A Mobile App for Room Acoustical Measurements

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Introduction

The assessment of room acoustical parameters is traditionally conducted with PC-based software or specifically designed measurement devices. Recently, however, mobile devices offer ever-increasing processing power, a graphical user interface and network connections. Thus, they seem to be perfectly suited for the determination of room acoustical properties. Since these smart devices are also commonplace, turning them into measurement tools could make additional tools unnecessary for quick and spontaneous room acoustical assessments. This contribution presents a multi-platform, easy to use, ISO compliant open-source measurement system to assess room acoustical properties and quality of speech transmission in a room. The measurement system is implemented as an installable hybrid mobile application.

Room Acoustic Parameters

The determination of room acoustic parameters is based on room impulse responses recorded at 44100 Hz sampling rate, which can be reduced to 22050 Hz to address the processing capabilities of older mobile devices. The recording is automatically triggered by an input signal exceeding a given threshold above a noise level estimation made at the start of a new measurement. The room impulse response is then recorded and stored for later export as a 16 bit PCM WAV file containing all measured impulse responses for a single measurement position. All results calculated by the application can also be exported as a preformatted text file, that can be easily imported into spread sheet applications such as Microsoft Excel or Apache Open Office Calc.
The room acoustic parameters included in the development of the app so far are reverberation time (RT20, RT30), bass ratio, clarity (C50, C80), definition (D50, D80), center time [1] and the speech transmission index (STI_{male}, STI_{female}) [3]. Their calculation is based on a room excitation by impulsive stimuli and is supported by a number of features such as an automated start- and endpoint truncation of room impulse responses as well as energy compensation for the truncation and an iterative SNR assessment [4]. An octave and third-octave band IIR filter bank [2] for signal analysis was implemented, as well as the option to use time reverse and zero phase filtering [5] for narrow filter bandwidths and short reverberation time measurements.

Supported Platforms

The application is available as an installable mobile app as well as as a web application for offline local use or remote online use, when hosted on a web server. It was developed as a cross-platform approach and thus supports the mobile platforms iOS starting with iOS 9 and Android starting with Android 5. A browser-based instance of the application is also available for Mozilla Firefox starting with v50 as well as Google Chrome v49+.

Comparison to Existing Systems

To evaluate the suitability of the application as a measurement tool, it was deployed on a smart device (Apple iPhone 4S). A variety of measurements were made and compared to the results of different room acoustic toolboxes as well as a measurement device manufactured by NTi Audio. All measurements on the smart device were conducted with the MicW i436 measurement microphone specifically developed for the use with mobile phones and tablets [9]. It is certfied as a class 2 calibrated measurement microphone according to IEC 61672.
For the first measurement a class room of the TU Berlin (MA005) was excited with a starter clap. Five impulse responses were recorded at the same position and truncated at the starting point 20 dB below their peak. The truncated recordings were averaged into a mean impulse response to obtain a higher signal-to-noise ratio and reduce the computational costs. This mean impulse response was filtered by a twelfth order octave band filter in bands ranging from 125 Hz to 8 kHz. The reverberation times extracted from the band limited impulse responses were compared with values from the ITA Toolbox [8] and the AARAE Toolbox [7], and delivered almost identical results (Figure 1).

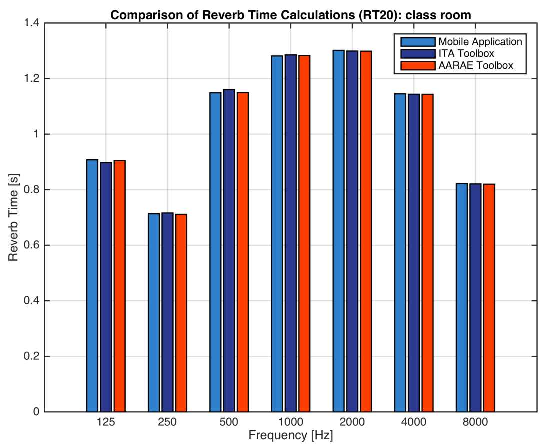

Figure 1: RT20 values calculated from measured room impulse responses with the developed mobile app, with the ITA toolbox and with the AARAE Toolbox. Excitation was done with a starter clap

A second measurement was conducted in a living room. The excitation was done via hand clap. Five room impulse responses were recorded and again truncated 20 dB below their peak. A mean impulse response was calculated and filtered in octaves. An endpoint truncation according to the algorithm proposed by Lundeby et al. [4] was done without truncation energy compensation. Subsequently the reverberation time RT20 was calculated by the presented applications algorithms and the two aforementioned toolboxes. The results can again show only minor deviations (Figure 2).

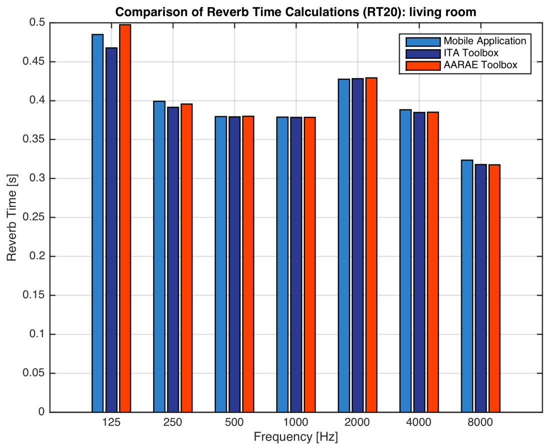

Figure 2: RT20 values calculated from measured room impulse responses with the developed mobile app, with the ITA toolbox and with the AARAE Toolbox. Excitation was done with a hand clap.

External versus internal microphone

Figure 3 shows the results of a reverberation time measurement in a living room. It was conducted with the MicW i436 as well as with the internal microphone of the smartphone in the same position. In the 125 Hz and 250 Hz octave bands the signal-to-noise ratio delivered by the built-in electret microphone with its non-linear frequency response [6] was obviously not high enough to obtain reliable RT20 values. The small differences at higher frequency bands are likely to be due to the directional characteristics of the internal microphone, as opposed to the omni characteristic of the external measurement microphone.

Mobile app versus NTi XL2 system

Since the mobile application was built for easy use and fast measurements, a comparison measurement with the NTi XL2 system was conducted [10] (Figure 4). The NTi XL2 was used in combination with the NTi 2230 measurement microphone. The smart device was again used with the MicW i436 external microphone. The measurement was conducted in a class room that was excited with a starter clap. Simultaneous recordings were conducted with the microphones of both systems positioned as close as possible to each other. The NTi XL2 system did not provide results below 500 Hz due to

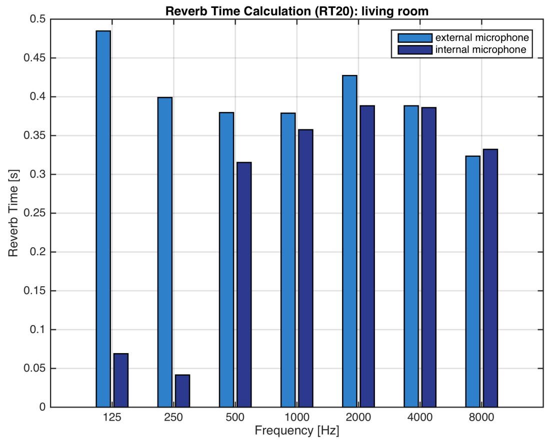

Figure 3: RT20 values calculated from measured room impulse responses obtained with the internal microphone of the smart device and the MicW i436 external class 2 measurement microphone.

the low energy in these bands given by the form of excitation, so they were left out of the comparison. As shown in Figure 4, the measured reverberation times differ by a maximum of 60 ms between the two measurement systems. It is unclear whether the differences are due to slightly different microphone characteristics, different algorithms for the calculation of the reverberation time, the different sampling rate (the NTi XL2 operates at 48000 Hz) or the slightly different recording positions.

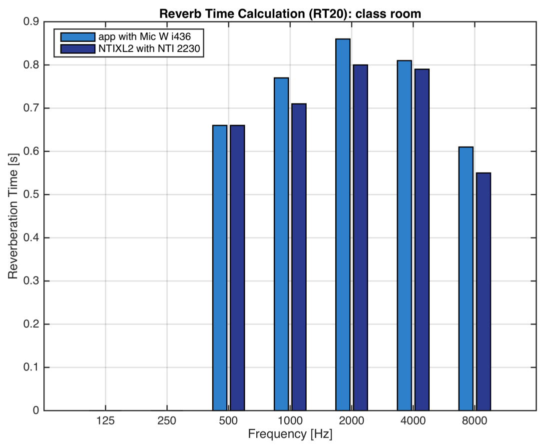

Figure 4: RT20 values obtained with the mobile application and the NTi XL2 system.

Discussion

In the development of the application, the limited capabilities, notably of older smart devices, have proven to be a source of potential problems, since the number of impulse responses to be kept in-memory during the calculation process was limited by their internal memory. This is particularly problematic for the filtering process in third-octaves and the subsequent truncation of the filtered signals, but has been addressed by optimising the number of impulse responses residing in memory at the same time and can further be improved by reducing the sampling rate to 22050 Hz.

The effects of the use of internal microphones across a wide variety of smart devices and their directional characteristics have yet to be studied systematically. However, already with the smartphone used in the test, the highpass characteristics of the internal microphone caused problems with the excitation of low-frequency reverberation times. Thus, the use of external measurement microphones is recommended.

Targeting multiple platforms with a single code base in the cross-platform development is slower and requires more processing power than a native approach on each single platform. Nevertheless, the convenience of a single code base for an open-source project will facilitate the further development of the mobile application, since every contribution to the project only has to be made only once and can then be deployed to all platforms.

The open-source approach provides a convenient platform to add new features as well as customizing already implemented features such as filters, onset detection and general audio processing. The first tests shown above suggest the presented application to be a suitable measurement tool. It provides the possibility of quickly assessing room acoustical properties with complete ISO compliance, when combined with a certified measurement microphone. With its open-source and cross-platform architecture, it can be particularly attractive for the use in an academic environment.

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