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Uncertainty analysis of user behaviour and physical parameters in residential building performance simulation

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ABSTRACT

The objective of this study is to analyse uncertainties in building simulation through a probabilistic approach. The EnergyPlus computer programme was used to assess a model of a low-income house located in Florianópolis, southern Brazil. Uncertainties of the user behaviour and physical parameters were obtained through literature review and field survey, respectively. The Latin hypercube was used to create a sample of uncertainties to analyse the thermal performance and energy consumption of the house. A sensitivity analysis using the Standardised Regression Coefficients was performed to obtain the most important parameters in the thermal performance and energy consumption. The results showed that the relative deviation with 95% confidence ranges from 6.6% to 21.5% on the degree-hour for heating and cooling, and from 19.5% to 43.5% on the energy consumption for heating and cooling, respectively. These percentage values are the uncertainties found in each analysis. The specific heat and thickness of materials, solar absorptances, ground temperatures, and the albedo (physical uncertainties) and the occupancy schedules, the equipment power and the number of occupants (user behaviour uncertainties) were important parameters in the analysis. Thus, such parameters must be measured or estimated by more precise methods as they most influence the simulation results.

1. Introduction

Building performance simulation is a well-known technique in the engineering field, and through it, many advantages in creating optimized designs can be achieved, and strategies for energy efficiency and renewable energy can be implemented [1]. However, a large number of parameters is required along with multidisciplinary knowledge of the user [2], which indicates that computer simulation programmes should be used with care.

There may be many uncertainties in a building performance simulation, including physical, scenario, design, and algorithms uncertainties [3]. These uncertainties take into account the measuring methods of the thermal properties of materials, the operation of the building, the weather files, and heat and mass transfer algorithms.

Thus, it is important to use techniques to quantify these uncertainties and to assess the impact of each parameter on the variable that is analysed via computer simulation.

According to De Wit and Augenbroe [4], the evaluation of the thermal performance of buildings still in design phase involves the consideration of uncertainties, and any result presented without confidence interval has no scientific value [5]. The uncertainty analysis helps to determine such interval and achieve valid and more realistic results.

The consideration of uncertainties in models not only implies variations on specific input parameters but also changes all the design of an experiment. Thus, a probabilistic approach is used instead of a common deterministic approach, which considers the intervals in output variables caused by uncertainty in the input parameters [6].

An uncertainty analysis is linked to a sensitivity analysis, which aims to determine the parameters that most contribute to the variability of results [7], i.e., the most important parameters of the experiment.

Summarizing, the uncertainty analysis refers to the probability distribution of the dependent variables (output), and the sensitivity analysis refers to the rank of the most important parameters (input) that generated the variation [3].

Breesch and Janssens [8] analysed the uncertainty in the prediction of thermal comfort by night natural ventilation strategies in an office building. According to the ATG thermal comfort method (adaptative temperature limit indicator, in Dutch) and the Latin hypercube sampling, the probability of good results was higher in cases with cross ventilation than in cases with unilateral

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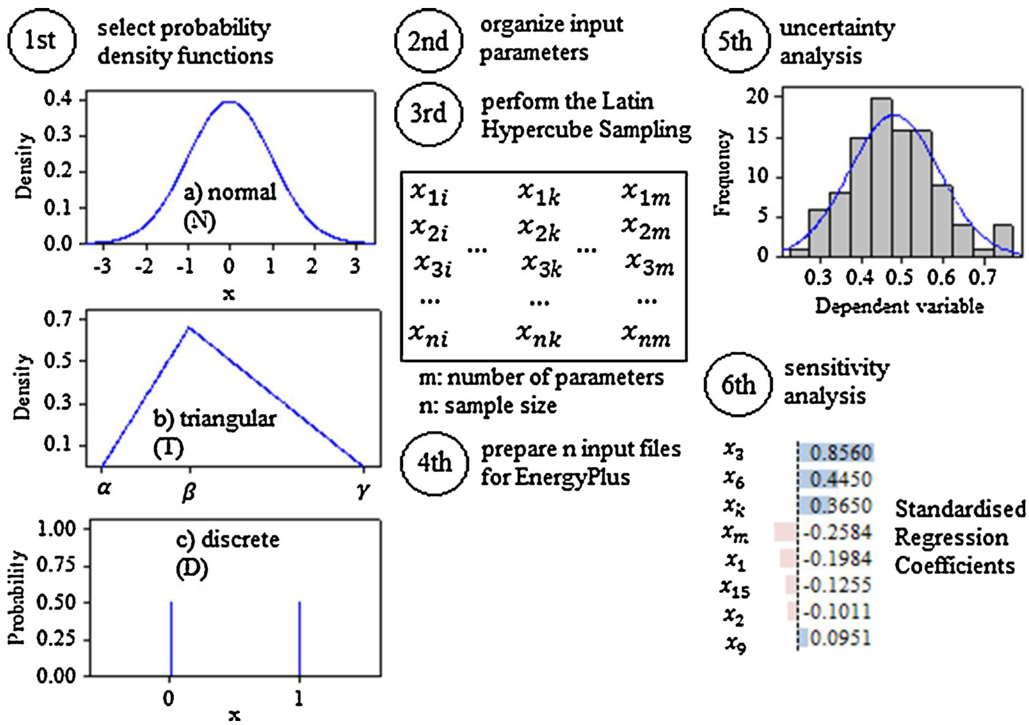

Fig. 1. Summary of the method.

ventilation, for the same wind direction. The sensitivity analysis with Standardised Regression Coefficients has pointed out, among the 72 parameters analysed, the internal loads as the most important parameters on the variability of the results.

Heo et al. [9] proposed a method for calibration of computer models for analysis of thermal performance from Bayesian approach, considering uncertainties in the input parameters, the simulation algorithms and measurement methods. The model used to illustrate the method was a commercial building with water heating system. The sensitivity analysis method by the Morris Elementary Effects [10] pointed out as important parameters those related to the opening of windows, internal set point temperature, air infiltration rates, discharge coefficient of the windows and equipment power in the internal zones.

Hopfe and Hensen [3] analysed two types of uncertainties in a computational model (physical and design uncertainties), in which the dependent variable was the energy consumption for air conditioning. The Latin hypercube sampling method with 200 random simulations was used for each type of uncertainty. The most important parameters were the infiltration rates in physical uncertainty and the floor plan area in design uncertainty. Therefore, in order to reduce the uncertainty of the results, they recommended more appropriate methods and accurate measurement of infiltration rates and quantification of the total floor plan area of the building.

The Efficiency Valuation Organization, through the International Performance of Measurement and Verification Protocol (IPMVP), defines conditions and calculation methods for determining energy savings in efficient designs [11]. The energy saving is a value that cannot be measured directly, as it refers to the energy that would be consumed with the implementation of an energy-efficient strategy. However, the previous installation would no longer exist for having its consumption measured. Thus, various estimation methods are applicable, including building computer simulation.

Therefore, in order to achieve more realistic results, one should include uncertainties in the assessment. The IPMVP [11] defines three types of uncertainties: modelling, sampling and measurement, which should be applicable to any energy efficiency project. In order to reduce uncertainty, better methods of estimation should be used, such as better measuring equipment, which adds costs to the project and should be included in the feasibility studies. The savings results should be presented in the form of intervals with a certain reliability (e.g., 95%). The only way to apply this protocol considering risk investment analysis is through the uncertainty analysis [9].

Uncertainty analysis is useful to assess building simulation models, as they are an estimation of real thermophysical phenomena. To contribute to this research field, this study aims to determine the uncertainty in thermal performance and energy consumption in a residential building generated from user behaviour and physical parameters, using computer simulation. These uncertainties are indicators of reliability of the building simulation approaches and could reveal which parameters cause most of the variation.

2. Method

All analyses were performed over a probabilistic approach, where the variability of output parameters (dependent variables) is determined by the uncertainty of the input parameters (independent variables). Thus, the method is organised according to Fig. 1. The computer simulations were performed using the EnergyPlus 8.0 programme.

EnergyPlus is a building simulation programme that can be used to model energy consumption, air conditioning, lighting, ventilation and other physical phenomena involving the performance of a building [12].

The steps were: (1) select the probability density functions for the parameters, (2) organize the input parameters (independent variables), (3) perform a random sampling with Latin hypercube, (4) prepare formatted input files for EnergyPlus, (5) perform uncertainty analysis and (6) perform sensitivity analysis.