



CATT-Acoustic

This article discusses CATT-Acoustic, software for room acoustics prediction, auralization, studio stereo, and surround reverberation. One of the leading modeling programs for architectural acoustics. CATT is now available in Version 9.0, using the highly advanced analytical engine The Universal Cone Tracer (TUCT).

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Bengt-Inge Dalenbäck of Sweden developed CATT-Acoustic. Although Dalenbäck has been involved with acoustics since 1981, his company, Computer-Aided Theater Technique (CATT) initially focused on software for lighting and theater decor design. Its first software, CATT-Lighting, was released in 1986, followed by CATT-Decor in 1987, and then CATT-Acoustic in 1988. CATT-Lighting was based on tracing rays defined by spotlight limits, but CATT-Acoustic was initially based on an image-source method. All three of these programs were implemented for the Commodore Amiga computer. In 1990, CATT-Acoustic for MS-DOS was released, and CATT-Lighting and CATT-Decor were discontinued. The first CATT-Acoustic version for Windows was released in 1996.

distance as the original object. This thinking can be further extended to higher-order images. The image-source method is geometrically accurate, but can require an enormous number of image sources to predict a full-length decay except in a few simple room shapes such as rectangular.

Pure ray-tracing methods are more computationally efficient but less geometrically accurate. To predict sound arrivals at a specific receiver position, an area or volume balloon surrounding the receiver must be specified and the "hits" of rays within this balloon must be tallied, or else the ray may be considered to be the axis of a cone or pyramid. A major benefit with ray-tracing variants is that diffuse reflections or scattering can be included. So in spite of the lower geometrical accuracy, the resulting acoustic prediction is much better than that of the image-source method alone.

To retain some of the image-source method's geometrical accuracy, the ray-tracing model's greater computational efficiency, and the possibility of including the necessary scattering, hybrid approaches have been adopted. One way to implement such an approach is to use the image-source method for early reflections, then switch to ray tracing for later reflections. This was the way CATT-Acoustic worked until 1998; the necessary frequency-dependent scattering has been included since about 1990.

Image-Source Method

An image-source method is based on the assumption that reflections can be modeled as a separate sound source located on the opposite side of the reflecting surface from the receiver. It would be placed in such a position that rays from that image source would approach the receiver with the same direction and intensity as the reflection does. It is closely analogous to what one sees when looking into a mirror: an image that seems to be located on the far side of the mirror at the same

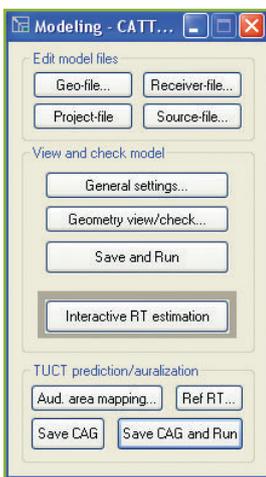


Photo 1: To use the Computer-Aided Theater Technique (CATT)-Acoustic software, start with the Modeling window.

When CATT-Acoustic V. 7.0 was released, it introduced randomized tail-corrected cone-tracing (RTC), a method Dalenbäck developed. Dalenbäck based the RTC method on the assumptions that in a closed room with no coupling effects, the growth in number of reflections is a quadratic function of time. This method can be used to compensate for the late part reflection loss associated with cone tracing. The updates to CATT-Acoustic V. 7.0 also incorporated a range of additions and improvements. RTC-II was rewritten for 32-bit Windows, and in 1998 array modeling was added, including the near-field. Similarly CATT-Acoustic V. 8.0, which is still based on RTC-II, added walkthrough convolution, real-time walkthrough auralization, and other features. It can handle semitransparent surfaces, thereby permitting acoustical prediction for rooms that are subdivided by heavy curtains and so forth.

In 2010, CATT-Acoustic V. 8.0 was released with a new analysis engine called TUCT initially to be used in parallel with the RTC to ease the transition to CATT-Acoustic V. 9.0 for current V. 8.0 users. The present CATT-Acoustic version, V. 9.0, is built around TUCT. The RTC-based prediction and auralization methods have been removed. TUCT uses several different algorithms for prediction, depending on the specific room being modeled. It also addresses RTC's shortcomings, especially regarding open and coupled rooms.

TUCT excels in auralization of open spaces and rooms with flutter echo problems, as well as large venues that have high absorption. For these spaces, it uses an algorithm that is not based on randomizing the direction of diffuse rays. Instead, it literally splits up rays into many diffuse sub-rays that continue to propagate. Such an algorithm would provide enormous calculation times, but Dalenbäck has shown a method by which it can be implemented with reasonable calculation times. TUCT is based on considerable development and refinement of that algorithm. The full reverb tail is used for auralization without the need for post-processing.

TUCT avoids one of the long-standing limitations of acoustical modeling programs based on geometrical acoustics by optionally including early reflection diffraction in its calculations (for one or two edges in a reflection path as well as specular-to-diffracted and diffracted-to-specular combinations). In some cases, this enables improved accuracy for the predictions (e.g., reflections from small surfaces including ceiling reflectors, sound from orchestra pits, or reflections from curved surfaces that are modeled using facets). TUCT calculates the effects of early diffraction using a secondary edge-source

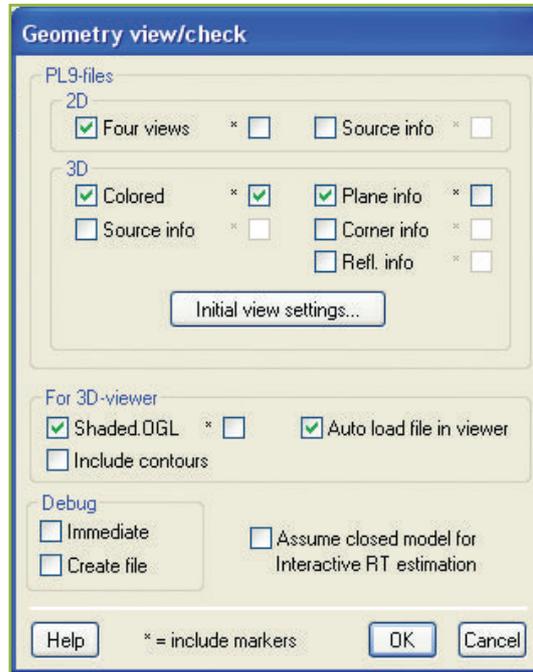


Photo 2: Viewing and debugging options are set in the Geometry view/check dialog.

method based on a discrete Huygens interpretation of the Biot-Tolstoy approach that has few limitations when used for room acoustics with finite edges and where infinite-length screen formulas are not applicable.

TUCT can utilize the speed advantages of multi-core processors, automatically selecting the number of threads or letting the user specify how many threads to use. The effects on the Speech Transmission Index (STI) of changing the

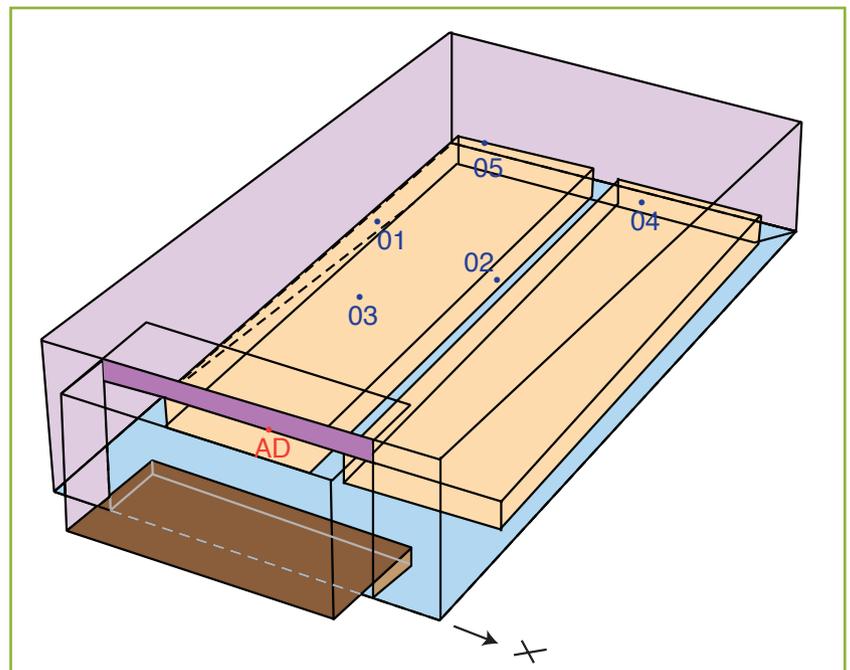


Figure 1: The 3-D model shows the geometry as well as the source (A0) and receiver (01 through 05) positions.

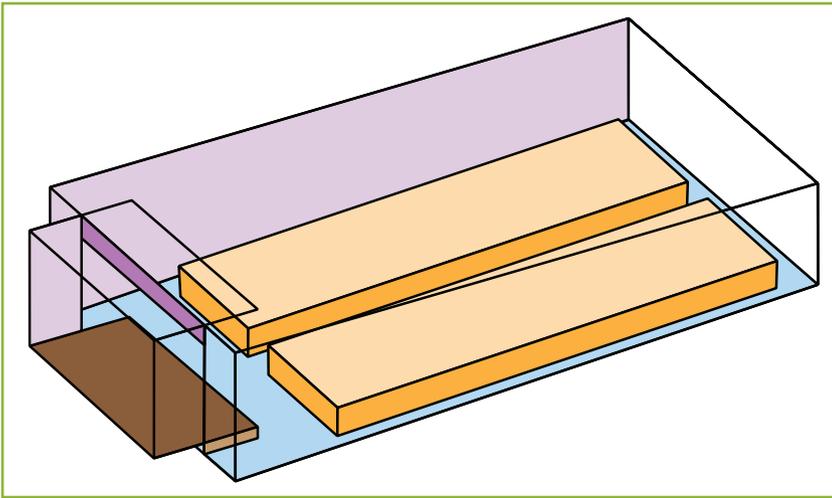


Figure 2: The shaded view is a 3-D rendering via the stand-alone OpenGL-based 3-D viewer.

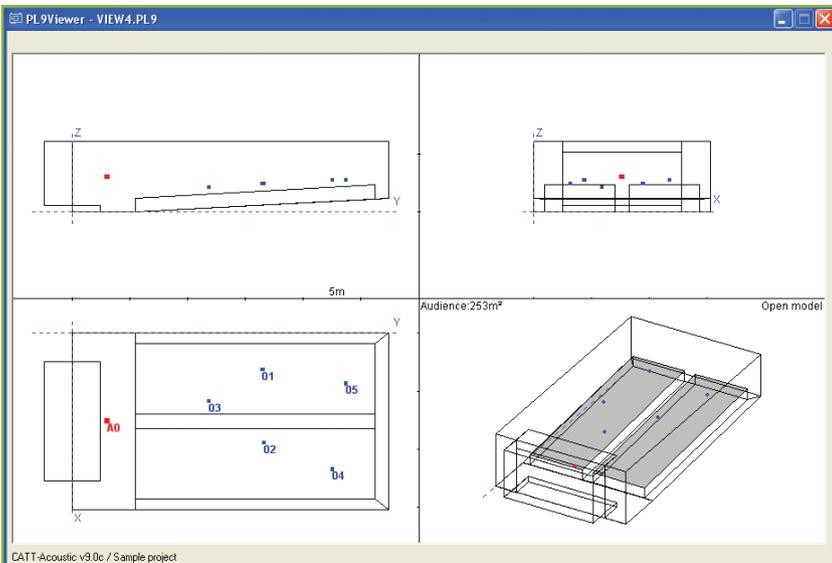


Photo 3: The View 4.PL9 window shows orthographic and parallel 3-D projection images of the model.

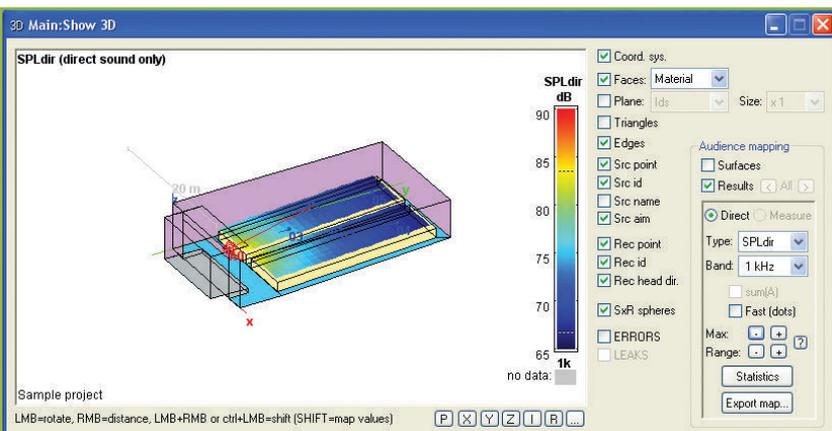


Photo 4: Direct sound mapping helps users select loudspeakers and mounting details.

background noise, overall level and EQ, and STI type can be studied interactively, including the effect on map statistics.

CATT-Acoustic uses three text-file types to input models: one or more files for the geometry (.GEO), one for the sound sources (.LOC), and one for the receivers'/listeners' positions (.LOC).

The GEO scripts include three main sections. First, there is a header section with global or local symbolic constant definitions that can be used to conform a general template to a specific room, scale factors to change feet into the default unit of meters, and so forth. Second is a "corner" section giving the coordinates of geometrical points in the room. Third is a "plane" section specifying which points define each plane, the absorption and scattering (which can also be taken from the Surface properties module), and transmission for semitransparent planes. An optional section can define geometrical markers that do not affect the prediction.

Alternatively, you can access AutoCAD software to create model geometry and import it as .CAD or .DXF files, or use SketchUp to create the geometry and import it to CATT-Acoustic with third-party SketchUp plugins.

The receiver file gives the locations of specific listener positions. The source file contains information about the type, location, aim, delay, and gain of the sound sources. The loudspeaker information includes directivity, which the user can enter via the Directivity module or can supply in SD0 (15° polar-interpolated); SD1 (10° full-space measured); SD2, which is Dynamic Link Library (DLL)-based for array modeling; or common loudspeaker format (CLF). Dalenbäck initiated the CLF project and has written all CLF software.

After you open CATT-Acoustic, you must first set up a project by specifying the input and output folders and the specific geometry, source, and receiver files. These are saved as a settings file. This information is entered using the General settings dialog on the Modeling window (see **Photo 1**).

While the model is being created, the Geometry view/check dialog can be used to set up various options (see **Photo 2**). After pressing Save and Run you can look at the model in either 3-D, 3D-rendered, or 2-D views (see **Figure 1** and **Figure 2**). The 2-D views are scaled, providing cursor position coordinates when you mouse over a place on the X-Y, Y-Z, or X-Z view. You can use the mouse to rotate the 3-D views (see **Photo 3**).

Several other graphics can be produced by the Geometry view/check process, one of which shows all the corner points identified by number. Another

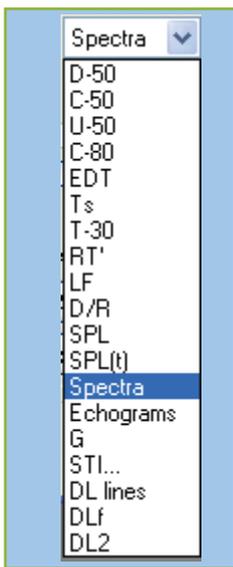


Photo 5: These parameters can be mapped after you click on the Map measures button.

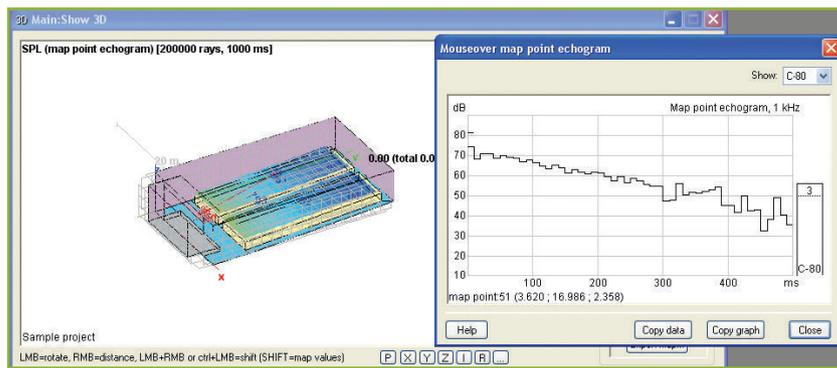


Photo 6: The echogram at a specific point can be displayed.

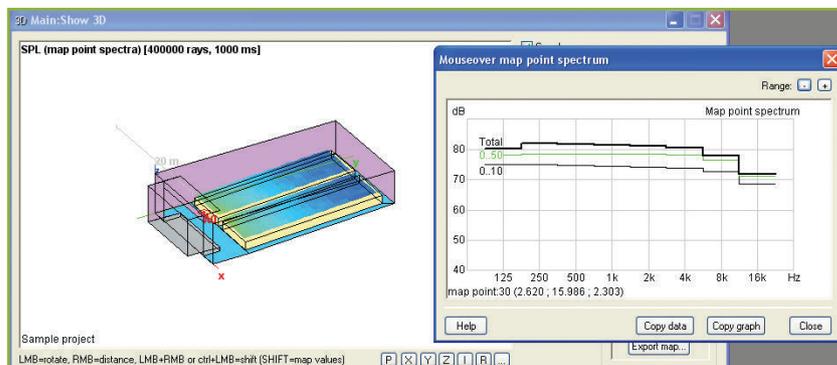


Photo 7: The sound pressure level (SPL) spectrum at a specific location can also be displayed.

graphic shows the planes one at a time with the points that define the identified plane, as well as the plane definition's surface area and location in the geometry files. Absorption, scattering, and transmission coefficients also appear in this graphic.

Interactive reverberation time (RT) estimation that is useful for initial data selection can be directly selected from the Modeling window. But, all main calculations are performed by the stand-alone TUCT module, which is activated via the lower part of the Modeling window. TUCT's Main:Actions window offers three options: Map Direct Sound, Predict SxR, and Map Measures.

Clicking on Map Direct Sound and performing the prediction shows results in the Main:Show 3-D window (see Photo 4). This image shows a mapping of the direct sound over all the model's audience planes. This facilitates checking loudspeaker coverage in the audience planes. (Naturally, with the omnidirectional source used in this sample prediction, the direct sound distribution is not very interesting.) If you hold down the shift key and mouse over the map, the direct SPL for the cursor location will be displayed at the bottom of the window.

Clicking the down arrow beside "Type" in the Main:Show 3-D window brings up a drop-down box that enables you to map the delay from the nearest source, or the source group with shortest delay, to any given point on the audience planes.

If you click the Map measures button on the Main:Actions window and perform the prediction, the display on the Main:Show 3-D window changes, providing many choices of calculated acoustical parameters for mapping.

Photo 5 shows the data choices that can be mapped from this window. Echograms are useful for evaluating the consistency of the decay curve and identifying the presence of flutter echoes.

Photo 6 shows an echogram for a specific location over the audience plane, which can be

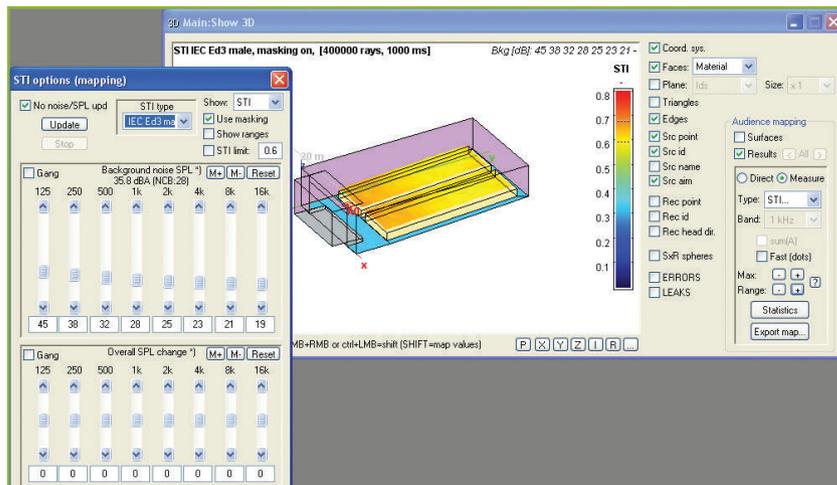


Photo 8: CATT-Acoustic provides extensive Speech Transmission Index (STI) prediction options.

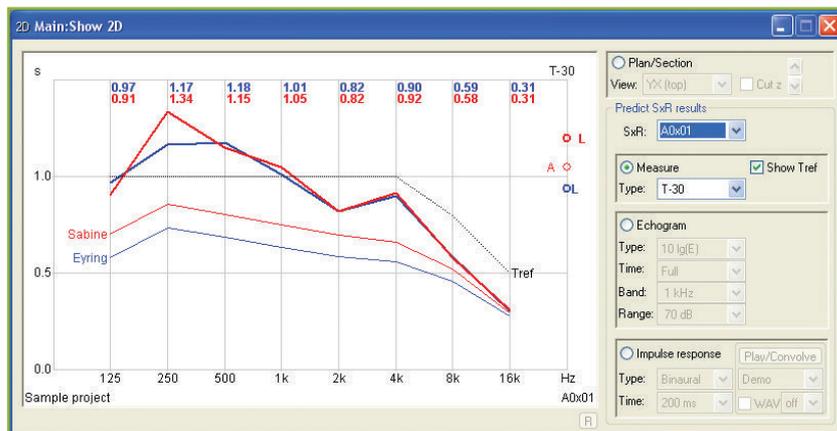


Photo 9: Predict SxR enables users to plot 18 different calculated acoustical parameters.

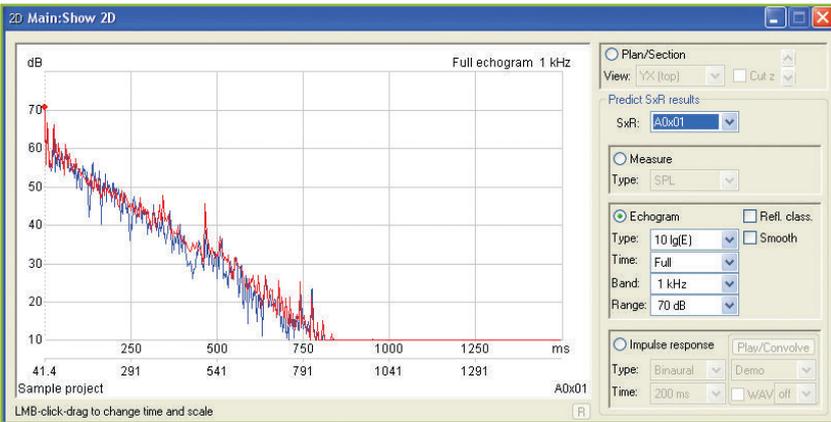


Photo 10: Detailed echograms can be displayed for each source and receiver combination.

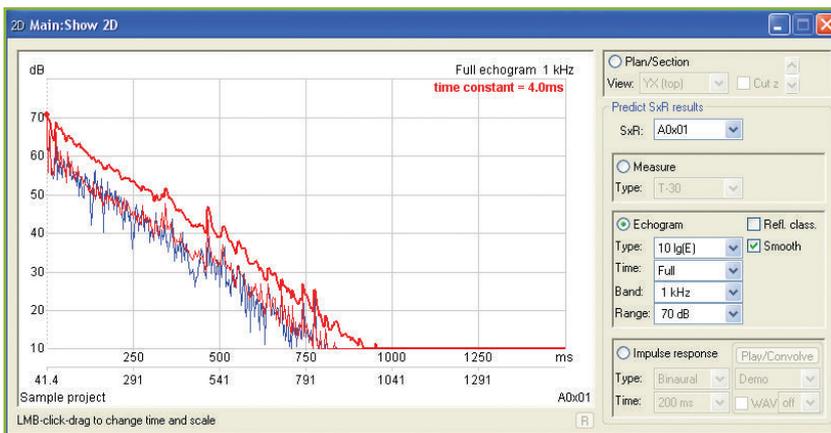


Photo 11: Detailed echograms can be displayed with smoothing included.

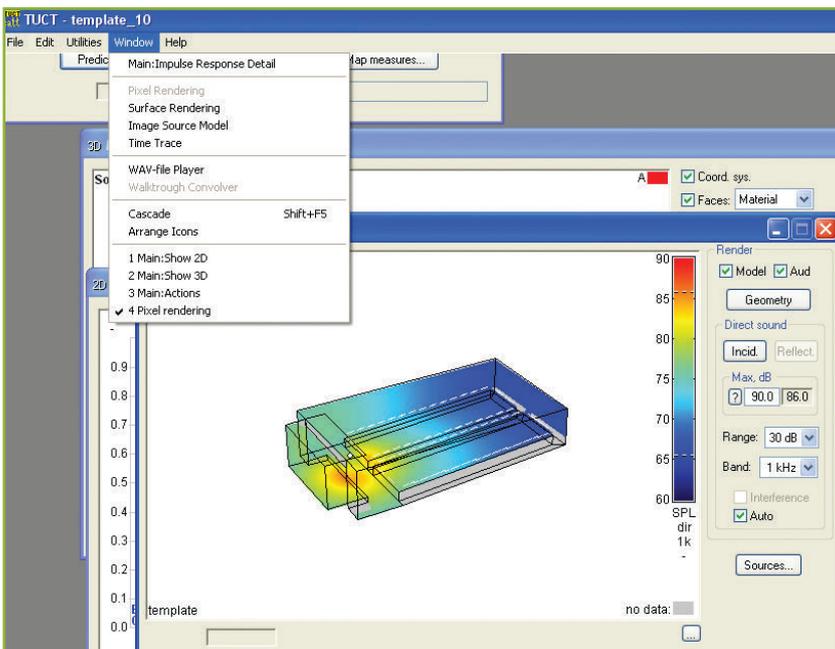


Photo 12: The Universal Cone Tracer (TUCT) Window menu offers additional displays.

selected by mousing over the location while in the Echogram function. More detailed echograms are available through the Predict SxR function. “Mapping” concentrates on overview of numerical measures rather than detail. In a similar manner, the octave-band SPL spectrum for a given point can be displayed (see **Photo 7**).

To predict speech intelligibility, STI can be mapped using any of six different methods corresponding to various STI standard editions and older variants with masking on and off (especially important since the 2003 edition where level-dependent masking was introduced). The level and spectrum of background noise can be varied and the effects can be seen on an updated plot without rerunning the simulation (see **Photo 8**).

The Predict SxR option is used to create more detailed echograms for all sources and receivers. These can later be used for auralization. After prediction is completed, the Main:Show 2D window can display plots of many acoustic parameters. **Photo 9** shows the parameters available for plotting (right-hand panel) and a T-30 plot (left-hand panel). **Photo 10** provides a detailed echogram produced at receiver 01 from source A0. The red graph line is the energy-based echogram; the blue is the octave-band filtered predicted room impulse response. **Photo 11** shows the same echogram with

Resources

AutoCAD, Autodesk, Inc., www.autodesk.com.

The Common Loudspeaker Format (CLF), www.clfgroup.org.

B. I. Dalenbäck, “Room Acoustic Prediction Based on a Unified Treatment of Diffuse and Specular Reflection,” *The Journal of the Acoustical Society of America (JASA)*, 1996.

M. Kleiner, B.I. Dalenbäck, and P. Svensson, “Auralization—An Overview,” *The Journal of the Acoustical Society of America (JASA)*, 1993.

SketchUp, Trimble Navigation, Ltd., www.sketchup.com.

U. P. Svensson, R. I. Fred, and J. Vanderkooy, “An Analytical Secondary Source Model of Edge Diffraction Impulse Response,” *The Journal of the Acoustical Society of America (JASA)*, 1999.

Source

CATT-Acoustic, CATT-Lighting, and CATT-Decor Computer-Aided Theater Technique (CATT) | www.catt.se.

smoothing added. Related displays are also available, including Schroeder curves, echo disturbance curves for speech and music, and both directional and polar echograms.

Auralization is immediately available from the SxR Main:Show 2-D window by selecting Impulse response and then Play/convolve. The convolution uses any of the anechoic files specified in the TUCT|File|Preferences dialog. Convolution can be prepared for binaural, stereo (two formats), or any of seven other formats. Second- or third-order B-format and various ITU 5-channel surround are also available but have to be selected before Predict SxR is performed. Extensive impulse response export permits use with external tools such as CATT MultiVolver, and CATT-Walker that enables real-time walkthrough auralization. Dalenbäck was co-author of the article that coined and defined the term auralization (see Resources).

TUCT Window Menu

In addition to the Map direct sound, Predict SxR, and Map Measures functions provided through the Main:Actions window, the TUCT Window menu offers several useful displays (see **Photo 12**). The first of these is a detailed impulse response including a frequency response and a spectrogram. The second is pixel rendering of direct or reflected SPL on all planes of the model, and/or the audience surfaces. The third is surface rendering similar to pixel rendering but using an absolute resolution such as 0.5 m × 0.5 m. The fourth is individual early reflection paths returned by image source method analysis, helpful for identifying surfaces involved in specific reflections heard at particular locations, (see **Photo 13**).

Another display available from the TUCT Window menu is the time trace, which provides an illustration of the sound wavefront propagating from the source. The user can mouse-click through the wavefront progress and can export a video. **Photo 14** shows a time trace, which is useful for spotting problems such as focusing. Finally the Walkthrough convolver can be used to create auralized sound tracks for attachment to walkthrough videos. The WAV-file player is a generally useful tool (e.g., for A/B listening tests).

The CATT-Acoustic's full version also includes the ReflPhinder for room impulse response and reflection analysis from measured B-format room impulse responses, the FIRverb Suite for natural music reverb impulse response creation (PureVerb), and multichannel convolution (MultiVolver). CATT also offers two free GratisVolver programs. GratisVolver is

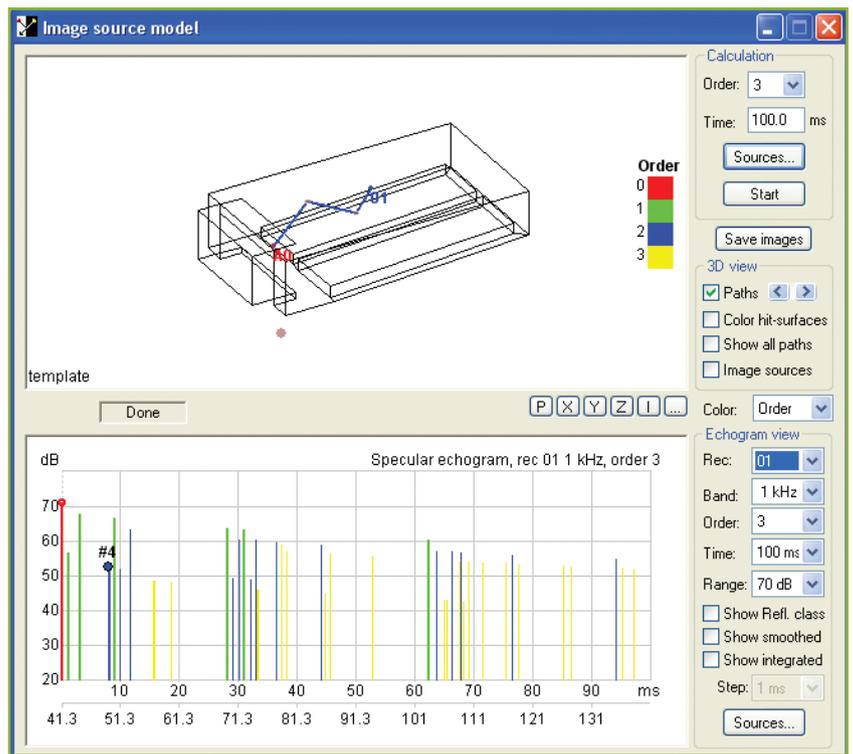


Photo 13: Reflection paths for specific echoes can be located via the image-source model display.

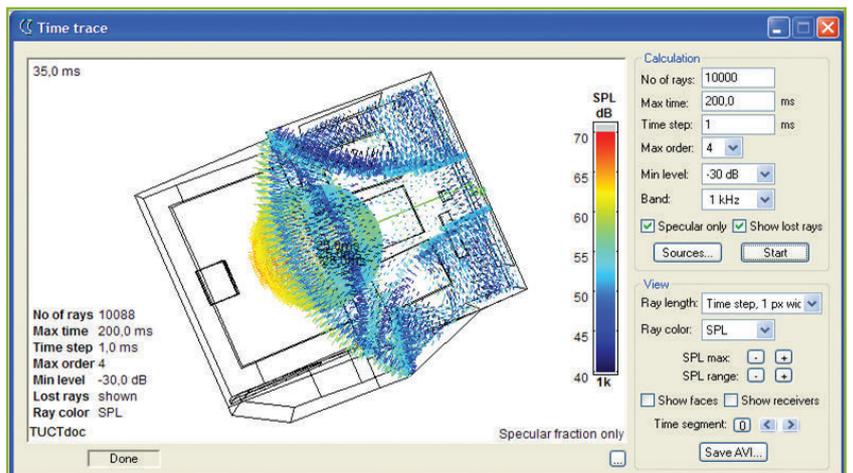


Photo 14: The time trace can be helpful in visualizing sound propagation in the room.

used to convolve measured room impulse responses with music or speech and also for deconvolving measured wet sweeps to retrieve a room's impulse response. A comprehensive, not time-limited demo version of CATT-Acoustic is available for download.

Dalenbäck is currently working on the next major software release, which will include a total change and fundamental improvement of how sound sources and especially arrays are handled. The previously mentioned DLL array interface will no longer be included. Instead, array modeling will be based on a new flexible array file format that can also handle curved line arrays with high-frequency line elements. 