H D - M P C

Hierarchical and Distributed Model Predictive Control of Large-Scale Systems

In this project we develop new and efficient methods for distributed and hierarchical control of large-scale, complex, networked systems with many embedded sensors and actuators, and characterised by complex dynamics and mutual influences.

At A Glance: HD-MPC

Hierarchical and distributed model predictive control of large-scale systems

HD–MPC

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Cooperation partner: University of Wisconsin-Madison (*USA*)

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Main Objectives

Manufacturing systems, traffic networks, process plants, electricity networks are often composed of multiple subsystems, characterised by complex dynamics and mutual influences such that local control decisions may have long-range effects throughout the system. This results in a huge number of problems that must be tackled for the design of an overall control system. Improper control and insufficient coordination of these large-scale systems could result in a hugely suboptimal performance or in serious malfunctions or disasters. Current centralised control design methods cannot deal with large-scale systems due to the tremendous computational complexity of the centralised control task and due to scalability issues and communication bandwidth limitations, all of which make on-line, real-time centralised control infeasible.

HD-MPC will focus on the development of new and efficient methods for distributed and hierarchical model-based predictive control of large-scale complex networked systems.

The main objective of the HD-MPC project is therefore to develop new and efficient methods and algorithms for distributed and hierarchical model-based predictive control of large-scale, complex, networked systems with embedded controllers, and to validate them in several significant applications. We will design these methods to be much more robust than existing methods in the presence of large disturbances, and component, subsystem, or network failures, with a performance approaching that of a fully centralised methodology. The resulting control methods can be applied in a wide range of application fields such as power generation and transmission networks, chemical process plants, manufacturing systems, road networks, railway networks, flood and water management systems, and large-scale logistic systems.

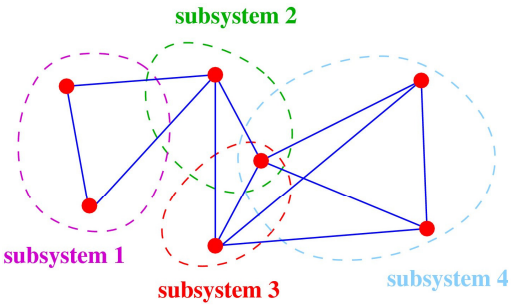
SEVENTH FRAMEWORK PROGRAMME

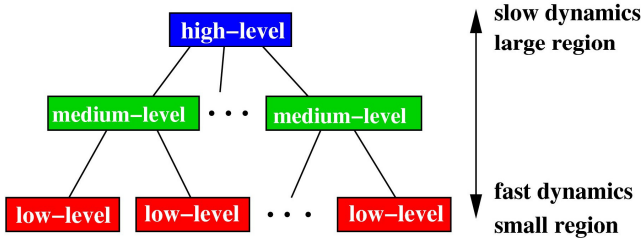
COOPERATION

European Commission
Information Society and Media

Technical Approach

The new structured and tractable control design methods for large-scale systems we will develop will be based on a hierarchical, distributed model-based control approach in which a multi-level model of the system is used to determine optimal control signals, and in which the controllers operate along several time scales and at different control levels. We will develop both the necessary new theory and the corresponding control design methods for using a combination and integration of techniques from computer science, operations research, optimisation, and control engineering. This will result in systematic approaches that outperform existing control strategies, which are often case-dependent and based on heuristics and simplifications.





In order to adapt to dynamic changes in the demands, the structure of the system, and the environment, adaptive on-line control is required. Therefore, we will use a *model-based approach*, which will allow the controller to predict the effects of future control actions on the system, and to take external inputs and demands into account.

We will also take various aspects of large-scale complex systems into account that are often not considered in current control methods such as their hybrid nature, the variety of – often conflicting – objectives and constraints that play a role, and the interactions between the different time scales of the system dynamics and the control actions. This implies that we need a *multi-level, multi-objective, distributed control* approach.

Other important aspects of our approach are *communication* of information between subsystems, and *cooperation* between their controllers towards a common goal.

In addition to performing fundamental research on hierarchical and distributed control of large-scale systems we also concentrate on applications, in particular on combined cycle plants (CCP), hydro-power valley operations, and water capture systems.

Key Issues

The key challenges that will have to be addressed are:

- developing new, efficient, robust, and scalable methods for *on-line*, *real-time* hierarchical and distributed control of large-scale systems,
- appropriately dealing with the computational complexity issues, various types of uncertainty, and coordination and cooperation[1] between the controllers both within and across the control levels,
- integrating the methods within currently deployed embedded sensor and controller structures, so as to allow practical implementation and smooth adoption of the new methods by industry.

In order to address these challenges and to achieve the objectives the research team gathers fundamental and technical core expertise in various fields such as systems and control, chemical engineering, mechanical engineering, electrical engineering, optimisation, operations research, and computer science.

Expected Impact

Due to the use of massive parallel computation and newly developed advanced optimisation and coordination approaches the new MPC methods for large-scale networked systems developed in this project will result in efficient and scalable control methods that – at a fraction of today's effort – can deal with systems that are one or more orders of magnitude larger than what current methods can handle. The new methods will also result in much higher dependability and availability, and significantly reduce maintenance times and costs.

[1] We use "cooperation" to indicate that the controllers actively contribute to achieve a common overall objective and that they actively support each other in order to obtain this objective.