An Exploratory Study of Solving the Traffic Sensor Location Problem from the Perspective of Traffic Safety

by **Zihan Liu**

Nowadays, sensors with strong perception capabilities, like LiDAR and HD cameras, are being piloted as traffic sensors to make transportation smarter and more sustainable [1]. Traffic accident monitoring and safety improvement is one of the application scenarios [2]. Before traffic sensors can function in the field, their location strategy is a critical decision to be made. The related discussion is generalized as the Traffic Sensor Location Problem (TSLP) [3]. The location strategy of traffic sensors is always determined by their functionality [4]. Over time, TSLP has often been discussed from the perspective of traffic flow, while the discussion from the perspective of traffic safety has been rather rare [5]. Facing this gap, this thesis aims to conduct an exploratory study of solving TSLP from the perspective of traffic safety. In this case, traffic sensors should be put where traffic accidents or near-accidents tend to happen, and TSLP is reduced to a problem of traffic accident/near-accident hotspot detection.

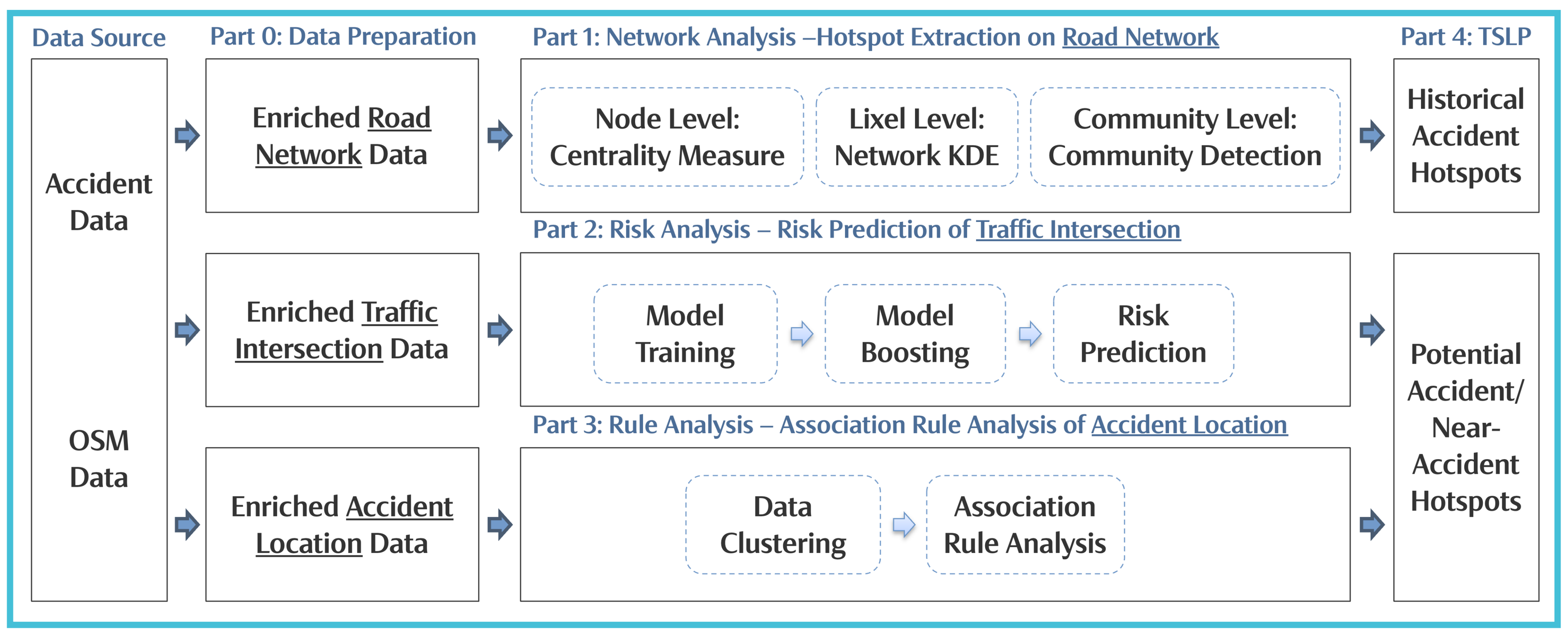

Fig. 1 The Workflow of Solving Traffic Safety-Oriented TSLP Proposed in this Thesis.

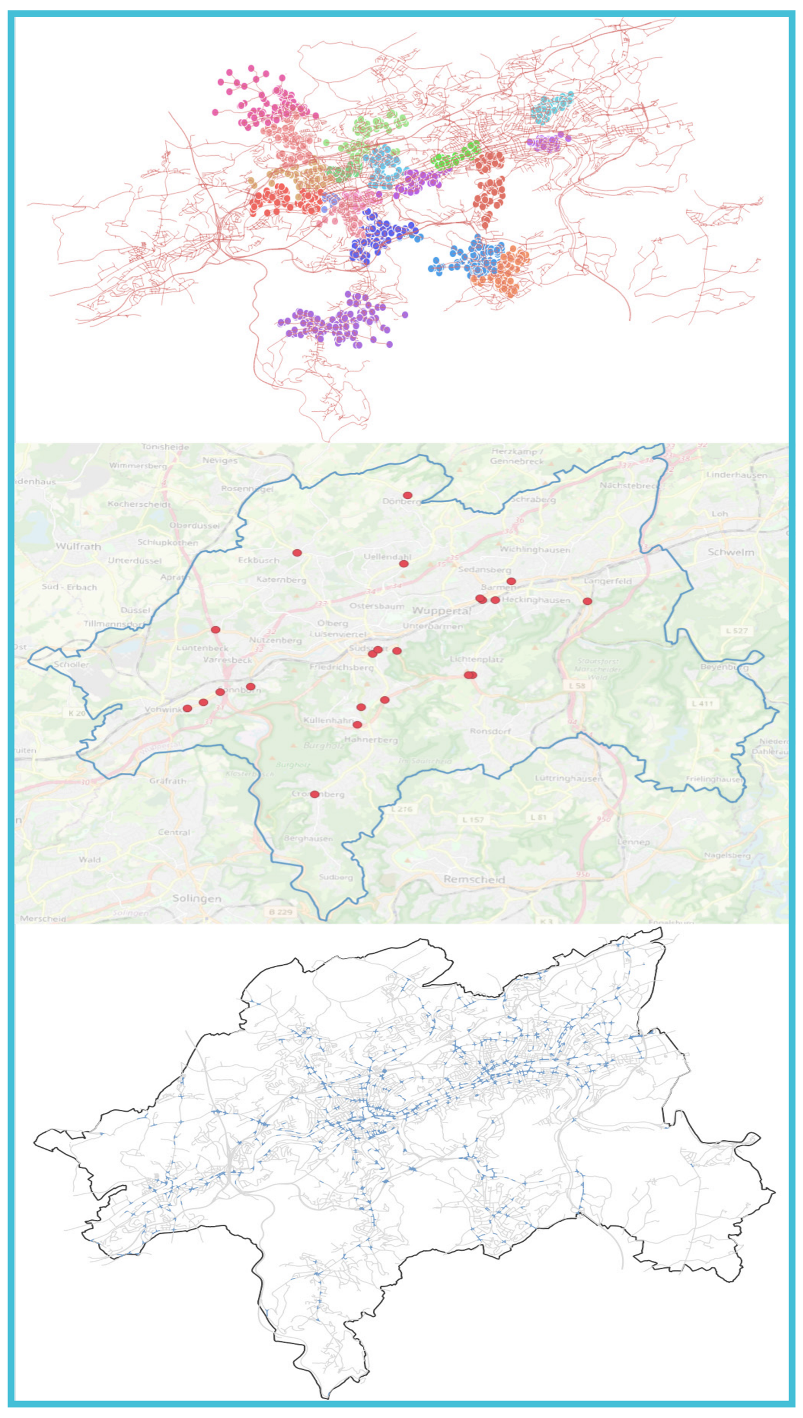

Fig. 2 Selected Results of Candidate Locations

Workflow

As shown in Fig. 1, the workflow proposed in this thesis consists of five sections, including three parallel analysis methods, aiming at three study objects, respectively.

Data Source: two data sources are required, namely traffic accident data and OSM data.

Part 0 - Data Preparation: data of three study objects, namely road network, traffic intersection, and accident location, are prepared. They are enriched with the accident and nearby geographic feature information from data sources for further analysis.

Part 1 - Network Analysis: uses network analysis methods by multiple levels (node, lixel and community levels) to detect the historical traffic accident hotspots on the road network.

Part 2 - Risk Analysis: uses machine learning methods to model the correlation relationship between traffic accident risk of traffic intersections and their nearby geographic features, and thereby predict the accident risk of traffic intersections.

Part 3 - Rule Analysis: uses data mining methods to detect the association rules between geographic features and accident locations.

Part 4 - TSLP: it is to connect the analysis results to location strategy, the extracted historical hotspots and predicted potential hotspots are candidate sensor locations.

Case Study

Study Area: Wuppertal, NW, Germany

Data Sources: two open data sources, namely German Accident Atlas and OSM

Data Preparation: includes four steps, namely road network modelling, road intersection detection, accident data filtering and data enrichment.

Network Analysis: on the node level, betweenness and PageRank centrality measures are used, on the lixel level, network KDE is used, and on the community level, the Louvain method of community detection is used to detect the hotspots on the road network.

Risk Analysis: a random forest classification model is trained with the data of the four nearby cities of Wuppertal, and the risk of traffic intersections in Wuppertal is predicted with the trained model.

Rule Analysis: accident data are clustered by attributes and using the community detection method respectively, and association rules between a cluster of accident locations and their nearby geographic features are analyzed.

TSLP: based on the analysis results, candidate sensor locations are obtained. Some selected results are shown in Fig. 2, including 1) detected high-risk communities on the road network, 2) predicted high-risk traffic intersections, and 3) adjacent accident locations on the road network of accident-associated geographic features (crossings).

Discussions

Three methods are oriented to different study objects and have different types of results and different characteristics. In practice, they should be selected as needed.

In network analysis, the main difficulty is to find effective centrality measures and community detection algorithms with reasonable practical meanings. Further work can be done by designing customized measures and algorithms native to this problem.

Both in risk analysis and rule analysis, the correlation/association relationship between traffic accidents (risk) and nearby geographic features are explored, and their results show strong consistency. Geographic features are not the cause of traffic accidents but can help to locate accident hotspots as their symptoms. Limited by data features, the current rule analysis is incomplete. Further work can be done by combining two methods with traffic intersection data and iteration.

Conclusions

With the case study, the effectiveness of the methodology is initially verified. Network analysis methods can effectively identify the historical accident hotspots on the road network. The correlation between accident risk and geographic features can be effectively explored, modelled, and used for risk prediction. The relevant discussion of TSLP have to continue, extend, and adapt to the new scenarios.

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References

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