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Predicting and optimising the airborne sound transmission of floor–ceiling constructions using computational intelligence

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Abstract

Computational intelligence (CI) techniques offer powerful alternatives for investigating acoustical issues and providing acoustical solutions to problems. This paper presents information on two CI techniques by applying them to the sound transmission performance prediction and design of floor–ceiling constructions.

First a simple neural network (NN) model for predicting the airborne sound transmission of typical floor–ceiling constructions is presented and explained in detail. This model is accessible to researchers with knowledge of neural network analysis (NNA) for further sophistication, specialisation or hybridisation. The model may also be used by architects and others with no knowledge of NNA and no access to any specialised neural network software. Evolutionary algorithms (EAs) were then applied to search the multidimensional space created by the neural network model in order to optimise the airborne sound transmission of floor–ceiling constructions within the range of design parameters utilised in buildings.

Keywords: Sound transmission; Computational intelligence; Neural network analysis; Evolutionary algorithms

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1. Introduction

There are at least two factors that make architectural and building acoustics design and research difficult: (1) the multiple parameters and multiple criteria aspects involved; (2) the large quantity of data measured under non-standard conditions, which blurs the inherent acoustic phenomena. These complex situations are not easily recognizable and therefore remain difficult to resolve using conventional methods [1]. On the other hand computational intelligence (CI) is one of the approaches to program computers in order to make them behave as if they were humans who can understand and tackle highly complex problems. The three major domains of CI are neural networks (NNs), evolutionary algorithms (EAs), and fuzzy logic (FL).

In connectionist models of computation, such as neural network analysis, attempts are made to simulate the powerful cognitive and sensory functions of the human brain and to use this capability to represent and manipulate knowledge in the form of patterns. Based on these patterns, neural networks model input–output functional relationships and can make predictions about other combinations of unseen inputs (inputs not used in the training process). EAs are defined as search procedures based on the mechanics of natural selection and can be perceived as a generalisation of genetic algorithms. Classical genetic algorithms operate on fixed length binary strings, which need not be the case for evolutionary algorithms [2]. With the ability of searching a large population (potential solutions), the EA can overcome the problem of local fitness optima to obtain the optima that are almost always close to global [3].

It is an enticing challenge to a theoretician to develop a new method suitable for solving the problem at hand. However, from the application point of view, the time for developing the technique has to be added to the computer time invested. In that respect, utilising a non-specialised and robust procedure, to which NNA and EAs belong, may be worthwhile. With the inherent power of CI, it is promising to use NNA and EAs to solve architectural and building acoustics problems that feature high dimensionality and multiple criteria.

Multivariate regression analysis [4] has been used to model the airborne sound transmission performance, sound transmission class (STC), of floor–ceiling constructions using the existing measurement data. However, it does not appear that NNA has been used previously to model STC of floor–ceiling constructions although it is not the first time NNA has been used on predicting sound transmission performance of walls [5,6]. The NN model is accessible to researchers with knowledge of NNA for further sophistication, specialisation or hybridisation. The NN model can also be used by architects and others who have no knowledge of NNA and do not have access to the specialised NN software but can use any standard spreadsheet application. The current work also investigates, for the first time, the application of EAs to search the large non-linear multidimensional space (potential solutions) provided by the NN model in order to optimise the STC of floor–ceiling constructions within the range of design parameters utilised in buildings.