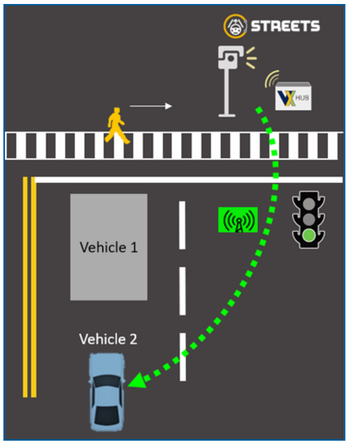
Perception Sharing for Cooperative Driving Automation (CDA)

In 2023, pedestrian and bicyclist fatalities together made up about 21 percent of all traffic fatalities in the United States.[1,2] Both drivers and automated vehicles often have blind spots or limited sight lines where they cannot see vulnerable road users. These visual limitations potentially contribute to those incidents.

Cooperative perception can help drivers and automated vehicles perceive vulnerable road users, other vehicles, obstacles on the road, and other objects by allowing vehicles and infrastructures to share the location data of nearby objects and additional helpful information with other roadway entities. For example, in figure 1, a roadside sensor can detect a pedestrian in a crosswalk and send nearby vehicles a message informing them of the vulnerable road user. Nearby vehicles can then determine if the pedestrian is a hazard and can provide a warning to their driver or perform an automated maneuver to ensure a crash is avoided.



Source: Federal Highway Administration (FHWA).

Figure 1. Illustration. Cooperative perception example scenario.[3,4]

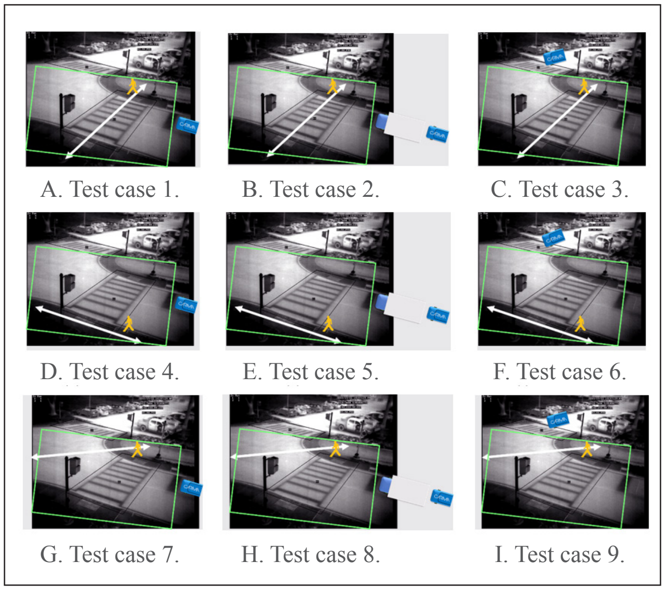
BENEFITS TO TRANSPORTATION

Cooperative perception improves the perception performances of automated vehicles and infrastructure, leading to enhanced situational awareness that could enable more effective safety and mobility CDA applications.[5] The enhanced situational awareness not only improves safety performance in immediate collision avoidance scenarios but also supports the automated driving system and CDA algorithms to better plan the vehicle's path, speeds, and accelerations.[5] Moreover, enhanced perception could also support motion planning for improved mobility and energy performances.[5]

RESEARCH FOCUS

To test the CARMA℠ cooperative perception system, the FHWA research team conducted a series of vulnerable road user scenarios[5] in which a pedestrian walked through a crosswalk at multiple angles with a stationary vehicle located on the approach to the crosswalk. In some cases, the stationary vehicle had an obstructed line of sight, and in some cases it did not (figure 2).

In these scenarios, a roadside unit equipped with a thermal sensor was used for object detection and perception, CARMA Streets℠[3] and Vehicle-to-Everything (V2X) Hub[4] was used for information processing and communication, and a stationary vehicle running CARMA Platform℠[6] was used to run the CARMA cooperative perception system.



All images source: FHWA.

Figure 2. Screenshots. Different vulnerable road user scenarios considering their intended path of travel and the location of the vehicle receiving the information.

EVALUATION OF THE CONCEPT

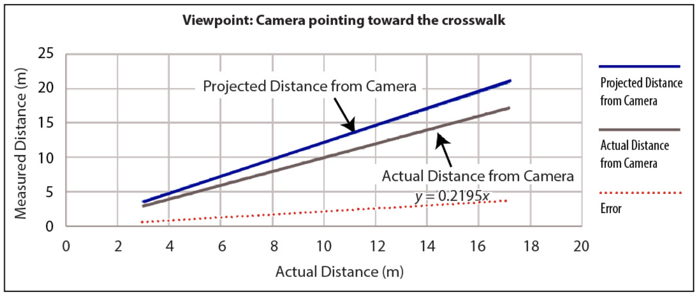
Independent evaluators from the U.S. Department of Transportation Volpe National Transportation Systems Center tested the CARMA cooperative perception system using the following criteria:

- Consistency and frequency of information sent from one system to another.
- Latency between vulnerable road user movements and detection.

FACT SHEET

Perception Sharing for Cooperative Driving Automation (CDA)

- Creation and transmission of a personal safety message (PSM).
- Translation of PSM information into an object that the cooperative automated driving system (C-ADS) can plan for.
- Difference between the vulnerable road user positions estimated by the infrastructure sensors (figure 3) and the C-ADS using LiDAR data (when both entities have clear lines of sight to the vulnerable road user).



Source: FHWA.

Figure 3. Graph. Difference between projected and actual vulnerable road user distance from the infrastructure sensor (camera).

RESULTS

The CARMA cooperative perception system successfully transferred and processed information in less than 6.5 ms, on average, from the time a vulnerable road user was detected to when the detection was communicated to the C-ADS, allowing the system to make safety decisions faster.

NEXT STEPS

Future research could potentially focus on the following areas:

- The careful calibration of infrastructure-based sensors in the deployment environment was found by the research team to be especially determinative in system efficacy. Achieving more accurate detection and perception could prove to be an essential component in cooperative perception technology's success.
- The standardization of sensor outputs of object detection and perception, especially standardized uncertainty measures, could significantly accelerate cooperative perception technologies by enabling effective data fusion.
- Standardized sensor application programming interface could also significantly accelerate cooperative perception technologies by enabling relevant software to work with different sensors from various vendors.
- Sensor fusion in the CARMA ecosystem could be tested in simulation to analyze effectiveness.
- Adaptive communication protocols could be developed, so that message content and broadcast are adjusted based on context (traffic situations).

REFERENCES

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6. FHWA. n.d. "carma-platform" (software and configuration files in GitHub repository). https://github.com/usdot-fhwa-stol/carma-platform, last accessed April 12, 2023.

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Saxton Transportation Operations Laboratory
https://highways.dot.gov/turner-fairbank-highway-research-center/labs/STOL

V2X Github
https://github.com/usdot-fhwa-OPS/V2X-Hub

CARMA Platform
https://github.com/usdot-fhwa-stol/carma-platform

For more information, please contact the CDA Program at CDA@dot.gov.

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