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Selection of window sizes for optimizing occupational comfort and hygiene based on computational fluid dynamics and neural networks

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ABSTRACT

The present paper presents a novel computational method to optimize window sizes for thermal comfort and indoor air quality in naturally ventilated buildings. The methodology is demonstrated by means of a prototype case, which corresponds to a single-sided naturally ventilated apartment. Initially, the airflow in and around the building is simulated using a Computational Fluid Dynamics model. Local prevailing weather conditions are imposed in the CFD model as inlet boundary conditions. The produced airflow patterns are utilized to predict thermal comfort indices, i.e. the PMV and its modifications for non-air-conditioned buildings, as well as indoor air quality indices, such as ventilation effectiveness based on carbon dioxide and volatile organic compounds removal. Mean values of these indices (output/objective variables) within the occupied zone are calculated for different window sizes (input/design variables), to generate a database of input–output data pairs. The database is then used to train and validate Radial Basis Function Artificial Neural Network input–output "meta-models". The produced meta-models are used to formulate an optimization problem, which takes into account special constraints recommended by design guidelines. It is concluded that the proposed methodology determines appropriate windows architectural designs for pleasant and healthy indoor environments.

1. Introduction

Natural ventilation is an energy-efficient alternative and, with proper design, it is able to create thermal comfort (TC) and healthy indoor conditions. From the point of view of natural ventilation strategies, it has been found that night-time ventilation is an effective method to provide thermal comfort conditions [1]. Therefore, natural ventilation during night hours may replace HVACs, especially in sparsely populated areas, which are free of thermal sources. As long as the external environment is free of high concentrations of pollutants, natural ventilation systems provide fresh air in the occupied zones and remove the internally produced pollution with minimum capital cost and environmental impact.

Building-envelope geometry is one of the key design elements to create the best indoor conditions, as it affects the interactions between the indoor and the outdoor environments. The influence of the openings has been discussed in numerous studies in the past, which provide important information regarding their effects on both TC [2,3] and indoor air quality (IAQ) [4]. In these investigations, TC and IAQ were addressed using Computational Fluid Dynamics (CFD) models. The implementation of well-known TC and IAQ indices in a CFD code provides local thermal comfort and health risk predictions.

The most common thermal comfort model is the Predicted Mean Vote (PMV) [5]. However, it has been proven that the PMV index is inadequate in case of natural ventilation [6]. On the other hand, there are thermal comfort models, which are more appropriate in cases of non-air-conditioned spaces, such as the PMV_{NV} [7] and $PMV(SET^{*})$ models [8]. For draught assessments, the Percentage Dissatisfied (PD) index [9] may also be used. Indoor air quality can be estimated by using the well-known ventilation effectiveness index, which defines the ventilation system removal efficiency of the contaminants involved [10].

In order to study indoor thermal comfort and contaminant concentration variations with respect to the architectural-elements changes, various geometrical configurations may be tested. This is easily performed by executing CFD parametric studies, leading to the best architectural design. Although this

Abbreviations: ANN, artificial neural networks; ASHRAE, American society of heating refrigerating and air-conditioning engineers; BZ, breathing zone; CFD, computational fluid dynamics; HVACs, heating ventilating and air-conditioning systems; IAQ, indoor air quality; IGC, initialization grid concept; LOO, leave-one-out; OZ, occupied zone; RBF, radial basis function; SQP, sequential quadratic programming; TC, thermal comfort; VOCs, volatile organic compounds.

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