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MODELING THE THERMAL PERFORMANCE OF A WINDOW TYPE AIR-CONDITIONING SYSTEM WITH ARTIFICIAL NEURAL NETWORKS

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Abstract. *Mathematical simulations of air-conditioning systems based on physical principles usually produce high precision results. Such simulations, however, tend to be time consuming and / or computationally expensive, turning out to be prohibitive in applications where a quick response is needed. A promising alternative to tackle this issue is the use of Artificial Neural Networks (ANNs), data driven, bio-inspired models that mimic (roughly) human cognition to solve predefined, specific problems. A remarkable characteristic of ANNs is their ability to generalize, that is, to learn based on a set of a priory labeled data and produce predictions for new (unseen) data quickly. In this work we employ ANNs to model the steady-state operation of a window type air-conditioning system. More specifically, based on experimental data, we build / induce models to predict the cooling capacity of the system. Ten different architectures of multilayer feedforward neural networks are considered in our empirical evaluation. Our results suggest that several configurations are capable of modeling the system with considerable accuracy (R^2 up to 0.97) in relation to the experimental results, considering only non-invasive measurements of temperature, humidity, and air flow levels from the device. Given that such measurements are readily available and can be obtained with a considerably low cost, our results suggest that these models are appealing for applications where low latency predictions are needed, such as, Internet of Things (IoT) platforms, Smart Buildings, and Control Systems.*

Keywords: *HVAC systems, air-conditioning systems, artificial neural networks, machine learning*

1. INTRODUCTION

The use of Heating, Ventilation, and Air Conditioning (HVAC) systems has increased significantly in past decades, with some authors even claiming that HVAC systems are no more a luxury but an essential item in everyday life (Pérez-Lombard *et al.*, 2008). On the other hand, such systems account for as much as 50% of energy consumption in a building, according to Pérez-Lombard *et al.* (2008). Other estimates suggest that, in countries with a tropical climate, consumption figures for HVAC systems can go even higher than 50% (Chua *et al.*, 2013). Given their increasingly adoption and high energy consumption, there is clear demand for the development of more efficient devices.

Models of Heating, Ventilation, and Air Conditioning systems play an important role in their design, development and performance analysis (Castilla *et al.*, 2013; Afram and Janabi-Sharifi, 2015; Afroz *et al.*, 2018). A better understanding of energy consumption behavior can, in turn, allow the development and adoption of efficient control strategies (Afroz *et al.*, 2018). In brief, according to Afram and Janabi-Sharifi (2014), who provide an in depth review of models in this particular reserch area, HVAC systems can be modeled by techniques that fall into three major classes or categories, namely: physics based (or white-box), data driven (or black-box), and hybrid models (or gray-box). Techniques from latter category are usually built by a combination of the former two, in which model structure comes from a physics based model and model parameters are estimated based on experimental data (Homod, 2013).

Techniques that fall within the first category, that is, physics based models, build an explicit mathematical model of the system. Simulations of air-conditioning systems are performed taking into account the conservation of mass, energy and momentum, requiring the simultaneous solution of non-linear equations sets (Homod, 2013). The iterative procedures employed to obtain such solutions have a relatively high computational cost (Hermes and Melo, 2009; Zeng *et al.*, 2015). Nevertheless, they are widely adopted due to their sound physical foundations and accurate results (Ploug-