Look-ahead Control Demonstrator Project

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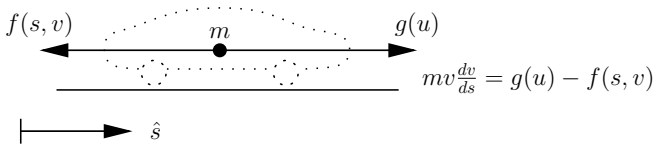
Summary

The focus is on minimal fuel consumption in heavy trucks. Information integration and modeling techniques permits optimized control of braking, acceleration and gear shifting. On-road tests show substantial reduction in fuel consumption.

Motivation

Consider a vehicle moving in one dimension,



and the minimization of the propulsive work W,

$$W = \int_0^{s_f} g(u)ds = \int_0^{s_f} (mv\frac{dv}{ds} + f(s,v))\, ds$$

with a constraint on the trip time. With few assumptions, it can be shown by variational calculus that a constant speed $v(s)$ is optimal. However, due to the large mass of a typical truck even moderate slopes become significant and it is thus not possible to keep the desired speed on all road profiles. Therefore, information about the road topography and modeling of e.g. gear shifts are key components in this application.

Look-ahead Control

Since the road slope is a function of the position s, a position-variant control law $u = u(x, s)$ is expected. The approach taken here is to repeatedly calculate the fuel-optimal control on line.

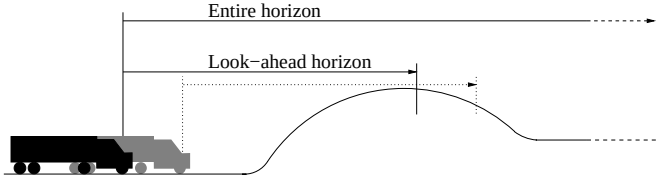
A drive mission is defined by the position $s \in [0, s_f]$. The look-ahead horizon is defined by $s \in [0, s_h]$ where $s_h < s_f$. The general problem is

$$J = \min_{u(s)} \left\{ \phi(x(s_f)) + \int_0^{s_f} L(x(s), u(s), s) \right\}$$

where L measures fuel and time use. However,

$$J \approx \min_{u(s)} \left\{ \tilde{R} + \int_0^{s_h} L(x(s), u(s), s) \right\}$$

is solved on line where $\tilde{R}$ is an approximation, obtained off line, of the residual cost.



A tailored dynamic programming algorithm is currently used for the optimization. On the standard portable computer used in the experiments, tenths of a second are needed to calculate a solution for a typical horizon of 30 steps of 50 m that gives 1.5 km look ahead.

Status

A demonstrator vehicle has been developed in collaboration with SCANIA. Experiments have been performed on a 120 km segment of a Swedish highway with a tractor and trailer combination that have a gross weight of 40 tonnes. In average, the fuel consumption is decreased about 3.5% without increasing the trip time and the number of gear shifts is decreased with 42% traveling back and forth, compared to the standard cruise controller. The work is reported in detail in [1, 2, 3]. The project milestone has been achieved.

Publications

[1] Hellström, E. (2007). *Look-ahead Control of Heavy Trucks utilizing Road Topography*. Licentiate thesis LiU-TEK-LIC-2007:28, Linköping University.

[2] Hellström, E., Ivarsson, M., Åslund, J., and Nielsen, L. (2007). Look-ahead control for heavy trucks to minimize trip time and fuel consumption. 5th IFAC Symposium on Advances in Automotive Control, Monterey, CA, USA.

[3] Hellström, E., Åslund, J., and Nielsen, L. (2008). Design of a well-behaved algorithm for on-board look-ahead control. IFAC World Congress, Seoul, Korea.