ODEON APPLICATION NOTE – Orchestra simulation and auralisation

JHR, July 2015

Scope

This is a guide how to simulate the sound of an orchestra in a room.

The method is intended for concert halls and similar venues. The simulations may be used for different purposes; e.g. to compare the sound in different listener positions within the same hall, to evaluate the balance between the instrument groups in a certain room design, or to compare the sound in a new hall design to that in another hall.

It is also possible to use the orchestra simulations as a music-training tool; to adjust the balance between individual instruments and between groups of instruments, and to evaluate different orchestra settings on the stage.

This application note refers to ODEON version 13, auditorium or combined editions.

Method

The principle is to model each single instrument as a point source with the appropriate directional characteristic. The instruments are located on the stage in a way that can be realistic for the concert hall and the music piece in question. Each instrument has been recorded in an anechoic room, and by convolving with the calculated room impulse response in a chosen receiver position, the instrument is auralised and the acoustics of the hall is inherent in the sound. Each instrument is modelled as a point source with a frequency dependent directivity pattern [1]. This is done for all instruments, string instruments being repeated in several positions to represent the wanted size of the orchestra. By combination of all auralised instruments the sound of the complete orchestra in the chosen receiver position is simulated. The method is further described by Rindel & Christensen [2] and Vigeant et al. [3].

Anechoic recordings for orchestra simulations

Six different fractions of orchestra pieces are available at the time of writing (2015). Two of them are recorded at the Technical University of Denmark in June 2005 [4], and the other four samples were recorded at the Technical University of Helsinki [5].

The wind instruments and percussion were recorded for each part with a few exceptions, where two instruments play the same part. The strings were recorded once or twice for each part, and that means the same recording has to be applied several times to create the number of string instruments required. For instance the 1st violin part was recorded twice, but for the Brahms symphony there should be 14 instruments in the 1st violin group, so each recording has to be applied for seven instruments. The Bruckner recording is an exception, since a larger number of anechoic recordings were made for the strings (eight 1st violins, four 2nd violins and violas and two cellos and double basses).

Figure 1 is a photo from the recording of a violin in the anechoic room. Synchronisation with the other instruments is established visually (monitor with conductor) and auditory (headphones with the sound of the orchestra).

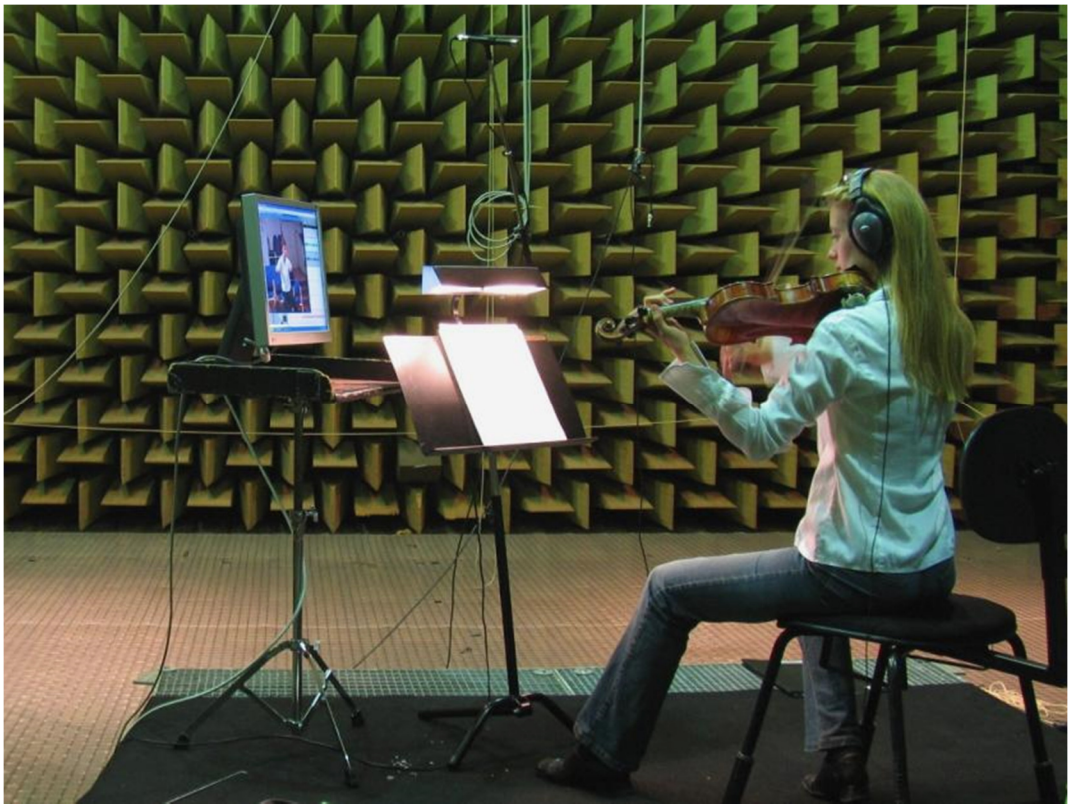


Figure 1. Recording of a violin part in the anechoic room at DTU. The conductor appears on the monitor and the sound of the orchestra in the headphones.

In Table 1 is listed the number of instruments suggested for the six different orchestra recordings.

Table 1. Number of instruments in the six samples of orchestra recordings (the number of strings are suggestions and may be changed according to the size of the hall). A few of the wind instruments are doubled (play in unisono), see comments.

	Brahms	Mozart	Mozart	Beethoven	Bruckner	Mahler
	Symphony no. 4, 3rd movement	Symphony no. 40, 1st movement	Aria from opera "Don Giovanni"	Symphony no. 7, 1st movement	Symphony no. 8, 2nd movement	Symphony no. 1, 4th movement
Duration	1m 28s	1m 51s	3m 47s	3m 11s	1m 27s	2m 12s
1st violin	14	12	8	12	16	16
2nd violin	12	10	6	10	14	14
viola	10	8	4	8	12	12
cello	8	6	4	6	10	10
double bass	6	4	2	4	8	8
flute (piccolo)	2	1	1	2	3	4
oboe	2	2	0	2	3	4
clarinet	2	2	1	2	3	5
bassoon	2	2	1	2	3	3
contra bassoon	1	0	0	0	0	0
French horn	4	2	2	2	8	7
trumpet	2	0	0	2	3	4
trombone	0	0	0	0	3	3
tuba	0	0	0	0	1	1
timpani	1	0	0	1	1	2
percussion	1	0	0	0	0	2
Singer	0	0	1	0	0	0
Total	67	49	30	53	88	95
Comments	hn4 = hn3				fl2 = fl1	fl2 = fl1, fl4 = fl3, cl5 = cl4

Orchestra size and setup

The instruments of the symphony orchestra are divided into four groups; strings, woodwind, brass and percussion. The strings consist of five sections; 1st violin, 2nd violin, viola, cello, double bass, and typical numbers in a large modern orchestra are (16, 14, 12, 10, 8), i.e. 60 strings with 1st violins as the largest group and double bass as the smallest group. A smaller orchestra, e.g. reduced in size for playing music from the 18th or early 19th century (Mozart, Beethoven) could be (12, 10, 8, 6, 4), i.e. 40 strings. String players (except double bass) are seated two by two, sharing one music stand.

The woodwinds are flute (including piccolo), oboe, clarinet and bassoon (including contra bassoon), and typical numbers in a classical symphony are (2, 2, 2, 2). This group is placed in the middle of the orchestra, behind the strings and in front of the brass, and they are usually arranged in two rows with the flutes and oboes on the first row. The four solo players (1st flute, 1st oboe, 1st clarinet, 1st bassoon) are seated close together in the middle, the second players further away from the centre line, and so on if there are more players.

The brass group counts French horn, trumpet, trombone and tuba, and typical numbers in a classical symphony are (4, 2, 0, 0). The percussion group is timpani (two or more instruments played by one person) and possibly more musicians to play on various other percussion instruments. In addition to this the orchestra can include harp and various keyboard instruments.

Figure 2 shows an example of the setup of a large symphony orchestra on the stage.

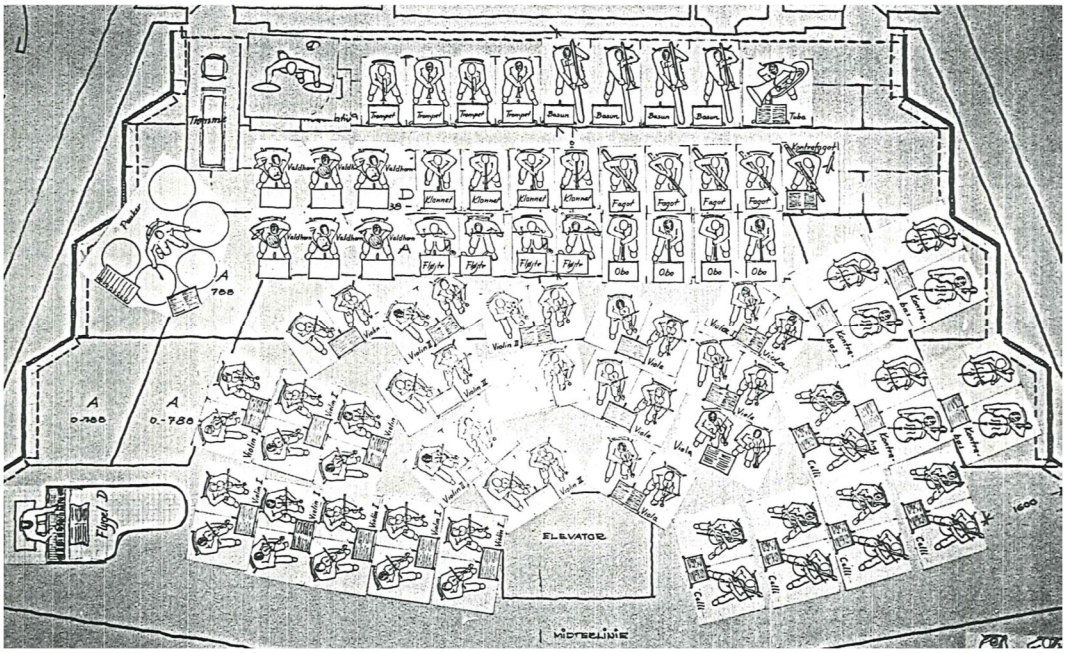


Figure 2. Example of setup for a large symphony orchestra in alternate American seating. Strings: 16+14+12+10+8 = 60. Woodwind: 4+4+4+5 = 17. Brass: 6+4+4+1 = 15. Percussion: 1+1 = 2. Grand piano: 1. Total: 95.

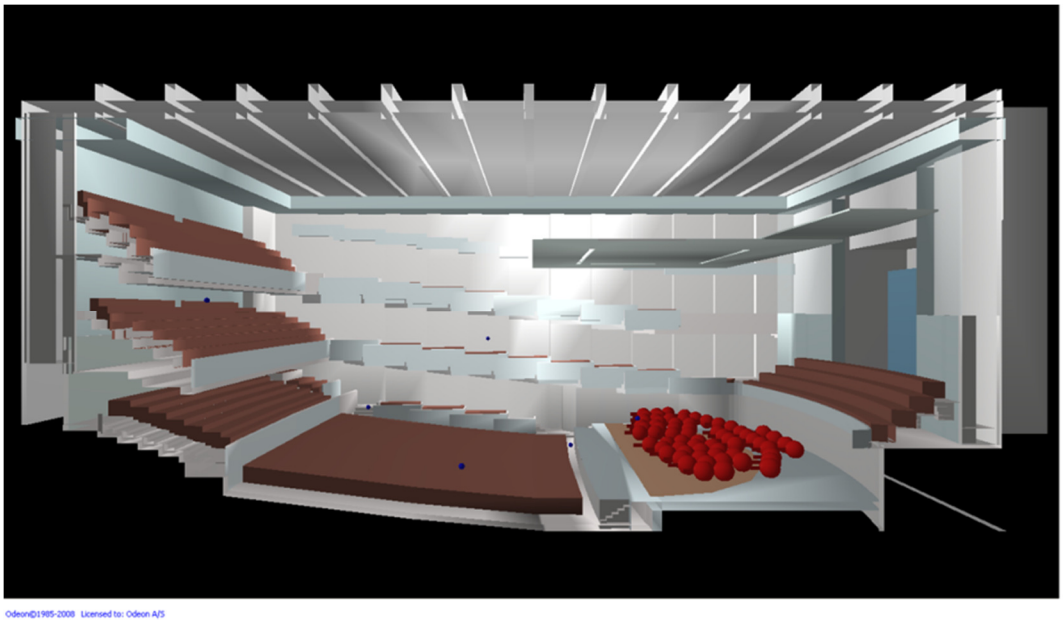


Figure 3. View into the Odeon model of a concert hall with orchestra setup. (Aarhus Symphony Hall, Courtesy of COWI and Artec, from ref. [2]*).*

In Figure 3 is seen an example of an ODEON model of a concert hall with the sound sources representing an orchestra on the stage. The grouping of instruments for the Brahms symphony is shown in Figure 4.

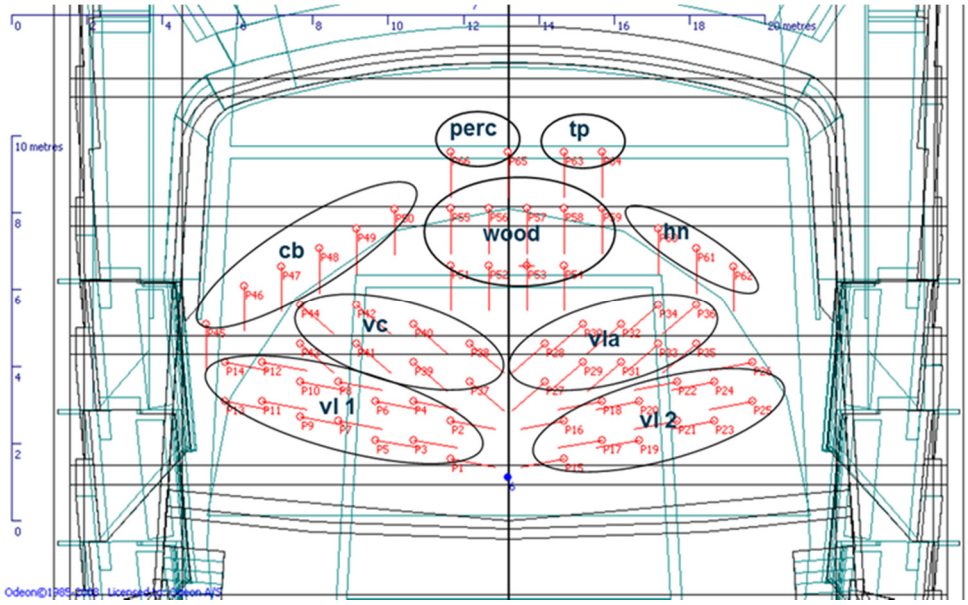


Figure 4. Position of the musical instruments on the stage, here for the Brahms 4th symphony. The German (European) seating for the strings is applied (from ref. [2]).

For further information about orchestra setup and orchestra sizes see the literature [6, 7].

Defining the sound sources

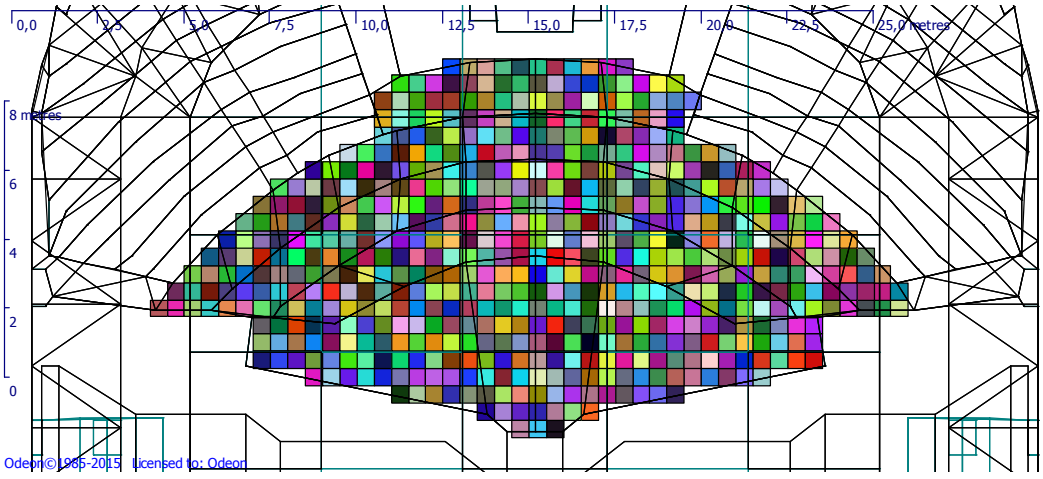


Figure 5. Grid covering the orchestra stage, grid sixe 0.5 m, height above floor 1.0 m.

For the creation of the point sources representing all the instruments it can be a good help first to define a grid covering the stage as shown in the example Figure 5. Open define grid , select the surfaces of the stage, and the size and height of the grid. Then click on one of the cells, where you want a point source and press *Shift+P*. Continue until all point sources are created, see Figure 6.

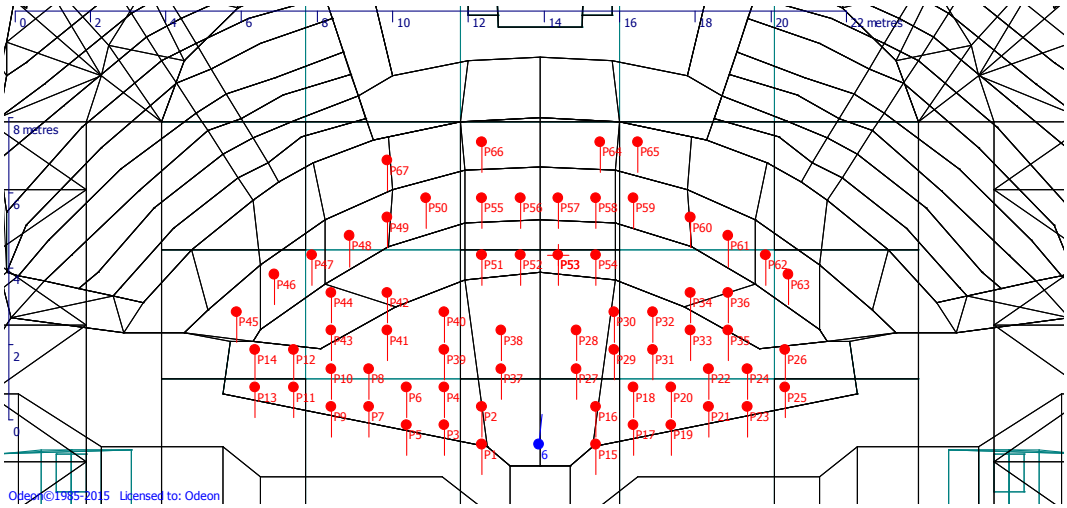


Figure 6. The 67 sources for the Brahms orchestra, all defined from the grid in figure 5, but still with the default directivity and orientation.

The point sources are by default omni-directional and have a default direction. So, the next step is to assign the proper directivities and turning the source in the right direction. When several sources share the same directivity and direction it is useful to apply the macro-function  in the *Source-Receiver List*. So, in this example the 1st violins are sources 1-14, and the macro is setup as shown in Figure 7.

Similarly for the 2nd violins (sources 15-26), violas (sources 27-36), celli (sources 37-44) and double basses (sources 45-52), and then for each group of wind instruments. The source directivities are found in the subdirectory "*Musical instruments*". Directivities are available for most instruments in the orchestra, except the double bass, tuba, timpani and the percussion, which are assigned omni source directivity.

The directivities of musical instruments applied here are from measurements performed in 2002 at the Technical University of Denmark by Felipe Otondo during the DOREMI project. Measurements were made in an anechoic room with 45° resolution both in the horizontal plane and the frontal vertical plane. Results for a number of tones were averaged to get the octave band directivity. The downward direction was not measured, but the downward directivities were interpolated between the nearest measured data.

The directivity of a singer is from data published by Marshall & Meyer [8]. For a detailed discussion of the directivity of symphony orchestra instruments see Pätynen & Lokki [9].

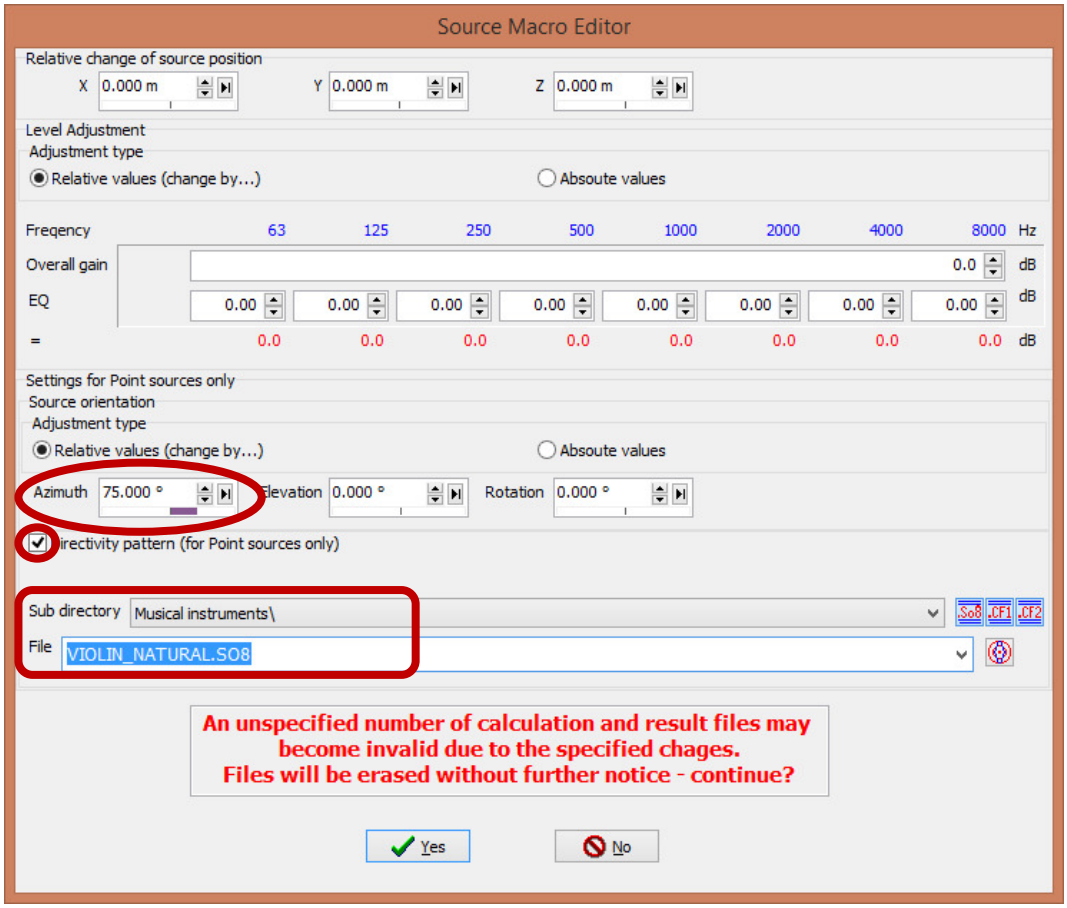


Figure 7. The Macro for assigning directivity to the group of 1st violins.

Preparing the job list

When all the sources are ready, the job list is set as shown in Figure 8. There must be one job for each instrument or group of instruments using the same sound recording. In the example in Figure 8 the 14 1st violins are divided into two groups, a and b, with seven point sources in each, because two anechoic recordings will be used.

For the Brahms symphony a total of 24 jobs are used, see Figure 9. It is very important that all jobs have the same receiver for calculating the impulse response, receiver R2 in this example. It is also necessary that the aiming point of the receiver is the same in all jobs, source 53 (1st oboe) in this example. If these conditions are not followed, it will not be possible to create a mixing of the results for all the instruments.

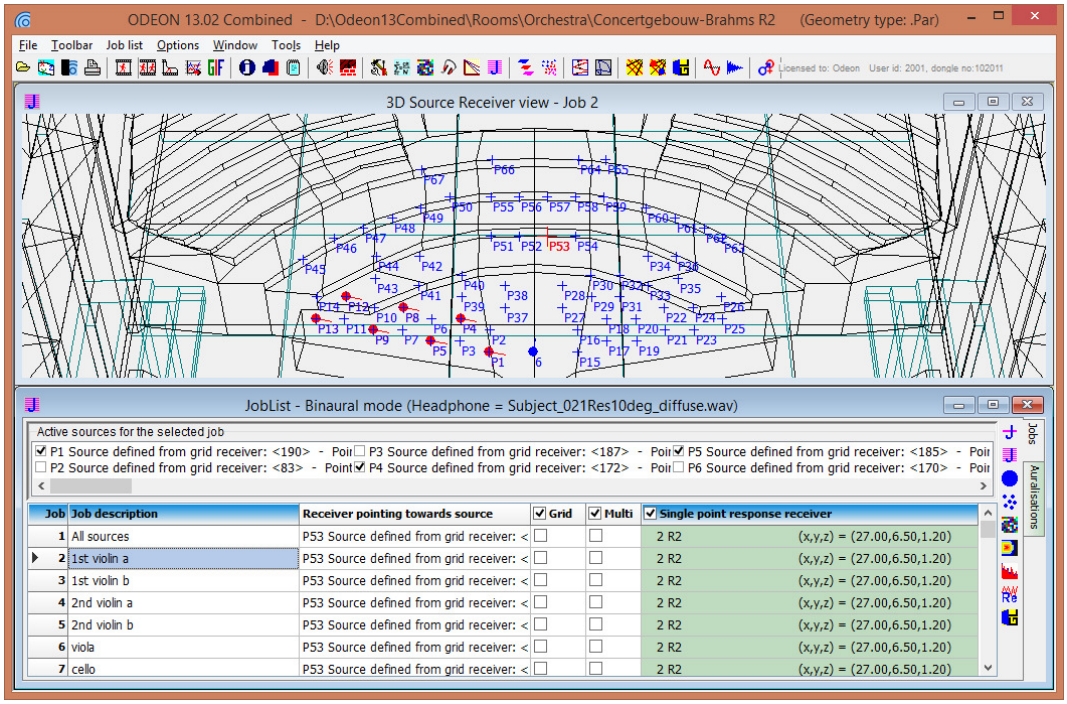


Figure 8. Starting the job list. Job no. 2 is for half of the group of 1st violins, sources P1, P4, P5, P8, P9, P12, P13. Job no. 3 will use the other half of this group of instruments.

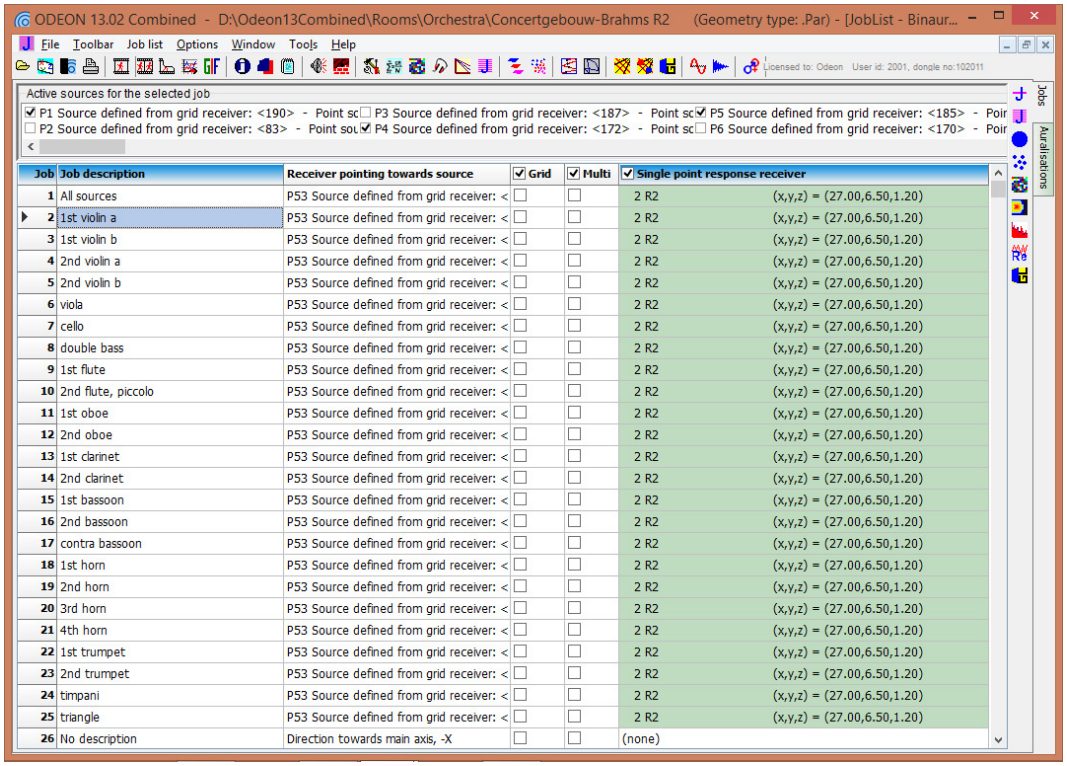
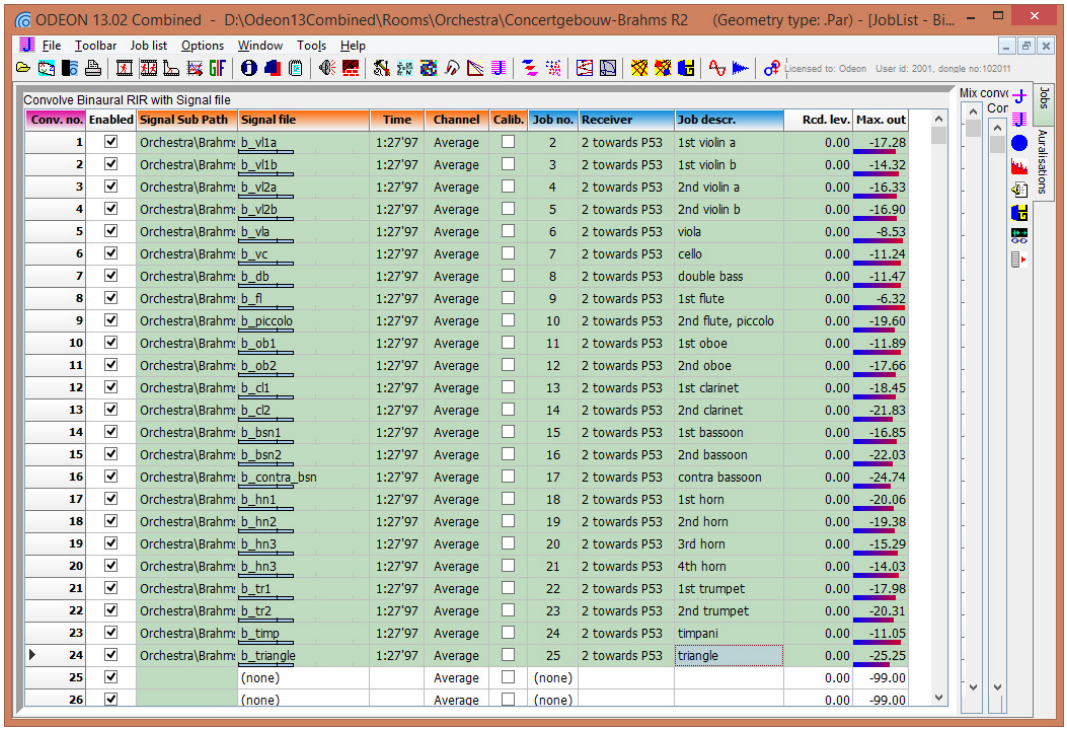


Figure 9. The job list for the Brahms orchestra (job 1 – all sources, is not used). NB: All jobs must have the same receiver and point at the same aiming point (the 1st oboe in this example).



Conv. no.	Enabled	Signal Sub Path	Signal file	Time	Channel	Calib.	Job no.	Receiver	Job descr.	Rcd. lev.	Max. out
1	☑	Orchestra\Brahm	b_vl1a	1:27'97	Average	☐	2	2 towards P53	1st violin a	0.00	-17.28
2	☑	Orchestra\Brahm	b_vl1b	1:27'97	Average	☐	3	2 towards P53	1st violin b	0.00	-14.32
3	☑	Orchestra\Brahm	b_vl2a	1:27'97	Average	☐	4	2 towards P53	2nd violin a	0.00	-16.33
4	☑	Orchestra\Brahm	b_vl2b	1:27'97	Average	☐	5	2 towards P53	2nd violin b	0.00	-16.90
5	☑	Orchestra\Brahm	b_vla	1:27'97	Average	☐	6	2 towards P53	viola	0.00	-8.53
6	☑	Orchestra\Brahm	b_vc	1:27'97	Average	☐	7	2 towards P53	cello	0.00	-11.24
7	☑	Orchestra\Brahm	b_db	1:27'97	Average	☐	8	2 towards P53	double bass	0.00	-11.47
8	☑	Orchestra\Brahm	b_fl	1:27'97	Average	☐	9	2 towards P53	1st flute	0.00	-6.32
9	☑	Orchestra\Brahm	b_piccolo	1:27'97	Average	☐	10	2 towards P53	2nd flute, piccolo	0.00	-19.60
10	☑	Orchestra\Brahm	b_ob1	1:27'97	Average	☐	11	2 towards P53	1st oboe	0.00	-11.89
11	☑	Orchestra\Brahm	b_ob2	1:27'97	Average	☐	12	2 towards P53	2nd oboe	0.00	-17.66
12	☑	Orchestra\Brahm	b_cl1	1:27'97	Average	☐	13	2 towards P53	1st clarinet	0.00	-18.45
13	☑	Orchestra\Brahm	b_cl2	1:27'97	Average	☐	14	2 towards P53	2nd clarinet	0.00	-21.83
14	☑	Orchestra\Brahm	b_bsn1	1:27'97	Average	☐	15	2 towards P53	1st bassoon	0.00	-16.85
15	☑	Orchestra\Brahm	b_bsn2	1:27'97	Average	☐	16	2 towards P53	2nd bassoon	0.00	-22.03
16	☑	Orchestra\Brahm	b_contra_bsn	1:27'97	Average	☐	17	2 towards P53	contra bassoon	0.00	-24.74
17	☑	Orchestra\Brahm	b_hn1	1:27'97	Average	☐	18	2 towards P53	1st horn	0.00	-20.06
18	☑	Orchestra\Brahm	b_hn2	1:27'97	Average	☐	19	2 towards P53	2nd horn	0.00	-19.38
19	☑	Orchestra\Brahm	b_hn3	1:27'97	Average	☐	20	2 towards P53	3rd horn	0.00	-15.29
20	☑	Orchestra\Brahm	b_hn3	1:27'97	Average	☐	21	2 towards P53	4th horn	0.00	-14.03
21	☑	Orchestra\Brahm	b_tr1	1:27'97	Average	☐	22	2 towards P53	1st trumpet	0.00	-17.98
22	☑	Orchestra\Brahm	b_tr2	1:27'97	Average	☐	23	2 towards P53	2nd trumpet	0.00	-20.31
23	☑	Orchestra\Brahm	b_timp	1:27'97	Average	☐	24	2 towards P53	timpani	0.00	-11.05
▶ 24	☑	Orchestra\Brahm	b_triangle	1:27'97	Average	☐	25	2 towards P53	triangle	0.00	-25.25
25	☑		(none)		Average	☐	(none)			0.00	-99.00
26	☑		(none)		Average	☐	(none)			0.00	-99.00

Figure 10. In the auralisation list the connection is established between anechoic recordings and calculated impulse responses. For example convolution no. 1 is violin 1a recording combined with job no. 2.

In the example in Figure 10, the calculations have been run and the *max. out* (rightmost column) shows values in the range -6 to -25 dB, which is good. In case of overload (> 0 dB) the row turns red instead of green. In that case, and also if the max. values are very low, it is necessary to adjust the global level in the *auralisation setup* (see below).

Auralisation through headphones or loudspeakers

Before the calculations start the *auralisation setup* window  is opened. Here it is decided whether the output should be for binaural listening through headphones or for surround sound presentation through loudspeakers, or both, see Figure 11. In case of overload (or too low output) the overall recording level must be changed.

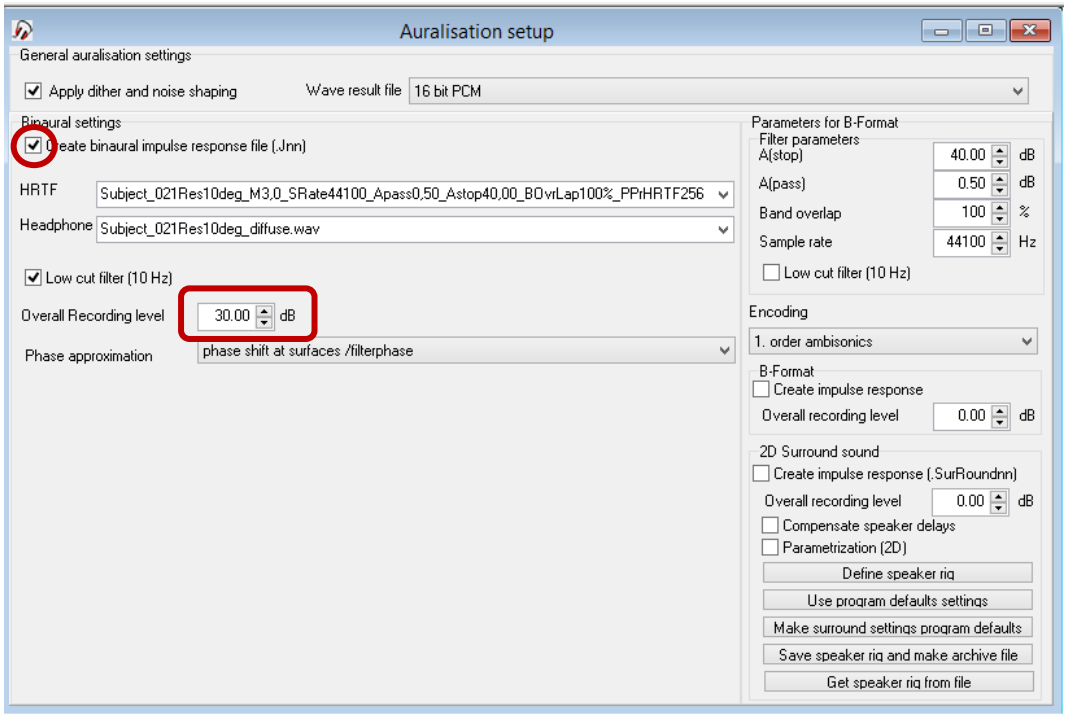


Figure 11. The auralisation setup, here for binaural presentation, only.

The auralisation mixer

The mixer can be used to combine any selection of instruments from the list of convolutions. For instance, this can be used for simulating a group rehearsal as in Figure 12, where mix no. 2 takes the strings alone, mix no. 3 only the wood winds and mix no. 4 the brass and percussion. With a limited number of instruments it is easier to hear the balance between each instrument, and if you want to adjust the balance, it can easily be done by changing the *mix. level* (in dB) of single instruments.

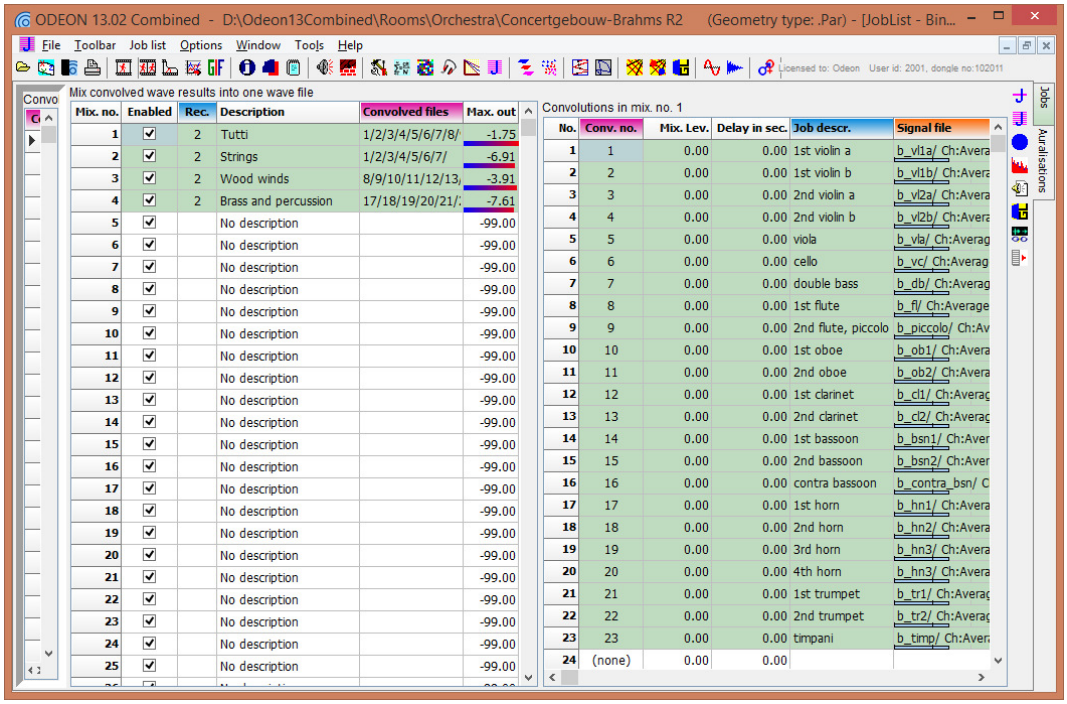


Figure 12. The auralisation mixer. Here mix no. 1 is set to combine convolutions no. 1 through 23.

How to change the listener position

An interesting application of the orchestra auralisation is to compare different listener positions in a hall. Before the position is changed, it is recommended to create a copy of the room model for later comparison. Since the receiver position is used in all jobs, the easiest way to change the receiver position is actually to open the *source-receiver list* and change the coordinates of the receiver, which is used in the job list. Then run all jobs again.

Alternatively, you can create additional jobs identical to the original ones, but with a different receiver. The maximum number of jobs is 300. Then a new series of convolutions and mixes can be added within the same room model. This method will allow you to compare different listener positions within the same room model.

How to import the orchestra setting from another room

Moving an orchestra setup from one room to another is not easy, and since halls are always different in size and geometry it may be better to create the setup from scratch. However, if the size and geometry of the stages are not too different, it may be possible to reuse the orchestra setup from another room.

First you should make sure that the orientation in the coordinate system is the same. If this is not the case, the new room should be reoriented and maybe also translated by use of the functions *CoordSys* and *MTranslate* in top of the room file, see Figure 13. The room file is opened in the text editor by clicking the icon . Use the F1 Help for an explanation of how to use these functions. Then save the room file and reopen in ODEON.

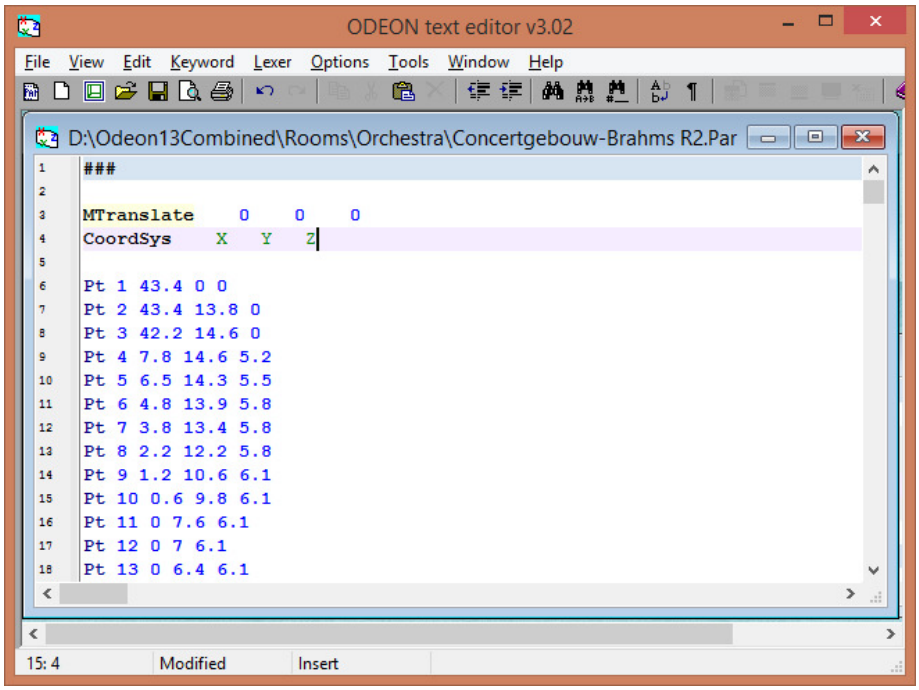


Figure 13. The room file is opened in the text editor and the functions for translation and change of coordinate system inserted in line 3 and 4.

To make the import to the new room, open *File/Import settings from another room*. Then select the room from which the settings should be imported. A menu pops up like the one in Figure 14. Check on *sources, receivers (source receiver list) and job list*.

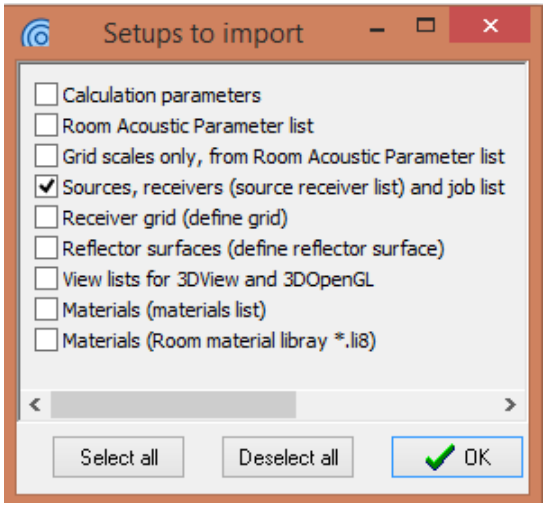


Figure 14. Import orchestra setting including job list from another room.

After import it may be necessary to adjust the position of the instruments on the stage. The *macro* function in the source-receiver list as described above will prove useful for this. The whole orchestra or selected groups of instruments can be moved with the macro.

References

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