AURA - Auralisation of acoustic heritage sites using Augmented and Virtual Reality. Project overview and methodological approach.

Raffaella Bellomini[1]; Chiara Bartalucci[1]; Lucia Busa[1]; Paola Pulella[1]

[1] Vie en.ro.se Ingegneria, Italy, raffaella.bellomini@vienrose.it

ABSTRACT
Auralisation, taking a listener to a concert or an opera in a virtual environment as bridge to new technologies, can offer a wide range of opportunities of building new audiences, new business models, new performance practices, exciting new aural experiences. In doing so, AURA creates a model for cross sectoral collaboration to foster creativity, to promote European heritage in new ways and to demonstrate European excellence in the world of music.
Keywords: auralisation, virtual reality, theatre

1. INTRODUCTION

Modern technologies are increasingly used for the enjoyment of cultural heritage. Theatre and musical performances are by their nature "immersive". This latter feature is achievable thanks to the tool of auralisation. Auralisation is the technique used for creating virtual soundscapes starting from 3D-models that recreate the sound environment of a real space. This implementation allows to define an immersive experience in which the user can move around in space and can experience how the architecture influences the sound.

The partnership of AURA (Auralization of acoustic heritage sites using Augmented and Virtual Reality) Project led by BGZ Berlin International Cooperation Agency GmbH includes the HTW Berlin University of Applied Sciences, Konzerthaus Berlin, University of Florence, Vie en.ro.se. Ingegneria S.r.l., Lviv Polytechnic National University, Lviv Tourism Development Center and Magnetic One. The AURA Project aims at setting immersive experiences of three theatres, investigated as case studies. Moreover, guidelines for the auralisation of virtual spaces will be drawn up, in order to make auralisation of cultural places accessible to future developments and uses.

New technologies will offer a wide range of opportunities to build new business models, new performance practices, new exciting auditory experiences. In this way, AURA will create a model of cross-sector collaboration to foster creativity, to promote European heritage in new ways and to demonstrate European excellence in the world of music.

Among the activities of the project, collecting the future users' feedback, such as the point of view of musicians, singers, designers and theatre-goers, has a crucial role for the implementation of the tool. Assessing audience experiences in auralised 3D models gives a key for understanding how and in what conditions auralisation can represent a rich and exciting alternative to the immersive nature of the live performance.

This latter aspect is of interest particularly for understanding how young people, who are the age group least likely to attend theatres [1], perceive the theatre experience

On the other hand, the experts' opinion is important for a meticulous comparison between the real and the virtual experience and for the definition of a model which can better fit the reality.

2. THE DEFINITION OF THREE VIRTUAL ENVIRONMENTS

2.1 The three theatres

The opera and music theatres of Berlin, Florence and Lviv, supported by technological and marketing partners, are committed to exploiting the potential that auralisation offers to musical arts and performances. The project investigates the result of three case studies that create a reproduction of the environments and produce new ways of experiencing music.

The three theatres which have been modelled and simulated in virtual reality are the Teatro del Maggio Musicale Fiorentino located in Florence, the Konzerthaus of Berlin, and Lviv National Academic Opera and Ballet Theatre named after Solomiya Krushelnytska in Lviv. The theatres differ in terms of architecture style and period of construction as well as acoustic features. As a matter of fact, they are characterized by different volume, number of seats and reverberation time, which affect the acoustic performance of the theatre. The above-mentioned values are presented in Table 1.

Table 1 – Features of the theatres
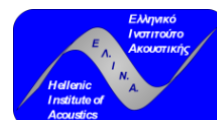
Concert Hall Theatre Location	Plan shape	Construction year	Volume [m³]	Number of seats
Grosser Saal Konzerthaus Berlin, Germany [1]	Shoebox	1818-1821	15000	1575
Sala Grande Teatro del Maggio Musicale Fiorentino Florence, Italy [2]	U-shaped	2009-2011	18000	1800
Lviv National Academic Opera and Ballet Theatre Lviv, Ukraine [3]	U-shaped	1897-1900	4549	1050

The synergic collaboration between the University of Florence and the HTW Berlin University of Applied Sciences resulted in the definition of three application for the simulation of virtual reality. Following theatres surveys, the Department of Architecture of the University of Florence has developed the visual 3D models of the inside, whereas the HTW dealt with the implementation of the audio reproduction. The combination of these two aspects makes the experience of immersion inside the theatre realistic: the more auralization and visualization are carefully implemented, the more they correspond to reality.

Figure 1 – Inside view of the 3D model of the "Konzerthaus" in Berlin, Germany.

Figure 2 – Inside view of the 3D model of the "Teatro del Maggio Musicale Fiorentino" in Florence, Italy

Figure 3 – Inside view of the 3D model of the "Lviv National Academic Opera and Ballet Theatre" in Lviv, Ukraine.

2.2 Implementation of apps

Thanks to the definition of 3D visual and acoustic models, the three theatres have been implemented in a specific software (Unity) and three applications for personal computers have been set.

In each of the theatres, the user can walk inside the room and make the instruments play.

For an easier control of the user experience, organized within the Project, some significant listening points have been set in order to allow a quick repositioning of the participant who is wandering inside the theatre. In the light of this, the most common listening positions (such as in the first row, in the last row, on the balcony) as well as positions only accessible to the performers (such as on the stage) have been defined.

For the audio simulation, two violins, a cello, a double bass, a flute, an oboe, a clarinet, a trumpet, a harp, a drum, a viola, a piccolo flute, a bassoon, and a horn have been positioned on the stage. The set of instruments can be switched on and off independently by the user of the application. The orchestra plays the 4th part "Golliwogg's Cakewalk" from "Children's Corner", a composition by Claude Debussy, During the exhibition, the avatars of the musicians are displayed, as shown in Figure 4, together with the corresponding audio reproduction.

Figure 4 – The avatars of the musicians playing inside the Konzerthaus of Berlin.

3. AN IMMERSIVE EXPERIENCE FOR THE PUBLIC

3.1 The audio and audio-video experience

Participants take part in an immersive experience designed by Vie en.ro.se Ingegneria S.r.L.: the two main activities consist of an audio experience and an audio-visual experience. At the beginning, the user listens to an auralized audio track of the Konzerthaus, the different listening positions inside the theatre and the different combination of instruments playing are written on the screen. During the listening, visual references of the inside of the theatre are not provided. The second part of the experience consists of an audio-visual immersion: the user listens to the auralized audio tracks of the three theatres and visualizes the corresponding space. This simulation is carried out with the Oculus, a virtual reality headset that allows to play the audio and the 360°-view of the space. The experience is repeated in the different listening points of the three theatres, play-ing different instruments. For the interaction of the participants, in order to simulate the use of virtual reality, the user is asked to independently choose the listening positions and instruments to be played within each of the three theatres.

The experience is held in the DIDA Extended Reality Laboratory in the Department of Architecture of the University of Florence. Inside the room five simulation stations are set with oculus connected to personal computers for a 1-hour experience.

During the simulation, users are asked to fill-in a questionnaire which is differentiated according to the prior knowledge of the users. Round Tables are organized for experts and technicians, whereas a quiz is arranged for involving younger participants.

Figure 5 – Test of the tool for the immersive experience using Oculus

3.2 The sample of participants

The sample considered for the investigation has been divided into three categories in order to understand how subjects can differently be enriched and positively influenced by the auralisation process. For this reason, the user experience and the analysis of their perception are differentiated.

Most of the participants (approx. 70) belong to the "General Audience", which includes students from middle and high schools and general non-expert public. The other two categories consider subjects who are interested in the theatres' features because of their jobs: on the one hand, "Experts" who perform inside the theatres, such as musicians, singers, conductors, actors, general expert public, music schools' students, and theatre lab participants (approx. 40); on the other hand, "Technicians" who deal with the design of spaces, such as architectural designers, acoustic designers, and architecture students (approx. 40).

Voluntary participants have been identified during academic courses organized by the University of Florence, other participants come from schools, music schools, and theatre labs. For a wider sharing, brochures have been published on social media.

Figure 6 – The arranged brochure for the identification of Technicians and Experts.

3.3 Questionnaires, Round Tables, Games

In order to receive the users' opinion on the immersive experience of auralisation, the assessing of the audience follows the participation to the experience.

Three questionnaires, one for each of the defined categories, have been drawn up by Vie en.ro.se Ingegneria S.r.L. and divided into sections. Participants are asked to fill-in the questionnaire, implemented on Google Form, during the experience. The first two sections can be filled-in before the start of the audio experience and allow to define the investigated sample, collecting personal information, and habits and behaviours related to the fruition of theatres. For experts and technicians, a deeper analysis is made on professional experience.

For the General Public, four additional sections are asked to be filled-in and concern the assessment of the audio experience (to be filled-in as soon as the audio experience is over) and of the audio-visual experience (to be filled-in as soon as the audio-visual experience is over). At the end of the whole simulation, a comparison between the two experiences and an opinion on future developments of the tool is investigated.

For questions related to the characterization of the samples and their assessment of different kinds of music performances, a literature review on the field has been done [4],[5],[6],[7].

Round Tables are organized for experts and technicians, in order to collect experts' ideas concerning pro

and cons of the tool, and potential use. Participants of these two categories are divided in groups and a list of topics is projected on a monitor as a starting point for a collective discussion.

Figure 7 – An extract from the Questionnaire for General Public implemented in Google Form.

The following questions are presented to the participants of the "Experts" category:

- Have you ever worked with immersive technologies (apps with augmented or virtual reality)? And if so, in what context?
- Do you think that the possibility to activate /deactivate the different instruments on stage is useful for your work?
- Do you think that listening from different points in the theatre is useful for your work?
- Do you think that this tool could be more effective for a specific kind of theatre (e.g., opera house, drama theatre, concert house, etc.) and a specific kind of performance (e.g., classical concert, jazz/modern concert, opera, prose, musical)?
- Do you think that knowing the architecture and the acoustics inside the theatre before your exhibition could be important for facilitating your performance?
- Do you think this tool can attract new audience to the theatre?
- Additional suggestions
  Questions related to the design of enclosed spaces are introduced to the participants of the "Technicians" category:
- After this experience, do you think it is important that this could become a commonly used tool to ensure a better architectural/acoustic quality of a theater project?
- Do you think that the auralisation tool is useful for your work?
- For acoustic designers: how do you think the auralisation tool can be useful for your work?
- For architectural designers: how do you think the auralisation tool can be an added value compared to traditionally used tools (e.g., rendering)?
- Do you think this tool could be useful for the choice of materials from an architectural and acoustic point of view?
- Can you think of another application in your field for which an auralisation like the one you just experienced would be useful?

- Additional suggestions

All the considerations and suggestions elaborated by experts and technicians are collected.

For involving younger participants, a link for having access to an online quiz is provided. The quiz is filled-in in real-time on mobile phones during the audio experience. During playback of different scenarios, people are asked to recognize the instrument, or the kind of instruments playing and define how far from the stage their listening position is.

4. CONCLUSIONS

The AURA Project has investigated the potential that auralisation offers to musical arts and performances. The tool of virtual reality has been implemented for three opera and music theatres in Berlin, Florence and Lviv. Thanks to the definition of audio-visual 3D-models a new way of experiencing theatres is presented. The aim of the activities of the project is profiling the different typologies of participants, both theatre-goers and people that usually do not go to theatres, regarding their habits and preferences with classical music performances. This experience allows to make them approach to the auralisation experience and receive feedback about the tool. The virtual reality is not intended to replace live performances but promote the use of theatres.

ACKNOWLEDGEMENTS

5. REFERENCES

[1] T. Hidaka, N. Nishihara. Favorable reverberation time in concert halls revisited for piano and violin solos. The Journal of the Acoustical Society of America 2192–2206, 151, 2192 (2022).

[2] J. Reinhold, S. Conta. L'acustica del nuovo teatro dell'opera di Firenze: scelte innovative in un teatro (quasi) classico. Atti del 39° Convegno Nazionale AIA 2012.

[3] T. Kamisinski. Acoustic Simulation and Experimental Studies of Theatres and Concert Halls. ACTA PHYSICA POLONICA A, 1, 118 (2010).

[4] Aristat Agency, Orchestral Audiences. A nation-wide study - 2013/2014 season. Association Française des Orchestres, 2015.

[5] T. Baker, Stop Re-inventing The Wheel. A guide to what we already know about developing audiences for Classical Music. Association of British Orchestras, 2000.

[6] C. Bradley, National Classical Music Audiences. An analysis of Audience Finder box office data for classical music events 2014-2016. The Audience Agency, 2017.

[7] P. Mills, M. Ricketts, N. Ponzoni, Opera for All Screenings. The Audience Agency, 2017.