Optimal Control of Coffee Roasting Processes with Model Predictive Control

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Introduction

- Roasting of coffee beans is a challenging task
- Various actuators need to be coordinated
- Nonlinear thermal behavior of coffee beans [1]
- Proposed solution/approaches [2]:
  - Model Predictive Control (MPC)
  - Digital Twin (DT) of coffee roaster $G(s)$

Methods

- Precise modelling of thermal processes
  - Characteristics and effects of actuators
  - Measurement devices
- Online parameter estimation for portability
- Generate optimal control actions by MPC

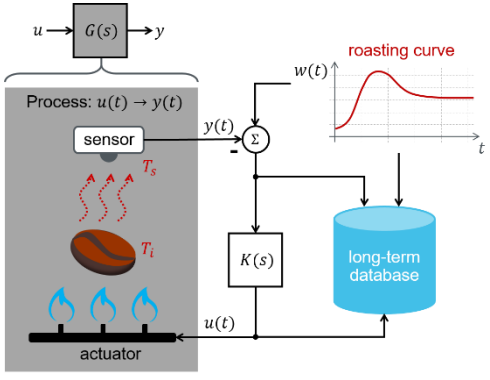

Figure 1: Digital Twin of the roasting process

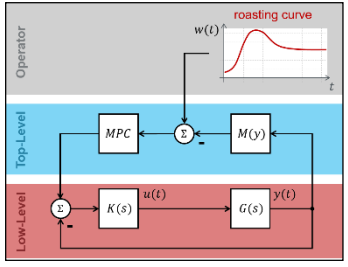

Figure 2: Control structure

Results

- Paramterisation of Digital Twin by predefined control sequence
- Comparison of MPC with conventional control:
  - Manually induce disturbance: Change in supply fan speed up to 30 %
  - Max. temperature deviation with MPC: < 2 % from its setpoint
  - Conventional control (PID-type): ~ 5 % around setpoint

Conclusion & Perspectives

- Prototype already shows better results compared to conventional control structures (~ 5 % to < 2 % deviation from setpoint)
- Presumably better reproducibility of roasting results
- Improvement potential by combination of DT with coffee bean model $M(y)$

References:

1. Di Palma, F.; Iacono, F.; Toffanin, C; Ziccardi, A.; Magni, L.: *"Scalable model for industrial coffee roasting chamber"*. Procedia Computer Science 180 (2021), ScienceDirect, Pp: 122-131.
2. Yao, Y.; Shekhar, D. K.: "State of the art review on model predictive control (MPC) in Heating Ventilation and Air-conditioning (HVAC) field". Building and Environment 200 (2021), ScienceDirect, Pp: 107952.