Digital & Documentation

V5 From virtual space to information database

edited by
Francesca 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.

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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DIPARTIMENTO INGEGNERIA CIVILE ARCHITETTURA

DAda Lab - Drawing and Architecture DocumentAction

PLAY - Photography and 3D Laser for virtual Architecture laboratorY

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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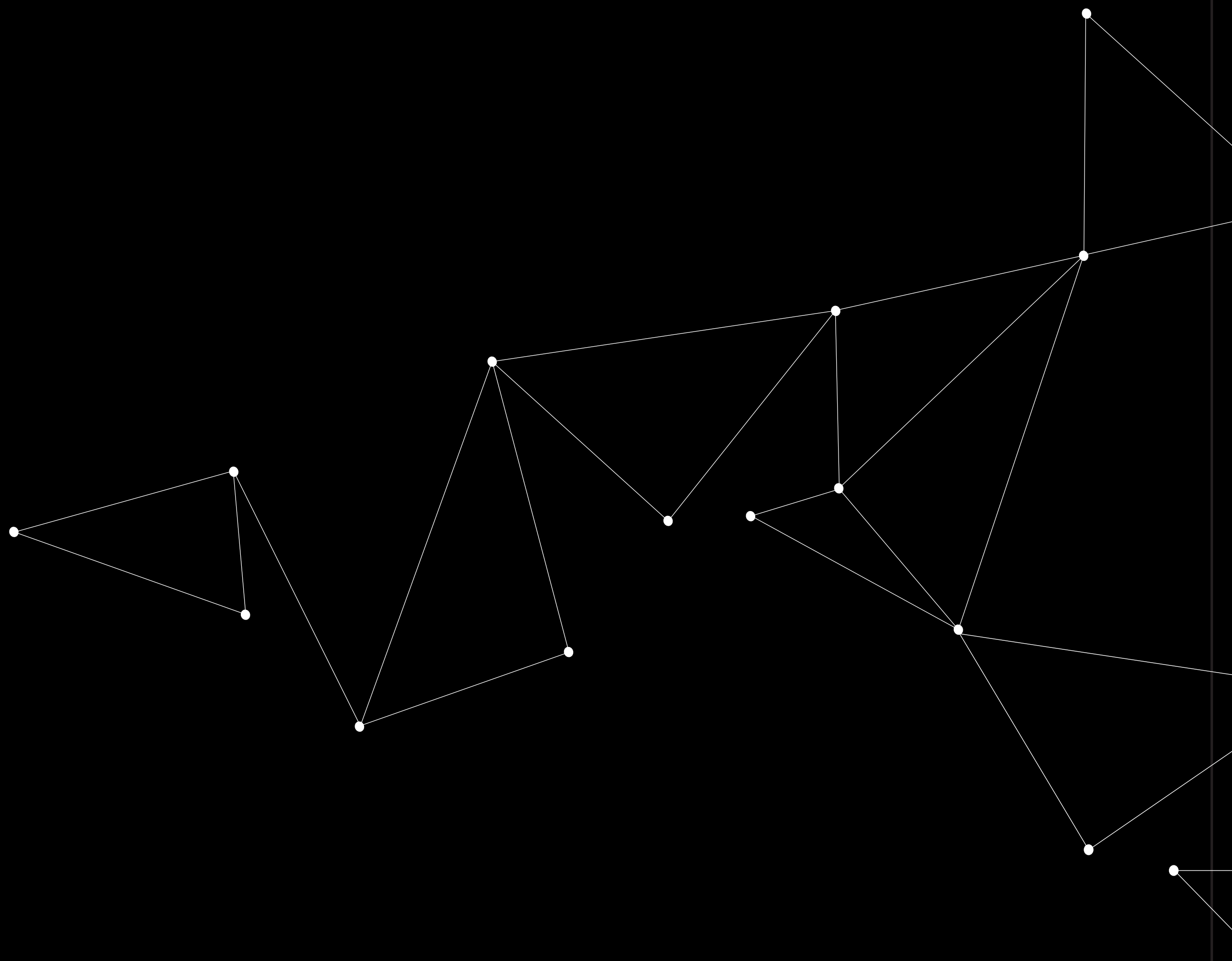

Presentations
FOREWORD

Francesca Fatta
President of UID - Unione Italiana Disegno

The digitization of Cultural Heritage involves not only engaging in critical and interpretive processes of analysis but also utilizing tools and technologies, thereby requiring specific technical skills. The science of representation, therefore, finds itself more than ever in a position to merge humanistic and technological disciplines in a holistic vision, in a continuous renewal and updating of communicative methods and tools.

Drawing represents the world by re-presenting it as a duplicate on the plane of the image. Whether for an existing reality or a design intention, there is always the need to understand the complexity of space and architecture, which over time has manifested in ever-evolving languages and techniques, from painting to photography, from cartography to satellite maps, to the most current interactive information systems.

Today, virtual reconstructions allow for the remote analysis of distant landscapes, knowledge of endangered heritage, and the revelation of archaeological sites no longer visible by reconstructing their original form. At the same time, expectations for the quality of digital products describing built heritage and enabling analysis and investigation at different scales are growing.

Models and information systems, constituting repositories of knowledge, simulation scenarios, and spaces of interconnection and interaction, have assumed an importance that is now an essential goal for all projects aimed at describing cultural assets. However, the volume of information constantly generating new products and the updating of tools and technologies capable of generating them prompt reflection on the "future" of these digital information products. How many of these digital outputs truly represent advancements for research in the field? In which direction is the virtual world moving? What are the most effective procedures for controlling and verifying digital duplicates? And how do different variations of virtual three-dimensional representation support the management of the built environment at various scales?

Researchers working in the field of architectural representation must consider and discuss the implications of the term "digital." In this regard, focus is required on the enormous amount of data we can produce, their actual quality, and the use of this information to structure new and increasingly in-depth knowledge that should be not only an endpoint but also the beginning of deeper consideration.

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University of L'Aquila

Pamela Maiezza received the master's degree in construction-Architectural Engineering in 2014, the 2nd level University master's degree in Architectural Design for the Restoration of Historic Buildings and Public Spaces in 2016, and the Ph.D. degree in Civil, Construction-Architectural, Environmental Engineering in 2019.

After obtaining the National Scientific Habilitation as associate professor in the sector 08/E1 DRAWING in the 2018-2020 session, she is currently assistant professor at the University of L'Aquila.

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Her main research activity is related to the topics of architectural documentation, representation and communication, specifically through the development of HBIM procedures and the experimentation with visual programming applications.

12 3D MODELS FOR ARCHITECTURAL HERITAGE DOCUMENTATION: TRANSPARENCY AND RELIABILITY ISSUES

Abstract

Digital modelling has multiplied the opportunities offered by graphic representation for the study, analysis, documentation, and enhancement of the architectural heritage. In particular, 3D models, intended both as a visual computing tool -that is, data processing and deepening of the characteristics of buildings- and as "complex" models -as they are connected to a heterogeneous information system- favour the documentation of the historical and architectural values of the heritage. In this context, Building Information Modelling (BIM), in its dual meaning of graphic representation and database, has amplified such potential, offering itself as an interactive platform where to manage the heterogeneous and multidisciplinary information inherent to the architectural heritage. However, these models are not a complete and exhaustive transcription of the characteristics of the object of study, but rather a critical selection of these, made according to the purposes of the representation and the specificities of the architectural object. For this reason, in order for the representation to have a scientific basis, it is necessary that the sources used for the realization of the model are declared transparently and that the interpretative level of the virtual reconstruction is clear.

The contribution deals with the issues of transparency of models and their reliability, in relation to both geometric and non-geometric contents. In particular, based on an experiment conducted on several case studies, it proposes a possible specific procedure for modelling transparency and reliability evaluation, necessary for the documentation of the architectural heritage through 3D models.

Introduction

Digital modelling has multiplied the possibilities offered by graphic representation for the study, analysis, and enhancement of the architectural heritage. 3D models, in fact, can favour the documentation of the historical and architectural values of the heritage and, at the same time, can be tools for communication and valorisation.

In this respect, 3D models must be intended both as a visual computing tool -that is, data processing and deepening of the characteristics of buildings - and as "complex" models -as they are connected to a heterogeneous information system.

The modelling of the architectural heritage can concern different themes. It may involve for example reconstructive hypotheses of past phases of a building or an urban context (Brusaporci et al., 2020).

Since what can be known is only current reality, the reference of these reconstructions is the survey of the present state. In addition, there is the critical analysis of the various archival documents, such as historical photos, drawings, and so on. The scholar, then, on the basis of the critical analysis of survey data and archival documents, makes interpretative choices. Similar interpretative problems can be found in the digital visualizations of hypotheses of projects never completed. In this case, the 3D model becomes an instrument for understanding how the artefact could appear and the current architectural values. The modelling of incomplete architectures is carried out on the basis of a critical overlap of the project with the survey of the current state. The digital

Fig. 1 – The different themes of 3D modelling for the architectural heritage.

reconstruction of unfinished architectures, therefore, raises important matters of interpretation: on the basis of a critical analysis, interpretative choices must be made, aimed at overcoming any inconsistencies and hypothesizing what in the project is incomplete or unclear. However, even when the modelling concerns existing buildings, digital visualization is not exempt from interpretative choices: for example, the interpretation of survey data, the reconstruction of non-geometric aspects such as the constructive technology, and so on. So, the declaration of the sources and the "interpretative" level of the information obtained with respect to the available data are two essential themes in the context of the representation of the architectural heritage. The issue of the model "Transparency" becomes essential, understood as the declaration of the information sources and the possibility of philological reconstruction of the choices made for the realization of the model. As it is essential to declare the level of reliability of the model, with respect not only to the geometry but also to the other information contents, such as the construction technology. In this context, Building Information Modelling, in its dual meaning of graphic representation and database, has amplified the potential for documentation, offering itself as an interactive platform where to manage the heterogeneous and multidisciplinary information inherent to the architectural heritage. At the same time, it has made the issues of transparency and reliability even more relevant. The proposed contribution deals with models for the documentation of architectural heritage, focusing in particular on the issues of transparency and reliability of the model.

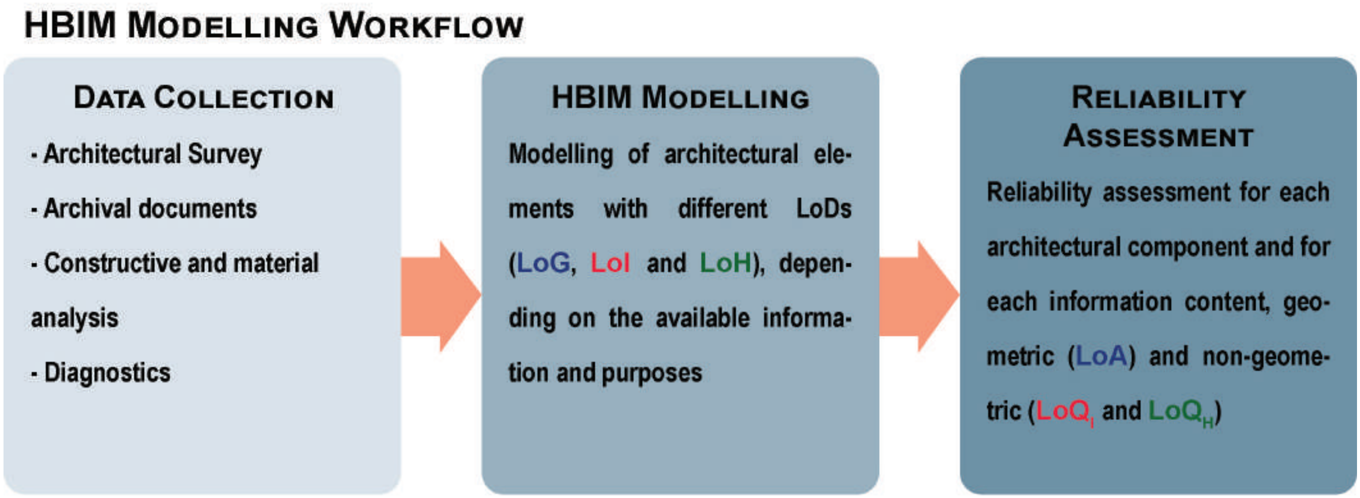


Fig. 2 – The HBIM modelling workflow: The model, created on the basis of the historical-critical analysis of the collected data, must be evaluated to declare its geometric and informational reliability.

3D models for architectural heritage: themes and issues

In accordance with Levi-Strauss's definition of models as "systems of symbols which safeguard the characteristic properties of experience, but which, unlike experience, we have the power to manipulate" (Lévi-Strauss, 2008), the digital interpretative model is configured as a simulation of reality (and not an uncritical mimesis), through which it is possible to investigate and get to know it, enriching our experience much more than it would be possible without the mediation of visualization (Maldonado, 2015).

This simulation does not only concern the geometric-dimensional characteristics of the building, but also includes the material, technical aspects and the historical-architectural values of the building.
The model consists of a simplification of the phenomenon, aimed at enhancing its most significant and representative aspects. In the necessary reduction of architectural complexity made during modelling, there is thus an increase in the level of knowledge of the object of study.
The constituent elements of the model are linked together by the same relationships that link the elements of the real object, building an analogy between the model and the

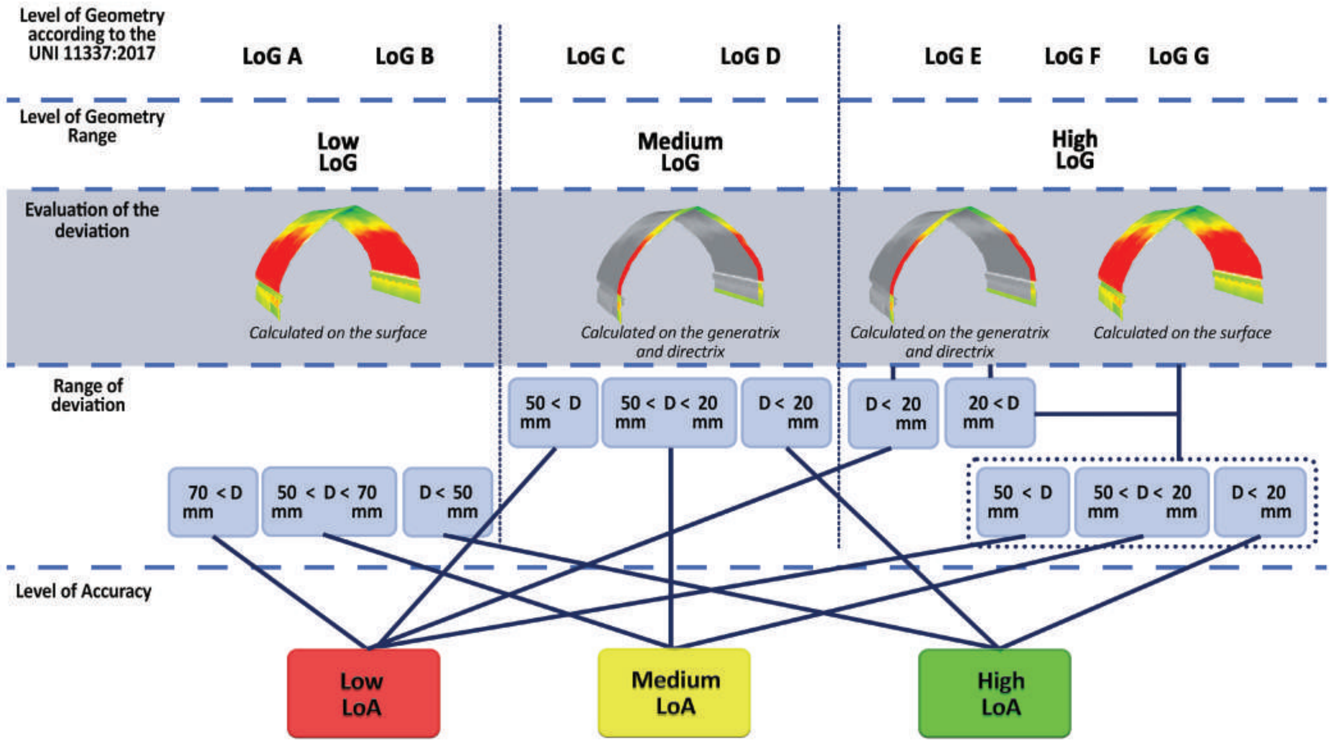


Fig. 3 – Evaluation of geometric reliability in terms of deviation between the point cloud and the model. Depending on the LoG of the element analysed, the deviation is evaluated on the entire surface, on the generatrixes and directrixes, or on both, according to different ranges.

modelled phenomenon (Docci and Chiavoni, 2017). Thus, "interpretive graphic models" facilitate the understanding of the building's distinctive features, providing the foundation for the study, reading and interpretation of architecture.

Due to its inherent characteristics, the study of architectural heritage constitutes an articulated process of building knowledge comprising a vast amount of heterogeneous data and information, the analysis and correlation of which is aided by the creation of digital models. For this reason, three-dimensional modeling can be traced back to Visual Computing, a technique for processing data based on their visual representation, through which to derive information and create new knowledge (Brusaporci, 2015).

During the modelling process, the architectural object is examined in its constituent aspects, which are then translated into three-dimensional digital elements. By modelling the building, the scholar analyses its architectural, spatial, technical, and material characteristics, as well as aspects related to architectural and constructional events and changes that have occurred over time, thus coming to understand its historical and artistic values.

Thus, the 3D model should be understood as a visual tool for studying and analysing architectural features and,

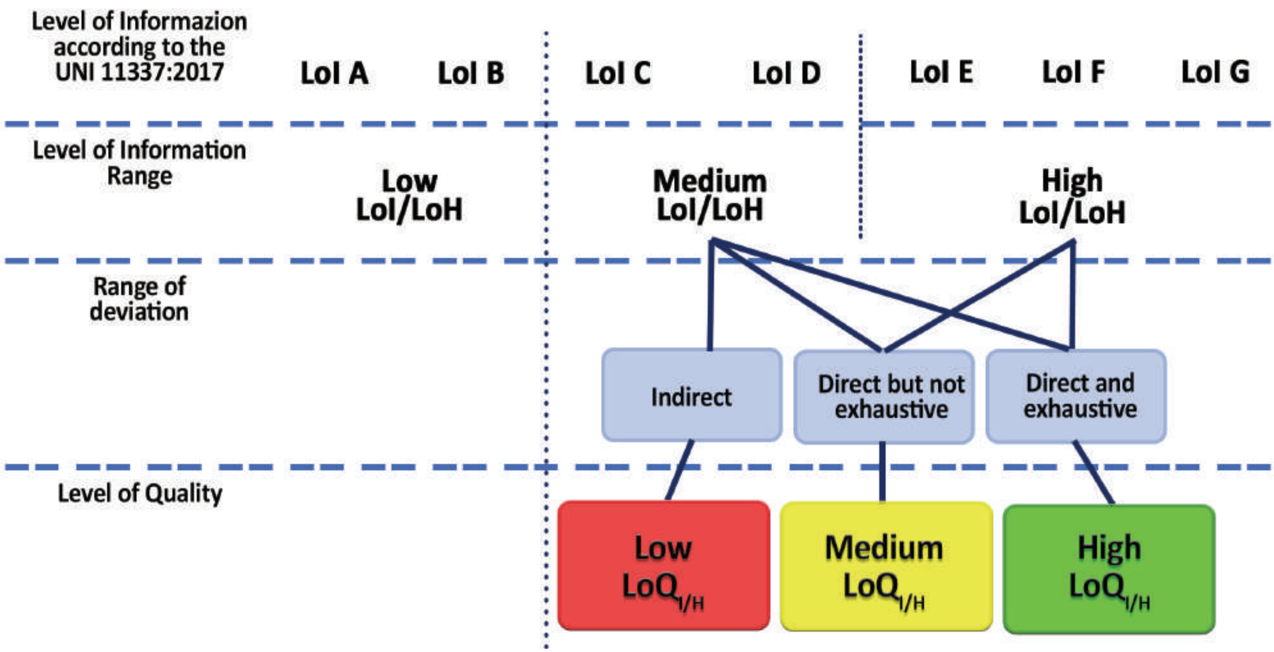


Fig. 4 – Evaluation of information reliability, depending on the LoD and the type of source (direct, indirect, exhaustive or otherwise).

Fig. 5 – With the same information, the higher or lower information level will require more or fewer hypotheses, with a consequent reliability that may be higher (fewer hypotheses) or lower (more hypotheses).

at the same time, verifying the hypotheses and research conducted on the architectural heritage.
Digital modelling, as well as drawing in general, is characterized by its heuristic nature, in that what is represented, two- or three-dimensionally, is the scholar's idea of the building or urban space being examined, which must be continuously verified through comparison with phenomenal reality.
Representation, therefore, takes the form of an iterative process consisting of the succession of hypotheses and validations, that is, of drawing and comparing the visualization with the perception of the reality studied.
The interpretive nature of this process is evident: it is the modeler-scholar who, based on his or her expertise and sensitivity, makes critical choices regarding both geometric and nongeometric aspects. For a scientific foundation of modelling, it is therefore necessary to consider the requirements of transparency and reliability [Centofanti, 2010].
Transparency, which originated in the field of archaeology, refers to the declaration of the sources used in making the model and the possibility of philologically reconstructing the choices made in relation to these. In view of the "opacity" of digital visualization, The London Charter (2009, p. 2) hopes "[...] that research results that include digital visualization should convey to users the state of the art, such as the distinction between evidence and hypotheses and between different levels of probability" [Bentkowska-Kafel et al. 2012].
The Principles of Seville (2012), introducing "Scientific Transparency," state that.: «All computer-based visualization must be essentially transparent, i.e. testable by other researchers or professionals, since the validity, and therefore the scope, of the conclusions produced by such visualization will depend largely on the ability of others to confirm or refute the results obtained».
The need to enable the testability of visualization by other scholars through the transparent presentation of the entire elaborative process (methodology, techniques, reasoning, origin and characteristics of the sources of research, results and conclusions) and the organization of metadata and paradata is, therefore, emphasized. (p.8).
Digital modelling and visualization of architectural heritage, moreover, pose the problem of the reliability of virtual reconstruction, referring not only to the geometric-dimensional aspect, i.e., the relationship between the restitutive model and measurement, but also to all issues inherent in the knowledge of a historic building (concerning, for example, the construction equipment or the historical sources on which reconstructive hypotheses of buildings that no longer exist or have been heavily modified have been advanced). To the issue of deviation, understood as deviation of the model from the real object represented by the point cloud [Quattrini et al., 2016; Apollonio 2017; Brumana et al. 2019], therefore, reflections related to the other information contents of the model as well can be added

[Apollonio and Giovannini, 2015; Bruno and Roncella 2018]. These issues are amplified in Building Information Modelling (BIM). Alongside the important possibilities offered by BIM in the field of architectural heritage documentation, there is an even more urgent demand for transparency of modelling and declaration of its reliability. As is well-known, in the BIM environment the geometric representation and the information enrichment are defined inside the level of development of the digital objects, whose increase corresponds to a linear increase in the quantity and quality of the information contained within the BIM objects. In international and national regulatory references (such as the English system PAS 1192-2, the American BIMForum and the Italian UNI 11337), the Levels of Development consist of both the graphic attributes (according to UNI 11337, geometric attributes - LoG) and the non-graphical ones (according to UNI 11337, information attributes - LoI). These levels, both concerning aspects that can be quantified and computable (e.g. dimensions, materials, costs, etc.), are not sufficient to exhaust the information needed to describe an architectural asset. Therefore, it becomes necessary to consider an additional level related to all those heritage-specific information, not covered in current BIM environments, which we can call Level of History (LoH) [Brusaporci et al., 2021], The new international standard UNI EN ISO 19650:2019

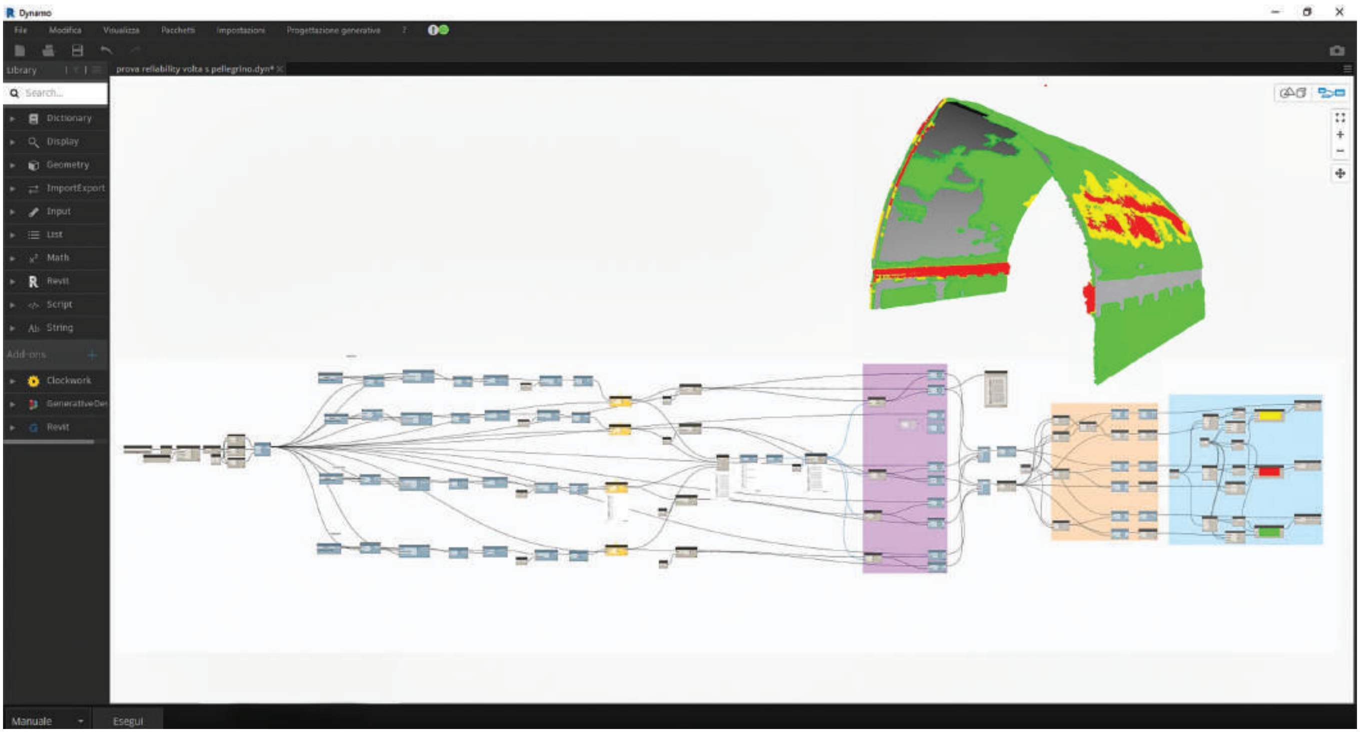
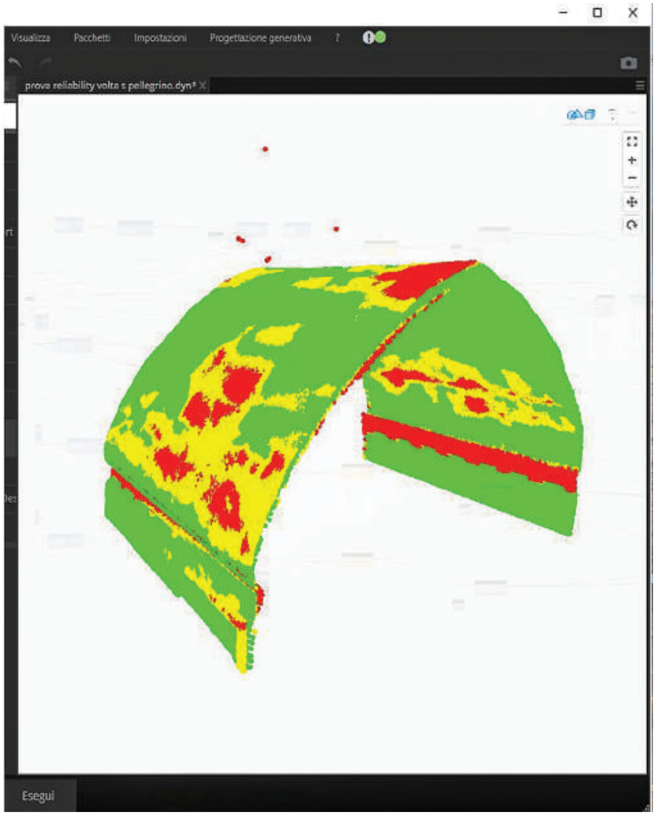


Fig. 6 –The Visual Programming Language (VPL) for calculating deviation and evaluating reliability.

proposed to replace the LODs with the Level of Information Need (LoIN), which, referring only to information necessary for the purposes of the model (thus, in the case of HBIM, also to information of a historical nature), can help overcome some of the limits deriving from the extension of the BIM procedure to historic buildings. However, to date, awaiting the transposition of the LoINs by national regulations (in Italy by UNI 11337-4), the LoDs are still in force, so the standard presented in the paper is referred to these.

Transparency and reliability: a standardization proposal for HBIM

Since the issues of "Transparency" and "Reliability" become even more important in the case of HBIM, where the geometric representation is enriched by heterogeneous information attributes, it is therefore necessary to define specific standards that can ensure the effectiveness of the HBIM process for the documentation and restoration project of historic buildings.
Regarding the transparent presentation of the entire modelling process, it is possible to exploit the potential of BIM for reconstructing the choices made, in relation to the sources used in the modelling. In fact, thanks to the BIM information base, it is possible to insert into the digital environment the



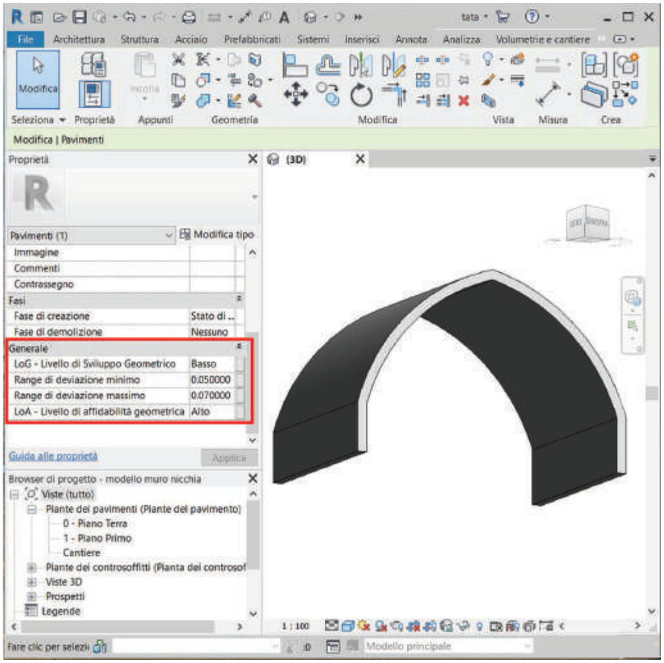


Fig. 7 – The Level of Accuracy, assessed through the VPL, is automatically displayed in the BIM environment.

documents based on which the BIM model was builted in all its aspects (architectural, structural, historical, etc.).

Considering that the reliability should cover all the heterogeneous information relating to the historic building and that a third level of development (the LoH) has been introduced, three levels of reliability have been considered:

1. Geometric reliability, called Level of Accuracy (LoA), evaluated through the measurement of deviation between the restitution model and the point cloud.
2. Informative reliability, called Level of Quality with subscript I (LoQI), relating to the non-geometric contents of the model. In turn, it is divided into several sub-levels, as many as the different types of information entered in the model: reliability of the construction equipment; reliability of the plant system etc.
3. Historic reliability, called Level of Quality with subscript H (LoQH), referring to the specific information content of the architectural heritage, that is, to all historical information concerning the process of formation and modification of the building.

In the proposed standard the reliability assessment, while remaining the same in methodological approach, differs according to the LoD of the specific architectural element.

The geometric reliability of the architectural element (LoA), in fact, is evaluated through the measure of the deviation (the range of deviation must be respected in the majority of the surface): on the entire surface of the architectural model element, for the low LoG; on the generatrix and directrix of the surface, for the medium LoG; on both of them for the high LoG. For each LoG, depending on the interval in which the value falls -average value over most of the surface- the Level of Accuracy can be low, medium or high, and, taking into consideration the greater geometric detail, the range of acceptable deviation becomes more restrictive as the LoD increases.

The LoQ concerns all information not related to the geometric shape which, therefore, cannot be evaluated in terms of deviation between the model and the point cloud. Considering this, also the stratigraphy of the architectural elements can be ascribed to the non-geometric contents since its knowledge is mainly linked to the diagnostic campaign and archival-document research. So, its reliability is of an informative type: the LoQ_I for the construction technologies.

The informative reliability depends on both the LoI and the sources used for modelling (direct, indirect, exhaustive or not). In the evaluation of the Level of Quality, only the medium and high LoI or LoH are considered, as in the low level there is no information, and specifically for medium LoI / LoH, the reliability (LoQ) can be low, medium, high, depending on whether the sources are, respectively, indirect, direct but not exhaustive, or direct and exhaustive.

In the case of high LoI / LoH, instead, the reliability can be: medium, if the sources are direct but not exhaustive, and high, if the sources are direct and exhaustive. Lastly, if there are only indirect sources, a high LoI or LoH is considered unreachable because of the excessive need to hypothesize.

From an operational point of view, the assessment of the geometric reliability is carried out through the visual programming language (VPL). The VPL allows for a semi-automatic procedure for evaluating the deviation between the point cloud and the model on the basis of the standards set out above, and declaring the Level of Accuracy, directly in the BIM environment.

The advantage of using VPL is that once the algorithm is set up, it can be reused many times for different components. In fact, by changing the inputs (e.g., model surface, range of deviation values, etc.), the calculation of the distance between the point cloud and the 3D model is automatically updated.

The informative reliability, on the other hand, is assessed through the use of view filters. For each informative reliability, 3 parameters were created and assigned to specific families: source, type of source (direct or indirect, exhaustive or non-exhaustive), reliability. Filters connected to the "reliability" parameter were then created for each type of reliability, which apply a graphical substitution showing the value of the reliability (low, medium or high).

Once created, these filters can be activated or deactivated in the views, depending on the type of reliability to display.

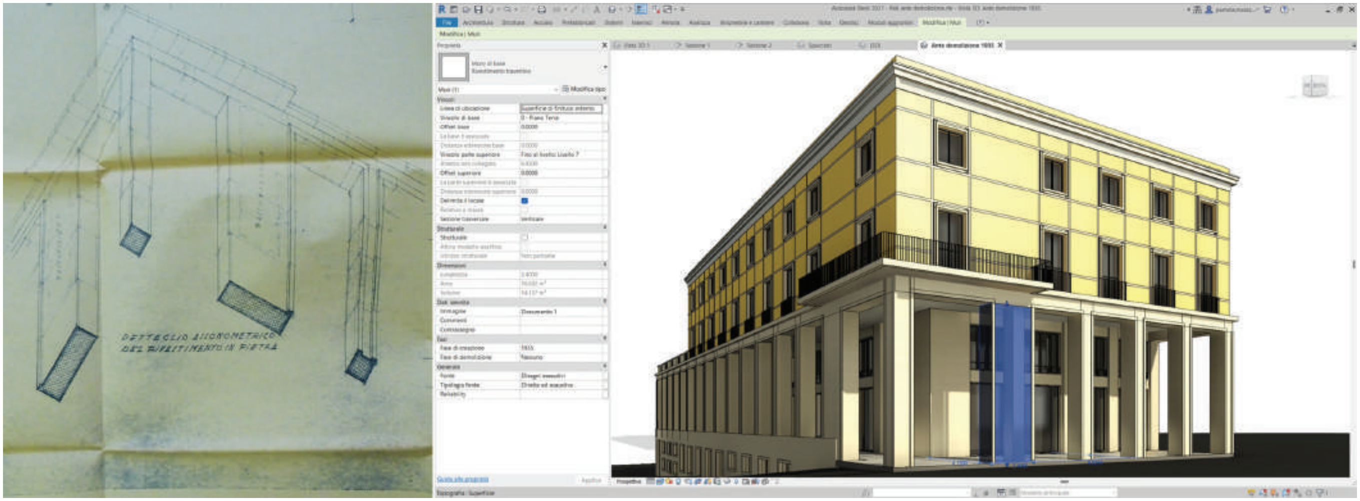


Fig. 8 – The informative foundation of BIM is exploited to declare the sources used for HBIM modelling.

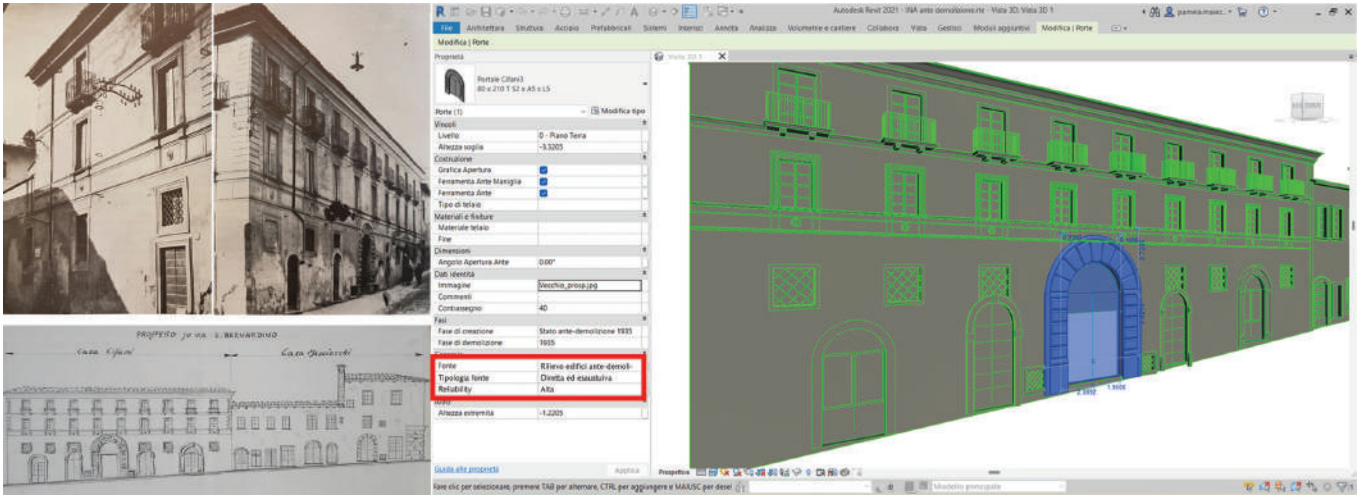


Fig. 9 – The assessment of the informative reliability (LoQH) relating to the specific non-geometric attributes of the architectural heritage (LoH).

Conclusion

The contribution is meant to be just a proposal that aims to exploit the BIM information foundation to insert the transparency and reliability requirements, fundamental for the documentation of the architectural heritage through 3D models. This procedure, developed today on the basis of the LoG and LoI defined by the the UNI 11337, can be adaptable also for the foreign regulations and for LoINs when their introduction will be effective.
In order to guarantee the model transparency, information and documents are linked to each digital object.
In addition, for each digital element the relative reliability level is declared, concerning the geometric (LoA), informative (LoQ_I) and historical (LoQ_H) aspects. Moreover, by inserting the level of reliability within the BIM environment as an attribute of the individual architectural components, transparency and interoperability between the various stakeholders is promoted.
The obtained result is a standard that can make the HBIM an effective procedure to be used for the documentation of the architectural heritage.

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