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Practical Applications of Uncertainty and Sensitivity Techniques in Building Energy Simulation

Houcem eddine Mechri[a], Vincenzo Corrado[a]

[a]*Department of Energetics, Politecnico di Torino - Corso Duca degli Abruzzi, 24 - 10129 Torino, Italy*

Abstract

This study is intended to address uncertainty issue associated with data used in building energy simulation. Through a deep scientific literature investigation, several applications were indentified, described and discussed, including the role of uncertainty and sensitivity analyses on parameter screening, reliability analysis, robustness design, decision making process, meta-model construction and embedded uncertainty and sensitivity. Furthermore the paper provides the reader with terminologies and notions about several uncertainty and sensitivity techniques.
Besides, the paper highlights the importance of involving the non-deterministic aspect of a data in a building energy analysis, by describing the uncertainty affecting data used during simulation, e.g. air flow rate, thermo-physical properties.

Keywords: Uncertainty and Sensitivity; Practical Applications; Building Energy Simulation; Data Uncertainty.

1. Main text

Since the 70's, sensitivity and uncertainty analyses have became more and more widely used in the different branches of engineering and they are well recognized as a necessary tool for a good modeling practice and for the development of straightforward decisions, conclusions and regulations.

In practice, the uncertainty analysis may be defined as the expected distribution of possible values for a model response following the perturbation of the input parameter within theirs respective ranges of uncertainties. The aim of uncertainty analysis is to establish how likely a particular state of the model occurs and gives information on how much the results are reliable. The purpose of the sensitivity analysis is more scrupulous as it deals with the relationship between the result variation and each input data uncertainty. A sensitivity analysis conducted on a model provides information about which of the input parameters has a significant impact on the simulation output so that to direct research priorities to reduce uncertainty on factors that are responsible of the biggest output variability.

The use of uncertainty and sensitivity techniques is largely diffused in many scientific disciplines. A range of applications includes water quality [Francos et al. 2003 and Van Griensven 2006], chemical engineering [Campolongo and Satlelli 1997], combustion mechanism [Tomlin 2006], nuclear reliability [Marques et al. 2005], aerospace engineering [Schuëller et al. 2005] and so on. Several studies have been carried out over the last decade on the impact of data uncertainties on building energy performance. The most important research were conducted by (i) Sten de Wit, Senior advisor at TNO Built Environment and Geosciences, on the identification of the most important parameter and decision making analysis for building thermal comfort [De Wit 2001], (ii) Krystyna

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Pietrzyk, researcher at the Department of Architecture Chalmers University, who performed a reliability analysis in air ventilation [Pietrzyk 2000] and (iii) Ian Alexander Macdonald who implement an uncertainty analysis algorithm into the ESP-r tool [Macdonald 2002]. Besides, a great work has been developed, since the 70s, for the definition of uncertainty and sensitivity techniques [Cukier et al. 1973, Morris 1991, Sobol 1993, Bettonvil and Kleijnen 1997, Saltelli et al. 2004].

Although the rich literature about the use of uncertainty and sensitivity techniques in different scientific disciplines, important problems arise. The literature failed to identify and to classify practical applications of uncertainty and sensitivity techniques. Indeed, the above mentioned studies use those techniques for different purposes that may be summarized and categorized into practical or defined applications. As a consequence, the identified applications may be applied to the building energy analysis or any other scientific disciplines.

Following, our intent in this work is to provide a list of practical applications of uncertainty and sensitivity. In addition, this work provides a state of the art of the uncertainties affecting the most important data used for building energy needs assessment and presents the most techniques for uncertainty and sensitivity analysis.

The study is based on the review of more than seventy papers. The selected papers were divided into three groups: papers describing the sources of uncertainties on the data used during building performance simulation, review papers of uncertainty and sensitivity techniques and papers reporting the application of novel approaches to real case studies and/or the application of existing to complex engineering problems.

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