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Advanced Scientific Working
-Essay-
Explicit Fuel Optimal Speed Profiles for Heavy Trucks on a Set of Topographic Road Profiles

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1 REFERENCE

Froeberg, Anders, Erik Hellstroem, and Lars Nielsen. Explicit fuel optimal speed profiles for heavy trucks on a set of topographic road profiles. No. 2006-01-1071. SAE Technical Paper, 2006.

2 ABSTRACT

The problem addressed is how to drive a heavy truck over various road topographies such that the fuel consumption is minimized. Using a realistic model of a truck powertrain, an optimization problem for minimization of fuel consumption is formulated. Through the solutions of this problem optimal speed profiles are found. An advantage here is that explicit analytical solutions can be found, and this is done for a few constructed test roads. The test roads are constructed to be easy enough to enable analytical solutions but still capture the important properties of real roads. In this way the obtained solutions provide explanations to some behaviour obtained by ourselves and others using more elaborate modeling and numeric optimization like dynamic programming.

The results show that for level road and in small gradients the optimal solution is to drive with constant speed. For large gradients in downhill slopes it is optimal to utilize the kinetic energy of the vehicle to accelerate in order to gain speed. This speed increase is used to lower the speed on other road sections such that the total average speed is kept. Taking account for limitations of top speed the optimal speed profile changes to a strategy that minimizes brake usage. This is done by e.g. slowing down before steep down gradients were the truck will accelerate even though the engine does not produce any torque.

3 Essay

3.1 What is the paper about?

- How to drive a truck such that the fuel consumption is minimized?
- Finding an optimal strategy.
- Understanding of the energy usage of a heavy truck.
- Proving the correctness of previous results mathematically.

3.2 Why is this relevant?

- Fuel is a large part of the operating costs of heavy trucks.

3.3 What have others done and why is this not sufficient?

- Use of simple models.
- Use optimal control theory approach (e.g. dynamic programming)
  → approximate solutions

3.4 What have the author's done and why is this better?

- Analytical derivation of efficient driving behaviour using a physical model of a heavy truck that can predict the fuel consumption while being manageable complex.
- Used model is very accurate and consists of:
  - Engine
  - Transmission
  - Final Gear
  - Wheels and Chassis

3.5 How did they evaluate their solution?

- The authors did not do a an evaluation in the sense of a simulation or real world experiments. Instead they created the physical model of a heavy truck and derived different optimal behaviour for different situations.
- They showed that:
  - for level roads maintaining a constant speed is optimal
  - for small gradients maintaining a constant speed is optimal
  - for steep uphill slopes maximum fuelling is optimal

- for steep downhill slopes cutting off fuel until desired velocity is reached afterwards is optimal
- when considering a maximum speed cutting of fuel to decelerate some time before the downhill slope to reach maximum velocity at the end of the slope is optimal. This point can be calculated.

3.6 Scientific Deficit

- No use of other economic factors apart from fuel consumption
  - *Passenberg, Benjamin, Peter Kock, and Olaf Stursberg. "Combined time and fuel optimal driving of trucks based on a hybrid model." Control Conference (ECC), 2009 European. IEEE, 2009.*
- Not applicable to unknown tracks
  - *Sahlholm, Per, et al. "A sensor and data fusion algorithm for road grade estimation." 5th IFAC Symposium on Advances in Automotive Control (2007). 2007.*

3.7 Scientific Contribution

- Fuel optimal solution for sufficiently small gradients is to keep speed constant
  - *Ivarsson, Maria, Jan Aslund, and Lars Nielsen. "Look-ahead control-consequences of a non-linear fuel map on truck fuel consumption." Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 223.10 (2009): 1223-1238.*
- Find optimal strategy for known tracks
  - *Sahlholm, Per, et al. "A sensor and data fusion algorithm for road grade estimation." 5th IFAC Symposium on Advances in Automotive Control (2007). 2007.*