Evaluation of Room Acoustical Simulation Software

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Introduction

For the evaluation of room acoustical simulation programs up to now three Round Robin Tests have been carried out by the PTB. Three halls had been selected for comparing the calculated room acoustical parameters with measured values, but it was clear that the results depend also on the accuracy and the reliability of the input data, as there are the frequency dependent absorption, scattering coefficient and the geometry. Nevertheless the analysis of all supplied data enabled an overview of the state of the art and a number of details about the performance quality of current programs[1]. In this paper some comments will be presented about the aims and the limits of such software comparisons

Aims of the Round Robin Tests

The main goal of these tests were to get an overview of the calculation properties and to document the state of the art of the current programs concerning the calculation uncertainties of the standardised room acoustical parameters [2]. A second aspect was to prove if these parameters are qualified to describe room properties sufficiently. Application problems of users on a non-skilled level appeared in the first phase of Round Robin III, where a simple room had to be calculated and severe errors occurred calculating the reverberation time [1].

For the development teams the Round Robins served as most valuable feedback to compare calculations with room acoustical data measured by several independent teams.

Questions

First of all we want to know, how reliable the calculated data are: What are the uncertainties and where are the limits today, e.g. for low frequencies; how are special cases like diffuse reflection and diffraction treated? Is it possible to get such information out of the data submitted by the participants when well defined data are used as input? How can a comparison be done if absorption data have to be estimated, because reliable measured data are not available? Are measured data qualified for serving as reference? Can the calculation speed be compared? Are the special features of the individual programs visible comparing only frequency dependent parameters which have been calculated for a limited number of positions?

Problems of comparison

The participating programs were not all at the same level of development: on the one hand, some well established commercial programs were represented by a number of users and on the other hand they should be compared with most recent developments of research institutes. For the latter ones the Round Robins were a welcome chance to get feedback for their developments, but in the final comparison they were treated separately in order not to disturb the evaluation of the efficiency of current room simulation software.

Of course, the calculation of the room acoustical parameters is only one of the features of the programs today, and one has to think about ways to compare also auralisations which are the most interesting result of a calculation process. But this would require a lot of constraints and prescriptions for application (source directivity, dummy head properties (head related transfer functions HRTF) etc.) and would generate a number of further problems to be solved.

A large number of calculated data has to be compared and in order to give an overview of the efficiency of the programs, mean values have to be built. For 12 source-receiver combinations in Round Robin II e.g. 9 parameters and 6 octave bands had to be calculated resulting in a number of 648 values which had to be administrated for each participant. Calculating mean values (over positions or octave bands) may help to reduce this number but it may also occur that important properties are hidden when a single value exceeds the expected range. Therefore, a visual control of all data by the co-ordinator is always required.

It is obvious that these tests cannot be considered as a competition for commercial software, because only the input and output data were handled by the co-ordinator and all performance features like the setting of calculation parameters were up to the users. Although a ranking of the participating programs is often asked for, the names of the programs were dealt anonymously and single ranking numbers describing the overall performance quality were not given in the recent Round Robins. Instead all individual results can be downloaded from the PTB web site, where the data are arranged in categories which can be selected by the user (http://www.ptb.de/en/org/1/17/173/roundrobin.htm) .

The presentation of the results in some cases is complicated by the fact that anonymity has to be maintained. Parameters which are not calculated by one of the programs will not appear in a graph where each program is represented by a number and this may serve as a hint for its identification. Further it has to be considered how the results of different users of the same software will be published. Building average values can only be representative if none of the users made an error. A visual control or the display of the calculated standard deviation is always necessary.

From the scientific point of view it seems important to find out, how the different programs are able to treat special situation like the sound field under balconies, coupled rooms or reflections on surfaces subjected to inhomogeneous sound incidence. Also the calculation of diffraction on obstacles

should be considered, but today only a few programs are capable of this. These problems could be subjects of a future round robin test because until now relative simple geometric conditions had to be modelled. Maybe also the calculation properties at low frequencies will be improved by new generations of room simulation programs, but this needs completely different algorithms to be applied.

Evaluation of calculation results

The reverberation time *T30* is mainly influenced by the absorption data and only to a low degree dependent on the position of sources and receivers. The comparison with the measured values, therefore, may be an indicator for the accuracy of the input data but may also serve for comparing the results of different programs concerning the complete decay process (-5..-35 dB) of the impulse response.

More detailed information can be derived from the locally depending values *EDT, D50* and *C80* which take the early reflections into account and which are sensitive to differences in the treatment of diffuse reflections. Also the local variation can indicate the quality of the internal algorithms. The parameter *G* as a power quantity reflects the amplitudes primarily of the direct sound and the first strong reflections and may often be governed by the distance between source and receiver. This could indicate rough calculation errors if the local variations do not follow the 1/*r* law of sound pressure. The comparison of *LF, LFC* and *IACC* take into consideration the directional properties of the received sound. Lateral sound incidence are evaluated by a figure-of-eight microphone or a virtual dummy head respectively. Calculation errors in the latter case may indicate wrongly programmed HRTFs e.g. .

Calculation of surface details

Another way to compare the facilities of software was applied in the 3rd Round Robin: well defined changes in the models like the position of curtains and the modification of the fine structure of diffusing walls were prescribed.

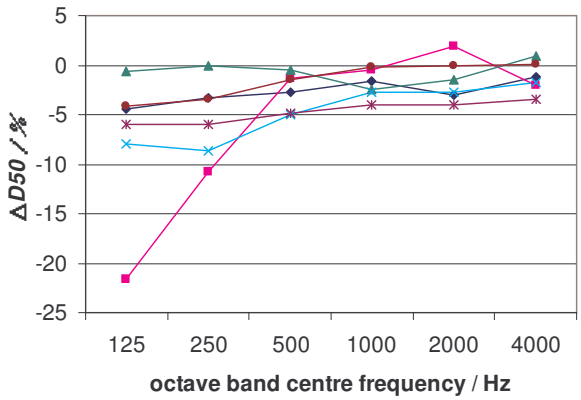

Figure 1: Calculation differences of *D50* between phase 2 and 3 of RR III (S2R3, curtains closed).

The wooden absorber wall and the diffusing ceiling of the PTB-Studio had to be modelled as a single plane in phase 2 and in detail in phase 3 [1]. The absorption was not changed, only the scattering coefficients had been reduced from the values measured in scaled models to a constant value of 20% for all frequencies.

In figure 1 the differences in the calculated *D50* values of both phases are plotted for all frequency bands, each curve represents one software; some are mean values of several users. It is obvious that only one of those curves shows a significant deviation from the others at low frequencies. The up to 20% higher values in the detailed model of phase 3 could be referred to the particular treatment of scattering in this program. In this case the detailed model supplied low frequency values much closer to the measured data.

Curtain position

Figure 2 shows a comparison of results between open and closed curtains in the 1 kHz octave for *D50*. As reference the measured values are plotted. The local variations and the general shift to lower values with closed curtains show a quite good agreement with the measurements (with ±σ indicators).

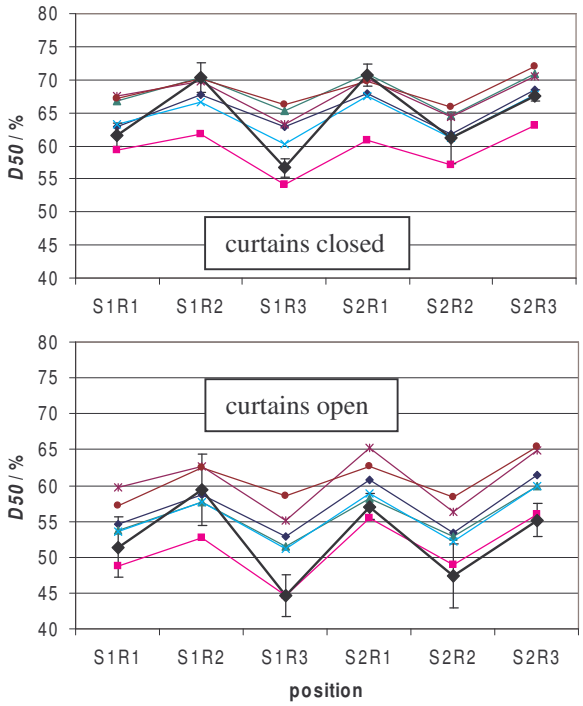

Figure 2: *D50* at 1000 Hz, black curve: measurement

This is representative for the results and may serve as an example for the variance of calculations with commercial programs and it may also show that uncertainties of absorption data does not restrict the evidence of the final results.

References

[1] Bork, I.: Vergleich von Rechnung und Messung beim 3. Ringvergleich zur Raumakustischen Simulation, DAGA 2003, Aachen

[2] ISO3382: Acoustics - measurement of reverberation time of rooms with reference to other acoustical parameters