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BIM Reverse Modelling Process for the Documentation of Villa Rufolo in Ravello

The primary purpose of this work is the definition of a protocol for the accuracy check in a BIM process, from digital survey to three-dimensional reconstruction. The development of a BIM model for existing buildings is, in fact, basically a reverse engineering operation and, as far as the reproduction of the geometries is concerned, a coded pipeline for the accuracy control is still missing. The result of the modelling process is a local volumetric entity where the object of interest is decomposed into portions and each element is described through a finite number of parameters. This model then becomes the repository of all the systematised data collected for Villa Rufolo, a landmark of the Amalfi Coast, to define an environment that can offer a valid support to decision-making processes for future restorations.

Keywords:
Scan-to-BIM; Level of Accuracy; statistical tolerance limits; parametric modelling; Cultural Heritage

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1. INTRODUCTION

Digitization and Cultural Heritage: a state of the art

Cultural Heritage is the result of historical stratification processes and architectural modifications performed over time. In this practice, maintenance and conservation interventions involve multidisciplinary teams of experts as architects, engineers, archaeologists and more, able to produce parallel and heterogeneous data flows that cannot be directly integrated (Arayici et al., 2017; Ronchi et al., 2019). To meet the need of managing such different sources of information, the research is moving towards the preparation of object-based interdisciplinary databases that allow to structure the documentation generated throughout the life of the building, useful for planning future interventions.
In recent years, there has been an increasing diffusion of the BIM (Building Information Modelling) methodology, mainly thanks to the introduction of regulations and standards that impose or at least regulate its use. In Italy, the application of UNI 11337:2017 standards are the backbone of the national strategy for the digital management of information processes, in place since the publication of the new contract code, which requires a progressive adoption of BIM.
In this context, the international scientific community has been working on Historic Building Information Modelling (HBIM), investigating on approaches suitable for the digitisation of the existing heritage (Bruno et al., 2018; Pocobelli et al., 2018). The research and studies carried out in this field focus on the reading of the artefact, the structuring of the information associated with it and the way in which the information and geometric gaps in this type of architecture can be managed. The most recent experiences of HBIM are addressing with particular attention the issue of Facility Management, to effectively guarantee permanent maintenance of the building (Hull et al., 2020; Moyano et al., 2020; Patacas et al., 2020).
The BIM industry is still mainly focusing on new buildings, but both the research community and the laser scanning industry are moving towards BIM for existing buildings, including built heritage (Volk et al., 2014). When regarding the case of existing buildings and the development of an As-Built BIM, point clouds are often used as a primary source for the digital reconstruction. In the manual Scan-to-BIM technique, the processed point cloud is imported in commercial BIM software and used as an underlay during manual model creation. This process is generally regarded as inefficient, inaccurate and error prone (Thomson, 2016). Several researchers tried to improve this step by introducing process automation and machine learning into the workflow (Pierdicca et al., 2020). The current Scan-to-BIM process in the construction industry however is still mainly manual or sometimes semi-automatic employing the use of BIM software plugins for better modelling from point cloud (Andriasyan et al., 2020). These examples however lack clear methods for geometric quality assessment of BIMs based on point clouds.
The number of articles on BIM for existing buildings and geometric quality assessment of the models is limited. Identifying the starting point in the literature is not difficult (Anil et al., 2011). The focus in this paper is mainly on the detection and classification of modelling errors or the ones appearing during the data collection or post-processing phase. Some researchers conducting Scan-to-BIM case studies already mention deviation analysis of the assembled BIM against the used point cloud as a part of their methodology (Brumana et al., 2018; Lo Turco et al., 2016). If such an analysis is executed, it is often done with the use of commercial BIM plugins to get an idea of the general deviations of certain selected surfaces by using a gradient colour map. Other frameworks, such as the Level of Reliability, are not limited to the analysis of the geometric attributes of the objects but also consider the ontological correspondence of the same to reality (Bianchini et al., 2018).
Among the building documentation specifications, the Level of Accuracy (LOA) from the USIBD (Graham, Chow, & Fai, 2018), not only gives us a clear definition of Measured Accuracy and Represented Accuracy, it also defines LOA classes. Suggested LOA ranges for specific standard and heritage building elements are available. Furthermore, the LOA guideline does not specify which method(s) should be used for assessing the accuracy, and for integration of the quality assessment results in the BIM.

Aims of the proposal and case study

The present study proposes the development of an HBIM model of the Villa Rufolo that systematises the existing information. The main objective is to respond to the problem of fragmentation and lack of information, by improving the tools provided by the HBIM technology: storage, digitisation and systematisation of historical data, interoperability between disciplines when carrying out interventions, management of costs, time, resources, etc.
The process starts from a point cloud obtained through integrated survey technologies (Morena et al., 2020), to create a parametric model in Autodesk Revit, to finally load the existing information of each element, as well as the historical information of the complex.
The model seeks to achieve efficiency in the management of the existing heritage through the monitoring and maintenance of it due to the application of an innovative and multidisciplinary technology that contributes to the protection of the historical-architectural heritage, thus avoiding its future decline and its loss. In addition to the orderly management of information, another key goal is to define a standardised framework for assessing the accuracy of Scan-to-BIM procedures, so that the products can be reused over time by practitioners in relation to specific objectives.
Villa Rufolo, our case study, is a landmark of Ravello (fig. 1). It was built between the twelfth and thirteenth centuries as a family residence and a material representation of social status. It has almost unique architectural features, which blend Arab-Byzantine typologies and ornaments with elements of local culture, to achieve the right language to express their acquired authority. In the period of maximum splendour, it is said that

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Fig. 1 - Villa Rufolo, view of the southern gardens.

the Villa had "more rooms than days of the year", although today it is possible to appreciate only some parts of the original construction, such as the Moorish cloister.

2. MATERIALS AND METHODS

Survey Project and Data Acquisition

To define a global reference system, common to all the digital objects produced as the result of the survey process, 14 control points are detected, homogeneously distributed over the entire site, using a GNSS system operating in nRTK mode. The accuracy of planimetry is ±1 cm and ±2.5 cm for altimetry.
The coordinates of these points are primarily used for georeferencing the photogrammetric model, which is divided into two flights, both automatic and with double grid: a first one for the acquisition of nadir images and a second one, with the optical axis tilted about 45 degrees, to survey the vertical walls and avoid any shadow cones. The image acquisition, realised with a DJI Phantom 4 is planned bearing in mind the project requirements - a Ground Sampling Distance (GSD) of about 1 cm - and, at the same time, with the aim of guaranteeing a high level of coverage of the external areas of the site.
The survey of the exterior is reinforced with 20 TLS scans from a Faro Focus3D X130, distributed around the gardens and central courtyard, acquired with a resolution of 6 mm at 10 m. This campaign has taken almost 5 hours, with a single-scan time of approximately 12 minutes.
Instead, the GeoSLAM ZEB1 is used for the digitisation of the interiors, a system that employs a Simultaneous Localization And Mapping (SLAM) algorithm to generate final models. More than any other solution, the quality of the produced data is highly dependent on how the acquisition campaign is conducted. It is important to inspect the site of interest to identify critical areas not detected during planning and remove any obstacles along the way. In addition to the focus on poorly

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referenced environments, transition areas and forward speeds, it should be remembered that full SLAM systems, such as the one employed, require self-intersecting paths to ensure an appropriate redistribution of the accumulated errors. At least one loop must be closed, although it is advisable to plan routes with several self-intersections. With these concepts in mind, the acquisition campaign is organised in this way (fig. 2):

- The First path includes the management offices on level 0 and the auditorium on level 1.
- The Second path covers the entrance at level 0, the west garden, the central court-yard, and the east garden.
- The Third path covers storage areas and rooms closed to the public located on level 1, as well as part of the east garden.
- The Fourth path takes place on the under-ground level, going through the lower part of the Moorish cloister up to the exhibition rooms in the current "theatre".
- The Fifth path covers all the "museum" rooms and the auditorium on level 1.

Digitising the entire scene has taken 2 hours.

3D Point Cloud Registration

High-level, point-based approach to data fusion has been opted for, although all raw data streams have been initially kept separate and processed independently. Only at the end the resulting point clouds are merged to obtain a complete 3D model. The processing of the raw data, coming from the acquisition phase, starts from the registration of the point clouds.
As far as photogrammetry is concerned, the cloud produced using the control points for absolute external orientation consists of approximately 48 million points.
Turning to TLS data, the clouds are characterized by a high degree of overlap and for this reason are registered employing a global bundle adjustment procedure, accomplished after a top view-based pre-registration. Given the set of scans, the algo-rithm searches for all the possible connections

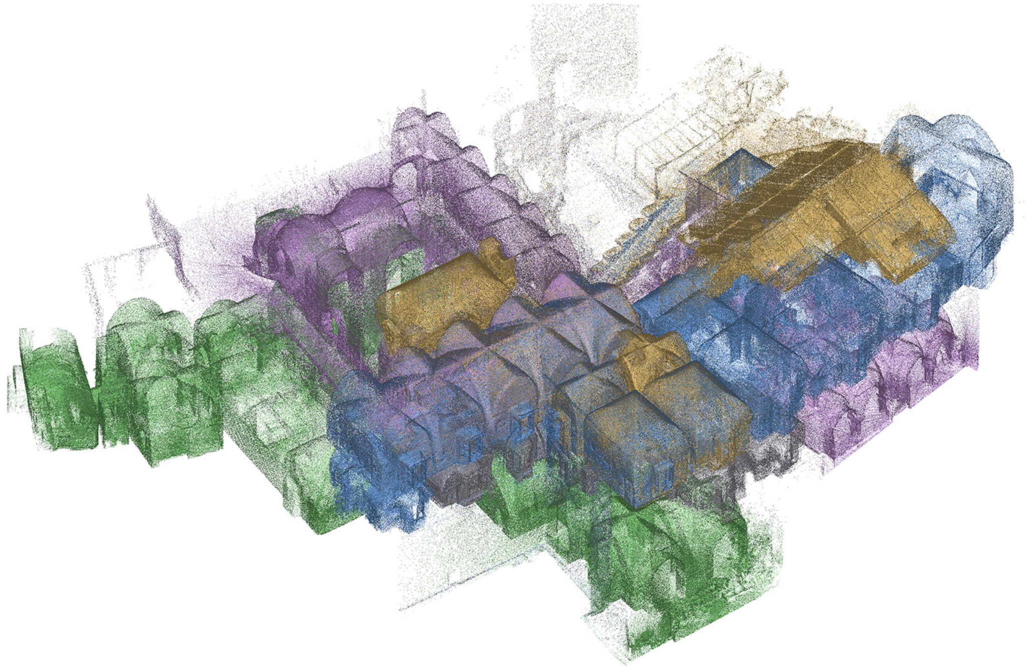

Fig. 2 - Axonometric view of the point cloud obtained through the registration of SLAM paths.

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between the pairs of point clouds with overlap. For each connection, a pairwise Iterative Closest Point (ICP) is performed and the best matching point pairs between the two scans are saved. A final non-linear minimization is run only among these matching point pairs of all the connections. The global registration error of these point pairs is minimized, having as un-known variables the scan stations. To define a global reference system and to assess the accuracy of the registration, the coordinates of the control points acquired with the GNSS system are also used in the procedure. The TLS final cloud is used to create a reference, indispensable for performing the final registration on the SLAM model.

Regarding the internal survey, conducted with the ZEB1, due to the low overlap between the five acquisition paths, a progressive registration approach based on an ICP pairwise algorithm is employed, each time choosing the reference path All preceded by a manual raw alignment. The resulting maximum value of the RMSE on all the registration pairs is about 1.74 cm.

Quality assessment

To ensure that data from a survey (as well as a BIM model) can be reused, it would be advisable to provide an indicator of the quality of the results. This should apply to both the survey and modelling phases. The definition of a required level of accuracy should be related to the purpose. For the case study, reference is made to the framework proposed by the USIBD, that is structured in two parts. The first part is referred to as Measured Accuracy and the second part is referred to as Represented Accuracy (Graham, Chow, Fai, et al., 2018). The Level of Accuracy (LOA) is structured in five incremental intervals, plus one that can be defined by the user. Each of them can be applied within the same project. This is because LOA may be applied to the individual elements of the building and not necessarily to the project in its totality. The LOA Framework is intended to be flexible enough to work on both small and large projects. It has also been designed to assist the specifier by offering suggestions for more commonly utilized LOA, differentiated for recent and historical buildings. In the first case, wider tolerances are accepted, in the second case more limited.

The first step, consisting in specifying a Measured Accuracy, is to determine a Primary Control Network. For the case study, this consists of the 14 control points acquired with a GNSS system operating in nRTK mode, which are used in the data processing phase. These are employed to define a geographical reference system, which is necessary for a global assessment of absolute accuracy. This type of evaluation is conducted independently for the photogrammetric and TLS point clouds. In both cases, the residual errors on the control points, defined as distances between the input (source) and estimated positions from the bundle adjustment, are employed.

The approach used for the SLAM model is completely different. The performance of the instrumentation tested, which has now been updated by several revisions, do not allow satisfactory acquisition of the flat targets used to materialise the control points. It is therefore not possible to carry out a global evaluation referring to the Primary Control Network. Alternatively, we opt for a local comparison with the TLS model, calculating the signed distance between the clouds using the M3C2 algorithm and analysing the distribution for the calculation of the appropriate tolerance interval. The procedure can be outlined in the following steps:

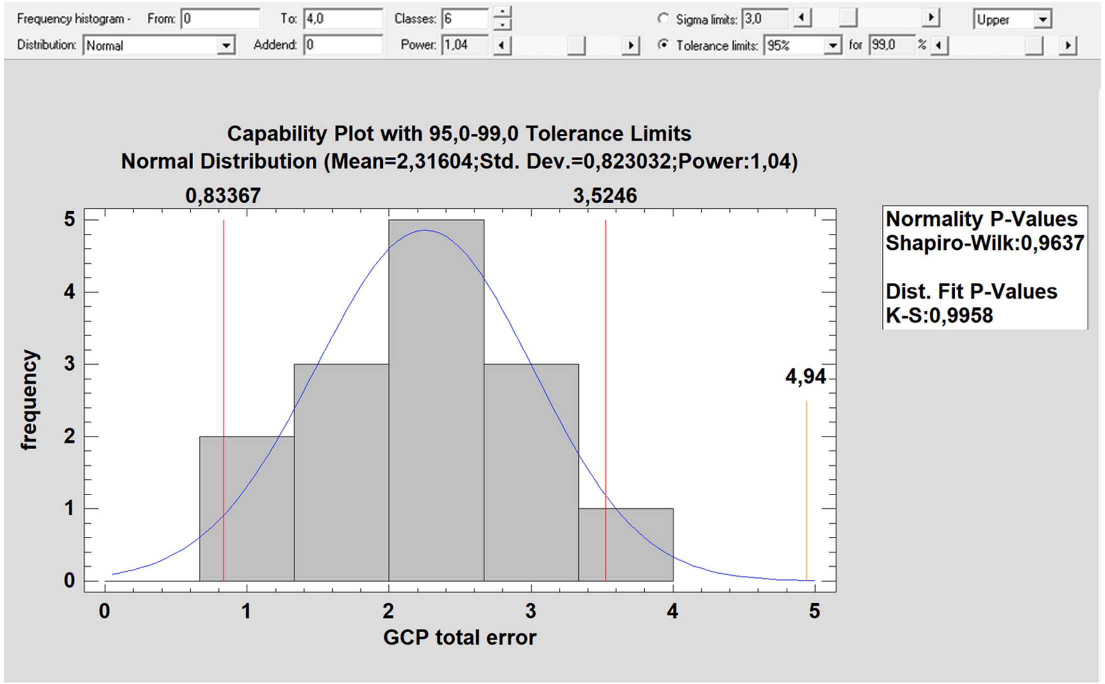

Fig. 3 - Normality test and transformation of the deviation distribution on photogrammetric control points.

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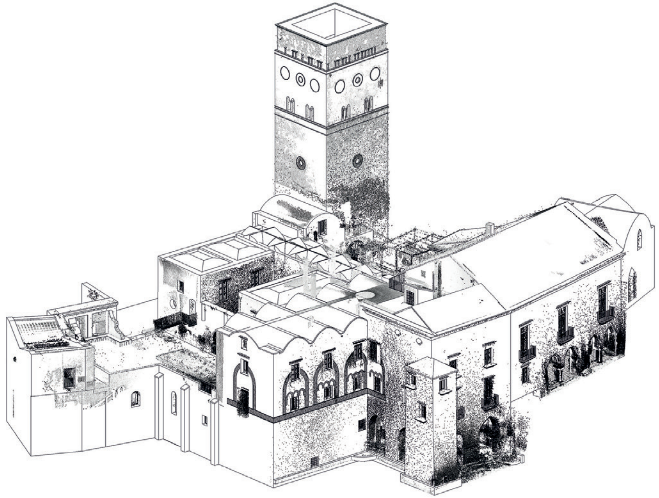

Class	Technological Element	Sub-Class	Constructive Elements
FN	Foundations	Fn Sf Pf	Wall Footing Spread Footing Pile Foundation
VS	Vertical Structures	Sw Nsw Cl Pl	Structural Walls Not Structural Walls Columns Pillars
HS	Horizontal Structures	Vl Dm Fl Bl Tc	Vaults Dome Floors Balcony Terrace
VC	Vertical Connections	St Rm	Stairs Ramps
EF IF	External Fixtures Internal Fixtures	Dr Wn Brs Dr Wn	Doors Windows Bars Doors Windows

- Test for normality. If normal distribution is tenable, we calculate normal tolerance limits.
- Search for normalising transformation (when the distribution is not normal). If acceptable transformation is found, we calculate normal tolerance limits from transformed data.
- Alternative distributions (when transformation approach fails). If a good fit is found, we calculate tolerance limits using the distribution.
- If all approaches fail, we calculate nonparametric tolerance limits.

It should be noted that all intervals are calculated with a confidence coefficient γ of 0.95 and a proportion P of 0.99. This does not apply to the non-parametric approach, where only one of confidence and proportion can be defined a priori. For the case study, however, it was never necessary to use this approach. Fig. 3 shows the range obtained for the photogrammetric cloud.

BIM Modelling

The creation of a BIM model for existing buildings is basically a reverse engineering methodology. In contrast to the processes of new construction, where starting from a high level of abstraction and logical design rules one arrives at the production of a physical object, the documentation of existing heritage involves the 'decomposition' of the artefact to analyse its functioning in detail, with the aim of reconstructing its underlying logic and rethinking it. As far as the reproduction of the geometries is concerned, the literature offers interesting applications (Camagni et al., 2019), but an holistic treatment is still missing.
The technique opted for is the Scan-to-BIM, a reverse modelling technique that uses digital sens-

Fig. 4 - Overall axonometric view of the BIM model.
Fig. 5 - Technological classification of the building elements described in UNI 10838:1999 and UNI 8290:1981.

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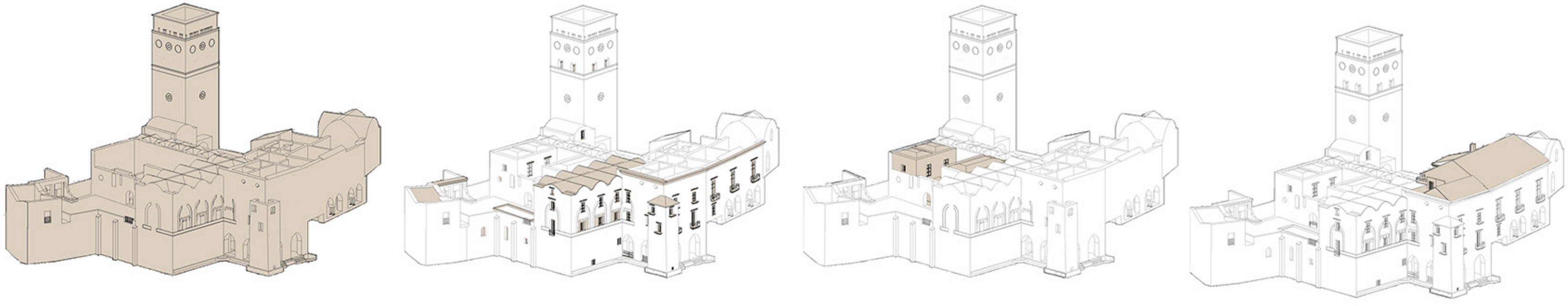

Fig. 6 - Chronological stratification of Villa Rufolo from the XII to the XX century.

ing technologies to obtain point clouds that become the basis for BIM modelling. In detail a four-step workflow is applied: purpose identification, data acquisition, integration and analysis, redesign.
Starting with the decision-making aspect, it is important to remember that the development of this BIM model is not linked to specific purposes or contingencies, which may be restoration work, structural consolidation, energy analysis or other. The target is therefore generic and aims to produce a BIM that, precisely because of its generality, is flexible and can become the container for all the heterogeneous information collected to date (fig. 4). Referring to the Italian UNI 11337-4 regulation (Pavan et al., 2017), a Level of Development (LOD) for the project should be defined at this point. However, the first difficulties arise. The standard levels are conceived with reference to a forward engineering methodology, where the geometrical and informative contents increase as one moves from the idea to the concrete object.
Based on these observations, referring to an existing building surveyed and then modelled, one might be led to attribute the product to a LOD F (realized structure), where the digital objects express the verified virtualisation of the individual building elements (As-Built situation), containing the trace of management, maintenance, repairs, and replacements carried out throughout the life cycle of the work. While this direct correspondence may apply to the geometric aspect (we will see that the problem is more complex than it seems), the same does not apply to the information content, which is dependent on the cognitive process.
A solution to the problem could be to decouple the two aspects, already identified by UNI standards as Level of Geometry (LOG) and Level of Information (LOI), which however cannot be treated separately today. A big problem concerns the geometry. Just think of the detailed knowledge of the stratigraphy that must be achieved to reach a LOD F. This is certainly a simple but revealing example. Returning to the case study, based on the above considerations, we could indicatively attribute it a LOD D, while reiterating the need to specifically define the contents necessary to describe the heritage and differentiating the geometric and material characterisation of the surfaces, attributable to a LOD F.
About data acquisition and integration, details have already been provided in the previous paragraphs. Turning to the analysis, automatic data segmentation is not employed in the proposed application. The structure investigated, characterised by numerous stratifications and modifications over the centuries, required a manual cataloguing of information, relying on the skills of qualified personnel capable of differentiating the elements studied by interweaving numerous parameters, which are difficult to manage simultaneously by an algorithm.
The final stage of the workflow involves redesign. Whenever measured data undergo transformation into a digital object, a method of representation must be chosen. In our case study, we do not opt for a well-defined method, but we prefer to start from the assumption of a level of Represented Accuracy to be respected, corresponding to USIBD LOA 20 (1.5 cm - 5 cm). In the first instance, the elements are modelled with a simple fit. Where the deviations between model and measured data exceeded this LOA, a detailed fit is applied.
The BIM hierarchical organisation criterion provides four semantic levels, developed in the Revit environment: the complete building, the historical stratification, the architectural/technological elements, and the architectural sub-components. Each of these semantic entities has a level of graphic and informative representation.

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Level	Sector	Category	Family	Type	Finish material	Colour
1	Auditorium	Doors	A-Internal	1.80 x 0.80		
		Windows	A-3 grids	1.70 x 1.00	Wood	White
			A-3 grids w/wood	1.60 x 1.10		
			A-Single grid	1.30 x 1.00		
		Walls	Basic Wall	1.20	Int-Ext Plaster	Cream
				0.80		
		Floors	Floor	A-auditorium	Ceramic Tile	Brown
				M-Museum		Pattern
		Vaults	Cross-Vault	.rfa	Concrete	Cream
	Offices	Windows	O-3 grids w/wood	2.80 x 1.10	Wood	Cream
			O-3 grids	1.75 x 1.00		
		Floors	Floor	A-auditorium	Ceramic tile	Brown
		Walls	Basic Wall	0.80	Int plaster	White
		Vaults	Cavetto-Vault	.rfa	Concrete	White
	Museum	Doors	M-Double Door	2.10 x 1.30	Wood	White
			A-Internal	1.80 x 0.80		
		Windows	M-4 grids	3.40 x 1.50	Wood	White
		Vaults	Cavetto-Vault	.rfa	Concrete	White
		Floors	Floor	M-Museum	Ceramic tile	Pattern

Fig. 7 - Chronological stratification of Villa Rufolo from the XII to the XX century.

To organise the architectural elements and sub-elements to model, the method described in the UNI 10838:1999 and UNI 8290:1981 standards is used, where the building is divided into classes of technological elements (foundations, vertical structures, horizontal structures, etc.) and sub-classes (plinth, column, masonry, etc.) (fig. 5). The great flexibility and the possibility to query a model that contains all the information available about a particular asset are the strengths of this application.

3. RESULTS

Survey Accuracy Assessment

As far as photogrammetry is concerned, a statistical upper tolerance range of (0 cm, 4.94 cm) is obtained for the residuals on control points, compatible with an LOA 20 (1.5 cm - 5cm). For the TLS cloud the upper range is (0 cm, 1.47 cm), which is consistent with a LOA 30 (0.5 cm - 1.5 cm).
Moving on to SLAM, where the analysis is local and uses relative distance to the TLS cloud, the comparison shows a two-side range of (-4.43 cm, 4.63 cm), compatible with an LOA 20. All intervals are calculated for a confidence coefficient γ of 0.95 and a proportion P of 0.99, commensurate the amplitude to the number of observations.

Historical stratification and facility mapping

The digital reconstruction of the structure is organised in several phases, considering the transformations undergone over time, from its construction to nowadays:

- The First phase, XIII Century, corresponds to the original structure and the fusion of Arab and Byzantine elements. The main tower is another characteristic element of this phase, as well together with the pointed vaults that predominate in most of the complex.
- The Second phase, XVI-XVII Century, relates to a period of abandonment and succession of owners, with the construction of a second level in concrete.
- The Third phase, XVIII-XIX Century, is referred to the restoration, the unification of properties and the creation of a gardens by Neville Reid.
- The Fourth phase, XX Century onwards, deal with the management of the structure by the Ravello Foundation and the construction of upper-level offices.

These historical phases find their expression in the BIM, configured following an ascending chronological order (fig. 6). In addition, a brief description of each one is added for a better understanding and differentiation. This information is linked to visualisation filters that allow easier management of the model through the chronological selection of constituent elements. In parallel to the stratigraphic analysis, a census of all the mechanical, electrical and water systems present in the structure has been carried out, collecting all the available information and making it flow into a special model, later federated with the architectural one.

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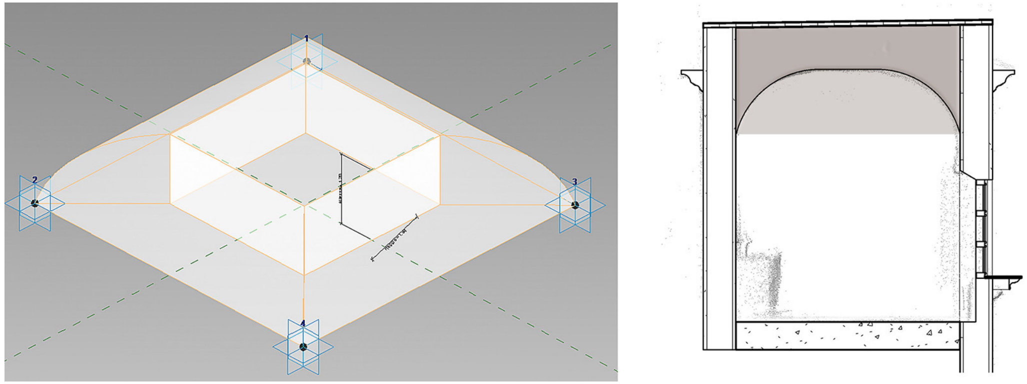
Reconstruction of geometric shapes

Identifying the families needed for the project, such as walls, roofs, doors, windows, and others, is an operation that precedes the actual modelling. The first step is to prepare an XLS file (fig. 7), organizing the corresponding family types by level. Being a historic building, the project does not fit into the available standardised components (e.g., variation in the wall thicknesses, classical columns and so on). Therefore, up to now, these elements must be modelled, or adapted from existing ones, in the dedicated family editor to configure the corresponding parameters, with the option to recur to sporadic in place-components if there is no other viable option. The presence of complex elements requires particular attention, i.e., for the classical elements, such as columns or capitals, libraries of RFA families are implemented. Elements as the windows and the classical columns have then been adapted, starting from downloaded families, accurately modified, and loaded into the BIM model.
Even though there is a great variety of different floor and wall types, it is possible to model them with sufficient accuracy via corresponding system families, once their stratigraphy has been set. The next step is to prepare parametric empty families to reproduce the full-centre and pointed arches taking care to activate the cut-geometry parameter. This kind of modelling is acceptable to define the arched voids within thick stone walls, because it respects the constructive system, although some as-built representations could require the modelling of each singular ashlar, but just in the rare cases it is proven to be necessary to treat each piece as separate element, being this operation the very opposite of a smart BIM approach.

The vaults are a challenge

Historical buildings are rich in unique elements, which are difficult to standardise and therefore they must be treated as generic families in BIM software; in these cases, is important to further assign appropriate IFC categories to said ele-



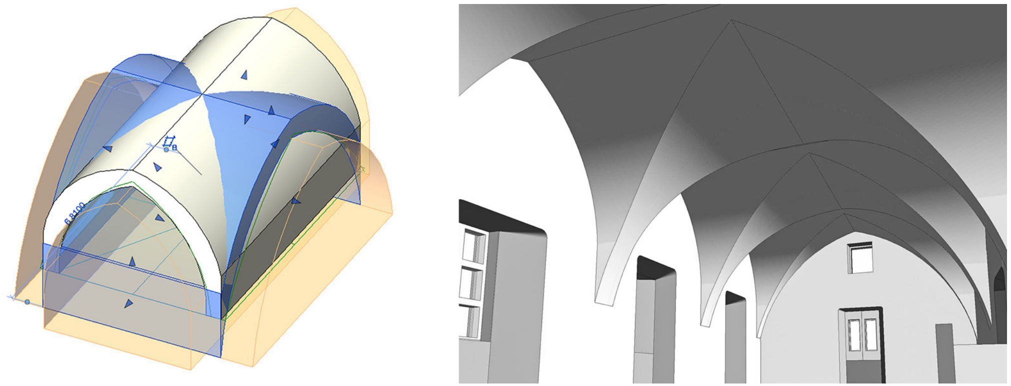


Fig. 8 - Empty adaptive family of the cavetto vault and its section representation.
Fig. 9 - Family of the cross vault and its insertion in the auditorium area.

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ments, or the proper identifier corresponding to the structural part as coded by the classification that one want to adopted (e.g., Omniclass, Uni-Class, etc.), to finally catalogue them. Among these objects, the vaults, which are very present in the case study, stand out, especially for the cross-vaulted and cavetto vaults. Adaptive families allow us to model them, thanks, above all, to their flexibility, which makes them suitable for reproducing variable geometries.
The cavetto vaults, dominant in the offices and rooms of the museum, are solved with the help of empty volumes and adaptive families (fig. 8). The cross vaults, on the other hand, are modelled as parametric families, taking care to adapt, each time, their dimensions, that slightly vary from one to the other (fig. 9). Thus, for the auditorium vaults, characterised by a high level of geometric similarity, a loadable parametric family is applied throughout the sector. The building is then divided into sectors, cataloguing, and modelling the vaults based on the areas they belong to. Unfortunately, given their high irregularity it is necessary to create a few tailor-made families to be more faithful to the real object. To model them, it is necessary to create opposite profiles in the shape of a pointed arch and generate an extrusion between them.

The control of uneven surfaces

The geometric and compositional complexity of Cultural Heritage, together with the phenomena of ageing and deterioration that can alter the material, make modelling particularly complex, especially if reference is made to the pre-modelled objects present in commercial software, designed for repeatable and standardised elements typical of new buildings.
To untangle this knot, the project has therefore resorted to specific families parameterised in the corresponding editor, to guarantee maximum correspondence and accuracy in the digitisation.
As mentioned in the previous paragraphs, we have referred to the USIBD standard. The Represented Accuracy, defined for the single structural elements, is expressed in relative terms through the signed distance between the modelled and measured data. The relative distribution is then analysed to define statistical tolerance intervals ($\gamma = 0.95$, $P = 0.99$) and verify compatibility with the characteristic ones of the LOA.
Together with the statistical analysis, the LOA intervals are also used to perform an in-process check of the modelled parts. Using the As-Built plug-in for Revit, able to calculate the distance between objects and the reference cloud, a visualization profile is structured where a specific colour corresponds to a certain LOA. This profile is then applied to the model surface with a 5 cm sampling mesh. This approach allows us to promptly correct any inaccuracies and to meet the pre-set accuracy, corresponding to LOA 20 for this case study. Fig. 10 shows an application to the perimeter wall of the Moorish cloister.

4. CONCLUSIONS

In this paper, the quality of a Scan-to-BIM technique for the heritage documentation is tested in a controlled environment. Quantitative and qualitative analysis of Measured Accuracy and Represented Accuracy are performed using a Primary Control Network and the global point cloud as reference. The main purpose of the study is, in fact, to define a general pipeline which, based on defined and consolidated specifications (such as the USIBD specification), makes it possible to define quality control parameters in an unambiguous and standardised way. This is clearly a key issue, as keeping track of this information within the model ensures that it can be reused, depending on the accuracy levels required by the specific application.
In particular, the proposed solution aims to solve the problem of ambiguity in the selection of an appropriate statistic (mean, standard deviation, etc.),

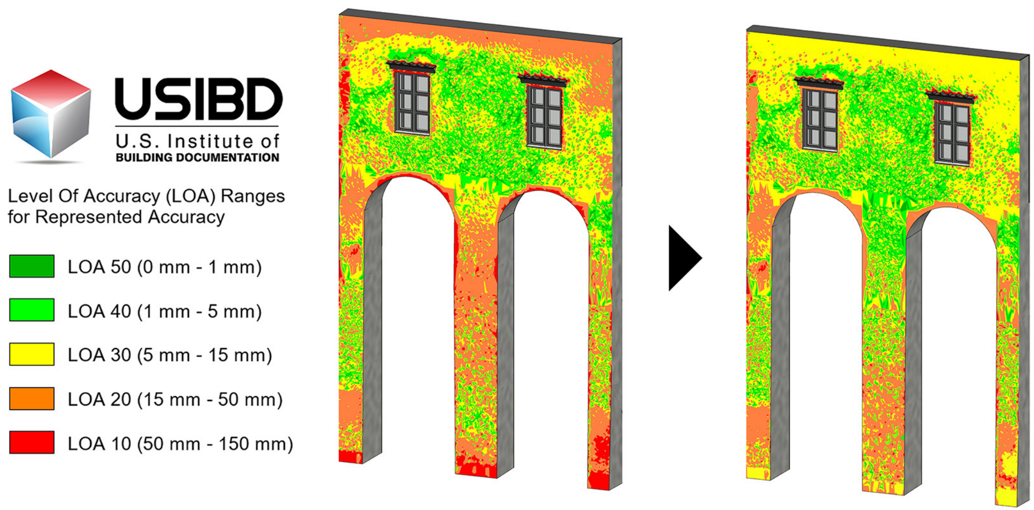

Fig. 10 - Analysis of the surface according to USIBD standards, and its subsequent re-modelling to reduce the geometric deviation interval.

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dependent on the nature of the error distribution. For this reason, we opt for statistical tolerance intervals that consider the required confidence level, the sampling carried out during the survey and the number of observations made. The strength of this solution lies in its flexibility, as information can be differentiated for structural elements, with several LOAs coexisting in the same project.
In parallel with the quantitative analysis, we also performed an in-process check of the Represented Accuracy, using a simple plug-in, proceeding to readjust the model according to the LOA intervals proposed by USIBD.
The lack of a holistic approach to solve this, as well as other problems, is essentially linked to the fact that the software available on the market is developed for new constructions, with the risk of committing methodological forcing when one decides to use it for existing structures. The same LODs are poorly adapted to Cultural Heritage, introducing a discrepancy between the geometric and informative components of the model. The latter should be restructured specifically for HBIM and EBIM.
Future developments of the work will be directed towards the standardisation of the Scan-to-BIM technique, especially about the Represented Accuracy, with the aim of inserting the data obtained from the analyses directly into the model in the form of parameters. Another objective is to redefine the reference tolerance intervals, commensurate to indicators directly related to the architectural representation, such as the degree of absolute definition of the drawing.
Finally, the most relevant information content for historic or existing buildings will be catalogued, which is essential to establish appropriate Information Levels for these categories of objects.

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