# Future cruise control to have environmental, safety features

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(Phys.org)—The cruise control on your auto can ease a long trip and keep you out of trouble by preventing you from speeding, if you have set it at the legal speed limit. As new cars are being outfitted with GPS, a predictive eco-cruise control system being developed by the Virginia Tech Transportation Institute will also be able to save fuel and reduce emissions, and is being fine-tuned for intelligent vehicle capability.

Climbing mountain roads, whether an interstate in Virginia or Colorado or a two-lane road in the Sierras, is the least fuel-efficient kind of driving. Using conventional cruise control does not correct that because it applies the throttle in the interest of steady speed, just as the driver would. Some big trucks have predictive eco-cruise control systems into which a route and a desired speed are set. This system uses GPS to identify road grades ahead and allows the truck to go slightly faster downhill and slightly slower uphill to achieve an average speed that saves fuel.

The challenge has been that there is greater diversity in economy and powertrain among autos than with commercial trucks.

Hesham A. Rakha, professor of civil engineering at Virginia Tech and director of the Center for Sustainable Mobility with the Virginia Tech Transportation Institute, along with other center researchers, students, and colleagues at other institutions, have been developing an eco-cruise control system that can be adapted to the wide range of passenger cars and light trucks sold in the U.S.

"In order to develop a system that could be validated on many models and widely adapted, we had to develop a powertrain module, a fuel consumption module, and an optimization module," said Rakha. "And it had to be simple – based on readily available data."

Thus, the Virginia Tech Comprehensive Power-based Fuel Model has the elegant solution of being based on publically available fuel economy data – those city and highway fuel consumption rates the EPA requires for new cars. "The majority of fuel consumption models have been developed as power-demand models. They have the advantage of providing detailed emission data, but have to be calibrated based on instrumented vehicles," said Rakha. "The Virginia Tech fuel-consumption model is also a power-based model but can be rapidly applied to new vehicles without the need for vehicle instrumentation. And we can still determine $CO_2$ emissions."

Rakha also indicated that "we needed a good fuel consumption model to evaluate the efficiency of cruise control. Consequently, we developed an equation that is a function of power squared to replace previous "bang on/bang off" or zero and one equations—no throttle or full throttle, with no partial throttle. We also wanted to be able to calibrate the model using data from vehicle manufacturers' websites, such as horse power and EPA ratings for highway and city fuel efficiency so that we could estimate fuel consumption for any vehicle."

The powertrain model also had the potential to be complex, since it must consider such factors as engine speed, power, torque, acceleration, resistance, and tire slip. Rakha and his colleagues developed a simple powertrain model that reflected driver throttle input that represents real-world driving, that is to say variability, such as due to traffic and road conditions, rather than, as in previous formulas, zero and full throttle only—full stop and pedal to the metal. The mathematical model-based simulations that incorporate variable throttle have proved consistent with field tests of vehicles driven on Interstate 81 near the Virginia Tech campus.

The optimization module puts it all together with the road ahead, determining the range of speed and gear levels for the vehicle in order to minimize power levels required to complete the trip, and recalibrating within minutes for any changes introduced to the program by the driver.

The approach uses dynamic programming to find the optimum gas pedal and gear input. It solves the problem by discretizing the solution space and assuming driver inputs are constant for short roadway segments. The system maintains the vehicle speed between a driver-specified lower and upper limit while maintaining the vehicle speed as close as possible to a driver-specified desired speed. For example, the driver might set the desired speed at 65 mph, the minimum speed at 64 mph and maximum speed at 70 mph while traveling on a 65 mph roadway. The system can then adjust the speed within this range as needed to minimize the vehicle's fuel consumption level.

The researchers described how it works in a presentation to the January 2012 Transportation Research Board annual meeting: "First, future topographic information is fed to the system from a device or sensor attached to the vehicle or using high resolution digital maps. Second, the user sets a target speed to cruise and specifies a speed range, or window, of allowable speed variation. Next, the system generates an optimal plan for throttle, braking levels, and gear selections over a predefined distance. The system continues to update these procedures over the entire trip."

The researchers simulated a New York to Los Angeles road trip and, to see how drivers actually behave, also did a field test on Interstate 81. They let students drive the speed limit between miles 118 and 132 in Virginia. Driving was conducted using a conventional cruise control system and manual driving. The study demonstrated that conventional cruise control systems produced fuel consumption savings ranging between 2 to 3 percent over manual driving. The same trip was also simulated using the proposed eco-cruise control system (since it is not yet installed in any vehicle). The eco-cruise control system produced fuel savings ranging between 5 to 15 percent. An earlier study compared the system to more aggressive driver behavior and was reported to be 60 percent more efficient.

Having tested the system on all kinds of roads across the country, the researchers report it will save about 5 percent fuel. "That is billions of gallons of automotive fuel and billions of dollars that could be saved. And there would be tons less $CO_2$ pumped into the atmosphere," said Rakha.

A new feature the researchers are working on now is eco-adaptive cruise control. "We want the driver to be able to tell the system how close to follow the car or truck in front in addition to the previously defined parameters," said Rakha.

"With eco-adaptive cruise control systems installed, the vehicle can slow down automatically to avoid getting too close to vehicles traveling ahead of you. You enter information into the system about how close you want to be to a car in front of you. For example, you can set the headway setting at 1 second. The system not only minimizes the fuel during cruising conditions but can also minimize the vehicle's fuel consumption levels while following other vehicles through the use of milder acceleration maneuvers," said Rakha.

An article about research to develop the fuel-consumption model appeared in the October 2011 issue of the *Elsevier* journal, Transportation Research Part D in the article, "Virginia Tech Comprehensive Power-Based Fuel Consumption Model: Model development and testing," by Rakha; Kyoungho Ahn, senior research associate with the Center for Sustainable Mobility; Kevin S. Moran, director of global products for advanced driver assistance systems at NAVTEQ, which makes digital maps for GPS systems; Bart Saerens, researcher, and Eric Van de Bulck, professor, both with the mechanical engineering department at the KU University of Leuven in Belgium.

The research to develop the powertrain model was published in the June 2012 issue of *IEEE Transactions on Intelligent Transportation Systems* in the article, "Simple Vehicle Powertrain Model for Modeling Intelligent Vehicle Applications," by Rakha; Ahn; and Waleed Faris, deputy dean and associate professor at the International Islamic University Malaysia; and Moran.

The research of the eco-adaptive cruise control system development was presented at the 92nd Transportation Research Board Annual meeting in Washington D.C., Jan. 14-17, 2013. The authors included Ahn, Rakha, and Sangjun Park, a 2008 Ph.D. graduate of civil engineering from Virginia Tech. The paper is entitled "ECO-Drive Application: Algorithmic Development and Preliminary Testing."

Park, Rakha; Ahn; and Moran presented the paper, "A Study of Potential Benefits of Predictive Eco-Cruise Control Systems," to the Transportation Research Board at the 2012 annual meeting.

The research on comparing the potential benefits of eco-cruise control systems relative to manual and conventional cruise control driving was also presented at the 92nd Transportation Research Board Annual meeting in the paper titled, "Fuel Economy Impacts of Manual, Conventional Cruise Control, and Predictive Eco-Cruise Control Driving," which is by Park, Rakha, and Ahn.