COMPUTATIONAL MECHANICS 2018
34th conference with international participation
Srní
October 31 - November 2, 2018

The study of possibilities towards to extending the hybrid electric vehicle mathematical model by predictive control algorithm

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The term of "Hybrid Electric Vehicle (HEV)" represents the vehicle as a general mechanical system which cannot be structurally modified (for example by a different type of engine), but the modification from point of view the driving processes can be done by using a suitable control strategy. The control strategy is a very broad term which consist many control possibilities, many control strategies etc. but it is possible to divide it unequivocally into many different control levels. The introduced control levels can be further subdivided in the two groups with respect to the type of controlled processes. The first mentioned group represents control processes that may be fixed only on the past and present vehicle states (for example the level of electric voltage is controlled by rectifier regulator with respect to the current state of charge). The second group is represented by processes that can be controlled based on the past, present and with look into the future – control with prediction horizon (for example the heating can be switched on before a significant outdoor temperature change, because the vehicle bodywork has some thermal capacity). The special cases of these controlled processes are processes with discrete control strategy, typically for example gear switching, which can be done before the following slope and not in the slope. The other similarly control processes in the group of the same control levels may be considered the problems with vehicle physical bounds, for example maximal engine power, maximal value of the friction forces between tire and road surfaces etc. that may be represented as an bang-bang control problem.

Some of these introduced control problems can be sufficiently implemented directly into the vehicle mathematical model (not into the upper control levels), because the mathematical model at the same time generates a feedback for implemented individual controllers. However the implementation the predictive control processes into common simulation software with directly time flow direction (in-time numerical integration, for example MATLAB-Simulink) is very complicated, because it is not possible to go forward in the time direction and from the physical point of view the vehicle is a general dynamic system. In this meaning, the special cases for mathematical model implementation are also the group of physical bounds, because they can be reached at a define integration time and subsequently the simulation has to be stopped.

The presented problem creates very diverse space for answer the question "How to make it in in-time numerical integration systems?" and with respect to very sundry controls problems. One of the possible answer may be inspired by basic thoughts of the Adaptive Cruise control (ACC) and extended concept named Cooperative Adaptive Cruise Control (CACC) [1, 2]. The basic different between ACC and CACC is the inputs information to the second (controlled) vehicle that is also the main advantage of this concept. The first vehicle in traffic

flow cannot be controlled with some predictive control horizon, because it has not the information about the situation ahead, but with compare to the second (next) vehicle, it has these information previously (in time direction). From the point of view of the second vehicle, the presented information contain many interesting facts, which may be used for its control and provided a predictive view to the future. The second vehicle has at the one moment (integration time) information about the past, current and future route and traffic properties (for example the current set of the traffic light in the next crossroad).

This is the first and most important knowledge for the extending an ordinary in-time mathematical model, but in general, the first and the second vehicle should be the same. The difference between mathematical model the first and the second vehicle can caused transmitting the wrong information. For example if the first vehicle has the automatically gearbox and the second (controlled) vehicle has a manual gearbox, the information about the setting suitable gear ratio is unusable. However, this contradictory concept property may be successfully used for control the specific control problem that is shown above like group of the physical bounds problems. This mentioned control problem group in general strictly restricted possible control interventions and it may caused inappropriately stopping the simulation, but in the same time it finds a location of the potential simulation stop points. The simulation stop is not desirable, so the request for the first vehicle mathematical model for this time is that the vehicle has to be without physical bounds and it may be used for finding the potential simulation stop points. This presented property is the second and the most important knowledge for the extending an ordinary in-time mathematical model.

Both of the possibilities how to extending the HEV mathematical model can be used separately, but the best extending of the HEV mathematical model can be achieved only by a suitable combination of presented approaches. Some of the required vehicle properties may be contradictory so the best solution of this problem is creating more than one “the first vehicle” and create the set of the simplest “the first vehicles” which each of those vehicles will be designed only for specific feature. The set of the simplest first vehicles can be implemented in the original mathematical model with the same integration time. The real simulation start is also the simulation start for set of the first simplest vehicles and with the reasonable time delay starts the second vehicle. The second vehicle has at each time point a big set of information from own future and on the basis of which it can manage its own internal processes. The design of the first vehicles, the value of the reasonable time delay and other mentioned parameters presented in this abstract will be investigated and the introduced extending HEV mathematical model will be developed with respect to this concept.

Acknowledgements

The work has been supported by the grant EU project “ADVICE” (ADvancing user acceptance of general purpose hybridized Vehicles by Improved Cost and Efficiency) number 724095 and the word of thanks bellows also to support program for young researchers and Ph.D. students named Mechatronika a adaptronika 2016 SGS16/208/OHK2/3T/12.

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