MODELLING ROOM ACOUSTICS

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1. INTRODUCTION

Computer modelling is commonly used in room acoustics to predict impulse responses (IRs), which can be used for, e.g., the calculation of room acoustical parameters or auralization. Some different coputer modeling methods that are in use today will be presented and their possibilities and shortcomings will be discussed.

2. COMPUTER MODELING

The modelling process needs to handle three separate parts: the source, the receiver, and the acoustic environment. A wide range of advancement is used for the modelling of these parts, reflecting the wide range of applications for computer modelling of rooms.

2.1. The source, the receiver and the acoustic environment

A source is usually modeled in terms of its directivity or using separate source simulation algorithms for, e.g., advanced loudspeaker systems. Multi-channel recordings have been suggested as better representations of music instruments.

The receiver is often modeled as a set of virtual microphones that represent real measurements. However, for auralization using headphone reproduction, the human head is represented by a set of head-related transfer functions (HRTF). A lot of research has gone into HRTFs with the aim of realistic reproduction of spatial sound field qualities.

The rooms that are encountered in modelling range from very small rooms such as car cabins, to huge concert halls and industrial buildings. Even outdoor spaces in cities might be studied with similar methods. Different computational methods can handle phenomena such as specular and diffuse reflection, edge diffraction, complex wall impedances and non-locally reacting boundaries, to various degrees. Air absorption is typically the only atmospheric effect that is considered in room acoustical modelling. Furthermore, transmission through wall partitions is handled in some room acoustics modelling methods but only to quite a simplified degree.

The calculation methods that are used can be based on solving the wave equation numerically, or use some approach which is based on the superposition of elementary solutions.

The latter approach is typically implemented using a combination of the image source method and ray/cone tracing. High accuracy has been demonstrated for mid to high frequencies and both specular and diffuse reflection can be handled this way. Extensions that handle edge diffraction have been presented as well. Beam tracing is an efficient method for handling specular reflection and diffraction, and the radiosity method can handle diffuse reflection efficiently.

The wave equation solution methods include finite element and finite difference methods, as well as boundary element methods. These methods all have a computation load which grows very fast with frequency so they can be used only at low to mid frequencies. Lately large-scale simulations have been presented that reach 1-2 kHz in small concert halls.

2.2. Evaluation of methods

The accuracy of room IR prediction methods has been evaluated through a series of International Round Robins, managed from the PTB in Germany. Quite a wide range of rooms have been measured and simulated. An important issue that is clear from the Round Robin tests is the testability of the results - the measurement uncertainty and the input data uncertainty must be small enough to make such comparisons relevant. A recent project in Japan has suggested openly available benchmark cases for the advancement of calculation methods in room acoustics. Well-controlled and systematic evaluations of auralization results is yet another important research topic.