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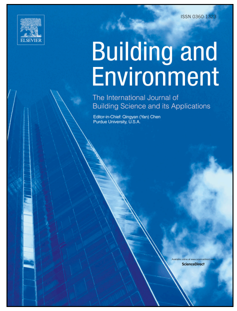

Simultaneous identification of dynamic model and occupant-induced disturbance for commercial buildings

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Simultaneous identification of dynamic model and occupant-induced disturbance for commercial buildings[☆]

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Abstract

A model of a building's thermal dynamics is needed for prediction-based control. The task of identifying a thermal dynamic model is made challenging by the presence of large unmeasured disturbances, especially the heat gain due to the occupants. In fact, identification of this "occupant-induced load" is also valuable for predictive control—especially in commercial buildings. We propose a method to identify both a model (of resistance-capacitance network type) and the unmeasured disturbances from measured input-output data. The method is based on the insight that the main contributor to the unmeasured disturbance, the occupant-induced load, is piecewise constant, especially in commercial buildings. This can be used to construct an augmented dynamic model so that disturbance estimation is converted to a state estimation problem. An outer-loop optimization identifies the best-fit parameter values. The effectiveness of the method is evaluated using data from a simulation model (under both open and closed-loop operations) and a real building.

Keywords: system identification, HVAC control, disturbance modeling, building thermal dynamics, data driven modeling

1. Introduction

A dynamic model of a building's zone temperature is useful in several applications, particularly model-based control of the heating, ventilation, and air conditioning (HVAC) system for improving indoor air quality and reducing energy use [1], limiting peak demand [2], or providing ancillary services to the power grid [3]. To be useful in online control computations, the model needs to be of low order. To model a building with a small number of parameters, the model needs to be identified from data. That is, the parameters need to be estimated from measurements of inputs (such as ambient temperatures and control commands) and outputs (indoor temperature).

Among many different classes of models, a commonly used subclass is the resistance-capacitance (RC) networks, in which an electrical analogy is used to model heat flow. Many methods for estimating parameters of an RC network model from data have been proposed in the literature; see [4, 5, 6, 7] for early work, and [8, 9, 10, 11, 12, 13] for more recent work. In such a model, the output is the building's indoor temperature and the inputs consist of signals such as rate of cooling/heating provided by the HVAC system and dry bulb temperature of the air outside the building. Another input that affects the temperature is the "occupant-induced" heat-gain, which consists of the heat released by the occupants' bodies and the heat gain due to appliances used by the occupants. This input is difficult to measure and is therefore best modeled as an unmeasured disturbance.

With the notable exception of [10, 11, 13], other papers cited above either neglect the effect of unmeasured disturbance altogether [8, 9, 12], use an unoccupied test building [5, 6], or utilize previous knowledge of the occupancy schedule or specific instrumentation to make knowledge of the occupant-induced load possible [4, 7]. The last approach is limited to specially instrumented buildings. Neglecting disturbance altogether is a poor choice: [10] showed that doing so results in poor model identification. This is not surprising since the occupant-induced heat-gain, the main component of the unmeasured disturbance, is not small. Sometimes it can be comparable to the cooling provided by the HVAC system.

In this paper, we propose a method to simultaneously estimate (i) the parameters of an RC network model of a building zone and (ii) the unmeasured disturbance that acts as an exogenous input, from measurements of input-output data. We call it the Simultaneous Plant and Disturbance Identification (SPDI) algorithm; it is based on the assumption that the unmeasured disturbance is dominated by occupant-induced load, and the latter is piecewise constant so that its time-derivative is mostly zero.

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