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PHE : The Past Has Ears project overview

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ABSTRACT

When we think about great architectural achievements in European history, such as ancient amphitheatres or Gothic cathedrals, their importance is strongly tied to their acoustic environment, an intangible consequence of the space's tangible construction and furnishings. We present an overview of the "Past Has Ears" project and current progress, exploring how the acoustics of heritage spaces can be documented, reconstructed, and experienced for spaces existing, altered, or destroyed.

Keywords: Archaeoacoustics; Digital heritage reconstructions; Audible virtual and augmented reality; Acoustic heritage; Methodology guidelines

1. INTRODUCTION

Hearing is one of our most pervasive senses. There is no equivalent to closing our eyes, or averting our gaze, for the ears. The acoustics of a site is ephemeral, while also a concrete result of the physical nature of the environment. Research regarding the acoustic heritage of a site, its cultural and sociological position, how it was used, plays a key role. This places the study of heritage acoustics at the intersection of many scientific disciplines. With the recent adoption of UNESCO resolution 39 C/49, "The importance of sound in today's world: promoting best practices", complementing the UNESCO Convention for the Safeguarding of the Intangible Cultural Heritage [1, 2], we are in a new era where acoustic soundscapes of places both existing and historical merit reflection, preservation, and scientific study.

Inspired by the project's namesake (Phé, for the constellation Phoenix), and the relatively recent fires at *Cathédrale Notre-Dame de Paris* (2019) and *Teatro La Fenice* opera hall [3] (1996, *Fenice* also meaning Phoenix), the PHE project focuses on the preservation, conservation, and reconstruction of heritage sites, bringing them back from the ashes for use by researchers, stake holders, cultural institutions, and the general public [4, 5].

2. PROJECT OVERVIEW

Three principal objectives have been identified concerning the project: *Documentation*, *Modelling*, and *Presentation*. These research concepts are directed towards three case studies, adjusting to the unique requirements of each site. The overlying goal being the formulation of techniques, tools, and a system prototype that is adaptable to various site conditions and test cases, providing a flexible yet realistic immersive audio rendering of historic states of cultural heritage buildings. It is intended that the results of such a project will facilitate increased acceptance and integration of acoustic aspects within heritage research and communication with the public.

Comprising research teams with experience in acoustic reconstructions and historical research, paired with national heritage monuments of acoustic importance, the project is developing a joint methodology for addressing relevant archaeological acoustics issues across Europe with historians of different disciplines. Three heritage sites from the participating countries (France, Italy, and the UK) join the consortium as active Associated Partners. These sites are the Tyndaris Theatre (IT), Cathédrale Notre-Dame de Paris (FR), and The Houses of Parliament (UK). Throughout the project, these institutions will participate as case studies for all 3 axes, representing public sites of importance in the form of an ancient Greek theatre (far from its original condition), a Gothic Cathedral (in the midst of recovering from a serious catastrophe, inaccessible to the public for some years), and the House of Commons Chamber (generally inaccessible to the public, of significant importance to UK politics and governance).

For historical research, PHE brings sound to the forefront of attention, focusing on analysis, recreation, and communication of the intangible heritage of sound and soundscapes. As an innovative research tool, historically authentic simulations and reconstructions provide a new perspective for understanding, interpreting, and experiencing the past. Such sensorial and perceptual experiences can confirm, or contradict, hypotheses and assumptions based on insufficient information or fragile extrapolations. The ability to take an immersive perspective provides the opportunity to re-contextualise interpretations of written documentation and witness accounts. Such understandings can be easily communicated to the public, through similar mediated experiences, rather than simply though traditional written elements, providing a new means of information transmission and community engagement.

The project further includes prototyping next generation exploration tools for presenting digital acoustic reconstructions to scientists and museum visitors alike. Presentation methods provide first-person in-situ or

off-site explorations, with the ability to experience various historical periods. For deteriorated sites, this approach provides access to situations impossible to experience on-site. On-site experiments with partner sites will take place in the later parts of the project. Additional uses include participative experiences, employing real-time reconstructions for on-site concerts and other events experienced within the acoustics of these heritage sites.

3. NOTRE-DAME (FRANCE)

The Cathédrale Notre-Dame de Paris is amongst the most well-known worship spaces in the world. Its large volume, in combination with a relatively bare stone construction and marble floor, leads to rather long reverberation times. The cathedral suffered from a significant fire in 2019, resulting in damage primarily to the roof and vaulted ceiling. Despite the notoriety of this space, there are few examples of published data on the acoustical parameters of this space, and these data do not agree. Archived measurement recordings from 1987 were recovered and found to include several balloon bursts. In 2015, a measurement session was carried out for a virtual reality project. Comparisons between results showed a slight but significant decrease in reverberation time (8%) in the pre-fire state. Measurements were recently carried out on the construction site, 1 year since the fire. Compared to 2015 data, reverberation time significantly decreased (20%). Preliminary results of these measurements provide documentation of the acoustics, both prior to and since the 2019 fire, and have been reported in [6].

The study of acoustics as intangible cultural heritage is an active field of research with implications beyond the scientific community. We are examining the potential influence of the acoustics of the "new" Gothic cathedral of Notre-Dame de Paris on the medieval singers who pioneered a style of plainchant known as the School of Notre-Dame using interactive virtual acoustic environments (VAEs) and real-time auralization. The experiment compared the approximated acoustics of the prior cathedral (torn down in 1163 CE to make room for Notre-Dame) with Notre-Dame which partially opened in 1182 CE. A speculative VAE of the pre-1163 cathedral was created by modifying a calibrated model of an extant and contemporaneous Roman basilica, while the early Notre-Dame VAE was generated by time-regressing a calibrated model of the modern cathedral to match its earlier state. A choir specializing in historically informed performance practices was studied as they sang *Organum Purum* and *Organum* Notre-Dame inside the VAEs of the pre-1163 cathedral and the early cathedral of Notre-Dame de Paris. Musical parameters were extracted from the recordings to examine what influence the different architectures may have had on musicians' performances [7, 8, 9]. This works builds upon previous studies concerned with methods for creation and calibration of historical acoustic simulations, as well as their objective and perceptual validations [10, 11].

Extending beyond the targeted site of Notre-Dame, similair techniques as mentioned above have been used to recreate the historical ambiences of a major heritage site for music in the Mediterranean region: the Pontifical Chapel of the Palace of the Popes in Avignon. This building, which was one of the major centres of polyphony in the 14th century, is still today one of the most suitable places in the region for the interpretation of medieval vocal music as instrumental music. The aim was to question the listening of 14th century heritage music through a corpus of polyphonic works, interpreted via an immersive virtual acoustic environment reproducing the papal chapel around 1362 [12]. This reconstruction enabled exploring new avenues of research into historically informed musical practices and the interaction between the musical gesture and sound space with which it resonates.

Bringing together acousticians, historians and religious anthropologists, we examined the lives of choirboys at Notre-Dame between the 14th and 18th centuries, estimating sound propagation by children's voices during liturgical celebrations based on their location inside the choir using acoustic simulations [13]. The enclosed liturgical choir of Notre-Dame created an acoustical subspace in the cathedral with suitable acoustics for the clergy within the choir, but not for the laypeople in the nave. Simulations demonstrated that this liturgy was probably destined just for the canons who sang it. In addition to testing source conditions within the chancel with and without the jubé, we also investigated the situation of singing from atop the jubé, as occurred on certain special occasions. While singing atop the jubé may have had visual appeal or ceremonial importance, simulations reveal that such change would have likely had a negative effect on loudness and clarity as perceived by the canons in the choir.

In public communications of research, and in honour of the International Year of Sound and for the 1 year memorial of the Notre-Dame cathedral fire, we created a virtual reconstruction of a concert in the cathedral, using close-mic recordings made on 24-April-2013 of a performance of *La Vierge* by Jules Massenet with 83 musicians, 6 singers and a 160 person choir spatially distributed throughout the cathedral, offering a natural spatial composition highlighting the complex acoustics and interactions between source and listener positions. This reconstruction[1] was carried out during the period of strict COVID-19 confinement. Distributed on-line, the website presenting this virtual reconstruction has been visited from

[1] Notre-Dame virtual concert: lavierge2020.pasthasears.eu

users around the world, including a listener opinion survey (see [14] for details). *Looking for Notre Dame / À la recherche de Notre Dame*[2] is a bi-lingual 3D sound experience that takes us into the mind of a young Victor Hugo as he begins his research for his future "cathedral novel", Notre-Dame de Paris. This series of audio fictions currently in production uses Victor Hugo's imagination to visit historic moments and acoustic reconstructions developed from the scientific research team [14, 15].

4. TYNDARIS (ITALY)

The ancient theatre of Tyndaris is situated on the northern coast of Sicily. It is surrounded by the remains of the city of Tyndaris, founded in 396 BCE by the Greeks as a colony for exiles of Messenia (modern Messina). Its shape has changed considerably over centuries: in the 4th century BCE a scenic building was added in front of the cavea, while during the late imperial age of the roman empire it underwent substantial modification for hosting gladiator spectacles and fights against ferocious animals. Destroyed by a landslide and two earthquakes, Tyndaris saw light again thanks to archaeological excavations begun in 1838 and later resumed between 1960 and 1998. The theatre again hosts concerts, but its current acoustic is compromised by many factors: lack of the original scenic building, providing useful reflections supporting the actor's voice; absence of a large part of the steps of the cavea and the general deterioration of the materials, impacting the reflectivity; and increased background noise levels due to traffic.

A combination of visual and acoustic experience in a virtual reality environment provides an immersive exploration of all the different phases of its evolution, reconstructed by modifying shapes and materials of a calibrated model of the existing conditions. The visual rendering consists of equirectangular panoramic images, reconstructed from several viewing points, each associated with a computed High Order Ambisonics (HOA) impulse response (IR). Anechoic samples are convolved with these IRs to create the virtual soundtrack for different points [16]. Resulting 360° video files are publicly available[3].

A subjective analysis of three types of Ambisonics recordings (i.e. chamber music, female speech and singing) has been conducted to be used for the calibration of a proposed acoustic shell to be installed in the orchestra. The recordings have been listened to by a range of users (not just experts) of different ages (18 to 50 years). The aim of this research is to design the acoustic shell based on the subjective feedback of the users. The recordings with the presence of a shell have been compared with the original conditions of the theatre and assessed based on subjective parameters like loudness, reverberance, apparent source width, definition, distance and coloration. The determination of its shape has been realised based on the results obtained by the evaluation of the subjective parameters.

Future developments will be focusing on the creation of a six-degree-of-freedom (6DoF) experience of the theatre across all the modifications that occurred throughout the centuries, both in Virtual Reality (VR) and on-site through Augmented Reality (AR), allowing visitors to experience the sonority of the theater using of cost-effective devices, such as smartphones or other Augmented Reality gear.

5. HOUSE OF COMMONS (UK)

As the elected house of the UK Parliament, the House of Commons has met in a number of spaces in and around the Palace of Westminster since the 14th century. A key development came in 1548, during the English Reformation, when the Commons took possession of the royal chapel formerly belonging to St. Stephen's College at Westminster: the first permanent home of the lower house of Parliament. Parliament remained here until the Palace fire of 1834, when the historic Commons chamber was gutted and demolished. Rebuilt in a consciously medieval Gothic style, the Commons was destroyed again during the Second World War, but was once again restored to a similar design. At each stage, the oppositional format of the chamber with benches on either side of a central aisle – recalling the layout of the lost St. Stephen's Chapel – was retained, thus shaping the architectural context and political culture of the UK House of Commons to this day.

This aspect of the PHE project explores the acoustic characteristics of the historic House of Commons chamber as it evolved within the former St. Stephen's Chapel between the 16th and 19th centuries, and in terms of its modern legacy. This lost building is compared with surviving spaces used for meetings of Parliament in Oxford during the 17th century, including the University of Oxford's Divinity School and Convocation House. Both survive with few interior changes, and are still accessible to visitors. The architectural similarities between the Holywell Music Room in Oxford, and the Commons chamber, as re-ordered by Christopher Wren c. 1707, are also remarkable. A study of this space as a potential comparator to the acoustics of the lost Commons chamber is ongoing. Results obtained from in-situ measurements of these parliamentary, and comparable related spaces, are presented in the companion paper [17], with a particular focus on speech intelligibility given their primary use as places for political speech-making and debate.

This work continues with the development of an acoustic model of the pre-1834 House of Commons, based on

[2] Notre-Dame audio fiction: lookingfornotredame.pasthasears.eu
[3] Tyndaris 360° reconstruction: youtu.be/H-75GT68DUE

information gathered from written sources[4], drawings and engravings of the site, as well as objective acoustic results obtained from the in-situ measurements of the spaces discussed above. As part of this reconstruction, the ventilator space above the ceiling of the historic Commons chamber has been added to the acoustic model. Here, women gathered to listen to political debates from which they were formally excluded during the early 1830s. Speech intelligibility across different measured positions where Members of Parliament spoke and listened will be assessed, with the aim of investigating the impact of acoustics in parliamentary debates and decision-making.

6. FINAL REMARKS

With a little over 1 year remaining in the PHE project, a significant portion of those months will be spent on experimental studies employing virtual reconstructions both on and off-site, contributing to fundamental studies on performance and listening conditions, navigable virtual and augmented reality, collaborative studies regarding social science and the humanities, as well as prototype museum exhibits. We all look forward to sharing these results with both the scientific community and the public at large.

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