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SPATIAL ACOUSTIC MEASUREMENTS IN CONCERT HALLS WITH A REDUCED VIRTUAL ORCHESTRA

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ABSTRACT

The Virtual Orchestra has previously been used to measure room acoustic conditions of major concert-halls. The idea is to simulate an actual orchestra on stage with an array of loudspeakers and then measure the spatial impulse response in the hall. This approach gives a more complete picture of the acoustic projection and reflection paths between the stage and the audience than traditional measurements with a single omni-directional loudspeaker in few positions.
However, the originally proposed system requires over 24 loudspeakers and is therefore not very convenient for consultants to use from the practical perspective.
In this paper a scaled-down version of the measurement system is presented. This system uses a total of 8 loudspeakers and the spatial impulse response is recorded by a standard A-format microphone. The results are presented with comparative spatial analyses and preliminary results from practical measurements in halls.

Keywords: *Room acoustics, measuremnts.* ***Note that the keywords insertion is mandatory.***

1. INTRODUCTION

The measurements with the Virtual Orchestra has previously been shown to provide new insights to sound behavior in concert halls and other performance spaces [1][2]. The method enables application of visualization methods [3] for beneficial evaluation and comparisons of the reflection patterns and other spatiotemporal features in different acoustic conditions. However, it is also clear that conducting measurements with 24 or more loudspeakers requires relatively complicated logistics, which is seldom possible in the consulting world. Hence, a more practical approach with a substantially reduced number of loudspeakers, yet mimicking the original spatial distribution of sources, has been experimented and applied recently in acoustic investigations.

2. MEASUREMENT SETUP AND ANALYSIS

The reduced measurement system consists of 8 loudspeakers: 6 pcs Genelec 8020D and 2 pcs Genelec 8030C. The 8020's are positioned on stands and placed to simulate the main part of instrument sections in typical orchestra seating layout. The larger loudspeakers (8030) are placed on the floor, to simulate the location of double basses and percussion sections.

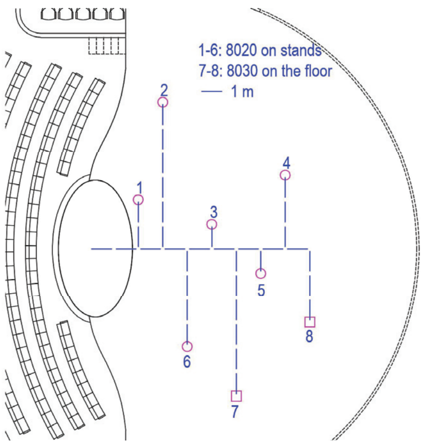

Figure 1. Applied loudspeaker layout.

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Loudspeaker output gains are calibrated using a pink-noise signal in-situ at 1 m reference distance in front of the final loudspeaker position. Floor loudspeaker levels are adjusted similarly with the loudspeaker pointing temporarily upwards. Although this method includes the influence of the floor reflection, the effect can be assumed nearly equal across different halls with relatively low contribution by the overall acoustic gain of a particular hall stage.
For the receiver, it was decided to use an A-Format microphone instead of the 6-capsule 3D intensity probe which was applied in the originally Virtual orchestra measurements and related studies. The actual measurements are done in practice using the REAPER software for playback and recording and spatial analysis and visualization is conducted using Python and Matlab scripts.
The recorded spatial impulse responses are analyzed with Spatial Decomposition Method (SDM) [4] and visualized using mainly the spatiotemporal and time-frequency visualizations [3].
The spatiotemporal analysis aims to estimate the direction-of-arrival for each audio sample in the measured spatial room impulse response [3]. The estimation is done in short overlapping analysis time-windows. The applied A-format microphone array contains four cardioid capsules in an open tetrahedral configuration at 24 mm distance between capsules. This type of receiver enables the use of so-called B-format signal processing.

Originally [4], the spatiotemporal analysis method is derived for open microphone arrays with omnidirectional capsules. The respective SDM analysis requires processing in short overlapping time-windows. Typical length for analysis windows for large acoustic spaces, such as opera and concert halls, is around 0,75 ms. This value is directly relative with the temporal resolution of the spatial analysis. That is, acoustic events, such as incident reflections that arrive more than 0,75 ms apart can be reliably discriminated from the data. The choice of analysis window is also guided by the dimension of the open microphone array. With larger inter-capsule distances, a longer analysis window is required to include sufficiently overlapping microphone signals for reliable directional estimates [1][4].

In contrast to original implementation with open microphone arrays, corresponding B-format signals analysis can be conducted with signal multiplications without time-windowing, as described in detail in [4],[5] and [6]. In order to obtain comparable results between open microphone array and B-format analyses, the temporal resolution of spatial information in sample-resolution was a low pass filtered with a 0,7 ms smoothing window for more stable application into visualization. Detailed discussion on the temporal resolution of analysis methods can be found in [4] and [5].

3. COMPARISON OF FULL VIRTUAL ORCHESTRA AND REDUCED SYSTEM

The performance of the applied 8-source loudspeaker array in comparison to full 24-source system was evaluated with spatiotemporal visualizations. An opera hall measurement with 24 sources was analyzed in parallel with the subset of source positions that match with the reduced measurement system. Receiver position distance was approximately 10 m and 2 m off-center to the left side.

A set of comparisons is presented in Figure 2. Energy accumulation over selected forward-integrating time windows is visualized from spatiotemporal analysis with two source configurations. Early lateral energy up to 30 ms from the frontal sector shows slightly reduced energy at the extrema of the stage area. Due to more sparse source positions, certain angles have less direct sound, which is a natural consequence. In the visualization method, the spatial responses from individual sources is combined as the energy average. The curves in Figure 2 are normalized to 0 dB for easier comparison. The median plane example in middle Figure 2 shows the direct sound and early reflections up to 80 ms. The spatial result with reduced a source number correspond closely to 24-source reference.
Directions and level of reflections from high elevations are represented accurately. The longer accumulation of lateral energy within time-window 0…200 ms (Figure 3, bottom) is reduced in 8-source configuration, which results from overall lower sound energy radiated from lesser number of equally powerful sound sources.

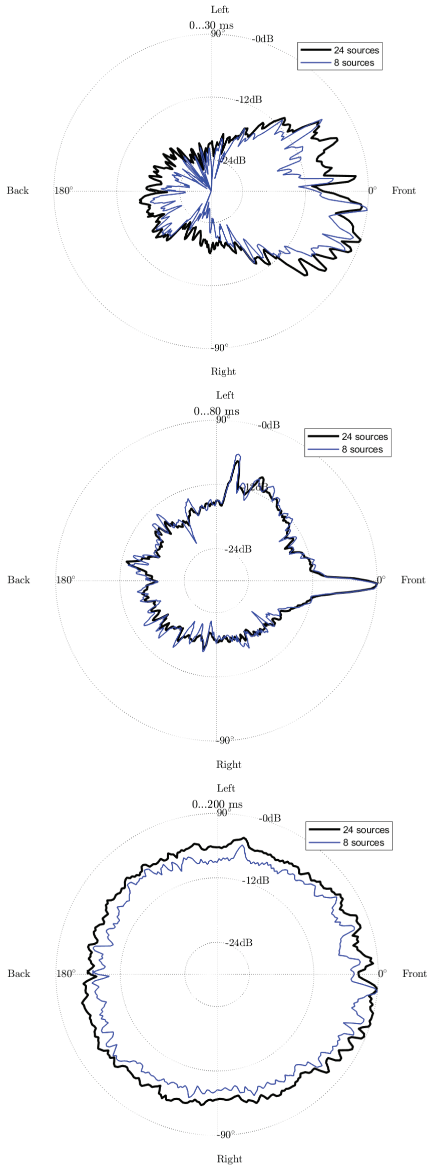

Figure 2. Comparison of energy directions from 3D impulse responses; top: lateral plane, time window 0…30 ms; middle: median plane, time window 0…80 ms; bottom: lateral plane 0…200 ms.

4. PRELIMINARY RESULTS

The method has so far been used in measurements at the Bolshoi Opera Hall in Moscow, in the Sibelius Hall in Lahti as well as some halls with electro acoustic enhancement systems, as part of Henrik Möller's PHD research.
Figures 4 and 5 shows example results.

In both cases, the precision of the analysis, was found to be adequate to make an evaluation of the reflection patterns in the rooms. Although the density of the directions from sound sources is naturally sparser in the reduced configuration, the key directions for prominent reflections and their time-of-arrivals remain informative and comparable to the full 24-source reference. In the 8-source configuration, reflection paths by single sources might be emphasized due to smaller base of data averaging. Therefore, the 8-source visualizations may increase the risk of misinterpretation between a highly local reflection phenomenon and a more general feature of the hall. However, this fundamental factor touches to some extent all possible acoustic measurements.

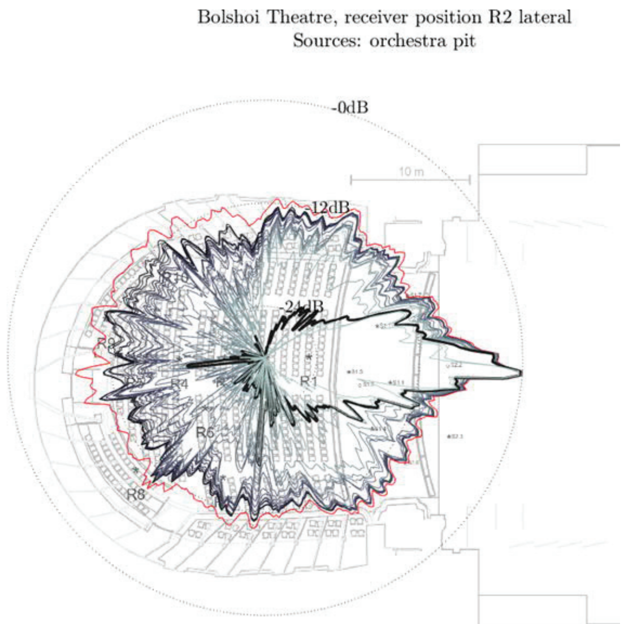

Figure 4. Measured 3D impulse response, lateral plane.

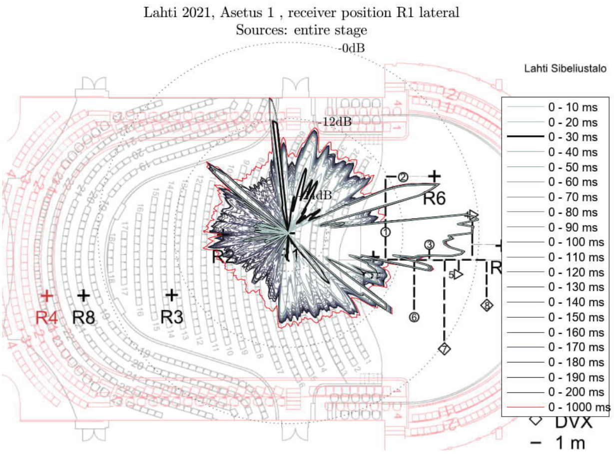

Figure 5. Measured 3D impulse response, lateral plane.

5. CONCLUSIONS

A smaller, more "travel friendly" version of the Virtual Orchestra has been presented. The first measurements done has shown that, for acoustic analysis of the space, the scaled down version, provides sufficient details for acoustic analysis of the reflection patterns. The reduced number of measurement sources may increase the uncertainty of interpreting single reflection patterns from the resulting visualizations.

It is yet to be investigated how well measurements done with the scaled down version can be used for auralization of rooms.

6. REFERENCES

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