A new tool for quick room acoustic assessment in architectural education

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ABSTRACT: A newly developed software tool allows to measure reverberation times and other room acoustic parameters using not more than a notebook computer and a low cost microphone. The software is designed for education and it guides through the measurement process. Measured results can be evaluated by comparing to references. Room acoustic improvements can be pre-calculated using an internal sound absorber data base. First technical and didactic tests have been performed successfully.

1 INTRODUCTION

In numerous rooms for communication and for education it is audible, that the room acoustic quality is considerably below optimal conditions. Even in new buildings this situation is frequently found. The main reasons are assumed to be a lack in attention for room acoustic aspects in building planning and a lack in room acoustic education of architects.

This project primarily aims at an improvement of the room acoustic education of architects. Indirectly it may also help to improve the attention for room acoustics in the long term.

2 OBJECTIVES AND AIMS

2.1 *Didactic approach*

Like most other people students of architecture usually have never dealt with acoustics before and so they need to be introduced from the basics.

As architecture covers a wide range of topics, only a rather small number of lessons is scheduled for teaching room acoustics. In their details curricula differ between universities. As an example at Wuppertal University students of architecture have a total of 15 lessons covering all aspects of architectural acoustics during their basic (bachelor) studies. Approximately one third of these lessons is available for room acoustics.

In consequence of these facts the introduction to general acoustics and to room acoustics is kept short. Then the students are 'thrown' into practical work, but it is essential to link this work to acoustic basics and thus give the students a chance to understand what they are doing.

The newly developed software tool enables small student groups to analyze existing rooms and to investigate room acoustic improvements on their own. If necessary they may use assistance from the tutors.

2.2 *Software design goals*

The software tool shall turn the students' personal notebook computers with just an attached low cost (10..20 €) microphone into a measurement device. This enables the students to perform room acoustic measurements using their own equipment and to keep this option for their further work.

As the software is intended to be used by acoustically unexperienced persons, preferred properties are

- The software shall be easily usable after a short introduction.
- The software shall guide users through the measurement process.
- The software shall be robust against handling errors to some extent.

Although it is not intended to achieve reference quality measurements, accuracy is aimed to be adequate to evaluate rooms for communication or education.

3 SOFTWARE DEVELOPMENT

3.1 *Development phases*

The measurement software is developed in two phases. In a first phase basic features are implemented and a first software version is ready for tests at the end of this phase. In the second development phase advanced features are integrated into the software. Both phases are completed by technical and by didactic tests.

3.2 *Basic features*

3.2.1 *Impulse excitation*

Impulse excitation is a precondition for low cost measurements, as simple excitation sources can be used. Tests have shown that up to classroom size (< 200 m³) a strong handclap is sufficient as an impulse source, if the noise floor is low. Larger rooms require more powerful sources like bursting balloons or package bubbles. In very large rooms (e.g. concert halls) very loud sources like bangers or alarm pistols may be needed. Then using an ear protection is advisable.

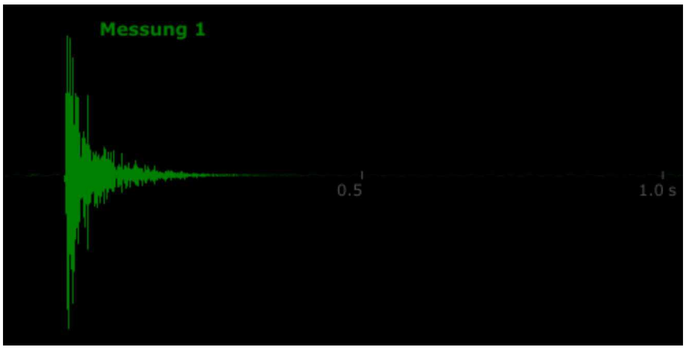

Figure 1. A room impulse response recorded using a handclap as impulse source (screenshot excerpt).

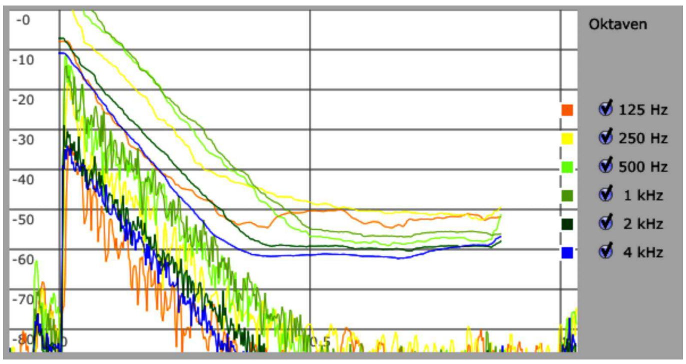

Figure 2. Octave band echograms and backward integrals from a handclap impulse measurement (screenshot excerpt).

3.2.2 *Octave band reverberation times*

Measured impulses are split into standard octave bands and reverberation times are derived by backward integration according to ISO 3382. Evaluation is concentrated to the six octave bands from 125 Hz to 4 kHz, where sound absorption data are available for most surfaces and numerical planning can easily be done.

3.2.3 *Averaging of multiple measurements*

As the reverberation time is a statistic measure, individual measurements may vary with source and receiver positions. Thus the software allows to average results from multiple measurements taken at different positions to reduce errors. A spread is shown for each individual measurement indicating its quality mostly resulting from the signal-to-noise ratio. If a single measurement appears as outlier in its spread or its values, it can be excluded from averaging.

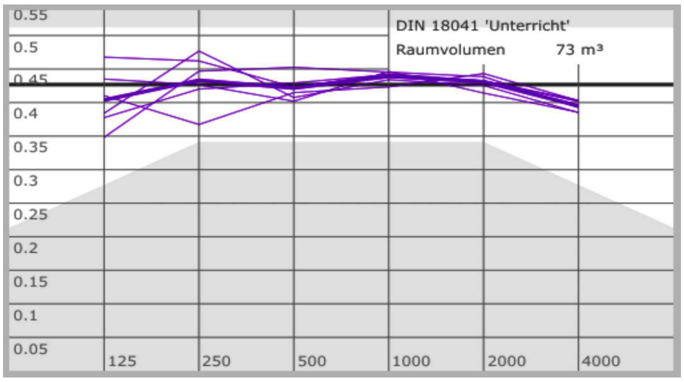

Figure 3. Octave reverberation times from six individual measurements, their avarages and DIN 18041 recommended values for a small classroom as a comparison (screenshot excerpt).

3.2.4 *Comparison to DIN recommendations*

Averaged reverberation times can be compared to recommendations from room acoustic standards. Currently DIN 18041 recommendations are implemented. Other standards can be added in future.

3.2.5 *Graphic and text output*

In addition to the graphic display (as shown in excerpts in figs. 1-3) numerical results can be summarized to an internal text editor and can be exported for further use.

3.3 *Advanced features*

In the second development phase advanced features are integrated into the software:

3.3.1 *Sine sweep excitation*

Alternatively to impulses a logarithmic sine sweep can be generated and played as an acceleration signal. Internally a corresponding inverse sweep is convolved with the received signal to calculate the room response impulse. Using this method a high signal-to-noise ratio can be achieved and measurements can still be performed when moderate background noise is present.

3.3.2 *Different reverberation time types*

In contrast to the basic feature, where only unspecified reverberation times (internally derived from T_{20} and T_{30}) are displayed for simplicity, different 'reverberation time types' (EDT, T_{20}, T_{30}) can be compared as an advanced feature.

3.3.3 *Early-late energy measures*

Whereas reverberation time is a statistic measure for a whole room, early-late energy measures (T_S, C_{80}, C_{50}/D_{50}) allow to evaluate and to compare the transmission quality of individual sound paths.

3.3.4 *Effect of persons calculation*

In most cases reverberation measurements are taken with only a few persons in the room. Corresponding reverberation times for the partial or fully occupied room can be calculated using absorption area data of persons.

3.3.5 *Additional absorber effects calculation*

Expectable reverberation times after optional room acoustic improvements can be calculated using absorption data from different sound absorber types.

3.3.6 *Design mode calculations*

After the types of additional absorbers have been selected the absorber's surface area can be varied continuously and the calculated effect on reverberation times can be observed in real time.

3.3.7 *Integrated sound absorber data base*

For the calculations a sound absorber database is integrated with the software. The database comes with a basic selection of absorbers and can be extended by the users.

3.4 *User levels*

Corresponding to the basic and advanced software features, two different user levels can be selected for operation.

3.4.1 *Standard user level*

The standard user level is intended for beginning users and for simple and quick measurements. In this level only the basic measuring features are 'visible' to the users. Reverberation times can be measured and can be compared to DIN recommendations.

3.4.2 *Advanced user level*

At advanced level, dedicated to experienced users, all measuring features are accessible. Measurements can be done with either impulse or sine sweep acceleration. Measured parameters include T_{30}, T_{20} and EDT reverberation times as well as early-late energy measures (T_S, C_{80}, C/D_{50}).

3.4.3 *Both level features*

In both user levels several measurements can be averaged and are compared to selectable standard recommendations. Measured reverberation times can be used as starting point to calculate the effects of additional absorbers or persons inside the room. In a 'design mode' absorber sizes can be varied continuously while effects are shown graphically in real time.

An absorber database is included for the calculations and can be extended by the users.

4 TESTING AND EVALUATION

An initial version of the software is functional since end of 2012 and has undergone first technical and didactic tests. Further testing is performed after each development phase.

4.1 *Technical testing*

Basic technical testing is performed continuously during development in order to avoid software errors. Beyond this three technical aspects are subject to specific tests:

4.1.1 *Algorithm comparisons*

Impulse responses from a variety of rooms are analyzed in parallel by the new software and several established scientific and commercial software applications as references. Preliminary tests have shown that results from the new software vary in a similar range as the established software applications among each other (Fig. 4).

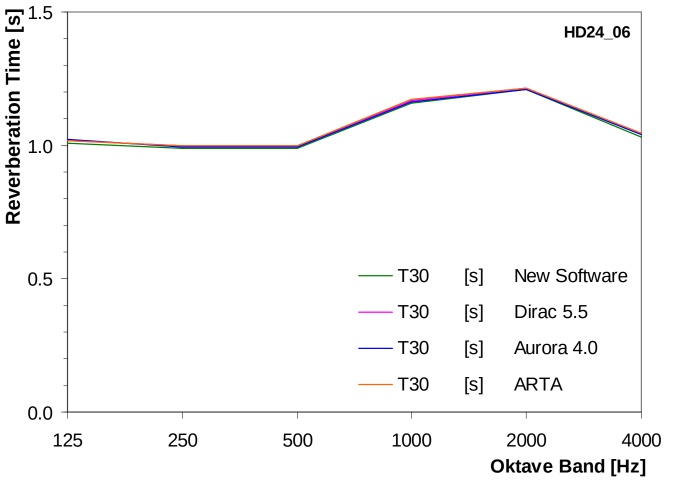

Figure 4. An example result from first algorithm comparisons. The new software was compared to three other software tools using previously recorded impulse responses of an auditorium. Included tools are ‘DIRAC’ (Acoustic Engineering: DIRAC), ‘AURORA’ (A. Farina: AURORA) and ‘ARTA’ (I. Mateljan: ARTA). Except from a few outliers up to 0.1 s all of the four software applications have agreed within 0.02 .. 0.05 s.

4.1.2 *Acceleration method tests*

Usually impulse accelerations are not exactly reproducible in their detail characteristics. Mostly the directional characteristics of the source is unknown and also the spectrum changes from one impulse to another. In addition common impulses are significantly longer than an ideal one sample impulse, the best possible approximation of a Dirac impulse in a digital system.

In these tests different types of impulse accelerated measurements will be compared to reproducible measurements using sine sweep acceleration radiated from a dodecagon speaker. The tests will be started as soon as the advanced features of the new software are functional.

4.1.3 *Hardware compatibility tests*

The new software is intended to be compatible with almost any audio hardware. Nevertheless a few limitations have been identified:

- In some computers the microphone signal path includes some signal processing to improve speech quality for voice over IP applications. Any kind of signal processing that affects the time or dynamic structure of the audio signal must be switched off for measurements.
- Some microphones or microphone inputs cut off low frequencies. For measurements covering the octave bands from 125 Hz to 4 kHz the spectral response of the audio path including the microphone should be reasonably flat from about 80 Hz to 6 kHz.
- Some low cost microphones or microphone preamplifiers are not well shielded against electromagnetic interference, resulting in an avoidable low signal-to-noise ratio.
- During first tests with students it was found that one of about twenty notebook computers could not be used due to incompatibility.

4.2 *Didactic testing*

In didactic tests the software in its current version is integrated into the students’ practical seminar work. Tutors observe how the students proceed using the software in order to identify opportunities for improvement.

Didactic test phases are performed with both the basic and the advanced software versions.

During the first didactic test phase at Wuppertal University a students excursion to a famous concert hall in a neighbouring city took place and a few sample measurements were made using the current software version (Fig. 5).

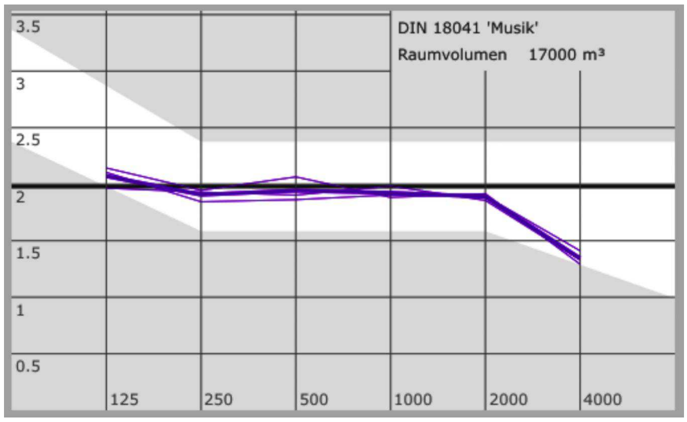

Figure 5. Reverberation times from (non representative) sample measurements inside a concert hall. For comparison the DIN 18041 recommendation for music rooms is shown (screenshot excerpt).

4.3 *Learning from test results*

The test phases are integral part of the development process. Test results are used for further improvement.

As an example from the first didactic test series it was learnt that a real time octave spectrum analyzer is helpful by making acceleration impulse and background noise spectra visible to the users before they start their measurements.

5 AVAILABILITY AND DISTRIBUTION

5.1 *'Beta' versions availability*

In spring 2013 the basic features are completed and the second development phase is starting. For test and evaluation 'beta' versions are available on request from the developer (www.eclim.de) or from Wuppertal University (www.btga.uni-wuppertal.de).

5.2 *Distribution of the final version*

Starting mid of 2014 the final software will be distributed free of charge to students and lecturers. The license will be restricted to non-commercial use.

Distribution will be organized via the German building physics education network 'Lernnetz Bauphysik' (www.lernnetz-bauphysik.de), and it will be open for other distribution channels.

6 FURTHER DEVELOPMENT

The current software version is developed for application under the MS Windows operating system. The user interface is labeled in German language.

Future development plans beyond this project include extensions to other software platforms (Mac OS and tablet computers) and multiple user interface languages.

7 ACKNOWLEDGEMENTS

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