PhD Proposal 2017

School: CentraleSupélec	
Laboratory: IETR	**Web site: http://www.rennes.supelec.fr/ren/rd/ash/**
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Collaboration with other partner during this PhD: **In France:**	**In China:**

Title: Distributed Model Predictive Control for Hybrid Systems	
Scientific field: Electrical, Electronic and Telecommunication Engineering, **Control Science**	
Key words: Model Predictive Control, Hybrid system, Distributed optimization	

Details for the subject:
(Maximal length of 2 pages, including images, list of reference, …The pdf file should not exceed 1Mo)
Background, Context:

Many different applications are composed of multiple subsystems that are characterized by complex dynamics and mutual influences between them. Such applications include finance, manufacturing systems, network and transportation problem, electricity network and so on. To achieve higher level of performance, a growing interest has been granted to model predictive control (MPC) due to its ability to handle constraints in an optimal control environment. In a few words, in MPC, the control input is computed by solving an optimal control problem over a given horizon, using a prediction model. Only the first element of the open-loop command sequence is applied to the system. At the next instant, a new optimization is performed based on current measurements. For complex systems, it is no longer possible to control each subsystem without taking in consideration its interactions whit the other subsystems. The relations between the subsystems can be linked to their dynamical interactions: for example, improving the thermal comfort of a single room requires considering the thermal interactions with the adjacent rooms. Subsystems can also be linked by sharing resources (Power allocation for instance). Using MPC, a solution could be to solve the resulting optimization problem from a centralized point of view. But due to the huge number of variables and the inherent complexity, combinatorial explosion makes the problem difficult to solve, and sometimes unfeasible in a given time. If each subsystem can be described with a hybrid representation, the complexity of the centralized problem increases even more. For this kind of systems, it then becomes necessary to define a model predictive control structure based on a distributed solution of a resulting mixed integer optimization problem [1].

This work deals with distributed model predictive control structure for large scale hybrid systems. The aim is to define methodologies to provide local controllers which solve some reduced optimization problems, but interact together such that the obtained solution is the same as the global one. To this purpose, communication between agents is required, and a coordination mechanism has to be developed
In the recent survey [2], many works have been proposed for continuous systems, and the assumptions that are made are no longer fulfilled in a hybrid context. The main part of this work will be then to construct theoretical mechanisms of distributed optimization and to associate the proposed structure with a methodology to set the control parameters such that it can handle real problems.

Research subject, work plan:

Research will be conducted at CentraleSupélec, in the campus of Rennes, under the supervision of Prof. Hervé Guéguen, and will feed into the work of the Control of Hybrid Systems team on distributed predictive control. Some techniques have already been developed [3,4] under some specific assumptions: the considered system is a linear system governed by discrete inputs, which is a very specific class of hybrid system. The main topic of this work is to extend the results to more general class of hybrid systems: Piecewise affine systems for which efficiency, performances, and stability proofs are expected to be mathematically studied. In order to structure the research, the following research tasks are proposed:

Task 1: development of coordination methods

Systematic methods will be developed to obtain coordination between the various local controllers in a distributed MPC setting for PWA systems. This in particular involves development of algorithms and procedures to let the local controllers agree on the appropriate values for shared continuous and discrete variables. This also includes analysis of convergence properties.

Task 2: development of computationally efficient methods

Once the basic coordination methods have been developed, approaches will be devised to speed them up by using approximations (based on e.g. simplified or reduced-size models) and by limiting the search space (by determining good initial solutions or by using parameterized control laws). This will typically result in faster approaches but with a lower overall control performance. Therefore, this task also includes examination of the trade-off between computational speed and efficiency.

References:

[1] Distributed Model Predictive Control based on Lagrangian Relaxation, R.Bourdais, H. Guéguen, A. Belmiloudi, Proceedings of ADHS, 2012.

[2] Architectures for distributed and hierarchical Model Predictive Control – A review, R. Scattolini, Journal of Process Control, vol 19, N° 5, 2009, pp 723–731.

[3] Renshi Luo, Romain Bourdais, Ton J.J. van den Boom, Bart De Schutter, Integration of Resource Allocation Coordination and Branch-and-Bound, Proceedings of Conference on Decision and Control, Osaka, Japan, 2015

[4] Amir Firooznia, Romain Bourdais, Bart De Schutter, A Distributed Algorithm to Determine Lower and Upper Bounds in Branch and Bound for Hybrid Model Predictive Control, Proceedings of Conference on Decision and Control, 2015