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Better weather predictions and more data on driving could accelerate the widespread deployment of automated and connected vehicles.

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Self-driving cars face a cloudy future

Better weather predictions and more data on driving could accelerate the widespread deployment of automated and connected vehicles.

Although they are already on the road, automated vehicles (AVs) don't perform well in bad weather. From January through August, the Regional Transportation District, the public transit agency for metropolitan Denver, Colorado, tested a driverless shuttle that looped between four local commuter rail stations on a predetermined route. The vehicle's sensors malfunctioned during snow and heavy rain, which led to service disruptions, according to a blog post by Dave Genova, CEO and general manager of the agency.

The performance of AVs in challenging weather conditions is improving, however. Atmospheric scientists and engineers from academia, the automobile industry, and technology companies are upgrading onboard hardware—cameras, lidar sensors, and radar units, for example—so AVs can better monitor weather conditions. At the same time, computer scientists are using artificial intelligence (AI) to safely navigate the roads.

AVs will need weather and pavement-condition forecasts more frequently than the 15-minute updates currently available from governments and companies. Some of that data could come from fixed roadside sensors that collect temperature, pressure, humidity, and other meteorological data. Additional information from onboard instruments, including windshield wipers and headlights, could be collected by and shared among the vehicles themselves.

A SELF-DRIVING SHUTTLE identical to the one shown here by EasyMile, a company headquartered in Toulouse, France, was tested earlier this year by the Regional Transportation District in Denver, Colorado. Snow and heavy rain confused the onboard sensors, disrupting the shuttle service.

To act like a human

Many vehicles on sale to the public have semiautonomous or driver-assist features. The most familiar is likely cruise control, which for decades has been used to maintain speed. Some vehicles, including models from Tesla, Volvo, and Audi, already have more advanced capabilities that automate such tasks as parking and lane centering. Fully autonomous, or self-driving, vehicles are still in the R&D phase and would ideally operate with no human driver, or a human would only intervene during poor conditions.

AVs sport an array of onboard sensors that mimic and aim to surpass a human driver's eyes. Cameras detect potential obstacles and environmental features near and far. Lidar units emit near-IR light pulses that bounce off nearby objects, and the light's travel time is used to calculate a three-dimensional map of the surrounding area. Radar sensors measure the Doppler shift of pulses to monitor mobile features, such as pedestrians, cyclists, and other vehicles. (For more information about AV hardware, see the Quick Study by Colin McCormick, Physics Today, July 2019, page 66.)

To gather and exploit even more data, researchers are considering vehicle-to-infrastructure communication in which AVs wirelessly connect to weather sensors. For example, employees of the US Department of Transportation's Smart Roadside program have been examining how to provide AVs with information about pavement and traffic conditions from weather sensors deployed along roads.

Vehicles with no drivers could be monitored by a person at a centralized location. Earlier this year in Florida, a driverless truck made by Starsky Robotics of San Francisco navigated along a highway for 15 kilometers. The truck maintained its speed and changed lanes. The driving decisions were monitored by someone in a control center who could take over if necessary.

Computer scientists are using AI to develop improved decision-making systems for AVs. Machine-learning and neural-network methods apply algorithms to data sets, and the results are used to inform probabilistic decisions. Such algorithms are based on AI that is used in image processing and in weather forecasting (see Physics Today, February 2019, page 17, and May 2019, page 32).

Some companies such as Vaisala, based in Helsinki, Finland, use environmental, industrial, and weather data coupled with AI to provide road-prediction and road-condition services to clients. Every 5–15 minutes they update information about moisture, snow, and ice for 2-kilometer road segments. In 2015 Vaisala started RoadAI, which uses vehicle-mounted cameras to spot upcoming cracks, potholes, and other road features that may affect AV performance.

One difficulty for AI methods is that they require large amounts of quality-controlled data to make statistically significant decisions. To meet that demand, companies are having their AVs drive millions of miles each year. "Techniques certainly exist to cull the data and get a sense of what's good, what's bad, and maybe what's questionable," says Curtis Walker, a meteorologist and AV scientist at the National Center for Atmospheric Research in Boulder, Colorado. But, he adds, "When it comes to quality control, there's always room for improvement."

Mobile weather stations

Automated vehicles can benefit from vehicle-to-vehicle communication via onboard sensors. Such buddy checks also provide a means to test whether an AV's own sensors are functioning properly. If a sensor detects rain and the AV "starts checking with the vehicles around [it]," says Walker, but "none of them are using their wipers or have their headlights on or have their antilock braking systems activated, then that vehicle might question its sensors."

In wintry conditions, snow and ice can quickly accumulate on the cameras or the lidar and radar units and blind the vehicle to environmental conditions it's supposed to monitor. "If the vehicle next to me has its headlights and wipers on, maybe I should too," says Walker. Vehicles could communicate to each other about other critical information, including friction and stability control, speed, direction of travel, and whether hard braking is necessary.

Vehicle-to-vehicle communication was demonstrated in Germany earlier this year by logistics company DB Schenker, vehicle manufacturer MAN Truck & Bus, and researchers from the New York campus of Fresenius University of Applied Sciences. A pair of trucks—electronically linked and driving in the same lane 20 meters apart—traveled some 35 000 kilometers back and forth between Nuremberg and Munich. The human drivers intervened an average of once every 2000 kilometers, mainly when other vehicles cut into their lane. The two trucks drove closer together compared with trucks without the technology, and fuel consumption was consequently reduced by 3–4%.

Vehicle-to-vehicle communication does have limitations. "An AV needs to have equipment and sensor systems so it is always safe and can operate without any connectivity," says Petri Marjava, a senior business development manager at Vaisala. He says that car companies are often protective of their data. "There needs to be a business case for the vehicle [manufacturers] to fetch that data from the fleet because everything has its costs," he says. Nondisclosure agreements with AV manufacturers often prevent researchers from sharing their safety and performance analyses.

AV research, says Walker, "is largely for the benefit of advancing the technology and certainly the product and ultimately profit, not so much to get peer-reviewed papers out there for the community to assess performance. Though there is room for that as well." Waymo, the self-driving R&D subsidiary of Alphabet Inc, in August released on its website AV sensor data that may be useful to researchers studying topics such as predicting vehicle behavior and sensing environmental conditions. The open data set contains 1000 road segments that each

THESE TWO AUTOMATED TRUCKS drove some 35 000 kilometers in Germany between Nuremberg and Munich earlier this year with minimal human intervention.

MAN TRUCK & BUS

span 20 seconds of driving in urban and suburban environments under various weather conditions.

Some car manufacturers are sharing with each other. BMW, Daimler, Ford, and Volvo announced in June that they were partnering with data service providers and national transportation authorities in six European countries to supply a common server that will receive, combine, and disseminate safety data to connected AVs. The pilot project comes after the European Parliament in April approved a revised general safety regulation that governs European Union motor vehicles. Among its new requirements are minimum mandatory safety technologies that must be installed in vehicles starting in 2022.

On every block

Walker says that weather is only one issue AVs face; ethical considerations and political regulations need to be addressed too. "If the vehicle has the choice to hit a deer or to steer off the road and hit a tree, possibly injuring the driver, will the vehicle always decide to take out the deer?" he says. "But then what if instead of a deer it's a kid who runs out chasing a ball or a toy or something?"

One solution could be AI software akin to MIT's Moral Machine platform. Researchers designed thought experiments of the moral dilemmas AVs could face and compiled 40 million decisions from millions of people in 233 countries on how a vehicle should act in those cases. Respondents showed a strong preference for an AV to hit a nonhuman animal if doing so was the only way to spare a child that darted into the road. The researchers say their results, which also included preferences for sparing more lives than fewer and young people over older people, could contribute toward a global, socially acceptable set of principles that the vehicles would abide by.

AVs also need frequent weather forecasts that predict conditions on a scale of a few kilometers or better. Better forecasts could come from the US National Weather Service, which currently provides predictions at a scale of about 30 kilometers, or IBM's forthcoming Global High-Resolution Atmospheric Forecasting System, a tool designed to provide hourly updates at 3-kilometer resolution. The constraints for providing weather predictions to people can be relaxed for AVs, which can take probabilities and use their AI algorithms to determine the most likely environmental conditions.

Besides better predictions and more data, AVs likely need improvements in pavement-condition characterization. To determine the road-friction threshold needed for safe driving, prediction models must account for local subsurface moisture, the road's material properties, how it was constructed, and how the materials respond to different weather.

Such models are currently used during winter weather in maintenance-decision support systems, says William Mahoney, a research director at the National Center for Atmospheric Research. Transportation departments use them to identify the best approaches for keeping pavement clear of ice and snow during storms. As federal and state highways are repaired and renovated, new road properties should be incorporated in pavement models, Mahoney says. He adds that designs and materials that improve the ability to collect weather and material data should be prioritized.

Mahoney expects a gradual transition to AVs. "We're seeing a build-a-little, test-a-little, and implement-a-little process." Once an AV can travel through short segments on predetermined routes or through restricted-lane areas, longer and more complicated routes may be possible. He says the automobile industry can learn from airline companies: Atmospheric scientists have helped improve airplane safety and reliability in adverse weather for decades. A similar team effort between the meteorology community and automobile industry is necessary to hasten AV development and adoption, he says.

But because of fierce competition for venture capital funding, vehicle companies often stay quiet about the development challenges they face. To address that problem, in 2018 Mahoney organized an American Meteorological Society summit that brought together the AV and meteorology communities at the National Transportation Safety Board in Washington, DC. "One of the things I've noticed over the last several years is that the [auto] companies and weather community are not working together as closely as they should," says Mahoney. "We're having mixed results so far, but we are working steadily to bring these communities together."

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