



## Deliverable 4.1

# 3D model of the Lviv Opera



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### **Project Information**

“AURA - Auralisation of Acoustic Heritage Sites Using Augmented and Virtual Reality” (project no. 101008547)

Project Website: <http://aura-project.eu>

Auralisation – the technique of creating virtual soundscapes in 3D models to provide the same immersive sound experience as the music performed in the real venue. AURA will explore exciting new opportunities that auralisation opens up for music performing arts and their traditional and new audiences.

### **Publisher & Project Coordinator**

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### **Project Partners**

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## Table of Contents

<b>3D Model of the Lviv Opera</b>	<b>4</b>
Digital Survey	4
<i>Acquisition and Processing of Laser-Scanner and Photogrammetric Surveys Data</i>	6
3D Model	8
<i>Classification of the 3D Elements and Development of a Materials Database</i>	9

## 3D Model of the Lviv Opera

The development of the 3D NURBS model of the Lviv Opera House based on the digital surveys, within the project "AURA - Auralisation of Acoustic Heritage Sites Using Augmented and Virtual Reality" (AURA - project no. 101008547), has been fully completed.

This model will be used to develop the auralisation of the Lviv Opera House (WP4).

### Digital Survey

The activity included laser-scanner surveys of the interiors of the Lviv Opera House and a SfM photogrammetric survey of the interior spaces of the main hall. These activities were preliminarily carried out by the working team of LPNU who acquired the metric data in B/W and took the photos, which were subsequently processed by the working team of UNIFI-DIDA.

From 18th to 22nd October 2021 a further mission to Lviv has been carried out by the working group of the Department of Architecture of Florence (UNIFI-DIDA), during which other laser-scanner scans have been performed for the acquisition of the external spaces, including the adjacent streets of Svobody Ave and Knyazya Yaroslava Osmomysla Square, this time with color acquisition, to integrate those elaborated by LPNU. During this mission, some color scans of the interior, including the main hall, corridors and foyer, were also redone.

The laser scanner survey has provided highly reliable metric data, which, mainly coloured point clouds, have been subsequently processed by a specific software, thus constituting a three-dimensional database that will serve as a support base for the development of the 3D model.

The data acquired by LPNU have been used for the realisation of the 3D model for the acoustic studies, while those acquired by UNIFI-DIDA will be used for the visualisation of the external spaces, in the form of a coloured point cloud.



*B/W point cloud of the main hall of the Lviv Opera House acquired and processed by the LPNU team*



*Photogrammetric coloured point cloud of the main hall acquired by LPNU team and processed by UNIFI-DIDA team*



*Coloured point cloud of the exterior of the Lviv Opera House acquired and processed by the UNIFI-DIDA team*



*Coloured point cloud of the main hall of the Lviv Opera House acquired and processed by UNIFI-DIDA team*

## Acquisition and Processing of Laser-Scanner and Photogrammetric Surveys Data

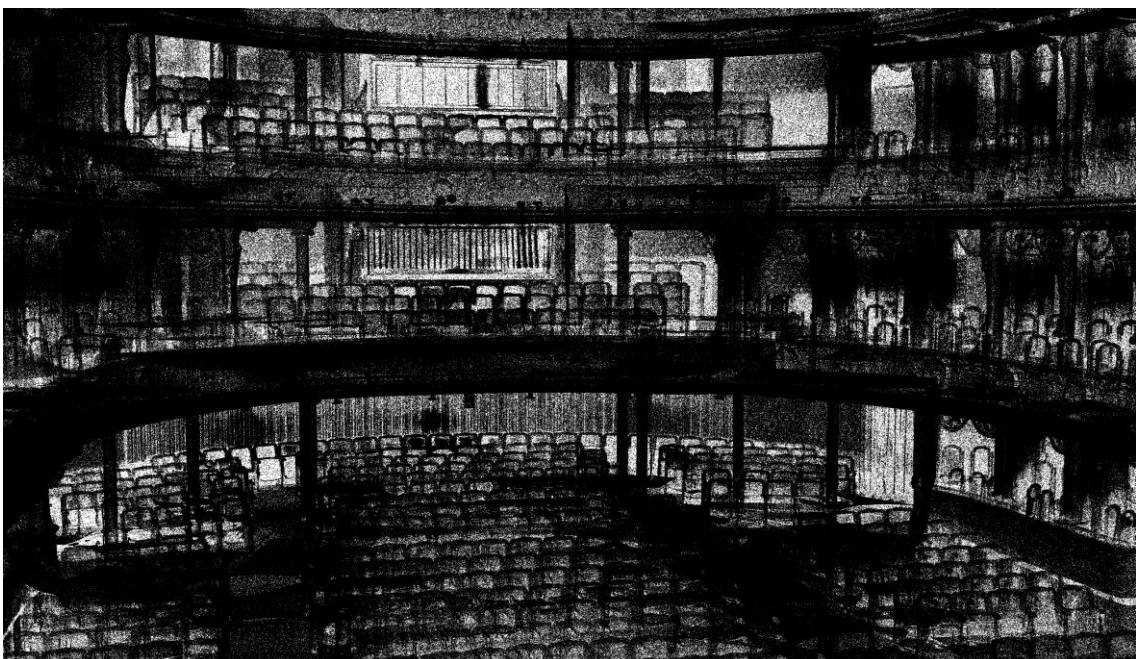
For the laser-scanner survey of the Lviv Opera House, two different instruments were used, a Leica Scanstation C10 and a Faro Focus M70, both with phase difference technology, through which about 320 scans were made: 160 for the acquisition of the B/W data of the interior and 160 for the colored data of the exterior and the internal spaces.

The large amount of data obtained from the laser-scanner survey campaign was subsequently processed, starting the phase of the registration of the point clouds. In this way, the approximately 300 scans were aligned, and after verifying the correct union, a single global point cloud was developed. This methodology has been applied both to the B/W scans and the coloured ones.



*B/W point clouds alignment phase*

From this global point cloud has been exported and decimated the part related only to the main hall, which has become the metric support for the development of the 3D model.



*Decimated point cloud of the main hall inserted within the 3D modelling software*

In parallel with the development of the laser-scanner point cloud, the photogrammetric survey of the main hall has been elaborated using the photos taken by the LPNU team.



*Alignment phase of the photos*

The 1600 photos were aligned using Structure from Motion processes and a coloured point cloud was created which was subsequently referenced using points homologous to that developed by the laser-scanner.



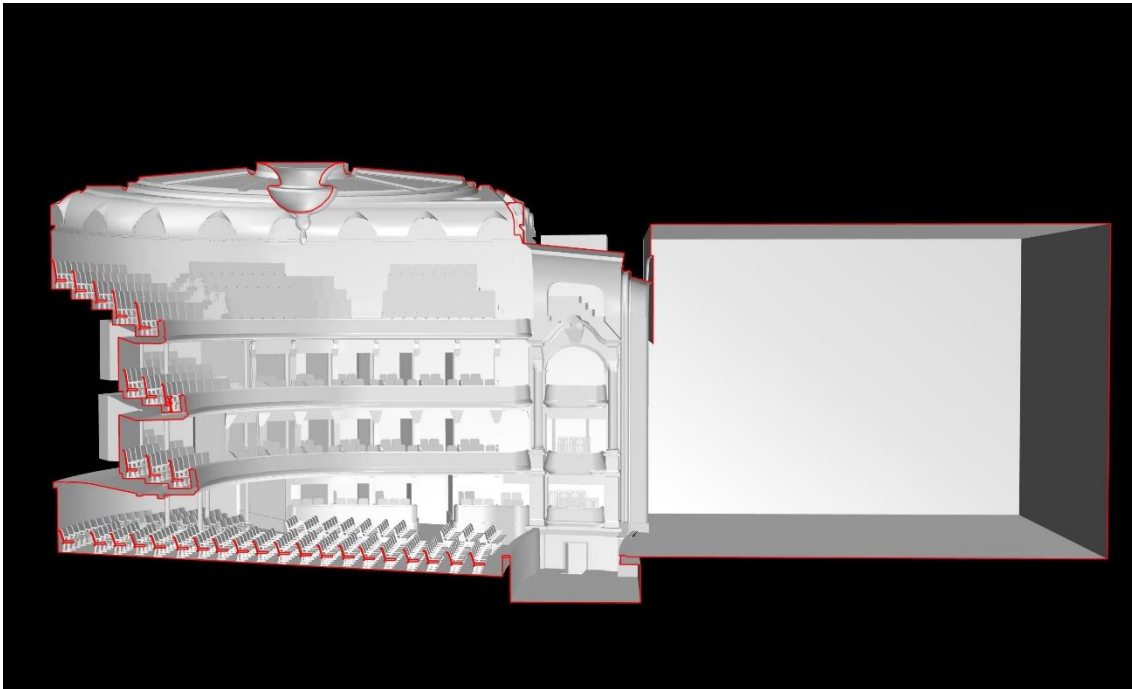
*Coloured point cloud of the main hall processed through SfM photogrammetric methodology*

## 3D Model

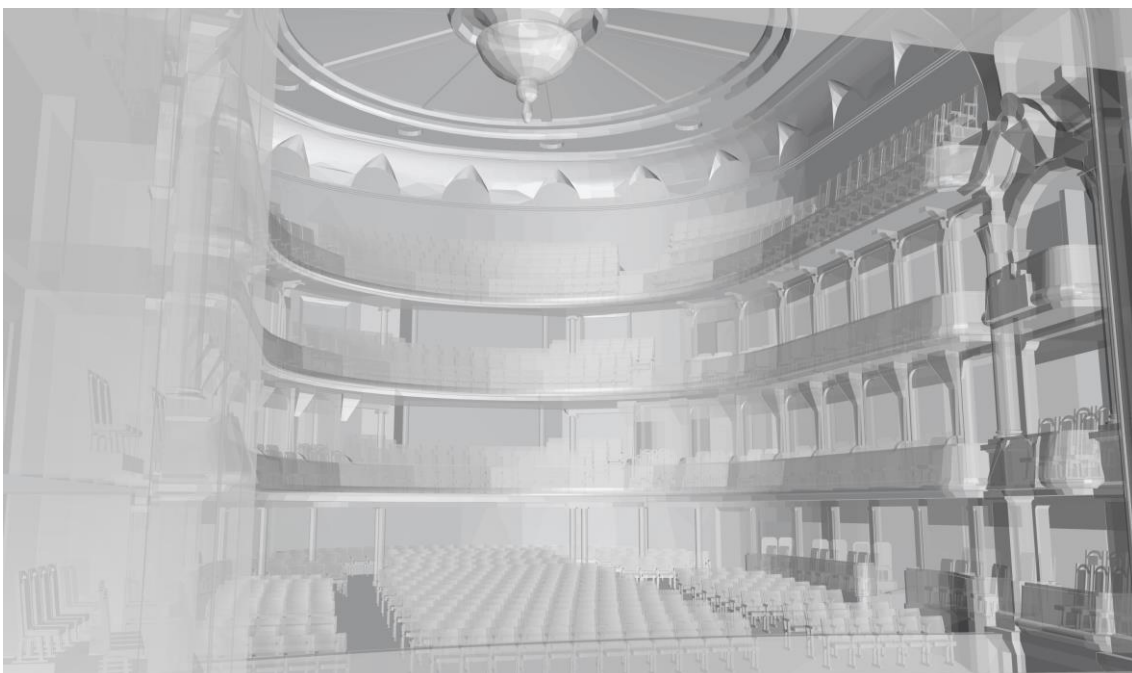
Based on the results of the laser scanner surveys conducted by LPNU team and their post-processing, a highly descriptive 3D NURBS model of the main hall of the Lviv Opera House was developed.

Each element present in the main hall has been geometrically modeled in 3D to obtain a digital twin on which all acoustic studies will be carried out.

The volumes and solids belonging to the 3D model have been geometrically simplified in some points, due to construction irregularities, but a level of accuracy of max. 10/20 cm was still maintained compared to the point cloud.



*Prospective section view of the untextured 3D model of the Lviv Opera House main hall*



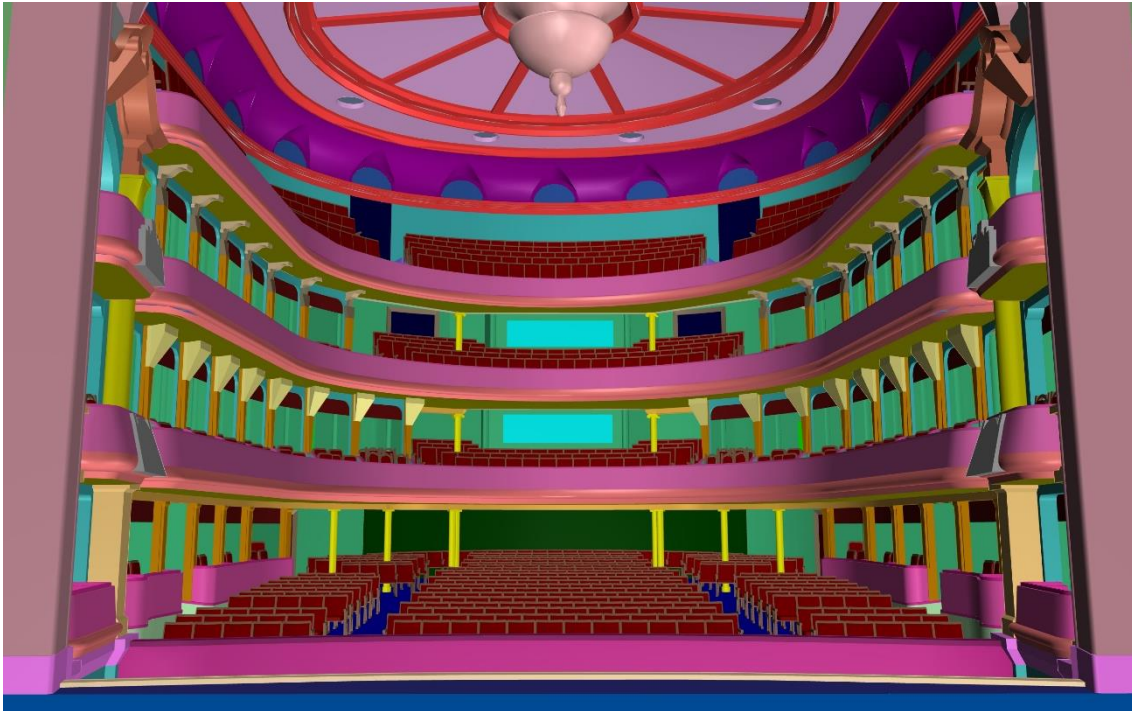
*Interior view of the untextured 3D model of the main hall*



## Classification of the 3D Elements and Development of a Materials Database

Subsequently a semantic classification of the elements present in the main hall was elaborated and for each of these a different material was assigned.

This methodology has been followed to facilitate the development of the subsequent auralisation process, which requires the subdivision of the elements of the 3D model, in order to associate them the acoustic parameters values.



*Different visualisations of the 3D model divided into component elements (each represented by a different colour)*



*Different visualisations of the 3D model divided into component elements (each represented by a different colour)*

The following table shows the development of the acoustic database on which to carry out the acoustic analysis necessary for the subsequent auralisation process.

ID	Element Description	TYP	Element Type / Component Description	MAT	Material Description
<b>CE</b>	Ceiling	<b>A</b>	Balconies lower ceiling lined with plaster	<b>cei-01</b>	Ceiling 01
		<b>B</b>	Balconies lower ceiling lined with fabric	<b>cei-02</b>	Ceiling 02
		<b>C</b>	Stage ceiling	<b>cei-03</b>	Ceiling 03
		<b>D</b>	Proscenium arch ceiling	<b>cei-04</b>	Ceiling 04
		<b>E</b>	Cloister vault with lunettes ceiling	<b>cei-05</b>	Ceiling 05
		<b>F</b>	Main hall ceiling	<b>cei-06</b>	Ceiling 06
<b>CN</b>	Cornice	<b>A</b>	Balconies cornice	<b>cor-01</b>	Cornice 01
		<b>B</b>	Main hall ceiling cornice	<b>cor-02</b>	Cornice 02
		<b>C</b>	Door cornice	<b>cor-03</b>	Cornice 03
		<b>D</b>	Lower proscenium cornice	<b>cor-04</b>	Cornice 04
		<b>E</b>	Stage cornice	<b>cor-05</b>	Cornice 05
<b>CU</b>	Curtain	<b>A</b>	Stage curtain	<b>cur-01</b>	Curtain 01
		<b>B</b>	Balconies curtain	<b>cur-02</b>	Curtain 02
		<b>C</b>	Door curtain	<b>cur-03</b>	Curtain 03
<b>DO</b>	Door	<b>A</b>	Wooden door	<b>dor-01</b>	Door 01
		<b>B</b>	Wooden door lined with fabric	<b>dor-02</b>	Door 02
		<b>C</b>	French wooden door	<b>dor-03</b>	Door 03
<b>FL</b>	Floor	<b>A</b>	Stage wooden floor	<b>flo-01</b>	Floor 01
		<b>B</b>	Apron wooden floor	<b>flo-02</b>	Floor 02
		<b>C</b>	Audience wooden floor	<b>flo-03</b>	Floor 03
		<b>D</b>	Balconies wooden floor	<b>flo-04</b>	Floor 04
		<b>E</b>	Orchestra pit wooden floor	<b>flo-05</b>	Floor 05
<b>HR</b>	Handrail	<b>A</b>	Balcony 00 plastered handrail	<b>hra-01</b>	Handrail 01
		<b>B</b>	Balcony 00 handrail lined with fabric	<b>hra-02</b>	Handrail 02
		<b>C</b>	Balcony 01-03 plastered handrail	<b>hra-03</b>	Handrail 03
		<b>D</b>	Balcony 01-03 handrail lined with fabric	<b>hra-04</b>	Handrail 04
		<b>E</b>	Orchestra pit wooden handrail	<b>hra-05</b>	Handrail 05

		<b>F</b>	Orchestra pit handrail lined with fabric	<b>hra-06</b>	Handrail 06
<b>LA</b>	Lamp	<b>A</b>	Pendant chandelier	<b>lam-01</b>	Lamp 01
<b>SC</b>	Sculpture	<b>A</b>	Proscenium tympana statue	<b>scu-01</b>	Sculpture 01
		<b>B</b>	Proscenium balconies statue	<b>scu-02</b>	Sculpture 02
		<b>C</b>	Proscenium arch statue	<b>scu-03</b>	Sculpture 03
		<b>D</b>	Balcony 02 support statue	<b>scu-04</b>	Sculpture 04
		<b>E</b>	Balcony 02 bust statue	<b>scu-05</b>	Sculpture 05
<b>SE</b>	Seat	<b>A</b>	Wooden seat 01 structure	<b>sea-01</b>	Seat 01
		<b>B</b>	Seat 01 fabric lining	<b>sea-02</b>	Seat 02
<b>ST</b>	Structure	<b>A</b>	Column	<b>str-01</b>	Structure 01
		<b>B</b>	Proscenium semi-column	<b>str-02</b>	Structure 02
		<b>C</b>	Balcony 03 structural support	<b>str-03</b>	Structure 03
		<b>D</b>	Lintel	<b>str-04</b>	Structure 04
		<b>E</b>	Proscenium arch	<b>str-05</b>	Structure 05
		<b>F</b>	Balconies lesene	<b>str-06</b>	Structure 06
		<b>G</b>	Proscenium lesene	<b>str-07</b>	Structure 07
		<b>H</b>	Proscenium tympana	<b>str-08</b>	Structure 08
<b>WA</b>	Wall	<b>A</b>	Wall lined with fabric	<b>wal-01</b>	Wall 01
		<b>B</b>	Wooden rear wall	<b>wal-02</b>	Wall 02
		<b>C</b>	Audience wooden basement wall	<b>wal-03</b>	Wall 03
		<b>D</b>	Stage wall	<b>wal-04</b>	Wall 04
		<b>E</b>	Plastered wall	<b>wal-05</b>	Wall 05
		<b>F</b>	Orchestra pit wall	<b>wal-06</b>	Wall 06
<b>WI</b>	Window	<b>A</b>	Rear window	<b>win-01</b>	Windows 01
		<b>B</b>	Zenithal aperture	<b>win-02</b>	Windows 02
		<b>C</b>	Lunette aperture	<b>win-03</b>	Window 03

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