The Exploratory Advanced Research Program Fact Sheet

Smart Vehicles, Smart Signals, Smart Cities

How Cyber Physical Systems Can Foster Traffic Synergy

Exploratory Advanced Research . . . Next Generation Transportation Solutions

As America's urban population multiplies, so does the number of cars on city streets. The resulting congestion can contribute to increased or unreliable travel time. For its *2016 Urban Congestion Trends* report, the Federal Highway Administration (FHWA) calculated the hours of congestion in 52 of the largest U.S. metropolitan areas at 4:43 hours, up from 4:22 hours 5 years earlier, as noted in the *2011 Urban Congestion Trends* report. The emergence of highly automated vehicles could help improve urban mobility if the cars can be safely integrated into cyber physical systems (CPS) that also include technologically advanced traffic signals and road sensors. In partnership with the National Science Foundation (NSF), the Exploratory Advanced Research (EAR) Program at FHWA is supporting three research projects with applications of CPS for highway transportation to understand how to scale public benefits of new technologies. Arizona State University and Ohio State University are working together on one of the projects, while the University of California (UC)–Berkeley and the University of Florida are separately conducting the other two.

The Traffic "Talk" of Tomorrow

Cyber physical systems consist of embedded computers that monitor and control physical processes, and feedback loops enable the components of the system to respond to each other. One transportation application of CPS is to get automated vehicles, traffic signals, and road sensors "talking" to each other within traffic operating systems. The potential benefits of this approach include more stable traffic flows, harmonized speeds through traffic signals, better use of highway capacity, and safer streets thanks to fewer driver errors.

Various vehicle technologies can be used to create CPS in transportation. Examples include cooperative adaptive cruise control to synchronize the speeds of multiple vehicles, lane-keeping steering assist to keep vehicles from drifting, collision mitigation systems to warn drivers of approaching dangers and take automated action to avoid them, and automated emergency braking for pedestrians. Sensors such as magnetic detectors, radar devices, cameras, and inductive loops embedded into highways also are part of the system. They keep tabs on vehicle speeds, the distance between vehicles, and other data. The elements within a CPS share information through wireless technologies such as vehicle-to-infrastructure, vehicle-to-vehicle, and dedicated short-range communications.

FHWA and NSF are jointly backing research that is designed to overcome the challenges to implementing safe, secure, and dependable CPS in transportation. The data from static road sensors, for instance, may be limited. Individual vehicles within automated platoons may need to join or leave the platoons at certain points to optimize the flow through intersections. Algorithms also must be able to predict numerous traffic scenarios, including interaction with vehicles operated by drivers, and to pinpoint failures. The three research teams are seeking solutions to these and other challenges by running software tests in simulation environments and by conducting field experiments.

From Simulations to Field Tests

Researchers at Arizona State and Ohio State Universities are working to develop a network that can coordinate a mix of automated and legacy vehicles on a complex road network. Within these collaborative vehicular systems, some vehicles are highly automated, securely talk to other cars, and use sensors and computing to interpret the behavior of cars that are not as technologically advanced. The two universities are developing simulation models independently and sharing them with each other, along with the results. The experiments progress from simple interactions, like opening a gap for another car within a fleet of automated vehicles, to more complex traffic scenarios, such as reacting to a stopped vehicle around a blind curve. The goal is to develop a distributed system calculus that could be scaled from integrating a few cars in a research environment to getting potentially dozens of them talking to each other and the infrastructure around them in real applications.

U.S. Department of Transportation
Federal Highway Administration

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© *University of Florida.* This self-driving vehicle, named NaviGator, is part of the University of Florida's research into cyber physical systems.

In addition to minimizing congestion and reducing driver errors, the CPS research at UC–Berkeley aims to curtail collisions at intersections and to contain the costs of city parking by reducing the time it takes to find open spots. To achieve these goals, researchers use existing automotive, communication, and computation tools to manage traffic at three levels—the vehicle, the road link, and the network link. The options include adjusting the speed and headway of automated vehicles, optimizing the timing of traffic signals and special lanes (like opening high-occupancy vehicle lanes to all traffic), and setting traffic signals to favor traffic on particular routes at specific times. The UC–Berkeley team is collecting field data in two locations—Arcadia in southern California and North Bethesda in the Washington, DC, area. At the latter location, researchers are pulling data from actual traffic as it moves through eight intersections, and they are building simulation models based on those real-life situations.

The CPS research under way at the University of Florida seeks to develop signal control strategies by optimizing the technology in automated vehicles and other sensor mechanisms. Researchers are developing algorithms that obtain the locations, directions, and speeds of vehicles as they enter the communications range of an intersection; send that data to the traffic signal; and calculate the best approach trajectories for each vehicle. By optimizing the signal timing, this approach can improve traffic flow and minimize travel time. Twice in 2017, the researchers tested some of their computer simulations on a closed-course intersection at the Florida Department of Transportation's Traffic and Engineering Research Lab in Tallahassee. Based on the lessons learned there, the team is enhancing the algorithm to implement a test bed on the university's Gainesville campus. The researchers are working to improve the accuracy of the information they receive from sensors and to extend the communications range so they can gather data from vehicles farther from the intersection.

EXPLORATORY ADVANCED **RESEARCH**

What Is the Exploratory Advanced Research Program?

The EAR Program addresses the need for longer term, higher risk research with the potential for transformative improvements to transportation systems. The EAR Program seeks to leverage advantages in science and engineering that could lead to breakthroughs for critical, current, and emerging issues in highway transportation by experts from different disciplines who have the talent and interest in researching solutions and might not do so without EAR Program funding.

To learn more about the EAR Program, visit www.fhwa.dot.gov/advancedresearch. The website features information on research solicitations, updates on ongoing research, links to published materials, summaries of past EAR Program events, and details on upcoming events.

All three projects demonstrate the potential of cyber physical systems in transportation. "As traffic increases in America's urban centers, cyber physical systems that get smart cars and smart signals talking to each other can help keep our streets safe and efficient," says Gene McHale of FHWA's Office of Operations Research and Development. "This in turn can improve overall mobility and help support economic vitality across State and urban areas."

Learn More

For more information about these EAR Program projects, contact Gene McHale or Govindarajan Vadakpat, FHWA Office of Operations Research and Development. McHale can be reached at 202-493-3275 (email: gene.mchale@dot.gov); and Vadakpat can be reached at 202-493-3283 (email: g.vadakpat@dot.gov).

Photo credit, page 1: © *University of Florida.* The University of Florida uses this signal controller to optimize signal phase and timings in real time as part of its research into cyber physical systems.

Federal Highway Administration. (2017). *2016 Urban Congestion Trends: Using Technology to Measure, Manage, and Improve Operations*, Washington, DC, obtained from: https://ops.fhwa.dot.gov/publications/fhwahop17010/fhwahop17010.pdf, last accessed April 26, 2018.

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