KTH Electrical Engineering

Distributed Road Grade Estimation for Heavy Duty Vehicles

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Abstract

An increasing need for goods and passenger transportation drives continued world-wide growth in traffic. As traffic increases environmental concerns, traffic safety, and cost efficiency become ever more important. Advancements in microelectronics open the possibility to address these issues through new advanced driver assistance systems. Applications such as predictive cruise control, automated gearbox control, predictive front lighting control, and hybrid vehicle state-of-charge control decrease the energy consumption of vehicles and increase the safety. These control systems can benefit significantly from preview road grade information. This information is currently obtained using specialized survey vehicles, and is not widely available. This thesis proposes new methods to obtain road grade information using on-board sensors. The task of creating road grade maps is addressed by the proposal of a framework where vehicles using a road network collect the necessary data for estimating the road grade. The estimation can then be carried out locally in the vehicle, or in the presence of a communication link to the infrastructure, centrally. In either case the accuracy of the map increases over time, and costly road surveys can be avoided.

This thesis presents a new distributed method for creating accurate road grade maps for vehicle control applications. Standard heavy duty vehicles in normal operation are used to collect measurements. Estimates from multiple passes along a road segment are merged to form a road grade map, which improves each time a vehicle retraces a route. The design and implementation of the road grade estimator are described, and the performance is experimentally evaluated using real vehicles.

Three different grade estimation methods, based on different assumption on the road grade signal, are proposed and compared. They all use data from sensors that are standard equipment in heavy duty vehicles. Measurements of the vehicle speed and the engine torque are combined with observations of the road altitude from a GPS receiver, using vehicle and road models. The operation of the estimators is adjusted during gearshifts, braking, and poor satellite coverage, to account for variations in sensor and model reliability. The estimated error covariances of the road grade estimates are used together with their absolute positions to update a stored road grade map.

Highway driving trials show that the proposed estimators produce accurate road grade data. The estimation performance improves as the number of road segment traces increases. A vehicle equipped with the proposed system will rapidly develop a road grade map for its area of operation. Simulations show that collaborative generation of the third dimension for a pre-existing large area two-dimensional map is feasible. The experimental results indicate that road grade estimates from the proposed methods are accurate enough to be used in predictive vehicle control systems to enhance safety, efficiency, and driver comfort in heavy duty vehicles. The grade estimators may also be used for on-line validation of road grade information from other sources. This is important in on-board applications, since the envisioned control applications can degrade vehicle performance if inaccurate data are used.

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