Road grade estimation by on-board sensors

Project within FFI

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Content

1. Executive summary

The project is a continuation of a IVSS project and has included a graduate student. FFI has supported the last 1.5 years of his doctoral studies. These ended in a happy way April 29, 2011 and the project ends thereby.

Besides the academic achievements and publications, both projects (IVSS + FFI) have been very successful. They have resulted in five patents, 11 master theses and new research applications.

Industrially, the acquired knowledge was a necessary part of Scania's ability to set standards and develop functionality that reduces fuel consumption and CO2. The platform and the knowledge acquired will also be used in projects with road safety measures. These features will be launched in the near future.

2. Background

In 2005 Scania launched the research project “Vehicle Control with anticipation” within the IVSS program (AL80 A 2005:3889). The project covered two graduate students, one located at KTH and one at LiU. Both graduate students were employed by Scania. The FFI project is a direct continuation of the previous IVSS project and includes funding for the graduate student who chose to continue to a doctorate.

3. Objective

An increasing need for goods and passenger transportation drives continued worldwide 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 project 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.

4. Project realization

The project has been staffed by an industrial PhD student employed by Scania. The graduate student has been supervised by KTH division of Automatic control.
The project has in a very good way strengthened the relations between KTH and Scania. The cooperation stretches back to 2002 and has covered several joint projects and doctoral candidates. After this project is completed, a new industrial PhD student is started up in cooperation.

5. Results and deliverables

5.1 Delivery to FFI-goals

In order to develop smarter and safer vehicles systems need more external information, both in terms of where other traffic is and how the state of the road is. This project provides information about current road gradient. Applications can be found in several areas like reduction of energy consumption, increased safety through reduced velocity over crests and before curves. It can also be used for advanced headlamp control.
The more general knowledge of how to learn the shape and hazards of the road can be used to detect and warn for dangerous spots (slippery or bumpy parts of the road).

6. Dissemination and publications

6.1 Knowledge and results dissemination

Besides the academic achievements and publications, the projects (IVSS + FFI) have been very successful. They have resulted in five patents, 11 master theses and new research applications.
Industrially, the acquired knowledge was a necessary part of Scania's ability to set standards and develop functionality that reduces fuel consumption and CO2. The platform and the knowledge acquired will also be used in projects with road safety measures. These features will be launched in the near future.

In addition to the current application the project also contributes expertise in control and signal processing. These are strategic skills that can also be used to develop other functions than the above. Building these competences helps the Swedish automotive industry strengthen its international competitiveness.

6.2 Publications

Dissertation;
Sahlholm, Per. Distributed Road Grade Estimation for Heavy Duty Vehicles, ISBN 978-91-7415-869-4.
http://kth.diva-portal.org/smash/get/diva2:408690/FULLTEXT01

Papers:
Maria Ivarsson, Per Sahlholm, Michael Blackenfelt, Karl Henrik Johansson, Lars Nielsen. Vehicle control using preview information, Reglermötet, Stockholm 2006-06-27

Per Sahlholm, Henrik Jansson, Ermin Kozica, Karl Henrik Johansson. A Sensor and Data Fusion Algorithm for Road Grade Estimation. IFAC AAC07, Monterey Coast, CA, August 20-22, 2007.

Per Sahlholm, Henrik Jansson, Magnus Östman, Karl Henrik Johansson. Automated Speed Selection for Heavy Duty Vehicles. IAVSD Symposium 2007, Berkeley, CA, August 13-18, 2007.

Per Sahlholm, Henrik Jansson Karl Henrik Johansson. Road Grade Estimation Results Using Sensor and Data Fusion. ITS World Congress, Beijing, China. October 9-13, 2007

Per Sahlholm, Karl Henrik Johansson. Road Grade Estimation for Look-ahead Vehicle Control. IFAC World Congress, Seoul, Korea. July 6-11, 2008.

Per Sahlholm, Assad Alam. A Method for Determining an Economical Speed for Heavy Vehicles. World Congress on ITS, New York, NY, USA. November 16-20, 2008.

Per Sahlholm. Improved Heavy Duty Vehicle Performance Through the Use of 3D Map Data. 15th World Congress on ITS, New York, NY, USA. November 16-20, 2008.

Sahlholm, P.. Iterative Road Grade Estimation for Heavy Duty Vehicle Control. Licentiate Thesis, KTH, 2008.

Sahlholm, P. and Wänglund, K.. Comparison of Road Grade Estimation Results Based on GPS Position and Velocity Data, 16th World Congress on ITS, Stockholm, September 21-25, 2009.

Sahlholm, P. and Johansson, K.H.. Road Grade Estimation for Look-Ahead Vehicle Control Using Multiple Measurement Runs, Control Engineering Practice. Vol 18, No. 11:13281341, 2010.

Sahlholm, P. and Johansson, K.H.. Segmented road grade estimation for fuel efficient heavy duty vehicles. Conference on Decision and Control, 2010.

Per Sahlholm, Ather Gattami, and Karl Henrik Johansson. Piecewise linear road grade estimation. SAE 2011 World Congress, April 12-14, 2011

7. Conclusions and future research

Access to stored road grade information yields significant advantages in HDV control. A system for obtaining such information using standard vehicles in regular operation has been developed and evaluated in this project. It has been shown through experiments that the proposed distributed road grade estimators generate results that are consistent with reference road grade profiles.

The generated estimates improve when additional measurements are used to create a profile.

The conducted research has been focused on highway applications, further research would be needed to extend the ideas to city streets. Other issues that have not yet been studied are connections to route planning and other traffic on the road.

8. Participating parties and contact person

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