ODEON workshop, BNAM 2024, Espoo, 23 May 2024

Welcome to learn about **measurements**, **simulations**, and **auralisations** with the ODEON room acoustics software. In this hands-on workshop you will learn how to do measurements using sine sweep signals, the ODEON Omni source and a 3D Ambisonics microphone. You will also work with a room model of an auditorium, with special attention to the surface materials. After import of some measured room impulse responses, you will try using the genetic material optimiser to find realistically adjusted absorption data of the materials. Further on, you will work with grid mapping of various room acoustic parameters, detailed analysis of the impulse response in selected receiver positions, and listen to you own auralisation. Try the new 360 auralisation with head rotation. Finally, you will have the opportunity to use ODEON's multi-source auralisation to play with a symphony orchestra, including possible adjustments of each musical instrument. No previous experience with ODEON is required.

Please make sure to download the latest version of the **ODEON Free Demo Version *(18.12)*** from https://odeon.dk/downloads/odeon-installations-updates/. You should bring your own computer with the above software installed. It is also recommended to bring a headphone.

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PROGRAM

1 **Measurements with the sine-sweep method**
Inverse filter, Ambisonics, BRIR Auralisering

2 **Sources, receivers, and simulating a point response – An auditorium**
The basic elements of a simulation. Materials. Sources and receivers. Room setup and calculation parameters.
The point response. The BRIR and auralisation with headphones. 360 auralisation with head rotation.

3 **Comparing measurements and simulations - The Genetic Material Optimizer**
The multi-point response. Import of measured data and comparison with simulated results in the multi-point response. Adjusting material data in a model of an existing hall.

4 **Using the grid response - An open-air theatre**
The example here is an ancient Roman theatre. The possible echo problems can be identified in the grid response and further analysed in the point response.

5 **BIM-support**. Demo of import of advanced room models.

6 **360 auralisation**
Hagia Sophia

7 **Multi-point auralisation - A concert hall**
The sound from a symphony orchestra in a concert hall is created for auralisation with the multi-source technique, which uses anechoic recordings of each musical instrument.

Case 1 - Measurements with the sine-sweep method

Demo of measurements using the Odeon Omni source, Inverse filter, a 3D field microphone, and Ambisonics auralisation with a measured binaural room impulse response (BRIR).

The sine-sweep measurement tool is found under the icon in the main toolbar.

Case 2 – An auditorium

Auditorium 21, Technical University of Denmark

1. Open the room

1.1. Click on 'Open Room' and the subfolder 'GeneticMaterialOptimization - Auditorium21DTU'. Open 'Auditorium21 at DTU'. The room comes with pre-defined materials, sources and receivers.

The room opens in 3D View . Use the mouse to turn, move, and zoom the model. The space bar will switch between some pre-set views. Click 'H' to highlight a surface, and click 'N' to see the coordinates of the corner points.

1.2. Open the 'Odeon Editor' to see how the room is defined by point coordinates and surfaces.

1.3. The 'Room Information' gives some basic data, e.g. the number of surfaces in the room.

2. Materials

2.1. Open the 'Material List' .
On the left side of the window are the surfaces in the room, and on the right side the library of materials with frequency dependent absorption coefficients. Scroll through some materials and notice how the colour behind the number changes according to the absorption coefficients. These are the '*acoustic colours*' applied in ODEON.

2.2. Open 'Quick estimate' to get estimated reverberation times according to Sabine and other statistical formulas. The page 'Alpha' displays the absorption coefficients of the applied materials. NB: In this model, some of the materials are generic and may not match the real materials in the room. We come back to this in the next case.

2.3. We make no changes for now, so you can close the materials window. Then open the '3D render' and see the acoustic colours in action. Use the mouse to turn, move, and zoom. Use the up/down arrows to move forward or back. For further information, press F1 (Help).

3. Investigate ray tracing

3.1. Open the '3D Investigate ray tracing' .

Source P1 is made active, and try to click 'Single forward' a couple of times to see the start of a ray. Then click 'Single ray' a couple of times, and finally 'Free run' . This illustrates the ray tracing, which is the basis for the acoustic simulations.

4. Global RT

4.1. Open the 'Global RT' and the ray tracing starts automatically. The attenuation of the sound energy as function of time is calculated from the history of all rays simultaneously. The calculations must be stopped manually. Then the reverberation times T_{20} and T_{30} are displayed.

5. Point response

5.1. Open the 'Job list' . The job list is used to select sources and receivers for a simulation.

5.2. Select a job, e.g. number 3, and then start a calculation by clicking 'Run single job' . When ready, click on 'View Single point response' . Here there are many options.

5.3. 'Parameter bars'. Use the left-right arrows to switch parameter. The actual data are found in 'Energy parameters'.

5.4. 'Decay curves'. Use the dot in the right side of the display to switch between decay curves for all frequencies, and detailed decay curves for a single octave band. The default time resolution is 1 ms, but this can be decreased by hitting Shift+R.

5.5. 'Reflectogram' can be shown alone or together with '3D reflection paths'. Use Ctrl+T to toggle between these displays.

The colour code for the reflections can be set for different applications, use Alt+S to change this. In the reflectogram, it is possible to zoom on a group of reflections (use the left mouse button from upper left to lower right corner of the zoom area). Zoom out by doing the opposite (from lower right to upper left). It is also possible to click on a single reflection in the reflectogram, and it will be shown in the 3D reflection paths.

5.6. BRIR (binaural room impulse response)

Use headphones, and listen to the impulse response . A better impression of the sound in the simulated room is obtained by using the 'Streaming convolution' and listening to the signal file 'Clapping (slow)'. This corresponds to what most acousticians use to do in order to get a feel for the acoustics of a room. Many other sound files with music or speech are also available. Compare with the original anechoic recording by checking: 'Listen to input signal'.

Case 3 - Comparing measurements and simulations - The Genetic Material Optimizer

1. Multi-point response

1.1. Continue with the 'Auditorium21 at DTU'. In the 'Job list', select job no. 1 where the 'Multi' option is ticked. Then start a calculation by clicking 'Run single job' . When ready, click on 'View Multi point response' . Here there are many options.

1.2. The first tab to be displayed is '3D Sources and Receivers'. Here it is possible to make groups of selected receivers, but for now just leave it with all receivers.

1.3. Look at the tab 'Statistics' to see average, min, max and standard deviation of simulated (and measured) acoustical parameters. Use the left-right arrows to switch parameter. A table with the actual data is found in 'Energy parameters'.

1.4. 'Simulated versus Measured'. Parameters are selected as above. Here are two plots at the same time; the one to the left shows variation with position for one octave band, and frequency is changed with the up/down keys. The one to the right shows variation with frequency for one position, and the receiver is changed with the R key.

1.5. Take a look at the results in 'Statistics'. The calculated reverberation times, e.g. T_{20}, are very different from the measured results. At most frequencies the measured RT is much longer than the calculated RT. The most obvious explanation is, that some of the absorption data applied for the calculations are wrong, i.e. the acoustical behaviour of some materials is not as expected.

1.6. Open '3D Render' and notice the position of sound absorbing materials according to the acoustic colours.

2. Use Material optimizer

By comparison of measured and calculated results, it is possible to tune the absorption coefficients of the materials to give the best possible match. It is recommended to have selected appropriate room acoustic parameters and entered appropriate room settings. In particular, the time needed for a single multipoint response should not be longer than necessary.

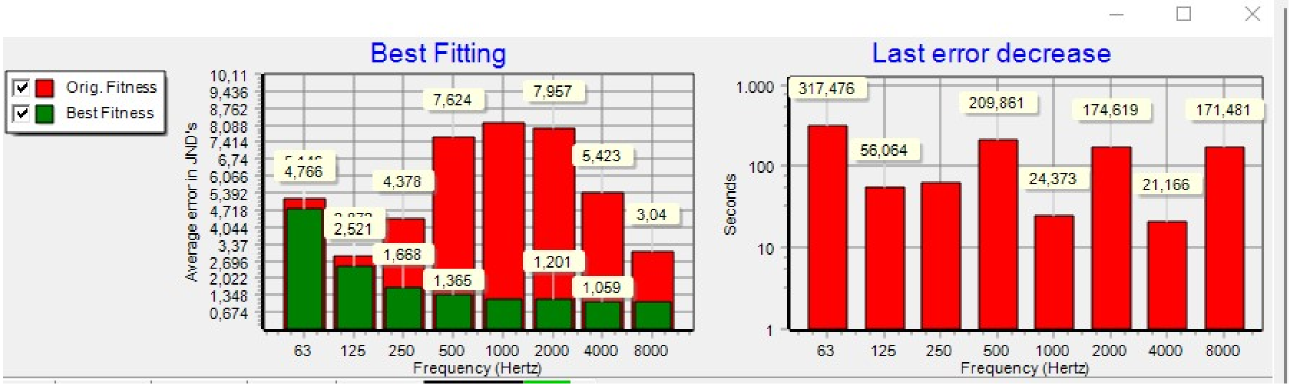
2.1. Set the number of late rays to be used for the calculations. This is done in the 'Room setup' . The number of late rays was originally 16 000, which is much more than necessary for reliable results. Click the 'Engineering' bar, and the number of late rays change to 1 000.

2.2. In the top menu bar, go to the Genetic Material Optimizer . Jobs 1 and 2 are both used for the optimization, which means two source positions and six microphone positions (active jobs in upper left corner).

2.3. Eleven different materials are used in this room model. Five of them are generic materials with frequency-independent absorption (# 1, 5, 9, 10, 11). It is important that materials with large area and high uncertainty are allowed to change within a sufficiently wide range during the optimization. Other materials, particularly those contributing very little to the total absorption area of the room, should be set with search range = 0 %. Thus, try setting the search range to 100 % for no. 1, 6, and 11, and 50 % for no. 2, 3 and 10, and 0 % for the rest.

2.4. Click on 'Start Calculation' near the top-left of the window.

2.5. Click on 'Stop calculation' when either: **a)** The average error in JNDs for the best fitting has gone low enough ('Best Fitting' graph), or **b)** it has been long since the last error decrease after many generations/individuals ('Last error decrease' graph).



- Remember that this process is iterative and will not finish until stopped manually.

2.6. Close the Genetic Material Optimizer, and 'confirm' to adjust the absorption coefficients.

2.7. Re-run the multi-point responses, and look again at the 'Simulated versus Measured and Targets'.

2.8. Open '3D Render' and notice the change of the acoustic colours, compared to the original materials (1.2 above).
It is possible to switch back and forth between original and revised materials. This is done within the 'Material list' using the 'Material archive' .

Case 4 – Using the grid response - An open-air theatre

Aspendos Roman theatre, Turkey

1. Open the room

1.1. Click on 'Open Room' , go into the folder 'ERATO Project' and find: 'Aspendos_Present_Empty_With_Stage'. The room comes with pre-defined materials, sources and receivers. Measurement results are also included.

1.2. Open the 'Job list' . Select job 1 and calculate the 'Multipoint response' by clicking 'Run single job' . When ready, click on 'View Multi point response' .

1.3. Take a look at the results in 'Simulated versus Measured and Targets'. Find the results for the parameter 'Echo (Dietsch)' at 1000 Hz. If this parameter exceeds 1.0 there is a high risk of a disturbing echo. None of the seven measured receiver positions exceed this limit, although some are close to the limit.

2. Doing a grid response calculation

2.1. Go to the 'Define grid' and prepare for a grid calculation.

2.2. Relevant surfaces for a receiver grid are pre-selected, but the resolution is too fine for calculations to be made within a reasonably short time. Click on the grid icon in the middle to see what the grid looks like. Press D to make the picture clearer. The distance between receivers is 1.0 m, which is quite small. Change this to 2.0 m a take a look at the new grid. Then close the 'Define grid' window.

2.3. In the 'Job list', activate the grid calculation in job 1, and then start running the job. This calculation may take a few minutes.

3. Use the grid response to find echoes

3.1. In the grid response, look at the parameter 'Echo(Dietsch)' at 1 000 Hz.

3.2. Press the 'I' key to disable interpolation. Select a receiver point in the grid with a high value > 1, and add this point to the receiver list with the Shift+R shortcut.

3.3. In the Job list, define a job with the source and this new receiver. Then run the Single Point Response.

3.4. In the Single Point Response, go to the 'Reflectogram'. The colour code of the reflections can be set for music, speech and more by hitting Alt+S. With the scale 'Speech', the reflections after 50 ms that can cause echo are shown in blue.

3.5. Hit the Alt+T key three times to look at each single reflection. This will display only the surfaces from which rays are reflecting, which can be useful if something has to be done to avoid the echo.

4. BRIR (binaural room impulse response)

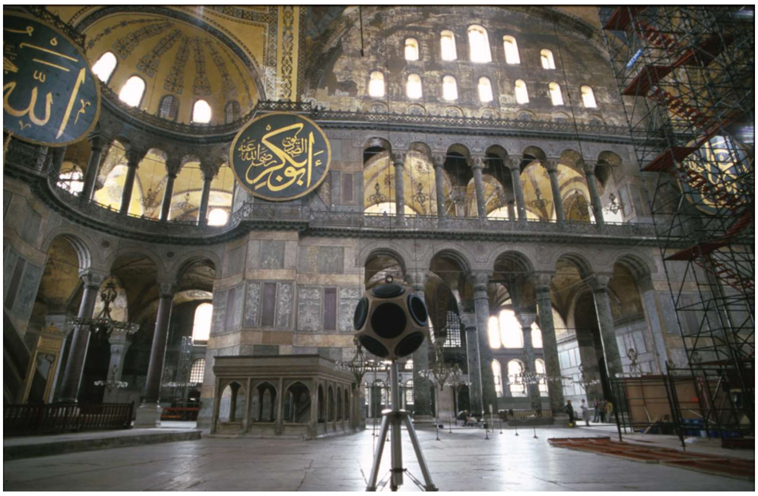
4.1. Use headphones, and listen to 'Streaming convolution' with the signal file 'Clapping (slow)' and other signals.

Case 5 - BIM-support.

Demo of import of advanced room models.

Case 6 - 360 auralisation

Hagia Sophia, Istanbul



1. Open the room

1.1. Click on 'Open Room' , go into the folder 'CAHRISMA Project' and find: 'Hagia Sophia'. The room comes with pre-defined materials, sources and receivers. Measurement results are also included.

1.2. Open the 'Auralisation Setup' – the Auralisation output has been selected to B-Format impulse response, which allows 360° Auralisation (Binaural Auralisation with head rotation allowed over headphones). In the lower left corner it is possible to select the ambisonics order (1st, 2nd or 3rd order). 3rd order allows slightly better spatial quality at the price of higher disk storage space and calculation time. Your choice (try with 3rd order - Odeon is fast 😉).

1.3. Open the 'Job list' and run all jobs (Alt+A shortcut).

1.4. When calculations have finished, select one of the first three jobs and open 'View Multipoint response' and notice the reverberation time of this unique room.

2. Auralisation with headphones

2.1. Then select the Auralisation tab-sheet in the Joblist. Select the first convolution (Job no. 4, Receiver 1 towards P1) Here the receiver is close to source 1.

2.2. Click the 360 Auralisation to play. NB: The sound card must be set to 2 channels, 16 or 24 bit, 44100 Hz.

2.3. Click the mouse in the 3D rendering and move mouse to change head orientation (left, right, up, down)

2.4. Change receiver position in the receiver dropdown list (top right side) and listen to the auralisation in other receiver positions.

Case 7 – A concert hall

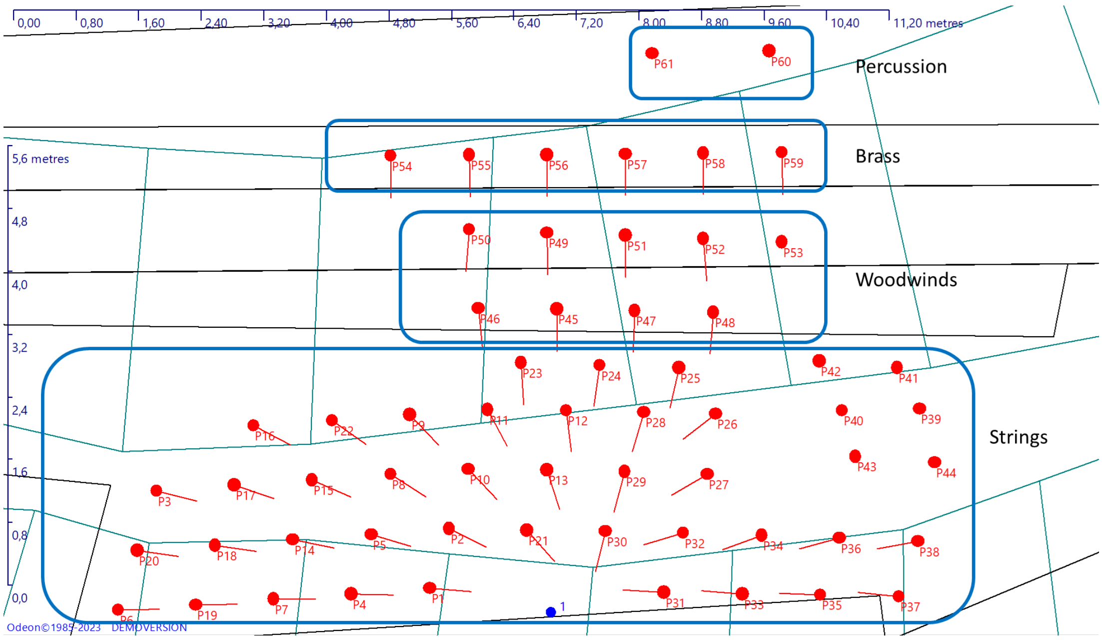
Liederhalle, Stuttgart

1. Open the room

1.1. Click on ‘Open Room’ , go into the folder ‘Liederhalle_Brahms_Symphony4_3rdmov’ and open the room with the same name. The room comes with pre-defined materials, sources and receivers.

1.2. Hit ‘3D Render’  in the toolbar to view the room. Hit ‘J’ once the show all sources and receivers. The receivers are in six different locations in the auditorium plus one receiver at the conductor’s place.

1.3. Open the ‘3D Source Receiver view’  to display all sources and receivers. A total of 61 sources are defined representing the musical instruments in a symphony orchestra. More details about the sources can be seen by zooming in and hitting Shift+D.



1.4. The orchestra is set for the beginning of a movement in a symphony by Brahms.
Each single instrument has been recorded in the anechoic chamber at the Technical University of Denmark. For the strings, only one or two individual recordings were made, and to form e.g. a full violin section – extra violins automatically were created using the *Odeon Audio Effects* tool, which is included in the full versions of Odeon Auditorium and Combined.

2. Preparing an auralisation at the conductor's place

2.1. Open the 'Job list' and go to the 'Auralisations' page. This is divided into three parts; the left side for each instrument by combining the source with the corresponding anechoic recording. The middle part is used to set up a mix of instruments, either a selected group of instruments or the full orchestra. The rightmost part of the window is where the actual selection of instruments in each mix is found.

2.2. In order to simulate a rehearsal situation, select mix number 3 'Conductor - woodwinds'. This involves 15 instruments. Start preparing the calculations by hitting 'Run single job' . Calculations will take a while.

2.3. When ready, use headphones to listen to the mix no. 3 by hitting 'Play wave file' . Then try to select a single instrument from the group shown in the window to the right, and start listening with 'Play wave file' .

2.4. In order to listen to the full orchestra, select mix number 1 'Conductor – tutti' and hit 'Run single job' . This will do the calculations for the rest of the instruments in the orchestra. When ready, listen to the full orchestra in mix number 5 by hitting 'Play wave file' .

3. Listen to the orchestra from a position in the audience

3.1. Choose one of the receiver positions, e.g. receiver 4, which is in mix number 5. Then start the calculations by hitting 'Run single job' . When ready, listen to the full orchestra in mix number 5 by hitting 'Play wave file' .

4. Using the Multisource/signal auralisation expert

4.1. In order to create an auralisation of the orchestra with a different receiver position, choose an empty mix number (e.g. mix. no. 7). Then open the 'Multisource/signal auralisation expert' .

4.2. Write a text in the first field, e.g. 'Receiver in left side'. Choose a receiver position, e.g. '3 Parterre – left'. The field 'Receiver looking at' can be left as 'Direction towards main axis, -X' or you can choose one of the instruments in the orchestra to define the direction of the receiver.

4.3. Hit 'Select multiple signal files' . Open the folder 'Brahms – No. 4, 3rd movement' and select all the signal files within that folder.

4.4. Hit 'Pair source with files' . This opens the same folder as above, and you need to go up one level to select the folder (not the single signal files).

4.5. Close the 'Multisource/signal auralisation expert' and confirm with 'Yes' to save the auralisation mix.

4.6. Point at the new mix number and start the calculations by hitting 'Run single job' . This will take a while because 61 now jobs have been generated with new ray tracing, point responses and convolutions. When ready, listen to the full orchestra in the new mix by hitting 'Play wave file' .

4.7. Hit '3D Render' in the right side of the Job list to view the room from the actual receiver position.