Abstract

With the rapid development of technology, modern industrial systems have reached unprecedented levels of complexity and diversity. System scales are continually expanding, internal mechanisms are becoming increasingly intricate, and the dynamic interactions and dependencies among variables are growing more complicated. This complexity poses significant challenges to accurately constructing control system models. Moreover, model inaccuracies often result in the degradation of control performance and the reduction of stability. To address these challenges, data-driven model predictive control (MPC) has become increasingly important. By utilizing historical data to design control strategies, data-driven MPC reduces dependence on precise mathematical models, significantly improves system robustness, and effectively addresses the challenges posed by complexity and uncertainty. To combine theoretical innovations with practical application, this dissertation focuses on the implementation algorithms of data-driven MPC to address issues such as poor data quality, uncertain disturbances, and model mismatches within systems. Additionally, a distributed advanced MPC software has been developed. By integrating theory with practice, the study demonstrates the potential of data-driven MPC in real-world industrial environments. The main contributions of this dissertation are listed as follows:

1. For unknown constrained systems with bounded disturbances, an input-mapping-based data-driven MPC with a data selection method is proposed. Based on multi-step data-driven MPC, a fully data-driven controller performance metric is designed. By incorporating a sliding window mechanism, the method selects data that effectively represents the system's characteristics, thereby improving system control performance. The recursive feasibility and asymptotic stability are proven and a simulation result demonstrates the superior control performance of the proposed algorithm compared to existing approaches. Moreover, the algorithm uses online historical input and state data to design control input sequences and predict future states, without the need for system parameter identification.

2. For distributed linear systems with unknown state coupling relationships, an input-mapping-based data-driven distributed MPC algorithm is proposed. This algorithm maps neighboring reference states to linear representations of their historical states, enabling unknown state coupling terms to be expressed as linear combinations of subsystem historical inputs and states, thereby reducing conservatism caused by unknown coupling matrices. The method further analyzes recursive feasibility and asymptotic stability of the closed-loop system. A simulation result validates the proposed method's superior control performance compared to existing approaches. Additionally, the proposed method eliminates the need for system identification, saving computational resources and demonstrating its practicality.

3. To address the growing complexity of industrial systems and the scalability limitations of traditional industrial software, a distributed advanced MPC software was

developed and its practical effectiveness in the coal chemical industry was explored. The software integrates advanced MPC algorithms with an intuitive user interface, optimizing the control of critical parameters in the gasification process. The software is highly scalable, making it suitable for large-scale systems, and it can significantly improve the production efficiency. In addition, the use of multiple temperature control units in the gasification process as an application example highlights the software's potential in real-world industrial environments, demonstrating its functionality and advantages.