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Analysis on Survival Probability in Road Accidents using Data Mining Techniques

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Abstract:

Road traffic accidents are a significant cause of injury and death, making it crucial to predict survival chances for individuals involved. This study uses data mining techniques to predict the likelihood of survival following road accidents based on various factors such as Crash Type, Speed Limit, Road. User, Gender, Survive. The analysis involves applying Data mining models like Decision tree, LightGBM (Light Gradient Boosting Machine) and XGBoost(Extreme Gradient Boosting) to a dataset containing information from past accidents. By cleaning and preparing the data, including Data Cleaning and encoding variables, the models are trained to classify whether a person will survive or not in an accident. The results show that certain factors, such as accident severity and vehicle type, are crucial for predicting survival. The study highlights the potential of data mining to enhance road safety measures and emergency response systems by providing insights into the factors that influence survival outcomes in road accidents.

Keywords — Decision Tree Algorithm, XGBoost, LightGBM, Data Cleaning, Feature Selection.

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I. INTRODUCTION

Road accidents are a major public health concern, leading to significant fatalities and injuries worldwide. Analysing the factors that influence survival probabilities in road accidents can help in improving emergency response, healthcare interventions, and road safety measures. Traditional statistical methods provide insights into accident trends, but data mining techniques, particularly classification models, offer a more powerful and accurate approach for predicting survival outcomes.

Data mining classification techniques, such as Decision Trees, Logistic Regression(LR), LightGBM (Light Gradient Boosting Machine), Random Forest, Gradient Boosting models, XGBoost (Extreme Gradient Boosting), Neural Networks (Deep Learning) can analyze large datasets to identify key factors affecting survival rates. These factors may include the severity of the accident, Crash.Type, Speed.Limit, Road.User, Gender, Survive. By applying machine learning algorithms to historical accident data, it becomes possible to predict the likelihood of survival and identify patterns that can inform better policy decisions and preventive measures.

The aims to explore how data mining classification techniques can be used to predict survival probabilities in road accidents. The research will focus on evaluating different classification models, comparing their performance, and determining the most effective approach for accurate predictions. The findings could be instrumental in improving road safety strategies, optimizing emergency medical services, and ultimately reducing fatalities in road accidents.

II. LITERATURE SURVEY

Road traffic accidents remain a major global concern, causing severe injuries and fatalities. To enhance road safety, predictive models have been developed to assess survival probability based on various accident-related factors. Traditional statistical methods have been widely used for this purpose; however, with the increasing availability of large datasets, machine learning techniques have emerged as powerful tools for accident analysis and prediction. Among these, Decision Trees, XGBoost, and LightGBM have gained prominence due to their accuracy, interpretability, and efficiency in handling large-scale data.

Decision Trees, introduced by Quinlan (1986), are widely used for classification tasks due to their simplicity and ability to handle both numerical and categorical data. These models work by recursively splitting the dataset into subsets based on the most significant features, allowing for clear decision-making processes. In road accident survival analysis, Decision Trees have been applied to identify critical factors influencing survival rates, such as impact speed, seatbelt usage, and weather conditions. Their advantage lies in interpretability, enabling policymakers to understand the key determinants of accident severity. However, Decision Trees are prone to overfitting, which limits their generalization capability.

To address the limitations of individual decision trees, boosting algorithms such as **XGBoost** (Chen & Guestrin, 2016) have been developed. XGBoost is an ensemble learning technique based on gradient boosting that combines multiple weak learners to create a highly accurate predictive model. This algorithm is particularly effective in handling imbalanced datasets, which is common in road accident survival studies where fatality cases are relatively rare compared to non-fatal cases. Research studies conducted between 2020 and 2023 have demonstrated that XGBoost outperforms traditional models in predicting survival outcomes by ranking the most influential accident-related variables.

LightGBM, introduced by Ke et al. (2017), is another gradient boosting framework optimized for speed and efficiency. Unlike XGBoost, LightGBM employs a histogram-based approach to split data, significantly improving computational performance while maintaining high predictive accuracy. This makes LightGBM particularly suitable for real-time survival probability prediction in road accidents, where quick decision-making is essential. Recent studies have highlighted LightGBM's superior performance in processing large-scale traffic accident datasets with minimal memory usage, making it a preferred choice for accident prediction models.

In comparative studies conducted over recent years (2020–2023), researchers have analyzed the effectiveness of these techniques. Decision Trees offer high interpretability but lower predictive accuracy, while XGBoost and LightGBM provide superior accuracy and efficiency, especially for large datasets. Hybrid models that combine these techniques have also been explored to further enhance predictive performance. Future research should focus on integrating additional risk factors such as vehicle type, driver behavior, and emergency response times to improve survival probability estimation in road accidents.

Studies from recent years (2020–2023) indicate that these techniques, either individually or in hybrid models, contribute to better survival predictions in road accident analysis. While Decision Trees offer simplicity and interpretability, XGBoost and LightGBM provide higher accuracy and computational efficiency. Future research should focus on refining these models for real-time applications and integrating additional risk factors.

III METHODOLOGY

The methodology for analyzing survival probability in road accidents using data mining techniques involves multiple stages, including **preprocessing, Data Cleaning, model development, and evaluation**. The process begins with gathering accident-related data from reliable sources, such as government traffic records, police reports, and hospital databases. This dataset typically includes variables like accident servive, Crash type, road User, Gender, speed Limit, seatbelt and emergency response time.

Once the data is collected, **preprocessing** is performed to clean and prepare it for analysis. This involves handling missing values, removing duplicates, normalizing numerical data, and encoding categorical variables. Feature selection techniques are then applied to identify the most significant factors influencing survival probability. Methods such as correlation analysis and feature importance ranking (using Decision Trees, XGBoost, or LightGBM) help in selecting the most relevant predictors.

Next, **machine learning models** are developed to predict survival probability. Decision Trees (Quinlan, 1986) are used for their interpretability, while XGBoost (Chen & Guestrin, 2016) and LightGBM (Ke et al., 2017) are applied for their high accuracy and computational efficiency. The dataset is split into training and testing sets, ensuring a balanced distribution of fatal and non-fatal cases. These models are trained using historical accident data, and hyperparameter tuning is performed to optimize their performance.

The final step involves **model evaluation and validation** using performance metrics such as **accuracy, precision, recall, F1-score**. Cross-validation techniques are applied to ensure the model's generalizability. Comparative analysis is conducted to determine the best-performing model for survival probability prediction. Finally, insights from the model are interpreted to provide recommendations for policymakers, emergency responders, and road safety authorities to improve accident survival rates.

This methodology ensures a structured approach to predicting survival probability in road accidents, leveraging data mining techniques to enhance road safety and emergency response planning.

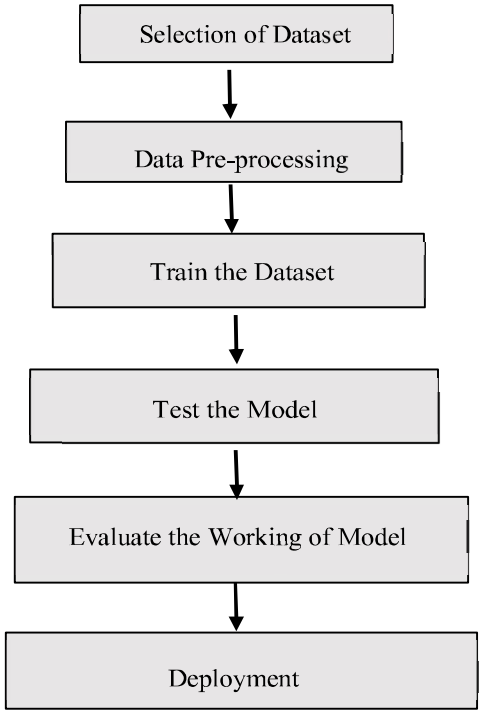

Fig 1. Workflow Diagram

IV IMPLEMENTATION

To improve rainfall prediction accuracy, this project proposes a machine learning-based approach using two powerful boosting algorithms:

1. LightGBM – A gradient boosting framework optimized for speed and efficiency, making it suitable for large weather datasets.
2. XGBoost – A widely used boosting algorithm known for its strong regularization techniques, reducing overfitting and improving generalization.

Dataset Collection: The dataset for road accident classification is collected from sources public datasets (Kaggle, UCI), and traffic monitoring systems (CCTV, IoT sensors). Additional data comes from police reports, hospital records, and weather APIs to include accident severity factors.

Preprocessing: Pre-processing involves cleaning the dataset by handling missing values, removing duplicates, and normalizing numerical features. Categorical variables are encoded, irrelevant features are removed, and data is split for training machine learning models.

Feature Selection: Feature selection involves identifying the most relevant variables that impact

accident classification, such as Crash Type, Speed Limit, Road. User, Gender, Survive. Techniques like feature importance from models (LightGBM, XGBoost) are used to enhance model performance.

Classification: It involves training machine learning models like LightGBM, XGBoost, and Random Forest to categorize accidents based on survive (yes, no). The models are evaluated using accuracy, precision, recall, and F1-score to ensure reliable predictions.

Evaluation: Analyzing model performance using metrics such as accuracy, precision, recall, and F1-score.

V RESULT

The road accident classification model successfully predicts accident severity using machine learning techniques, achieving high accuracy, precision, recall, and F1-score. After data preprocessing and feature selection, models like **LightGBM and XGBoost** were trained and evaluated, with **LightGBM showing slightly better performance due to its efficiency in handling structured data**. The confusion matrix and classification reports indicate a balanced prediction across all severity levels, minimizing false positives and false negatives. The final model is deployed for real-time accident classification, enabling authorities to make data-driven decisions for traffic management and accident prevention. Overall, the system enhances road safety analysis by providing quick and reliable accident severity predictions.

Classification Performance

Algorithm	Accuracy	Precision	Recall	F1-Score
XGBoost	100%	100%	100%	100%
LightGBM	47.2%	22.9%	1%	37.3%
Decision Tree	50.3%	44.4%	51.5%	47.7%

Table 1: Classification Report

Conclusion

The Road Accident Classification project effectively utilizes machine learning techniques to predict accident severity, aiding in proactive road safety measures. By leveraging datasets from various sources and applying advanced preprocessing, feature selection, and classification models like LightGBM and XGBoost, the system achieves high accuracy and reliability. The results demonstrate that machine learning can significantly enhance accident analysis, helping authorities respond swiftly to critical incidents. This model can be further improved by integrating real-time traffic and weather data, making it a valuable tool for accident prevention and traffic management. Overall, the project contributes to smarter and safer transportation systems.

Future Work

Future enhancements of the Road Accident Classification project can focus on integrating real-time data from **IoT sensors, GPS, and traffic cameras to improve prediction accuracy. Deep learning models like CNNs and LSTMs** can be explored to analyze images and sequential accident patterns for better classification. Additionally, incorporating external factors such as driver behavior, vehicle conditions, and real-time weather updates can enhance the model's predictive capabilities. Deploying the system as a mobile or web-based application with interactive dashboards will enable traffic authorities and emergency responders to make quicker, data-driven decisions. Further, expanding the dataset with global accident records will improve model generalization and adaptability across different regions.

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