DATABASE OF OMNIDIRECTIONAL AND B-FORMAT ROOM IMPULSE RESPONSES

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ABSTRACT

This paper introduces a new database of room impulse responses. This database differs greatly from previously released databases as it contains over 700 impulse responses. The impulse responses are measured in three different rooms each with a static source position and at least 130 different receiver positions. Each measurement position is recorded with both an omnidirectional microphone and a B-format microphone.

Index Terms— Room impulse response, architectural acoustics, reverberation

1. INTRODUCTION

Convolution reverberation has become increasingly popular as more impulse responses (IRs) are becoming available along with more advanced tools to manipulate those IRs. IRs also give insight into how sound waves travel through a room allowing researchers to define and refine theories and models to better predict how the acoustics of a space will sound and why.

If a room is considered to be a linear time-invariant system, then taking a measurement of that system allows predictions and simulations to be made. When the system being examined is a room, an IR is measured by recording sounds like a pistol shot or popped balloon and the subsequent reverberation. By convolving that recording with a recording of a sound source without reverberation, the result sounds as if that sound source was originally recorded in the room that was measured.

Convolution can create a far more natural sounding artificial reverberation than other techniques, but has its limitations. Specifically, convolution reverberation is limited by the IRs that are available. A single IR can only accurately represent the exact sound source and receiver configuration that were used during the measurement. A single IR cannot create a moving sound source or receiver position and it does not provide complete information about measurements from other locations in the same room.

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1.1. Other Available Databases

A number of databases of IRs are currently available. The Aachen Impulse Response (AIR) database [1] is explicitly developed for hearing aid research. It uses a dummy head to create head shadowing effects in the IRs. By introducing these effects, the IRs are considered binaural room impulse response (BRIRs). 64 IRs (without a dummy head) and BRIRS (with a dummy head) are measured in total across four different rooms ranging from 12 m^3 to 370 m^3. The measurement technique used is a maximum length sequence; see [2, 3]. There are a maximum number of six different source and receiver configurations in a single room.

The Multichannel Acoustics Reverberation Database at York (MARDY) is a collection of multi-channel IRs recorded in the recording studio at the University of York [4]. Eight multi-channel IRs are recorded in the same studio with two different acoustic panels and four different source and receiver configurations.

Murphy recorded a third collection of IRs measured in a series of sites with significant archeological acoustics[5] using a setup designed by Farina and Ayalon[6]. The setup consists of a cardioid microphone and a first order Ambisonic B-format microphone. The IRs from the cardioid microphone can be combined with other IRs to create a stereo pair. The two microphones are mounted on a rotating turntable so that they automatically moved and took a total of 72 measurements across 5° intervals of a full circle. The IRs are measured with a logarithmic sine sweep [7, 3]. In [6], Farina and Ayalon also use a dummy head to capture BRIRs.

Waves Audio Ltd. uses the rotating turntable setup also used in [5] but includes a binaural dummy head to create BRIRs [8] as done in [6]. The IRs are mixed to various output formats using the measured IRs and virtual microphones. They are available online[1] and intended for use with the Waves IR products. The IR library is intended for music production and includes over 100 different spaces with up to three source and receiver configurations for stereo and surround IRs.

All of these databases are limited in some way according to physical constraints, whether by the microphones or the

[1] http://acoustics.net

Fig. 1. The Soundfield microphone and Genelec speaker during measurements in the classroom.

source and receiver configurations. In particular, they do not provide a dense grid of measurements across a single room. The collection described in [5] does measure 72 locations in the same room, but those 72 measurements are very near each other especially relative to the size of the spaces being measured. Acoustics research has repeatedly reported that acoustic metrics can vary greatly across a single space (see [9, 10] for a sample of these findings), but the currently available databases do not provide sufficient real-world data for analysis. Many researchers record their own measurements for their research, but do not release those measurements for others to use. A publicly-available database that broadly samples across a room is needed. The database presented here provides an order of magnitude more measurements and covers significantly greater percentage of the floor area than previous publicly released databases.

2. MEASUREMENT TECHNIQUE

All three sets of IRs were measured in spaces at Queen Mary, University of London, London, UK. The rooms have different acoustic properties, but all have significant reverberation times. All IRs were measured with a Genelec 8250A loudspeaker as the source and each receiver position was measured with an omnidirectional DPA 4006 and a B-format Soundfield SPS422B; the loudspeaker and Soundfield microphone can be seen in Fig. 1.

It is a less complicated process to simulate binaural measurements from omnidirectional IRs than it is to remove binaural information from binaural IRs. While the Aachen Impulse Response database was intentionally designed for applications that prefer binaural information, our database is designed to be as flexible as possible. The physical labor required to record a set of measurements in a single room is prohibitive and time-consuming, so only two different microphones were selected. The sound source was kept static and the receivers moved around the space as is common in IR databases and as two of the three rooms measured have a clear single location for the sound source (lecturing platform or stage) with multiple listening locations.

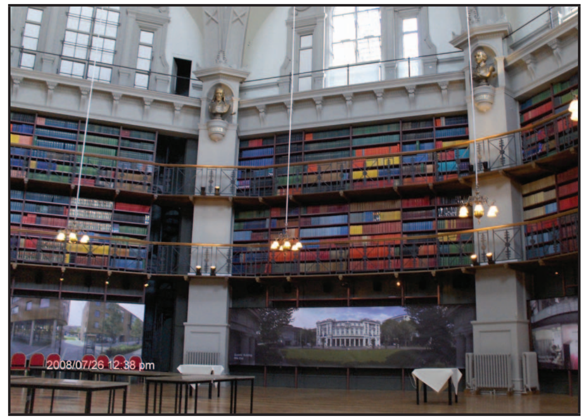

Fig. 2. The Octagon.

Omnidirectional IRs were recorded with a DPA 4006 and with the W-channel of the Soundfield microphone. The Soundfield microphone does not have a flat frequency response, particularly at higher frequencies whereas the DPA 4006 has a much flatter response. The more accurate capture of the high frequencies may be preferred for some applications.

The IRs were measured using the logarithmic sine sweep described in [7]. This approach has been shown to minimize harmonic distortion and increase the signal-to-noise ratio without needing to average multiple measurements, see [3].

3. DATABASE OF IMPULSE RESPONSES

All IRs were measured at Queen Mary, University of London. Each measurement has source and receiver heights of 1.5 m.

3.1. Classroom

A set of 130 IRs were taken within a classroom in the School of Electronic Engineering and Computer Science. The room measures roughly 7.5 x 9 x 3.5 m (236 m^3) with reflective surfaces of a linoleum floor, painted plaster walls and ceiling, and a large whiteboard. When in use for lectures the room is filled with desks and chairs. These were stacked and

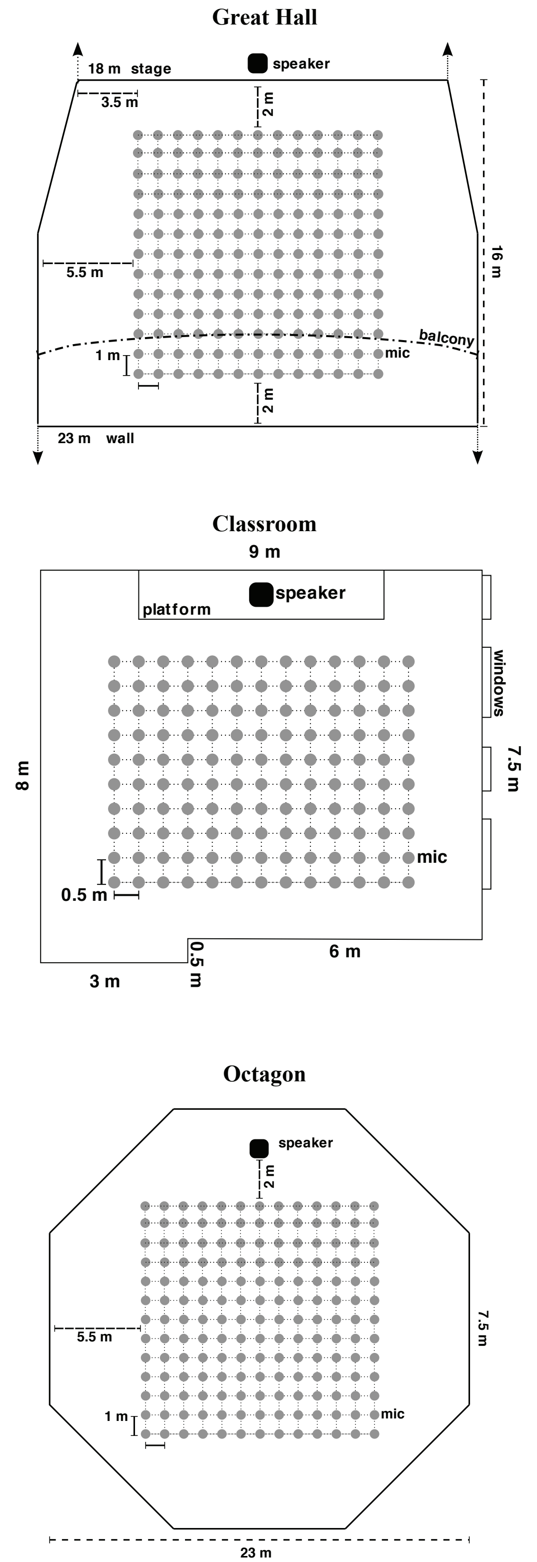

Fig. 3. Source and receiver positions of the three rooms.

moved to the side against the windows during the measurements. Measurements are 500 cm apart arranged in 10 rows and 13 columns relative to the speaker, with the 8th column directly on axis with the speaker. Fig. 1 shows the classroom and the dimensions of the room and the receiver positions can be seen in Fig. 3.

3.2. The Octagon

The Octagon is a Victorian building completed in 1888 and originally designed to be a library. It is currently used as a conference venue, but the walls are still lined with books with a wooden floor and plaster ceiling. As the name suggests, the room has eight walls each 7.5 m in length and a domed ceiling reaching 21 m over the floor, with an approximate volume of 9500 m^3. A set of 169 IRs were measured in the centre of the room. A photo of the room can be seen in Fig.2 and a diagram of the room and the speaker and microphone positions are in Fig. 3.

3.3. The Great Hall

The Great Hall is a multipurpose hall that can hold approximately 800 seats. The hall has a stage and seating areas on the floor and a balcony. The microphones were placed in the seating area on the floor, roughly a 23 m x 16 m area, which was cleared of chairs. The microphone positions are identical to the layout for the Octagon, 169 IRs over a 12 m x 12 m area. Fig.3 shows the area where the IRs were measured, but the room is significantly bigger as the balcony extends 20 m past the rear wall.

4. REVERBERATION TIME

Frequency-dependent reverberation time ($RT_{30,f}$) is a measure of the time-frequency envelope of reverberation. RT_{30} is the time an IR takes to decay 60 dB and is extrapolated from the measured time the sound takes to decay 30 dB.

The RT_{30} for each room can be seen in Fig. 4. Each line represents either the omnidirectional IR measured by the DPA 4006 or a B-format channel averaged over all the receiver positions within that room. The omnidirectional measurement is the black line with the other colors representing the B-format. The error bars show the standard deviation of the reverberation time for that channel. The omnidirectional microphone recorded more variations in the RT_{30} at 125 Hz and in the Great Hall it measured a much longer average RT_{30} than the B-format microphone. The four channels of the B-format remained very similar across the frequency bands with the exception of the Z-channel, represented by the red line. The Z-channel had lower RT_{30} values in the lowest frequency band for both the classroom and Octagon than the other channels.

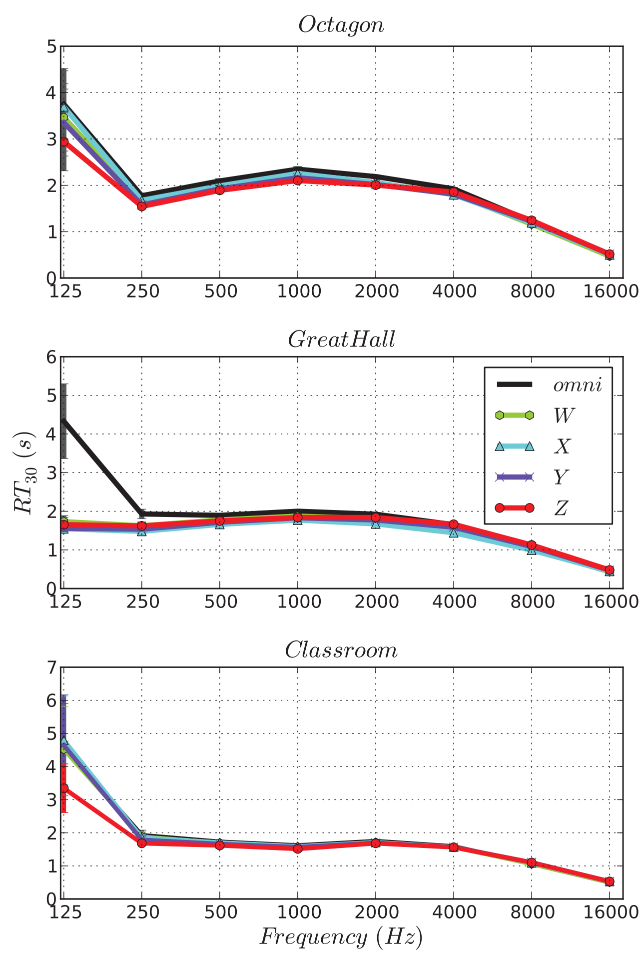

Fig. 4. Reverberation times of the three rooms. The omnidirectional measurement is the black line with the other colors representing the B-format channels.

5. AVAILABILITY

The C4DM RIR database is available for download from http://isophonics.net/content/room-impulse-responses. All IRs are mono 96 kHz, 32 bit wav files including the B-format IRs, so four files are required for a full 3D B-format IR. The database is released under the Creative Commons Attribution-Noncommercial-Share Alike license with attribution to the Centre for Digital Music, Queen Mary, University of London.

6. CONCLUSIONS

A new database of IR measurements has been introduced to fill a gap in available data sets. Previous data sets were not focused on sampling the breadth and width of the acoustics of a room and often were limited to fewer than a dozen source and receiver configurations or a sampling area of a few square meters. The C4DM RIR Database provides up to 169 source and receiver configurations across a 169 m^2 area in three different acoustic settings with two different receivers totaling over 700 different IRs.

7. REFERENCES

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