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ODESSA – Orchestral Distribution Effects in Sound, Space and Acoustics: An interdisciplinary symphonic recording for the study of orchestral sound blending

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Abstract

ODESSA is a collaborative project between the Université de Montréal, McGill University and Detmold University of Music aiming to study orchestral blending effects, examining how instrumental sounds are sculpted by the conductor, the musicians and the hall acoustics and how the sound changes when heard and recorded from different perspectives. This project is realized in the context of the ACTOR (Analysis, Creation, and Teaching of Orchestration) Partnership, which involves a diverse international team of composers, music theorists, musicologists, computer and signal processing scientists, psychologists, acousticians, sound recordists and conductors. ACTOR's main goals are to develop a perceptually based theory of orchestration and to create new tools for music analysis, composition, teaching and mediation.

Keywords: orchestral blending, timbre, ACTOR, concert hall acoustics

1 INTRODUCTION

ODESSA – an acronym for "Orchestral Distribution Effects in Sound, Space and Acoustics" is a project created jointly by members of the Université de Montréal, McGill University and Detmold University of Music aiming to study orchestral blending effects. Approaches to achieve this goal consist of investigations on how instrumental sounds are sculpted by the conductor, the musicians and the hall acoustics and how the sound changes when heard and recorded from different perspectives. The framework of this project is the 7-year project ACTOR (Analysis, Creation, and Teaching of Orchestration), a partnership, which involves a diverse international team of composers, music theorists, musicologists, computer and signal processing scientists, psychologists, acousticians, sound recordists and conductors.

At the core of the ODESSA project is a complex multitrack recording of the Orchestre de l'Université de Montréal performing excerpts from Tchaikovsky's Sixth Symphony, "Pathétique". More than 50 microphones are used in a combination of close microphone pick-up and ambient recording. Concurrently, the acoustical balance of the instruments is examined employing techniques such as 3D intensity probes and an acoustic camera. Excerpts of the recording of varying instrumental combinations are used as listening test stimuli with the purpose of investigating timbral blending effects.

1.1 ODESSA GROUP

Under the combined leadership of four researchers of the ACTOR Partnership, the ODESSA project consists of a complex multitrack recording, a joint music production and evaluation of an orchestral recording realized at Salle Claude-Champagne, Université de Montréal's concert hall, on September 29-30, 2018. Under the baton of conductor Jean-Francois Rivest, the Orchestre de l'Université de Montréal performed excerpts from Tchaikovsky's Sixth Symphony, "Pathétique". Led by recording producer (Tonmeister) Martha de Francisco a multimicrophone recording of the rehearsal was realized with more than 50 microphones used in a combination of close microphone pick-up and ambient recording. Concurrently, the balance of room acoustics and musical instruments was examined by acoustician Malte Kob with the students Cosima Riemer, Caspar Ernst and Stefanos Ioannou from Detmold University of Music and Dorothea Lincke from TU Berlin employing techniques such as 3D intensity probes and an acoustic camera. Excerpts of the recording of varying instrumental combinations are used as listening test stimuli with the purpose of investigating timbral blending effects. Caroline Traube contributed with the study of the performers' role in the shaping of instrumental timbre and to the sound analysis and perceptual evaluation of the recorded excerpts. She also led the complex organisation of the event, which involved coordinating several teams of technicians and students, as well as the research equipment provided by the three collaborating institutions. An online resource and a video recording from the "Music mediation" programme of the University of Montreal document the entire project [1, 2].

1.2 RESEARCH OBJECTIVES

The ODESSA project's interdisciplinary character establishes an array of diverse research questions and objectives. Approaching the main topic of "orchestral blending" from different perspectives will provide insight in music composition, musical performance, musical acoustics, psychoacoustics, room acoustics and sound recording. With the combined data from the recording, the various audio tracks and microphone groups, the acoustical measurements from the hall and the timbre analysis of the whole process, we intend to offer to the ACTOR community in particular (and to the musical world at large) a vast array of tools to study the combination of timbres and orchestral instruments, as well as the interaction between instruments and the surrounding acoustics.

One of the main objectives of this project is to trace instrumental blending in an orchestra by listening to and analyzing the sound of instruments as recorded from different perspectives. The aim is to present the research community with audible information of the sound of single instruments and orchestral sections in the close range, as well as the sounds that are heard at more distant perspectives with the help of group, main and ambient microphones. By comparing the close-microphone pick-up and the ambient recordings the researchers aim at shedding light at the importance of reflected sound for our perception of instrumental blend.

The study of the acoustical balance of the instruments of the orchestra as well as the distribution of the sound energy on stage and in the hall will be used to verify and confirm orally established findings of instrumental nuances and the detail of ambient characteristics of the symphonic sound in the space as perceived by the conductor and the recording professionals.

2 METHODOLOGY

2.1 Selection of excerpts from the Pathetique Symphony

The Pathétique symphony lasts about 45 minutes and it has the following instrumentation:
- Woodwinds: 3 flutes (3rd doubling piccolo), 2 oboes, 2 clarinets, 2 bassoons
- Brass: 4 horns, 2 trumpets, 3 trombones, 1 tuba
- Percussion: timpani, bass drum, cymbals, tam-tam
- Strings (string strength on the recording day): 9 violins I, 8 violins II, 5 violas, 7 celli, 4 double basses (32 in total).

Prof. Jean-François Rivest developed a list of music segments for the recording which present different thematic complexes such as orchestral groups, compositional groups, composite melodic line, and the aggregation of individual instruments in a section. Here are a few examples of the excerpts that were recorded, as described by Maestro Rivest:

> "In order to listen individually to different orchestral groups, we recorded certain passages with only the winds, only the brass, the percussion instruments or the strings and finally we recorded the whole tutti. This is the simplest yet most important way to delve into the construction of the orchestration of the symphony. The coda of the 3rd movement or the fugal development at bar 270 in the 1st movement are good examples. One will be able to hear each of these sections separately and in various 'takes' and microphone settings."
>
> "Often, the composer will combine various instruments from different families into one melodic line and other instruments will perform the countersubject or harmony and the accompaniment. This

> describes an orchestration by compositional groups. For example, we recorded the beginning of the 4th movement with the countersubject alone (with its haunting combination of high bassoon, low flutes and progressively added clarinets and oboes). Then, we recorded the main musical element in the whole string section and finally we recorded the tutti. Another good example is the re-exposition of the second theme of the 1st movement, at bar 305 (arguably the most well-known melody of the Pathétique). We recorded the harmony only (double-basses, trombones, timpani, horns, cellos and violas), then the counter-melody only (oboes, clarinets, bassoons and added violas and cellos at bar 309), then the melody itself (violins, flutes and added bassoons and clarinets, from bar 311), and finally the whole tutti."
>
> "One of the most striking orchestration features of the Pathétique is the invention of the composite melodic line in the violins at the beginning of the 4th movement. The listener hears a descending scale, but individual violins take turns with weird leaps exchanging the relevant notes that form this scale. We therefore recorded each violin section separately (with their very strange broken lines) and then both sections together to demonstrate Tchaikovsky's trait of genius. The recording of this passage was asked for by many of our colleagues from ACTOR."
>
> "Finally, another interesting aspect of orchestration is the building or aggregation of individual instrumentalists to form a string section: many individuals playing the same line become one line of music. We wanted to show that on the one hand there is a clear de-individualization and grouping effect that takes place the more violins play together, but on the other hand we wanted to illustrate the fact that there is a lower limit, a number under which it is not possible for a few violins to sound and blend like a section. In order to explore that, we used the same melody, the second theme of the 1st movement in the first violins (from bar 89) recording the same melody with one violin (the solo concertmaster), 2 violins, 3 violins, 4 violins, 6 violins, and finally the whole section. We even did a recording where the front of the section leads and one where the back of the section leads, which showed us interesting psychological aspects of orchestration."

A short summary of the musical excerpts that have been performed in the frame of ODESSA is given in Table 1.

Table 1. Selected excerpts and their related research question or characteristic orchestral gesture.

Excerpt	Subject
MOV. I, bars 305-309	How a poetic demand from the conductor can change the orchestra's playing
MOV. I, bars 305-313	Hyper-romantic counterpoint, a study of orchestration strata
MOV. I, bars 89-97	The perception of individual violins or of a section of violins
MOV. I, bars 170-185	Counterpoint and orchestration as a way to enhance energy
MOV. I, bars 284-304	Hyper-romantic counterpoint and the building of a climax
MOV. III, bars 196-256	Contrast between pointillistic motives and linear horizontal ascending energy lines
MOV. III, bars 221-229	Alternating sections between strings and woodwinds
MOV. IV, bars 19-23	Composite violin line (only violins)

2.2 Recording the ODESSA project

The complex sonorities of a symphony orchestra, as a result of a cooperation of the playing technique of the musicians, the sound radiation of the instruments and the acoustic influences of the room, represent a major challenge for recording professionals [3].

In order to create a sonically convincing recording of a large ensemble performing in a concert hall, skilled recording engineers learn to discern the acoustic components that appear almost simultaneously when music is being played, the direct sound as well as the sound reflections that result as the waves emanating from the sound sources expand and bounce off the walls, floor and ceiling in multiple reflections, developing a diffuse sound field. The sequence in the right proportions of direct sound, early reflections and the ensuing reverberation are important for the tonal impression of a musical performance [4]. Learning to discern the nuances of close and reflected sound in various layers of its expansion constitutes one of the main practices of expert recording engineers for classical music, and it marks a point of departure for the recording of the ODESSA project.

The ODESSA recording is based on a number of arrays of microphones placed in various distances of the musical instruments in order to reconstruct the natural sonic sequence in the hall. A team led by Jack Kelly and Diego Quiroz from McGill University prepared a recording system with 50 studio microphones and digital recording technology in HD at 96 kHz, 24 bit. The microphones have been carefully positioned and fine-tuned by ear. In Figures 1 and 3 the microphone positions of the orchestra recording are indicated.

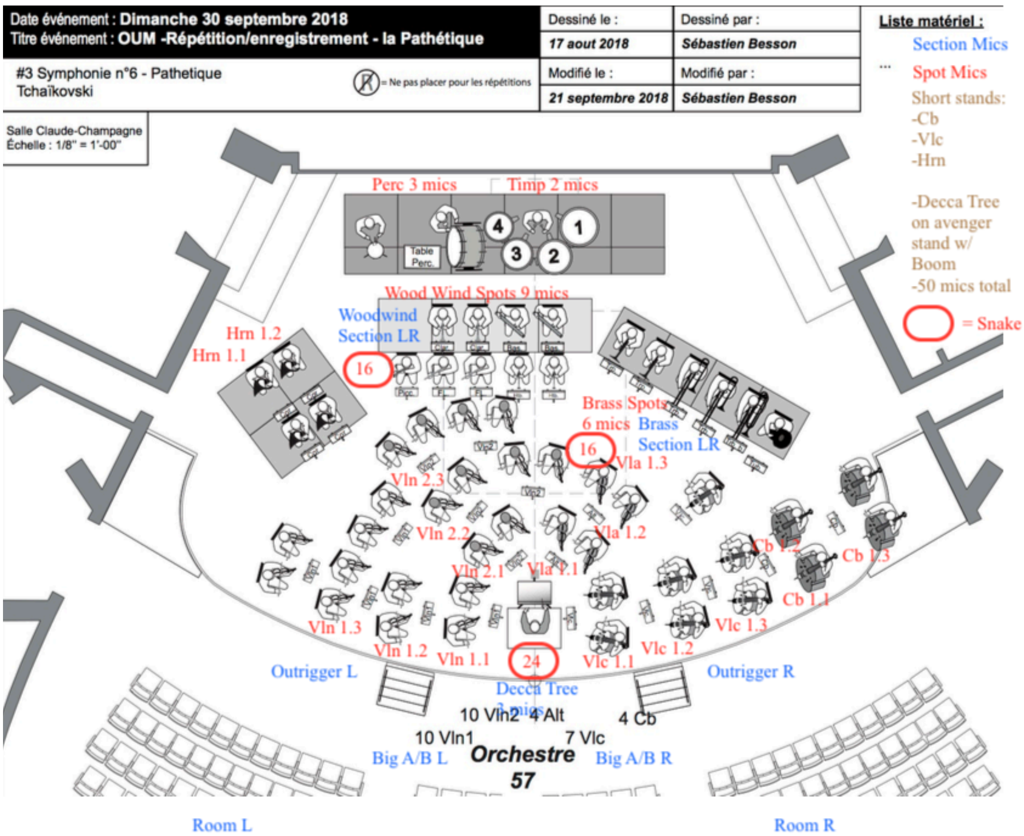

Figure 1. Orchestra seating arrangement and microphone placement.

The main array consists of a modified "Decca Tree" [5] suspended above the conductor with flanking microphones (outriggers). This array of omnidirectional studio microphones is responsible for the capture of the general, balanced and blended sound of the full orchestra. Besides, a large number of spot microphones in the close range of the orchestra provides a near sound picture of each instrument meant to increase the definition of their sound and to intensify their tonal characteristics. Additionally, two further levels of distance, the AB microphones (in front of the first row of the audience) and the furthest room microphones (on the balcony) define the most distant layers of sound. In postproduction the recorded material is edited and mixed to resemble the closest representation of a natural listening experience in the concert hall. The recorded material (in multitrack, stereo and binaural) will be presented to the research community for evaluation. The online resource will serve as a conduit [1].

Figure 2. ODESSA recording session: the Orchestra of the University of Montreal (OUM) recorded under an extensive cloud of microphones. In the foreground the acoustic camera. Colour code for microphones: red = Decca Tree, green = Outriggers, blue = AB, yellow = Spot microphones.

2.3 ACOUSTIC MEASUREMENTS

Along with the orchestra recordings an extensive assessment of acoustical properties of the Salle Claude Champagne was performed. The aim of such investigations is the characterization of the acoustic boundary conditions that musicians and conductors experience when performing music as well as the assessment of acoustic measures that correlate with the perception of music listeners. Earlier studies indicate that acoustic conditions not only affect the listeners' impression of music [6, 7] and can be described by acoustic measures [8], but also significantly impact on the musicians' performance [9, 10, 11, 12, 13, 14, 15]. A number of useful parameters have been proposed in [8] which can be derived using impulse response and sound level measurements. To allow the evaluation of these and more complex parameters, the following measurements have been provided:

- Reverberation time (EDT, T20, T30)
- SDM measurements with intensity probe and sweeps [16]
- Speech transmission index (STIPA) from musicians' positions to other musicians' and listeners' positions
- Noise criterion curves according to ANSI/ASA 12.2-2008

Several loudspeaker (omnidirectional and directive) and microphone positions have been used to evaluate the parameters. Their positions are indicated in Fig. 3. Using the SDM analysis the direction of sound impact at specific locations can be visualised. Among other interesting findings the statement that the balcony position is Martha de Francisco's favourite listening position could be confirmed: At this position a very good balance of direct sound and listeners' envelopment could be observed due to the ceiling reflection (see Fig. 4).

During the orchestra performance additional measurements have been performed:

- Acoustic camera recordings
- Contact microphone recordings on first violins

The acoustic camera allows a visualisation of the orchestral balance and sound pressure distribution at the listener's location and is used to validate and extend earlier findings related to sound propagation and perception within ensembles [17, 18].

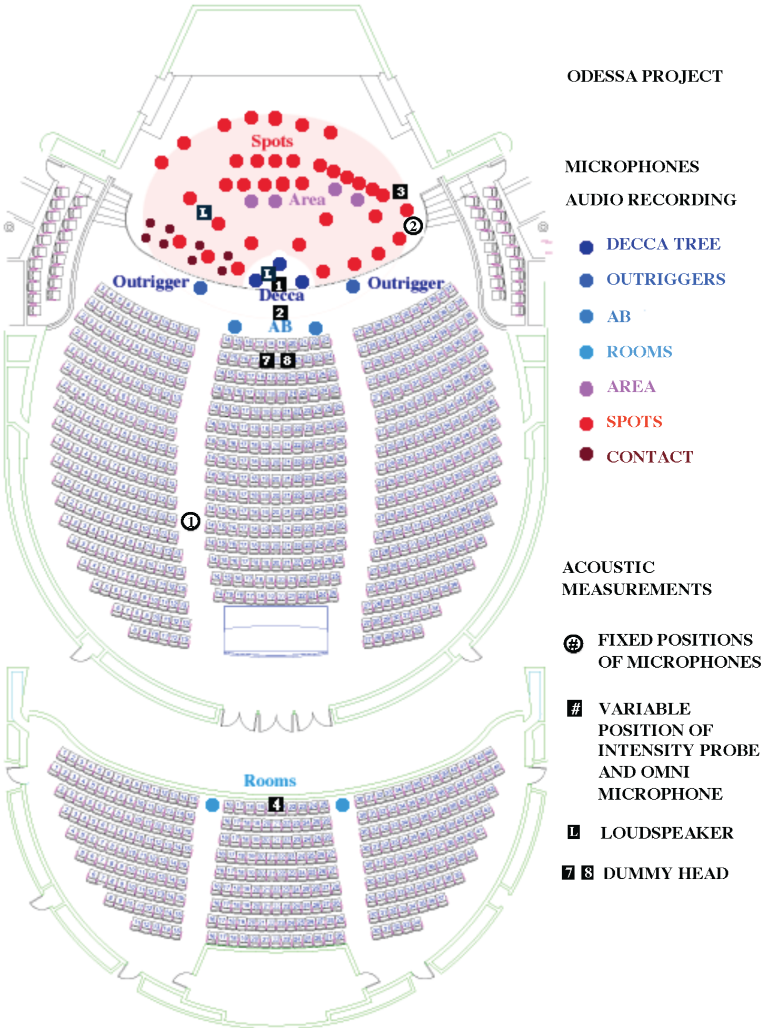

Figure 3. Location of loudspeakers and microphones for the acoustic evaluation.

The contact microphones were used to investigate the coherence among single instruments within an ensemble, see next section and [19].

A third set of measurements is currently performed under laboratory conditions in Detmold and other places: Directivity measurements of instruments. Since the sound radiation from musical instruments can be very complex in various domains (space, time, frequency), the effect of the instruments' orientation, construction, playing style and fingering techniques have a a strong impact on the perception of musical sounds. This research area also impacts on the virtualisation of orchestration using computer programs and virtual acoustic environments [20] as planned in the ACTOR project. An upcoming research interest is the relevance of directivity data on the evaluation of acoustic measures [21].

For future studies in other concert halls a set of measurements is currently developed for an acoustic description of recording environments. Directives for such a recommendation would be, among others: ease of acquisition and interpretation, high reproducibility, good correlation with subjective cues.

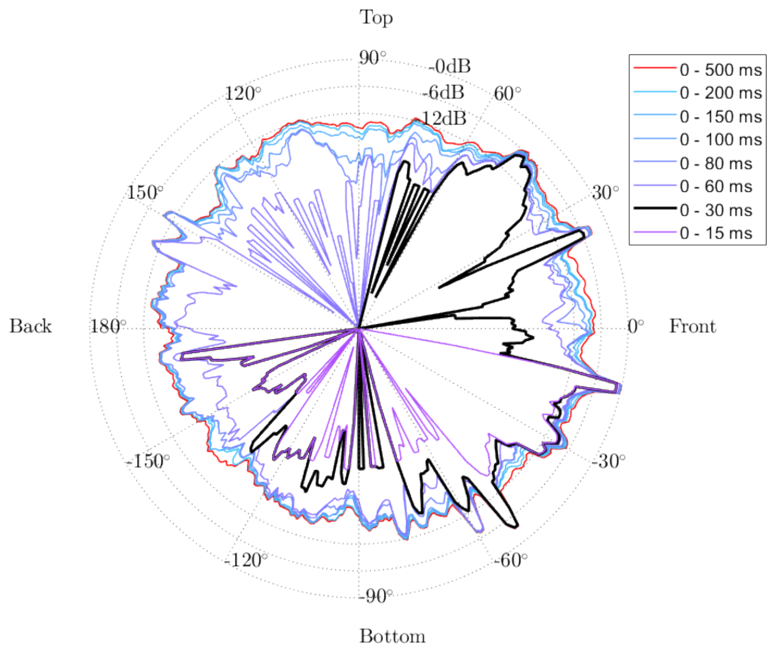

Figure 4. Direction of sound incidence from the stage to the balcony, visualised for various time frames using the SDM method [16], calculation by Dorothea Lincke using a Matlab script by Sebastià Amengual [22].

2.4 Perceptual evaluation

On a perceptual level, timbre blend can be defined as the auditory fusion of concurrent instrumental sounds. When blending occurs, the individual sounds become less distinct [23]. Some instruments of the orchestra blend more easily than others. For example, the horn is generally considered as an easily blendable instrument [24]. The oboe, on the other hand, does not blend easily because of a prominent formant structure which makes its timbre stand out [25, 24, 26]. Blending effect also depends on other factors. It increases drastically when instruments are played in unison and with synchronized attacks. Performance-related factors include tuning, pitch modulation (as vibrato) and articulation. When instruments are played on different notes, blending depends on which instrument is assigned to the higher voice [23].

The degree of perceived blend can be measured in several ways. One approach consists in deducing blend from increasing confusion in the identification of instruments in a mixture [25]. A more direct measure is done through rating scales [25, 24, 26, 27].

In the context of a student work a first study on the perception of blend was undertaken by Stefanos Ioannou, who investigated the conditions that perceptually contribute to the impression of a blended sound, based upon a listening test using the recordings of Mov. 1 bars 89-97. In this movement, the violins were captured by microphones placed at different distances from the stage (including contact microphones) and in groups of various sizes (from 1 to 8). For this segment, the results are given in [19].

In the next stage of this project, performance-related factors will be investigated such as the pitch and timbre tuning which occurs when violinists attempt to achieve blending within their section. Fundamental frequency (mean value as well as modulation depth and rate) and acoustic descriptors related to timbre (such as spectral centroid) will be tracked over time. Finally, blending effect on dyads and triads will also be analyzed on the basis of previous research [23], exploring the role of the extensity (auditory size as a dimension of timbre [28]) and of the instrument directivity and radiation into the acoustic surrounding space.

3 CONCLUSIONS

The ODESSA project "Orchestral Distribution Effects in Sound Space and Acoustics", allows insight in how orchestral sound works as examined in a multidisciplinary context of music performance, acoustics, perception and audio engineering. It enables researchers to investigate timbral blending effects, and it demonstrates the impact of the acoustics on our perception of music. In addition to the Performance Axis' activities that enabled the recording of the project, in the Musical Analysis Axis of the ACTOR partnership the researchers will realize perceptually relevant analysis of the recorded data. Detailed kinds of analysis will be performed: sound analysis, perceptive analysis and an analysis of how the instrumental and orchestral sound changes with the distance.

The ODESSA project brings together an array of experts in different disciplines who for the first time join forces to explore their research topics. In an unprecedented way, an intense convergence of several types of expertise and technical means developed over many years have come together to give insight into how orchestral sound works in all its complexity.

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