ABSTRACT

Improving safety and mobility remains significant challenges in modern transportation systems. Supported by advancements in sensing, communication, and edge computing, smart infrastructure has the potential to reduce the number of crashes and alleviate congestion. When collaborating with connected and automated vehicles (CAVs), the infrastructure-vehicle cooperation system enables the collection of continuous, and high-quality vehicle trajectory data over time and space, which can be used to 1) provide real-time warnings to human drivers for collision avoidance; 2) estimate accurate traffic state and optimize traffic flow; and 3) detect abnormal driving behaviors caused by human errors or vehicle system failures.

This dissertation investigates the role of smart infrastructure to enhance driving safety by providing a detection and mitigation framework from detecting abnormal driving behaviors to issuing advanced warnings to human drivers. It also demonstrates how smart infrastructure can be utilized in mobility applications by reconstructing missing vehicle trajectories, ultimately contributing to the operations of safter, more efficient, and more resilient transportation systems. The first part of this dissertation (Chapters 2 and 3) explores infrastructure-based warning systems for human drivers in crash imminent situations. Through two driving simulator studies, this research examines the optimal design of advanced warnings and evaluates how uncertainties in warnings influence driver's trust and safety performance. The second part of this dissertation (Chapter 4) investigates how smart infrastructure can be leveraged to detect abnormal driving behaviors. The detection results can be used as triggers for issuing advanced warnings. Finally, the third part of this dissertation (Chapter 5) switches to the mobility perspective and explores how vehicle data collected from the infrastructure can be integrated with CAV data to reconstruct complete vehicle trajectories from partial observations. Specifically, this work incorporates the lane-changing (LC) behaviors in the reconstruction process, which is usually ignored in existing studies.

Keywords: Smart Infrastructure, Advanced Warning; Driving Behavior Analysis, Trajectory Reconstruction, Anomaly Detection