Editorial: Special Issue on Model Predictive Control under Disturbances and Uncertainties: Safety, Stability, and Learning

Model Predictive Control (MPC) has established itself as one of the most powerful advanced control strategies, combining conceptual simplicity with the ability to handle constraints and optimize performance. However, the presence of disturbances and uncertainties in real-world systems imposes significant challenges, necessitating robust, adaptive, and computationally efficient solutions. This Special Issue of the *International Journal of Robust and Nonlinear Control* is dedicated to advancing the state-of-the-art in MPC under disturbances and uncertainties, with a focus on safety, stability, and the integration of learning techniques. We are proud to present a collection of 19 high-quality papers that address these challenges and push the boundaries of MPC research.

The Call for Papers for this Special Issue invited contributions on novel theoretical developments, innovative design and analysis tools, and practical applications of MPC in the presence of disturbances and uncertainties. The response from the research community was overwhelming, and after a rigorous peer-review process, 19 papers were selected for publication. These contributions reflect the latest advancements in disturbance and uncertainty modeling, robust and adaptive MPC, learning-based approaches, and applications across diverse domains such as robotics, automotive systems, energy systems, and aerospace.

The accepted papers cover a wide range of topics, organized around the following key themes:

1. Robust and Stochastic MPC

Liu et al. [1] introduce a stochastic MPC framework for discrete nonlinear systems using a multi-step control strategy, while Parsi et al. [2] propose a scalable tube MPC approach for uncertain linear systems using ellipsoidal sets. Manzano et al. [3] explore input-to-state stability in predictive control based on continuous projected kinky inference, providing theoretical guarantees for uncertain systems.

2. Learning-Based and Data-Driven MPC

Yang [4] presents a data-driven MPC framework for unknown linear systems using online learning, and Klöppelt et al. [5] introduce a novel constraint-tightening approach for robust data-driven predictive control. Pan et al. [6] bridge the gap between data-driven methods and stochastic MPC, offering new insights into data-driven stochastic control.

3. Disturbance Estimation and Rejection

Fang et al. [7] develop an integrated MPC scheme with disturbance preview, enhancing performance in the presence of known disturbances. Gao et al. [8] demonstrate practical applications of disturbance rejection in a parabolic trough solar field, and Yu et al. [9] combine model-free predictive control with a linear extended state observer for disturbance estimation in power converters.

4. Safety and Stability in MPC

Kögel et al. [10] address safety-critical applications in autonomous systems through hierarchical MPC and planning. Hall et al. [11] investigate stability and feasibility in switched systems with transient unsustainable modes, and Zhan et al. [12] design terminal weights and constraints for economic MPC in wave energy converters.

5. Applications of MPC in Complex Systems

Shi et al. [13] tackle robustness and security in networked control systems under communication constraints and deception attacks. Yu et al. [14, 15] apply MPC to automotive systems, including semi-active suspension control and autonomous vehicle drifting. Bastos et al. [16] explore dynamic tube MPC for soft manipulators with fluidic actuation, addressing challenges in soft robotics.

6. Computational and Methodological Advances

Shmaliy et al. [17] introduce robust H_2-finite impulse response state observers for uncertain and disturbed systems, with applications to quasi-periodic processes. Cai et al. [18] propose a mixed logical dynamical modeling framework for piecewise affine systems with dead zone constraints. Pohlodek et al. [19] provide a flexible platform, HILO-MPC, for integrating machine learning with optimal control and estimation methods.

These contributions not only advance theoretical understanding but also provide practical insights and solutions for real-world challenges. The integration of machine learning techniques with MPC represents a promising direction for enhancing the robustness and performance of control systems in uncertain environments.

We would like to express our sincere gratitude to all the authors who contributed to this Special Issue. Their innovative research and dedication have been instrumental in shaping this collection. We are also deeply thankful to the reviewers for their rigorous and constructive feedback, which ensured the high quality of the published papers. Special thanks go to the editorial team of the *International Journal of Robust and Nonlinear Control* for their support and guidance throughout the process.

We hope that this Special Issue will serve as a valuable resource for researchers, practitioners, and students in the field of MPC and beyond. By addressing critical challenges and exploring new methodologies, the contributions in this issue pave the way for future advancements in robust and nonlinear control. As the field continues to evolve, we look forward to seeing how these developments will inspire further innovation and collaboration across disciplines.

Guest Editors

Wen-Hua Chen, Loughborough University, UK
Mark Cannon, University of Oxford, UK
Rolf Findeisen, TU Darmstadt, Germany
Jun Yang, Loughborough University, UK

References

1. Liu X, Feng L, Kong X, Lee KY. Stochastic model predictive control based on multi-step control strategy for discrete nonlinear systems. *Int J Robust Nonlinear Control*. 2022;1-21. doi: 10.1002/rnc.6178
2. Parsi A, Iannelli A, Smith RS. Scalable tube model predictive control of uncertain linear systems using ellipsoidal sets. *Int J Robust Nonlinear Control*. 2022;1-22. doi: 10.1002/rnc.6485
3. Manzano JM, Muñoz de la Peña D, Limon D. Input-to-state stable predictive control based on continuous projected kinky inference. *Int J Robust Nonlinear Control*. 2022;1-16. doi: 10.1002/rnc.6525
4. Yang L, Li D, Ma A, Xi Y, Pu Y, Tan Y. Input-mapping based data-driven mode lpredictive control for unknown linear systems via online learning. *Int J Robust Nonlinear Control*. 2022;1-29. doi:10.1002/rnc.6237
5. Klöppelt C, Berberich J, Allgöwer F, Müller MA. A novel constraint-tightening approach for robust data-driven predictive control. *Int J Robust Nonlinear Control*. 2022;1-22. doi: 10.1002/rnc.6532
6. Pan G, Ou R, Faulwasser T. Towards data-driven stochastic predictive control. *Int J Robust Nonlinear Control*. 2023;1-23. doi: 10.1002/rnc.6812
7. Fang X, Chen W-H, Liu F. An integrated model predictive control scheme with disturbance preview. *Int J Robust Nonlinear Control*. 2022;1-13. doi: 10.1002/rnc.6271
8. Gao X, Wei S, Wang M, Su Z. Optimal disturbance predictive and rejection control of a parabolic trough solar field. *Int J Robust Nonlinear Control*. 2022;1-18. doi: 10.1002/rnc.6443
9. Yu X, Chen W, Wang F, Ke D, Xu L, Rodriguez J. Model-free predictive control of non-isolated two-stage AC–DC–DC converter based on linear extended state observer. *Int J Robust Nonlinear Control*. 2022;1-16. doi: 10.1002/rnc.6468
10. Kögel M, Ibrahim M, Kallies C, Findeisen R. Safe hierarchical model predictive control and planning for autonomous systems. *Int J Robust Nonlinear Control*. 2023;1-19. doi: 10.1002/rnc.6808
11. Hall R, Bridgeman L. Switched systems with transient unsustainable modes: Stability and feasibility. *Int J Robust Nonlinear Control*. 2023;1-17. doi: 10.1002/rnc.6730
12. Zhan S, Chen Y, Ringwood JV. Terminal weight and constraint design for wave energy converter economic model predictive control problems. *Int J Robust Nonlinear Control*. 2023;1-23. doi:10.1002/rnc.6841
13. Shi T, Guan Y, Zheng Y. Model predictive control of networked control systems with disturbances and deception attacks under communication constraints. *Int J Robust Nonlinear Control*. 2022;1-19. doi: 10.1002/rnc.6363
14. Yu S, Guo J, Xu M, Zhang S, Zhuang Y, Lin B. Road preview MPC of semi-active suspension

with magneto-rheological damper. *Int J Robust Nonlinear Control*. 2023;1-24. doi: 10.1002/rnc.6625

15. Shi Z, Chen H, Yu S, Findeisen R, Guo H. Nonlinear model predictive control for autonomous vehicle drifting. *Int J Robust Nonlinear Control*. 2023;1-20. doi: 10.1002/rnc.6697
16. Bastos G, Franco E. Dynamic tube model predictive control for a class of soft manipulators with fluidic actuation. *Int J Robust Nonlinear Control*. 2023;1-20. doi: 10.1002/rnc.6598
17. Shmaliy YS, Manzano OGI, Lucio JAA. Robust H_2 -finite impulse response state observers for uncertain and disturbed systems with applications to quasi-periodic processes. *Int J Robust Nonlinear Control*. 2022;1-16. doi: 10.1002/rnc.6347
18. Cai X, Zhang X, Lou X, Wu W. Mixed logical dynamical modeling and model predictive control of piecewise affine systems with dead zone constraints. *Int J Robust Nonlinear Control*. 2022;1-19. doi:10.1002/rnc.6520
19. Pohlodek J, Morabito B, Schlauch C, Zometa P, Findeisen R. Flexible development andevaluation of machine-learning-supported optimal control and estimation methods via HILO-MPC. *Int J Robust Nonlinear Control*. 2024;1-25. doi: 10.1002/rnc.7275