature selection and parameter tuning to enhance the performance of the machine learning model. It also prioritizes high-risk alerts to minimize response delay.

Adaptive Learning-Based Methodology

The system supports adaptive learning by using newly available accident records to retrain the machine learning models. This enables the framework to adapt to changing traffic patterns and environmental conditions, thereby improving long-term prediction performance.

Hybrid Intelligence Methodology

The proposed framework combines rule-based reasoning, constraint analysis, optimization strategies, and machine learning. By integrating these complementary techniques, the system achieves improved accident severity prediction and more reliable real-time alert generation.

Automated Workflow Methodology

The complete workflow, from data collection to alert notification, is automated. The system performs preprocessing, feature handling, prediction, risk evaluation, and alert dispatch without manual intervention. This reduces human effort, saves time, and improves scalability.

System Architecture

The proposed Accident Severity Prediction and Real-Time Alert System follows a modular and layered architecture. This design improves scalability, maintainability, and reliability. Each module performs a specific task and interacts with other modules through well-defined interfaces.

Historical Accident Data

This module stores past road accident records collected from traffic departments and public datasets. It contains attributes such as date, time, location, and severity. These records help the model learn historical accident patterns.

Environmental Data

Environmental data include weather conditions such as rain, fog, temperature, visibility, and road surface condition. These factors significantly affect road safety and are important predictors of accident severity.

Temporal Data

Temporal data represent time-related information such as hour of the day, day of the week, week, and season. Accident risk varies across peak traffic hours and seasonal conditions; therefore, temporal features improve the predictive capability of the model.

Data Collection

In this stage, historical accident data, environmental data, and temporal data are gathered and integrated into a unified dataset. Reliable data collection improves the overall robustness of the system.

Data Preprocessing

Preprocessing includes handling missing values, correcting inconsistencies, removing noisy records, and transforming categorical features into numeric form. This step makes the dataset suitable for machine learning.

Feature Extraction and Selection

This module identifies the most relevant parameters affecting accident severity. Irrelevant and redundant attributes are removed to improve efficiency and model performance.

Machine Learning Model

The system uses machine learning algorithms such as Random Forest and Logistic Regression. Random Forest improves prediction performance through ensemble learning, while Logistic Regression provides probabilistic interpretation of severity outcomes.

Accident Severity Prediction

Using trained models and real-time contextual inputs, the system predicts accident severity as Low, Medium, or High. Accurate severity prediction supports faster and more informed response actions.

Alert Decision Module

This module evaluates the predicted severity using threshold-based criteria. If the predicted probability of high severity exceeds a predefined threshold, the system triggers an alert.

Emergency Services Notification

When high severity is predicted, alert messages are sent to emergency services such as ambulances and rescue teams. This helps reduce casualties and improves response efficiency.

Traffic Authorities Notification

Traffic authorities receive alerts to regulate traffic flow, reduce congestion, and take preventive action in the affected zone.

Nearby Hospitals Notification

Nearby hospitals are informed in advance so that they can prepare for emergency treatment and reduce delays in care.

Safety Recommendation Module

This module provides safety recommendations to drivers, such as reducing speed and exercising caution in bad weather or high-risk zones.

Results

The proposed Accident Severity Prediction and Real-Time Alert System was evaluated using a historical accident dataset enriched with environmental and temporal features. Experimental analysis showed that the system was able to classify accident severity effectively into low, medium, and high categories.

Among the evaluated algorithms, the Random Forest model performed better than Logistic Regression because of its ability to capture complex interactions among weather, temporal, and road-related features. Logistic Regression also produced competitive results, though its accuracy was slightly lower.

The alert decision component also performed effectively, generating notifications only when the predicted severity crossed a predefined risk threshold. This helped reduce unnecessary alerts while maintaining timely response support.

Discussion

The experimental findings indicate that environmental and temporal factors are highly significant in predicting accident severity. Weather conditions, time of occurrence, and road conditions all contribute substantially to accident outcomes.

The Random Forest model outperformed Logistic Regression in handling multiple interacting variables and generating more accurate severity predictions. The alert mechanism was effective in sending notifications only for high-severity conditions, which helped reduce false detection and improved operational usefulness.

Although the proposed system demonstrated promising results, its performance depends on the quality and availability of real-time input data. Nevertheless, the results validate the usefulness of combining machine learning with real-time alerts for road safety management.

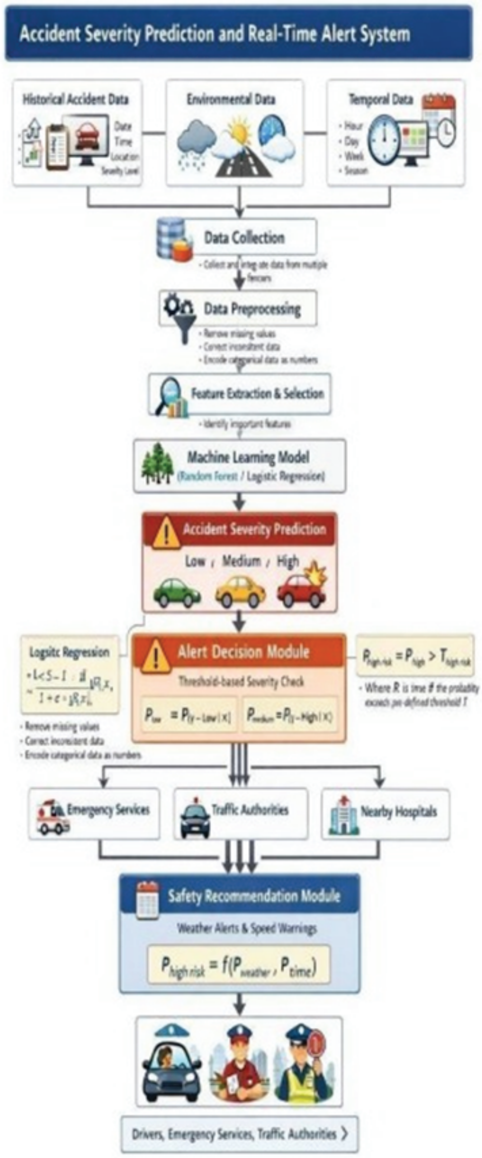

Figure 1. *System architecture of the Accident Severity Prediction and Real-Time Alert System using Environmental and Temporal Factors.*

Conclusion

This paper presented an Accident Severity Prediction and Real-Time Alert System based on environmental and temporal factors. The proposed system integrates machine learning-based severity prediction with automated alert generation for emergency response.

Performance analysis shows that the Random Forest model

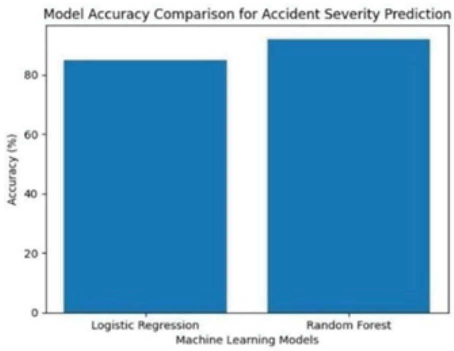

Figure 2. *Experimental results of the Accident Severity Prediction and Real-Time Alert System using Environmental and Temporal Factors.*

performs better than Logistic Regression in predicting accident severity, making it a more suitable option for deployment. The integration of prediction and alerting improves the practical utility of the system by supporting quicker intervention from emergency services, hospitals, and traffic authorities.

The proposed framework can be extended further to improve driver awareness, support advanced intelligent transportation applications, and contribute more broadly to road safety enhancement.

Future Scope

The system can be extended by incorporating live traffic sensors, GPS-based vehicle streams, and IoT-enabled road infrastructure for higher-quality real-time data. Additional deep learning methods and ensemble optimization techniques may further improve prediction accuracy. The alert mechanism may also be enhanced through mobile applications, geofencing, and multilingual warning systems to better support drivers and emergency response teams.

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