Models for the energy performance of low-energy houses - DTU Orbit (09/11/2017)

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The aim of this thesis is data-driven modeling of heat dynamics of buildings. Traditionally, thermal modeling of buildings is done using simulation tools which take information about the construction, weather data, occupancy etc. as inputs and generate deterministic energy profiles of the buildings. This approach often fails in predicting the actual heat consumption of buildings once they are constructed. The approach taken in this work is deriving models from observations collected after the construction, aiming at describing the actual characteristics of the building.

Identification of heat dynamics of buildings is needed both in order to assess energy-effciency and to operate modern buildings economically. Energy signatures are a central tool in both energy performance assessment and decision making related to refurbishment of buildings. Also for operation of modern buildings with installations such as mechanical ventilation, floor heating, and control of the lighting effect, the heat dynamics must be taken into account. Hence, this thesis provides methods for data-driven modeling of heat dynamics of modern buildings.

While most of the work in this thesis is related to characterization of heat dynamics of buildings, the first topic analyzed is the variation of presence of occupants. As buildings get more energy-effcient, internal loads and user-behavior increasingly influence the energy consumption. Most simulation tools use deterministic occupancy profiles to simulate internal loads. However, such occupancy patterns will largely depend on the specific use of the building, and hence the profiles must be empirically based. A probabilistic method for modeling timedependence and dynamics of presence of occupants is developed and applied by estimation and model validation on data from an office building. The approach to modeling occupants' presence provides a flexible method where no assumptions in the application.

The rest of the thesis deals with statistical modeling of heat dynamics of buildings. First, discrete-time models are applied. Discrete-time models are computationally relatively simple and provide a flexible framework for dynamical modeling as a natural extension of the often-used static energy-balance models. The importance of applying dynamical models, even for deriving thermostatic or steady-state properties, is stressed, and methods for doing so are outlined.

Since heat transfer is fundamentally described by partial differential equations, modeling of heat dynamics using differential equations is an obvious approach. A quasi-Gaussian maximum likelihood estimation technique, where the likelihood function is evaluated using the extended Kalman filter on state-space models, is used. In this framework - referred to as "grey-box" modeling - one-step predictions can be generated and used for model validation by testing statistically whether the model describes all variation and dynamics observed in the data. The possibility of validating the model dynamics is a great advantage from the use of stochastic differential equations compared to ordinary differential equations.

The strengths of the discrete-time and the continuous-time approach are discussed. Besides the parametrization, which is directly physically interpretable, grey-box models intrinsically provide variable prediction uncertainty, which is important in relation to design of controllers and decision making for comfort requirements. In the framework of stochastic differential equations, there are normally more parameters related to noise processes than in discrete-time models which increases the complexity of the estimation. Here, the state space formulation is often used. Since there is normally infinitely many state space representations corresponding to a transfer function model, structural identifiability is important in relation to state space modeling.

A low-energy building in Sisimiut, Greenland is used as a test-building. The building is well-insulated and features large modern energy-effcient windows and oor heating. These features lead to increased non-linear responses to solar radiation and longer time constants. The building is equipped with advanced control and measuring equipment. Experiments are designed and performed in order to identify important dynamical properties of the building, and the collected data is used for modeling.

The thesis emphasizes the statistical model building and validation needed to identify dynamical systems. It distinguishes from earlier work by focusing on modern low-energy construction and going further into studying and characterizing the dynamical properties of the fitted models.

General information

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