Ansprechpartner:

Jochen Illerhaus M.Sc.

IRS, Raum 201/2

Tel.: 0721/608-42707

jochen.illerhaus@kit.edu

Beginn: ab sofort möglich **Dauer:** 6 Monate

☒ simulativ ☐ anwendungsorientiert ☐ theorieorientiert

Ihre Interessen:

☒ Optimierung ☐ Modellierung
☒ Programmierung ☒ Numerische Verfahren
☐ Neuronale Netze ☒ Simulation

Bachelor-/Masterarbeit

Linear Model Predictive Control for Smart Thermostats Across Multiple Apartments

Motivation:

The European Union aims to achieve carbon neutrality by 2050. Residential heating is a major contributor to current CO_2 emissions and must therefore undergo significant reductions in the near future. While new construction can employ a wide range of strategies to lower emissions, existing buildings remain a challenge. One promising approach is the installation of smart thermostats, which can adapt to occupant preferences and thereby lead to substantial energy and CO_2 savings.

Although many current smart thermostat applications focus on local optimization, at the apartment or zone level, the research project D2HeaTEC plans to optimize thermostat operation across multiple buildings and incorporate information about heat production systems. To study this, D2HeaTEC will install approximately 500 smart thermostats and other sensors in at least 70 real occupied apartments. A model predictive controller (MPC) will eventually manage room temperature setpoints to ensure occupant comfort and minimize CO_2 emissions. This controller will run on an external server (not embedded hardware) and update every five minutes. Despite this generous allowance of computational resources, meeting performance goals remains challenging due to the multi-day prediction horizon and the large number of temperature zones involved. In addition, controller stability is a key concern. Linear Model Predictive Control is a promising approach to address both performance and stability requirements.

$$
\begin{aligned}
\min \sum &\mathrm{CO_2 Production}\\
\text{s.t.}\quad &\mathrm{aceptable\_comfort} \leq \mathrm{comfort}\\
&\frac{\mathrm{d}}{\mathrm{d}t}\mathrm{state} = A \cdot \mathrm{state} + B \cdot T_{\mathrm{setpoint}}\\
&\mathrm{temperatur} = C \cdot \mathrm{state}
\end{aligned}
$$

Task:

The thesis should begin with a review of the existing literature on linear programming-based model predictive control (MPC) systems in the context of thermostat control. Informed by the literature and the latest plans from the D2HeaTEC project, a linear dynamic system model should be selected and a linear control problem suitable for MPC should be proposed. The controller must ensure occupant comfort and minimize total CO_2 emissions across multiple apartments. The design should be modular to allow individual residential units to be added or removed, and it should incorporate external inputs such as heat production data and ambient temperature as measurable disturbances that do not require a model.

A minimal implementation of the designed controller should demonstrate its effectiveness. This demonstration may be based on a combination of preliminary measurement data from the real system and synthetic data. The performance of the controller should be compared against a baseline consisting of individual PI controllers in each temperature zone, without any optimization. A trade-off among prediction horizon length, stability (assessed empirically in simulation), energy savings, computational load, and occupant comfort is expected and should be quantified. The scalability of both the method and its implementation should be addressed. Practical issues such as communication delays and sensor noise may be ignored. The findings should be presented in an original thesis written in either German or English.