Automated Speed Selection for Heavy Duty Vehicles

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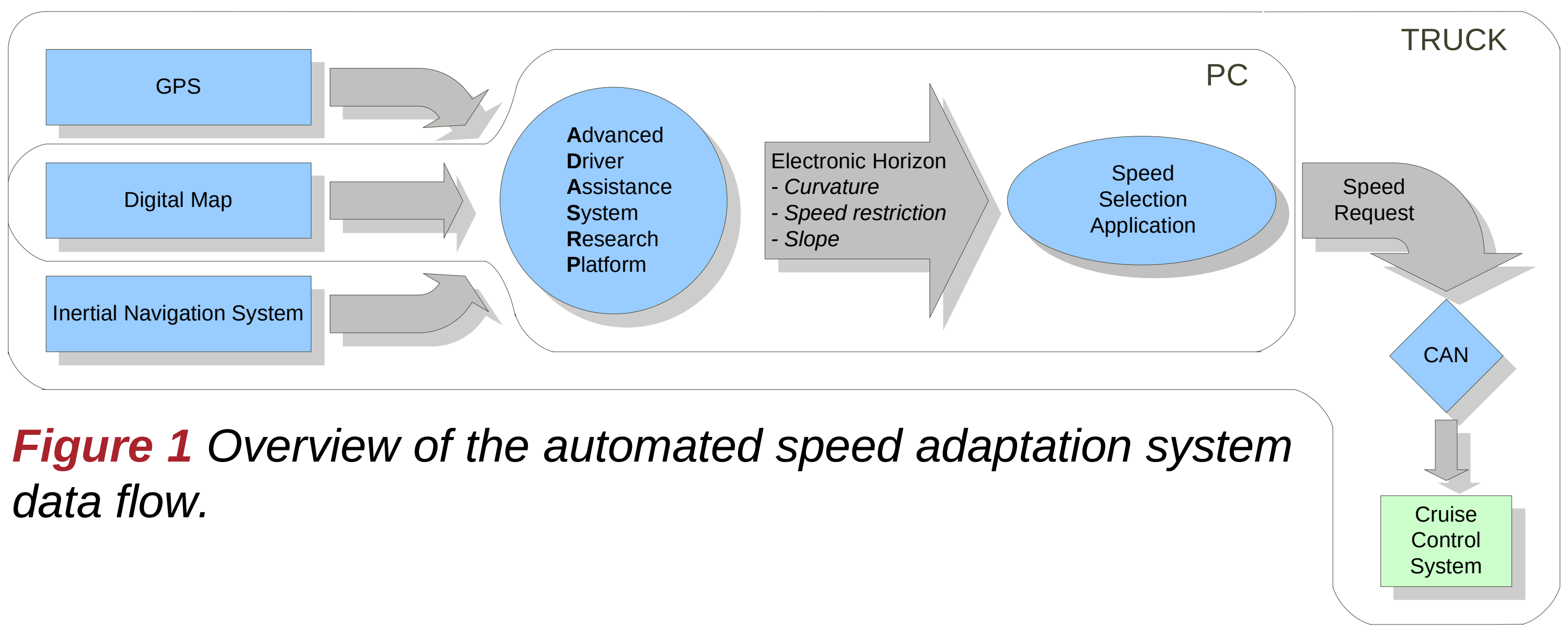
Many different advanced driver assistance systems are currently being developed to improve road safety and vehicle performance in many areas. The aim of this project has been to create a cruise control system which takes the legal speed limit and road geometry en route into account when determining the appropriate vehicle speed. The system uses a digital map to gain information about curvature and speed limits, and a vehicle model to calculate appropriate control actions. When lowering the speed is required the system coasts with no fueling, thus saving fuel and brake wear.

System Description

The developed cruise control system consists of four main parts. A set of sensors are used for positioning the vehicle. A digital map application then uses the vehicle position and direction of travel to extract an electronic horizon with information about the road curvature, road slope and legal speed limit en route. The speed selection algorithm uses the electronic horizon and a vehicle model to calculate a safe and economical speed profile for the vehicle. A modified version of the stock embedded cruise control system actuates the speed selection in the truck. A complete report on the project can be found in [1]. The system is visualized in Figure 1.



TRUCK

PC

GPS

Digital Map

Inertial Navigation System

Advanced
Driver
Assistance
System
Research
Platform

Electronic Horizon
- *Curvature*
- *Speed restriction*
- *Slope*

Speed Selection Application

Speed Request

CAN

Cruise Control System

Figure 1 *Overview of the automated speed adaptation system data flow.*

Speed Selection

The system calculates the appropriate speed at every time step by finding the maximum speed which does not exceed, or cause the vehicle to exceed in the future, either of the reference speed set by the driver, the legal speed limit or the speed mandated by road curvature. To avoid wasting energy through braking the fueling is instead cut-off ahead of time, leading to a gradually lowered speed due to friction forces. A simple longitudinal vehicle model is used to find the proper fuel cut-off point needed to coast down to a speed which will be required later on. The model is shown in Equation 1. The factors influencing speed selection, and an illustration of the associated final speed profile are shown in Figure 2.

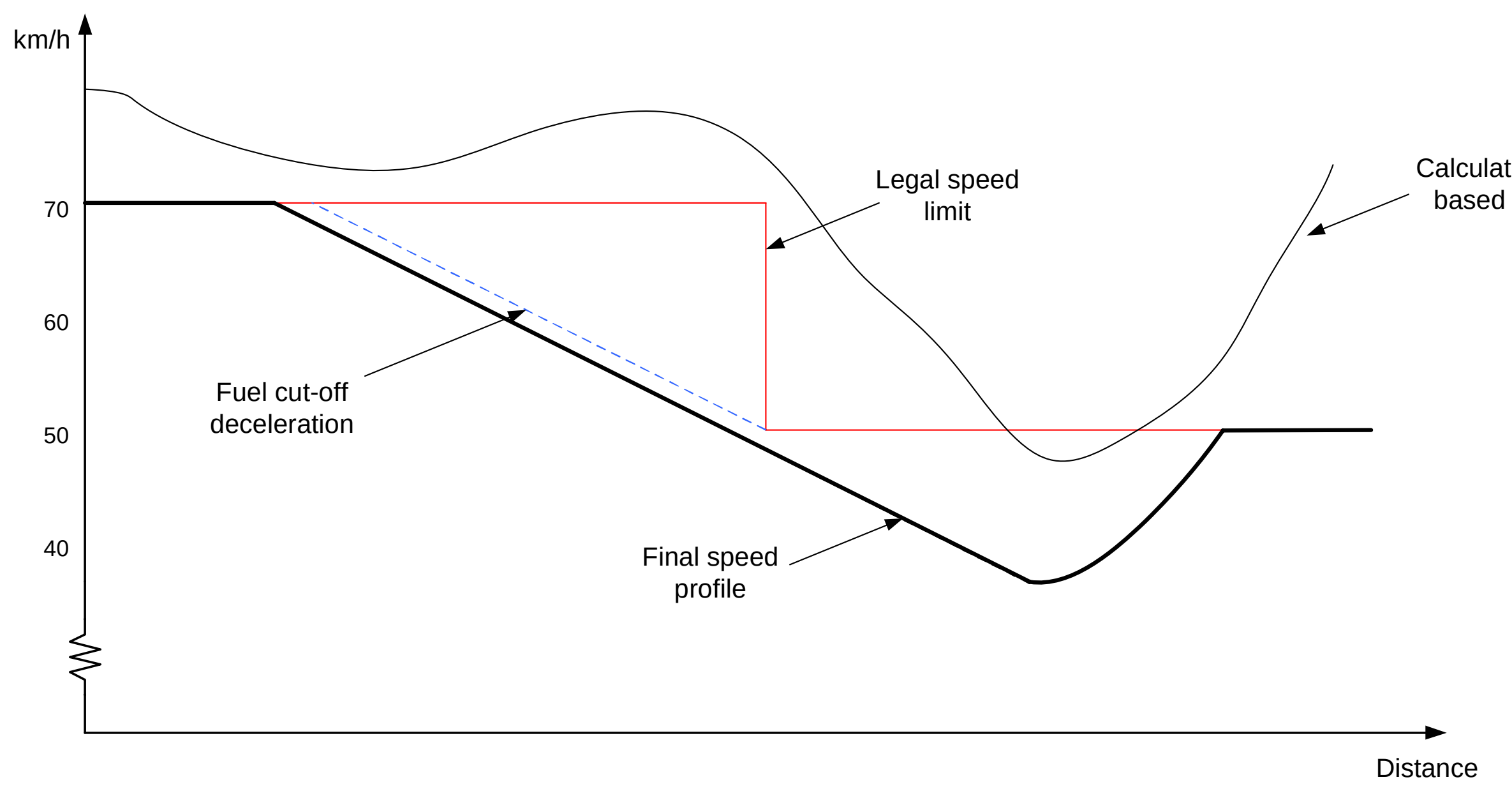


Figure 2 *Final speed profile calculation based on electronic horizon features. An upcoming decrease in speed limit would govern the the speed choice, if the following sharp bend did not mandate an even earlier fuel cut-off.*

The maximum speed based on the road curvature is determined by mandating that the lateral acceleration should be kept below a threshold, in our case 0.15*g. The lateral acceleration is determined through Equation 2, where K is the curvature. The road crossfall E is set to 0 due to lack of data.

$$(J_w + mr_w^2 + i_t^2 i_f^2 J_e) + \ddot{\theta}_w = i_t i_f (M_w - M_{fr:e}) - mc_{r2} r_w^2 \dot{\theta}_w - \frac{1}{2} c_w A_a \rho_a r_w^3 \dot{\theta}_w^2 - r_w m (c_{r1} + g \sin\alpha) \qquad (1)$$

$$a_{lat} = \frac{v^2 K}{g} - E \qquad (2)$$

Results from Implementation

Real world tests of the system have shown that the positioning accuracy is perceived to be good enough for the intended purpose. The vehicle slows down in advance of upcoming speed limit changes and curves as anticipated. However delays in the actuation and data processing subsystems generally make the reactions somewhat late. The road slope data is necessary to obtain a reasonable fuel cut-off point for slowing down, but sometimes it is not enough. If a hill is long and steep the system will hit its lower speed setpoint threshold of 30 km/h, while the vehicle accelerates down the slope. In some cases using the brakes can be justified, despite the effect on fuel economy!

Measurement results from four different drives on two stretches of a winding countryside road close to Södertälje, Sweden are shown in Figures 3 and 4.

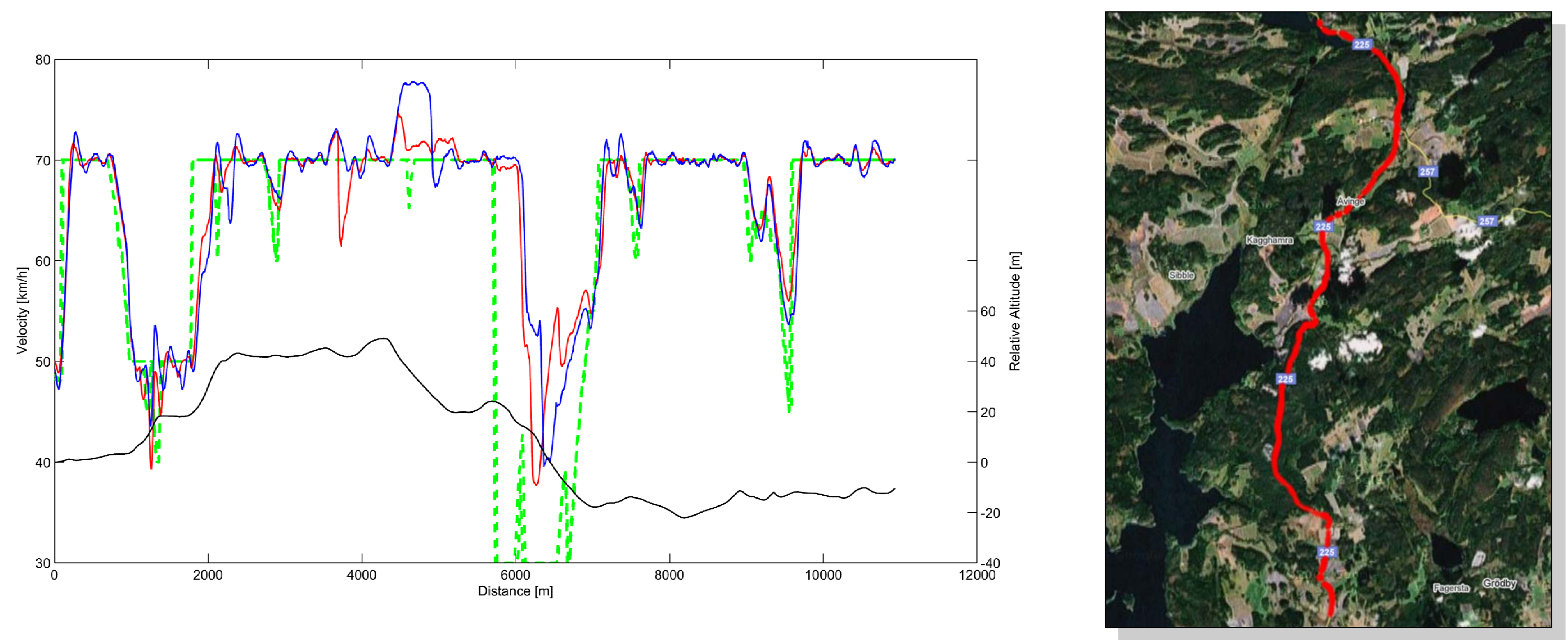


Figure 3 *System speed request (dashed, green) and actual vehicle speed (solid blue and red) for two traversals of the road on the right. The road altitude profile (solid, black) explains the behavior around 6000m, the hill is to steep to handle. A map of the road (red) is shown in the right.*

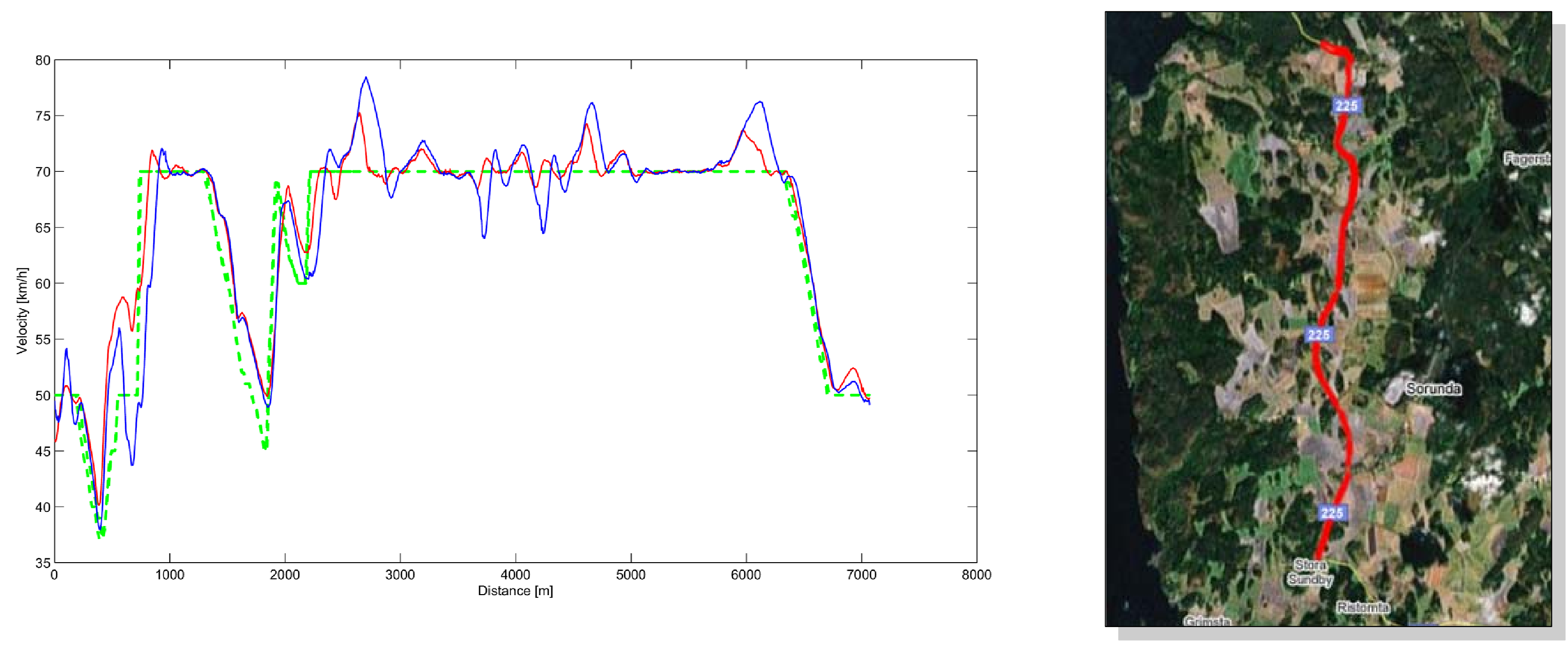


Figure 4 *Presentation correspondent to Figure 2, but for another part of the road, and without altitude. The true speed is consistently somewhat delayed, causing it not to come down far enough in many curves.*

Conclusions

The project has shown that map supported speed adaptation algorithm can work with the map data used. However several improvements are needed before the driver can feel confident that the system will handle upcoming curves and speed limits. Most notably delays in the processing and actuation parts need to be addressed, and the ability to use the brakes to slow down in downhill sections has to be added.

References

[1] Östman, Magnus. Map Supported Speed Adaptation. MSc. Thesis report, Machine Design, Royal Institute of Technology, 2007.