# AURALISATION OF CONCERT HALLS USING MULTI-SOURCE REPRESENTATION OF A SYMPHONY ORCHESTRA

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## 1 INTRODUCTION

The multi-source auralisation technique is based on anechoic recordings of each single instrument in the symphony orchestra. Although the accurate synchronisation of the instruments cannot be perfect, the advantages of this technique include increased realism in terms of localisation and apparent source width, and the possibility to compare different orchestra setups and the interaction between the instruments and the hall. In some concert hall designs with audience seats at the sides or behind the orchestra it is particularly interesting to have the possibility to compare in advance different listener positions; the new suggested method should allow to evaluate the balance and blend in such cases. The multi-source auralisation was first presented by the authors[1] in 2007.

## 2 NEW DEGREES OF FREEDOM IN AURALISATION

### 2.1 Recordings in anechoic chamber

The multi-source auralisation technique implies that each musical instrument must be recorded separately in an anechoic environment, see Fig. 1. In order to catch some (limited) information about the directional radiation of the sound, a multi-channel recording method was use, allowing an auralisation technique that includes this directional information[2,3,4].

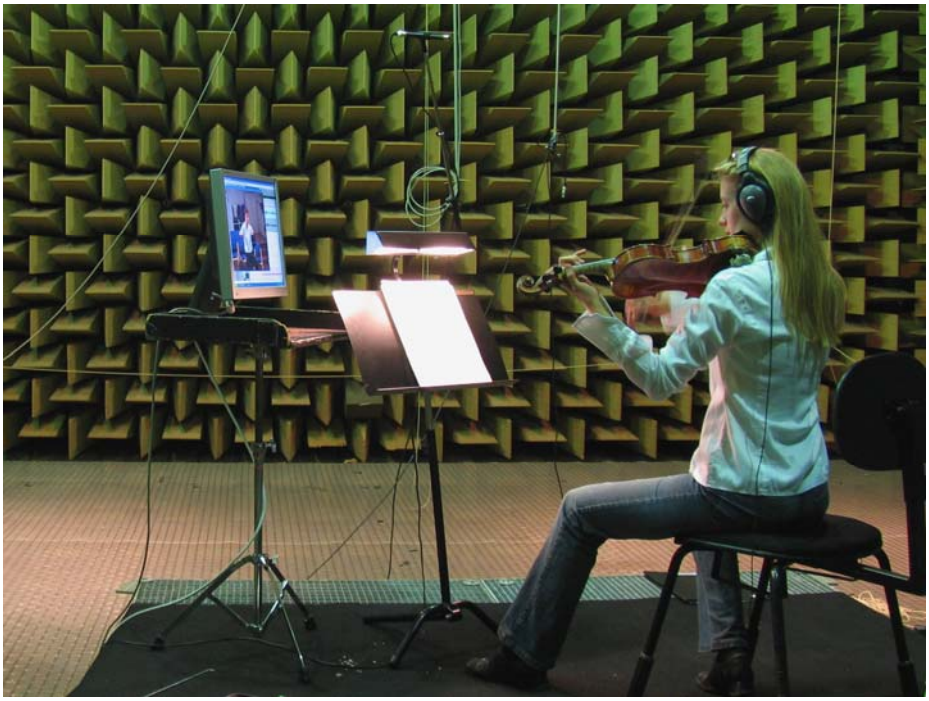

Fig. 1. Recording of a violin part in the anechoic room at DTU, June 2005.

The recordings were made in the large anechoic room at the Technical University of Denmark during June 2005. Five microphones were used in a distance of 3 m from the centre: front, right, back, left, and top. Three different music pieces were recorded, but here is only referred to the Brahms 4$^{th}$ Symphony, beginning of 3$^{rd}$ Movement (duration 1 m 28 s).

One obvious problem in these recordings is the synchronisation between the instruments. Both visual and audio cues were applied; a monitor showed a video recording of a conductor, and a total orchestra recording of the piece was presented through headphones, see Fig. 1. Still, small time differences between instruments were unavoidable.

## 2.2 Orchestra setup on stage

The multi-source method offers several new degrees of freedom in the auralisation. First is the location of the instruments on the stage; a standard setup can be aimed at, but the user has the freedom to try other setups. This implies that the user should have some musical background and knowledge about symphony orchestras.

Whereas the wind and percussion instruments are represented as individual sources each playing a separate part, the strings in a symphony orchestra are playing in groups. Thus the user also has to decide the size of each group of strings, and – as in a real orchestra – this should be decided particularly for each musical piece and within the realistic limits of the concert hall that is considered. So, for a Mozart symphony the string section should be smaller than for a Brahms symphony, whereas a Mahler symphony would require an even larger string section.

In the simulations referred to here, the number of musicians in each string group is simply represented by the number of sources, even though the auralisations may be made from the same recording. As an example the double bass part was recorded from one musician, only, but in the setup six sources were entered to represent the double bass group.

## 2.3 Balance between instruments

When it comes to putting all the instruments together and start listening to an auralisation, another new degree of freedom appears. Since the musicians during the recordings couldn't hear in a realistic way how they would blend into the orchestra, and since there was no conductor to rehearse the orchestra, the sound levels of the instruments may not be in a good balance. So, somebody has to rehearse the simulated orchestra, listening carefully to smaller groups of instruments from the conductor's position in front of the orchestra, and adjusting the level of each instrument to make a good balance. Typically this is done between the string groups, then between the instruments in the wood winds, and similarly in the brass and percussion. Finally, the balance between the groups of instruments is adjusted. This procedure should be done with reference to the score of the music, and obviously it should be done by someone with a sufficient musical background. There is no objective criterion to help in this process; the preferred balance is actually a matter of musical taste. In addition it can be mentioned, that the balance between the instruments is also to some extend influenced by the concert hall in question, and particularly by the surfaces near the stage.

# 3 EXAMPLE – A SIMULATED BRAHMS ORCHESTRA IN A NEW CONCERT HALL

## 3.1 Orchestra setup in the hall

The new Symphonic Hall in Aarhus, Denmark has been chosen as an example for this paper. The Odeon model was kindly made available by Richard Ballinger from COWI, who has been the acoustic consultant on the project in cooperation with Artec, being the acoustic designers for the symphonic hall. A view into the Odeon model of the hall is seen in Fig. 2.

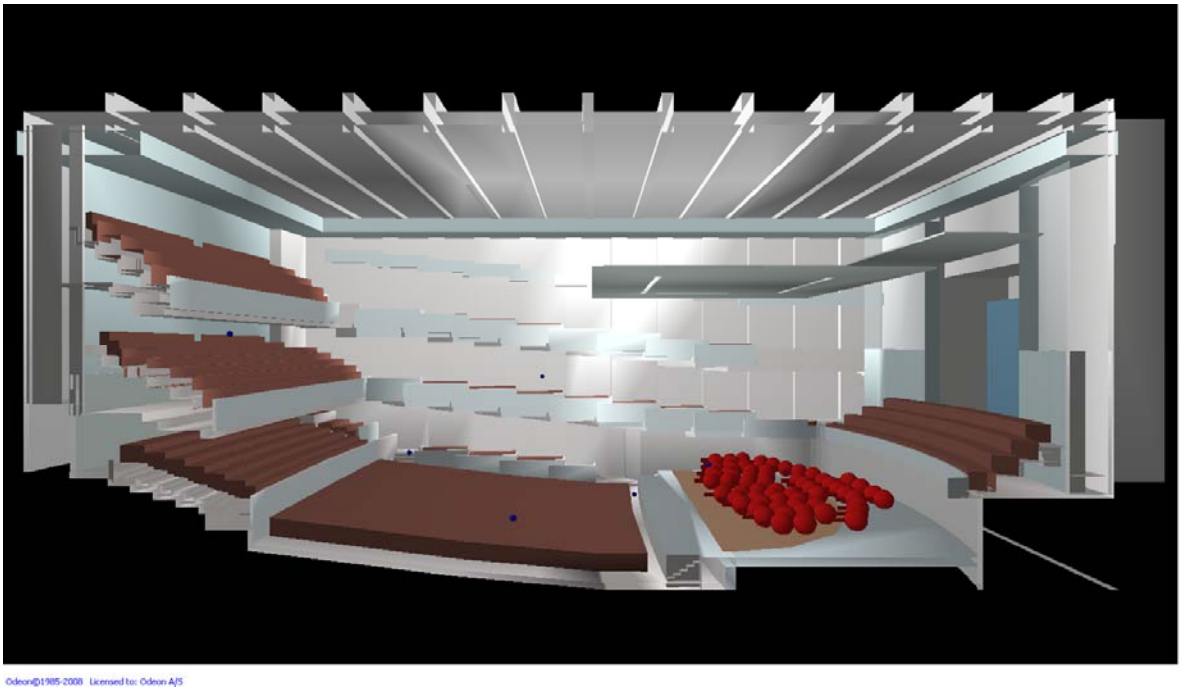

Fig. 2. View into the Odeon model of the Aarhus Symphony Hall. Courtesy of COWI and Artec.

The orchestra setup is for the Brahms 4$^{th}$ Symphony. In Fig. 2 the red points represent the sound sources. As discussed in section 2.1 there are many possibilities for how the orchestra is arranged on the stage. Here has been chosen a setup of the strings with the second violins to the right, opposing the first violins, and the celli and double basses in the left side behind the first violins. The woodwinds are on two rows behind the strings, the French horns are to the right and the trumpets behind, next to the percussion (timpani and triangle), see Fig. 3.

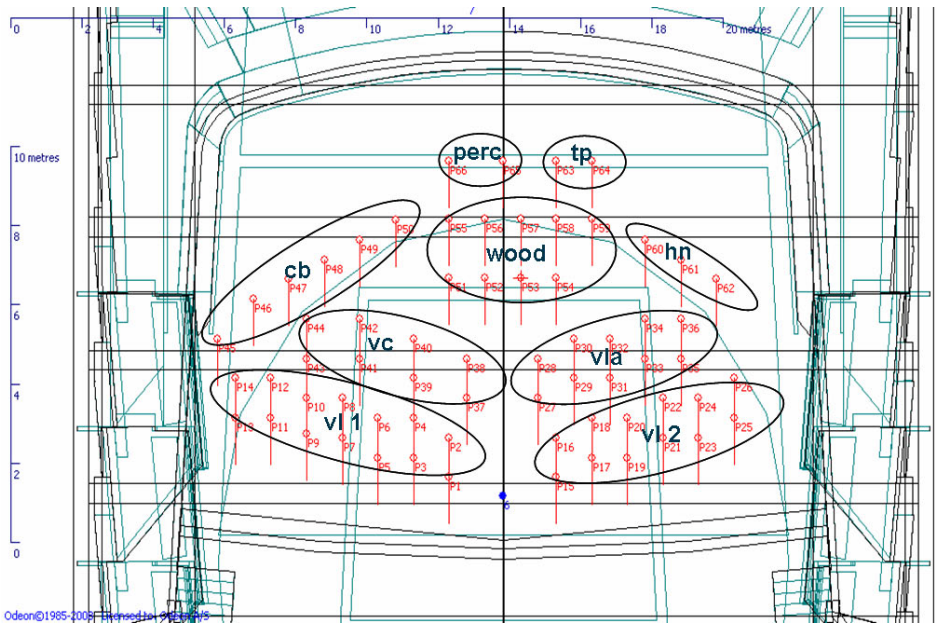


Fig. 3. Position of the sound sources on the stage.

## 3.2 Results

Listening to the auralisations in different receiver positions can be described as follows. With a good sound reproduction system It is possible to localise the different instruments, and thus the apparent source width (ASW) of the simulated orchestra is very good. Comparing a position on the stalls to a position in the first rear balcony, see Fig. 4, it is possible to hear the longer distance to the orchestra and the listener envelopment (LEV) is clearly different.

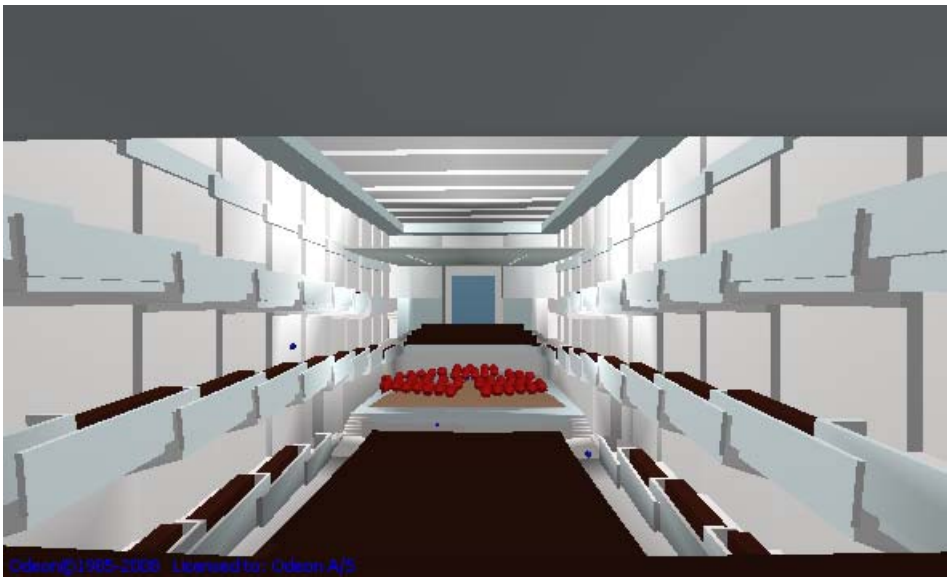

Fig. 4. View from a listener position in the balcony.

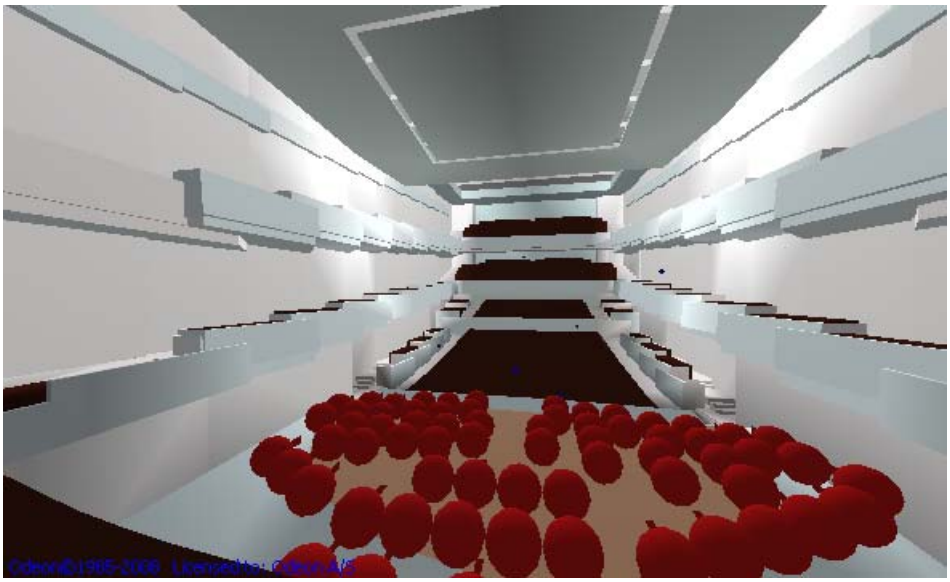

Fig. 5. View from a listener position behind the orchestra.

A listener position behind the stage is also tried, and as could be expected the balance between the instruments is very different in this case; French horns and trumpets are much stronger because they are so close, whereas the violins are relatively weak compared to a listener position in front of the orchestra.

Another interesting comparison is between the hall with a full audience compared to the hall with empty seats. By changing the absorption coefficient of the seating area, it is simple to shift between full and empty hall. Listening to the auralisations demonstrates a clearly more reverberant hall in the empty state.

# 4 ADVANTAGES AND DISADVANTAGES WITH THE MULTI-SOURCE AURALISATION

## 4.1 Improved realism of acoustic simulations

With the proposed multi source auralisation method it is possible to overcome the previous problem of representing a large orchestra by a point source. Thus the new method leads to much more realistic sounding auralisation, and it is possible to evaluate the ASW, the localisation of the instruments and the balance between groups of instruments. The latter may be particularly interesting in a hall with seats behind the orchestra or in other unusual areas.

## 4.2 Suffering musical quality in auralisation

With the current anechoic recordings there are obvious drawbacks in terms of the musical quality of the auralisation. The main problem is the lack of temporal precision; so some instruments may seam to be a little behind the other instruments and this may be quite disturbing. Also the overall musical expression may not be so good, because the usual musical interpretation by the conductor during a performance is not included.

# 5 CONCLUSION AND FUTURE PERSPECTIVES

It is found that the new multi source auralisation technique offers a significant improvement in the realism of orchestra auralisation compared to a representation of the orchestra as a point source. Thus, the possibility of using auralisation as a tool in the design of concert halls is improved, allowing evaluations of ASW, localisation and balance between the instruments, and in particular the evaluation of listener positions that are not in front of the orchestra.

The drawback of the multi source auralisation is that the user has the full freedom in choice of the positions of the instruments on the stage and the dynamic balance between the instruments. Thus, unless a preset orchestra setup is applied, the user has a freedom, which may not be wanted, and which can be both time consuming and demanding. Thus, the possibility to offer of a package-solution that can easily be applied to the user's own hall design will be considered in the future.

The directional characteristics of the musical instruments are important for a realistic orchestra auralisation and there are several possible solutions to this problem. The very simple option, which was applied in these first attempts to apply the multi source method, is to neglect the different directional characteristics and instead apply an omni-directional characteristic to all instruments. A better solution, although not perfect, would be to apply a fixed directional characteristic to represent each musical instrument, and apply this to the anechoic recording from a position in front of the instrument. However, as shown by Otondo & Rindel[3] this method may not be realistic to some instruments that can have very different directional characteristics for every single tone. Thus, a better method is the multi-channel representation of each musical instrument[3,4]. This has previously been done with five and thirteen channels, and in the future this may also be tried with twenty channels. However, considering an orchestra with say sixty musicians that should be represented with twenty channels each, this will require a mix of 1200 auralisations. Although this should not be a major technical problem, it will be very demanding in terms of the management of the large number of simulations.

# 6 ACKNOWLEDGEMENT

The anechoic recordings of the Brahms symphony were made in collaboration with the Tivoli Symphony Orchestra, Copenhagen. The preparation of the multi-channel anechoic recordings of the Brahms symphony was made by Michelle Vigeant as a part of her PhD project in a cooperation between the University of Nebraska-Lincoln and the Technical University of Denmark. The Odeon model of the new Aarhus Symphony Hall was kindly made available by Richard Ballinger from COWI, who has been the acoustic consultant on the project in cooperation with Artec, being the acoustic designers for the symphonic hall.

# 7 REFERENCES

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