Predicting Pedestrian Violations in Urban Intersections: A Comparison of Random Forest and XGBoost Models

2. Safety modelling, crash analysis, and evaluation techniques

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Background

Urban intersections are nodes of high risk for traffic violations, especially those related to Vulnerable Road Users like pedestrians. Illegal crossing during the red-light or intergreen phases increase the risks of collision and continue to be a headache that challenges the efforts toward urban mobility. Despite the further development of Advanced Driver Assistance Systems, pedestrian deaths have increased steadily over the last decade (Yusuf et al., 2024), again indicating a greater need for effective road safety interventions.Pedestrian crossings within city centers, especially in business districts, endure a higher violation rate. While the crashes occurring in these areas are not as severe as those in travel lanes, their frequency is very high (Islam et al., 2022).

The paper presents an analysis of pedestrians and vehicles' behavior at two highly congested locations in Athens, Greece- Panepistimiou Street & Omonoia Square and Panepistimiou & Vasilissis Sofias Street-in the frame of the PHOEBE project (PHOEBE, 2023). In this paper, the application and comparison of the Random Forest and XGBoost models is implemented, using machine learning techniques to predict illegal crossings. The results will contribute to enhancing predictive safety models and improving urban traffic management strategies.

Methods

For this study, two datasets were collected at Panepistimiou Street & Omonoia Square and Panepistimiou & Vasilissis Sofias Street in Athens. These locations were chosen as part of the EU PHOEBE project to provide a representative sample of urban traffic scenarios, including various types of vehicles, pedestrians, and cyclists. Additionally, the aforementioned streets are exposed to a large volume of both pedestrians and vehicles, thus exposing the potential threat of conflict among them.

The dataset consists of smartphone camera footage collected at both locations with a duration of one peak hour. A computer vision algorithm was structured in order to extract the data from the videos and more precisely the YOLOv8 is employed for object detection, the ResNet-50 for feature extraction, and Kalman filtering for trajectory tracking. Two datasets for each location were created per frame of the video recordings. One of the pedestrians and their coordinates, crossing compliance, trajectory path and vehicle data with speeds, proximity with pedestrians, traffic light status, coordinates and Time to Collision metric. Regarding the preprocessing of the data, one of the key components was the frame synchronization, as a pedestrian is independently tracked from a vehicle. For frames where no corresponding vehicle or pedestrian was present, placeholder values were used to maintain data integrity.

Two machine learning models were developed and compared for the prediction of illegal pedestrian crossings: Random Forest is a decision-tree-based ensemble learning method known for its interpretability, while XGBoost is a gradient boosting algorithm optimized for imbalanced datasets. The models were trained using features such as pedestrian and vehicle trajectory paths, ground plane coordinates and confidence scores. A train-test split was done, with 80% going to training and 20% to testing, while undersampling was used to balance the dataset. Hyperparameter tuning was performed by grid search, optimizing parameters such as the number of estimators, learning rate, and tree depth.

The performance of the models was then measured by accuracy, precision, recall, F1-score metrics, and confusion matrices to find out the predictive capability. This paper, after comparing different models for two locations, will conclude by explaining the advantages of each ones of the two machine learning models for real-time pedestrian safety analysis and urban traffic management.

Results

The results of the Random Forest and XGBoost models in predicting illegal crossings in two different locations in Athens returned very high accuracy, precision, recall, and F1-score values, although they did differ by location based on specific characteristics of each. For an intersection like Omonoia Square, with less crowded traffic, the Random Forest and XGBoost models also perform quite well, around 95% or more. The Random Forest algorithm showed a very good result: 96% precision and 95% F1-score. XGBoost showed very good recall at 95%, but it had about 30% longer training time due to the gradient boosting mechanism.

On the other hand, the much more complex and busy Panepistimiou Street proves to be quite difficult for both models. In this case, XGBoost outperforms Random Forest with 93% accuracy against its 88%, with higher recall and F1-score at 92%, reflecting better handling of the more complex patterns of pedestrian non-compliance in crowded areas. Random Forest, though producing slightly lower overall metrics, but still remains an efficient alternative with lower computational loads for less demanding environments.

Discussion and Conclusion

These results clearly demonstrate the Random Forest effectiveness and computationally efficiency in simple scenarios and the XGBoost's better performance in complex environments and its suitability to highly congested urban locations such as Panepistimiou & Vasilissis Sofia's Street. This comparison accentuates the need to adapt predictive models to specific urban traffic conditions if their full usefulness is to be realized.

This paper presents the efficiency of Random Forest and XGBoost in predicting illegal pedestrian crossings at urban road intersections. The results show that both models are performing well, but their applicability depends on the environmental complexity. In less crowded intersections, like Omonoia Square, Random Forest had comparable accuracy and precision with lower computational demands, hence being practical for simpler scenarios. Conversely, in much more congested and dynamic places, such as the Panepistimiou & Vasilissis Sofia's Street, the model XGBoost outperformed Random Forest by handling the data pattern with high complexity, though it requires more time in training.

Results highlighted the key contributions of the machine learning models tuned for safety in urban traffic. Integration into predictive safety analysis frameworks will enhance traffic management strategies to minimize collision risks among pedestrians. Future research studies also need to be considered for feature engineering, like time-to-collision metrics, and scalability assessment of these models across diverse urban settings.

Selected references

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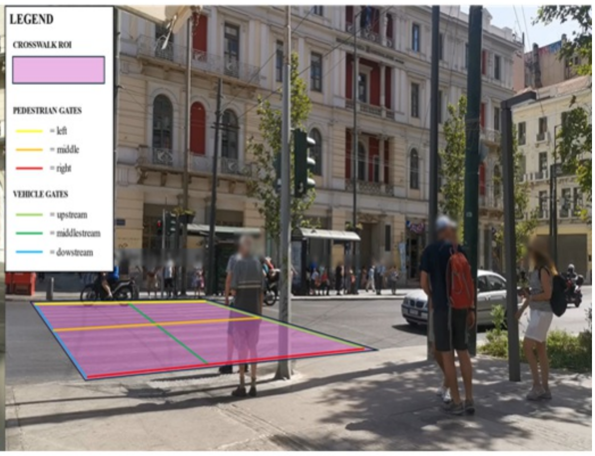
Yusuf, S. A., Khan, A., & Souissi, R. (2024). Vehicle-to-everything (V2X) in the autonomous vehicles domain–A technical review of communication, sensor, and AI technologies for road user safety. Transportation Research Interdisciplinary Perspectives, 23, 100980. https://doi.org/10.1016/j.trip.2023.100980

Location Panepistimiou & Vasilissis Sofia's Street



Location Panepistimiou Street & Omonoia Square