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SURVEY AND ACOUSTIC CORRECTION OF THE BOBOLI AMPHITHEATER USING AUDIO-VISUAL MODEL

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ABSTRACT

The research is part of a renovation project for the Boboli amphitheater supported by the Uffizi Gallery, with analysis to correct the acoustics of a historic open-air theatre space. The acoustic correction starts with the design of a modular temporary stage and continues with the insertion of an electro-acoustic system proposed in various configurations, evaluated according to the scheduled performance. In parallel, the geometric survey of the area is developed with a laser scanner for auralisation and the creation of an audio-visual model.

Keywords: *historical site, outdoor sound diffusion, electroacoustic system, virtual reality.*

1. INTRODUCTION

The present research started from the contents of a degree thesis [1] discussed at the University of Florence in which various competences collaborated, and which was aimed at defining a method of audio-visual representation of design solutions referring to a particularly significant historical environment for the city of Florence: the amphitheater of the Boboli Garden. From 1637, the amphitheater was used by the Medici for grand ducal festivities, dance and music performances. Recently, the Uffizi Galleries had the objective of recovering the amphitheater's function as an open-air theatre and hosting performances. In particular, it is planned to hold classical music and opera concerts, and to restore the architectural, sculptural and plant components to their best condition.

2. A HISTORICAL THEATRE SPACE: THE BOBOLI AMPHITHEATRE

In 1550, Tribolo began the construction of a large amphitheater, exploiting the artificial depression created by the earthworks on the hill behind the Palazzo for the construction of the Palazzo itself. The work was then continued by Davide Fortini, Bartolomeo Ammannati, Giovanni Fancelli and Giulio Parigi, with various modifications to the original project. Especially in 1630, the building site required heavy earthworks, which almost completely cancelled the initial planting. Before the inaugural performance in 1637, the stalls were completed with the entrance balustrade and the four monumental pillars, and the connection with the palace was solved by demolishing the drawbridge [2].
The theatre was designed to accommodate ballets on horseback, opera-tournament forms, rich in choreography and allegorical machines, and was inaugurated for the first time with the night carousel in 1637 [3]. During the Lorena Regency, the theatrical function of the site was abandoned. The architectural layout was definitively altered in 1764 with the silting up of the cavea and the consequent loss of the lower architectural orders, the disappearance of the internal distribution system and the entrance balustrade. In 1790 the cavea was enriched with the Egyptian obelisk,

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which came from the Villa Medici in Rome and was definitively completed in December 1840 with the placement of a large thermal pool from the Roman period. During the 20th century, the Boboli Amphitheatre again provided the ideal setting for important theatrical performances; memorable was the concert directed by Pietro Mascagni in 1906, and in 1937 the stage set designed by Michelucci at Boboli for Monteverdi's "*L'incoronazione di Poppea*" [3].

3. METHODOLOGIES

3.1 The laser scanner geometric survey

The digital laser scanner survey was carried out by the Extended Reality Laboratory (DidaLXR) of the University of Florence in collaboration with the Uffizi Gallery by using two different instruments: a Zoller-Fröilich 5016 and a Leica Geosystem RTC 360. Both these instruments cover a complete rotation angle on the vertical and a field of 320 degrees on the horizontal axis with a range of 180 and 130 meters respectively and have an accuracy of two millimeters within 10 meters with normally reflecting materials. The measurement system of each single point reached by the laser signal is based on the phase variation between the emitted signal and the reflected signal and allows the collection of a myriad of vectorial points, representative of all the surfaces visible from the point of capture (see Fig. 1).

Figure 1. Point cloud processed by laser scanner survey; survey points highlighted.

The point cloud, consisting of points characterized by spatial coordinates (x, y, z) and color values (R, G, B), was produced based on approximately three hundred scanning locations. This was subsequently processed in Autodesk Recap, both for alignment and subsampling operations, producing a lightened version with a density of 10 mm. It is necessary then to clean of recorded objects deemed irrelevant, such as vegetation and moving subjects that had accidentally entered the field of view.

The point cloud was then used as a starting point for the creation of a metric and visual digital model; in fact, this dataset was imported into Autodesk 3D Studio Max using the point cloud sharing options of the Autodesk suite and treated as a Virtual Reality (VR) acoustic design environment. In this way, the complex point cloud data was used as an accurate and versatile reference system, serving as the basis for the modelling of essential components functional to the presentation of the resulting acoustic system. The design developed in 3D Studio Max was then used directly for the generation of panoramic views equirectangular suitable for producing the contextualization VR presentation of results.

3.2 The acoustic model for simulations

For the acoustic analysis, a simplified model was created in Autodesk Autocad and imported into the EASE® 5.0 software (see Fig. 4). This process is parallel to the 3D laser scanner geometric survey, as the amount of detail in the point cloud model is too much for any acoustic simulation. The program provides the possibility of importing different sound sources from the connected site, and choosing from commercially available models, characterized by spatial directivity.

For the source model used (a line array loudspeaker), it was configured both the angle of each individual loudspeaker (see Fig. 2), to direct the sound emission to the relevant areas, as well as the Gain and Delay parameters of the sound signal. Figure 2 shows the configuration of the line array loudspeaker and a comparison between an omnidirectional and a line array sound source.

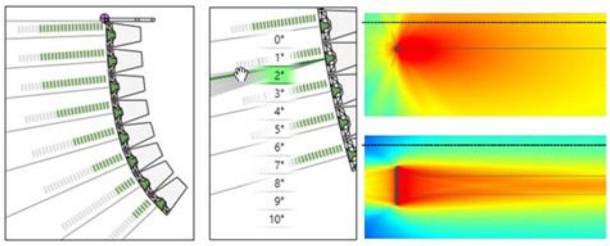

Figure 2. Left and center, line array configuration; right, above, omnidirectional source emission; below, line array.

3.3 Acoustic analysis

There are six hypotheses of set-up configuration inside the amphitheater required by the Uffizi Gallery: acoustic concert, cinema, opera concert, opera theatre, experimental

theatre and fashion show. These configurations required different performance of the sound sources and of the stage to acoustically cover the listening area as evenly as possible. In the research, all configurations were simulated in a synthetic manner and the two extreme cases were investigated in depth: the acoustic concert (configuration C1), placed in the middle of the lawn, therefore more favorable, and the opera concert (configuration C2), which uses the entire space including the tiers of seats, therefore more complex. A movable wall stage and a sound diffusion system are proposed for both these configurations.
The stage, designed in accordance with the requirements of temporariness and dismount ability, is therefore composed of milled, easily transportable modules and rests on a steel structure of telescopic pillars and truss beams (see Fig. 3).

Figure 3. The reflective design stage, modular and easily demountable.

The dimensions of the stage are fully adjustable at the time of assembly as the roof panels are connected by a tie rod system to a beam behind. This makes it possible to change the inclination of the roof, which is essential for directing sound and increasing acoustic performance as required. The side walls also rotate on internal hinges to change their configuration and acoustic behavior [4].

4. RESULTS AND DISCUSSIONS

The simulations show that the stage configuration is not sufficient to guarantee suitable sound distribution in the listening area, which is approximately 80 meters long; an electroacoustic system must therefore be inserted to achieve greater uniformity of sound levels, as the last rows of receivers suffer from excessive sound pressure decay.
For both C1 and C2 configurations, a line array system placed solely on the stage was initially assumed. This type of arrangement generally involves the insertion of a vertical system at the sides of the stage that reinforces the sound in the last rows, and a system of horizontal loudspeakers placed on the platform (see Fig. 4). In this way, a reduction in the spatial decay of the Sound Strength between the higher and the lower levels in the stalls from 16 dB to 14 dB is achieved in the configuration C1. On the other hand, the decay between the first and the last row in the center axis of the stalls shows changes from 13.5 dB to 12.0 dB (see Fig. 5).

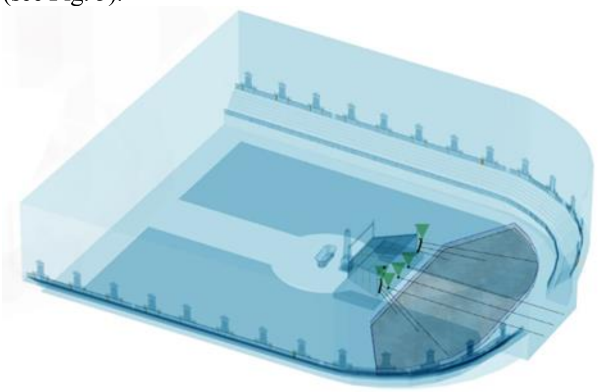

Figure 4. Insertion of loudspeakers, marked with green arrows, in configuration C1: three KK52 models for the platform (the Kobra from K-array) and two KK102 models for the vertical boxes on the side of the stage.

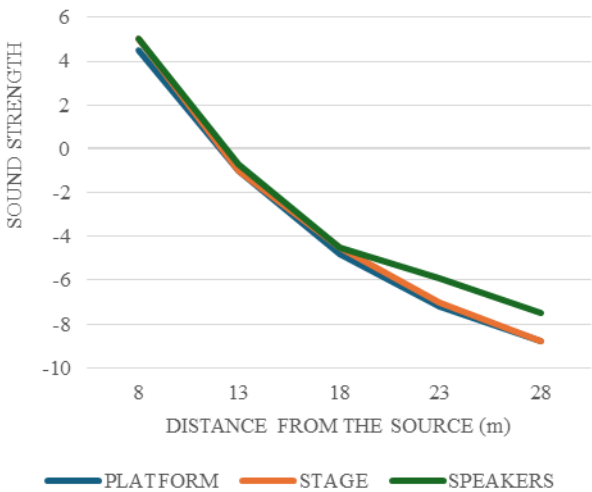

Figure 5. Variation of Sound Strength calculated at different distances from the source along the central axis of the stalls in C1 configuration; without correction (platform only), with stage, with stage and line array speakers.

In the configuration C2, the spatial decay in Sound Strength is 13 dB between the first and last row only with stage and loudspeakers near this. To limit this problem, two reinforcing loudspeakers were placed in the middle of the amphitheater near the obelisk. In positioning these loudspeakers, it was necessary to set the values of delay, i.e. the delay with which the loudspeaker should emit sound in relation to the speakers on the stage, and gain, to maintain the feeling of prominence of the sound emission from the stage. The models K-array's Kobra 52 cm and Python 102 cm were chosen (see Fig. 6). With this solution, there was a reduction in the spatial decay of the Sound Strength between the higher and the lower levels in the stalls from 14.0 dB to 10.5 dB (see Fig. 7). On the other hand, the decay between the first and the last row in the center axis of the stalls shows changes from 10.2 dB to 6.5 dB (see Fig. 8).

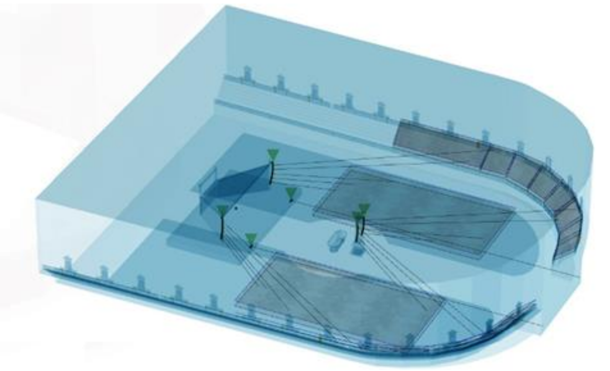

Figure 6. Insertion of loudspeakers, marked with green arrows, in configuration (C2): two KK52 models for the platform (the Kobra from K-array), two KK102 models for the vertical boxes on the side of the stage and two KP102 models (the Python form K-array) in the center of the stalls.

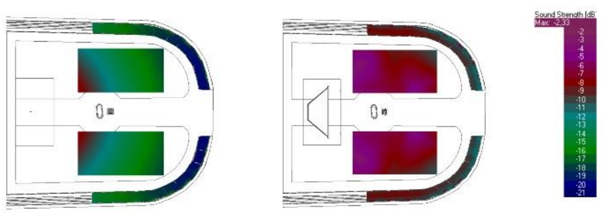

Figure 7. Comparison of Sound Strength spatial distribution in configuration C2 without correction (only with platform) and with loudspeakers.

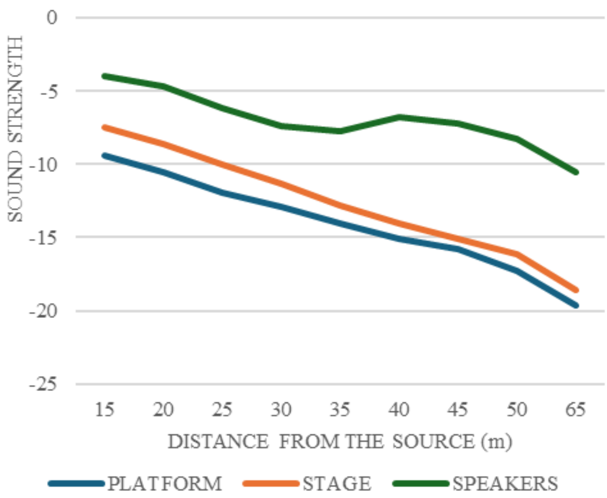

Figure 8. Variation of Sound Strength calculated at different distances from the source along the central axis of the stalls in C2 configuration; without correction (platform only), with stage, with stage and line array speakers.

4.1 The audio-visual model

The study is concluded with the preparation of Virtual Reality, combining the results of the acoustic auralization and point cloud survey to create a 3D model that mirrors the acoustic behavior experienced in the real place, bringing the listener into an immersive virtual environment. The auralization files were obtained with the plug-in Aurora of Audacity®, from an anechoic track and the impulse response simulated from Ease® [5]. The composition of the VR system was conducted using the GN PanoVR6.1 software in which the convoluted audio files were inserted for some critical locations. In this way, the virtual tour created allows the user to make a series of movements within the point cloud, the visualization of the project stage insertion and the appreciation of listening to a song as in reality (see Fig. 9).

Figure 9. Virtual reality of configuration C2 realized with the point cloud, available at the link https://www.didalxr.it/anfiteatrobobolivr/ .

5. CONCLUSIONS

The research showed how the combination of various disciplines can lead to more accessible results. The laser scanner survey made it possible to appreciate the acoustic results of the noise maps in 3D.
The main problem in this open space is sound dispersion caused by the large size of the amphitheater (approximately 80 m deep) that makes it necessary to insert an electroacoustic line array system on the stage and in the stalls. In this way it will be possible to achieve good levels of sound decay and use the ancient Boboli amphitheater as an open-air music space.

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