



# The Critical Digital Model and Two Case Studies: the Churches of Santa Margherita and Santo Spirito in Bologna

Fabrizio Ivan Apollonio<sup>1</sup> · Federico Fallavollita<sup>1</sup> · Riccardo Foschi<sup>1</sup>

Accepted: 21 March 2023  
© The Author(s) 2023

## Abstract

Two case studies of hypothetical reconstruction are presented according to the principles of the Critical Digital Model [Apollonio et al. 2019]. One of the case studies is an architecture that was designed but never realized, and the other is the reconstruction of a historical art exhibition hosted into an architecture still existing today. This study is part of a wider research which is being currently carried out in the international Erasmus + project CoVHer. The main objective of the CoVHer project is to identify shared standards for the construction, evaluation and sharing of 3D hypothetical reconstructions. This research exploits the diversities of the two case studies to classify and re-define the methods of digital representation, which deal with the geometrical/mathematical nature of the models themselves and tries to define good practices to produce scientifically valid, sharable, and reusable 3D reconstructions.

**Keywords** Design analysis · Hypothetical reconstruction · Proportional analysis · Architectural heritage · Geometric analysis

## The Research

The academic community do not share standards for the modelling and critical evaluation of hypothetical reconstructions yet. Two important documents were developed to try to address this issue, the “*London Charter*” [Hugh 2009] and the

---

✉ Federico Fallavollita  
federico.fallavollita@unibo.it

Fabrizio Ivan Apollonio  
fabrizio.apollonio@unibo.it

Riccardo Foschi  
riccardo.foschi2@unibo.it

<sup>1</sup> Department of Architecture, Alma Mater Studiorum University of Bologna, Via dell'Università 50, 47521 Cesena, Italy

“*Seville Principles*” [Principles of Seville 2017], they defined some theoretical principles but were not exhaustive for practical cases. Thus, some international projects brought forward the objectives of these two pioneering documents regarding digital documentation, for example, the “*Inception-project*” (Horizon 2020) [Inception European Project 2015], the DFG Research Network: “*Digital 3D Reconstructions as Tools of Architectural Historical Research*” [DFG Research Network 2018], and now the CoVHer project [CoVHer Project 2022]. In particular, this paper shares some concepts, firstly developed in the context of the CoVHer Erasmus+ project, with the scientific community and aims to foster discussions about the topic of shared standards for the modelling and evaluation of virtual 3D reconstruction of architectures that are damaged, no longer exist, or were designed but never built.

Today there are several methodologies to create 3D models, and some are more robust than others for creating scientifically valid and accurate products. Keeping under control the dimensional accuracy and quantifying numerically the quality of some properties of the models could play an important role in the validation phase and would improve the shareability and comparability of models built by different scholars. The innovation, therefore, is not in the methodology itself but in the clear identification of some concepts and classifications (e.g., definitions, and terminology) that would help the scientific community to better share 3D models as scientific products.

Within the numerous experiences concerning the hypothetical reconstructions of historical artefacts [Piotr et al. 2019], the two case studies presented here concern the reconstructions of the church of Santa Margherita as it was designed by Agostino Barelli in 1685 [Alessio 2015], and the reconstruction of the exhibition curated by Antonio Canova in the church of Santo Spirito in 1816 [Apollonio et al. 2021], both in Bologna. Each case differs from the other concerning the use of sources and the digital representation method/language adopted. The former reconstruction is only based on documental historical sources, the latter relies on historical documental sources together with the real building that came down to us with minimal variations. Thanks to the different nature of these case studies, the potentialities and criticalities of mathematical/polygonal modelling can be put into comparison; this introduces the opportunity to define a set of good practices that relate the “mathematical modelling language” (continuous or discrete) to the scope of each element. The two case studies allow discussing the distinction between the Raw Model (RM) and the Informative Model (IM) [CoVHer Project 2022]. The RM is a digital model obtained through quasi-automatic procedures from the raw data captured from real sources (photogrammetry, laser scanner).

The IM, on the other hand, is a model enriched with information processed and interpreted by an author. One of the aims of this paper is to clarify the conceptual difference between RM and IM.

Another opportunity for discussion derived from these case studies is the deduction of architectural modularity approached from two different starting points: real remains, and drawn sources. The research of modularity should always start from the historical units of measurement, probably used by the original designer, compared with the available evidence, no matter which is the reference source.

Thus, also in this case, geometry and mathematics can help to rationalise the process of reconstruction and to share objective data, and most importantly subjective inferences, unambiguously.

## S. Margherita

The lost church of S. Margherita in Bologna is one of the numerous examples of no longer existing architectural manufacts which we know about only thanks to documental sources that retrace its history. The first documental sources (that have come down to us) of the homonymous monastery trace back to the XII century, however, the version datable back to the 1685 (ca.) designed by Agostino Barelli is the richest in details and extensively documented version among the multitude of variations that the church went through [Alessio 2015]. Barelli's drawing depicted two sections and the lateral façade. The 3D reconstruction is based on this project and aims to reproduce that version of the church as close as possible to the author's will (Fig. 1).

Barelli's project probably never saw the light, or at least it is highly probable that it was widely modified due to financial difficulties already started during the great plague of 1630 [Alessio 2015], which threw the building sector into a crisis that saw its worst period in 1700. In fact, a new document by Barelli depicting a much more modest plan and section for the same church datable only one or two years later (ca.) would reinforce this hypothesis. It is also probable that in later times the church was enriched with new altars of which we have a few drawings and sketches made by Angelo Venturoli in 1782 and 1792. For this reason, the 3D



**Fig.1** Hypothetical reconstruction of the church of Santa Margherita as designed by Agostino Barelli in 1685, Bologna

critical reconstruction was complemented with a series of appended 3D variants depicting the most probable later configurations that were realized in place of the original project (Fig. 2).

The preliminary modularity analysis and study of geometrical rules permitted the identification of probable deformations on the paper support and rationalized the drawing process.

## S. Spirito

The reconstruction of the church of the Spirito Santo in Bologna (Fig. 3), via Alfredo Testoni 4/b (before in via De' Gombruti 1213) had to combine the documental data relative to its conditions about two centuries ago and the reality-captured data retrieved from the laser scanning of the actual building that has come down to us. The church, founded in the second half of the XVII century, was expanded three times up to 1788 when it was redecorated by the architect, based in Bologna, Giuseppe Jarmorini (1732–1816). After that renovation, the building didn't receive any major change, until 1943 when its roof was demolished due to the bombardment of World War Two. The damaged parts were then restored during the eighties (as they were before the bombardments), and from that date, the church remained in a good state of preservation. The building nowadays is not a consecrated church but it houses the archives of the Advocacy of the State [Apollonio et al. 2021].

The 3D reconstruction process aimed to reproduce the church as it was in 1816 when it housed the important public exposition curated by Antonio Canova regarding the showcasing of several important paintings reclaimed from the French. The 3D model of the building was constructed starting from the 3D point cloud



**Fig. 2** Hypothetical reconstruction of the church of Santa Margherita variant as designed by Angelo Venturoli in 1792, Bologna



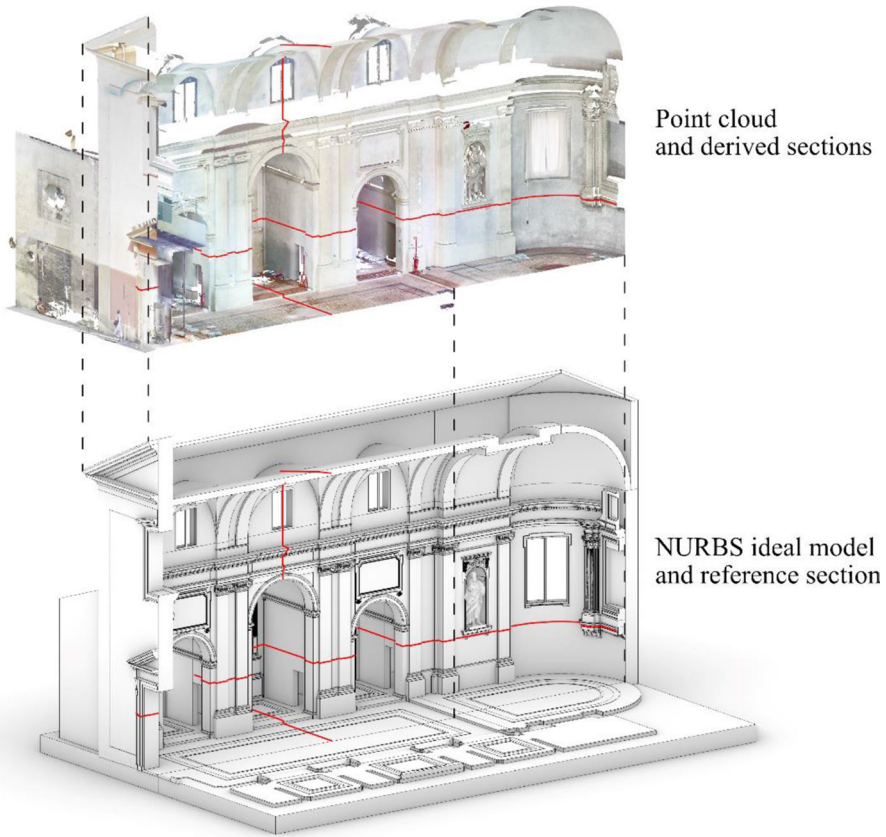
**Fig. 3** Hypothetical reconstruction of the church of Spirito Santo as it might have been during the exhibition curated by Antonio Canova in 1816, Bologna

captured through a laser scanning campaign. The 3D point cloud was then imported into CAD software and used as a reference to produce the ideal mathematical model (Fig. 4). The reconstruction was requested by the Pinacoteca Nazionale di Bologna [Pinacoteca Nazionale di Bologna 2021] and was aimed to visualize the layout of the disposition of the paintings at the historical exhibition by Canova, thus the architecture was not the main object of study. However, the process of reconstruction was an opportunity to study the geometrical proportioning, dimensioning and composition of the architectural elements of the church. As often happened in buildings from the Renaissance onwards, it was observed that the church was designed following a rigid modularity system that used as the base module the width of the Ionic pillars. Since the object of study was the event held inside the church, the reconstruction focused only on the interior of the building.

This case study presented the challenge of populating the architecture with furniture and characters, the presence of models of different natures required critical thinking about which representation method (mathematical/polygonal modelling) was more suitable for each element while guaranteeing the scientific value of the 3D reconstruction and at the same time versatility of use for different purposes (analysis and visualization).

## Conclusions

The presented research tries to clarify some theoretical principles and develop good practices usable in applicative cases. It proposes to systematize the creation and validation of the Critical Digital Model which is a subgroup of hypothetical 3D virtual reconstructions that follows the principles of the scientific method. In this



**Fig. 4** Process of reconstruction of the hypothetical model of the church of Santo Spirito, starting from the Raw data from laser scanner up to the NURBS ideal model

way, the 3D model itself could become a source of study to foster research in the field of hypothetical reconstructions. The novelty presented in this research does not consist in the methodology itself; today several different methodologies can produce scientifically valid 3D hypothetical reconstructions; what is missing is the sharing of concepts and terms at the international level that would set the 3D virtual reconstruction as a true autonomous discipline.

**Acknowledgements** CoVHer (Computer-based Visualisation of Architectural Cultural Heritage) is an Erasmus Plus Project (ID KA220-HED-88555713). It is a 36 monthly project and it started in February 2022. There are seven principal partners from five different European countries. The partners are University of Bologna (Bologna, Italy), Hochschule Mainz University of Applied Sciences (Mainz, Germany), Politechnika Warszawska (Warsaw, Poland), Universidade Do Porto (Porto, Portugal), Universitat Autònoma de Barcelona (Barcelona, Spain), Tempesta Media SL (Barcelona, Spain), Interessengemeinschaft für semantische Datenverarbeitung e.V (München, Germany). The scholars currently involved in the project are (the order of persons follows the institution to which they belong): Fabrizio Ivan Apollonio, Federico Fallavollita, Riccardo Foschi, Irene Cazzaro, Piotr Kuroczyński, Jan-Eric Lutteroth, Igor Bajena, Krzysztof Koszewski, Franczuk Jakub, Karol Argasiński, Joao Pedro Sampaio Xavier, Clara Pimenta do Vale, Hugo Pires, Juan Antonio Barceló Álvarez, Evdokia Tzerpou,



Marc Hernández Güell, Raquel Garcia, Pol Guiu and Mark Fichtner. For more detailed information, compare the two websites: [www.CoVHer.eu](http://www.CoVHer.eu) and <https://erasmus-plus.ec.europa.eu/projects/search/details/2021-1-IT02-KA220-HED-000031190>.

**Funding** Open access funding provided by the University of Bologna within the CARE-CRUI Agreement.

**Data availability** Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

## Declarations

**Conflict of interest** On behalf of all authors, the corresponding author states that there is no conflict of interest.

**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

## References

- Apollonio, Fabrizio Ivan, Fallavollita, Federico, and Foschi, Riccardo. 2019. The Critical Digital Model for the Study of Unbuilt Architecture. In *Workshop on Research and Education in Urban History in the Age of Digital Libraries* 3–24. Cham: Springer.
- Apollonio, Fabrizio Ivan, Fallavollita, Federico and Foschi, Riccardo. 2021. La ricostruzione digitale della mostra allo spirito santo. In *Antonio Canova e Bologna. Alle origini della Pinacoteca*, ed. Alessio Costarelli, 104–113, Milano: Electa.
- Costarelli, Alessio. 2015. La scomparsa chiesa parrocchiale di Santa Margherita a Bologna: arredo interno e vicende costruttive. In *Strenna Storica Bolognese, anno LXV – 2015*, eds. Comitato per Bologna Storica e Artistica&nbs, 103–130. Bologna: Patron Editore.
- CoVHer Project. 2022. Official website. [www.CoVHer.eu](http://www.CoVHer.eu). Accessed 28 November 2022.
- DFG Research Network. 2018. Digital 3D Reconstructions as Tools of Architectural Historical Research. Webpage. <https://www.gw.uni-jena.de/en/faculty/juniorprofessur-fuer-digital-humanities/research/dfg-netzwerk-3d-rekonstruktion>. Accessed 18 November 2022.
- Denard, Hugh. 2009. The London Charter. For the Computer-Based Visualisation of Cultural Heritage, Version 2.1. <https://www.londoncharter.org>. Accessed 18 Noember 2022.
- Inception European Project. 2015. Webpage of the inception European project. <https://www.inception-project.eu/en>. Accessed 18 November 2022.
- Kuroczyński, Piotr, Pfarr-Harfst, Mieke and Münster, Sander (eds.). 2019. *Der Modelle Tugend 2.0: Digitale 3D-Rekonstruktion als virtueller Raum der architekturhistorischen Forschung*. Heidelberg: arthistoricum.net.
- Principles of Seville. 2017. International Principles of Virtual Archaeology. Ratified by the 19th ICOMOS General Assembly in New Delhi. <http://sevilleprinciples.com>. Accessed 18 November 2022.
- Pinacoteca Nazionale di Bologna. 2021. Web page of the exhibition “Antonio Canova e Bologna, alle origini della pinacoteca”. <https://www.pinacotecabologna.beniculturali.it/it/2-non-categorizzato/2976-antonio-canova-e-bologna-alle-origini-della-pinacoteca>. Accessed 28 November 2022.

---

**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Fabrizio Ivan Apollonio** Full professor at University of Bologna, Department of Architecture, Ph.D. in architectural representation and survey, at University of Ancona. His research interests are aimed in particular at the survey with photogrammetric and laser scanner technologies and at the digital modeling of architecture and their applications aimed at the fruition, study and documentation of Cultural Heritage. He currently focuses his research on the theme of hypotheticala/virtual reconstruction of disappeared and/or never built architectural and archaeological works. He published essays, reports, papers and books about urban surveying for the protection of architectural heritage and about architectural drawing. Author of "*Architettura in 3D. Modelli digitali per i sistemi cognitivi*" (2012), editor of three volumes "*I colori di Cesena. Lascena urbana della città*" (2008). PI of research MURST-PRIN in 2000 and 2003 on the urban iconography. Editor of exhibitions "*Architecture of the sacred space*" (Bologna, 1996, Vatican City, 1998); "*Cesena. The urban scene of the city*"(2007- 2008). He has been a speaker in several national and international conferences, meetings and congresses giving reports, presenting papers/posters a holding lectures in Seminars, Summer schools and Masters.

**Federico Fallavollita** Federico Fallavollita is associate professor at the Department of Architecture of University of Bologna where he teaches courses of drawing at the single cycle degree/combined bachelor and master's in architecture and first cycle degree Bachelor in Industrial Design. He graduated with honours in architecture at Sapienza University of Rome. In 2008 he obtained a PhD in Sciences of Representation and Survey at the Department: History, Design and Restoration of Architecture at Sapienza University of Rome with a thesis entitled: The ruled surfaces and developable surfaces, a reading through the virtual lab. He deals with the issues of representation and survey of architecture. He is mainly interested in renewal of descriptive geometry through the new informatics tools. His research focused as well on the hypothetical virtual re-construction of architecture never built or lost. He is coordinating an Erasmus Plus Project entitled CoVHer (Computer-based Visualisation of Architectural Cultural Heritage, [www.CoVHer.eu](http://www.CoVHer.eu)).

**Riccardo Foschi** Research fellow, tutor, and adjunct professor at the University of Bologna. Ph.D. in 2019 in architectural representation with a thesis on the parametric modelling of origami applied to architecture that gave birth to a book on the same topic. His research interests are in the fields of digital representation for Archviz, NURBS and Mesh modelling for architecture and product design, architectural survey (laser, photogrammetry, photometric stereo), computational parametric and algorithmic modelling, folded surfaces modelling and analysis, applied origami, digitisation of artistic heritage, digital reconstruction of unbuilt or lost architectonic heritage, VR/AR/XR. In recent years he collaborated with European projects and international research groups aimed at defining shared standards and good practices for the 3D reconstruction of cultural heritage at the international level. He also collaborated to create and organize museum exhibitions about digitized cultural heritage.