Model Predictive Control study using laboratory processes

Graduate

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Introduction: This project examines the application of Model Predictive Control (MPC) to laboratory processes from the Control Theory laboratory. MPC performance is compared with the classical linear control approach, Linear Quadratic Regulator (LQR), in fixed-value and follower-control applications. MPC is a variant of discrete-time control, in which the optimal control variable is continuously computed every sampling instant by solving an optimisation problem. By solving the problem online, MPC can utilise any information about the reference and any known disturbances to calculate the ideal output. The problem is formulated as a quadratic objective function and a predictive plant model, similar to LQR, enabling direct comparison based on the resulting optimised cost.

Approach: In this work, four laboratory plants were modelled using the descriptions and parameters provided in the Control Technology course materials. The filling process is represented as a first-order system. The Direct Current (DC) motor process is a first-order lag system. The servo process is a second-order system, an extension of the previous structure that introduces a spindle. The magnetic levitation setup, once linearised, is an unstable second-order system with one right half-plane pole. For all the processes, an LQR was designed. For the MPC formulation, four variants were designed to assess the influence of reference and disturbance preview: a simple controller using only the current reference, one using information about the future reference, one incorporating both the future reference and the current disturbance, and one incorporating both the future reference and the future disturbance.

Conclusion: Experimental results on the laboratory plants agree with simulated behaviour, demonstrating that the MPC regulator outperforms the LQR in both reference tracking and disturbance rejection. The most basic MPC variant is superior to LQR, and the stepwise inclusion of the preview shows incremental improvement, with the final variant achieving the best performance. Overall, the results validate control theory expectations.

Figure 1: Picture of laboratory plant wall depecting all four processes.
Own presentment

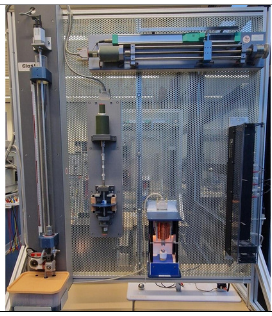


Figure 2: Picture of the magnetic levitation process balancing a magnetic ball using MPC.
Own presentment

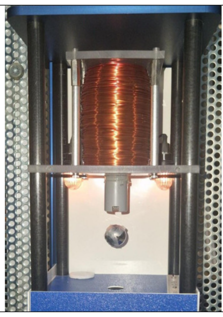
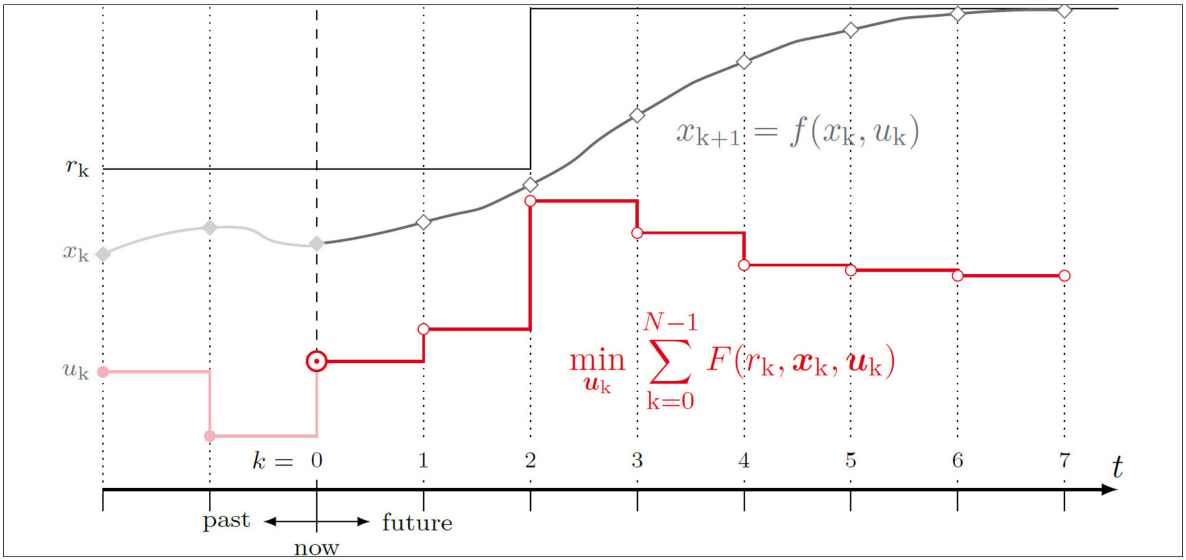


Figure 3: Depection of the receding horizon concept MPC is based on.
T. Besselmann & K. Stadler, MPC (MSE) Autumn 2024: Script.



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Subject Area
Regelungstechnik / Control Theory

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