Master Thesis Project

Design and Implementation of a Cooling System Controller

Description

Heating, Ventilation and Air Conditioning (HVAC) systems play a fundamental role in maintaining acceptable thermal comfort and CO₂ levels. Stochastic Model Predictive Control (SMPC) techniques are known to bring significant energy savings potential. Developing effective SMPC-based control strategies for HVAC systems is nontrivial since buildings dynamics are nonlinear and influenced by various uncertainties (outdoor temperature, occupancy and solar radiation).

HVAC with advanced controls instead aim at mitigating these inefficiencies by adding to the decision process information (e.g., knowledge about weather forecasts) and models of the dynamics of the system (e.g., a physical model of the built environment plus statistical models of the occupancy patterns).

An important project under development at the KTH Main Campus is the KTH HVAC project (http://hvac.ee.kth.se/), which aims at experimentally testing and evaluating innovative control strategies for HVACs. Within this project, the HVAC systems can be remotely controlled and monitored thanks to the integration of information coming from the building management facility.

The dedicated KTH HVAC testbed is hosted in one of the buildings in the KTH campus (see Figure 1). The testbed comprises advanced sensing and actuating capabilities, and is located in the ground floor of a seven-story office building and consists of four rooms: a laboratory and three student rooms.

Fig. 1: KTH Main Campus panoramic view and testbed building.
All the rooms are equipped with a Building Automation System (BAC), SCADA and PLCs, a wireless sensor network, an actuator network and a weather station, which allow to monitor continuously the status of the system (CO₂ levels, temperatures, humidity, external weather conditions, see Figure 2).

The BAC gathers data from weather forecasts services and is integrated with web-based scheduling services of the occupancy of the various rooms (calendars). All this collected information can then be used to control the HVAC system in an efficient and predictive way.

As schematized in Figure 2, the HVAC system of the testbed is composed mainly of two parts: the ventilation system, supplying fresh air, and a radiator heating system.

Fresh air is supplied by the central balanced ventilation system. Part of this generated airflow is conveyed directly into the room, while part can be further cooled by a cooling coil. The controllable actuators of the ventilation system are three: two dampers, which regulate the opening of the inflow and outflow ducts, and a valve, which regulates the temperature of the air chilling circuit.

The heating system uses radiators as final units with hot water provided by district heating. The district heating hot water temperature is determined by the outdoor temperature. The only actuator for heating that can be controlled in the testbed is thus the valve regulating the hot water flow.

Figure 3 depicts the architecture of the implemented control system. The indoor temperature and air CO₂ concentration levels (both to be considered as comfort indicators) are controlled through the ventilation system and radiators, which are actuated using low-level proportional-integral controllers. The set-points for the low-level controllers are computed by the novel SMPC strategy at each time instant, based on new measurements and updated information about weather and occupancy patterns.

The inputs of the SMPC for HVAC control are, at every time step, i) occupancy levels, ii) weather conditions, and iii) measurements of the current state of the building. The output is instead a heating, cooling and ventilation plan for the next N hours, where N is the prediction horizon. Only the first step of this control plan is applied to the HVAC system. After that, the whole procedure is repeated. This introduces feedback into the system, since the control action is a function of the current state and currently acting disturbances. In our case the computed outputs are, at every current point in time, set-points to the ventilation system and to the radiators. In particular, they are the mass air flow rate, the supply air temperature and the radiators mean radiant temperature.
The aim of this thesis work is to develop and implement on the KTH HVAC testbed a low-level controller for the cooling system that tracks the set-point computed by the SMPC controller. Starting from April/May 2014.

Useful prerequisites
Basic concepts in dynamical system and control, identification, Matlab/Simulink and general programming skills

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References