Abstract tutorial: “Optimal control of hybrid powertrain with the Pontryagin Minimum Principle”

Hybrid vehicle uses at least two energy sources for their propelling, one of them being reversible. Typically, one or more electric machines are coupled to an Internal Combustion Engine in order to reduce the fuel consumption. This tutorial will start by the presentation of the different quasi-static models used for the hybrid vehicle modeling. Then, the energy management will be presented as an optimal control problem. After a quick introduction to the optimal control theory, a basic application in simulation of the Pontryagin Minimum Principle will be illustrated through an example. Practical aspects such as the choice of the fuel consumption model (i.e. analytical versus interpolation over lookup table) or the simplification of the energy storage dynamics will be discussed. The basic algorithm will be extended with the analysis of some theoretical difficulties such as mode selection (engaged gear selection or IC engine on/off management) or management state constraints due to limited energy storage capacity. The resulting algorithm will be used to illustrate a component sizing problem.

Real time algorithms, namelyEquivalent Consumption Minimization Strategy, will be derived from the optimal control algorithm by an online adaptation of the co-state value. The possible approaches range from simple P or PI controller up to more complex predictive algorithm.

Sébastien Delprat

S. Delprat is professor at the University of Valenciennes et du Hainaut Cambrésis and works at the Laboratory of Industrial and Human Automation control, Mechanical engineering and Computer Science (LAMIH) UMR CNRS 8201. His main research interests are in nonlinear systems control and in particular automotive control with some applications such as vehicle platooning, driveshaft control for hybrid vehicle. He has been working on hybrid vehicle energy management since the beginning of his PhD work in 1999 in collaboration with PSA Peugeot Citroen. He mostly work on the application on the Pontryagin Minimum Principle for the optimal control of hybrid powertrains with some focus on some difficult theoretical points such as state constraints or binary variable optimization (e.g. IC engine on/off). He has been developing control algorithms for different hybrid vehicles ranging from micro to full hybrids and also fuel cell hybrid. He recently collaborated with VALEO within the BELHYSYMA project for the control of a new low cost hybridization system.