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Room Acoustic Optimization with Variable Thickness Columns

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Abstract

In this work, a rigorous and practical design method for room acoustics is proposed. The ability to control acoustic characteristics has a wide range of applications, such as a car interior with controlled engine noise, barrier structures to suppress industrial and traffic noise, and design of concert halls and recording studios. The approach used in this work is based on installing rectangular columns with various thicknesses at some parts of room boundaries. This is a practical approach as the manufacturing and the installation are simple, compared to designs obtained using a topology optimization approach [1], and is utilized in some of the advanced acoustic rooms.

A crucial task in the design process is to determine the effective layouts (i.e. thicknesses) of columns, and an optimization method can be used to achieve this potentially very challenging task in an efficient manner. For instance, in [2], rooms with evenly distributed frequency response are designed by finding optimal layouts of columns installed at one of the walls. In their work, the deviation between the obtained and ideal frequency responses is computed and a metamodel of the deviation is minimized to design the room. The work proposed here uses a rigorous optimization method based on the sensitivity analysis. The Helmholtz equation is solved using a finite element method to find the acoustic pressure field distribution. The performance of the room is expressed in terms of the acoustic pressure field, and its sensitivity with respect to the thicknesses of the columns is computed by solving an adjoint problem in a similar manner as [1]. One difference is that the gradients of the stiffness matrix with respect to the column thicknesses need to be computed in our work, instead of the effective density of the material.

Our current investigation focuses on the implementation of the method in 2D problems, where the objective is to minimization of the acoustic pressure level within a prescribed region of a room. We have conducted studies on the effects of various properties of the problem such as the room shape, frequency of the noise, location of the observation region, and materials used for the columns, which have resulted in several different designs of optimal acoustic rooms.

[1] Dühring, M. B., Jensen J. S., and Sigmund O. "Acoustic design by topology optimization", *Journal of Sound and Vibration*, Vol. 317, No. 3-5, pp. 557-575, 2008.

[2] Xiaotian, Z., Zhemin Z., and Jianchun C. "Using optimized surface modifications to improve low frequency response in a room", *Applied Acoustics*, Vol. 65, pp. 841-860, 2004.