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Virtual reality inside the Greek-Roman theatre of Tyndaris: comparison between existing conditions and original architectural features.

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ABSTRACT

Archeoacoustics has become a field of great interest in the last decades, which has constantly bridged the knowledge of three main disciplines: acoustics, archaeology, and computer simulation. This synergy is considered very beneficial when the cultural heritage subject to be studied is a historic construction of the Roman or Greek Age. The case study relies on the reconstruction of the acoustic conditions of the theatre of Tyndaris, located in Sicily, South of Italy. This paper deals with the application of the Ambisonics methodology to recording audio in combination with the panoramic view taken in one of a few selected locations across the theatre. The sound signal during the post-processing has been auralized in two digital environments: the existing conditions and the original reconstruction. The absorption coefficients of the digital models have been calibrated with Ramsete based on the measured results. The difference between the two outcomes has been compared.

1. INTRODUCTION

The virtual acoustic reconstruction of archaeological sites opens the possibility to experience new feelings of immersive visits by including a dynamic audio to the playback recordings [1]. This paper deals with the immersive exploration of a 3D sound applied to the Greek-Roman theatre of Tyndaris.

From a site survey, several impulse responses (IRs) of the existing conditions have been gathered [2]. In order to proceed with the auralization, different phases were considered necessary to achieve the objectives, as summarised below:

- Selection of a recording sample undertaken under anechoic conditions;
- Realization of an acoustic model to be calibrated with the measured IRs;
- Elaboration of 3rd Order Ambisonics (3OA) IRs gathered by the digital model;
- Convolution of the anechoic signal with the 3OA digital IRs;
- Creation of binaural soundtracks to be listened by using a Head Mounted Display (HMD) device, or similar.

The immersive listening experience has been realised by combining the audio output with a visual rendering, consisting of panoramic images taken at the specific locations selected for the acoustic measurements [3].

Before gathering the 3OA IRs related to the original shape of the theatre, a calibration process of the absorption coefficients has been carried out with the 3D model representing the existing conditions.

2. ENVIRONMENTAL BACKGROUNDS OF THE SITE

1.1 Original Construction

The town if Tyndaris is located on the norther coast of Sicily, Italy. The theatre has been built by Greeks during the 4th century BCE, having an original capacity of 3000 seats [4]. It represents one of the few Hellenistic monuments survived as an important document of the architectural traditions. The construction of the Hellenistic period was composed of a *cavea* having a diameter of 76 m, and the orchestra of 23 m width [4]. The Hellenistic scene remained untouched during the Roman period but has been destroyed during the Middle Age.

1.2 Existing Conditions

During the 1st century BCE, the Romans modified the theatre into an arena by lowering the level of the orchestra of 0.9 m and by destroying the first four steps of the *cavea* to build a podium of 2.5 m height [4]. This represents the main change with respect to the Hellenistic construction.

Nowadays, the damage of further architectural elements compromises the faithful integrity of the original acoustics as it should be perceived inside the Hellenistic theatre. The absence of a scenic building useful to support the sound reflections and the deterioration of the stone as finish material of the *cavea* determine a noticeable change

3. DIGITAL MODELS

1.3 3D Model of the actual condition of the theatre

The numerical model has been realised in AutoCAD software by the creation of 2261 3D faces. The AutoCAD layers have been grouped based on the existing finish materials and architectural components and then exported in dxf format, ready to be used for the acoustic calibration. The software chosen for the calibration and simulations is Ramsete 3.02.

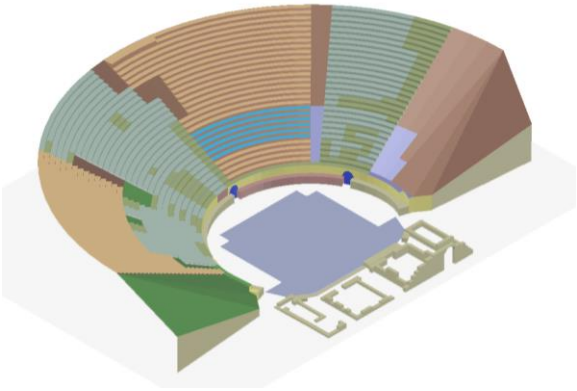

Figure 1 – View of the 3D model representing the existing conditions of the theatre of Tyndaris.

The calibration process of a digital model consists of a loop procedure of room acoustic modelling to increase the accuracy of the simulated results. As such, the absorption coefficients have been tuned based on the measurements undertaken in situ [5]. Figure 1 shows the digital model representing the existing conditions of the theatre.

1.1 3D Model of the Hellenistic shape of the theatre

Based on archaeological anastylosis and previous literature, a digital model of the theatre representing the Hellenistic architectural features has been realised similarly to the model representing the existing conditions.

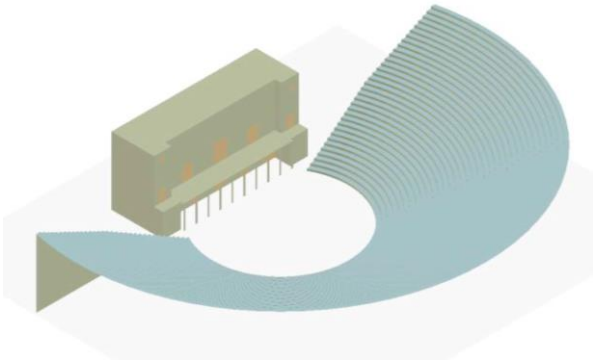

Figure 2 – View of the 3D model representing the Hellenistic shape of the theatre of Tyndaris.

The main characteristic regards the front of the *koilon*'s wings that should not be linear but presenting a slight inclination, without the termination of any *parodoi.* Figure 2 shows the digital model representing the Hellenistic shape of the theatre.

4. IMMERSIVE AUDIO APPLICATION

Once the absorption coefficients of the 3D models have been calibrated, the 3OA IRs can be gathered with Ramsete and be exported in B-Format [6]. The 3OA IRs represent the environmental conditions of the two "room" types to be used for the convolution with anechoic recordings of speech and/or music. The convolution of the sound signal with the IR has been developed using the plugin Aurora suitable for Audacity software [7].

The sound signal selected for the convolution is a faithful reconstruction of a musical performance reflecting the composition written by Euripides for the choir of Orestes in 408 BCA [7].

5. VISUAL COMPONENT AND VR REALIZATION

A 360° view taken at each receiver position has been considered as the visual rendering, although the use of photogrammetric scan would be improving the fully immersive experience.

The panoramic photos having equirectangular format have been associated with the corresponding 3OA IRs. The panoramic photos have been converted into a .mov file by using FFmpeg software. The combination of the 3OA audio with the image/video has been realised with the extended version of Spatial Media Metadata Injector modified by Prof. Farina to accept HOA audio files.

The results are stored in video files with proper metadata which allow them to be watched with an HMD (such as an Oculus Quest 2) or on Youtube.

Figure 3 – Rendering of the 3D model representing the existing conditions of the theatre.

Figure 4 – Rendering of the 3D model representing the Hellenistic shape of the theatre.

Figures 3 and 4 show the rotation of the immersive experience taken at the same position in the *cavea*, related to the existing conditions of the theatre.

6. CONCLUSIONS

The archaeological sites have always been investigated under an architectural perspective throughout the centuries. It is practice of recent decades to make the ancient monuments usable to community by exploring the VR composed of audio-video rendering.

On this basis, this paper explains how a 3OA audio file can be merged with a panoramic view of the theatre of Tyndaris. Two 3D models have been explored and compared, in particular the existing conditions and the Hellenistic shape. The audio files have been gathered from the IRs elaborated with Ramsete after a calibration process of the absorption coefficients with the measured values. Thereafter, the 3OA IRs have been convoluted with a sound signal reproducing a musical/vocal performance.

While future research studies will be focusing on the photogrammetric scan of the archaeological sites, at this stage the available tools are 360° photos taken at each position of the acoustic measurements across the cavea. The panoramic views have been transformed into .mp4 files by using the software FFmpeg Thereafter the 3OA audio has been combined with the video using the same software. Then the metadata have been modified with Spatial Media Metadata Injector in order for the audio to be read as spatial audio. The result is a 3 degree of freedom (3dof) VR that faithfully reproduces the directivity of the audio in combination with the visual exploration.

7. ACKNOWLEDGEMENT

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