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Referee's report on dissertation thesis

Author: Ing. Pavel Otta
Title: Multiple-Domain Optimal Control
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Ph.D. candidate, Ing. Pavel Otta, submitted his thesis on multiple-domain optimization for longitudinal vehicle motion. An advanced algorithm for solving complex optimization problems was thoroughly developed and validated on benchmark problem set, e.g. legged robot and six mass motion optimizations. These optimization developments achieved is due to deep candidate's knowledge on the thesis topic and quadratic programing (QP), in particular. Option to switch between the time and spatial domain in the longitudinal vehicle motion, called speed profile, optimization turned out beneficial for tracking and controlling the vehicle on the road.

The optimization problem solved in the thesis is very current problem as to the demand on more sustainable transportation and fuel saving. Due to the speed profile optimization only, emissions will drop despite a truck is considered on the road[1]. The goals of the thesis are gradually and exhaustively addressed within QP. Beginning the thesis the long optimization horizon is tackled by the speed profile optimization sampled in acceleration preventing an oversampling of long routes. As regards affine constraints involvement, their burden on the speed profile optimization is relaxed algorithmically by their (de)activation and the optimization problem sparsity needed for long horizons is obtained. Transitioning to the spatial domain the state constraints are equipped with simple bounds. On the other hand, the vehicle dynamical model becomes then non-linear with singularity for zero speed. Deriving the quadratic dynamical model in incremental form both the non-linearity and singularity are avoided.

The speed profile optimization in acceleration brings in a distributed speed profile optimization along a long route. Based on acceleration sampling the condensed sparse optimization problem is formulated where constant speed modes are eliminated from. Together with affine constraints activated when traffic lights are hit the algorithm for speed profile optimization is tailored for model predictive control (MPC). Downdates or updates due to activated or deactivated constraints and the optimization problem sparsity make this algorithm effective in repetitive optimization for real-time control on embedded devices. ***Altogether this constitutes complex candidate's contribution to the theory of speed profile optimization in application to optimal speed advisory for vehicles.***

The methods used in the thesis are adequate for developing the QP, starting with exact model discretization, via bisection method for terminal constraint optimization, and ending with exact and projected line search method for solving the QP. Projected line search algorithm computes Newton direction step to evaluate whether this step leads to a feasible solution of face problem or not. Thus, the so-called breakpoint is evaluated and in the latter case one or more (affine and box) constraints that were previously inactive are activated to find at the end the optimal solution of QP.

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[1] L. Eriksson, A. Thomasson, K. Ekberg, A. Reig, M. Eifert, F. Donatantonio, A. D'Amato, I. Arsie, C. Pianese, P. Otta, M. Held, U. Vögele, Ch. Endisch, "Look-ahead controls of heavy duty trucks on open roads — six benchmark solutions," Control Engineering Practice, vol. 83, pp. 45-66, 2019.

As pointed out in the thesis, travel time optimization only leads to excessive fuel consumption. Hence, a minimum fuel or energy optimization is required to achieve both a fuel cut and a dropping in emissions. These achievements depend on the type of vehicle in operation as also mentioned in the thesis. ***Could you, please, explain or demonstrate own experience how much differ efficiency functions used in (2.13) between various types of vehicles?*** For instance, between a truck and a hybrid car.

For the distributed speed profile optimization, the route is separated into stages with constant road grade (slope) and speed limit. This separation is a demanding prerequisite of the speed profile optimization that can hardly include casual events like vehicle accidents. Involving these events into the algorithm for solving QP for the purpose of vehicle speed profile optimization is open problem. ***Nevertheless, could you discuss a potential of the algorithm for solving QP to address the open problem?***

At last, only a few formal notes are to be checked/answered in the thesis:

- What results the number of inner iteration of the projected line search algorithm (Algorithm 4 in the thesis) compared to outer iteration of Algorithm 5 in the performed benchmark tests?

- On pg. 11 the dimension of vector r is N+1 (and not N).

- On pg. 18 the dimension of vector b is 2mM+M+4 (and not 3mM+4).

- In Fig. 2.15 (pg. 33) the solution to sub-problem p3 (not p2) is recorded. And in Fig. 2.16 (pg. 34) the traffic light was considered in the optimization to pass after (not before) the red light.

- The text above (3.35) on pg. 63 needs a better reformulation due to inadequate English usage. Check a clause „*when the affect of not optimal active constraints in the working set has larger effect that the free components if and only if*".

The submitted Ph.D. thesis significantly shifts forward the theory of speed profile optimization toward implementable optimal speed advisory system for climate neutral vehicle operation. Candidate's previous research results on speed profile optimization and implementable algorithm for solving the QP have been published or accepted for publication in several impacted journals and prestigious conferences. The candidate is main author of vast number of these publications.

With respect to the achieved goals and high quality of the submitted Ph.D. thesis I recommend this thesis to

pass

for the thesis defense.

In Prague, 1.3.2024

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doc. Ing. Jaromír Fišer, Ph.D.