Virtual reconstruction and 3D modeling for the auralization of acoustic Heritage: the case study of the Teatro del Maggio in Florence

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Introduction to AURA project

This paper illustrates the phases of digital laser-scanner survey and 3D modeling of the Teatro del Maggio Musicale Fiorentino in Florence. In particular, the research involves the creation of a NURBS model functionally subdivided into its components in relation both to the specific needs of auralisation projects and in function of the experiential visualization aimed at the project AURA - Auralisation of Acoustic Heritage Sites Using Augmented and Virtual Reality, co-funded by the Creative Europe Call[1] (Bertocci, Lang et al., 2021).

The Teatro del Maggio Fiorentino, designed by architect Paolo Desideri of ABDR Studio, is a structure that rises between the historic center of Florence and the Parco delle Cascine and contains three theatrical venues: the 1800-seat opera house, a 2000-seat open-air cavea and, soon to be opened, a 500 to 1000-seat auditorium. The project presented in this paper considers the opera house hall: the large main hall with cladding and complex finishes in pear wood and copper mesh with stalls, gallery and side boxes. For the completeness of the perceptive experience towards which the project aims, the external spaces of the theatre have also been taken into consideration, with the avenue of access, the entrance and the paths that the public goes through to reach the internal hall.

Teatro del Maggio: digital survey for the virtual reconstruction and visualization

The development of laser scanning technologies allows to obtain three-dimensional point clouds highly reliable and also provided with color data, thanks to the integration of cameras in the instrumentation, which can be used for the creation of virtual environments using Virtual Reality technologies.

[1] The AURA project was co-funded by the Creative Europe Programme of the European Union and involves German, Italian and Ukrainian partners collaborating with their distinct expertise in the creation and implementation of the experiment, involving groups of stakeholders covering the aforementioned perspectives to identify new values for creative production, auditory experience and cultural industries with the use of cutting-edge technologies.

The purpose of the survey of the Maggio Musicale Fiorentino theater is to provide the reliable metric and morphologic data for the development of a 3D NURBS model and a highly descriptive point cloud to be used as a background for the visualization of the virtual environment. In order to plan digital survey campaigns, a preliminary analysis of the building and its urban and landscape context is necessary, and a storyboard of the final experience must be developed, evaluating the user's paths and the quality of the laser-scanner stations to be acquired.

In fact, the acquisition phase of the 3D laser scanner data included the accurate planning of the positioning of the stations to avoid the formation of cones of shadow on the surfaces, also in consideration of the furniture and decorative elements present in the interiors.

The digital survey of the Teatro del Maggio Fiorentino was carried out using two instruments: a laser scanner Z+F 5016 for the exteriors, the entrance, and the monumental environment of the main hall, and a Faro Focus M70 for the service areas, corridors, and connecting areas with the galleries.

The overall point cloud was rendered through the acquisition of 177 color scans using a Z+F 5016 laser scanner, and 109 scans made with the Faro Focus M70. The data acquired, recorded using the Leica Cyclone software, produced a colored point cloud of the entire complex (Fig. 1) and the surrounding environment, well balanced in the representation of the original color of the elements and therefore highly descriptive (Cioli and Ricci, 2020).

Fig. 1. Panoramic view of the colored point cloud of the interiors of the main hall

3D Modeling and development of acoustic databases for auralization projects

The phase of elaboration and post-production of the acquired data has been developed pursuing two complementary and methodologically propaedeutic objectives for the auralization of the acoustic Heritage of the Teatro del Maggio. The first one concerns the elaboration of a highly descriptive 3D model of the main hall, using a geometric-morphological support obtained from the laser-scanner survey. The second involves an accurate process of semantic and material subdivision of the architectural, furniture and acoustics elements present in the room, carried out through specific on-site visual inspections.

The first phase of 3D modeling has involved the elaboration of 2D digital drawings in CAD environment, through a careful discretization of the data extracted from the global point cloud developed by the laser-scanner survey. These drawings (plans, elevations and sections) were then imported into a specific NURBS modeling software and were used as the geometric basis for the development of the model of each single element present in the room. For some instances with complex geometry, a portion of subsampled point cloud was directly imported, and from this, through specific algorithms, the three-dimensional surfaces were extracted directly within the modeling software. The volumes and solids belonging to the 3D model have been geometrically simplified in some points, due to construction irregularities, but a level of precision of max 5/10 cm has been maintained compared to the point cloud. In addition to the architectural elements, also the panels and the acoustic curtains have been modeled, this time referring also to the technical documentation, as they were hidden and not completely acquired by the laser-scanner. Particular attention was paid to the furniture elements, such as benches and seats, since their large presence is relevant in the acoustic study of the room and consequently in its auralization.

Simultaneously to the modeling phase, a semantic classification of the single elements has been developed, through a subdivision in typological categories (ceilings, doors, floors, steps, walls, etc.) and, to each of them, a different material has been associated and codified. This methodological process has allowed the creation of an acoustic database containing, in the form of an informative table, the coding of the different elements subdivided by single material, to which, in the auralization phase, it is possible to associate the values of the single acoustic parameters (scattering, absorption and transmission frequency etc.). At the same time, in addition to their coding, the materials have been sampled through photographic surveys and for each of them a photo-realistic texture has been realized in order to map all the surfaces of the 3D model (Fig. 2).

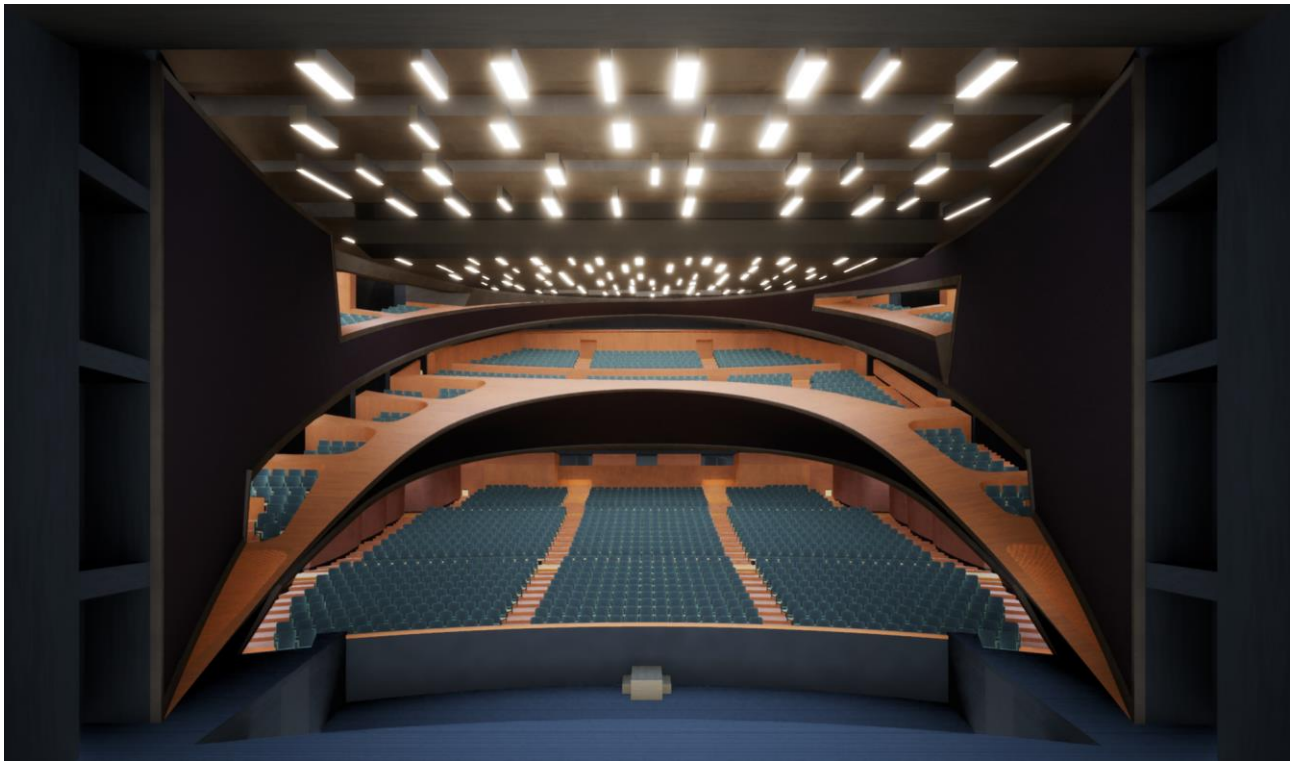

Fig. 2. Perspective view of the textured 3D model

Conclusions and further goals

The solution proposed within the AURA project and presented in this paper for the case study of the Teatro del Maggio in Florence, foresees not only to develop multisensory 3D models based on reliable metric-morphological supports, but mainly to create a scientific and replicable methodology of the workflow of the elements classification and virtual reconstruction aimed at auralization and its dissemination.

The multimedia experience of the developed digital outputs will be perceived by the users through Augmented, Mixed and Virtual Reality (AR, MR, VR) tools and applications. This kind of integrated and immersive approach, in which photorealistic visualization and acoustic rendering are combined with direct and simulated user interaction, can contribute significantly to communication and dissemination purposes within Institutions that base their essence on Cultural Heritage.

The future goals of the experimentation of virtual reconstruction presented in this paper lead not only to the process of auralization of the model, based on the semantic and material classification realized, but also to further studies on informative and parametric modeling.

If in this case it has been tested the Scan-to-NURBS modeling and the creation of parallel informative databases, the next steps will involve the development of case studies in which the modeling will take place through Scan-to-BIM methodology, so as to directly associate the acoustic parameters to individual elements, creating an informative, shared and embedded infrastructure of the object of study.

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Author Contributions

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Writing – original draft: Stefano Bertocci wrote the paragraphs “Introduction to AURA project” and “Conclusions and further goals”, Federico Cioli wrote the paragraph “Teatro del Maggio: digital survey for the virtual reconstruction and visualization”, Andrea Lumini wrote the paragraph “3D Modeling and development of acoustic databases for auralisation projects”

References

Bertocci, S., Lang, F., Sauter, C., Sieck, J. and Shakhovska, N. (2021). ‘Il progetto AURA: proposta di auralizzazione di alcuni teatri europei per la creazione di paesaggi sonori virtuali’, Paesaggio Urbano – Urban Design, 2 (2), pp. 84-89

Cioli, F. and Ricci, Y. (2020). L’Officina Profumo-Farmaceutica di Santa Maria Novella. From the Point Cloud to the Virtual Reality, *Proceedings of the 42th International Conference of Representation Disciplines Teachers,* Milano, pp. 1958-1973. DOI: 10.3280/oa-548.107

Droste, M., Letellier, J., Böhm, C. and Resch, T. (2020). Combining high-fidelity visuals and spatial acoustics in virtual reality. Auralization of a virtual string quartet. *Proceedings of the Culture and Computer Science – KUI Conference,* Berlin, pp. 179-192.

Kleiner, M., Dalenbäck, B. and Svensson, P. (1993). ‘Auralization - An overview’, Journal of the Audio Engineering Society, 11 (41), pp. 861–875.