



Contents lists available at ScienceDirect

Journal of Sound and Vibration

journal homepage: www.elsevier.com/locate/jsvi

A fast Galerkin-based method for eigenfrequencies in acoustics of small rooms with slanted boundary planes

Mezhlum A. Sumbatyan^{a,*}, Michael Yu. Lannie^b, Vittorio Zampoli^c

^a Southern Federal University, Institute for Mathematics, Mechanics and Computer Science, Milchakova Street 8a, Rostov-on-Don 344090, Russia

^b Research Institute for Building Physics, Locomotive Travel 21, Moscow 127238, Russia

^c University of Salerno, via Giovanni Paolo II, n. 132 - 84084 Fisciano (SA), Italy

ARTICLE INFO

Article history:

Received 4 June 2015

Received in revised form

30 December 2015

Accepted 4 January 2016

Handling Editor: R.E. Musafir

Keywords:

Mode frequencies

Slanted planes

Galerkin's numerical method

Small studios acoustics

ABSTRACT

This paper proposes a Galerkin-type numerical algorithm for an efficient calculation of low eigenfrequencies for rectangular parallelepiped rooms with slanted boundary planes, in the frequency interval (0, 200) Hz, with the volume $V \leq 200 \text{ m}^3$. The main idea of the algorithm is to apply a system of Galerkin's basis functions which are orthogonal, after a certain change of variables, in a unit cube. As a result, the problem is reduced to a classical problem of the computational algebra about eigenvalues of a symmetric matrix. If applied to any parallelepiped of non-splayed geometry, the algorithm automatically gives the known classical modes. For rooms with the splayed planes, the sought mode frequencies can precisely be calculated in real time on a personal computer, by taking from 11 to 13 basis functions along each coordinate axis. Some particular examples are considered, in order to demonstrate the capability of the proposed algorithm, as well as its precision with a change of basis functions. It is also seen from the discussed examples that splaying the boundary planes can indeed make more uniform distribution of the low natural frequencies.

© 2016 Published by Elsevier Ltd.

1. Introduction

It is known (see, for example [1, p. 342]) that in designing small studios and listening rooms “colorations largely determine the quality of sound”. According to this author's definition ([1, p. 156]), colorations mean frequency-response aberrations, which are unwanted. Hence, it is important, as underlined in [1], “to determine which, if any, of the hundreds of modal frequencies in a room are likely to create colorations”. A good sounding in small studios may be attained by providing a sufficiently uniform distribution of natural frequencies in the low-frequency range. Since the Fifties, it was acknowledged that this can be attained by arranging a particular slant of some boundary planes [2], since this guarantees the axial and tangential modes to be absent [1].

Many authors devoted significant effort in order to provide a uniform distribution of the spacing of sequential eigentones [3–9] by an optimal sizing of rectangular parallelepiped rooms, without any splaying. Below we show, see Eq. (1.1), that asymptotically, for high frequencies, the number of eigenmodes versus frequency can be approximated by a cubic function. In principle, a good sounding is achieved if the frequency distribution on the interval 16–200 Hz is close, as much as

* Corresponding author.

E-mail addresses: sumbat@math.rsu.ru (M.A. Sumbatyan), mlannie@mail.ru (M.Yu. Lannie), vzampoli@unisa.it (V. Zampoli).

possible, to a certain cubic parabola of this type (see also Fig. 5, in Section 3), a property which usually takes place for higher frequencies only. This resulted in some recommendations well known in the classical literature, and the investigations in this direction continue even now [10–12]. Many authors have discovered their own “best” and “worst” room proportions for parallelepiped geometries, some of them contradicting each other. Cox and D’Antonio [13] formulate the optimal proportions problem as an optimization problem, to provide the flattest form of a modal decomposition response line versus frequency, over the range 20–200 Hz. Several hundred optimal geometries for parallelepiped rooms have been discovered in [13], starting for the optimization search from different initial proportions, and it is established that the increase in room volume leads to an increasing number of acceptable proportions. More details on the numerical results are given by the same authors in [14]. The results for optimal proportions are presented as diagrams, and the respective tabulated geometries can be found on the web-site [15]. The authors [13–15] reasonably claim that the flatness of the frequency response diagram is a more adequate criterion than the uniform spacing between the modes. However, it is conceivable that these two different criteria have some connections.

The most negative influence on sound perception in the case of small rectangular parallelepiped rooms is connected with the axial modes, which in larger rooms are heard as flutter echoes, the phenomenon of a periodic repeating reflection of the sound between two parallel walls perceived by the listener at a certain fixed position. A number of classical handbooks and monographs, as well as many journal-published works, emphasize that splaying the walls can reduce the flutter-echo phenomenon, and this is closely related to the fact that slanted boundaries automatically provide the validity of the second Bonello’s criterion (no coinciding natural frequencies) [6].

At the same time, some doubts have recently been expressed about the efficiency of the application of slanted walls to this aim [16]. It is claimed in [16] that slanting a wall does not resolve the parallel-wall problem since it only changes the period and the mode frequencies, as demonstrated in Fig. 2. The same Fig. 2 shows, recalling the “mirror image” concept, that the image of the right side of the true room, which is marked by heavy lines, is parallel to this side. This automatically predetermines that the path $A-B-C-D-C-B-A$ is closed, hence a person staying at the point A and clapping his/her hands can hear a signal with a temporal period corresponding to this path length. Similarly, a longer path $A-B-C-D-E-F$ and back corresponds to a closed path which can clearly be seen from Fig. 3 as a “forward-and-back” propagation between other two parallel lines, namely between two virtual images of the left side of the true room containing the points A' and F' . We

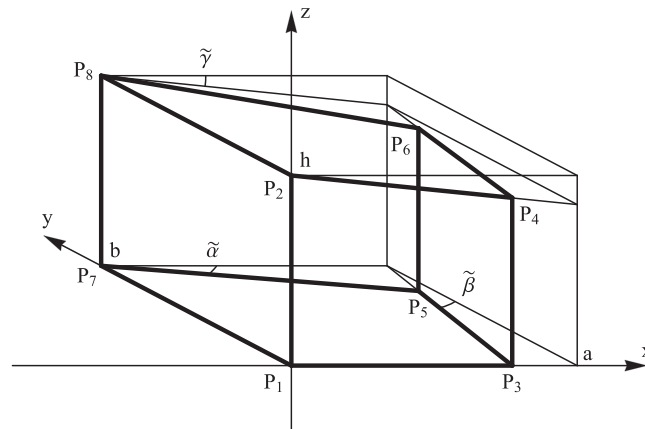


Fig. 1. Geometry of the room with sizes and slanted boundary planes.

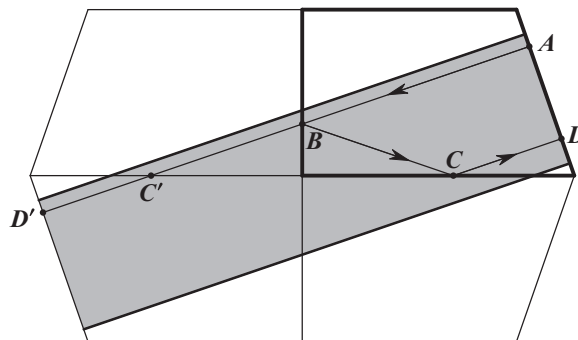


Fig. 2. A rectangular room with a slanted wall: virtual images for a scattering by the right angle.

Download English Version:

<https://daneshyari.com/en/article/6754669>

Download Persian Version:

<https://daneshyari.com/article/6754669>

[Daneshyari.com](https://daneshyari.com)