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Research Notes

Vulnerable Road User: Accurate and Reliable Detection Using Roadside-Assisted Cooperative Driving

Investigating Communications Systems to Enhance the Safety of Vulnerable Road Users at Intersections through Roadside-Assisted Cooperative Driving.

Advanced Research

May 2025

Project Title: Connected and Automated Vehicle Cross Cutting Research

Task Number: 4067

Start Date: June 30, 2023

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WHAT IS THE NEED?

Every day 10 people die on California's transportation system and at least two of them are pedestrians and bicyclists. Data from the United States Department of Transportation indicates that 40% of the 5.8 million US crashes in 2008 were intersection related, and 55.7% of intersection crashes are attributed to driver recognition errors such as inattention or distraction. Sharing road space with motorists, especially at intersections, pedestrians and cyclists suffer much higher risks of injury or death from collisions, as they usually do not have an external protective device. In California, 893 pedestrians were killed, and more than 14,000 pedestrians were injured on roadways in 2018. Even worse, California has the most pedestrian fatalities in the United States, about 25% higher than the national average. To address this issue, the California Department of Transportation (Caltrans) initiated the Pedestrian Safety Improvement Program to identify and address systemic threats to pedestrian safety across the state. The long-term goal is to drive these numbers of accidents and deaths attributed to driver recognition errors toward zero. This is possible with high-definition sensor technology that is rapidly becoming available and being installed in intersections.

WHAT ARE WE DOING?

The research team will leverage the existing upgraded infrastructure at the Smart Intersection along the Riverside Innovation Corridor in Riverside, California, which includes advanced roadside sensors (e.g., Light Detection and Ranging (LiDAR), a fish-eye camera, and a high-resolution pinhole camera) and wireless communications (e.g., cellular

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networks, and WiFi). A high-resolution roadside sensor-based traffic surveillance, or object perception, pipeline will be developed with an advanced LiDAR and computer vision algorithm. The algorithm will include a few major functions: object perception (i.e., object detection and classification, multi-object tracking, cooperative perception, and motion prediction), conflict (potential collision) prediction, and risk mitigation. The proposed algorithm will be implemented in a state-of-the-art connected and automated vehicle simulator called CARLA and perform comprehensive testing for different conflict scenarios involving both vehicles and vulnerable road users (VRUs).

By leveraging the existing infrastructure and equipment, the researchers will implement different components and perform system integration for prototyping. The major components will include: the inference pipeline, risk identification, and information distribution from the infrastructure to target road users (e.g., VRUs and connected vehicles); on-board driver-vehicle interface for advanced driving assistance of the target vehicle; and mobile applications to enable the target VRU to receive warning messages. This system will be able to detect, classify, track and predict the motion of individual road users (e.g., pedestrians, cyclists, and vehicles) within or approaching the intersection in real-time, identify the potential collisions between VRUs and connected vehicles, and send warning signals to specific connected traffic participants (with onboard units or smart phones) via wireless communications, to mitigate imminent safety risks.

WHAT IS OUR GOAL?

The proposed work aims to improve the safety of VRUs, e.g., pedestrians, cyclists, and maintenance workers, at intersections using advanced roadside sensing and infrastructure connectivity. The proposed system is intended to detect, classify, track, and predict the motions of traffic (including VRUs) in real-time. Trajectory predictions will be used to evaluate collision risks, and warning signals will be communicated to connected VRUs and vehicles.

The anticipated outcome is a decrease in crashes (especially involving VRUs) at intersections, thus enhancing the safety performance of the system. Crash-related congestion and environmental impacts would also be decreased, thereby enhancing throughput and sustainability.

WHAT IS THE BENEFIT?

The findings from this project are expected to advance the state-of-the-practice for connected infrastructure and emerging advanced roadside sensing technologies to support the introduction of connected and automated vehicles (CAVs) in a realistic mixed traffic environment. Results from this study will also significantly improve safety for VRUs at intersections throughout California.

Results from this proposed research will not only promote safety but also transportation equity and accessibility. Active travel, such as walking and cycling, is a healthy, accessible, and affordable form of mobility. However, it brings safety concerns to active travelers when interacting with motorized vehicles. One of the challenging technical and political questions regarding CAV adoption is how to ensure that CAVs can be deployed in a non-detrimental way when interacting with other non-CAV road users, including active travelers. The expected results from this project will promote the cooperation between VRUs and connected vehicles to improve the overall safety performance at intersections.

WHAT IS THE PROGRESS TO DATE?

Since the last update, the research team achieved several key milestones in their project. A complete pipeline was developed for Vulnerable Road User (VRU) detection, classification, localization, tracking, trajectory prediction, conflict prediction, and warning dissemination. To enhance detection accuracy, the team implemented multi-modal and multi-node sensor fusion algorithms, integrating LiDAR and camera data. These perception algorithms were rigorously evaluated using both proprietary and open-source datasets, yielding quantitative results.

The Task 2 report was completed, and the team continued to collaborate with the Strategic Highway Safety Plan (SHSP) Emerging Technologies #3 working group to ensure alignment with stakeholders. In parallel, a comprehensive literature review on VRU perception was finalized and submitted to an open-access journal.

The procurement of equipment and supplies for field deployment was completed.

After field testing and evaluation at the designated intersection, the UC Riverside team submitted a draft of the final report, which is currently under review.

IMAGES

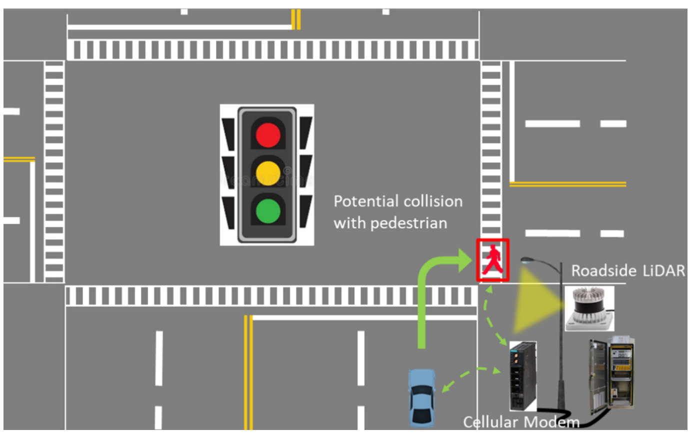

Image 1: VRU collision avoidance using roadside sensor

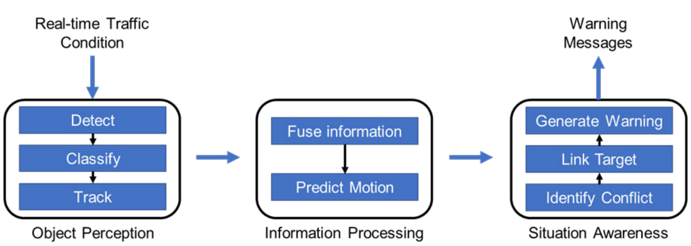

Image 2: Flowchart of the proposed algorithm

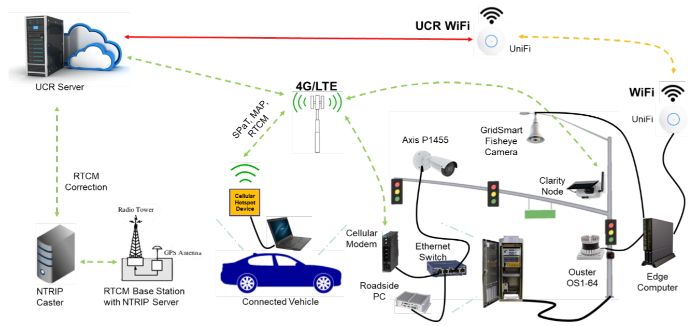

Image 3: Existing smart Infrastructure at the intersection of University and Iowa Avenues near UCR