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Scan-to-HBIM Reliability

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Abstract: The modeling of the historical architecture can be characterized by different levels of geometric development, more or less advanced, which correspond to different values of deviation between the real object and its three-dimensional representation. The aim of the paper is a critical study of the different levels of geometry (LoG) that the architectural elements of a model can have in relation to the efforts required to achieve them and the modeling objectives. More specifically, the contribution of this study proposes—on the basis of a survey campaign of a case study conducted by drone—the evaluation of the deviation between the point cloud and HBIM models with the different levels of development in order to assess their reliability according to specific objectives, such as the documentation of the architectural asset, feasibility study, restoration project, etc.

Keywords: HBIM modeling; level of geometry (LoG); accuracy; deviation; reliability

1. Introduction

The well-known advantages of building information modeling (BIM) in the architecture, engineering and construction (AEC) sectors have made this process a reality in the existing as well as the architectural heritage.

However, HBIM (historic building information modeling) poses the problem of how to represent the complex forms of historic architecture within a standardized parametric environment. In addition to the lack of BIM libraries for the architectural components of historic buildings, the question arises as to the means with which to reconcile the irregularity and uniqueness of the architectural heritage with a modeling logic based on the typification of the elements [1]. In particular, it is necessary to choose whether to return the modeling to parametric and reusable objects at the expense of model accuracy, or to prefer a greater adherence to the survey data by modeling the architectural component with the specific features that distinguish it, thus setting aside, or reducing, the benefits of standardization.

The modeling of the historical building can then be characterized by different levels of geometric development, more or less advanced, which correspond to different values of deviation between the real object and its three-dimensional representation. The acceptability of these deviations, i.e., the reliability of the model, will have to be assessed on the basis of the purposes of the representation, as well as in consideration of the characteristics of the study objective [2,3].

The paper presents a critical study of different levels of geometry (LoG) of the model's parametric architectural element, highlighting the differences between the real geometry and the modeling, and taking into account the modeling efforts and the modeling goals. More specifically, the contribution proposes the evaluation of the deviation between point clouds by drone photogrammetry—a solution often necessary to survey architectural elements of building façades whose height above the ground does not allow for direct surveys or the use of laser scanning—and HBIM models with different levels of development, in

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order to assess their reliability according to specific objectives, such as the documentation of the architectural heritage, feasibility study, restoration project, etc.

The experimentation to support the study was conducted on a window on the second floor of Palazzo Camponeschi (16th century), the current headquarters of the Rector's Office of the University of L'Aquila (Figure 1).

Figure 1. Window of Palazzo Camponeschi, L'Aquila (16th century): textured mesh model.

2. State of the Art

The three-dimensional modeling of an architectural heritage—especially the HBIM—is onerous in terms of time, effort, and thus also of cost due to its often complex and irregular shapes. Several lines of research have sought an optimization of the scan-to-BIM process, from the point of view of both the quality of three-dimensional representation and the reduction in time consumed.

With regard to the first line of research, we recall the studies focused on the attempt to make up for the shortcomings of BIM in the modeling of irregular shapes through the integration with non-uniform rational basis spline (NURBS) surfaces [4]. In 2017, Banfi [5] proposed protocols called the GOG (grade of generation) to develop and support the generation of HBIM models, ranging from simplified types (GOGs 1–8), which use simplified functionalities integrated into the BIM applications (i.e., based on extrusion, subtraction, and other modeling functionalities) to the NURBS-based types (GOGs 9, and other mod10). In particular, the multislice-based wireframe model (GOG9) and the cloud-based model (GOG10) aim to maintain the morphologic richness and precision acquired by the survey for all those architectural elements whose ideal modeling would lead to an excessively high deviation between the model and the real object. Brumana et al., in 2018, proposed protocols based on GOG to define new LOGs for complex architectural element [6].

Banfi [7], again in the context of the grades of generation (GOG), focuses on modeling various architectural vaults with the goal of demonstrating how the concept of te parameterization of a NURBS surface can be associated with a BIM object and BIM database.

The second line of research, aimed at improving productivity and containing costs for the three-dimensional representation of historical architecture, includes experiments relating to parametric modeling, also based on the visual programming language (VPL) [8]. Such research focuses on identifying mathematical rules and parameters to create flexible and adaptable models from which the desired model can be obtained as a variation of the generic kind [9]. In particular, Lo Turco et al. [10] apply the semantic decomposition method to model the decorative elements of architectural heritage windows, opening up the possibility of encoding geometric parameters in the VPL environment, which are useful for defining freeform or complex geometries within the BIM environment. On the other hand, Lanzara and Capone [11] define through VPL an algorithmic generative tool based on the definition of geometric rules and construction techniques for modeling the complex decorative apparatus of domes.

The irregularity and complexity of the forms of historical architecture, from which these studies are based, pose the question of assessing the accuracy of 3D representation with respect to reality [12]. Moreover, the issue of the geometric reliability of the model becomes even more essential for historic/heritage building information modeling (HBIM) because of the specific nature of BIM based on the use of standardized and typed 3D objects, which are difficult to reconcile with the uniqueness of historical buildings [13].

The accuracy of the 3D model is measured in terms of deviation, that is, the distance between the model and the point cloud, a three-dimensional cast of the real object [3]. Bonduel et al. [14] propose a standardized method for assessing scan-to-BIM accuracy based on a quality evaluation on a macro-scale followed by an analysis of the individual BIM elements (micro-scale). On the other hand, Wang et al. [15] apply the issue of reliability assessment to the BIM model of a subway station.

Finally, in defining the level of accuracy (LOA), it is crucial to cite the interesting distinction made by the U.S. Institute of Building Documentation [16] between measured accuracy—"the range of standard deviation that must be obtained from the final measurements taken regardless of the method used to acquire those measurements"—and represented accuracy—"the range of standard deviation that must be obtained once the measured data are processed in some other form, such as a linework or model" (p. 12). Measured accuracy can also be unspecified and left to the building documentation professional who will determine the measured accuracy LOA needed to achieve the specified represented accuracy.

With regard to the level of accuracy (LoA), Maiezza [17] and Maiezza and Tata [18] propose three possible levels of geometric accuracy level (LoA). These are defined as a function of the deviation measured on most of the elements considered, i.e., the standard deviation resulting from the comparison between the point of cloud and the surface of the model or the one resulting from the generatrix and directrix of the same surface and the slices extracted from the point of cloud.

As reported by these studies, in the presence of models with a low level of model development, the level of accuracy (LoA) can be: low, when the deviation between the point of cloud and model is greater than 70 mm; medium, when the value ranges between 50 mm and 70 mm; high, when the value of the standard deviation is less than 50 mm.

In the case of models with a medium level of model development, the LoA is evaluated by comparing the deviation values between the surface's generatrix and directrix with respect to the slices extracted from the point of cloud. In this case, the level of accuracy is low for values above 50 mm, medium for values between 20 mm and 50 mm, and high for values below 20 mm.

For models with a high level of model development, the LoA is estimated in relation to the deviation values of both the generatrix and directrix, both to the entire surface. When the deviation related to the generatrix and directrix is greater than 20 mm, the deviation measurement of the point of cloud and the surface is omitted, and the LoA is low. Otherwise, the LoA is low when the measured deviation between the surface and point of the cloud is greater than 50 mm, medium when the deviation is between 20 mm and 50 mm, and high when this deviation is less than 20 mm.

As highlighted by these studies [17,18], the acceptability of these deviations, and therefore the reliability of the model, has to be assessed on the basis of the purposes of the representation, as well as in consideration of the characteristics of the object of study [2].

3. Methodology

As previously mentioned, in recent years, there has been a widespread use of BIM methodologies for new and existing constructions, confirmed by the spread of international and national standards and the obligatory use of BIM in public procurement (in addition to the Italian standards D.M. n.560 of 2017 and D.M. n.312 of 2021, we note the Road Map document toward the mandatory BIM of the German Bundestag Federal Ministry of Transport and Digital Infrastructure). As a consequence, several lines of research aimed at optimizing scan-to-BIM processes and assessing the accuracy of the 3D model obtained from the critical reprocessing of acquired data have been developed.

The research presented here is part of this line of investigation and, drawing on the authors' previous experience [1,2,17,18], defines a workflow for assessing the accuracy of HBIM models in relation to the specific project purposes for which they were developed.

The survey of the artifact represents the first phase of the entire process as, through the use and integration of different procedures (laser scanning or terrestrial and/or aerial photogrammetry), the geometric and dimensional data necessary for the successive modeling and reliability assessment of the model are acquired. The reliability of the integrated survey procedures is recognized by numerous experiments [19–21]. However, in this specific case, it was considered appropriate to proceed with drone photogrammetry as this solution is able to survey architectural elements of building façades located at a considerable height, obtaining results, such as point clouds, with high levels of precision.

The crucial moment of the workflow is that of HBIM modeling. This is based on the critical analysis of the data deriving from the survey phase but is also influenced by the goals and objectives to be pursued. From the earliest design phases, it is important to define the level of detail and geometric development that the models must respect according to the different purposes and uses.

Finally, to assess the accuracy of the model (LoA) in relation to the modeling purposes, it is necessary to compare the HBIM model with the data acquired from the survey carried out using UAV digital photogrammetry. The comparison was carried out by means of a cloud-to-mesh (C2M) analysis, available within the open-source software Cloud Compare, which permits the assessment of the formal similarity degree between the two models by highlighting, with a false-color map, the less corresponding areas. The deviation in the values of the standard deviations and the mean distance between the mesh model and the point cloud is due to the different LoGs used in the modeling and can therefore be attributed to the approximation of the geometric detail of the model with a low LoG compared to the others.

Similarly to the level of geometric development (LoG), the accuracy (low, medium, or high LoA) can also be defined a priori according to the use of the model. Therefore, if at the end of the process, the geometric accuracy assessment (LoA) does not satisfy the deviation values identified in the initial phases, i.e., the LoA is inadequate for the intended purpose, it is necessary to adjust the model according to an iterative process that leads to meeting the minimum requirements for the different levels of development.

4. Results

This section focuses on some features concerning the workflow illustrated in the previous one through the application of the procedure to one of the windows of Palazzo Camponeschi, located in the historical center of the city of L'Aquila. The experimentation is part of the University projects started after reconstruction and restoration activities and aimed at digitizing the building heritage. The choice to analyze the window on the second floor of Palazzo Camponeschi is also associated with its type and characteristics. Indeed, being a Baroque window, it presents unique peculiarities that require considerable effort in the modeling phase. However, it is the complexities of the architectural element that allow the proposed procedure to be stressed and validated.

4.1. Drone Survey

The studied window is on the second floor, at a height of about 10 m from the ground. The street on which it faces is quite busy and has a width that does not exceed 8 m. Considering these circumstances, the height at which the architectural element is located, and the narrowness of the road, it was considered that the most effective technique to employ in the survey was that of the SfM (structure from motion), upon realizing the pictures by a drone [21,22]. The use of the drone permits to obtain horizontal photos along with a reduction in the areas of shadows that would otherwise be present with a TLS (terrestrial laser scanner), but also with photos taken from the ground, which would have also presented a very disadvantageous angle.

The used drone (DJI Mini 2 drone with sensor: 1/2,3″ CMOS; lens: FOV: 83, format 35 mm equivalent: 24 mm, aperture: f/2.8), because of its small size and its handling, is well suited to the urban context characterized by relatively narrow spaces. In addition, the very low weight allowed it to be operateed without having to stop vehicular traffic. The greatest difficulties were found in the constant presence of several aerial cables along the elevation, and the instability of the wind at varying heights, because the different heights of the surrounding buildings caused irregular and relatively changeable local currents.

In the photographic campaign, 42 shots were taken at a distance between 1.5 and 6 m from the subject. The photographs were generally taken with a horizontal visual axis, but also with a visual axis facing downward, in an attempt to minimize shadows. The obtained dataset was processed with the AgiSoft Metashape 2.0.2 software, according to the workflow provided by the program (Figure 2). From the first step of the photo alignment, a sparse cloud of about 40k pt was obtained, which, after some filtering operations, was reduced to 20k pt. On the basis of the latter, the dense cloud was elaborated on a more circumscribed area of the model, consisting of 740k pt. A new filtering operation reduced the cloud to 670k pt. The mesh, characterized by 175k faces, was then processed on this basis.

Mesh processing was not performed at the highest level of detail, but at the level defined as 'medium' in the software. This is because the result obtained at the highest level of definition was excessively affected by the noise present in the dense cloud, partly due to the non-optimal lighting conditions of the portion of the façade where the window is located, and partly due to the presence of reflective surfaces [23]. As for the lighting, it was realized during the processing that the presence of the gutter directly above the window greatly reduced the brightness of the photos in the highest part of the window frame. On the other hand, the lower portion of the window and especially the adjacent portions of the wall were strongly illuminated by direct sunlight. Direct sunlight also gave rise to reflection phenomena, both on the windows and especially on the glass parapet. The juxtaposition of the glass parapet and the window glass panes generated further reflections that created problems for the software algorithm, partially compromising the results obtained not only on the reflective surfaces, but also in the surrounding areas, like the window's inner frame.

Upon analyzing retrospectively the photos that make up the dataset, we realized that in the time taken to make the photographs, the light conditions had undergone some slight variations that, although limited, were still able to produce repercussions on the results that were obtained with this technique. One of the most difficult aspects to manage is the variability of lighting, because often when the variations in brightness are progressive and not rapid, the operator, who is focused on drone piloting, does not realize the change in lighting, thus sometimes compromising the outcome. The other problem encountered was in relation to the presence of reflecting surfaces, which is also common to other survey techniques. However, the results offered by the SfM technique, in this case, do not seem to be particularly poor or compromising with respect to the final result.

The model obtained was finally exported in '.e57' format to be used in the subsequent steps of the study.

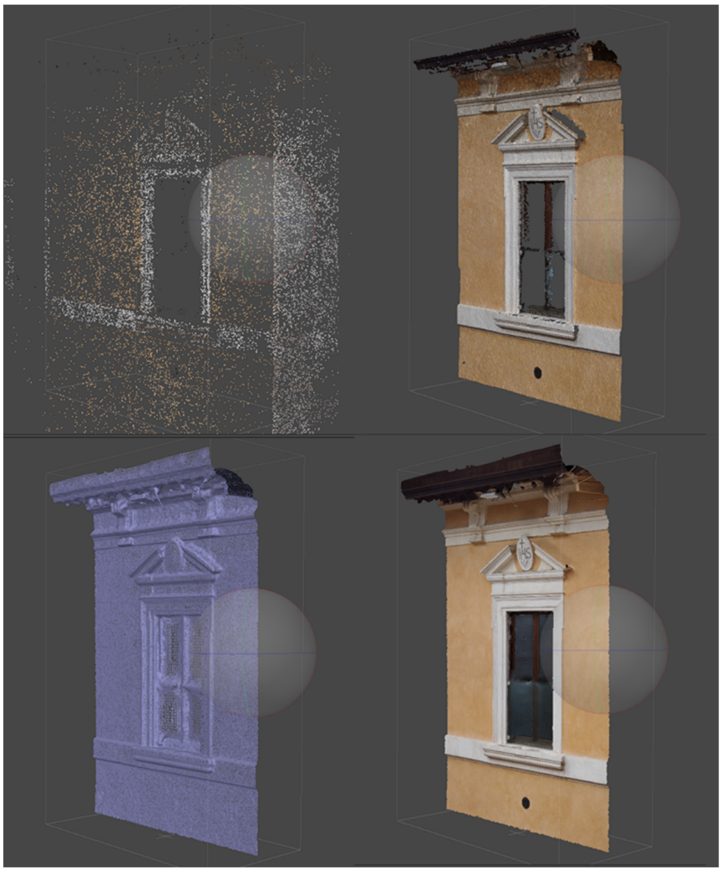

Figure 2. Processing of photogrammetric drone survey: sparse cloud, dense cloud, mesh model, textured mesh model.

4.2. The Modeling of the Historical Building: Critical Analysis and Identification of Levels of Development

The HBIM procedure is based on the digital translation of the historical building into its virtual reproduction through the integration of different survey techniques and the use of the resulting data (i.e., point clouds) as a starting point for the creation of the digital replica. The modeling process, in this case, constitutes the critical act of restitution, based on the understanding of what has been surveyed, the semantic decomposition of the point cloud, and finally, the realization of the HBIM model. Although the phase of acquisition of the current status of the asset, especially from a geometric point of view—thanks to the use of instruments and technologies capable of generating a real clone of reality in a digital environment—is characterized by high speed and accuracy, there is a gap between the acquired data and the three-dimensional HBIM models' restitution.

This gap is above all amplified, usually, by parametric modeling, which leads to a more difficult modeling process and to resulting in models that deviate more from reality, especially if compared to other kinds of models (mesh, NURBS, etc.).

As established first for LoDs by the UNI 11337-4:2017 standard, and then for LOINs by the UNI EN ISO 19650:2019 and UNI EN 17412-1:2021 standards, Italian Levels of Development or Level of Information Need of the three-dimensional objects are mainly defined on the basis of the purposes and objectives to be met with the models (Appendix A).

Both levels depend on the project or process phase and a measurement of the deepening and the stability, or quality, of the information content linked to each of the three-dimensional elements.

In the case of historic buildings, in particular, the choice of the level of development to be achieved must include considerations relating to the type of element, its characteristics, its possible present or absent uniqueness, the availability or unavailability of the information necessary for the knowledge of the asset (e.g., information relating to the construction equipment), and their reliability.

Finally, as also highlighted in the LOINs by the UNI EN 17412-1:2021 standard, the whole modeling process also depends on the degree of parameterization, and consequently, of the reproducibility that is intended to confer to the modeled elements.

All these aspects contribute to define which is the best modeling method and procedure to follow, and concur, together with the level of geometric development, to determine the effort, both in terms of difficulty and timing, which is necessary for the realization of the parametric model of the architectural component.

Therefore, The HBIM parametric modeling is influenced by numerous factors, more or less objective, and derives from a critical phase of analysis carried out by the modeler—and, in general, by the client, which, in the case of a public tender, is the one to define the characteristics of the model elements—who determines the choices on the basis of their previous knowledge and experience.

Based on the circumstances, the modeling of the same element can therefore be different and the three-dimensional model could be considered acceptable with a more or less high level of development, and consequently a more or less high deviation.

Although the UNI EN ISO 19650 standard has already been adopted in Italy, and thus LoINs are already applicable at a regulatory level, it was decided to base the present study on LoDs, which are still in force today, despite the continuing absence of a reference scale required from the new Public Contracts Code to facilitate its applicability in common practice and, specifically, in public procurement. This choice finds further justification in the flexibility of the proposed procedure and in its applicability to other scales of detail or development degrees, including LOINs.

In fact, precisely because the choice of a level of development of a three-dimensional object derives from multiple subjective and objective factors, three different levels of development of the object model, deriving from grouping the LoDs provided by the UNI standard in three main levels, were identified:

- Low LoG, corresponding to a simplified model from the point of view of geometric information content (Italian LoD A and LoD B);
- Medium LoG, corresponding to a model defined from the point of view of geometric complexity (LoD C, LoD D);
- High LoG, corresponding to a detailed and realistic model (LoD E, F and G).

Therefore, assuming, for example, the creation of a model for one of the first design stages recognized at a regulatory level, such as the Technical and Economic Feasibility Project, a simplified model with a low LoG, corresponding to a LoG A or B, and consequently a higher deviation, might be acceptable. At the same time, depending on the purpose, aims, and design stage, it may not be worthwhile to waste excessive time on the preparatory phase for modeling (i.e., the analysis, recognition, and breakdown of the components that make up the architectural element) or in the modeling phase.

On the contrary, assuming the creation of the HBIM model for a conservation or restoration project, a model with a high LoG (LoG E, F, or G) and a minimum deviation from the real object will be required. The latter is fundamental especially in the hypothesis of using the model to evaluate out of plumb or swellings. Therefore, in this case, it will be appropriate to devote time both to the first phase of analysis—identifying, for example, all the components that make up an architectural element such as a window—and all the moldings which constitute them (Figure 3). This effort, as previously mentioned, could be accentuated in the case of a non-unique element, which could therefore be modeled with a high degree of parameterization according to the BIM logic (e.g., parameterization on the various axes and creation of nested families) and make it possible to take advantage of the benefits deriving from the possibilities of its future reuse in spite of the major effort required for the realization of the 3D parametric element.

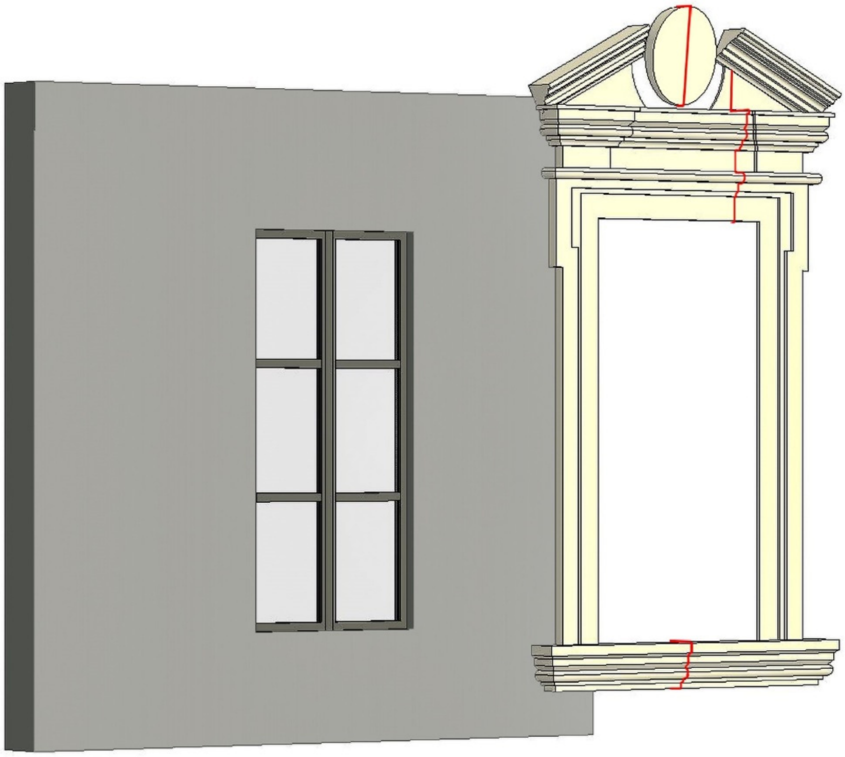

Figure 3. Three-dimensional modeling of the window of Palazzo Camponeschi with the multiple forms of directrix of the highlighted geometric elements.

In the case of the studied window for the modeling with a low LoG, it was decided to considerably simplify the decorative apparatus present on the external façade. All the elements that compose it have therefore been modeled as simple parallelepipeds extruded along different directions. On the contrary, in the case of the high LoG, the profiles of the moldings have been identified and the latter have been modeled in detail. Finally, in the case of the medium LoG, an intermediate approach between the two was adopted, that is, the elements have all been modeled but with simplified moldings compared to the high LoG.

4.3. Evaluation of the Model Accuracy

The level of geometry reliability of the HBIM model (LoA) is closely related to the objectives of the project for which it was created. As previously highlighted, the LoA of the three-dimensional representation with respect to the real object (i.e., the point cloud derived from the survey performed using different acquisition techniques) is evaluated according to the standard deviation obtained by comparing the two entities [24]. If the distance between the three-dimensional model and the point cloud is greater, the model is closer to ideal restitution; on the other hand, if the distance between the two is smaller, then the model is closer to the real object: the as-built model [25].

In the case of models developed for the first design phases recognized at the regulatory level, since a simplified geometric development level is required, it is acceptable that a low-to-medium level of accuracy is achieved [17,18]. In the passage to a detailed geometric development level, the LoA can take on values ranging from low to high. For example, in the case of a model realized in view of a restoration or maintenance project, it is desirable to reach a high level of geometric accuracy [17,18] as the model must be as close as possible to the construction. The case differs when the model is used for communication or enhancement, for which, even if the LoG is high, the LoA may be low or medium in view of the interrelation with other software or digital applications.

Therefore, to assess the reliability of the model's level of geometric detail according to the representation purposes as defined in the previous section, the geometric accuracy (LoA) of the HBIM model developed for the Palazzo Camponeschi window was calculated through a C2M analysis.

In particular, the test showed that:

- For the low LoG, the analysis returns a standard deviation value of more or less 30 mm (Figure 4). The level of accuracy (LoA), evaluated according to the deviation between the whole surface and the model of the architectural element, fits a high level since the deviation between the points and the surface is <50 mm [17,18].

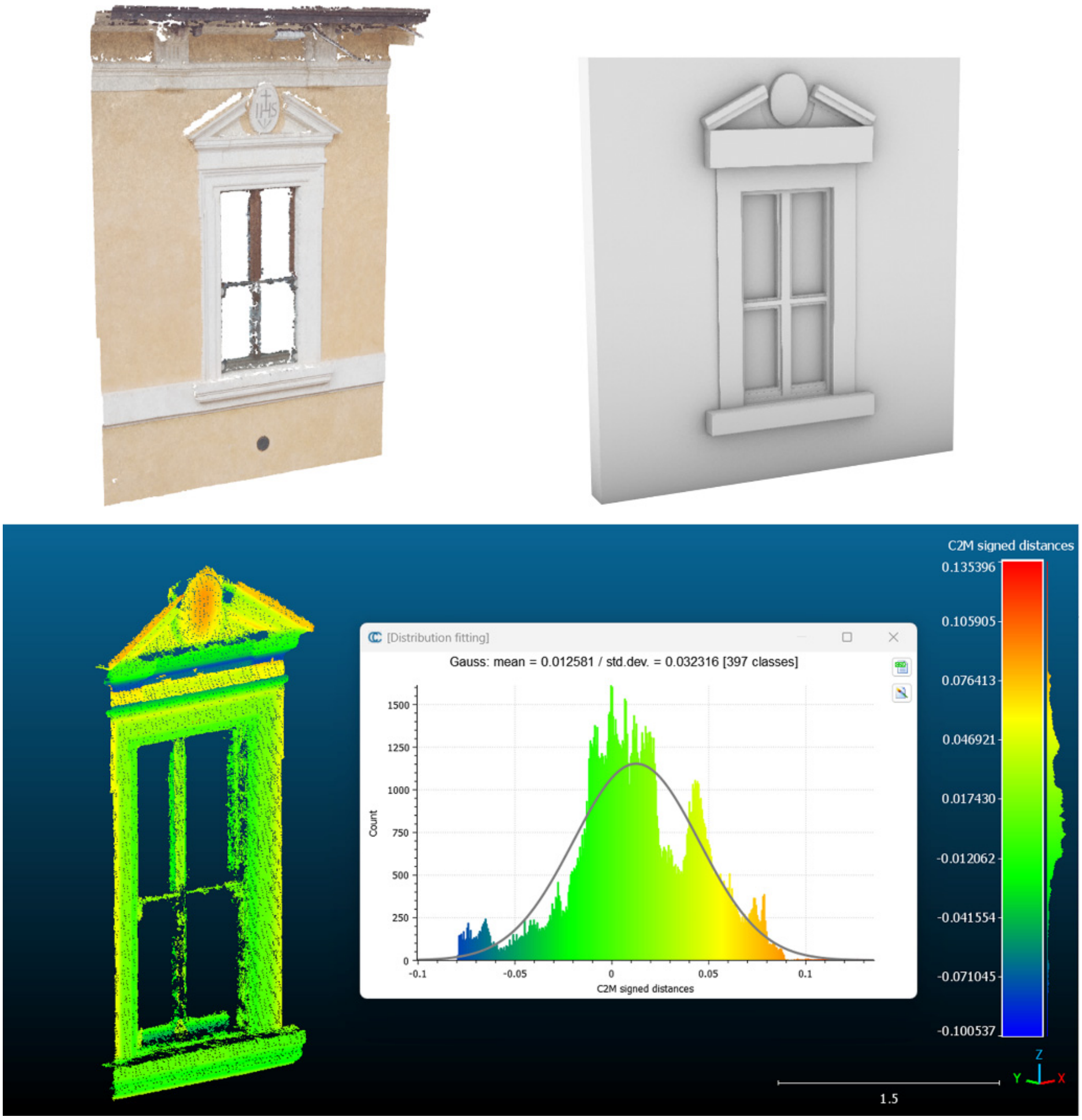

Figure 4. Geometric accuracy of the HBIM model of the Palazzo Camponeschi's upper–window: deviation between the point cloud and the model with low LoG.

- For the medium LoG, the comparison between the generatrix and directrix of the surface and the slices extracted from the point of cloud returns a standard deviation value of about 17 mm (Figure 5); therefore, the LoA achieved corresponds to a high level [17,18].

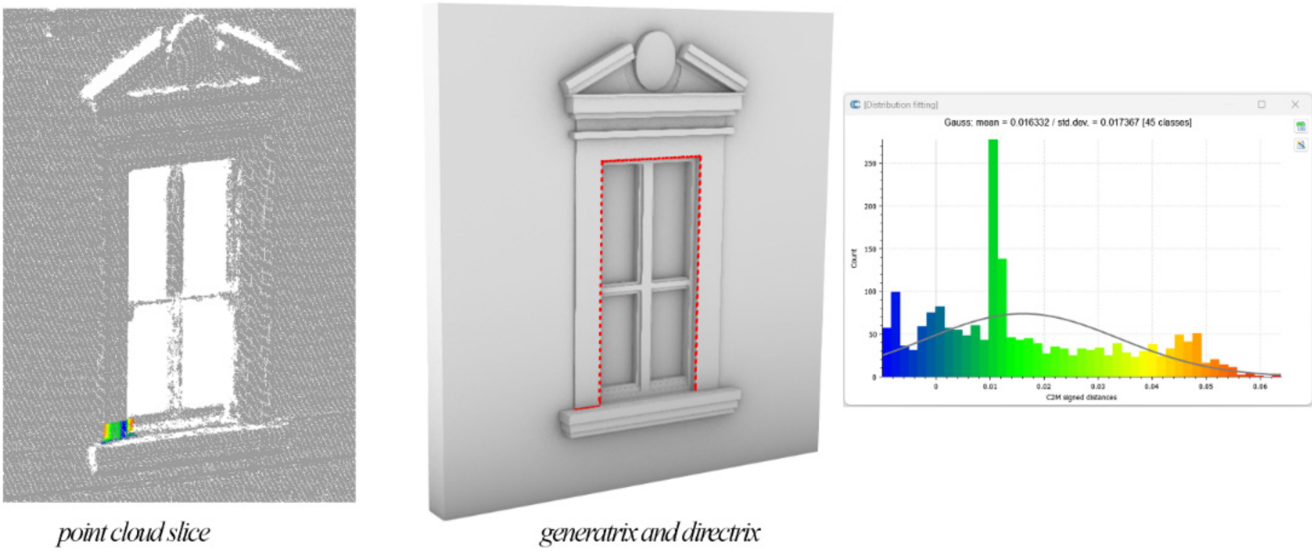

Figure 5. Geometric accuracy of the HBIM model of the Palazzo Camponeschi's upper–window: deviation between the point cloud and the model with medium LoG, evaluated with respect to the generatrix and directrix (highlighted in red in the figure).

- For the high LoG, the standard deviation value was measured of both the generatrix and directrix of the surface with respect to the slices extracted from the point of cloud (SD = 10 mm), and then the value obtained between the entire surface and the model of architectural element (st. dev < 15 mm) (Figure 6). The LoA corresponds to the high level since the deviation between the points with respect to both the generatrix and directrix and the surface is <20 mm [17,18].

For all three models, rather small deviation values were obtained (high LoA for all three LoGs).

In the case of the low LoG, the test showed that the achievement of deviation values were comparable to those considered acceptable for a high LoG and a deviation evaluated on the surface corresponding to the average LoA. Such accuracy, depending on the specific purposes and characteristics of the architectural object, may not be required. For example, in the case of a model for one of the first design stages (e.g., Technical and Economic Feasibility Project) for which a low LoG has been decided, even higher deviation values would have been acceptable, corresponding to a medium or low LoA. At the same time, the LoA achieved for the high LoG could be deemed suitable for the modeling needs required for the conservation and restoration project.

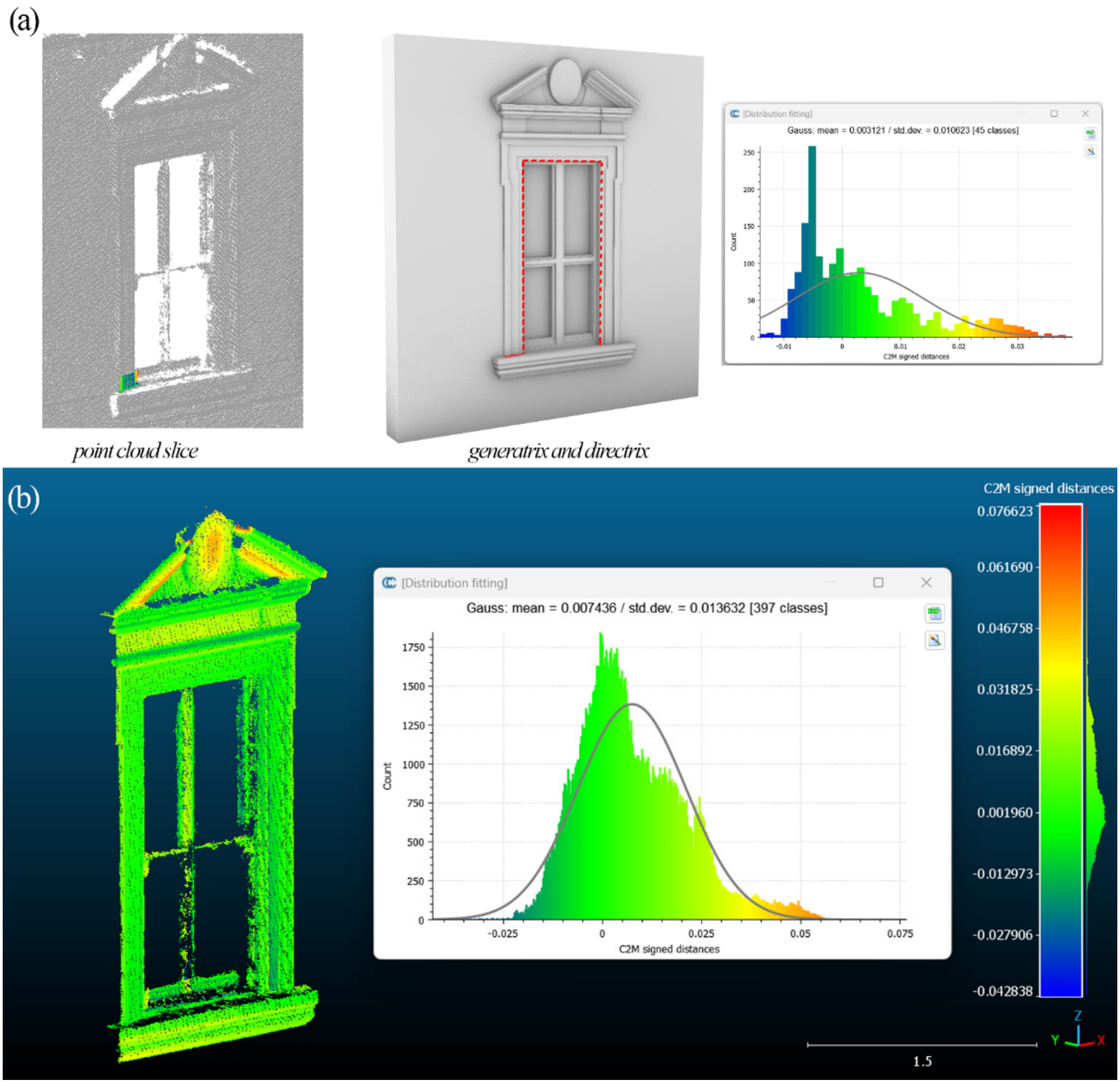

Figure 6. Geometric accuracy of the HBIM model of the Palazzo Camponeschi's upper—-window: deviation between the point cloud and the model with high LoG, evaluated with respect to the generatrix and directrix (**a**) and with respect to the entire surface (**b**).

5. Conclusions

Nowadays, building information modeling is an essential reality in the AEC (architecture engineering construction) industry, sanctioned even at the regulatory level. The advantages and potential of semantic modeling based on objects enriched by heterogeneous information have by now been incorporated by both international and national standards, which are increasingly moving toward the introduction of mandatory BIM, at least for public tenders.

The increasingly imminent mandatory use of BIM processes for the performance of public contracts makes the definition of a reference standard necessary and undelayable.

If the standardization of the BIM process for new construction does not present particularly critical issues, the same does not apply to the existing one, especially in the case of buildings belonging to architectural heritage. As is well known, in this field, the lack of information availability is accompanied by difficulties in modeling the complex forms of historical architecture. The issue of the reliability of the HBIM model concerning the architectural asset then becomes crucial.

With regard to geometric modeling, in particular, standardizing the HBIM process means defining, on the one hand, the geometric detail that the model must possess in order to achieve the set goals and, on the other hand, the acceptable reliability of the three-dimensional representation with respect to the real object, evaluated in terms of deviation. Specifically, according to the objectives of the modeling (e.g., feasibility study, restoration project, etc.) and the characteristics of the architectural object (more or less the complexity of the forms, the possibility of parameterization or the uniqueness of the elements, etc.), the level of geometric development (LoG) of the components that will constitute the model must be established. In parallel, again based on these factors, the level of accuracy (LoA) to be achieved, that is, the maximum acceptable deviation, must also be defined. At the end of the modeling, the geometric reliability should be evaluated through a comparison between the model and the point cloud and, if it is not satisfactory, adjusting the model according to an iterative process thus becomes necessary.

An interesting development in this line of research concerns the systematic extension of such reasoning, in the contribution applied only to two examples (feasibility study and restoration project), to the wide range of possible purposes of an HBIM model, simultaneously also taking into consideration what may be the different characteristics of the buildings belonging to the architectural heritage.

The objective of such a study would be to correlate to these aspects (architectural purposes and architectural features) the level of geometric development to be achieved with the related level of reliability so as to define an operational standard regarding HBIM modeling, which would be useful especially in the case of public tenders.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The levels of development (LoD) have been defined in Italy by the UNI 11337:2017, part four. This standard defines the LoD as a measure of the "nature, quantity, quality and stability of the data and information" associated with each three-dimensional element that makes up the model. The transition from one LoD to the next involves a higher degree of development and a more detailed object, based on more reliable information, both from a geometric (LOG—geometric development level) and an informative point of view (LoI—development level of the non-graphical attributes). Therefore, with an increase in the LOD, the UNI standard provides for an increase both in the quantity of attributes held by the BIM object and in their quality and stability, understood in the sense of granularity, reliability, and data consolidation.

These levels of development are now being updated and will be permanently replaced in Italy by the Level of Information Requirements (LOINs), or Level of Information Need, as defined by the English original standard, with the aim of ensuring a greater flexibility and effectiveness in BIM processes.

LOINs are one of the most significant introductions made by one of the latest BIM regulations, which is the international UNI EN ISO 19650:2019 standard, of which UNI 11337 stands out as complementary, which follows the transposition by the CEN of the standards EN ISO 19650-1, EN 19650-2, EN ISO 19650-3, and EN ISO:19650-5.

LOINs must be respected by each element of the model, and the standard underlines that the required level of information is strictly dependent on the type of use and needs and should be determined by the minimum amount of information necessary according to its purpose, with the aim of "meeting each relevant requirement, including the information requested by the other persons in charge and no more". The purpose of defining this level of information requirement is therefore to avoid an overabundance of unnecessary information, which negatively affects the development of the project and the fluidity of information exchange flows.

This makes the definition of the contents to be included in the models flexible and adaptable, in particular for historical building; therefore, rather than attempting to reach and satisfy specific LoDs classified and defined for new buildings, it is possible to establish a priori, based on the purposes of the model, the kinds of information that must be inserted within the elements and exclude those that are not necessary. Finally, of those that are necessary, in the case of historic buildings, it is necessary to distinguish which ones can be investigated and are thus available in case of need (for example, information regarding the construction equipment of the architectural components), and which ones, instead, are simply available or absent (for example, those associated with history deriving from archival and bibliographic research) and therefore cannot be searched for and inserted into the model.

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