Safe Operation of Automated Vehicles in Intersections

Developing a framework to identify intersections whose instrumentation is critical to ensure safe and efficient AV operation.

Identifying the Need

Intersections create greater risks when compared to streets. The paths of vehicles, bicycles, and pedestrians cross each other within intersections, creating "conflict zones" and the potential for crashes. The absence of lane markings, split phases, complex vehicle trajectories, invisible vehicle approaches, illegal movements, the simultaneous interactions among pedestrians, and the presence of bicycles and pedestrians all prevent determining who has the right of way and results in higher rates of incidents and accidents.

An intelligent intersection could mitigate the inherent risks of navigating through an intersection through the acquisition and processing of appropriate sensor data and then the generation of Infrastructure to Vehicle (I2V) messages. I2V messaging is currently being employed for connected vehicles. These messages can provide complete phase information, predict the signal phase and timing in the next cycle, accurately assess the occupancy of blind zones, and warn of the danger from traffic signal violators. Autonomous vehicles (AVs), in contrast, rely solely on on-board sensors to navigate through the street environment.

In addition to providing actionable data for driving, data collected at intelligent intersections can then be analyzed to identify where the application of limited capital and maintenance resources (across all intersections in the transportation network) can reduce the greatest risks, providing the greatest benefits.

What is the goal?

The overall purpose of this project was to describe the technology needed for safe and efficient operation of signalized intersections in the presence of connected and automated vehicles (CAVs). In addition to the potential of infrastructure to vehicle (I2V) information, infrastructure sensors themselves can also be used to routinely monitor safety-critical dynamics of modes, such as drivers yielding to pedestrians, pedestrians crossing on red, red-light running, etc., over long periods of time.

Project Description

The following three areas were explored in this project:

1. Demonstrate if an autonomous vehicle, with vision and radar sensors but without infrastructure assistance, can encounter hazardous situations that could lead to crashes in intersections

2. Illustrate which hazardous situations (that autonomous vehicles cannot address) can be avoided by appropriate infrastructure sensors

3. Demonstrate #1 and #2, listed above, in the real-world environment

Projected Benefits to California

Forty percent of crashes, 50 percent of serious collisions, and 20 percent of fatalities occur in intersections. Bay Area fatalities increased 43% between 2010 and 2016 to reach 455 killed, of which, in San Francisco, 62% were cyclists or pedestrians. Identification of intersections, where proper instrumentation could improve the safety and mobility of the travelers, is critical for fulfilling the goal of Toward Zero Deaths (TZD) – a strategic priority for Caltrans, the Department of Motor Vehicles (DMV), and the US Federal government.

Caltrans and the DMV are engaged in the design, testing, and modification of rules for the deployment of Autonomous Vehicles in California. In regulating AVs on freeways, Caltrans can rely on the on-board sensing and control capability of AVs. However, in the complex environment of urban intersections this on-board capability alone will not be sufficient except in the simplest intersections. In most intersections, safe operation of AVs will require augmentation of their capabilities with infrastructure-based sensing. Such sensing capability must be provided by Caltrans and local transportation authorities both because they own and operate the intersection and because this capability will be provided to all AVs.

The research is a step towards specifying what these sensing capabilities should be and will have immediate value in terms of calibrating intersections safety and suggesting directions to improve safety. An Intelligent Intersection does not require costly physical modification of road infrastructure but provides the functionality to communicate with all connected agents in the intersection, including bicyclists and pedestrians.

What is the progress to date?

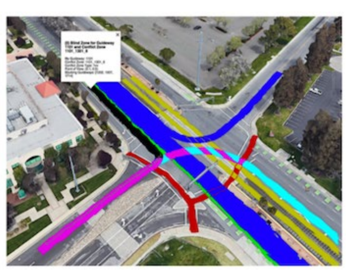
This project is complete. The focus was to develop methodologies to identify intersections whose instrumentation is critical to ensure safe and efficient AV operation. This research demonstrated that an automated vehicle with vision and radar sensors but without infrastructure assistance can encounter hazardous situations that could lead to crashes, and it was shown that the hazardous situations can be avoided by appropriate infrastructure sensors.

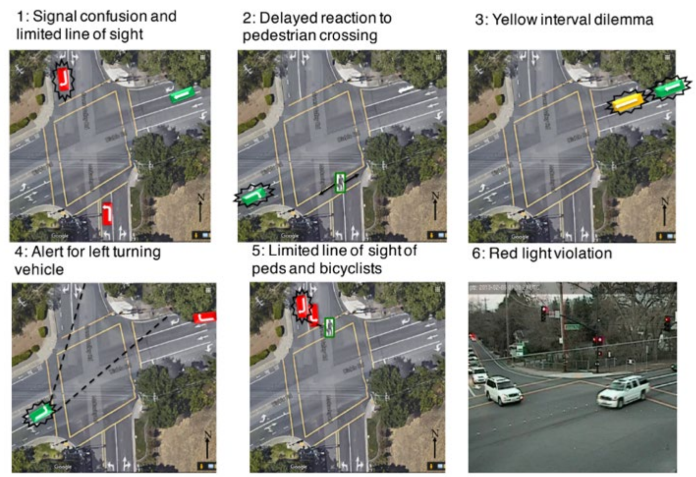
Beyond infrastructure elements, an assessment of different traffic signal control types is also important. Finally, although our choice of parameters for clustering intersections was related to the concept of guideway/conflict zones and crashes, future extensions of this work will also seek to cluster intersections using the number and types of guideways, conflict zones and blind zones as clustering criteria.

Final Report

[Safe Operation of Automated Vehicles in Intersections (ca.gov)]

Images





About the Author

Alex Kurzhanskiy received his M.S in Applied Mathematics & Computer Science from Lomonosov Moscow University and his Ph.D. in Electrical Engineering & Computer Science at Berkeley. He joined PATH as a Postdoctoral Researcher in 2008 and in 2011 he became a part of PATH research staff as an Associate Research Engineer. He has 15 years of experience working in the transportation field and is a specialist in scalable data-rich distributed software systems, GIS and spatial analysis, transportation data analysis, and decision support.

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