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Development of techniques for the minimization of fuel consumption in road vehicles via optimal scheduling of velocity and gear shifting with known road data

ABSTRACT

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Ph.D. Thesis Abstract: Development of techniques for the minimization of fuel consumption in road vehicles via optimal scheduling of velocity and gear shifting with known road data

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This thesis, deals with the problem of reducing fuel consumption of conventional road vehicles, with major emphasis on medium and heavy duty commercial trucks equipped with conventional powertrains. The main idea is the exploitation of technologies already available to guarantee large diffusion of the proposed techniques and high impact on a short time horizon.

The knowledge of the characteristics of the road to drive stretches the paradigm of energy saving from the power generation within the vehicle alone, towards the exploitation of this additional information for fuel consumption minimization. The goal is to exploit this information, in particular road grade or elevation for modulating vehicle speed and optimizing gear shifts. The key is to deliver mechanical power available in a fashion that maximises the final objective of transportation: elapsed distance.

Nowadays, one of the approaches used to pursue this objective is to perform an instantaneous optimization, based on either some optimality or heuristic principle. On the other hand, the vast majority of the approaches presented in literature, formulate and solve an optimal control problem. Its solution can be approached using optimal control methods or dynamic programming, although at the price of dealing with a potentially prohibitive computational load if suitable model assumptions and simplifications are not made.

In this work, in order to make this approach practical, the optimal control problem has been reformulated and split with the objective of optimizing velocity and gear shifts into two sequential steps. The subsequent reduction of the computational complexity of the problem, has allowed to use dynamic programming for its resolution with a dramatic reduction of both calculation time and the hardware resources. Afterwards, with the necessary modifications to the model equations and cost function, a gradient-based iterative method has been developed and applied, resulting in a consistent reduction of the memory

requirements and a further reduction of the calculation time. Nonetheless, because of the application potential of the technique, a patent has been applied for.

Another approach that is used in practice in order to reduce the computational burden consists in solving the optimal control problem on a horizon of limited length and updating the solutions periodically (receding horizon). This leads to the additional advantage of achieving adaptivity to environmental changes and unpredicted disturbances. Although this approach cannot formally guarantee global optimality, a careful choice of the optimization horizon and update distance should be made. In fact, it has been shown that the right choice provides results nearly coincident with the ones obtained on the full horizon with the same problem structure and system equations.

In this regard, the aforementioned split optimal control problem has been solved in e receding horizon scheme using dynamic programming, achieving excellent results in terms of calculation time and goodness of the solution.

The aforementioned approaches have been applied to the case of a heavy-duty truck and the results obtained in simulation confirm the literature ones. Indeed an average fuel consumption reduction of 3-4% is possible, in comparison with a conventional fixed-point cruise controller, with no increase (or even a reduction) of the travel time in many different load cases and with different desired average speeds.