Look-ahead Control Demonstrator

PhD Student Erik Hellström, Associate Professor Jan Åslund, Professor Lars Nielsen
Division of Vehicular Systems, Department of Electrical Engineering

Look-ahead control

A model predictive controller has been developed to control the vehicle. In each iteration the problem horizon is truncated and discretized and then solved by means of dynamic programming. The horizon in the experiments was 30 steps of 50 m, giving a 1500 m look ahead. The prediction model includes continuous as well as discrete parts and time delays. It predicts vehicle motion and energy consumption as a function of the road slope and the control signals fueling, gear and brake torque.

The objective is to minimize the energy and time required for a given drive mission with the constraint that the vehicle is kept inside a desired velocity interval. Denote the fuel use *M* and the trip time *T*, the cost function for a position interval $[s_0,s_f]$ is

$$J = M + \beta T\,;\quad M = \int_{s_0}^{s_f} \frac{dm}{ds}(x,u)\,ds\,,\quad T = \int_{s_0}^{s_f} \frac{ds}{v}$$

where $\frac{dm}{ds}(x,u)$ is the mass flow of fuel as a function of the states x and controls u. The scalar factor β determines the trade off.

Algorithm development

A tailored dynamic programming algorithm is devised. A pre-processing stage limits the state space prior to the optimization. The controls are calculated by inverse simulation rather than straightforwardly quantizing the control space and this is combined with a search method that relies on that optimal paths do not cross. With this design, a satisfactory solution is calculated in tenths of a second on a modern laptop computer.

Demonstrator

A prototype demonstration is implemented in collaboration with SCANIA. Experiments are performed on the highway E4 between the cities of Södertälje and Norrköping in Sweden, see Figure 3. The truck is a SCANIA tractor and trailer with specifications according to Table 1. The algorithm controls the vehicle by adjusting the set speed to the conventional cruise controller, see Figure 1. All communication is done over the CAN bus.

Figure 1: Information flow.

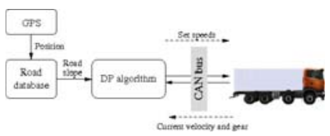


Table 1: Truck specifications.

Component	Type	Characteristics
Engine	DC9	cylinders: 5
		displacement: 9 dm^3
		max.torque: 1,550 Nm
		max.power: 310 Hp
Gearbox	GRS890R	12 gears
Vehicle	-	total weight: 39.410 kg

Figure 2: A SCANIA tractor and trailer.

Figure 3: Altitude along the trial route.

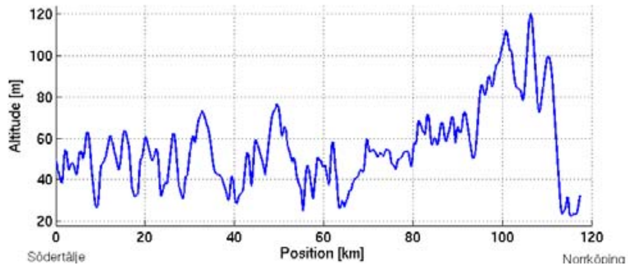
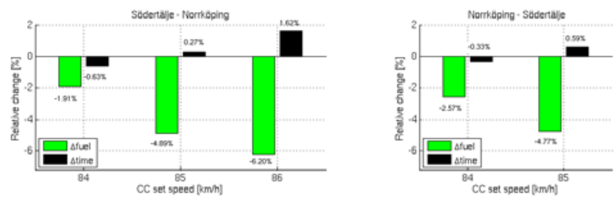
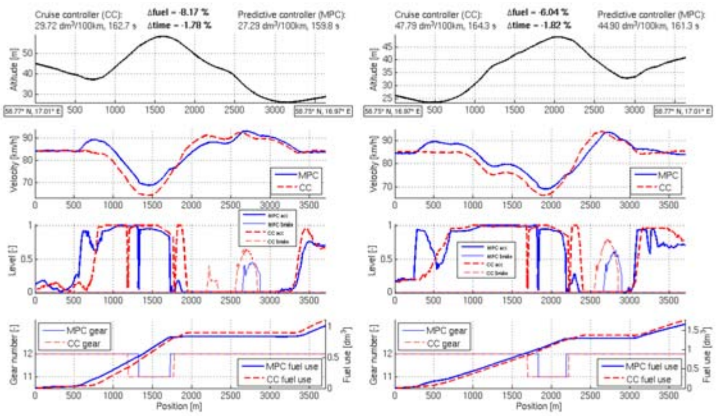


Figure 4: Trial run results.



Each trial run consisted of one drive with look-ahead control (MPC) and one with standard cruise control (CC). The set point for the cruise controller was the only parameter varied in order to receive a trip time close to the one obtained with look ahead. The relative change in fuel consumption and trip time (Δfuel, Δtime) are shown in Figure 4. Detailed characteristics in both directions on one piece of the trial route are shown in Figure 5.

Figure 5: Controller characteristics.



The average results in both directions that are made with the same set speed are also calculated. These show that the fuel consumption could be decreased with 3.53%, from 36.33 L/100km to 35.03 L/100km, with a negligible reduction of the trip time (0.03%) in comparison with the CC. Also interesting to note is that the mean number of gear shifts on this route decreases from 20 to 12 (-42%) with the MPC.

Summary

The control algorithm perform well on board in a real environment. Due to the large vehicle mass moderate slopes becomes significant. The look-ahead control mainly differs from conventional cruise control near significant downhills and uphills where the look-ahead control may slow down or gain speed prior to the hill. The prediction model is of hybrid nature and has time delays which turns the optimization into a challenging task. A careful application of dynamic programming make experimental evaluation possible.