

Digital ecosystems for the virtual fruition of Porta Aurea in Ravenna

Original

Digital ecosystems for the virtual fruition of Porta Aurea in Ravenna / Giovannini, Elisabetta Caterina (PROSPETTIVE MULTIPLE: STUDI DI INGEGNERIA, ARCHITETTURA E ARTE). - In: Digital & Documentation Vol. 5 - From virtual space to information database / Picchio, F.. - Pavia : Pavia University Press, 2023. - ISBN 978-88-6952-176-8. - pp. 128-147

Availability:

This version is available at: 11583/2982839 since: 2023-10-07T20:33:11Z

Publisher:

Pavia University Press

Published

DOI:

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Digital & Documentation

V5

From virtual space to information database

edited by
Francesca Picchio



PROSPETTIVE MULTIPLE
STUDI DI INGEGNERIA
ARCHITETTURA E ARTE



PAVIA UNIVERSITY PRESS

Francesca Picchio

edited by

DIGITAL & DOCUMENTATION

VOL. 5

From Virtual space to Information database



PaviaUniversityPress

Digital & Documentation. From Virtual space to Information database / Francesca Picchio (edited by) - Pavia: Pavia University Press, 2023. - 240 p. : ill. ; 21 cm.

(Prospettive multiple: studi di ingegneria, architettura e arte)

ISBN 978-88-6952-175-1 (brossura)

ISBN 978-88-6952-176-8 (Open Access)

The present publication is part of the series "Prospettive multiple: studi di ingegneria, architettura e arte", which has an international referee panel. "Digital & Documentation: From Virtual space to Information database" is a scientific text evaluated and approved by the Editorial Scientific Committee of Edizioni Pavia University Press of University of Pavia.

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Edizioni dell'Università degli Studi di Pavia
Via Luino, 12 - 27100 Pavia (PV)
Tel: +39 0382 987743 / 985047
Fax: +39 0382 985047
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EDITING
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GRAPHIC PROJECT
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PRINTED BY
DigitalAndCopy S.A.S., Segrate (MI)

ISBN 978-88-6952-175-1 (brossura)

On cover: Graphic photocollage by F. Picchio

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The volume consists of a collection of contributions from the seminar "Digital & Documentation: From Virtual space to Information database", realized at the University of Pavia on the day of September 19th, 2022. The event, organized by the experimental laboratory of research and didactics DAda Lab. of DICAr - Department of Civil Engineering and Architecture of University of Pavia, promotes the themes of digital modeling and virtual environments applied to the documentation of architectural scenarios and the implementation of museum complexes through communication programs of immersive fruition. The fifth Digital and documentation conference was also the inaugural event of the first Pavia DigiWeek, held from 19 to 23 September 2022 in Pavia.

The event has provide the contribution of external experts and lecturers in the field of digital documentation for Cultural Heritage. The scientific responsible for the organization of the event is Prof. Francesca Picchio, University of Pavia.

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This publication is made with the contribution of DICAr, Department of Civil Engineering and Architecture of University of Pavia, through the joint research of the experimental laboratories DAdA Lab - Drawing Architecture Document Action and PLAY - Photography and 3D Laser for virtual Architecture Laboratory.



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The event "Digital & Documentation, V.5" has seen the participation of professors, researchers and scholars from University of Pavia, Politecnico di Torino, University of Rome "La Sapienza", University of Palermo, University of Catania, Politecnico di Milano, University of Ferrara, University of Florence, University of Basilicata, University of L'Aquila, University of Salerno, Gdańsk University of Technology (Poland), Nanyang Technological University (Singapore), Universitat Politècnica de València (Spain), University of Salerno, University of L'Aquila, Lublin University of Technology (Poland), Cracow University of technology (Poland), University of Cordoba (Argentina).

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INDEX

PRESENTATIONS

Francesca Fatta	President of UID - Unione Italiana Disegno	10
Sandro Parrinello	Scientific Responsible for Pavia DigiWeek 2022 and for D&D Conferences	12

FOREWORD

FRANCESCA PICCHIO

DIGITAL TOOLS BETWEEN VIRTUAL AND INFORMATION REALITY	14
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PART 1 - PERCEPTION: VIRTUAL SPACES, SIMULATIONS AND INTERACTIONS

KEYNOTE SPEAKERS

01	JACEK LEBIEDŹ VIRTUAL REALITY AS A TOOL FOR DEVELOPMENT AND SIMULATION. RESEARCH PROJECTS AND EXPERIENCE OF THE GDAŃSK UNIVERSITY OF TECHNOLOGY	19
02	DAVIDE BENVENUTI FROM DRAWING TO ANIMATION. THE CREATION OF VIRTUAL PLACES AND THE DEVELOPMENT OF STORYTELLING FOR CONSTRUCTING NARRATIVE PATHS THROUGH DRAWING	33

PART 1 - PERCEPTION: VIRTUAL SPACES, SIMULATIONS AND INTERACTIONS

PANELISTS

03	FLAVIA CAMAGNI SPATIAL PERCEPTION IN ARCHITECTURAL PERSPECTIVES: VISUALIZATION THROUGH AR AND VR SYSTEMS	53
04	FRANCESCA GALASSO REVEALING THE INVISIBLE: DIGITAL SIMULACRA AND VIRTUAL USE OF LOST ARCHAEOLOGICAL HERITAGE	65
05	ANDREA LUMINI, FEDERICO CIOLI PROJECT AURA: ACOUSTIC SIMULATION OF THEATRE HALLS _ FROM DIGITAL SURVEY TO VIRTUAL RECONSTRUCTION	79
06	XIN WU, MARIANNA CALIA, MARGHERITA TRICARICO FROM SURVEY TO SIMULATION OF A VIRTUAL SPACE: UNESCO WORLD HERITAGE SITES IN SOUTH EAST CHINA AND ARCHAEOLOGICAL HERITAGE IN BASILICATA	95
07	SOFIA MENCONERO SIMULATION OF SPACE IN PIRANESI'S <i>CARCERI</i> BETWEEN ARCHITECTURE, PERSPECTIVE AND PERCEPTION	113
08	ELISABETTA CATERINA GIOVANNINI DIGITAL ECOSYSTEMS FOR THE VIRTUAL FRUITION OF PORTA AUREA IN RAVENNA	129

PART 2 - INFORMATION DATABASES AND INFORMATION SYSTEMS FOR ARCHITECTURE

PANELISTS

- | | | |
|----|---|-----|
| 10 | FABIANA RACO, LUCA ROSSATO, MARCELLO BALZANI
DIGITAL DOCUMENTATION FOR THE ENHANCEMENT OF BRAZILIAN CULTURAL HERITAGE:
MUSEO DO IPIRANGA, PARQUE DA INDEPENDÊNCIA AND MONUMENTO À INDEPENDÊNCIA | 151 |
| 11 | FAUSTA FIORILLO, FRANCO SPETTU
DATA MANAGEMENT, EFFICIENT USE, AND SMART ACCESS TO REALITY CAPTURE DATA VIA WEB PLATFORMS | 163 |
| 12 | JORGE LUIS GARCÍA-VALLDECABRES, LUIS CORTÉS MESEGUER, CONCEPCIÓN LÓPEZ GONZÁLEZ
THE POTENTIAL OF BIM AND GIS MODELS FOR SUSTAINABLE WEALTH MANAGEMENT | 179 |
| 13 | PAMELA MAIEZZA, ALESSANDRA TATA
3D MODELS FOR ARCHITECTURAL HERITAGE DOCUMENTATION: TRANSPARENCY AND RELIABILITY ISSUES | 193 |
| 14 | ELISABETTA DORIA
DATABASES AND DRAWINGS TO SUPPORT THE DEVELOPMENT OF THE DOCUMENTATION PROJECT
THE CASE STUDY OF 'LE TORRICELLE' IN VERONA | 205 |
| 15 | ANDREA DI FILIPPO
TRACEABILITY OF GEOMETRIC ATTRIBUTES IN BIM MODELS FOR THE HERITAGE DOCUMENTATION | 221 |

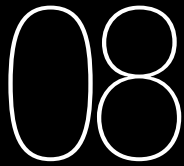
EVENT PHOTOGALLERY 232



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Politecnico di Torino

Assistant Professor at the Department of Architecture and Design (DAD) of Politecnico di Torino. She specialized in the digital acquisition, documentation and critical analysis of the architectural and archaeological heritage using the latest computer technologies, tridimensional models and digital environments. Her research interests are related to the disciplines of drawing, survey and digital representation of architecture. In recent years she has dealt with the use of IT applied to CH. She investigates the use of ontologies, BIM and H-BIM platforms to manage virtual reconstruction processes and digital collections for museums.



DIGITAL ECOSYSTEMS FOR THE VIRTUAL FRUITION OF PORTA AUREA IN RAVENNA

Abstract

The presented study is focused on communicating and visualizing architectural representations through computational and digital methods in the context of transversality and trans-disciplinary knowledge. In particular, the study enlightens the role of digital ecosystems in the communication processes of built cultural heritage, which is intended as a medium for the visualization of the n-dimensional levels of knowledge that can be collected in virtual reconstruction processes according to different kinds of resources.

The study involved different applications and tools for creating digital ecosystems that manage diverse information: digital galleries, 3D models, drawing annotation systems, and a Social Virtual Environment (SVE) platform.

The study focused on the dissemination and virtual musealisation of a monument that is no longer extant and has always aroused the interest of many scholars and archaeologists: Porta Aurea in Ravenna. The Roman Gate was built in 43 AD at the behest of roman Emperor

Tiberius Claudius. The existence of large and heterogeneous documentation allows the possibility to investigate the theme of digital ecosystems for museum collections. In particular, digitization processes' role in creating digital environments for different types of fruition: research and dissemination for a large public.

Immersive digital environments can shift the focus from the management of the museum space, the container of the collection, to the exhibition itself. The SVE platform used in the study is a novel solution for developing a digital environment accessible by any web browser. A room dedicated to the Porta Aurea fragments at the National Museum of Ravenna also offers new perspectives on using virtual environments for disseminating museum collections replicating the environment to which they belong. The solution differs from the website, the two-dimensional ancestor of virtual environments, making a novel way of fruition that is no longer passive but active, interactive, and participatory.

Introduction

The Oxford English Dictionary defines an ecosystem as “a biological community of interacting organisms and their physical environment.” If we pause to analyze, one of the main aspects of an ecosystem is to consider it as the sum of its constituent elements. Just as a natural ecosystem has inherent rules that are not necessarily perceivable or identifiable, the digital ecosystem is a system that is instead designed and developed with the ambition of permanence over time and eventual implementation. Within a digital ecosystem, the rules are defined in the design phase and are closely related to the end-use type. Therefore, it is necessary to determine what are the goals and objectives of the digitization process of the asset that will be fruited, the kind of target audience, and the types of visualization of the data, whether it is informative, three-dimensional, or reused within a predetermined narrative path.

One of the main benefits of digital ecosystems is to deposit primary resources within a system accessible through different devices and possibly through applications that allow the retrieval of resources in an organized and semantically classified manner.

In the case of cultural heritage, we are witnessing the proliferation of digital data production of various kinds with the advent of massive digitization. Specifically, it should be remembered that “raw” data will have to be reworked and post-processed to reach the end users. How the data is transformed into information or displayed on the Web is only the tip of the iceberg of the digital ecosystem: the front end. The back end is generally hidden but necessary to organize data and information to be easily retrievable.

The paper aims to investigate a possible pipeline for building digital ecosystems in museums. Beginning with the digitization process, which cannot be excluded from the ecosystem design process, digitized objects undergo various transformations, qualitative in resolution, allowing

them to be accessible in different ways depending on the software used.

Once the assets of interest have been identified, the digital curatorship is responsible for selecting and classifying the content. Then there is the digitization phase regarding the documentary/archival and physical material. The first acquisition phase is generally carried out using the best quality and most appropriate tools. On the other hand, the information processing phase requires a critical *a priori* analysis depending on the desired output. Generally, the outcome requires a reduction/retopologization of the raw material, both bi-dimensional and three-dimensional. Different versions of the same digital object at different resolutions are developed depending on the final platform. The type of information also changes, is reused, or possibly reorganized depending on the chosen narrative.

In the architectural heritage field, at the content organization stage, there is also a semantic structuring of information related to the architectural features of the building and its architectural elements. In creating digital ecosystems, structuring information is a part of the process that has become unavoidable. The necessity to interconnect heterogeneous data is evident in architectural representation, for example, related to architectural drawings. In analyzing architectural drawings, the granularity of information is relevant, and it is essential to add a diverse semantic level of knowledge. Speaking of iconographic apparatus, i.e., the “complex of representations in the art relating to a given subject”¹ appears reductive in architecture. Classifying resources based on iconographic representations in humanities remains fundamental, especially in the archaeological and archival fields. Leading digital platforms in digital humanities use iconographic recognition and classification to organize their content. These systems generally collect bi-dimensional digitized institutions’ contents. In recent years many museums have embraced the digitization challenge, creating three-dimensional digital collections that are unfortunately not linked to the original content.

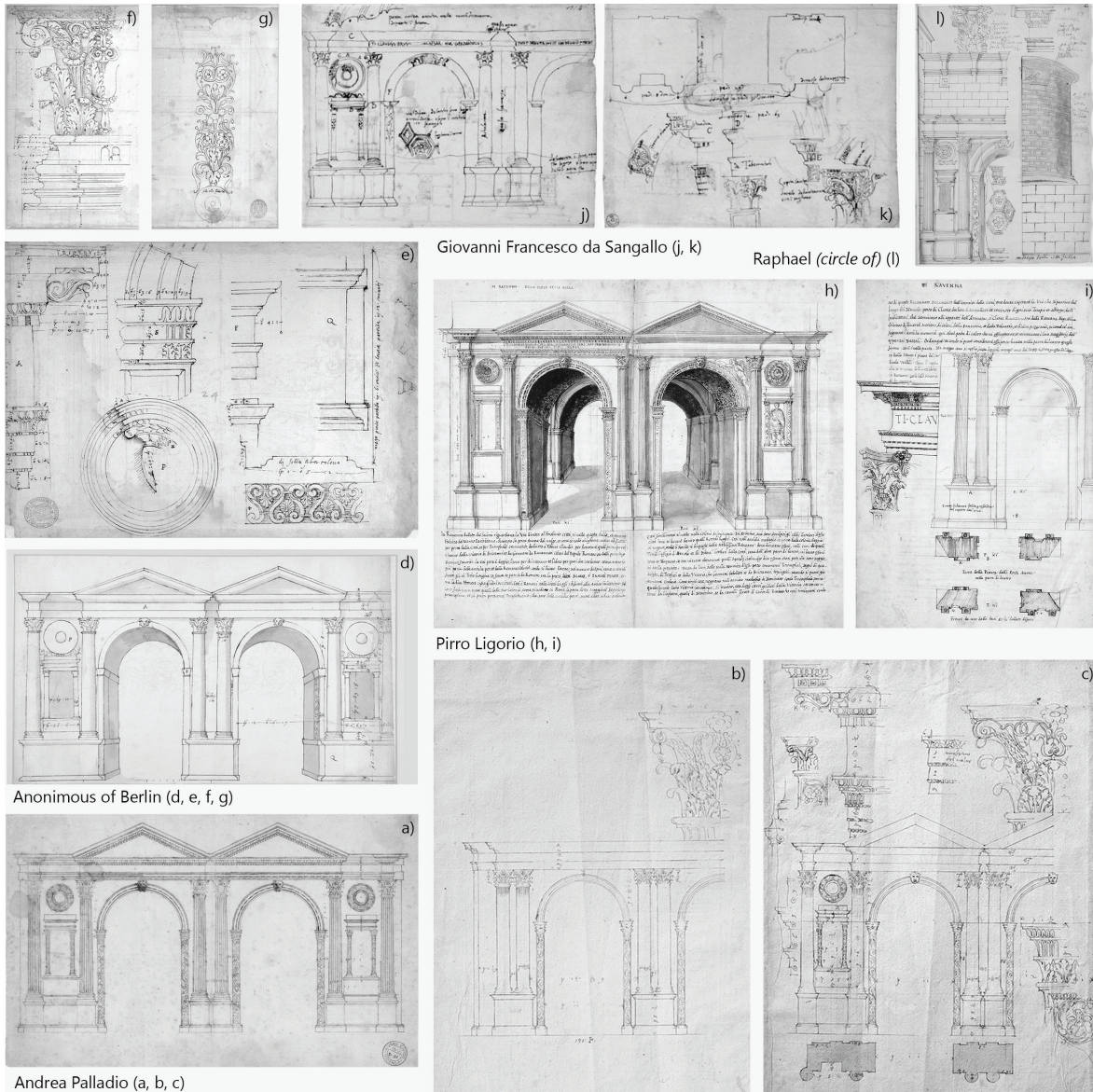


Fig. 1 – Collection of drawings representing Porta Aurea in Ravenna. Image layout by the author.

Porta Aurea: an integrated approach for the creation of a digital ecosystem

This study proposes in an organized manner the digitization processes put in place for the virtual reconstruction hypothesis of Porta Aurea². The paper presents a methodological workflow for the possible use and reuse of digital assets for the virtual fruition of the museum collection of existing architectural fragments and beyond. The research began with the historical analysis of existing documentation regarding Porta Aurea in Ravenna: an ancient Roman gate destroyed in 1582. Today, some fragments remain in the National Museum in Ravenna, and some ruins at the city walls. The events inherent in the architectural apparatus and excavation campaigns at the walls have been extensively investigated by both local historians and scholars who have been involved in analyzing the collection of architectural drawings related to the Roman Gate. (Rossi, 1572; Rosi, 1939; Tosi, 1986; Savini, 1996, 1997; Novara, 2002; Ranaldi, 2015) The gate was in the past represented by several authors: Giovanni Maria Falconetto (1520), Giovanni Francesco da Sangallo (c.a. 1526), Andrea Palladio (1545), Anonymous of the Raphael circle (c.a. 1150), Anonymous of Berlin (c.a. 1580). (Fig.1)

In recent years, the extensive documentation available has allowed further investigation of the documentary, archival and photographic funds for a virtual reconstruction hypothesis according to the drawings developed by Andrea Palladio. [Apollonio and Giovannini, 2015].

The analyzed and digitized resources belong to different archives and institutions and were part of the data collection and gathering for the dissemination of the study beyond the virtual reconstruction. Other research outcomes related to the semi- automatic generation of Architectural elements and using data, metadata, and paradata for the virtual reconstruction processes were previously published. [Apollonio and Giovannini, 2015; Giovannini, 2017].

The workflow can be divided into three main parts: Data collection, Data Modelling, and Data Representation & Visualization (Fig.2). This research explore the digitization processes and post-processing phase of sources and resources for the creation of a digital environment accessible online. The developed Virtual Reality (VR) is based on the room dedicated to Porta Aurea at The National Museum of Ravenna.

The process involved digital acquisitions of documentary heritage, photogrammetric acquisition of archeological fragments and laser scanning acquisition of the archaeological evidence.

The Data Modelling phase was performed using resources collected and digital acquisition to obtain metric information for the development of both virtual space for VR and digital assets to be displayed using Social Virtual Environment (SVE).

The data representation and visualization phase involved a workflow for digital post-processing of assets to be uploaded and reused through low-cost web applications: Sketchfab and Mozilla Hubs³. Hubs is a web-based virtual collaboration platform. (Iglesias, Jenkins and Morison, 2021) Hubs is considered a Social Virtual Reality, an emerging medium that invites multiple users to join a collaborative virtual environment (VE) and can support remote communication in a natural and immersive way. (Li *et al.*, 2021) The platform, developed by Mozilla, was used during the COVID emergency when the virtual space was implemented as a solution for attending conferences and for education purposes (Hagler, Lankes and Gallist, 2022), allowing the creation of digital replicas of real space. The Virtual Reality installation lets users interactively explore a virtual space that hosts several digital 3D models and other digital content. The content for creating the scene can be selected from 3D models available online on the Platform Sketchfab. To enrich the scene and manage diverse content, Mozilla offers Spoke, a built-in scene editor for creating environments to publish Hubs rooms. (Fig. 3)

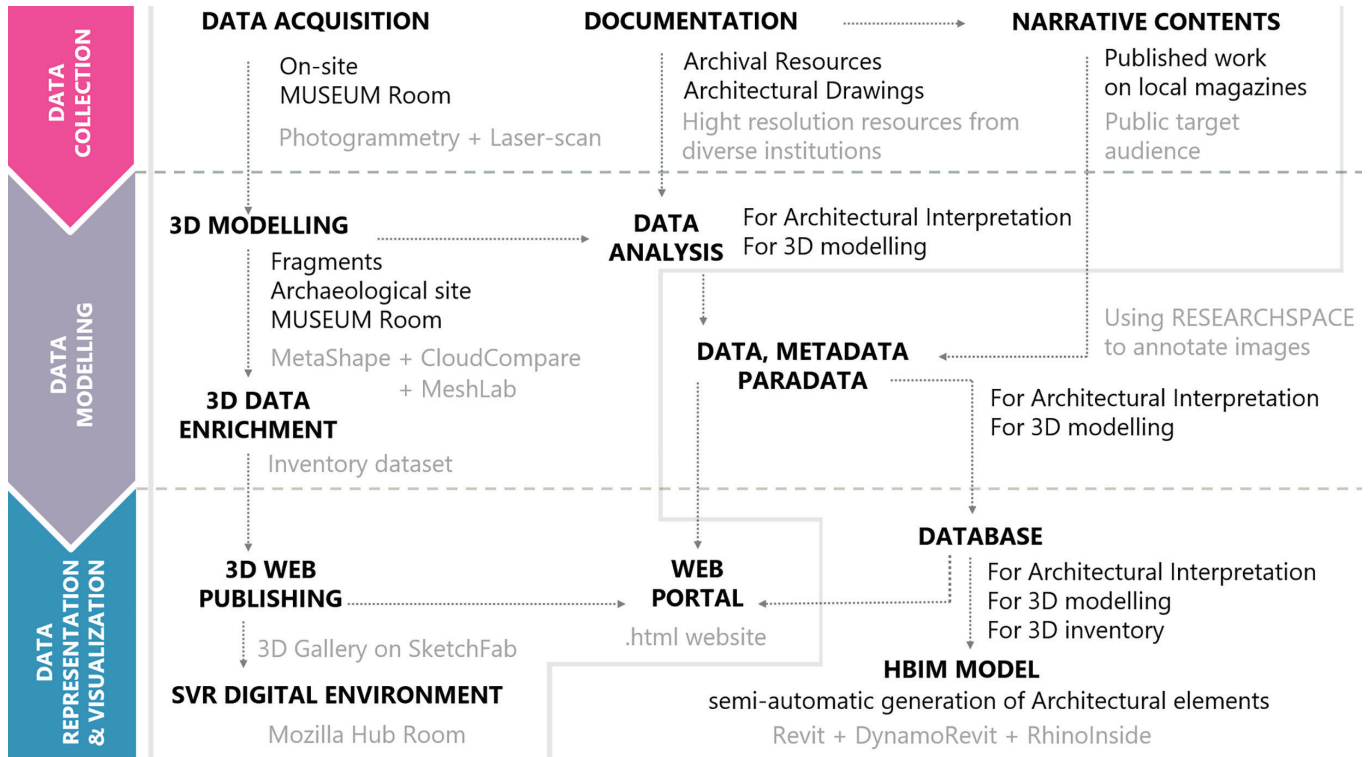


Fig. 2 - Methodological Workflow for the creation of a digital ecosystem, including processes and software.



Fig. 3 - Collection of Mozilla Hubs rooms and user interface of a default virtual scene.

Porta Aurea: online repositories and digitization processes for documentary heritage

A preliminary search of the online iconographic apparatus on Porta Aurea was carried out using iDAI⁴ (Fig. 4) and CENSUS⁵ (Fig. 5), both developed by German institutions. The two databases are structured differently and seem not to communicate with each other. A comprehensive view of the material regarding Porta Aurea is possible only by cross-referencing the data exported from both portals. iDAI is a two-dimensional digital ecosystem where various resources are organized and classified using specific semantic web tools. Although it proposes itself

as a structured platform to collect data of heterogeneous types, it is not very effective in visualizing the contents. iDAI acquires the data from the photographic digitalized archives of the Italian Ministero per i Beni Culturali e Ambientali (MiBACT).

CENSUS proposes a simpler relational scheme that relies on the iconographic recognition within the resource and, in some instances, allows the material, digitized at high resolution, to be viewed more efficiently through a web interface. CENSUS also encodes resources using inventory numbers, making it possible to uniquely identify resources and request them from individual institutions in high definition. In systems of this type, the third dimension is still unfortunately absent. (Fig. 6)

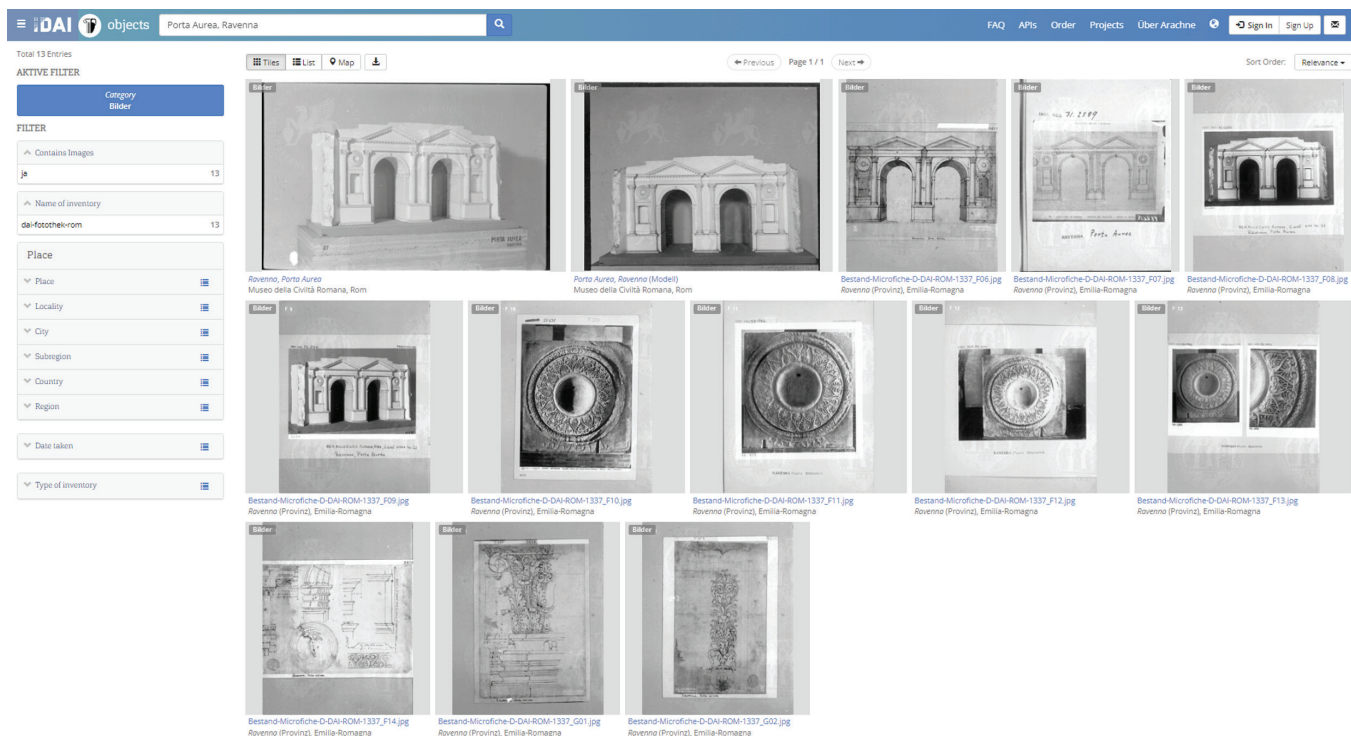

















Fig. 4 - iDAI interface with retrieved content about Porta Aurea in Ravenna.

The *Soprintendenza Archeologia, Belle Arti e Paesaggio per le province di Ravenna, Forlì-Cesena e Rimini* also own partially digitalized documentary heritage. For example, archeological reports and survey drawings documenting the excavation campaign supervised by Domenico Maioli on the city wall in 1906-1908. Then, the resources available at the drawing and photographic archives were collected and digitized. During the excavation campaign, new fragments were discovered and are nowadays exposed in the "Sala della Porta Aurea". Each fragment is described in the inventory of the Museum and documented by black

and white pictures, part of the photographic archive. Its material was divided as follows:

- 5 images concerning photocopies of the drawings by Palladio⁶ and Sangallo⁷
- 24 images concerning excavations at Via di Porta Aurea dated 1907-1908, some published in Rosi (1939) and Savini (1996, 1997)
- 10 images of fragments of the roman gate before the current arrangement, dated 1937-1939
- 56 images, which were digitized during the research conducted. The selected images refer to the present

CensusID	154850
Name	Porta Aurea
Status	Monument
Location	Ravenna
Inventory no.	land side

Description	History	Provenance	Relationships	References	Map	Log
Census Document(s) List						
			> Biondo 1444-1450 (Fauno 1543) > Italia Illustrata > fol. 136 v > A			
						
						
						

Description	History	Provenance	Relationships	References	Map	Log
Census Document(s) Images						
Mantova, Palazzo d'Arco: > Zodiacal Cycle > east wall > Cancer, main field						
Firenze, Uffizi, GDSU: > inv. 2057 A r > B						
Firenze, Uffizi, GDSU: > inv. 2057 A r > D						
> Biondo 1444-1450 (Fauno 1543) > Italia Illustrata > fol. 136 v > A						
Vicenza, Museo Civico: > D. 31 r						
Berlin, SMB-PK, Kunstbibl.: > Codex Destailleur A > fol. 28 v > A						
Berlin, SMB-PK, Kunstbibl.: > Codex Destailleur A > fol. 39 r > C						
Torino, AST: > Ligorio, Antichità XV > fol. 015 v > A						
Torino, AST: > Ligorio, Antichità XV > fol. 014 v - fol. 015 r > A						
London, RIBA: > Palladio, vol. XII > fol. 12 v > B						
Torino, AST: > Ligorio, Antichità XV > fol. 014 v - fol. 015 r > B						
Torino, AST: > Ligorio, Antichità XV > fol. 016 v > C						
Torino, AST: > Ligorio, Antichità XV > fol. 015 v > D						
London, RIBA: > Palladio, vol. XII > fol. 12 r > F						
Berlin, SMB-PK, Kunstbibl.: > inv. HdZ 1245 r						
Kassel, MHK, Schloss Wilhelmshöhe, Graphische Sammlung: > inv. Fol. A45 > fol. 59 r > C						

Description	History	Provenance	Relationships	References	Map	Log
Class	architecture					
Type	city gate					
Material	brick marble					
Present Condition	destroyed damaged/fragmentary					
Original	yes					
Number	01					
Descriptive Details	podium gateways, 2 columns, 6 niches, 2 tondi, 2 entablature attic, aedicula (?)					

Fig. 5 - Census interface with retrieved content about Porta Aurea in Ravenna. Image layout by the author.

arrangement and are dated between 1978 and 1991. In particular, the objects refer to the “saletta del primo chiostro” now renamed the “Sala della Porta Aurea”. A Canon EOS-1Ds Mark II with a 100mm lens with a fixed focal length of 50mm was used for the image acquisition. (Fig. 7) An x.rite color checker was used for color balance. The predominantly black-and-white images are on a paper card that is accompanied by a variety of information: the image’s title, the year of production, the location of the find within the Museum, and the inventory number of the original negative from which the photo was developed. There are

Fig. 6 - Knowledge structure behind iDAI (right) and data model of CENSUS (bottom). diagrams available on the respective web pages of the online databases.

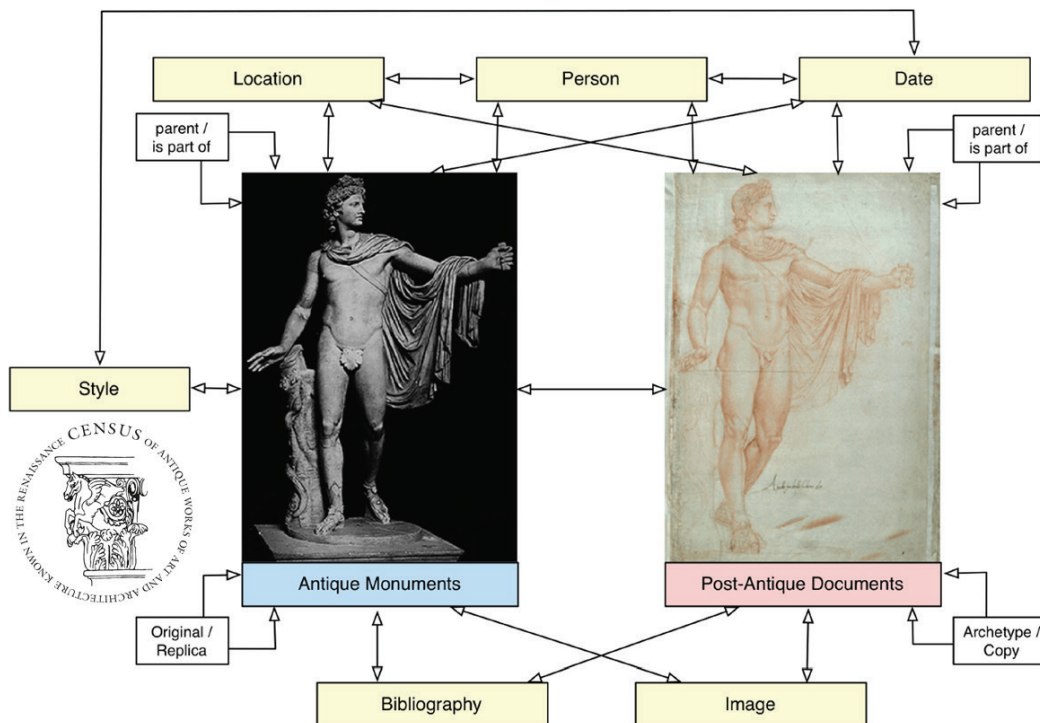
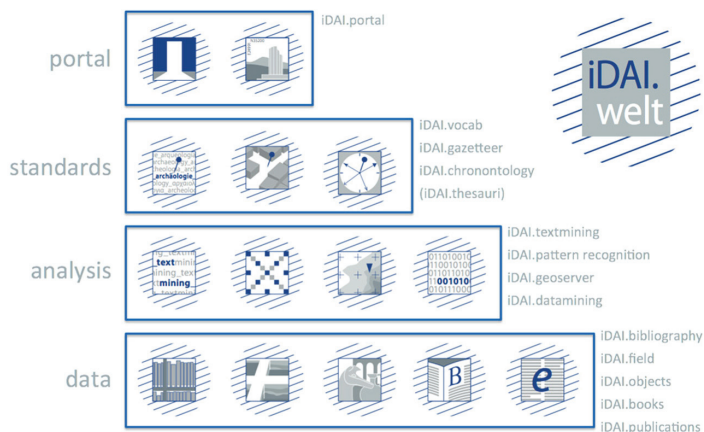




Fig. 7 - Digital acquisition of the photographic archive.

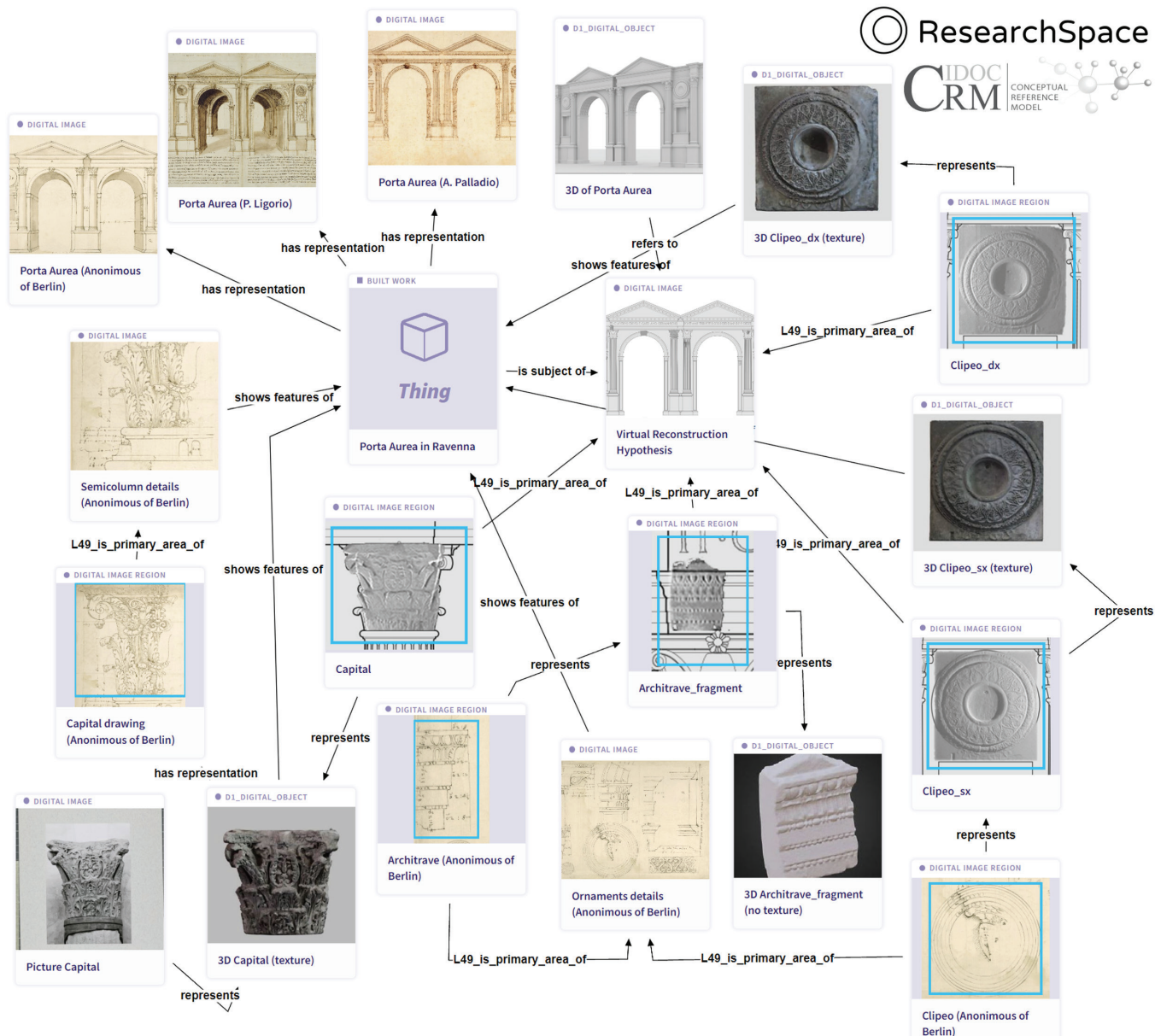
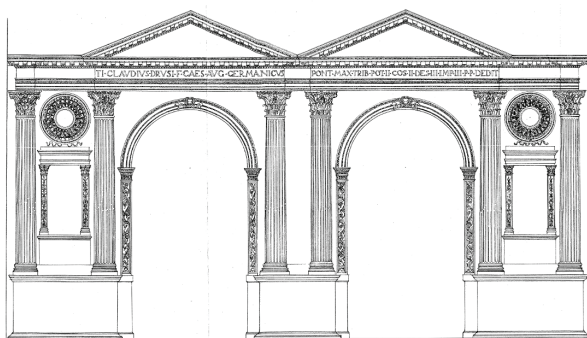


Fig. 8 - ResearchSpace Knowledge Map of 3D model of the virtual reconstruction hypothesis based on fragments, historical sources and drawings. Image by the author.

often annotations on the cards giving the inventory number of the fragment depicted. This information was collected and associated with the digitized source using knowledge patterns for metadata enrichment in ResearchSpace⁸. (Fig. 8) ResearchSpace is a web-based tool used to support research in museums, cultural institutions, and many other institutions that work with cultural collections. It is a platform that is generally used to manage museum collections in a bi-dimensional digitized format with the possibility of being implemented with embedded three-dimensional content. (Giovannini, 2021)

The documentary acquisition campaign considered the drawings drawn up during the Via di Porta Aurea⁹ excavations. These are the survey drawing of two circular towers and their respective longitudinal and cross sections. Accompanying the survey drawings is a report on the excavations and a reconstructive hypothesis made by Domenico Maioli. The hypothesis was drawn up on Roman feet based on the drawing by Giovanni Francesco da Sangallo. The drawing archive also contains a second reconstructive hypothesis¹⁰ made by G. Rosi for the execution of a reconstructive model for the *Augustan Exhibition of Romanity in 1937-1938*. (Ranaldi, 2015) The model is now preserved at the Museum of Roman Civilization. (Fig. 9b)



The acquisition campaign complemented the archival and documentary acquisition campaign at the room of the National Museum in Ravenna, which collects the remaining marble fragments as evidence of the monument. The acquisition was made by laser scanner technology with a Leica C10 all-in-one. The digital acquisition was made at a medium resolution to capture the museum space and at a high resolution for the archeological fragments attributed to the monument. (Fig. 10) Some of them were difficult to access because they were high in the walls.

A parallel photogrammetric acquisition campaign was carried out to create a digital gallery of the Porta Aurea artifacts. The acquisition allowed obtaining metrically accurate objects that were scaled according to the point cloud obtained by the laser scanner and were adequately textured.

Data from the inventory and the photographic archive were cross-referenced with data on the museum layout to create a digital inventory into ResearchSpace and identify the location of the various fragments within the room.

According to iconographical and archival resources, the research identified ten fragments that belong to the Roman Gate. (Fig.11)

For each fragment was developed a 3D model with the highest resolution. The points clouds of single objects were

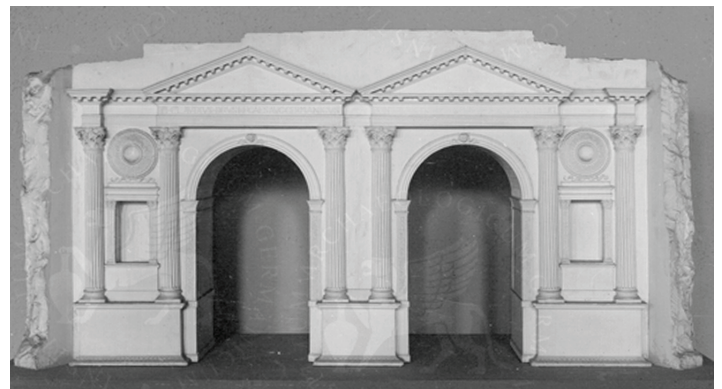


Fig. 9 - Drawing of the reconstructive hypothesis of Porta Aurea by G. Rosi (left) and relative physical model (right - image from iDAI platform).



Fig. 10 - Sala della Porta Aurea at National Museum of Ravenna. Fragments of Porta Aurea. Pictures by the Author.

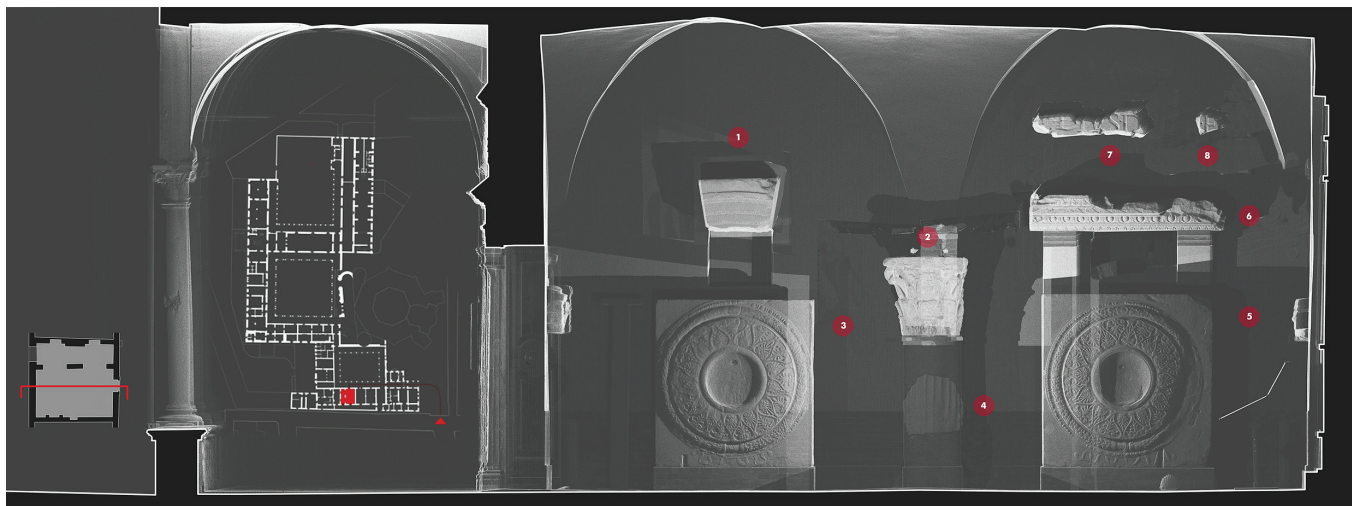


Fig. 11 - Porta Aurea Room at National Museum of Ravenna. Point cloud obtained from Leica C-10. Section of the room with archaeological fragments of the Roman Gate. Image by the Author.

extrapolated from the room's point cloud. Then each point cloud was imported into MeshLab¹¹ and converted into a mesh using the Poisson surface reconstruction algorithms packed in the software. The 3D models obtained were collected and published online in SketchFab. (Fig.12)

A second digital acquisition campaign was carried out at the walls near Via di Porta Aurea where the remains of the two circular towers that surrounded the monument were found during excavations for the street opening. (Fig.13) The distance between towers matches the measure indicated by A. Palladio in its drawing for the plan of the gate.

This information was used to decide to represent the gate with a double central plinth, one for each semi-column. The solution differs from the hypothesis proposed by G. Rosi, who presumably followed the drawings of the Anonymous of Berlin. His solution presents a single plinth supporting the two half-columns in the middle of the gate.



Creating a digital environment for the online Porta Aurea Room using Hubs

A digital replica of the Porta Aurea room was made to create the virtual environment. The point cloud was used to model the room in a NURBS model, using Rhinoceros. For online optimization and fruition, the model was textured using an image obtained from the photogrammetric acquisition of the room's floors. This choice was dictated by the presence of the *Palladiana*, which makes the space unique and recognizable. In addition, it was chosen to dedicate the room solely to the fragments of Porta Aurea, deleting from the digital model the structures that support other pieces in the real environment. The textured model was then exported in .obj format and uploaded within sketchFab. The platform's interface allows setting up the VR fruition by arranging the starting point of view to visit the space. (Fig. 14).

The most significant fragments related to Porta Aurea were imported into Sketchfab to be reused in the digital room space and recreate the Museum environment. The 3D models obtained from Metashape were reduced to be imported online with a 75% reduction for texture definition and brought down to 750.000 faces using the Quadric Edge



Fig. 12 - 3D models obtained from Laser scanner point clouds with no textures: capital, entablature and fragment of the archivolt. 3D gallery by the author.



Fig. 13_ Point cloud obtained from laser scanning acquisition. Plan view with dimensions. The Roman Gate was framed by two round towers (bottom). Front view of evidences of the towers with superimposition of hypothetical virtual reconstruction based on A. Palladio drawings and dimensioned using photogrammetric acquisition of fragments conserved in the Museum (top). Image by the Author.

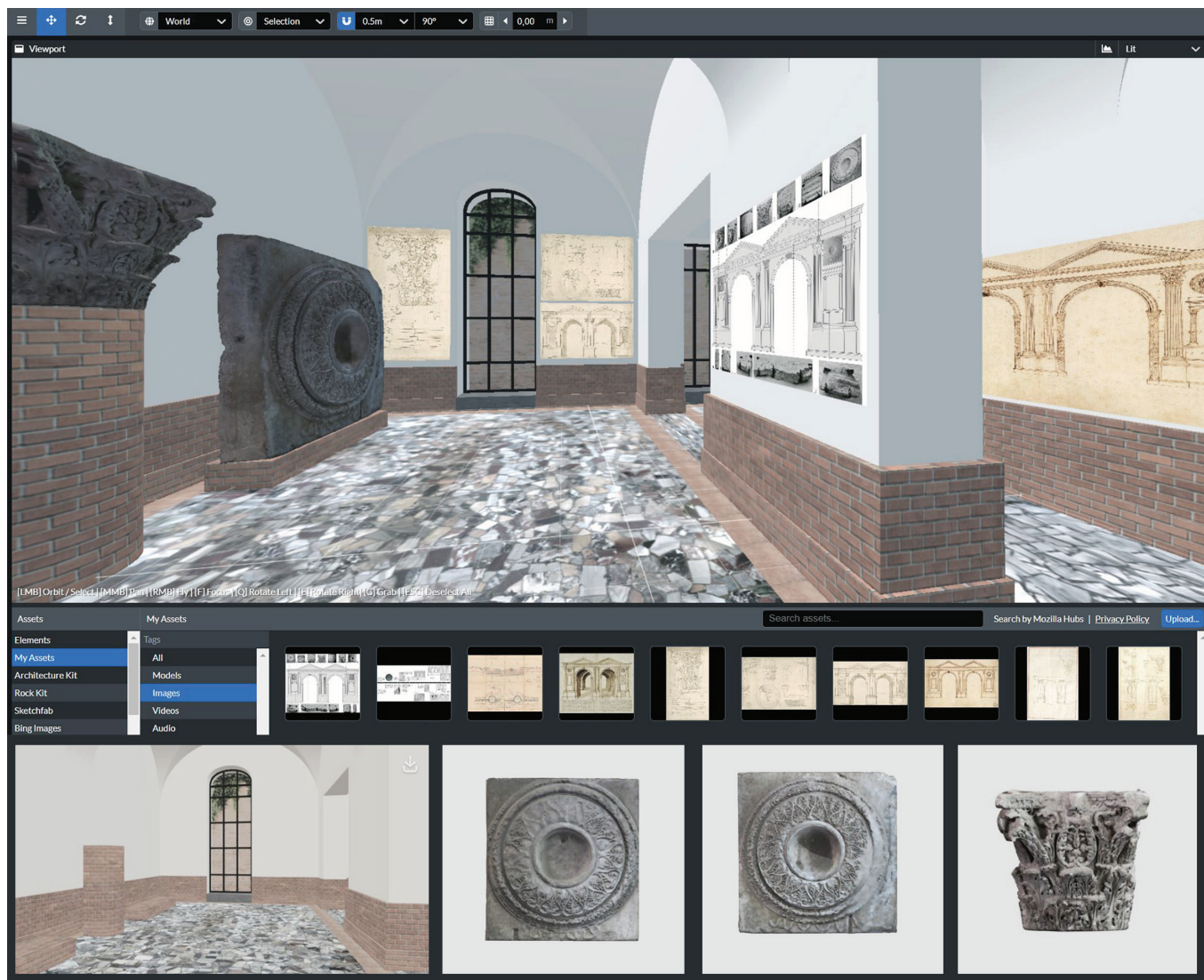
Collapse Decimation (with texture) filter in MeshLab. The filter simplifies a textured mesh using a Quadratic based Edge Collapse Strategy, preserving UV parametrization. (Garland and Heckbert, 1998) This reduction allows for an optimized fit within the maximum of 200 MB set by the platform included in the low-cost PRO version of SketchFab. MeshLab was also used for setting up the origin of the 3D model. These models constitute the core of the digital collection and can then be embedded within any HTML-based application.

Switching from Sketchfab to Spoke subsequently required a second retopologization of meshes. The built-in scene editor allows a maximum of 128MB per scene (*Spoke Scene*). This bottleneck had not been considered during the initial research phase and required a rethinking of the scene. In the first stage, the Spoke scene was planned to contain the ten original fragments. Then, only the most recognizable elements of the

monument were chosen: the clypeus and the capital of the semi-column. The models were further reduced to 100.000 faces with a further 50% reduction for textures. At this point, it was possible to fit them within the reconstructed model of the museum hall. (Fig. 15) Spoke allows retrieval of the models from SketchFab using their URL address. The room, imported in Spoke with 3D models, was scaled and reorganized, developing a single scene. The room was then enriched with the iconographic apparatus collected during the research phase. The images were uploaded as separate digital assets, scaled, and organized on the room walls. Because 3D models, images, sounds, and videos can be imported into the scene using a URL address, the drawings, already published online in ResearchSpace, were reused instead of duplicated. The final scene was published online as a Hubs room, and it is possible to navigate within it by knowing its URL address. (Fig. 16)

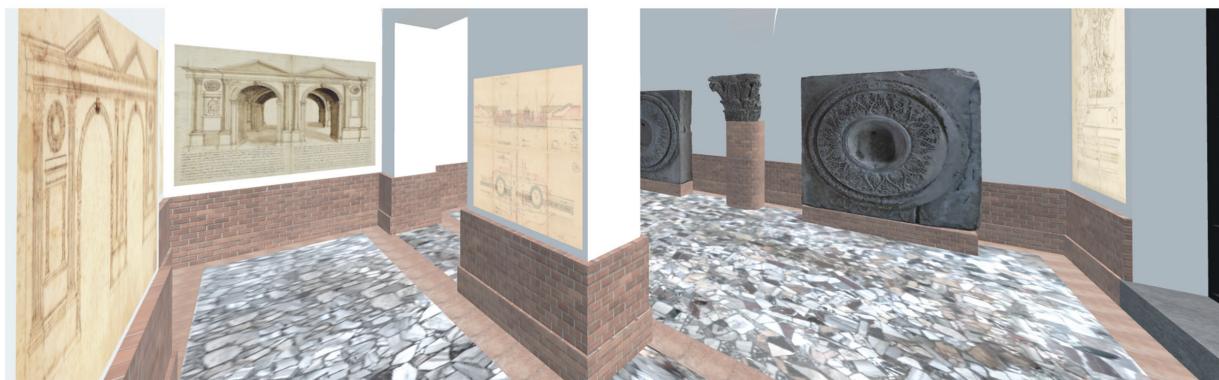
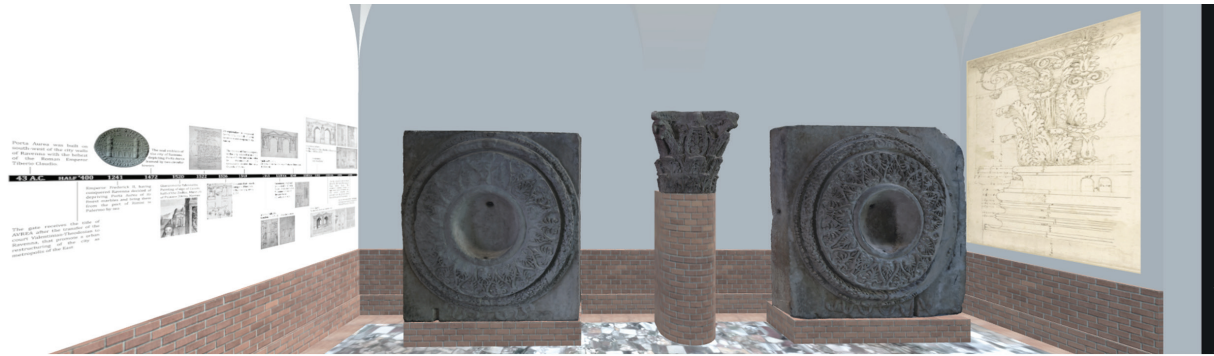


Fig. 14 - textured 3D model of the Porta Aurea room visualized in the SketchFab 3D editor. Image by the author.



Above, Fig. 15 - Digital asset used for the Spoke Scene. 3D gallery by the author.

In the next page: Fig. 16 - Views of the Porta Aurea Room hosted by Hubs. Spoke scene by the author.



Conclusions

This study proposes a methodological workflow developing a digital environment related to cultural heritage and Museum collections. The VR environment offers a novel way to fruition digital assets for the public. The experience is configured as a parallel activity to access Museum collections. The virtual space, as an access point to broader and more heterogeneous content, goes beyond the limits of the real Museum environment and allows different thematic insights. The amount of data acquired, especially regarding the photographic archive, has not been addressed in the prototype, and their digital exhibition would merit further investigation.

This experimental and prototype phase has highlighted the opportunities offered by the Mozilla Hubs platform and the critical issues related to Spoke, especially regarding the resolution of files, both 3D models and images that were resized to populate the scene. An alternative to this solution is to use the room and 3D models as the basis of the spoke scene and place assets in the room afterward.

A relevant consideration regards Copyright, privacy, conditions, and terms of use of the collected assets. As far as 3D models are concerned, there is no legislation on the subject, and it is clear that the resulting product is the product of the person who took the photos. Regarding the documentary and archival heritage, a serious problem arises since the material, once uploaded, is in the first phase stored on an external server and can then be downloaded by any user who has access to the scene. It is possible to avoid the issue by disabling the default user interaction with image elements.

Finally, it is possible to assert that SVE systems can be employed in the museum dissemination pipeline (Giovannini and Bono, 2023).. The experience is not a surrogate of the Museum visit. The VR experience can follow normal museum activities, allowing the setting up of diverse temporary and thematic exhibitions alongside

Notes

¹ Translated by the author from *Enciclopedia Treccani*, noun *iconografia*, retrievable at <https://www.treccani.it/vocabolario/iconografia/> (last visit, January 2023)

² The study was carried on in 2013 for the development of the bachelor degree in Architecture with a dissertation entitled "*IN LOCO VRBI DICITVR PORTAVREA: Dal disegno al modello digitale, studio per una ipotesi ricostruttiva della Porta Aurea di Ravenna ai fini della fruizione museale*".

³ <https://hubs.mozilla.com/>

⁴ iDAI (<https://idai.world/>) is the portal for digital archaeological knowledge and it was developed by the German Archaeological Institute (DAI), a worldwide networked research institution in the field of archaeology and ancient history.

⁵ <https://database.census.de/>

⁶ AFSn 32992, AFSn 32993 e AFSn 32994 copies of Andrea Palladio drawings conserved at RIBA (SD170/PALL/XII/12 recto/verso) and at Museo Civico di Palazzo Chiericati in Vicenza. The drawing (Inv. D 31) represents the facade oriented to the city of Ravenna.

⁷ AFS 5-D-9 e AFS 5-D-10 copies of the Sangallo il Giovane drawings conserved at the Gabinetto dei Disegni e delle Stampe delle Gallerie degli Uffizi in Florence. The drawing (2057 A recto) represents a survey of Porta Aurea.

⁸ <https://researchspace.org/>

⁹ Savini (1996, 1997) discusses this extensively.

¹⁰ Copies of the drawings can be found within the dossier U8-2670 "*RAVENNA - Progetto di ricostruzione dell'antica Porta Aurea di Ravenna – elaborati grafici*"

¹¹ <https://www.meshlab.net/>

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