Proceedings of the 19th World Congress
The International Federation of Automatic Control
Cape Town, South Africa. August 24-29, 2014

Frequency-Domain Identification of a Ventilated Room for Model Based Control

David Sturzenegger [*,***] **Dominik Keusch** [*]
Leonardo Muffato [**] **Dominique Kunz** [**] **Roy S. Smith** [*]

[*] *Automatic Control Laboratory, ETH Zurich.*
[**] *SAUTER AG, Basel, Switzerland.*
[***] *Corresponding author: sturzenegger@control.ee.ethz.ch.*

Abstract: Efficient and accurate modeling techniques have become increasingly important in the context of model predictive control (MPC) for building automation. For modeling single-input single-output systems such as a ventilated room (with either constant air flow or constant supply temperature), system identification methods are promising and provide insight into the physical nature of these systems. In collaboration with the company SAUTER an office type test room was instrumented for experiments. Three models for the room were derived: i) an empirical transfer function estimate (ETFE) derived from a pseudo-random binary sequence input signal; ii) an ETFE derived from a relay feedback approach; iii) a physics based resistance-capacitance (RC) model.
Using additional validation data, the different models and approaches were compared in terms of accuracy and efficiency. The effect of air mixing dynamics was demonstrated in an additional experiment to be one of the main differences between the experimentally identified and the RC model. An additional pole can be added to the RC model in order to compensate for the differences.

Keywords: Model predictive control, Building automation, System identification.

1. INTRODUCTION

The application of model predictive control (MPC) for the control of heating, cooling, ventilation and blind positioning in buildings has recently gained much attention within the control community, see e.g. Siroky et al. (2011); Oldewurtel et al. (2012); Ma et al. (2012); Sturzenegger et al. (2013); Bengea et al. (2014).
In a building control context, MPC is often considered as a whole building supervisory control. Nevertheless, it may be interesting (potentially as a first step towards whole building MPC) for single room applications as well. In both cases efficient and accurate modeling techniques are becoming increasingly important since cost effectively generating a model is usually the dominant obstacle.

Two principal ways exist for modeling buildings: identification and physics based approaches. While the former have their benefits, due to time and building usage constraints, it is often impractical or even impossible to excite buildings sufficiently for the identification of multi-input multi-output whole building models as required in a supervisory MPC. For this use we advocate physics based models together with an online adaptation of a few parameters usually related to the faster dynamics of the model.
For single-input control of a room however, identification approaches are an interesting alternative avoiding the physics based approaches' need for construction data.

In this paper we show the results of several experiments conducted in a well instrumented ventilated test room (see Section 2) of the company SAUTER [1]. In the experiments we fixed the air flow rate to the test room and used a heating device to excite the thermal room dynamics. Section 3 shows the results of the identification experiments. We calculated empirical transfer function estimates (ETFE) on one hand from an experiment with a pseudo-random binary sequence (PRBS) signal as input and on the other hand in a closed-loop identification setup with a relay feedback controller. In Section 4 we show the results of a validation experiment. Using this data we compared several models: the model identified in Section 3; a physics based model generated from construction data; and a modified version of the latter. The modification consisted of an additional pole and compensated for discrepancies found when comparing the identified and the physics based model in the frequency-domain. In Section 5 the results are discussed and conclusions are drawn in Section 6.

[1] http://www.sauter-controls.com (last accessed: March 2014)

2. EXPERIMENTAL SETUP

A rectangular room located at SAUTER's headquarter and production site in Basel was chosen as experimental facility. The system was defined to be the whole room, including the walls, ceiling and floor. Figure 1 shows a map of the room's surroundings. The room comprised a ventilation unit having air inlet and outlet in the nearby control room, a heating device in the supply air duct and ten temperature sensors. Active cooling of the supply air was not possible. All components are illustrated in Figure 2. To avoid excessive heating up of the control room, the door from the control room towards the big storage hall was kept open.

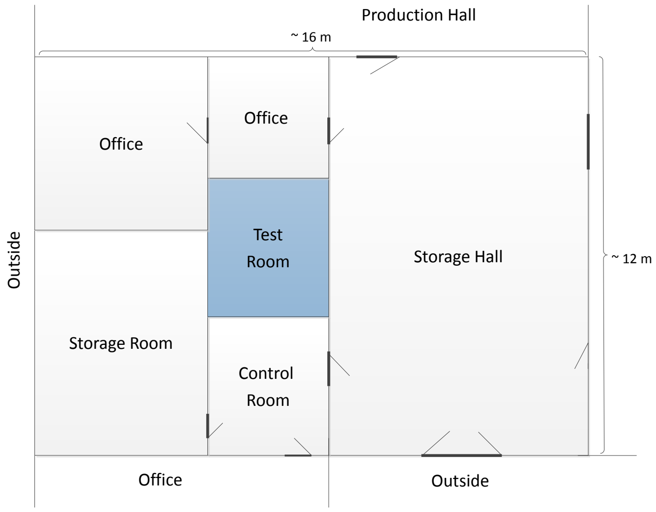

Fig. 1. Room surroundings.

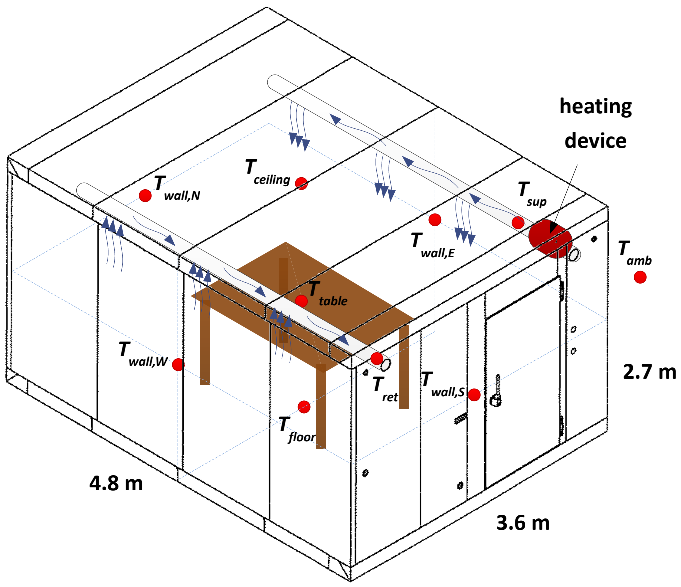

Fig. 2. Experimental setup. Red dots denote temperature sensor locations.

Temperature Sensors. All temperature sensors have been acquired from the company Innovative Sensor Technology AG [2]. Prior to the system identification, a test was conducted to compare the steady-state measurements and sensor dynamics. The static differences of the sensors were measured to lie within 0.12 °C and the temperature values after a temperature step (but before equilibrium was reached again) were found to differ at most by 0.25 °C. This was sufficiently accurate in the context of the planned experiments. Table 1 details the location of the sensors. The sensors on the walls, ceiling and floor were attached at a distance of approximately 10 cm off the wall to reduce direct influences from the wall temperature.

[2] http://www.ist-ag.com (last accessed: March 2014)

Table 1. Temperature sensor locations.

Sensor	Location
T_{amb}	In the control room.
T_{sup}	Supply air duct after the heater.
T_{ret}	Return air duct.
T_{table}	On the table in the center of the room.
$T_{ceiling}$	In the center of the ceiling.
T_{floor}	In the center of the floor underneath the table.
$T_{wall,N}$	In the center of the wall opposite the door.
$T_{wall,W}$	In the center of the wall left from the door.
$T_{wall,E}$	In the center of the wall right from the door.
$T_{wall,S}$	In the center of the wall next to the door.

Actuators. A heating device from the company VEAB Heat Tech AB [3] was used. The device takes as input a 0-10 V signal and produces a pulse width modulated heating power signal with a maximum value of 1800 W. To be able to exactly predict switching times in the identification experiments [4], we decided to modulate the signal ourselves by applying either 0 V or 10 V. These input values resulted in instantaneous changes of the heating power to 0 W or 1800 W, respectively. Our modulation period was chosen to be 20 s. Since the minimum time between two switches of the heating device is 5 s, this modulation was capable of producing 0%, 25%, 50%, 75% and 100% of the maximum heating power. Due to temperature limitations of the heater, it was not possible to use it for a longer period in 75% or 100% mode. Hence, it was subsequently never used more than in 50% mode.

Data Acquisition. For acquiring the sensor measurements a data logger from the company Fluke [5] was used. The sampling time of the data acquisition was set to $t_{\text{samp}} = 10$ s.

3. IDENTIFICATION EXPERIMENTS

The system was mainly influenced by three variables: i) the surrounding air temperature, T_{amb}, influencing the supplied air temperature and the heat gain to the room's outer wall layers; ii) the (volumetric) ventilation air flow rate, $\dot{V}$, and iii) the power of the heating device, $\dot{Q}_{heat}$. The heat gain to the room air from the ventilation can be modeled as

$$C_{air}\rho_{air}\dot{V}T_{amb} + \dot{Q}_{heat} \tag{1}$$

with C_{air} and ρ_{air} being the heat capacity and density of air at 22 °C, respectively. The heat loss due to the air flow leaving the room was modeled accordingly as

$$-C_{air}\rho_{air}T_{ret}\dot{V}.$$

In the present experiments, $\dot{V}$ was set constant to $\dot{V}_0 = 180$ m^3/h, which corresponds to an air change rate of 5 1/h. This is a typical configuration for a heating case. In this work we considered the system to have just,

$$\Delta\dot{Q}_{heat} := \dot{Q}_{heat} - \dot{Q}_{heat,ss},$$

[3] http://www.veab.com (last accessed: March 2014)
[4] For the validation experiment, the original modulation was used.
[5] http://www.fluke.com (last accessed: March 2014)

Download English Version:

https://daneshyari.com/en/article/712217

Download Persian Version:

https://daneshyari.com/article/712217

Daneshyari.com