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Multi-Channel Orchestral Anechoic Recordings for Auralizations

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ABSTRACT

Multi-channel orchestral anechoic recordings were obtained at the Technical University of Denmark (DTU) in June 2005. Every orchestral part of specific movements of two symphonies, Brahms' Symphony No. 4, 3rd movement, and Mozart's Symphony No. 40 in g minor, 1st movement, were digitally recorded using five 0.5" DPA microphones, with four surrounding the musicians in the horizontal plane and the fifth directly above. The recordings were made in DTU's large anechoic chamber, which has free space of about 1000 m^3 and a lower frequency limit of 50 Hz. Each musician was recorded individually, and to assist with overall synchronization of all recordings, the musicians listened to the piece over headphones and viewed a video of a conductor while playing. In general, for the string parts, two to three individual musicians were recorded, and only one instrumentalist was recorded for the remaining brass, woodwind, and percussion parts. These recordings have been edited for use in room acoustics modelling software programs to create auralizations that include some of the directional characteristics of each instrument, as individual instruments, small ensembles, or an entire orchestra.

INTRODUCTION

Room acoustics computer modelling programs provide a useful tool for both designing and researching acoustically sensitive spaces. The algorithms of these software packages have made major advances in the last two decades, and programs have been compared more recently in a detailed round robin study in 2005 [1,2]. In addition to the programs providing numerical predictions of room acoustics parameters, such as early decay time (EDT) and clarity index (C80), these programs are capable of providing aural simulations, or auralizations, by convolving the binaural room impulse response (BRIR) with an anechoic recording [3,4].

Anechoic recordings must be used in the convolution process to ensure no room effects from the recordings are being incorporated into the auralization. However, few high quality anechoic recordings exist. The most extensive solo instrument and speech recordings were made as part of the Archimedes project and are available on CD [5,6]. These recordings were made with a single microphone positioned directly in front of the instrumentalists. A few years later, a CD was released by Denon with several full orchestral anechoic recordings [7]. As few anechoic chambers are large enough to house an entire orchestra, these recordings were made on the stage of Minoo Civic Hall in Osaka, Japan, with the stage surrounded with highly absorptive materials. The recordings were made predominantly from two microphones positioned above the conductor; however, the recordings from some microphones located next to each section were mixed in for those instruments that sounded too quiet in the overall recording. The primary problem with using these recordings in the auralization process is that each instrument cannot be captured individually, which means that neither the directivity of each instrument nor that of the orchestra can be reproduced.

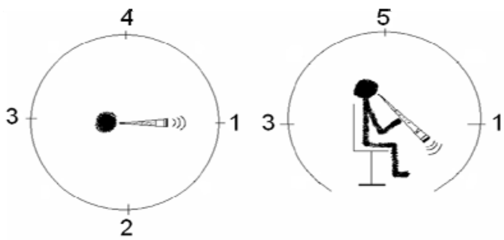
Meyer has shown through extensive studies how the directivity of different instruments varies as a function of frequency [8]. In general, instruments tend to be less directional at low frequencies and become more directional as the frequency increases. Previous work has shown that incorporating source directivity into auralizations can, in general, improve the quality of the reproduction [9-12].

Five-channel anechoic recordings of each instrumental part for two symphonies, Brahms' Symphony No. 4, 3rd movement, and Mozart's Symphony No. 40 in g minor, 1st movement, were recorded at the Technical University of Denmark (DTU) in 2005 and will be described in detail in this paper. More recently, higher resolution orchestral recordings of each individual instrumental part have been made by Pätynen *et al*, with 22 microphones of four symphonic excerpts [13].

MULTI-CHANNEL ORCHESTRAL ANECHOIC RECORDINGS

Musicians

The Tivoli Symphony Orchestra (as it is known in the summer [14]) and the Sjællands Symphony Orchestra, Copenhagen Philharmonic (as it is known in the winter [15]) desired high quality anechoic recordings of the orchestra. Their intent was to create an interactive website similar to Aalborg Symphony Orchestra's website, as an educational tool for the general public [16]. The orchestra hired a private company to make single-channel recordings, AM-Multimedia, for their own use. The DTU co-authors of this paper obtained permission to record the individual musicians as well using a five-channel microphone set-up, as shown in Figure 1. For the string parts, two to three different musicians were recorded individually, and for each of the remaining parts one instrumentalist was recorded.



Source: Adapted from Otondo and Rindel 2004, 2005 [9,10]

Figure 1. Five-channel microphone setting for the anechoic recordings of each individual instrument.

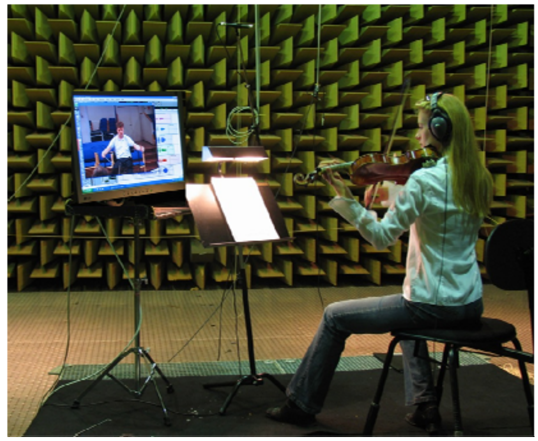
Recording set-up

The recordings were made in the Technical University of Denmark's large anechoic chamber, which has an approximate free space of 1000 m^3 and a low frequency cut-off of 50 Hz. The 'floor' of the room is made up of thin steel wires in tension (called a "tension wire grid"), to be acoustically transparent, as there is another 4 m of room below, also lined with absorptive wedges. The overall height of the room is about 8 m.

Five 0.5" DPA microphones connected to five individual pre-amplifier units were used to make the recordings. Four microphones were positioned in the horizontal plane, evenly spaced around the musician, with the fifth microphone positioned directly above the player. The microphones were suspended from a large circular ring that is attached to the ceiling of the chamber and were positioned about 2 m away from the musician. All five microphones were connected to a digital recorder, the Fostex 24 Track Digital Recorder type D2424LV.

Synchronization

Since each musician was recorded individually, measures had to be taken to ensure the recordings could be synchronized when combined at a later date. Two techniques were employed to assist the musicians: (1) the musicians wore headphones that were playing a MIDI recording of the entire piece; and (2) the musicians could view a recording of the conductor on a monitor, as shown in Figure 2.



Source: Jens Holger Rindel

Figure 2. A violinist being recorded listening to the full score over headphones and watching a video of the conductor for synchronization purposes.

Level equalization

At the start of each recording day, a calibration tone was recorded on each of the five channels. For most of the recordings, the pre-amplifier settings were not altered, with a mean recording level of -7 dB (re: 0 dBFS). In an attempt to equalize the levels across the recording days (i.e. different instruments) and channels, adjustments between about -6 dB to +4 dB were made as shown in Table 1. The two exceptions were the trumpet and timpani recordings (Figure 3), which were set at -13dB (re: 0 dBFS) and -23 dB (re: 0 dBFS), to be in line with the levels at which these instruments were recorded, in order avoid drastically increasing any noise in the recordings. Therefore, when using these recordings in auralizations, the levels from these two instruments must be adjusted when mixing all instruments together. In addition, not all instrumentalists necessarily played at the same level, so additional adjustments in level also need to be made in order to balance the sections in an auralization.

Table 1. Level adjustments for each instrument recorded and for each channel recorded.

	Level Change to Each Channel to Achieve -7 dB (re: 0 dBFS) Mean* (*exceptions noted*) Across All 5 Channels (dB)				
Instrument	**Ch. 1**	**Ch. 2**	**Ch. 3**	**Ch. 4**	**Ch. 5**
Violin, Viola	-5	-5	-4	-5	-4
Cello, Double Bass	-5	-6	-4	-4	-4
Bassoon, Cont. Bassoon	-3	-4	-4	-5	-4
French Horn, Oboe	+4	+4	+3	+3	-4
Clarinet, Flute, Piccolo	+4	+3	-2	+3	-4
Timpani *set to -23 dB	0	0	0	0	0
Triangle (lots amp. needed)	+15	+14	+17	+16	+16
Trumpet *set to -13 dB	+1	+1	0	0	-10

Source: Vigeant 2008 [17]

Source: Jens Holger Rindel

Figure 3. A percussionist playing the timpani. All musicians were recorded playing on the platform shown in this photo.

Parts Edited

The process of transferring the digital recordings from the Fostex recorder and converting the format to .wav was not straightforward. The entire 250 GB of data, which was stored on several different cards, had to be first transferred to an external small computer interface (SCSI) drive from the recorder. This SCSI device was then connected to a computer running Linux, which had compatible software to convert the Fostex formatted files to .wav format. Finally, the files could be transferred from the computer running Linux to a conventional PC running Windows XP.

Limited written records were kept of the recordings, so identifying each recorded part and dissecting the recordings was a relatively complex task. It was first identified that one movement from each of the following pieces was recorded: (1) Brahms' Symphony No. 4, 3rd movement; and (2) Mozart's Symphony No. 40 in g minor, 1st movement. Igor Stravinsky's *Circus Polka: For a Young Elephant* was also recorded, but has not been further processed. Each of the recorded movements were approximately 4-5 minutes in length; however only the first minute was edited, as more recordings were made of the first parts of the movements, which allowed for greater choice in finding as close to flawless takes as possible. In addition, the shorter .wav files helped to keep the file sizes more manageable.

The scores were obtained for the Brahms and Mozart symphonies in order to identify all of the instrumental parts recorded, e.g. the 1st and 2nd parts for the wind instruments, which in some cases had relatively minor differences in the score. For most of the recorded string parts, more than one musician was recorded, but only the recordings from the best players were edited for final use. A total of 21 different instrumental parts for the Brahms symphony and 14 for the Mozart symphony were extracted from the raw recordings, and are summarized in Table 2.

Table 2. Number of parts and number of musicians recorded for the Brahms and Mozart symphonies.

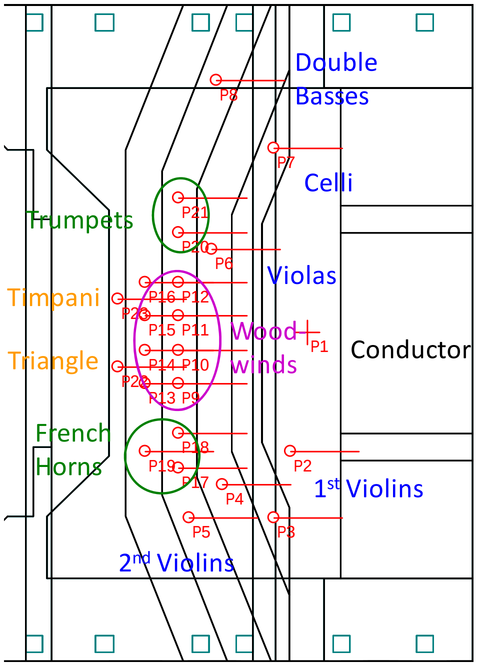
Brahms - Symphony No. 4, 3rd movement	Mozart - Symphony in g minor, 1st movement	Number of Musicians Recorded
1st violins	1st violins	3
2nd violins	2nd violins	3
Violas	Violas	3
Celli	Celli	1
Double Basses	Double Basses	2
Flute	Flute	1
Piccolo	*None*	1
Oboe, 1st & 2nd	Oboe, 1st & 2nd	1
Clarinet, 1st & 2nd	Clarinet, 1st & 2nd	1
Bassoon, 1st & 2nd	Bassoon, 1st & 2nd	1
Contra Bassoon	*None*	1
French Horn, 1st, 2nd & 3rd	French Horn, 1st & 2nd	1
Trumpet, 1st & 2nd	*None*	1
Timpani	*None*	1
Triangle	*None*	1

Source: Adapted from Vigeant [17]

APPLICATIONS OF THE RECORDINGS

These recordings have been used in many auralization studies. The first application of these recordings was done by Vigeant *et al* [12,17], where different methods for modelling an orchestra were compared: (1) as a surface source and (2) a single point source, each convolved with a single-channel combined anechoic recording of the entire orchestra; and as individual point sources for each instrument or instrumental section using either a single-channel recording (3) or all five-channels (4). An example of the point source configuration for this study is shown in Figure 4. From subjective listening tests, significant increases in the ratings of realism and source width were found for the multi-source auralizations over the surface source and single point source, but minimal improvements were found when increasing the number of channels from 1 to 5 in the multi-source model. In addition, the effectiveness of modelling the orchestra with the multi-source multi-channel method was investigated to determine the effect of a subject's ability to hear a difference in different orchestra configurations [12]. In some instances, the multi-source 5-ch model was found to be more effective than the multi-source 1-ch model. Further investigations have been conducted to examine different techniques for modelling the string sections in an attempt to achieve the chorus effect, including using multiple single-channel sources to model several individual instrument in each string section with either omni-directional directivities applied to each source [18,19] and with time-shifts [20] or with some sources with directivities applied [21].

Unfortunately, these recordings are not available for wide distribution, since copyright permission was not obtained from the orchestra and individual musicians. However, 22 channel anechoic orchestral recordings are available for download from the recordings made by Pätynen *et al* [13].



Source: Adapted from Vigeant, Wang, and Rindel 2008 [12]

Figure 4. Point-source representation for each individual instrument or instrumental section used in [12]. Note that two sources were used for both the 1st and 2nd violins, while individual sources were used for the violas, celli and double basses. Each of these sources represented several players. Individual point sources were used for the remaining instruments.

SUMMARY

Five-channel anechoic orchestral recordings were made in the Technical University of Denmark's large anechoic chamber. Each individual instrumental part was recorded for three pieces, one by Brahms, one by Mozart, and a third piece by Stravinsky. For the Brahms and Mozart symphonies, the raw recordings were edited to extract each instrumental part for use in room acoustics modelling programs to generate auralizations.

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