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Editorial

Introduction to the Special Issue on Energy Efficient Buildings

The current energy prices are at a historically high level. This, combined with technological advances, has led to a surge in the interest in energy savings in buildings. Buildings are traditionally the domain of civil engineers, but from a modeling, control and optimal operation point of view, there are strong similarities with industrial processes, where use of control and other system engineering methods have a long history. It is therefore strongly desirable to get a transfer of knowledge between the fields. Over the last few years, there have been a number of dedicated sessions on buildings at the American Institute of Chemical Engineers Annual meeting and building control sessions at meeting organized by IFAC (International Federation of Automatic Control) and at the American Control Conference, among others. This growing interest and importance of the subject motivated the Editorial Board to suggest a special issue on "Modelling, control, optimization and monitoring of energy-efficient buildings". A call for contribution was sent to selected groups who have been active in the area, and in addition a general call was sent to the community, including in eletter (Nov. 2012) and the CAST email list. Eventually, a total of seventeen papers were submitted. Subsequently, the papers went through the regular JPC review process. Thirteen papers were finally accepted and are included in the special issue.

In *Thermal comfort control using a non-linear MPC strategy: A real case of study in a bioclimatic building* Castilla et. al., present a hierarchical thermal comfort control system with two layers. The upper layer includes a non-linear model predictive controller that allows to obtain a high thermal comfort level by optimizing the use of an HVAC system in order to reduce, as much as possible, the energy consumption, with PID controllers at the lower level. The effectiveness of the proposed control system is discussed using suitable real results obtained in a bioclimatic building.

In the paper *Inference of building occupancy signals using moving horizon estimation and fourier regularization*, Zavala studies the problem of estimating time-varying occupancy and ambient air flow signals using noisy carbon dioxide and flow sensor measurements. A moving horizon estimation approach is utilized and demonstrated to be robust to high levels of noise. Computational experiments with simulated and real data are used to demonstrate the effectiveness of the approach.

Touretzky and Baldea in their contribution titled *Nonlinear Model Reduction and Model Predictive Control of Residential Buildings with Energy Recovery* focus on understanding the dynamic behavior of buildings with an emphasis on energy management. First singular perturbation arguments are used to provide a theoretical justification for the empirically-acknowledged multiple time scale dynamic response of buildings. Then reduced order models are derived to describe the dynamics in each time scale for a prototype residential building.

Scherer et. al., in *Efficient Building Energy Management Using Distributed Model Predictive Control* present a distributed model predictive (DMPC) scheme for the efficient management of energy distribution in buildings. Extensions are proposed for the distributed controllers aiming to overcome difficulties that arise from the direct application of a standard DMPC formulation. Simulation and experimental results obtained in a solar energy research center located in Almera, Spain, are reported and discussed, showing promising results for the proposed control strategy.

In *Low computational cost technique for predictive management of thermal comfort in nonresidential buildings* Garnier et. al., present an efficient approach that minimizes energy consumption while still ensuring thermal comfort. A predictive control strategy for existing zoned HVAC systems is proposed and the PMV (Predicted Mean Vote) index is utilized as a thermal comfort indicator. In order to test this strategy, a non-residential building located in Perpignan (south of France) is modeled using the EnergyPlus software. The twofold aim is to limit the times during which the HVAC subsystems are turned on and to ensure a satisfactory thermal comfort when people are working in the considered building. This predictive approach is shown to meet thermal comfort requirements while minimizing energy usage.

In the contribution titled *Learning Decision Rules for Energy Efficient Building Control*, Domahidi et. al., suggest an automated rule based contrl (RBC) synthesis procedure for binary decisions that extracts prevalent information from simulation data with hybrid model predictive control (HMPC) controllers. The result is a set of simple decision rules that preserves much of the control performance of HMPC. The suggested methods are evaluated in simulation for six different case studies and shown to maintain the performance of HMPC despite a tremendous reduction in complexity.

In the paper *Intelligent BEMS (Building Energy Management Systems) design using detailed thermal simulation models and surrogate-based stochastic optimization*, Kontes et. al., consider the possibility of utilizing models constructed in the building design phases for the reason of estimating energy performance to be also utilized for the purpose of feedback control. An online process is presented where a stochastic optimization algorithm utilizing a detailed thermal simulation model of the building along with

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historical sensor measurements and weather and occupancy forecasts is used to design effective control strategies for a predefined period.

Vana et. al., describe the complete process of MPC implementation for a real office building in Hasselt, Belgium in the paper *Model-based energy efficient control applied to an office building*. Starting with building description and data collection, followed by the discussion about the suitable model structure design and proper identification methods selection, the paper attains to a flexible two-level control concept. Finally, the proposed control scheme leads in average to a 17% energy consumption reduction compared to the conventional control strategy.

In the paper titled *Partially-Decentralized Control of Large-Scale Variable-Refrigerant-Flow Systems in Buildings* Jain et.al., consider the problem of designing a scalable control architecture for large-scale variable-refrigerant-flow (VRF) systems. Using a gray-box modeling approach, and by exploiting the one-way coupling between the fluid dynamics and thermal dynamics, individual linearized models for each class of dynamics are derived. A partially-decentralized control architecture is proposed. Communication is limited to one-way sensor information flow from the individual decentralized controllers to a global controller, leading to a simple yet highly effective control architecture which easily scales for systems with a large number of evaporators.

In the paper *Decentralized Predictive Thermal Control for Buildings*, Chandan and Alleyne study the problem of decentralized control design for thermal control in buildings, to achieve a satisfactory trade-off between underlying performance objectives and robustness to failures. An output-feedback, model predictive framework is used for decentralized control which is based on a reduced order system representation. It entails the use of decentralized extended state observers to address the issue of unavailability of all states and disturbances.

Marawan et. al., develop a Demand-Side-Response model, which assists electricity consumers exposed to the market price to independently and proactively manage air-conditioning peak electricity demand in *Demand-Side Response Model to Avoid Spike of Electricity Price*. The results indicate the potential of the scheme to achieve financial benefits for consumers and target the best economic performance for electrical generation distribution and transmission.

In *Energy Efficient Control of HVAC Systems with Ice Cold Thermal Energy Storage*, Beghi et. al., utilize Thermal Energy Storage (TES) systems reduce energy costs and consumption, equipment size and pollutant emissions. The paper presents a model-based approach with the aim of increasing the performance of HVAC systems with ice Cold Thermal Energy Storage (CTES). Standard control strategies are compared with a Non-Linear Model Predictive Control (NLMPC) approach.

In *Predictive and interactive controllers for solar absorption cooling systems in buildings* Herrera et. al., propose a predictive control approach for a solar powered hot water storage (SHWS) system which interacts with a simple thermal building control. The primary objective of this first controller is to optimize the use of the solar energy in order to ensure the cooling requirement of the building. The second controller is dedicated to the control of the building temperature. Using a model of the building thermal behavior, it sends its predicted operating profile to the SHWS controller. The performances of these two interacting controllers are illustrated by various simulations on a TRNSYS model of the building and its subsystems.

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