Thesis Title: Smart-sensing-based Traffic Monitoring and Safety Risk Prediction

Abstract:

Despite continued efforts to enhance traffic safety, vehicle crashes and injuries remain a persistent challenge, highlighting the urgent need for more effective traffic monitoring and risk management strategies. This thesis presents an integrated framework that leverages vehicle trajectory data collected from smart sensors and Vehicle-to-Everything (V2X) communication to enhance roadway monitoring and safety risk prediction. First, a deployable real-time traffic monitoring system is developed, consisting of a long-range radar sensor, a roadside unit, and an edge computing device. The system achieves real-time high detection accuracy and extended detection range through cooperative perception and C-V2X communication. Second, to provide localization of the detected objects, a novel road geometry estimation model is proposed based solely on vehicle trajectory data. This model estimates lane nodes by applying a Gaussian Mixture Model to the lateral distribution of vehicle positions, offering a cost-effective alternative to traditional mapping methods that rely on expensive mobile mapping systems. Finally, the thesis introduces a vehicle group (VG)–based risk prediction framework that considers both continuous vehicle motion and inter-vehicle interactions. Both Logistic Regression and a Graph Neural Network (GNN) model are employed to predict VG risks with high accuracy. To better understand the prediction results of the GNN model, the GNNExplainer is used to interpret critical vehicle-level features contributing to the risk. This thesis makes contributions to developing a comprehensive and scalable solution for trajectory-based traffic monitoring and risk management. The overview of the thesis is shown in Figure 1.

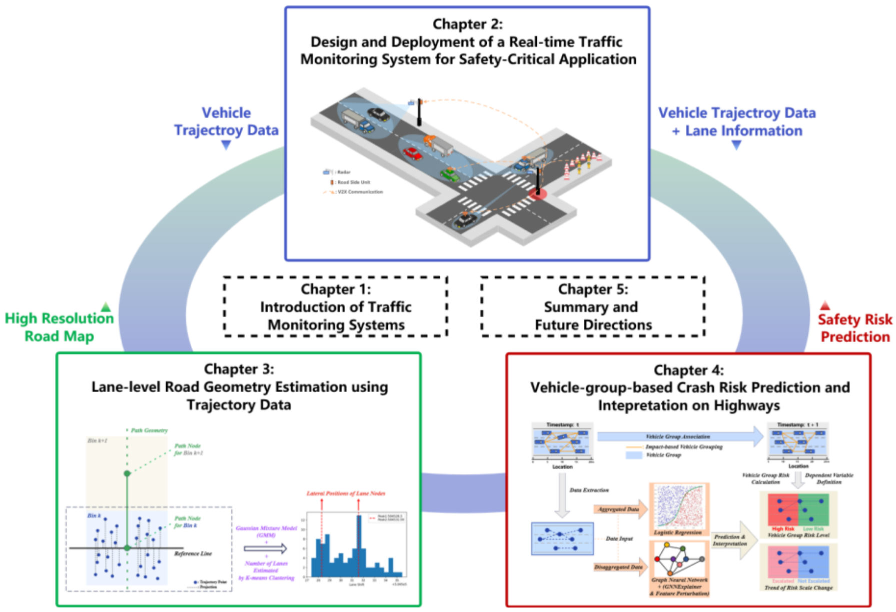

Figure 1. Graphical overview of this thesis