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Partitioning approach oriented to the decentralised predictive control of large-scale systems

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ABSTRACT

In this paper, a partitioning approach for large-scale systems based on graph-theory is presented. The algorithm starts with the translation of the system model into a graph representation. Once the system graph is obtained, the problem of graph partitioning is then solved. The resultant partition consists in a set of non-overlapping subgraphs whose number of vertices is as similar as possible and the number of interconnecting edges between them is minimal. To achieve this goal, the proposed algorithm applies a set of procedures based on identifying the highly connected subgraphs with balanced number of internal and external connections. In order to illustrate the use and application of the proposed partitioning approach, it is used to decompose a dynamical model of the Barcelona drinking water network (DWN). Moreover, a hierarchical-like DMPC strategy is designed and applied over the resultant set of partitions in order to assess the closed-loop performance. Results obtained when used several simulation scenarios show the effectiveness of both the partitioning approach and the DMPC strategy in terms of the reduced computational burden and, at the same time, of the admissible loss of performance in contrast to a centralised MPC strategy.

1. Introduction

Large-scale systems (LSS) present control theory with new challenges due to the large size of the plant and of its model [1,2]. The goal to be achieved with control methods for this kind of systems is to obtain a reasonable solution with a reasonable effort in modelling, designing and implementing the controller.

Model-based predictive control (MPC) has been proved to be one of the advanced control techniques widely accepted for the control of LSS [3]. Applications to different large-scale infrastructures as drinking water networks [4], sewer networks [5], open-flow channel networks [6] or electrical networks [7] proves the applicability of this technique. The main reason is due to once obtained the plant dynamical model, the MPC design just consists in expressing the desired performance specifications through different control objectives (e.g., weights on tracking errors and actuator efforts as in classical linear quadratic regulation), and constraints on system variables (e.g., minima/maxima of selected process variables and/or their rates of change) which are necessary to ensure process safety and asset health. The rest of the MPC design is automatic: the given model, constraints, and weights define an optimal control problem over a finite time horizon in the future (for this reason the approach is said predictive). This is translated into an equivalent optimisation problem and solved on line to obtain an optimal sequence of future control moves. Only the first of these moves is applied to the process, as at the next time step a new optimal control problem is solved, to exploit the information coming from fresh new measurements. In this way, an open-loop design methodology (i.e., optimal control) is transformed into a feedback one.

Nevertheless, the main hurdle for MPC control (as any other control technique) when applied to LSS in a centralised way, is the non-scalability. The reason is that a huge control model is needed, being difficult to maintain/update and which needs to be rebuilt on every change of the system configuration, e.g., when some part of the system should be stopped because of maintenance actions or malfunctions. Subsequently, a model change would require re-tuning the centralised controller. It is obvious that the cost of setting up and maintaining the monolithic solution of the control problem is prohibitive. A way of circumventing these issues might be by looking into *decentralised* MPC (DMPC) or *distributed* MPC techniques, where networked local MPC controllers are in charge of controlling part of the entire system. The main difference between distributed and decentralized MPC is that the former *uses* negotiations and re-computations of local control actions within the sampling period to increase the level of cooperation, whereas the latter does not (at the benefit of computation time, but at the cost of optimality).

The industrial success of the traditional centralised MPC (CMPC) drives now a new interest in this old area of distributed control, and

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