Paper Objectives

- This study investigates a possible fuel saving and greenhouse emission reduction strategy using an eco-cruise control system.
- The eco-cruise control system employs adaptive cruise control integrated with road topography information.
- The feasibility of eco-cruise control systems is evaluated using a newly developed fuel consumption model and field data.

Introduction

- Roadway grade is one of the major variables that affect vehicle fuel consumption levels. On upgrade sections, vehicles exert additional power to overcome the grade resistance, thus consuming more fuel than under normal conditions.
- Studies have shown that a roadway grade results in significant increases in vehicle fuel consumption and emission levels. Park and Rakha (2006) demonstrated that a 6 percent increase in a roadway grade could increase vehicle fuel consumption levels in the range of 40 to 94 percent, and even a 1 percent grade could cause 13 to 18 percent increases in fuel consumption.
- Cruise control is a system that automatically maintains the speed of a motor vehicle by changing the accelerator pedal position. However, when the vehicle encounters hilly terrain these cruise control systems can consume excessive fuel by trying to maintain a preset speed.

System Description

- The proposed eco-cruise control system allows the vehicle to travel at a lower speed as it travels along upgrade sections and speed up as it travels downhill within a preset speed range with the objective of enhancing vehicle fuel economy and reducing CO₂ emissions.
- The key input variables to the eco-cruise control system are the cruise speed and a speed range. The speed range identifies the maximum and minimum speed the driver is willing to accept.
- Using the input speed, the system maintains the cruise control speed on flat roadways.
- Once a vehicle encounters an uphill road section, the eco-cruise control system lowers the target speed to reduce the engine load and reduce fuel consumption. On the other hand, when the vehicle travels along a downhill section, the system increases the target speed within the desired speed range.
- This mechanism allows the vehicle to use the force of gravity to its advantage. The desired speed range is a user input. For instance, if a driver sets the speed range at 10 percent and the cruising speed at 100 km/h, the vehicle will maintain a speed between 90 km/h and 110 km/h.
- In order to maintain and adjust the vehicle speed, a vehicle powertrain model is integrated with the eco-cruise control system since the vehicle fuel consumption rate is impacted by the instantaneous power and other powertrain characteristics.

Fuel Consumption Models

- The Virginia Tech Comprehensive Power-based Fuel Model (VT-CPFWM) is utilized in this study because of its simplicity, accuracy, and ease of calibration. The fuel consumption model utilizes instantaneous power as an input variable and can be calibrated using publicly available fuel economy data (i.e., city and highway fuel consumption rates). The VT-CPFWM model can be easily implemented within microscopic traffic simulation software or vehicle operational control systems.

Simulation Results of Eco-Cruise Control System

- The fuel consumption model is formulated as follows, where $\alpha$ is the fuel consumption rate (g/s or l/s) for idling conditions and $P(t)$ is the instantaneous total power in kilowatts (kW). The model coefficients ($\alpha_1$, $\alpha_2$) are estimated using the fuel consumption rates of the standard fuel economy cycles (i.e., city and highway fuel economy data).

$$FC(t) = \frac{\alpha_0 + \alpha_1 P(t) + \alpha_2 P(t)^2}{\alpha_0} \quad \text{if } P(t) < 0$$

$$FC(t) = \frac{\alpha_0}{\alpha_0} \quad \text{if } P(t) > 0$$

Eco-Cruise Control Testing along Highway Sections

Interstate 81 Case Study

- The study evaluates the eco-cruise control system along a 45-km segment.
- The study section contains multiple uphill and downhill segments, including a 4.34 km, +4 percent grade section and several -4 percent downhill slopes.
- The simulation results on a section of Interstate 81 show that, on average, the eco-cruise control system can save 10.33 percent in fuel consumption and CO₂ emission levels.

VA Route 7 Case Study

- The estimated fuel consumption rates were compared to the measured fuel consumption rates of a traditional cruise control system of a sample test vehicle, a 2005 Honda CR-V.
- The data were collected from an OBD reader to obtain fuel consumption data.
- A portable GPS unit was utilized to collect second-by-second location and altitude data.
- For the specific example illustration on VA Route 7, the proposed system improves the vehicle fuel economy by 34 percent compared to traditional cruise control methods.

Conclusions

- The eco-cruise control system regulates a vehicle speed based on the roadway grade.
- It is expected that the implementation of the eco-cruise control system can help achieve better fuel economy and improve air quality.
- The research demonstrates that further enhancements to the proposed eco-cruise control system are achievable if the vehicle has access to roadway topography data.
- Further research is required to develop pro-active eco-cruise control systems that utilize roadway topography data to enhance the system performance.

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