Modelling of Heat Flux in Building Using Soft-Computing Techniques

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Abstract. Improving the detection of thermal insulation failures in buildings includes the development of models for heating process and fabric gain -heat flux through exterior walls in the building-. Thermal insulation standards are now contractual obligations in new buildings, the energy efficiency in the case of buildings constructed before the regulations adopted is still an open issue, and the assumption is that it will be based on heat flux and conductivity measurement. A three-step procedure is proposed in this study that begins by considering the local building and heating system regulations as well as the specific features of the climate zone. Firstly, the dynamic thermal performance of different variables is specifically modeled. Secondly, an exploratory projection pursuit method called Cooperative Maximum-Likelihood Hebbian Learning is used to extract the relevant features. Finally, a supervised neural model and identification techniques are applied, in order to detect the heat flux through exterior walls in the building. The reliability of the proposed method is validated for a winter zone, associated to several cities in Spain.

Keywords: Computational Intelligence, Soft computing Systems, Identification Systems, Artificial Neural Networks, Non-linear Systems.

1 Introduction

The identification of thermal insulation failures (TIF) could significantly increase building energy efficiency and substantially contribute to reductions in energy consumption and in the carbon footprints of domestic heating systems. Conventional methods can be greatly improved through the application of learning techniques to detect the TIF when a building is in operation through heat flux model - heat flux through exterior walls in the building-.

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Nevertheless, predicting the thermal dynamics of a building is a complex task. The dynamic thermal performance of a building has mainly been used to estimate its power requirements. As an example, the difficulties of obtaining a black-box model for a generic building are documented in [1]. Furthermore, [2] cites examples of the errors associated with different kinds of techniques while providing possible solutions. Also, in order to determine the thermal insulation failures local building regulations need to be analysed in order to profile the premises and the legal specifications for the physical parameters.

This research represents a step forward in the development of techniques to improve dynamic thermal efficiency in existing buildings through a modelling of heat flux in the building. Although this may appear simple at first sight, noise due to occupancy and lighting profiles can introduce distortions and complicate detection. A three-step procedure for testing and validating the model is proposed: firstly, the dynamic thermal behaviour of a specific configuration is calculated using HTB2 software [3]. The outcome of the HTB2 should then be post-processed to obtain a suitable dataset. Subsequently, the dataset is analysed using an exploratory projection pursuit (EPP) [4, 5] called Cooperative Maximum-Likelihood Hebbian Learning (CMLHL) [6, 7], extract the dataset structure and key relationships between the variables. A model is then produced, at the modelling stage, to estimate the heat flux through exterior walls in the building at a specific configuration.

This paper is organised as follows. The following Sub-Section 1.1 details the problem description. Section 2 introduces the unsupervised connectionist techniques for analysing the datasets in order to extract their relevant internal structures. Section 3 deals with classical identification techniques used in the system modelling. Section 4 describes the case of study details and the multi-step procedure. Section 5 describes the results obtained and finally, the conclusions are set out and comments are made on future lines of work.

1.1 Spanish Regulations and the Problem Description

In 2007, several regulations on buildings and construction were approved in Spain. Firstly, the minimum pre-requisites for energy efficiency with which buildings must comply are given in the European Directive 2002/91/CE [8]. Project and specifications, the constructing conditions and the basic requirements in Spain are specified in the CTE (Código Técnico de Edificación [Building Regulations]) [9]. One of the basic requirements is document HE1 that considers the energy consumption limitation in buildings [9] and its updates.

The local regulations shall be analysed to extract the minimum requirements and parameters for heating systems and thermal comfort, and the energy efficiency certifying procedure as well. In Spain, the energy efficiency is calculated as the ratio of combustible consumption needed to satisfy the energy demand of the building. The energy efficiency in the case of buildings constructed before the CTE approval is still an open issue, and the assumption is that it will be based on heat flux and conductivity measurement.