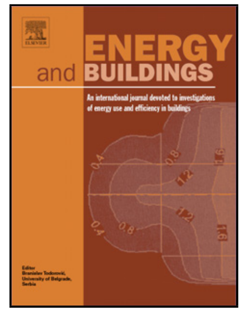

Title: A Low-Complexity Control Mechanism Targeting Smart Thermostats

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A Low-Complexity Control Mechanism Targeting Smart Thermostats

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Abstract

This paper introduces a low-cost, high-quality Decision Making Mechanism for supporting the tasks of temperature regulation of existing HVAC installations in a smart building environment. It incorporates Artificial Neural Networks and Fuzzy Logic in order to improve the occupants' thermal comfort while maintaining the total energy consumption. Contrary to existing approaches, it focuses in achieving significantly low computational complexity, which in turn enables its hardware implementation onto low-cost embedded platforms, such the ones used in smart thermostats. Both the software components and hardware implantation are described in detail. To demonstrate its effectiveness, the proposed method was compared to ruled-based controllers, as well as state-of-the-art control techniques. A simulation model was developed using the EnergyPlus building simulation suite, a detailed modeled micro-grid environment of buildings located in Chania Greece and historic weather and energy pricing data. Simulation results validate the effectiveness of our approach.

Keywords: Decision Making, HVAC control, Neural Network, Fuzzy Logic, Hardware Prototyping

1. Introduction

Buildings are immensely energy-demanding and are expected to consume even more in the near future. It has been estimated that the amount of energy consumed in European Union's (EU) buildings reaches around 40–45% of the total energy consumption, whereof two-thirds of which is used in dwellings [1]. More thoroughly, in the current decade the energy demand of the tertiary and residential sectors has increased by 1.2% and 1.0% per annum respectively [2]. As a result energy usage in the above sectors is responsible for approximately 50% of the greenhouse gas emissions [3]. Hence solutions that promise to alleviate these drawbacks are a prerequisite of next-generation's buildings' infrastructure.

There are a number of ways to reduce the energy consumption, and subsequently the ecological footprint, of a building. Among others, buildings can be designed more efficiently at the planning stage which, whilst ideal, is not always an option. Existing buildings can be retrofitted to improve energy efficiency – although that can be financially prohibited and disruptive, taking into account that building components are often slowly replaced, mainly due to their increased cost. A more practical approach is to use software-based solutions to ensure efficient management of energy consumption. For instance, Building Energy Management Systems (BEMS) are computerized platforms that enable building operators to monitor and control at real-time different systems including heating, ventilation and air conditioning (HVAC).

The problem of deciding upon a HVAC configuration is a well-established challenge that has been attracting the interest of many researchers over the years. Based on relevant literature, there are two mainstream ways of controlling an HVAC system. The first one corresponds to systems that support online decision making. These systems are reactive to climatic conditions, building operation as well as occupancy variation [4]. On the other hand, the second approach refers to a Model Predictive Control (MPC) which estimates the optimum decision making strategy to be implemented [5]. Both of these approaches exhibit advantages and disadvantages. For instance the online control systems can react only to the actual building conditions, while an MPC can move forward in time to simulate the impact of alternative control operating scenarios.

Despite the significant progress made in optimal nonlinear control theory [6] [7], the existing methods are not, in general, applicable to large scale system (LSS) because of the computational difficulties associated with the solution of the Hamilton-Jacobi partial differential equations. Similarly, although MPC for nonlinear systems has been extensively analyzed and successfully applied in industrial plants during the recent decades [8] [9], it likewise encounters dimensionality issues: in most cases, predictive control computations for nonlinear systems amount to numerically solving a non-convex high-dimensional mathematical problem whose solution may require formidable computa-

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