Research explores ways to improve GPS accuracy for traffic safety applications

Lane-departure or lane-keeping systems, which alert distracted drivers when they’re straying from their lanes, have the potential to greatly improve driver safety. A 2017 study found that they reduce crash and injury rates by 11 and 21 percent, respectively. However, the Global Positioning System (GPS) technology needed to make them widespread has yet to be perfected.

A lane-keeping system needs to have an extremely accurate GPS—down to 2 to 4 inches. But those systems can cost thousands of dollars and must be installed in the factory. For lane-keeping systems to be truly useful to the wider public, they need to be less expensive and easier to install after market.

One way to make these systems more affordable would be to use low-cost GPS antennas; however, along with their reduced cost comes reduced accuracy. In a Roadway Safety Institute project, researchers are seeking to solve this problem by quantifying and adjusting for the errors generated by a low-cost GPS antenna.

“If we could determine the errors and then resolve those errors, it could potentially open the door for using low-cost devices like your cell phone,” says Rhonda Franklin, principal investigator of the project and a professor in the University of Minnesota’s Department of Electrical and Computer Engineering (ECE). Granted, the RSI-funded study is preliminary and the possibility of using a cell phone antenna for a lane-keeping system is a long way off, Franklin says. However, she and fellow researchers Robert Sainati from ECE, Demoz Gebre-Egziabher from the Department of Aerospace Engineering and Mechanics, and a team of students decided to tackle some emergent questions: why are high-quality antennas so accurate, and can antennas be calibrated outside of the lab?

Franklin led a team that took two GPS antennas—one high-cost and the other low—and put them in the controlled environment of an anechoic (echo-free) chamber to test how they “see” satellite signals. From this, the researchers gained an understanding of the antennas’ “phase center”—the point where satellite signals hit the antenna. They found that this point has a tendency to
wander, which causes GPS readings to be off by a few millimeters or even centimeters. This can cause large errors in calculating position since the signals from multiple satellites are not hitting the same point on the antenna.

Gebre-Egziabher tackled the second part of the problem: calibrating an antenna outside of an anechoic chamber. After collecting 48 hours’ worth of data from high- and low-cost GPS antennas placed outside, his team set about trying to create error models that could calibrate the antennas to the needed level of accuracy.

“If you could do that, people wouldn’t have to spend a lot of money on calibrating antennas in expensive anechoic chambers,” Gebre-Egziabher says.

The ultimate goal of this work is to make lane-keeping systems available to more people. If low-cost GPS antennas could be made as accurate as high-cost antennas without built-in calibration, these systems could be mass-produced and sold as an add-on to retrofit existing cars. More people would be likely to buy them and benefit from their safety features.

Getting to this point, however, will take more work. The researchers now know that the calibrations can be done, but the data-collection apparatus they used had some flaws. With more funding to continue its effort, the team would set up a new experimental apparatus and collect additional data, Gebre-Egziabher adds.

Better prediction of train arrival times promises safety benefits

A new model developed by Roadway Safety Institute researchers can more accurately predict train arrival times at railroad crossings—a finding with both safety and congestion-relieving benefits. Incidents at highway-rail grade crossings are a serious safety challenge: in 2015, there were nearly 3,000 collisions between vehicles and trains at grade crossings, resulting in 230 fatalities. In addition, lengthy train crossings can cause congestion on surface streets, leading to delays and blocked roads for emergency vehicles.

“Blocked crossings and the resulting surface street traffic delays are major concerns for emergency service vehicles as well as the general public,” says Daniel Work, an associate professor of civil and environmental engineering at Vanderbilt University and the study’s principal investigator. Effective management of emergency response resources on the road network requires knowledge of when trains will arrive at grade crossings. Trains blocking the grade crossings temporarily prevent emergency vehicles from accessing parts of the community they serve, Work says.

To combat this issue, Work, along with Vanderbilt graduate student Will Barbour, sought to generate accurate
estimated times of arrival for trains at grade crossings over a long time horizon, which could then be used to proactively address surface transportation safety, manage emergency response, and support in-vehicle driver alerts on personal navigation devices.

“This is a challenging problem because the variability of travel times on the United States freight rail network is high due to large network demands relative to infrastructure capacity,” Work says. To address this challenge, he says the project became the first to look at the potential for high-fidelity freight rail data to be used to predict arrival times.

The advanced model researchers developed used a number of inputs, including train-positioning information, properties of the train, properties of the network, and the properties of potentially conflicting traffic on the network. The work was conducted in two phases. First, the researchers developed a historical algorithm to accurately model delays using train-positioning information. Next, they integrated real-time train position information into the forecasts and used data shared by passenger rail service provider Amtrak and Class I freight railroad CSX Transportation to test and validate the proposed algorithms.

Using the new model, researchers found that estimated time of arrivals at control points located close to grade crossings were dramatically improved—particularly for predictions made multiple hours from a crossing, which are valuable for proactive safety measures such as early warning applications and emergency response management systems. In the future, Work says the research team hopes to continue refining the model by incorporating additional inputs—such as weather, crew changes, route topography, and events in which trains meet or pass one another—to increase prediction accuracy.

Transporting crash modification factors to a future with automated vehicles

As automated vehicles improve in capability and increase in market share, they will change many aspects of highway safety—including the methods used for making decisions about safety.

For the past two decades, data-based tools in AASHTO’s Highway Safety Manual—known as crash modification factors (CMFs)—have provided highway safety practitioners with an empirical way to predict the safety consequences of highway engineering decisions.

“Simply put, a crash modification factor is a way to measure the effectiveness of a particular treatment or design element,” says Gary Davis, a professor in University of Minnesota’s Department of Civil, Environmental, and Geo-Engineering. “While the application of an appropriate CMF can influence the decision to implement a particular project, the misapplication of CMFs can lead to misinformed decisions—and automated vehicles have the potential to reduce the accuracy of CMF predictions.”

The CMFs in the Highway Safety Manual represent the current prevailing driver and vehicle conditions in the United States. To assess the transferability of existing CMFs to new situations such as vehicle automation, an explanation of how the modification achieves its effect will be needed. However, there is currently little guidance on how such explanations might be posed and tested. In a Roadway Safety Institute project, Davis sought to shed more light on how CMFs work by uncovering how one particular CMF—pedestrian hybrid beacons—could modify the likelihood of pedestrian crashes.

A pedestrian hybrid beacon, designed for use at midblock crossings and uncontrolled intersections, is activated when a pedestrian wanting to cross pushes the call button. The signal then initiates a yellow-to-red lighting sequence consisting of steady and flashing lights that directs motorists...
to slow down and come to a stop. To explore this issue, Davis and his research team first created a micro-simulation to develop an explanation of how pedestrian hybrid beacons could modify crash likelihood. Since existing studies indicated that they can affect both pedestrian and driver behavior, researchers included both possibilities in their model. Based on the results from the simulation, their working hypothesis is that pedestrian hybrid beacons achieve their crash reduction effect in large part by modifying pedestrian behavior. If valid, this explanation has implications for the transferability of the associated CMFs, because sites with a large number of inattentive pedestrians would gain the greatest safety benefits from pedestrian hybrid beacons.

Perhaps most important, this research illustrates the process for assessing how other CMFs might work. “To explain a crash modification factor you need a framework for stating hypotheses and then deriving testable predictions from those hypotheses,” Davis says. “A good starting point is roughly consistent estimates for the target CMF from higher-quality studies. Then, you need to gain insight into the relevant crash events by reviewing crashes that have been investigated and reconstructed in detail.” Once these elements are in place, Davis explains, this research demonstrates how to construct a model that can make predictions about crash events, which can be compared to data to either confirm or refute the explanatory hypotheses. “A well-confirmed explanation then guides decisions about applying an estimated crash modification factor to new situations,” he says.

Sensor technology key to automated vehicles

Connected and automated vehicles (CAVs) have the potential to transform the future of transportation—but they can’t be effectively connected or automated without sensors. Lidar, radar, cameras, and maps all need to be working together to assure CAV occupants a safe and reliable ride. During a recent Roadway Safety Institute seminar, Curtis Hay of General Motors (GM) talked about his work developing the sensor technology used in GM’s emerging lines of automated vehicles.

“There’s a lot of focus these days on getting vehicles to communicate with each other, and having a vehicle communicate with a stoplight or a traffic sign,” Hay said. “Vehicle communication is really inseparable from the sensors in vehicle automation.”

CAVs have great potential to reduce crashes and increase fuel efficiency. They might also be used to provide ride-sharing services and minimize the number of people owning cars. But they first need to be proven safe, and for this they need to be able to sense their environment. A variety of different sensor technologies can be used in a CAV, and each one has its benefits and drawbacks. Radar, for example, is good at detecting and avoiding other cars, but it can’t detect painted lane lines. Cameras can fill this gap, but neither cameras nor radar can tell a car where it is relative to its destination or to an upcoming stoplight; for this it needs Global Navigation Satellite Systems (GNSS). However, even
GNSS can fail if a vehicle is driving in a city with tall buildings or through a tunnel, where the signal is deflected. To account for this, the vehicle needs a detailed map, motion sensors, radar, cameras, and/or lidar to ensure that it stays on course until the satellite signal comes back.

“Cars are effectively becoming a collection of computers that happen to have wheels and brakes and a transmission,” Hay said. “Every single one of these sensors…is critical for a reliable and safe operation.”

To illustrate how far GM has come with the development of these technologies, Hay showcased a video about the GM Super Cruise—a feature that was included in the 2018 CT6 Cadillac model that can automatically steer and adjust the car’s speed without the driver’s hands on the wheel. This feature, Hay explained, is only partially automated—the driver still has to pay attention and execute complicated maneuvers such as merging—but GM is developing and testing technology to further advance Super Cruise automation.

“We have a long way to go before we are fully autonomous,” Hay said, “but we are taking the steps to get there.”

Sleep apnea study honored with research partnership award

Truck drivers who don’t follow through with employer-mandated treatment for obstructive sleep apnea (OSA) have a higher risk of serious crashes, according to Roadway Safety Institute (RSI) research. This ongoing work, which has implications for both trucking companies and policymakers, was honored with the 2019 Robert C. Johns Research Partnership Award given by the Center for Transportation Studies (CTS) at the University of Minnesota.

“Our study examined the first-ever employer-mandated program for diagnosing and treating this dangerous disease,” says Stephen Burks, professor of economics and management at the University of Minnesota Morris (UMM) and an RSI researcher. “We found a large and statistically significant association between non-adherence with OSA treatment and preventable tractor-trailer crashes.”

The research team analyzed a program that Schneider, a major motor carrier, had initiated to screen, diagnose, and treat its drivers for OSA. The work involved a mix of disciplines including economics, human factors, medicine, and statistics.

“Our findings reinforced the decision by Schneider to continue its OSA program,” Burks says. The results have also been cited by at least one other large motor carrier in its decision to institute an OSA program internally.

In addition to UMM and Schneider, partnering organizations were Harvard Medical School, Precision Sleep Solutions, and the Virginia Tech Transportation Institute.

In ongoing research, the project team is analyzing differences in per-member, per-month medical insurance costs that are associated with the OSA program (other than those of the OSA program itself). The goal is to determine if the carrier can fund the OSA program from the savings generated in medical insurance claims, Burks says.

The Robert C. Johns Research Partnership Award is presented annually to a team of individuals who have collaboratively drawn on their diverse expertise to achieve significant impacts on transportation.

Institute awards Student of the Year

Each year, the Roadway Safety Institute selects one graduate student for its Outstanding Student of the Year Award, sponsored by the U.S. Department of Transportation (USDOT). This year’s recipient is Jake Achtemeier, an assistant scientist with the University of Minnesota’s HumanFIRST Laboratory. He is advised by Nichole Morris, director of the lab.

Achtemeier is working toward a master’s degree in human factors and ergonomics. His thesis, “Weather and Infrastructure Design Impacts on Mobility of Low Vision Pedestrians,” assessed the impacts of severe winter weather on
how visually impaired pedestrians’ navigate and use infrastructure in outdoor urban environments.

Achtemeier holds a bachelor’s degree in cognitive science from the University of Wisconsin-Stout. He has worked on driving simulation studies examining the effectiveness of in-vehicle messaging in dynamic work zones, connected-vehicle technology via lane boundary guidance systems in snowplows, and ITS device development and field testing for curve speed warnings. He is currently working on simulation and field-testing studies for bicycle collision warning V2V systems in addition to pedestrian-infrastructure utilization focus groups for the visually impaired.

His research interests in the fields of transportation and cognition include high-performance driving capability, reading and semantic performance while driving, and signal detection in visual psychology. His passion for transportation studies is complemented with his hobby and lifestyle of being an automotive enthusiast, fabricating turbocharger systems, and engine management programming on various platforms of cars for competition.

Achtemeier received a $2,000 award from the Institute and was presented with a certificate from USDOT officials at a ceremony held in conjunction with the Transportation Research Board (TRB) Annual Meeting in Washington, DC, in January.