Robust Model Predictive Control by Scenario-based Multi-stage Optimization

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Abstract: Model-predictive control has become the standard solution to multivariable control problems in the processing industry due to its ability to handle constraints, large numbers of inputs and outputs, and strongly coupled plants by a unified approach. While industrial solutions are usually based on linear models that are fitted to measured data in the process of controller development, nonlinear model predictive control using rigorous plant models gains increasing attention. It offers the potential to not only track references and reject disturbances but to optimize the plant performance online by the use of economically motivated cost functions. Due to the advances in numerical optimization and the development of algorithms that provide fast feedback, the scope of application is steadily widening to faster plants. Model-predictive control performs an open-loop optimization over a finite prediction horizon at each sampling time. Stability of the control loop and near-optimality of the control inputs therefore critically depend on the accuracy of the model that is used in the optimization. Feedback is only provided by the re-initialization of the computation based on the available information, and usually by a bias correction of the reference values and the constraints that assumes a constant mismatch between the prediction by the model and the behavior of the true plant. Robustness of model predictive control therefore is an issue of high practical and scientific interest. Most approaches to guarantee robustness are based upon a min-max formulation in which the control inputs are optimized for the worst case in a set of possible true controlled systems. This approach is necessarily restrictive and does not take the presence of feedback into account, i.e. the fact that in the next step the controller can, to some extent, react to the observed plant-model mismatch, whereas in the min-max approach only one fixed input sequence is optimized for all admissible true systems or disturbances. In this contribution, we propose a new approach that takes the presence of feedback into account. The uncertainty is formulated by means of a tree of scenarios, and it is assumed that the information about the true state of the plant becomes available at each sampling instant, corresponding to a node in the scenario tree. Different control sequences are allowed along the branches of the scenario tree, however they must satisfy the so-called non-anticipativity constraints. This means that control inputs that are computed based upon the same information must be identical. The new formulation leads to challenging numerical problems because the size of the optimization problems that have to be solved online increases according to the number of leafs of the tree. We demonstrate the potential of the approach by simulated realistic examples of chemical or biochemical reactors.

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