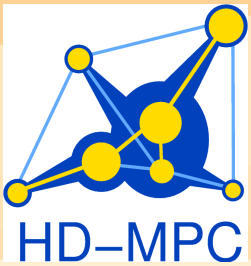
HIERARCHICAL AND DISTRIBUTED MODEL PREDICTIVE CONTROL
OF LARGE-SCALE SYSTEMS

HD-MPC



Key Innovation

Manufacturing systems, traffic networks, process plants, electricity networks are often composed of multiple subsystems, characterized by complex dynamics and mutual influences such that local control decisions may have long-range effects throughout the 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.

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 (MPC) of large-scale, networked systems with embedded controllers, and to validate them in several significant applications. This will result in systematic approaches that outperform existing control strategies, which are often case-dependent and based on heuristics and simplifications.

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.

Technical approach

The new structured and tractable control design methods for large-scale systems we develop are 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 develop both the necessary new theory and the corresponding control design methods using a combination and integration of techniques from computer science, operations research, optimization, and control engineering. In order to adapt to dynamic changes in the demands, the structure of the system, and the environment, we use a model-based approach, which allows the controller to predict the effects of future control actions on the system, and to take external inputs and demands into account.

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Project website

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Community contribution to the project

2000000 Euro

Project start date

September 1, 2008

Duration

40 months

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

A first collection of HD-MPC results has been published in the special issue of the *Journal of Process Control* on HD-MPC (vol. 21, no. 5, June 2011).

Demonstration and Use

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. In addition, the HD-MPC methods we have developed have also been applied to freeway and urban traffic networks, surface water networks, and baggage handling systems.

Scientific, Economic and societal 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.

Project partners	Country
Delft University of Technology	NL
Electricité de France SA	FR
Katholieke Universiteit Leuven	BE
Politecnico di Milano	IT
RWTH Aachen	DE
Universidad de Sevilla	ES
Universidad Nacional de Colombia	CO
Ecole Supérieure d'Electricité	FR
Inocsa Ingeniería S.L.	ES
University of Wisconsin-Madison (cooperation partner)	USA

First achievements

We have developed several new approaches for hierarchical and distributed model predictive control (MPC) for large-scale systems, as well as novel distributed optimization methods for MPC. The effectiveness of the methods has been demonstrated on a four-tank set-up and a hydropower valley case study.