

Towards a Methodology for the Digitisation of Unbuilt Cities: from ‘Drawn’ Architecture to 3D Landscape

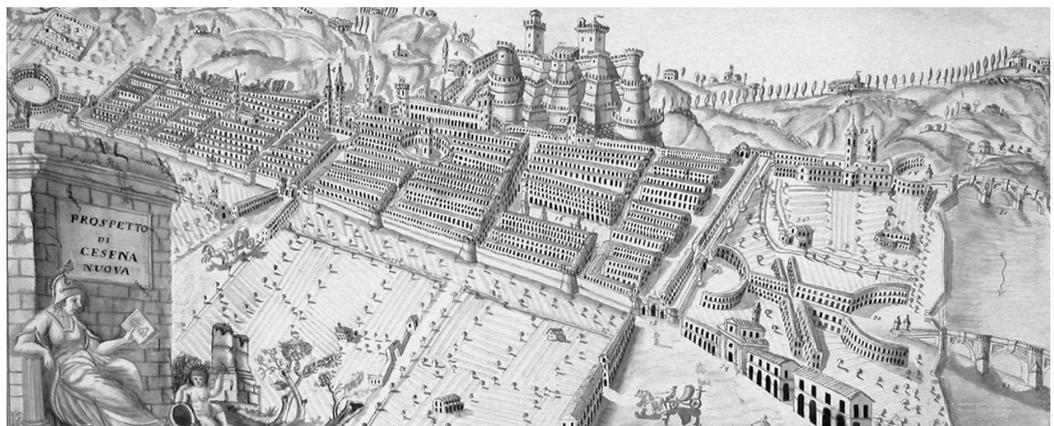
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Abstract

The paper illustrates the first step of a methodological workflow under development for the valorisation and communication of the documentary heritage. Archival drawings offer numerous insights into the past. Still, they often remain hidden from a broader audience in favour of specific and disciplinary studies that pertain to the history of architecture but also overlap with the science of representation. Digital technologies now allow the reconstruction or reinvention of a past that never existed, made up of ‘drawn’ architecture that, thanks to 3D modelling, can take shape and be narrated interactively and engagingly. Studies of this nature have often been undertaken by the discipline of Disegno, facing the complexity of virtual reconstruction at an architectural scale. This work illustrates a process that aims to systematise hypothetical virtual reconstruction within an urban context. This approach was made possible thanks to the Atlases of Mauro Gudi (1761-1829), an Italian architect from Cesena (Emilia Romagna) who, from the 18th century until his death, dedicated himself to the study of numerous architectural themes: public buildings, palaces, temples and churches. In particular, in Atlas 48, conserved at the Malatestiana Library of Cesena, project drawings can be consulted, accompanied by a textual description of two utopian projects for the cities of Cesena and Cesenatico: New Cesena and New Cesenatico.

Keywords

Architectural drawings, knowledge representation, 3D modelling, virtual reconstructions, unbuilt heritage.



Mauro Gudi (1821)
*Prospetto della città di
Cesena Nuova*, Biblioteca
Malatestiana - Cesena, IT
(Atlante 48, c.14).

“Così come l'èkphrasis trasforma le parole in immagini mentali, la ricostruzione 3D traduce l'immaginazione in realtà visibile permettendoci di vedere ciò che il tempo ha nascosto”

ChatGPT 2025

Introduction

The patrimonialisation of cultural heritage is a complex and multiform process that is not limited to the conservation and valorisation of tangible artefacts but also extends to the intangible dimensions of culture, including ideas, projects, and visions never realised. In this context, drawings of never-built architecture represent a valuable resource to enrich the historical narrative of a specific building or architectural site.

Archives and Libraries, custodians of numerous drawings, sketches, and plans of buildings that were never realised for various reasons, offer a unique and fascinating perspective on the history of architecture. Including drawings of architecture never built in heritage processes means recognising the value of unrealised ideas and visions as an integral part of cultural heritage. Although not tangible, these designs are significant testimonies of human creativity and contribute to a comprehensive and rich picture of architectural history.

For example, existing historical buildings are the materialisation of only one of many design possibilities, thus, examining unbuilt projects allows us to discover the different proposals considered during the design process. This multi-perspective narrative approach can reveal how design decisions were influenced by economic, political, aesthetic, or technical factors, offering a deeper understanding of the dynamics that led to the building's final realisation. Thanks to new digital technologies, such as 3D modelling and computer visualisation, unbuilt heritage can be visualised and understood.

Unbuilt heritage is also a fruitful field of research for virtual reconstructions, which are intended as a process of knowledge rather than merely digital reproductions of buildings.

Virtual reconstructions traditionally focus on the 3D model as the primary element and as the digital access point to semantically structured information and data collection. In contrast, this research takes a novel approach, exploring the role of knowledge representation using the uncertainty scale developed for the critical digital model and further implemented in the context of the *CoVHer Erasmus+ project* [1].

This approach aims to change the 3D model-based visualisation by enlightening critical reasoning and scientific processes through semantic labelling 3D models.

The objective is to enhance critical reasoning and scientific processes in virtual reconstructions through colored visualisation and standardise the documentation methodology behind 3D modelling.

This approach can significantly improve the visual understanding and appreciation of virtual reconstructions, emphasising the role of documentary heritage and architectural drawings.

To enhance the comprehensibility of the methodology developed in this preliminary study, the primary phases of the research are outlined below. This begins with the selection and identification of documentary sources that align with the objectives of the digital representation of Mauro Guidi's utopian project for 'New Cesena' [2]. The first phase involved data collection and digitisation, which yielded digital copies of Mauro Guidi's Atlases, generously provided by the Malatestiana Library in Cesena. Following this, a two-step analysis of the drawings was conducted.

The first step entailed analysing the drawings on an urban scale, after which the focus shifted to an architectural scale. During this phase, a comparison was made between the drawings and their handwritten descriptions (data analysis & Interpretation). Ultimately, the levels of knowledge were represented as defined among the reconstructive objectives and in relation to the iconographic sources using the 'LoRef - Level of References', along with the calculation of 'Average Uncertainty - AU (Data Representation)'. To visualise the results, a *HeritageMap* was employed, serving as an access point to the developed digital repre-

sentations, which are beneficial for both dissemination purposes and promoting scientific research (Data Visualisation).

This research emphasises the importance of developing a workflow to document the reconstruction process as effectively as possible by integrating various online and accessible open tools aimed at managing, publishing, describing, and visualising all the steps that contributed to the creation of hypothetical 3D models.

Furthermore, in accordance with the FAIR principles [Wilkinson et al. 2016, pp. 1-9], the data used in the research are shared and publicly available for consultation and validation.

The rhetorical device known as *ekphrasis* perfectly describes the effort of the documentation process that, with this case study, we try to carry out. In fact, as the Greeks used *ἔκφρασις* to define a “descriptive discourse that vividly brings the object before the eyes” [3], to highlight particulars that would otherwise be invisible to untrained eyes, the accurate and comprehensive data documentation effort not only improves transparency and readability and fosters the reusability of the reconstructive products but also helps reveal particulars normally invisible to laypersons. This contributes to a better understanding of the object of study and connects with it while limiting misconceptions and historical falsifications as much as possible.

Mauro Guidi architectural background and references

The architect Mauro Guidi (1761-1829), largely ignored by contemporary chroniclers and seemingly forgotten, was rediscovered by Nazzareno Trovanelli, who in 1901 ensured that Cesena City Council could purchase his manuscripts and drawings from the descendants of the Marquis Melchiorre Romagnoli.

This is how his Atlases arrived at the Malatesta Library in Cesena. Atlases are huge volumes that contain drawings, studies, and architectural projects.

In the library are conserved several volumes:

1. book on civil architecture of various works, the most beautiful in Rome and others invented, 1794, 35 plates (Atlas 38);
2. thoughts on architecture, 1790, ca. 186, of which 9 are text, and 177 plates (Atlas 43);
3. thoughts on civil architecture, 75 plates (Atlas 39);
4. mechanics (Atlas 40);
5. works invented and executed in the countryside, 60 plates (Atlas 54);
6. thoughts of temples and towers, 93 plates (Atlas 44);
7. sepulchral buildings, 96 plates (Atlas 41);
8. thoughts of fountains, 94 plates (Atlas 45);
9. churches and other buildings, 59 plates (Atlas 42);
10. various buildings, 59 plates (Atlas 46);
11. plans and elevations of houses, palaces, villas and other buildings, 71 plates (Atlas 47);
12. new Cesena and New Cesenatico, 204 plates (Atlas 48).

In volume 48 of the Atlases, Guidi proposed two utopian projects for New Cesena and New Cesenatico. These projects can be considered utopian and ideal because they were conceptualised at a mental and philosophical level and, therefore, considered abstract and far from practical realisation [Gori 2005, pp. 42-83; Pistocchi 2010, pp. 109-133].

Although Guidi's past projects for his Atlases have recognised the influence of French utopian design (Étienne-Louis Boullée and Claude-Nicolas Ledoux), more recent studies have shown that he was probably inspired by Borromini's designs, or rather by the Baroque architectural school at the turn of the 17th and 18th centuries. Also, as a result of his studies at the Accademia di San Luca, among others, he probably also took inspiration from Filippo Juvarra and Alessandro Antonelli (fig. 1) [Pistocchi 2010, pp. 109-133].

Examples of this connection are the similarities between Juvarra's 'ideas' for the square of Porta Palazzo in Turin (Turin, Musei Civici) and Guidi's project for the façades of a Palace (Atlas 48, c. 51). This possible inspiration is also evident in Guidi's proposal for a palace façade with a giant order (Atlas 48, c. 68), which was already proposed by Antonelli's project for Piazza Castello in Turin (Turin, Albertina Academy) [Lo Turco et al. 2023, pp. 214-226].

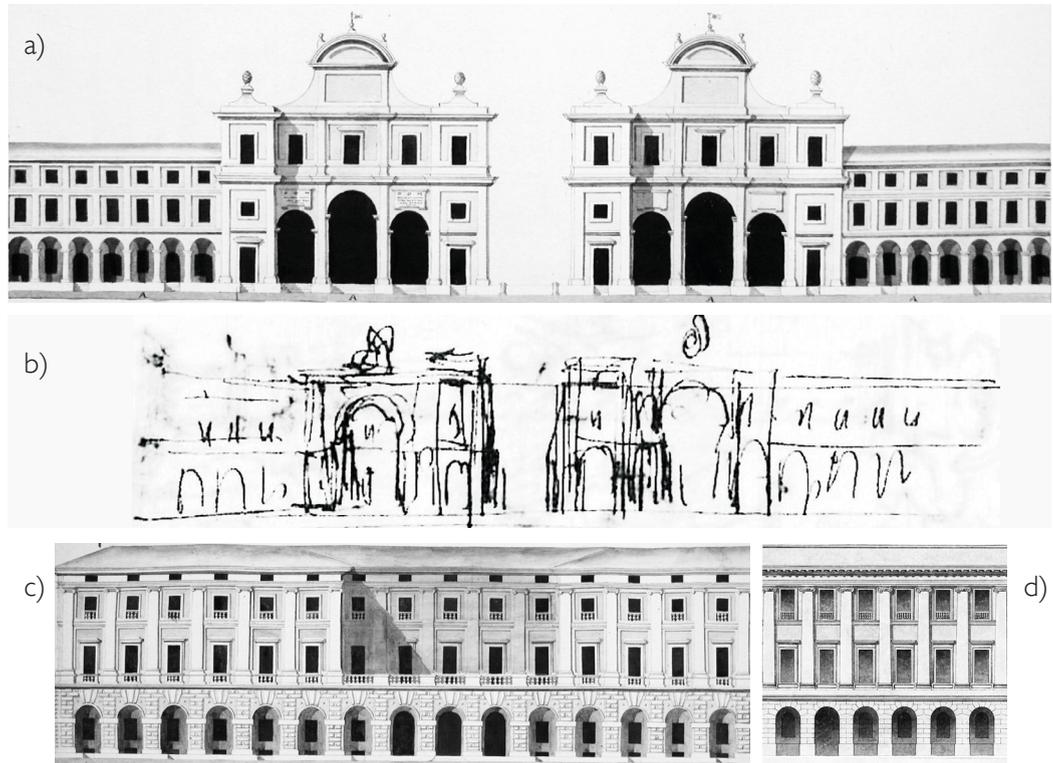


Fig. 1. Comparison between design projects for buildings facades: a. Mauro Guidi, 1821 (Biblioteca Malatestiana, Cesena, Atlante 48, c. 51); b. Filippo Juvarra (XVIII sec.) Torino, Piazza Vittoria (<https://www.palazzomadamatorino.it/it/archivio-catalogo/piazza-vittoria-di-torino/>); c. Mauro Guidi, 1821 (Biblioteca Malatestiana, Cesena, Atlante 48, c. 68); d. Alessandro Antonelli (graphic elaboration by E.C. Giovannini).

Mauro Guidi Atlas 48 and the project of 'New Cesena'

In Atlas 48, Guidi proposed a radical reorganisation of the urban layout of Cesena and Cesenatico, aiming for a rational and ideal transformation that would have changed the image of the two cities. Unfortunately, his ideas were never brought to life, but they represent an interesting example of the urban vision of the time.

In the Napoleonic era, between Illuminism and the Conservative Order, a period marked by profound political and social upheaval, the concept of utopic architecture flourished, reflecting the ambitions of the time to create ideal societies through urban planning and monumental construction. Classical architecture, focusing on symmetry, proportion, and harmony, became a fundamental element of these utopian visions. The revival of Greco-Roman architectural forms during this time was an aesthetic preference and a deliberate ideological statement. The widespread adoption of neoclassical architecture symbolised power, stability, and connection to a revered past.

This approach is evident in Mauro Guidi's work. Recurrent projects have a central or symmetrical plan, combining pure geometric forms to create designs for various buildings. The Atlas 48 is made up of 207 papers or 'carte' (c.), which include, both for the new Cesena and the new Cesenatico projects, a series of manuscript papers describing the various projects, numbered in the order they are described: each design project usually have a short textual description and at least a plan and a view of the main facade. Sections and other details eventually enrich this content. Each drawing has a graphic scale that uses Cesena's foot and presents numbers and letters that help to 'read' the drawings according to their descriptions. Within this ongoing research phase, we have begun analysing the documents and drawings describing New Cesena to classify and organise the buildings from a typological point of view. Faedi [2005, pp. 182-207] already published a previous classification and census of all of Mauro Guidi's work on the occasion of the conservative maintenance interventions concluded in 2005 on the entire corpus of Mauro Guidi's drawings, under the coordination of the Superintendence for the Historical and Artistic Heritage of Bologna.

Towards a 3D Atlas of New Cesena

The development of a 3D Atlas for the city of New Cesena was born to bring to light the utopian project of the city of Cesena and to analyse not only Guidi's productive activity but also its relationship with the context. Considering that it is a neoclassical style project, the second objective of this ongoing research is also to identify, where possible, a grammar of the architectural forms and languages used by the architect, taken and reinterpreted based on studies carried out at the Accademia di San Luca in Rome. This process offers a fascinating study of Guidi's work and architectural precedents that, starting with the same building plan, offer multiple formal solutions for the elevation towards the streets (e.g., noble palaces). Using new technologies also offers an unprecedented opportunity to disseminate this type of study. *HeritageMap* was used as an initial point of access to information, allowing the analysis and research on Atlas 48, which is dedicated to Cesena. The *HeritageMap* [Giovannini, Bono 2024, pp. 72-89] developed here differs from an Historical geographic information system (HGIS) in that it allows the structuring of heterogeneous data about a non-existent heritage. In fact, in virtual reconstructions of buildings that were never built or no longer exist, it is impossible to georeference the buildings' positions precisely or define an overall metric accuracy. In this case, we use a map aimed at a typological study on an architectural scale. Still, this research cannot ignore the urban scale, as the entire layout of the new city refers, in fact, to a context that existed and corresponded to a historical configuration of Cesena.

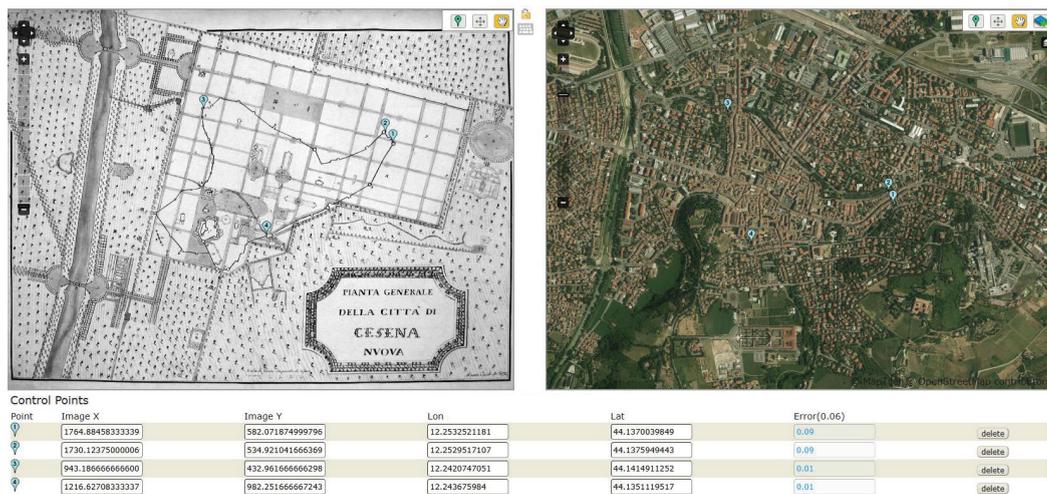


Fig. 2. Mapwarper user interface for rectifying Mauro Guidi's Map of New Cesena and Terrestrial Map of the City of Cesena. Graphic elaboration by E.C. Giovannini.

As can be seen from the city's general plan (Atlas 48, c. 14), the architect represents Cesena and its walls, which aimed at a complete reorganisation of the city. It is thanks to the presence of the city walls that the plan can be georeferenced to the layout of the portion that still exists today.

Four main points were identified, corresponding to some existing city gates: *Porta Santi*, *Porta Trova*, and *Porta Montanara*. This made it possible to superimpose the drawing on a satellite view of the city using *Mapwarper*, a free, open-source tool for rectifying maps [4]. It connects Guidi's map proposal to contemporary GIS coordinates (fig. 2). As the project for New Cesena shows, Guidi's settlement is based on the centurion method. This method is underpinned by logic dictated by reason and the utopia of good government that could only be achieved after Napoleon's fall.

Guidi indicates with numbers some of the buildings in the description of the *Pianta Generale della città di Cesena Nuova* (c. 14). As shown in figure 3, initial typological macrocategories were identified using *Umap* Layers, including the main new streets and hamlets.

Fig. 3. *HeritageMap* for the 3D Atlas of Mauro Guidi, 1821, *Pianta Generale della città di Cesena Nuova*: New Cesena and its georeferenced layers (Biblioteca Malatestiana, Cesena, Atlante 48, c. 15) (graphic elaboration by E.C. Giovannini).



Uncertainty of position of buildings within the map: four Levels of References

The first approach to the Atlas 48 was performed by analysing all available documentation. To obtain a reliable position of the described and depicted buildings within the utopian project of Mauro Guidi, the analysis started with comparing the numbering available in the plan's textual description (c.5) and it was clear that they differs both from the numbering present in the 'elevation' (c.15) and from the order in which the buildings are described (from c.6 to c.13ter) and depicted (from c. 16 to c. 133) within *Tomo I* (1821).

Thanks to the recognisability of the numbered buildings and places on both plan layout, indicated with numbers from 1 to 46 (c. 14 and c. 5), and the ones depicted in c. 15, with numbers from 1 to 30, it was possible to place some indicated buildings, churches and squares with a certain reliability.

There was, then, a need for a conceptual approach to highlight the logical and semantic connections between the positioning of the buildings that doesn't have a clear position according with available documentation.

A 'Level of Reference' (LoRef) [Giovannini 2017, pp. 212, 229; Giovannini, Torresi 2024, pp. 2971-2994] was therefore introduced to clarify the relationship between the position within the map (c. 14) and the building's descriptions. Both textual and visual description (building's plans) were compared to obtain a reliable or multiple reliable (e.g. noble palaces). A 4-colour scale has been identified to distinguish the types of available sources useful for positioning buildings (figs. 4, 5, 6).

LoRef	Description	LoRef
1	Georeferenced point	1
2	Reliable position according to c.14 and/or c.15	2
3	Reliable position according to c.14 and/or c.15 and additional textual description	3
4	Multiple reliable poitions according to c.14 and/or c.15 and additional textual description	4

c.14	c.15	Carta	Titolo Disegni di Ponti / Bridges	Descr.	LoRef
A		c. 14	Ponte Clemente Esistente		1
24	25	c. 14	Nuovo Canale Naviglio		2
5		c.33	Prospetto per lungo del ponte sul fiume Savio... Pianta del ponte...	c. 9v	2
		c.38	Pianta e Prospetto del Ponte da farsi sopra del Rubicone, detto di S. Lazaro	c. 10r	4

c.14	c.15	Carta	Titolo Disegni di Nuove Porte / New City Gates	Descr.	LoRef
		c. 39	Prospetto di un Arco Trionfale, salita del Ponte, e Spaccato dell'Arco di mezzo ed altri ornamenti, del Ponte di S.Lazaro	c. 10r	3
14-22	17	c. 40	Pianta e Prospetto della Porta che guarda al Nuovo Ponte. Pianta e Prospetto della Porta detta de Santi	c. 10r/v	3
28-29	12-13	c. 41	Pianta e Prospetto della Porta Ravennate. Pianta e Prospetto della Porta Cervese	c. 10v	3
31-32	14	c. 42	Pianta e Prospetto, della Porta Montanara. Pianta, e Prospetto, della Porta, che guarda al ponte Vecchio	c. 10v	3
30		c. 43	Pianta e Prospetto della Porta di S. Maria del Monte. Pianta, e Prospetto, della Porta della Pescaria	c. 10v	3

Fig. 4. 'Level of References' (LoRef) for each building of New Cesena described in *Tomo I*: Bridges and New City Gates. (analysis and graphic elaboration by E.C. Giovannini).

c.14	c.15	Carta	Titolo Disegni di Piazze / Squares	Descr.	LoRef
	11	c. 16	Pianta della Gran Piazza di figura Ovale fuori della Porta de Santi per il Corso delle Carrozze, e prospetti de suoi ornamenti	c. 6r	2
	2	c. 34	Pianta di una Piazza e Giardini sulla linea del Corso di là del ponte verso il passo di Forl...	c. 9v	2
		c. 35	Prospetto della Piazza coll'Arco Trionfale sulla linea del Corso... Spaccato dell'Arco Trionfale... Spaccato... de Giardini	c. 9v	4
		c. 55	Pianta di tutta la piazza Comunale, e Prospetto del Pubblico Palazzo, ed altri Fabbricati	c. 12v	2
40	6	c. 56	Piedistallo che si farà sotto al Pontefice. Pianta e Spaccato della Chiesa di S. Anna sulla Piazza Pubblica. Pianta e Prospetto di un Tempio ove vi anderà sotto il Pontefice di Bronzo... Prospetto del Fabbricato intorno alla Piazza. Pianta e Prospetto di una Fontana, di fronte all'altra	c. 12v	2
		c. 60	Macchina funebre da erigersi nel Campo Santo. Fontana della Piazzetta	c. 13r	4
46	16	c. 61	Piante e Prospetti di due Colonne Piramidali da inalzarsi nella Piazza Nobile	c. 13r	2
		c. 62	La statova di Cesena sopra di un Piedistallo, e suoi Ornamenti da inalzarsi nella Piazza Nobile	c. 13r	2
41	9	c. 101	Pianta della Piazza detta del Campanone con sei Chiese all'intorno, e la Torre del Campanone nel mezzo isolata	c. 13bv	2
		c. 102	Pianta ed elevazione dell'Antica Torre del Campanone Isolata	c. 13bv/ 13tr	2
c.14	c.15	Carta	Titolo Disegni Chiese e Parrocchie / Churches & Parishes	Descr.	LoRef
17		c. 99	Pianta della Chiesa, e Convento dell'Osservanza	c. 13bv	2
		c. 100	Pianta, e Prospetto della Facciata dell'Osservanza	c. 13bv	2
		c. 103	Spaccato della Chiesa detta La Crossetta. Spaccato della Chiesa della B.V. dell'Orto. Spaccato della Chiesa del Suffragio. Spaccato della Chiesa della R.R.M. di S. Chiara. Spaccato della Chiesa Paroc. di Boccaquattro	c. 13tr	4
		c. 104	Spaccato per il Longo della Biblioteca Malatestiana. Spaccato per il Longo della Chiesa de RR. PP. S. Francesco	c. 13tr	4
	3	c. 105	Pianta Spaccato per lungo e Prospetto della Chiesa de RR. PP. Capuccini	c. 13tr	4
8	23	c. 106	Pianta Spaccato in lungo e Prospetto di fuori della Chiesa Paroc. di S. Michele ne Suborghi	c. 13tr	2
12	29	c. 107	Pianta Spaccato in lungo, con Facciata, della Chiesa Paroc. di S. Bartolomeo ne Suborghi	c. 13tr	2
27	30	c. 108	Pianta, Spaccato in Longo e Prospetto della Chiesa Paroc. di S. Pietro ne Suborghi	c. 13tr	2
		c. 109	Oratorio della B.V. della Neve. Pianta e Spaccato della Chiesa della B.V. di Loreto. Pianta e Spaccato della Confrat. di S. Marino	c. 13tr	4
26	28	c. 110	Pianta, Prospetto e Spaccato della Chiesa della B.V. delle Rose	c. 13tr	2
		c. 111	Pianta, Spaccato e Prospetto della Confraternita Chiesa di S. Martignano	c. 13tr	4
		c. 112	Pianta, Spaccato in lungo e Facciata della Chiesa Confraternita di S. Crispino e Crispiniano	c. 13tr	4
		c. 113	Pianta, Spaccato in lungo e Facciata della Chiesa confraternita di S. Giuseppe	c. 13tr	4
		c. 114	Pianta, Prospetto, e Spaccato, della Chiesa delle R.R. Monache dette Le Capuccine	c. 13tr	4
		c. 115	Pianta, Spaccato in lungo e Prospetto della Chiesa delle R.R. Monache Convertite	c. 13tr	4
		c. 116	Pianta, Spaccato in lungo e Prospetto, della Chiesa delle R.R. MM. Monache di S. Biagio	c. 13tr	4
		c. 117	Pianta, Spaccato in lungo e Facciata della Chiesa delle R.R. Monache dello Spirito Santo, dette Santine	c. 13tr	4
		c. 118	Pianta, Spaccato per lungo e Facciata della Chiesa delle R.R. MM. Monache di S. Catterina	c. 13tr	4
	4	c. 119	Pianta, Spaccato in lungo, con Facciata della Chiesa de R.R.P. di S. Fran. di Favola	c. 13tr/v	2
		c. 120	Pianta, Prospetto, e Spaccato della Chiesa Parocchiale di S. Cristina	c. 13tr	4
		c. 121	Pianta, Spaccato in lungo e Prospetto della Chiesa Paroc. di S. Martino	c. 13tr	4
		c. 122	Pianta, Spaccato in lungo e Facciata della Chiesa Paroc. di S. Zenone	c. 13tr	4
		c. 123	Pianta, Spaccato in lungo e Prospetto della Chiesa Paroc. di S. Giovanni Evangelista	c. 13tr	4
		c. 124	Pianta del Piano Terreno della Chiesa e Convento di S. Croce	c. 13tr	4
		c. 125	Pianta, Prospetto, e Spaccato per lungo della Chiesa di S. Croce	c. 13tr	4
		c. 126	Pianta e Prospetto, o sia Facciata delle due Chiese di S. Filippo, e Celestini col suo Collonato	c. 13tr	2
		c. 127	Pianta, e Spaccato per Longo della Chiesa de Celestini	c. 13tr	2
		c. 128	Pianta della Chiesa di S. Filippo e S. Severo col suo Collonato al di Fuori, e gradinate	c. 13tr	2
		c. 129	Pianta dei sotterranee, e Spaccato in Longo della Chiesa co suoi Sotterranee di S. Filippo, ove si vede anche il suo Collonato nell'Altre di fuori	c. 13tr	2
		c. 130	Pianta dell'Loggiato della Cattedrale, e Chiesa de R.R.P. del Carmine con una Porzione di d. Catt.	c. 13tr	2
		c. 131	Spaccato della Chiesa dei Rev. P. Carmelitani, con le sue Logge di fronte alla Cattedrale colli Campanili consimili, e in mezzo la Strada del Borgo, con li Spaccati di detti Loggiati	c. 13tr	2
		c. 132	Pianta e Spaccato in lungo della Cattedrale	c. 13tr	2
		c. 133	Pianta e Prospetto di una Macchina per l'Esposizione del S.S. Sacramento nella Cattedrale. Pianta e Prospetto di un Altare Isolato nella Cattedrale	c. 13tr	2
c.14	c.15	Carta	Titolo Disegni di Palazzi Nobili - Isolati / Building Blocks	Descr.	LoRef
		c. 67	Pianta di un Palazzo Nobile con Portico	c. 13br	4
		c. 68	Prospetto di un Palazzo, e pianta del Portico, ed Atrio con Loggia in mezzo	c. 13br	4
		c. 69	Pianta di un Palazzo Nobile	c. 13br	4
		c. 70	Pianta di un Palazzo Nobile senza Portico	c. 13br	4
		c. 71	Pianta di un Palazzo Nobile	c. 13br	4
		c. 72	Pianta di un Nobile Palazzo	c. 13br/v	4
		c. 73	Prospetto di due Idee di Palazzi senza Portico	c. 13bv	4
		c. 74	Due Prospetti di palazzi senza portici	c. 13bv	4
		c. 75	Prospetti di due Palazzi senza Portico	c. 13bv	4
		c. 76	Prospetto di due Idee di Palazzi senza Portico	c. 13bv	4
		c. 77	Prospetto di due Palazzi senza Portico	c. 13bv	4
		c. 78	Prospetto di due Palazzi senza Portico	c. 13bv	4
		c. 79	Idee di due Tronchi di Palazzi senza Portico	c. 13bv	4
		c. 80	Due Prospetti di Palazzi senza Portici con Ringhiere	c. 13bv	4
		c. 81	Idea del primo Cortile di ogni palazzo Nobile con loggie e ringhiere...	c. 13bv	4

Fig. 5. 'Level of References' (LoRef) for each building of New Cesena described in Tomo I: Squares, Churches & Parishes and Building Blocks (analysis and graphic elaboration by E.C. Giovannini).

c.14	c.15	Carta	Titolo Disegni di Palazzi Nobili - Isolati / Building Blocks	Descr.	LoRef
		c. 82	Prospetto di Palazzo con Portico. Prospetto di un Palazzo con Portico	c. 13bv	4
		c. 83	Porzione di Tre Facciate di Palazzi con Portici	c. 13bv	4
		c. 84	Porzione di un Prospetto di un palazzo con portico. Tronco di un Prospetto di un Palazzo con ringhiera e Portico	c. 13bv	4
		c. 85	Idea di un Prospetto di Palazzo con Portico. Prospetto di un Palazzo con Portico	c. 13bv	4
		c. 86	Idea di un Palazzo con Portico. Idea di un Palazzo con Portico	c. 13bv	4
		c. 87	Idea di un Palazzo con Portico. Prospetto di un Palazzo con Portico	c. 13bv	4
		c. 88	Due Prospetti di palazzi con portici, cioè una Porzione, o Tronchi	c. 13bv	4
		c. 89	Idea di un Palazzo con Portico. Idea di un Palazzo con Portico	c. 13bv	4
		c. 91	Due Tronchi di Facciate di Palazzi con Portici	c. 13bv	4
		c. 92	Prospetto di un Palazzo con Portico. Prospetto di un Palazzo con Portico	c. 13bv	4
		c. 93	Idea di un Prospetto, di un Palazzo con Portico. Porzione di un Palazzo di Facciata	c. 13bv	4
		c. 94	Prospetto di un Palazzo con Portico. Prospetto di un Palazzo con Portico	c. 13bv	4
		c. 95	Un'idea di Facciata per un Palazzo con Portico. Prospetto di un Palazzo con Portico	c. 13bv	4
		c. 96	Prospetto di un Palazzo con Portico. Prospetto di un Palazzo con Portico	c. 13bv	4
		c. 97	Tronco di una Facciata di Palazzo con Portico e Loggia. Porzione di un Prospetto di un Palazzo, con Portico, e Loggia	c. 13bv	4
		c. 98	Idea di un Prospetto di un Palazzo con Portico e Loggia. Porzione di una facciata di un Palazzo con Loggia e Portico	c. 13bv	4
c.14	c.15	Carta	Titolo Disegni di Edifici Pubblici / Public Buildings	Descr.	LoRef
25		c. 17	Pianta, Prospetto _e Spaccato del Porto del Canale Naviglio, e Magazeni con Molino	c. 6v	2
20		c. 18	Pianta e Prospetti di dentro di una villa per il Spaseggio, detta Montagnola	c. 6v	2
		c. 19	Pianta, e Prospetto della Gualchiera e Ramiera	c. 6v	4
		c. 20	Pianta, Prospetto e Spaccati di un Molino a Olio, Buono, e tristo, ove vedasi in Grande le due Macine in Castello che girano sopra una Spina	c. 7r	4
	26	c. 21	Pianta, Prospetto e Spaccati di un Molino da Grano con sei Macine	c. 7r	4
		c. 22	Pianta del Bagno	c. 7v	2
7	19	c. 23	Prospetto di fuori del Bagno. Spaccato per il Largo del Bagno. Spaccato per il Longo del Bagno	c. 7v	2
		c. 24	Pianta del Campo Bovario, o sia Mercato del Bestiame	c. 7v/8r	2
16		c. 25	Prospetto principale del Campo Bovario, o sia luogo dove si farà il Mercato de Bestiame. Prospetto al di dentro del sud. Campo Bovario. Spaccato per il Longo al di dentro del Campo Bovario	c. 8r	2
		c. 26	Pianta del Campo Mortuario e sua Chiesa	c. 8r/v	2
	24	c. 27	Prospetto di Fuori del Campo Mortuario. Spaccato per il largo della Chiesa. Fabbriato, e Sotteranei, o Cattacombe. Pianta de sotteranei, o Cattacombe del Campo Mortuario	c. 8v	2
		c. 28	Prospetto esterno del Campo Mortuario, e Facciata della Chiesa e Portico per Largo. Prospetto interno per lungo del Campo Mortuario, e Spaccato della Chiesa, Cattacombe, ed atrio	c. 8v	2
		c. 29	Pianta per lo Spetale per ogni sesso	c. 8v/9r	2
10	25	c. 30	Spaccati delli due cimiteri interni, e Capelline per li Uomini, e per le Donne. Spaccato delle due Corsie del Nuovo Ospedale per gli Uomini, e per le Donne ed il luogo dell'Altare. Prospetto di fuori di tutto l'Ospedale, per gli Uomini, e per le Donne, col le sue Porte dingresso	c. 9r	2
	1	c. 31	Pianta e prospetto del Portico, o Loggiato, che da Cesena porta alla Chiesa della B.V. detta del Monte...	c. 9r	2
		c. 32	Pianta e Prospetto del Campanile da collocarsi nel Piazzale del Monte Isolato. Pianta e Prospetto del primo ingresso del portico che conduce alla B.V. del Monte...	c. 9r/v	2
6		c. 36	Pianta di un riposo da caccia	c. 10r	2
		c. 37	Prospetto al di fuori del riposo di caccia. Prospetto e Spaccato... interno...	c. 10r	2
		c. 44	Pianta e Prospetto di una Fabbrica, per la Cunza delle Pelle Bovine e Sovine. Pianta e Prospetto della Macellaria, e Pellatojo per i maiali	c. 10v	4
35		c. 45	Pianta e Prospetto della Cavallerizza. Pianta e Prospetto della Caserma de Soldati	c. 11r	2
36		c. 46	Pianta e Prospetto della Dogana. Pianta e Prospetto del Forno Pubblico	c. 11r	2
		c. 47	Pianta, Spaccati, e Prospetto dell'Anfiteatro, per la Caccia del Toro e altri Spettacoli	c. 11r/v	4
34		c. 48	Pianta, Prospetto e Spaccato ... di un Anfiteatro o sia Guoco del Pallone	c. 11v	2
		c. 49	Pianta della Beccaria. Pianta della Pescaria	c. 11v	4
		c. 50	Pianta della Posta delle Lettere	c. 12r	4
		c. 51	Prospetto della Posta delle Lettere e Case de Particolari. Prospetto della Dispensa e Case de Particolari. Prospetto della Beccaria, e Case. Prospetto della Pescaria e Case	c. 12r	4
38		c. 51b	Pianta del Teatro a Pian Terreno	c. 12r	2
		c. 52	Spaccato interno di un nuovo Teatro...	c. 12r	2
33	5	c. 53	Pianta della Fortezza	c. 12r/v	1
		c. 54	Prospetto della Fortezza di tre Ordini...	c. 12v	1
		c. 57	Pianta del Pian Terreno con suo portico, e del Piano Nobile con sua Reggia scala del Palazzo della Comune	c. 12v/13r	4
		c. 58	Spaccato della Sala e Atrio. Spaccato della Scala, atrio e Sala. Pianta del Pian Terreno, e Nobile, e Spaccati della Reggia Scala, e Sala del Palazzo della Comune	c. 13r	4
		c. 59	Pianta, Prospetto e Spaccato ... di una Sala da Ballo, co suoi Palchi e Cantorie	c. 13r	4
		c. 63	Pianta e Prospetto del Locale degli invalidi d'ogni sesso con Chiesa, e Case Particolari alle due parti oposte	c. 13r/v	4
		c. 64	Due Filatoj per li Oziosi, e Zitelle, e Donne maritate, che non hanno volontà di far bene, con le sue Macchine, e Chiesa. Pianta e Prospetto	c. 13v	4
		c. 65	Pianta e Prospetto del Orfanotrofo, e Pericolanti, con Chiesa	c. 13v/13br	4
		c. 66	Pianta, e Prospetto degli Opedali degli Alunni d'ogni sesso di S. Tubia, Congregazione di Carità, e sue Chiesa	c. 13br	4

Fig. 6. "Level of References" (LoRef) for each building of New Cesena described in Tomo I: Building Blocks and Public Buildings. (analysis and graphic elaboration by E.C. Giovannini).

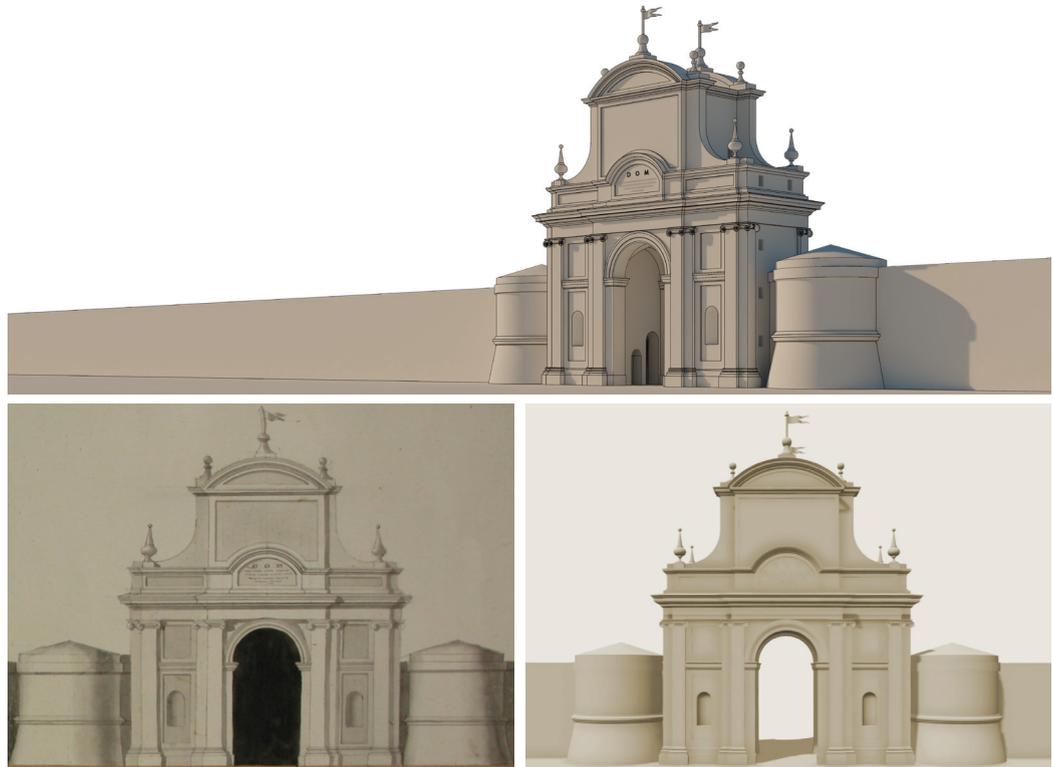


Fig. 7. On the top, human height perspective of Porta della Pescaria. On the bottom, a comparison between Mario Guidi (1821) original drawing (*Pianta Generale della città di Cesena Nuova*, Biblioteca Malatestiana - Cesena, IT, Atlante 48, c. 15) and 3D model (graphic elaboration and 3D model by R. Foschi).

3D modelling of Porta della Pescaria

Porta della Pescaria (fig. 7), one of the city gates designed by Guidi, is presented as an exemplificative case. Since it was never built, the only direct sources available were the plan and facade published on the Atlas 48, *Carta 43*, in 1821 [Guidi 1821]. The represented level of detail of these authorial sources was close to that of a 1:100 scale, this level of detail was insufficient to redesign the ornaments in minute detail, in fact they were roughly sketched by the author which only allowed us to recognise the classical order used, and to infer the overall global proportioning but not to redraw accurately the smaller details such as the moulding profiles. Thus, for the ornaments, this lack of detail was compensated by gathering and referring to secondary sources drawn at a bigger scale. In particular the Ionic order was redesigned based on the first book of the treaty by Andrea Palladio *I quattro libri dell'Architettura* [Palladio 1570 pp. 28-36], the mouldings of the capital and base were redesigned strictly referring to the proportioning described by Palladio, while the ratio between the height and the width of the pilaster was recalculated based on Guidi's drawing, in particular Palladio's Ionic column was 9 diameters high, while Guidi's pilaster in this case was about $10 + 1/3$ diameters. Furthermore, Palladio's Ionic was drawn with entasis, while Guidi drew a straight shaft. Architecture that used classical orders was often globally proportioned based on the diameter of the column, however, in this case, a strict relation between the width of the pilaster and the proportions of the other parts of the architecture was not observed, thus the architecture was proportioned using mainly the *piède di Cesena* (equal to about 54 cm) and its multiples and submultiples (1 foot was divided in 10 ounces) as shown in figure 8. Only the main facade and the ground floor plan of the city gate were drawn by Guidi, and no sections or additional plans were found and probably even drawn. Thus, the rear facade was hypothesised to be symmetric to the main facade, and the internal development of the floors was redesigned based on inferences gathered from the available drawings, personal experience and logical deduction. The staircase on the left highlighted the presence of at least an additional floor; its height was determined by multiplying the plausible height of the rises for the number of steps in a

Fig. 8. Critical redrawing of the plan of Porta della Pescaria based on Mauro Guidi's *Pianta e Prospetto della Porta di S. Maria del Monte*, 1821 (Biblioteca Malatestiana, Cesena, Atlante 48, c. 43) (analysis and graphic elaboration by R. Foschi).

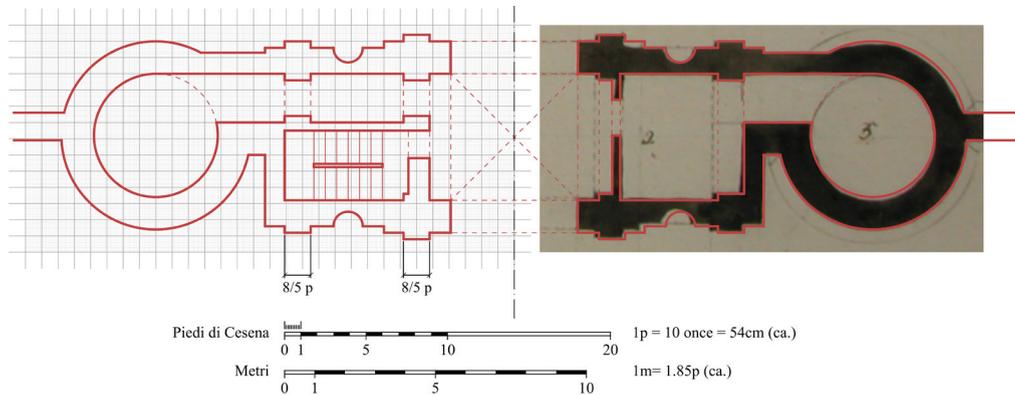
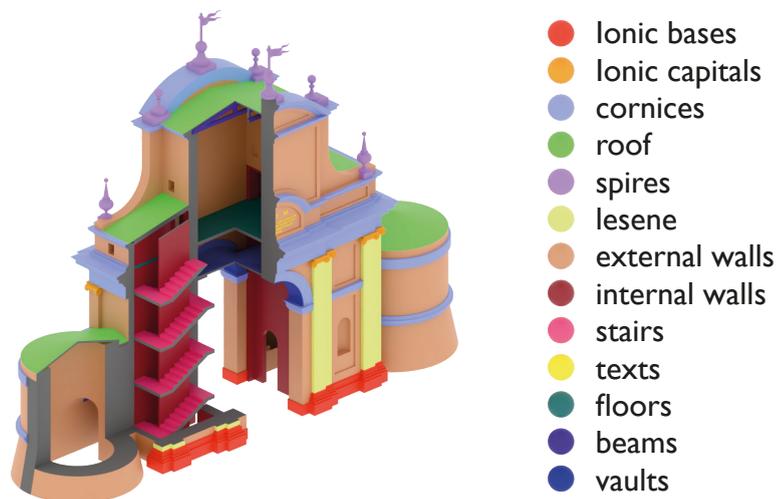


Fig. 9. Semantic segmentation of Porta della Pescaria. (analysis, graphic elaboration and 3D model by R. Foschi).



way that all the flights of stairs resulted in the same height. As a consequence, eight ramps of seven steps with about 20 cm rise and 37 cm tread each were hypothesised. In this way, the height of the resultant ceilings allowed a semicircular double barrel vault at the ground floor while guaranteeing a minimum height at the first floor of about 170 cm. More floors interrupted by the central arch could fit in the height of the building; however, the presence of only one staircase on one side of the arch suggested the absence of additional intermediate floors on both sides of the arch, which would have been hardly accessible on the side where the staircase was not present at ground floor. This was the reason why the solution with only one continuous floor connecting both sides of the arch was preferred.

The model was semantically segmented to simplify future consultation and improve its reuse (fig. 9), and its elements were created as closed, watertight, non-intersecting solids. The chosen representation method was the continuous mathematical method (NURBS) to enable for a better control and accuracy of all the features from a geometric point of view. The unit of measurement chosen for the preliminary analysis and the critical proportioning was the *Piede di Cesena* converted into cm at the moment of vectorisation and 3D modelling in order to improve its comparability to other models and simplify its integration in systems and environments based on contemporary units of measurement.

Uncertainty assessment

The assessment of the uncertainty was performed in *Blender* through a custom open-source plugin developed in the context of the *CoVHer project*, available for free as *Blender Uncertainty Calculator* [5]. The plugin allowed us to apply to each element of the model a certain

level of uncertainty chosen from a given scale of 7 levels of increasing uncertainty and to calculate the Average Uncertainty Weighted on the Volume (AU_V) and the Average Uncertainty Weighted on the Volume and Relevance (AU_VR), refer to the following paper for more info about how these formulation were conceived and why are important [Foschi et al. 2024, pp. 4440-4454]. The AU_V resulted in 27% and AU_VR 36%.

These values tell us that the overall reconstruction is mildly uncertain but is more uncertain in the most relevant parts. This happened because the reference drawings were lacking and the level of detail insufficient, especially for smaller ornaments.

The uncertainty scale used was developed for the critical digital model [Apollonio et al. 2021, 3-24] and improved over the years to extend its robustness and versatility [Apollonio et al. 2024, 476-498], each level is selected based on some characteristics of the sources used such as their completeness, author, readability, level of detail and so on, as described in figure 10.

Documentation of the reconstruction process and publication of the 3D model

The documentation of the reconstruction process was synthesised on the Idovir platform [Grellert et al. 2024, pp. 103-114] [6], which was used to upload and publish the sources and add comments and explanations via textual notes and images.

Levels	Description
1	The analysed feature of the 3D model is derived mainly from good-quality. - REALITY-BASED DATA which reach the target LoD.
2	Reliable conjecture, based mainly on clear and accurate DIRECT/PRIMARY SOURCES which reach the target LoD. - When REALITY-BASED DATA are unavailable, available but unusable, or not reaching the target LoD.
3	Conjecture, based mainly on INDIRECT/SECONDARY SOURCES, by the SAME AUTHOR/S, which reach the target LoD, or logic deduction/selection of variants. - When DIRECT/PRIMARY SOURCES ARE AVAILABLE, but minimally unclear, damaged, inconsistent, inaccurate, or not reaching the target LoD.
4	Conjecture, based mainly on INDIRECT/SECONDARY sources by DIFFERENT AUTHOR/S (or unknown authors) which reach the target LoD. - When DIRECT/PRIMARY SOURCES ARE AVAILABLE, but minimally unclear, damaged, inconsistent, inaccurate, or not reaching the target LoD.
5	Conjecture, based mainly on INDIRECT/SECONDARY SOURCES by the SAME AUTHOR/S which reach the target LoD - When DIRECT/PRIMARY SOURCES ARE NOT AVAILABLE or unusable.
6	Conjecture, based mainly on INDIRECT/SECONDARY sources by DIFFERENT AUTHOR/S (or unknown authors) which reach the target LoD. - When DIRECT/PRIMARY SOURCES ARE NOT AVAILABLE or unusable.
7	Conjecture, based mainly on personal knowledge due to missing or UNREFERENCED SOURCES
8	Not relevant, not considered, left unsolved, missing data, and missing conjecture (does not count for the calculation of the average uncertainty)

Assign Uncertainty Level	
	Uncertainty 1 (0–14%)
	Uncertainty 2 (14–28%)
	Uncertainty 3 (28–43%)
	Uncertainty 4 (43–57%)
	Uncertainty 5 (57–71%)
	Uncertainty 6 (71–86%)
	Uncertainty 7 (86–100%)
	Abstention

AU_V = 27%
AU_VR = 36%
(Relev. ornaments and vaults x 10)

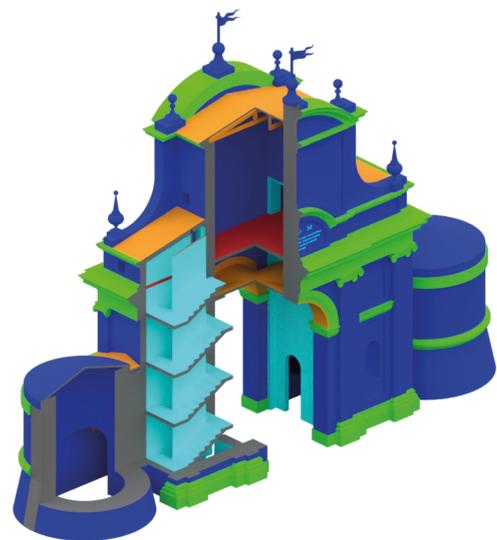


Fig. 10. Uncertainty Assessment via custom Blender Plugin (analysis and graphic elaboration by R. Foschi).

The 3D model was published on two platforms: *Sketchfab* and the *CoVHer* repository [Bajena et al. 2024, 115, 126]. The first platform is a commercial service owned by a private company (*Epic Games*), which is very user-friendly and has a simple and straightforward publication workflow (fig. 11). It is often chosen by scholars because it has an advanced render engine and various useful features for the addition of notes for more effective storytelling, dissemination and provides an easy way to embed the 3D model into other websites for a fast live 3D preview, however, it misses specific features for a proper querying and investigation of the reconstruction and its semantic structure. On the contrary, the *CoVHer* repository is a free and open platform, specifically developed for the scientific context, that offers a robust way to upload 3D hypothetically reconstructive models, allowing for complete semantic and ontological descriptions of data (fig. 12). Furthermore, all data are machine-readable and easily interrogable [Bajena, Kuroczyński 2024, pp. 467-488].

Fig. 11. *HeritageMap* descriptive panel for Porta della Pescaria: textual description (Biblioteca Malatestiana, Cesena, Atlante 48, c.10v); drawings (Biblioteca Malatestiana, Cesena, Atlante 48, c. 43); 3D models (graphic elaboration by E.C. Giovanni, 3D models by R. Foschi). The 3D model of Porta della Pescaria is labelled with uncertainty colour scale (<https://skfb.ly/p9P8Q>) and with white uniform coloured texture (<https://skfb.ly/p9PqR>).

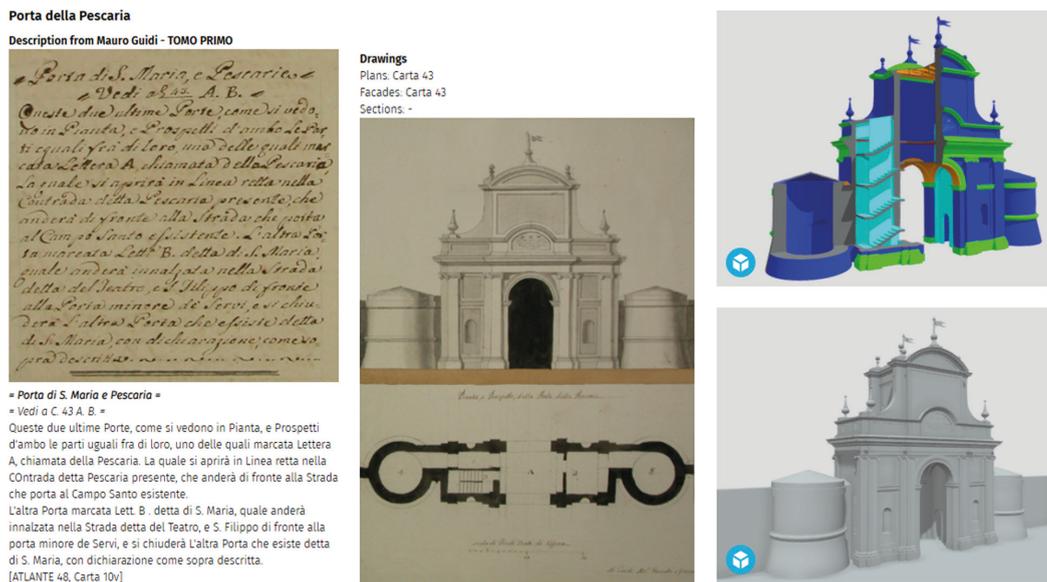
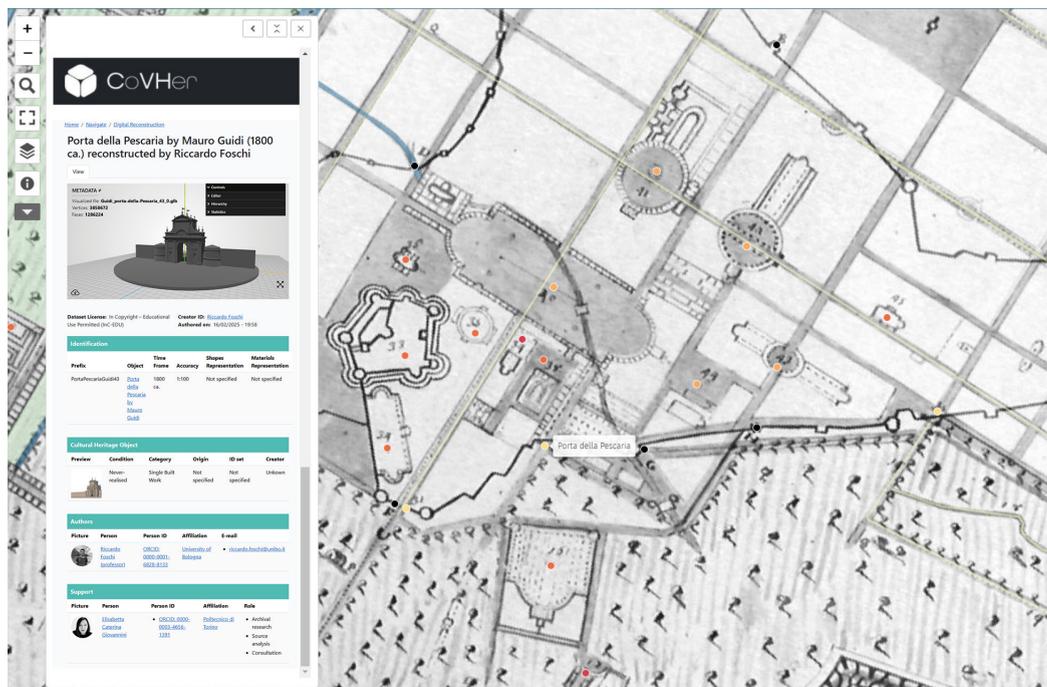


Fig. 12. *HeritageMap* descriptive panel for Porta della Pescaria. Mauro Guidi (1821), Pianta e Prospetto della Porta di S. Maria del Monte. Pianta e Prospetto, della Porta della Pescaria (Biblioteca Malatestiana, Cesena, Atlante 48, c. 43) interlinked with 3D metadata available at CoVHer platform (<https://repository.covher.eu/wisiki/navigate/4595/view>) (graphic elaboration by E.C. Giovanni).



Conclusions

The research activity, which has just begun, uses a *HeritageMap* as an access point and data management tool for Mauro Guidi's documentary heritage for New Cesena. This approach represents a significant step towards the accessibility and integrated management of data on cultural, urban and territorial heritage. The platform allows you to aggregate and consult heterogeneous information in 1D, 2D and 3D format as shown in figure 11. One of the central aspects is the effort made to make usable even the sources that, for reasons of protection or rights, cannot be published online: these data are managed through systems that discretise the primary source, while still offering tools to identify its presence and context. The *HeritageMap* developed is open to interoperability thanks to the connection with other platforms and the management of data according to the principles of Linked Open Data 3D, favouring a transparent and collaborative digital ecosystem. This approach not only improves the availability and understanding of sources, but also allows for the dynamic integration of data from different institutions and disciplinary fields. This is the case for research at both the urban and architectural scale. The *HeritageMap* thus becomes a point of reference for the documentation, valorisation and sharing of cultural heritage, with a focus on sustainability and responsible and transparent access to information.

Credits

In this contribution, whose authors shared the methodological framework, E.C. Giovannini is author of Mauro Guidi *architectural background and references*, *Mauro Guidi Atlas 48* and the project of *New Cesena, Towards a 3D Atlas of New Cesena, Uncertainty of position of buildings within the map: four Levels of References*. R. Foschi is author of *3D modelling of Porta della Pescaria, Uncertainty assessment, Documentation of the reconstruction process and publication of the 3D models*. *Introduction and Conclusions* were written jointly by the authors.

Notes

[1] *CovHer Computer-based Visualisation of Architectural Cultural Heritage Erasmus+ project*. Accessible at <https://covher.eu/>

[2] The *HeritageMap '3D Atlas of New Cesena'* was developed by E.C. Giovannini. Accessible at https://umap.openstreetmap.fr/it/map/mauro-guidi-atlante-3d_1175159

[3] L'èkphrasis è "un discorso descrittivo che pone l'oggetto sotto gli occhi con efficacia": voce èkphrasis, in Treccani. *Enciclopedia dell'Arte Antica*, 1994 (trans. by the authors).

[4] *Mapwarper* is a 'georectification' service to warp or stretch images and maps on real world coordinates. Available at <https://mapwarper.net/>.

[5] The *Blender Uncertainty Calculator* was developed by R. Foschi. Available at <https://github.com/rikkarlo/Blender-Uncertainty-Calculator>.

[6] IDOVIR, *Infrastructure for Documentation of Virtual Reconstructions*. Accessible at <https://idovir.com/p/cm7p07hu-701xo14m48y0r0xdq>.

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To cite this chapter: Elisabetta Caterina Giovannini, Riccardo Foschi (2025). Towards a methodology for the digitisation of unbuilt cities: from 'drawn' architecture to 3D landscape. In L. Carlevaris et al. (Eds.), *èkphrasis. Descrizioni nello spazio della rappresentazione/èkphrasis. Descriptions in the space of representation*. Proceedings of the 46th International Conference of Representation Disciplines Teachers. Milano: FrancoAngeli, pp. 1245-1258. DOI: 10.3280/oa-1430-c820.