Auralization creation: collaboration between Sorbonne Université and Theatre Projects

David Thery, Brian F.G. Katz, David Poirier-Quinot

Technical report

Auralization creation: collaboration between Sorbonne Université and Theatre Projects

David Thery and Brian F.G. Katz and David Poirier-Quinot
Sorbonne Université
Institut Jean le Rond d'Alembert, Lutheries-Acoustique-Musique

March 2020

1 Introduction

This document presents the technical work performed during the collaboration project conducted with Theatre Projects, an acoustic consulting practice based in London, with an acoustic design office in Paris led by Sebastien Jouan. It includes the creation of two auralizations: a multimodal auralization of an Atrium which was a large space surrounded by glass, for which several acoustic treatment options were proposed, and an audio-only auralization of an Auditorium where intrusive noise was coming from a sub-space (Galleria), to be treated with an acoustic isolating box. The Atrium auralization was complimented by a visual model of the space rendered in VR over an HMD, with the audio rendered binaurally, while the Auditorium was rendered over a multi-speakers systems.

This technical work was performed at Sorbonne Université (SU), with additional details available online [1].

[1] `http://www.lam.jussieu.fr/Projets/index.php?page=GlassHouse`

2 Atrium auralizations

2.1 Base acoustical simulations

Auralizations of the Atrium, showing the impact of acoustic treatment, were generated according to geometrical and acoustic material details provided by the acoustician (TP).

Impulse responses were generated using CATT-Acoustic v9.1 (TUCT2 v2). The geometrical model was based on a preliminary model furnished by TP and architectural files furnished by the architect. The model was revised from the ODEON model principally to take advantage of the semi-transparency functionality available in CATT-Acoustic. This transparency was applied to the metal balcony terraces to represent the apparent scaffolding design.

A total of 12 Sources and 2 Receiver positions were defined for the simulation, as detailed in the GA model in Fig. 1. Source stage center was used for the conference voice. Sources B1-B3 were used for live music. Sources D0-D1 were used to replicate a stereo amplified event. Sources C0-C6 were used to create the distributed noise for the conference dinner attendees.

Natural acoustic sources were modelled as omnidirectional. The amplified stereo sources were modelled, based on prescriptions from TP, as a pair of DB E8 90x50 [2]. Receivers were modelled as Second order Ambisonics (2nd-HOA), allowing for spatial audio rendering of the auralizations using playback systems with head-tracking and dynamic update. CATT-Acoustic was configured using Algorithm 2, providing a detailed simulation without statistical approximations of the late reverberation. Ray tracing was carried out using 300000 rays, which were followed for 5000 ms propagation to ensure adequate representation of the complex acoustics of the space.

Two listening positions were defined: 01 near the stage (according to architectural plans) and the 02, at the rear of the event related occupied area, near the opening in the floor towards the Galleria. These two positions are marked in the GA model by blue dots on the floor for visual reference. Several avatars are also included in the visual model to help with judging the scale of the room and the central position on stage. The material definitions (absorption coefficient, diffusion characteristic dimension) of the various surfaces, using the CATT format, were as in Table 1:

The following configurations were simulated in CATT: 1) no absorption, 2) lightdiffusers absorption on the side walls, 3) AQflex on the side walls, 4) AQflex+Lightdiffusers on side walls.

Configuration 4, presenting a combination of translucent curtains and inflatable Qflex AQtube low frequency absorbers, for which the highest absorption performance of the 2 materials was selected for each octave band. The resulting reverberation times for the different absorption configurations are shown in Fig. 2. These results are averaged over all source positions, to provide a reasonable average response for the room.

[2] `https://www.dbaudio.com/global/en/products/series/e-series/e8/`

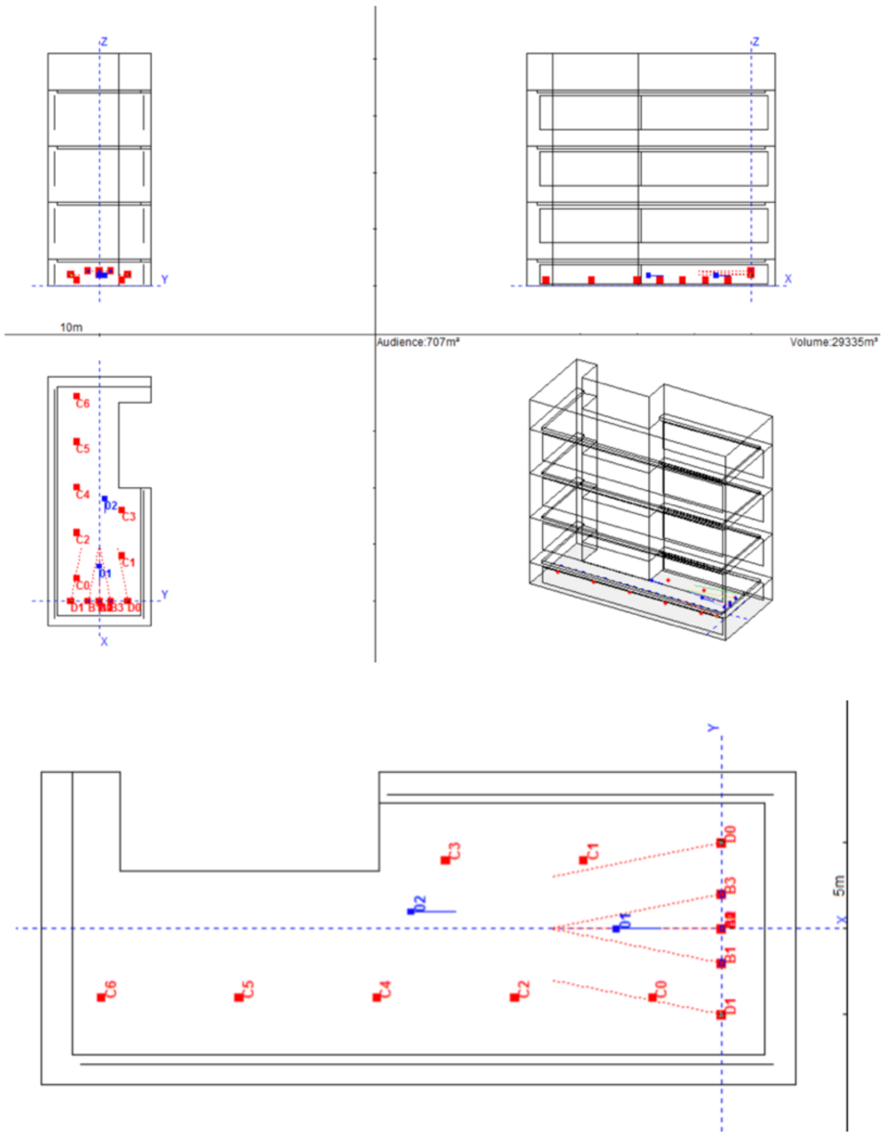

Figure 1: GA model of the Atrium, showing sources (in red) and receivers (in blue) positions.

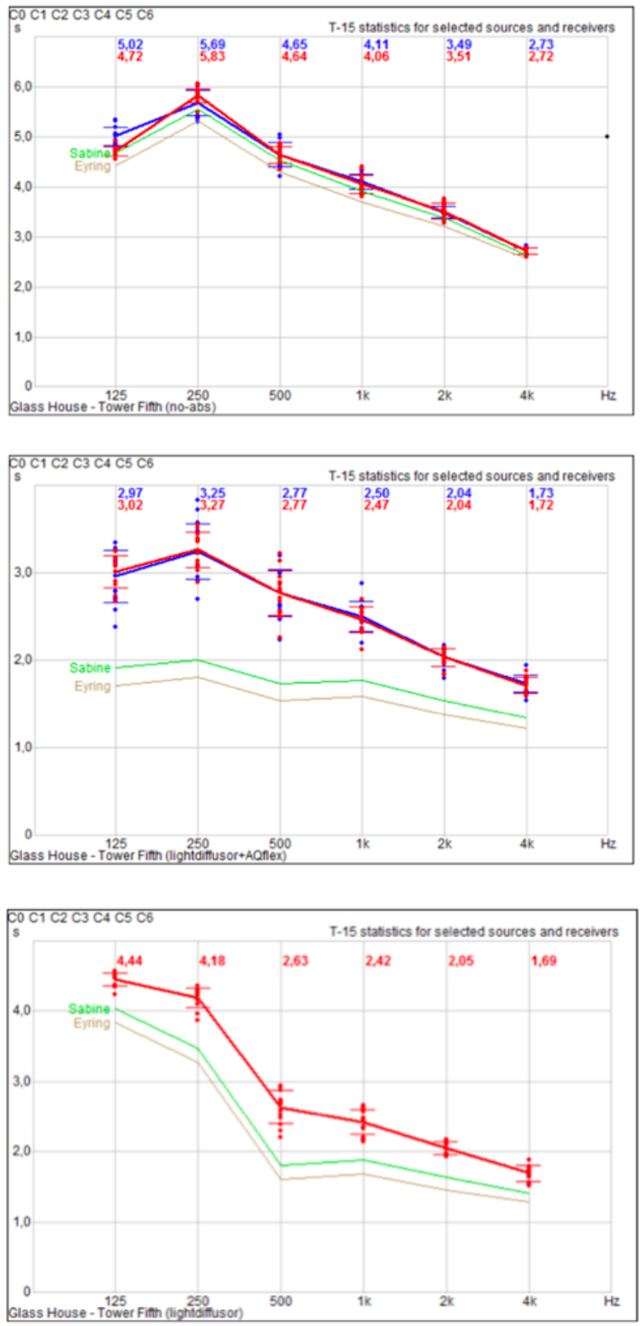

Figure 2: Reverberation times in the Atrium for the various S-R pairs.

Table 1: Absorption data (in percentages) for the different material assigned to the surfaces in the Atrium, from TP specifications.

Octave band	125	250	500	1000	2000	4000	Scattering
Baswa	17	48	70	80	85	65	estimate(0.05)
MetalGrill	15	05	03	03	02	02	estimate(0.05)
MetalGrWtr /Transp	1/95	1/85	2/75	2/75	3/75	3/75	estimate(0.02)
Floor	01	01	01	01	02	02	estimate(0.4)
Ceiling	15	05	03	03	02	02	estimate(0.5)
LightDiffuser	07	20	60	50	57	60	estimate(0.01)
AQFlex	50	52	58	35	20	12	estimate(0.7)
LightDiffuser+AQFlex	50	52	58	50	57	60	estimate(0.7)

Table 2: Absorption data (in percentages) for the different material assigned to the surfaces in the Atrium, from TP specifications.

Octave band	125	250	500	1000	2000	4000	Scattering
Portal	80	25	08	03	02	01	estimate(0.01)
Galleria	30	30	30	30	25	25	estimate(1)
GlassWall / Ceiling / Core	15	05	03	03	02	02	estimate(0.4)

This auralization was presented to TP and the Client in the virtual reality simulation room on-site at the university.

2.2 Coupling Atrium and sub-space

To examine the impact of the coupling between the Atrium and the Galleria, the GA model of the Atrium was extended to include a simplified version of the Galleria (see Fig. 3). The purpose of this auralization was to examine specifically the impact of the noise from an event in the Galleria disrupting an event in the Glass House. The architectural opening between the two spaces was modelled as either open or closed portal.

The Material definitions for the Galleria (see Table 2 were selected to replicate the estimated reverberation time of 2.0 s, as prescribed by TP. The opening between the two volumes was modelled either as open, without any surface, or with a surface representing a transmission loss of Rw = 35 dB, as prescribed by TP. It should be noted that, between Glass Atrium version 1 and version 2, the acoustic absorption originally prescribed for the core (a baswa acoustic plaster) was defined by the Client as an acoustically rigid/diffusing glass finish. Two Source positions were placed in the Galleria, for the event noise, and two Receiver positions, for calibration of the Galleria acoustic conditions. The coupling condition for the sources in the Galleria led to changes in the relative SPL. The difference observed for Source E0+E1 to Receiver 1 and 2 is on the order of 30 dBA.

Regarding the visual model, which was provided as a simple support for reference in the model, the visual model was not modified to take into account the change to the Core. However, after comments by the Client, the exposed

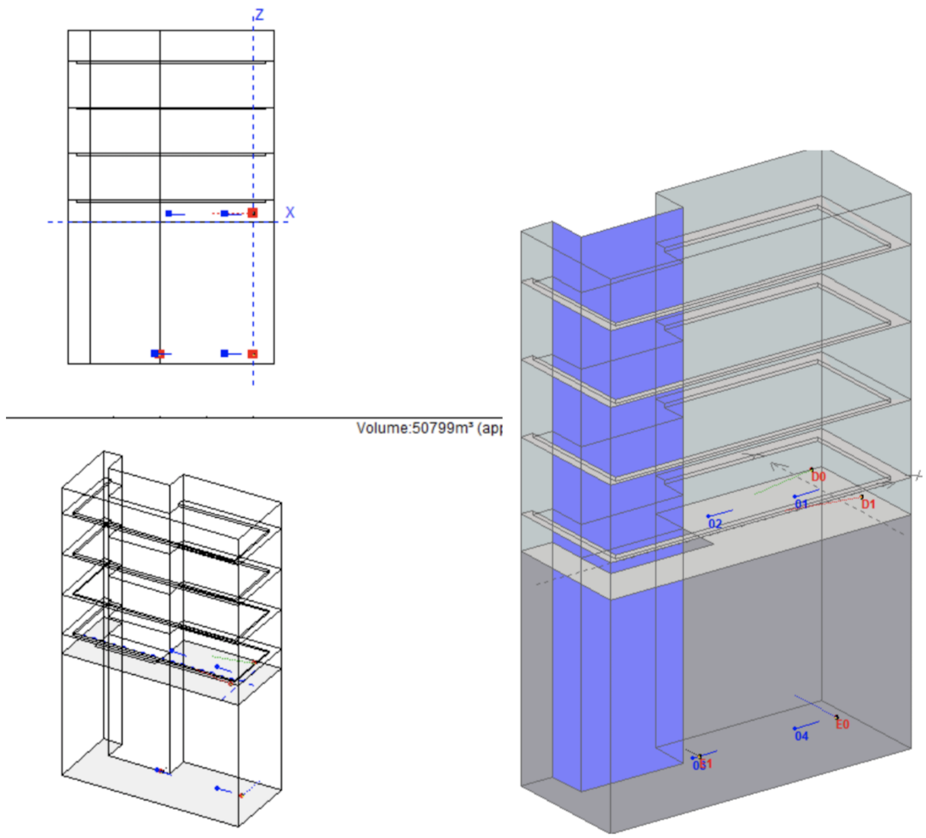

Figure 3: GA model of the Atrium V2, extended to include the sub space Galleria, from which the intrusive noise was coming.

metal terraces were refined as painted white.

A subset of the acoustical conditions from Atrium version 1 was recreated for the auralizations of version 2 (for the two different demands previously described). Contrary to the previous two auralizations that were presented in the laboratory to the client and TP (see the MAX interface for the Atrium auralizations in Fig. 4), this auralization was provided for presentation by TP to the Client outside of the University. 360° video files were furnished and installed on an Oculus Go portable VR headset, that was provided by SU to TP (they had no prior experience using this device), allowing them to present the auralization outside of the facilities of the University. To provide a fallback presentation method in the event of technical problems, simple front-view videos were also provided, rendered with binaural audio. All auralizations should be listened to over headphones. Due to the portable nature of the version 2 auralizations, and the importance of listening level where experiencing these auralizations, an audio calibration auralization was also provided for a rendering in the Galleria in the middle of the event. This auralization had no accompanying image. The playback volume of the system should be adjusted first with this auralization, to present a realistic level of being immersed in the event. All subsequent auralizations in the Atrium were presented at a level relative to this set level. As such, the level should not be altered after the calibration step if one is interested in maintaining a realistic representation of the intrusive noise from Galleria as heard in the Atrium.

2.3 Atrium VR visual model

To compliment the auralization, a visual model of the Atrium was created, allowing for the production of 360° images that would serve as a base for the flat and 360° auralization video, the latter exported for rendering in the Oculus Go [3], that provides a resolution of 1280 x 1440 per eye, better than the wired Rift and Vive that provide 1080 x 1200 per eye. The model primarily handled from the Architect's model in Revit [4] was modified in Blender, and rendered in Cycles [5].

An example of a 360° rendering is depicted in Fig. 5.

3 Auditorium noise demonstration

An audio-only auralization was constructed in a sound isolated listening booth ($12m^2$, $26m^3$), where the measured equivalent noise level L_{Aeq} was 20 dB (equivalent to the theoretical PNC10/15. An array of four speakers was employed to render the noise emanating from the Galleria through the building structure into the Auditorium. Speakers were located near the floor at the four corners of the room, to take into account the most likely surface of transmission

[3] https://www.oculus.com/go/

[4] https://www.autodesk.com/products/revit/overview

[5] https://docs.blender.org/manual/en/latest/render/cycles/index.html

Figure 4: Max Presentation Patch: enables to instantly toggle the *sound reproduction system (Ambisonic or Binaural)*, the *position in the Atrium (close or farther)*, the *acoustical treatment*, and adjust *volume*.

Figure 5: Equirectangular projection of a 360° image of the Atrium, from the viewpoint of one of the defined position.

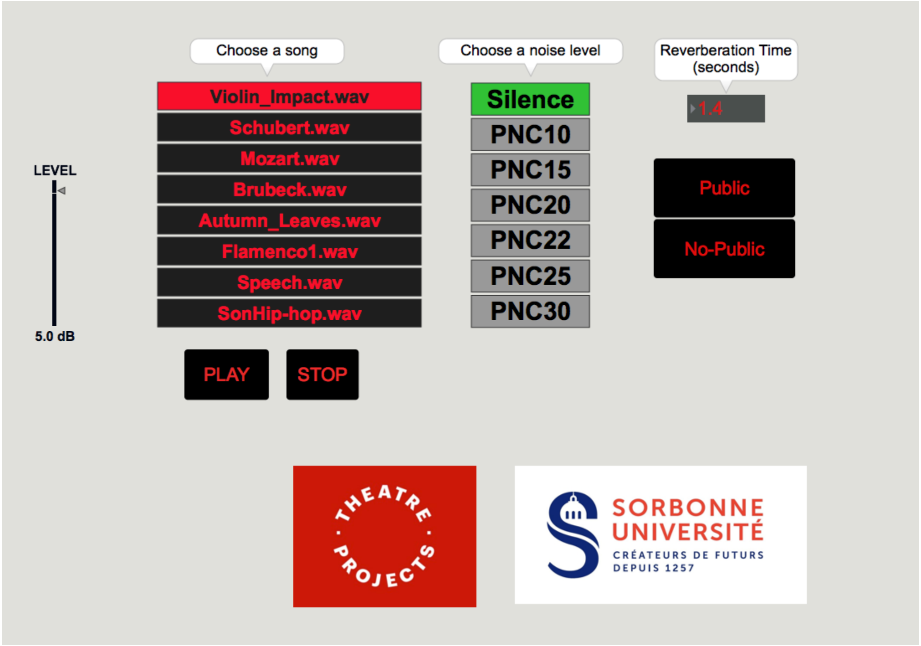

Figure 6: PNC demonstration interface, that allows for switching between sound source, PNC level, Reverberation Time, and presence of public.

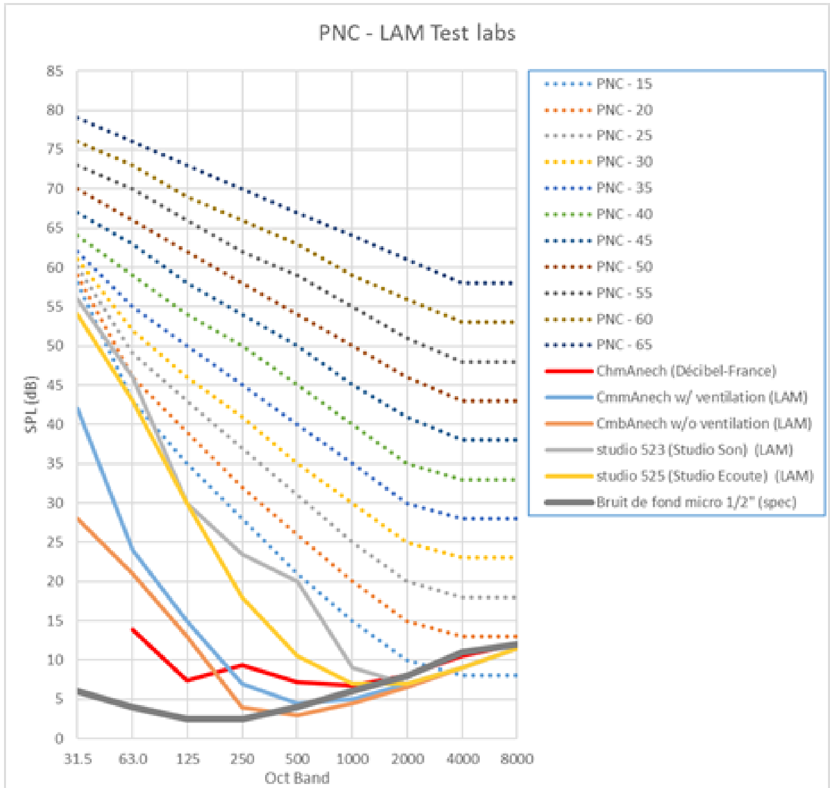

Figure 7: PNC curves representing the SPL level as a function of frequency, in addition to noise level in the different spaces of the University. Of interest are Studio 523 (Gray) and Anechoic chamber (Orange).

(the floor). Using noise spectra provided by TP, seven different background noise levels were generated. The sound stimuli was a filtered version of a recording made of a student gathering in a courtyard with amplified music (crowd noise), considered comparable to an event in the Galleria. Fig. 7 shows the spectra measured in the listening room of the different background noise levels, in addition to the background noise floor of the isolation booth.

Several use cases of the Auditorium were simulated, at typical listening level for a seating position midway in the hall (listening level 65-75 dB. Stimuli included unamplified chamber music, jazz ensemble, and a conference. In particular, a violin recording was presented in priority as it provided solo passages and significant dynamic variations, allowing a better assessment of the overall listening experience including the intrusive Galleria noise. These stimuli were reproduced with the inclusion of an adjustable reverberation to replicate the adjustable absorption conditions of the performance space. These stimuli were rendered over an independent surrounding speaker array composed of eight speakers (four dedicated to simulate the stage in front of the listener and four located at the 4 corners close to the ceiling to simulate the room reverberation). Stimuli were spatialized using the SPAT library running in MAX , using a VBAP3D panning method. The provided reverberation times were defined by TP, varying from 1.0-1.6 sec (adapted for speech and music). The various options of this demonstration are visible in the control interface (see Fig. 6). This auralization was presented to TP and the Client in one of the acoustic isolation booths on-site at the university, the studio 523 on Fig. 7.