JSACE 3/36

Building Information Modelling from Cadastral Plans and Application to an Italian Case Study Building Using Innovative Strategies

Received
2024/01/16
Accepted after revision
2024/08/29

Building Information Modelling from Cadastral Plans and Application to an Italian Case Study Building Using Innovative Strategies

Massimiliano Pepe*, Federica Francesca Tana, Donato Palumbo, Enrico Spacone
University "G. d'Annunzio" of Chieti-Pescara, InGeo, 65127, Pescara, Italy

*Corresponding author: **massimiliano.pepe@unich.it**

https://doi.org/10.5755/j01.sace.36.3.36077

Abstract

This paper explores the applicability of different methods to construct a Building information System Model (BIM) from 2D plans and, more specifically, cadastral plans. The explored procedures use three different approaches to build BIMs: one manual, one semi-automatic based on Rhinoceros/Grasshopper, and one based on Artificial Intelligence (AI). To analyse the performance of the three methods, the case study of a masonry building located in an Italian historic centre is used. The fastest is the AI-based method, although it has some limitations in automatic recognition of some objects. This latter aspect was further explored by analysing a very large dataset of cadastral plans. The results show good recognition of wall elements, but problems arise in the recognition of other elements, such as doors and windows. The manual method, on the other hand, allowed for the construction of a detailed model of the considered structure. However, the method requires strong user interaction and longer time frames than the AI-based method. The semi-automatic based method requires quite a lot of pre-processing but through an algorithm in Grasshopper a fast and detailed modelling of the structure is obtained. The paper also outlines future scenarios for the full exploitation of cadastral data.

Keywords: 2D plans; BIM; cadastre; AI; Rhinoceros/Grasshopper; accuracy.

Introduction

The construction of semantic 3D models of cadastral property is one of the cogent research topics in different countries (Pedrinis and Gesquière, 2017). To obtain a digital transformation of the existing building stock, each country tries to identify methods and criteria for the construction of an updated cadastral database based on 3DGIS-Geographic Information System or Building information System - BIM (Oksana et al., 2019; Andrianesi et al., 2020). The digital model, previously considered exclusively vector-based, particularly if two- dimensional, is increasingly taking three-dimensional connotations, so that the use of BIM models becomes almost indispensable. BIM contains accurate geometric data and building information, which can support the management of land and property information in large buildings (Atazadeh et al., 2017). In recent years, the construction of a three-dimensional (3D) cadastre has become worldwide need to overcome

Journal of Sustainable Architecture and Civil Engineering
Vol. 3 / No. 36 / 2024
pp. 82-93
DOI 10.5755/j01.sace.36.3.36077

the limitations of the 2D approach and the fact that the legal boundaries of parcels of land used for registering legal status are usually fixed in 2D space (FIG joint, 2020). Moreover, it is difficult to reflect the vertical dimension of the legal status of real estate objects, which may be important in today's land registers with most of the 3D relationships recorded administratively, as an attribute of defined parcels using condominium or title legislation. In 2010, the Joint Commission Working Group 3 and 7 on 3D cadastres of the International Federation of Surveyors (FIG) prepared a questionnaire on the future development of 3D cadastre that was then filled in by professionals from different countries. The results were described in the work of Oosterom et al. 2014. Since then, similar surveys have been developed and implemented in several countries (Bieda et al., 2020). Currently, there are several methods for BIM creation from architectural plan recognition. Pizarro et al., 2022 classify these methods as either rule-based or learning-based (such as Deep-learning, Machine learning and Generative-based models). Sun et al., 2019 describe the generation of a 3D cadastral model based on six perspectives: organization, legal aspects, coordinate reference system and elevation system, data standards, geometry and users. Their model was validated on a case study in Multihuset (Sweden) to represent cadastral boundaries and visualize 3D real estate units and obtain as output both an IFC model and a CityGML model. Hajji et al., 2021 describe an integrated approach based on BIM and 3D GIS for the implementation of a 3D cadastre in Morocco based on the following steps: i) construction of a conceptual data model (CDM) based on an extension of CityGML; ii) development of a BIM modelling process based on the model specifications then translated into CityGML format; iii) implementation of a 3D geodatabase in ArcGIS. In addition, studies have also been conducted to explore data standards that can enhance interoperability between BIM and GIS, as demonstrated in the research conducted by Janečka (2019). Therefore, each country handles cadastral information differently; consequently, geographic context plays an important role in managing geospatial information.

In recent years, several inquiries have been conducted regarding the fusion of cadastral data and BIM (Atazadeh et al., 2021). These investigations primarily focused on incorporating legal details, including legal boundaries and attributes (El-Mekawy, Paasch, and Paulsson 2014; Rajabifard, Atazadeh, and Kalantari 2019); nevertheless, they have been constrained in examining the integration of cadastral survey data into BIM. The identification of a suitable strategy plays therefore an important role in the construction of BIMs useful in different applications. Furthermore, the retrieval of documents on the internal geometry of a building in historic centres assumes a key role. In these latter cases, cadastral plans may be the only tool for constructing BIMs. Since many works present in the literature show a manual transformation, the contribution intended to be provided in the paper is to identify innovative strategies for the construction of BIM.

In order to identify an efficient method for obtaining a BIM model, 2D floor plans for a historic property extracted from the Italian cadastral database and generated with a specific procedure is illustrated. Before describing the proposed method and its application to the case study of a historic building, a brief description of floor plans inferred from the Italian cadastre is provided.

Brief History of the Italian Cadastre and Type of the Available Plans

With the Messedeglia Law or Land Equalization Law (L.3682/1886), the Italian cadastre, (Nuovo Catasto Geometrico Particellare or New Geometric Land Register), was created together with the new parcel cadastre (Nuovo Catasto Terreni or NCT), which replaced the old pre-unification cadastres, and the new building cadaster (Catasto Edilizio Urbano or CEU), which was the evolution of the 1877 Urban Cadastre. The cadastral planimetry is the technical drawing (normally in a 1:200 scale) of a property unit registered in the Land Registry, from which it is possible to deduce, in accordance with cadastral rules, contours, subdivision and destination of internal rooms, metric data and other information (Bruni,1893). In 1962, the new Italian urban building cadastre (Nuovo Catasto Edilizio Urbano or NCEU) was introduced. It collects all the information relating to a real estate unit such as: i) the exact geographical location; the property size; iii) the intended use; iv) the cadastral income. A plan view of all perimeter and interior walls, access and interior doors, passageways and windows, and other light openings are represented. The plans had to contain an indication of the boundaries with private property and public areas, the orientation of the sheet, the average height of the rooms, an indication of the "kitchen" room and accessory rooms with their use (bathroom, cellar, etc.). Pursuant to Article 5 of Finance Ministerial Decree 701/1994, all plans of urban properties, in raster or vectorial format were submitted to the cadastre by January 1, 2002; the Decree also required that other graphical drawings, such as additional metric data (introduction of the compulsory calculation of cadastral surfaces, using the 'polygon calculation' criterion, for property units registered in the ordinary cadastral categories of groups A, B and C) be prepared in digital format, together with declarations of new construction and variation of urban property units. The compilation of the technical documents for the CEU updating is carried out through online submission of the document produced by means of the computer procedure known as Docfa. The new documents consist of data models that describe the general characteristics of the building and planimetric graphical drawings (Scricco et al., 2016). They are drafted by qualified technicians and can be consulted at the Agencies of the territory of the relevant Provinces subject to the owner's authorization or authorization by the competent authorities.

Methods

The methods identified and tested for constructing a BIM from 2D plans can be of 3 types:

- manual;
- semi-automatic;
- AI-based automations.

Manual methods for constructing the BIM model from the detailed scale of the individual building unit to the urban scale involve direct modelling using BIM software such as Antodesk Revit, Graphisoft Archicad, ACCA Edificius, etc. (Miller et al., 2017; Waas, 2022; Heidari et al., 2023; Costantino et al., 2023). Once analysed the cadastral documentation, it is possible to identify the characteristics of the building to be modelled and proceed to import the cadastral plans of the individual real estate unit in the pdf format (a document file format developed by Adobe) at the relevant floor within the reference BIM software, making sure to scale the model correctly. Next, it is necessary to set the reference grids, passing through unambiguous points on the plan (found on each level of the building) to guarantee matching between the different floors. We then proceed with the geometric modelling of the elements deduced from the plans, attributing the qualitative characteristics from the information provided by the Docfa data models:

- external and internal walls of given height and thickness;
- openings of given width and material and assumed standard height;
- stairs (of given step size and conceivable riser);
- load carrying structure (if represented);
- slabs (of conceivable thickness)
- roof (if visible type with indication of internal heights).

The workflow of the manual method to be implemented in Autodesk Revit can be graphically represented as shown in **Fig. 1**; the workflow can be summarized in main 4 steps and once the cadastral plan was inserted in the appropriate scale of representation, it is possible to set the project in Autodesk Revit keeping in mind the layers and the layers involved. In this way, it is possible

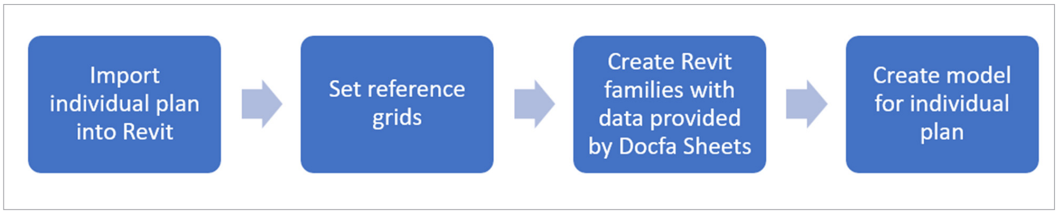


Fig. 1

Workflow pipeline for building a BIM model manually with Autodesk Revit to build the families of the objects in the cadastral plan, such as those generated by the Docfa software. For each plans, it is possible to build a controllable and reliable BIM model.

Semi-automatic methods allow the construction of a BIM by first categorizing all objects and then automatically transforming them into parametric objects. A high-performance working environment based on the use of parametric modelling software is used, i.e. McNeel Rhinoceros (or Rhino) in combination with the corresponding Grasshopper plug-in (Pepe et al., 2019; Costantino et al., 2022; Kang, 2023). Rhinoceros is commonly used in 3D modelling since it can create NURBS (Non-Uniform Rational Basis-Splines) surfaces of three-dimensional shapes of any nature and complexity. Moreover, Rhinoceros in combination with Grasshopper allows for the creation of dynamic, real-time variable associated geometries. More specifically, Grasshopper supports sophisticated dynamic models used to explore different design solutions. The use of this semi-automatic method involves a workflow characterized by 4 main steps: i) creation of the elements in Rhinoceros software on a specific imported floor plan; ii) construction of a suitable algorithm capable of parameterizing the different objects that characterizes the floor plan under consideration; iii) processing of the model in Rhinoceros/Grasshopper environment; iv) import and management of the model in Autodesk Revit. **Fig. 2** summarizes the process for semi-automatically building a BIM from a floor plan. **Fig. 2** shows the different steps for building BIM through a semiautomatic procedure, and in different colours, the software used to build a parametric model.

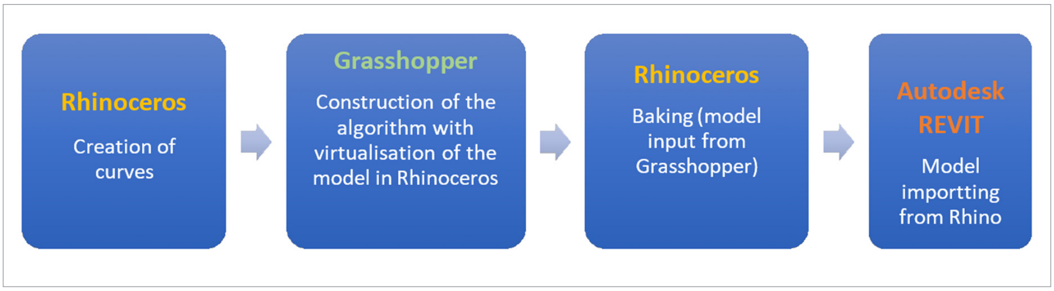


Fig. 2

Workflow of semi-automatic method for the construction of a BIM model

The key of the semi-automatic method lies in the construction of the algorithm on Grasshopper, structured by the breakdown of the building or housing unit into its main components:

- outside walls;
- interior walls;
- openings (doors and windows);
- floor slabs.

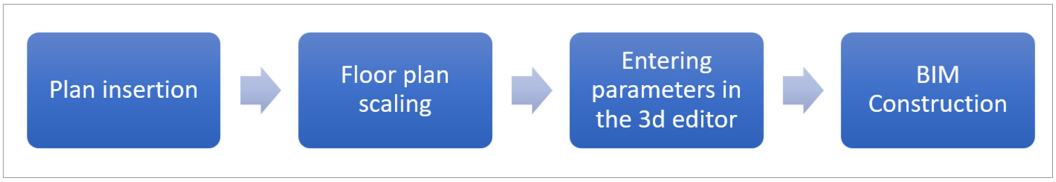
The breakdown into these main elements is performed in Rhinoceros by drawing NURBS curves, which then become the input for the development of surfaces and extrusions through the construction of the algorithm in Grasshopper. The combination of these extrusions will create the parametric model, which can be imported into Revit to obtain the BIM model.

As for AI-Based models, to reconstruct the geometries and elements of a building, AI-based software needs information, such as wall thicknesses, window and door measurements. In this environment, the parametric creation of objects from cadastral plans can be schematized, as shown in **Fig. 3**, in 4 main steps: i) Image insertion, ii) model scaling and (iii) input of editor parameters, (iv) BIM model creation. Each step is characterized by a high degree of automatism and simplicity of application.

While manual and semi-automatic models allow the construction of all the elements of a building, AI-based models follow a statistical analysis. It is necessary to evaluate how well the automatic classification generated by the AI algorithms enables the construction of BIM objects. To assess the quality

Fig. 3

Workflow for BIM creation in AI-based software



of the classification, Precision, Recall and Overall Accuracy (OA) are performance indicators used for statistical analysis (Pepe and Parente, 2018; Zeybek, 2021). The following definitions are introduced: True Positives (TP) are the number of features (masonry, windows and doors) that belong to a particular class, True Negatives (TN) are the number of features that do not belong to a class but have been incorrectly assigned to a class other than their own, False Positives (FP) occur when features do not belong to a class but have been positively predicted for the class and False Negatives (FN) are features that belong to a class but have not been predicted as any class in the image. The formulas for the above performance indices are as follows (Yekeen et al., 2020; Chen et al., 2022):

$$Precision = \frac{TP}{TP + FP} \tag{1}$$

The Recall is the ratio of the correctly classified positive classes:

$$Recall = \frac{TP}{TP + FN} \tag{2}$$

The Overall Accuracy is the ratio of the correct predictions over total observations:

$$\text{Overall Accuracy} = \frac{TP + TN}{TP + FN + FP + TN} \tag{3}$$

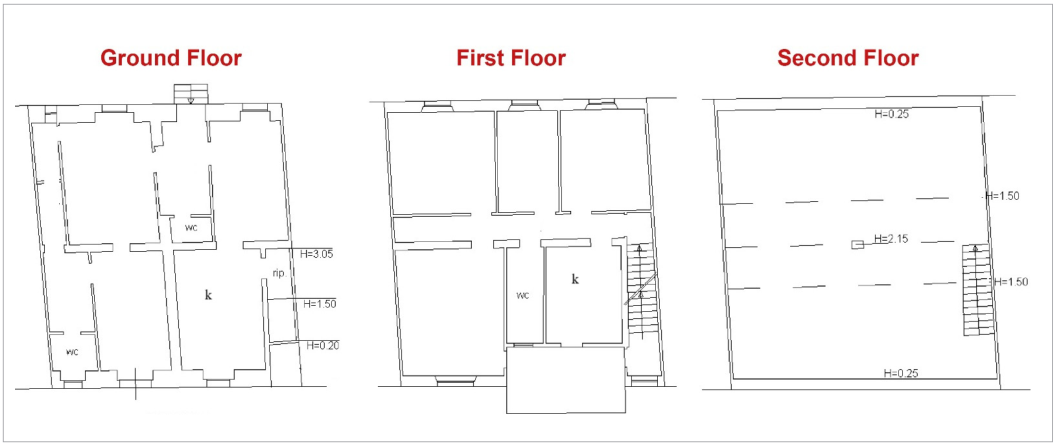
Dataset

For the development and experimentation of this research, a historical building from the early 1900s is used as case study. The building consists of two units, forming part of an in-line aggregate, located in the historical centre of an Italian town. The dataset taken into consideration is characterized by 3 cadastral plans (see **Fig. 4**) with a scale of representation of 1:200. This way, it is possible to deduce the geometric characteristics of the building and its consistency.

From the analysis of the plans, it is possible to deduce that the building is subdivided into three floors above ground, with two sides facing two different roads and two bordering on other residential units, it has a masonry load-bearing structure and a double-pitched roof. More specifically, it consists of a first

Fig. 4

Cadastral plans of the case study building



residential unit on the ground floor, with two entrances located on both streets, and includes four main rooms, two bathrooms and other service rooms. The second unit has a ground-floor access from the street to the southeast, with an internal staircase leading to the first floor where the flat includes five main rooms, with a toilet and a balcony. Another internal staircase connects the first to the second floor (the attic). The attic is characterized from a single room by different heights.

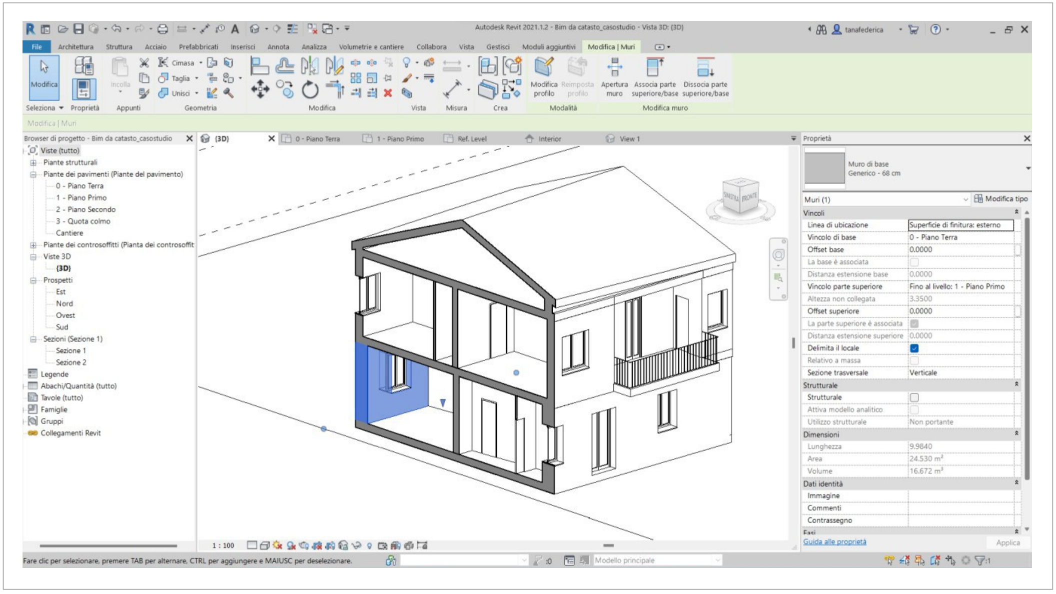
BIM Obtained from the Dataset

Manual method

BIM construction by manual method is based on the use of the Autodesk Revit software. Within this software, the layers were created from the reference dimensions deduced from the cadastral data. The plans of the dataset were then inserted within the relevant plan views, scaled and the reference grids were set. Next, the necessary families were set up for modelling the building components. Different types of walls were identified, and a different family with generic material properties was created for each type, as no information was available on the walls' materials' characteristics. Similarly, all the other elements characterizing the building were modelled:

- the floors were modelled with standard thickness as type and thickness were not available;
- the openings, with known width and unknown height (based on their graphic representation, the windows were distinguished from the doors at the building entrance);
- the overhanging balcony on the first floor;
- the staircases, with known shape and step size (the step height was computed from the inter-storey heights and the slabs' thickness);
- the double-pitch roof type and its slopes were computed from reference heights at the ridge and at the intersections with the perimeter walls included in the plan.

Fig. 5 shows the model obtained in Autodesk Revit which is characterized by strong human interaction but allowing for a high degree of detail with respect to cadastral information inferable from floor plans.



Proprietà

Muro di base
Generico - 68 cm

Muri (1) — Modifica tipo

Vincoli	
Linea di ubicazione	Superficie di finitura: esterno
Vincolo di base	0 - Piano Terra
Offset base	0.0000
La base è associata	☐
Distanza estensione base	0.0000
Vincolo parte superiore	Fino al livello: 1 - Piano Primo
Altezza non collegata	3.3500
Offset superiore	0.0000
La parte superiore è associata	☑
Distanza estensione superiore	0.0000
Delimita il locale	☑
Relativo a massa	☐
Sezione trasversale	Verticale
Strutturale	
Strutturale	☐
Attiva modello analitico	☐
Utilizzo strutturale	Non portante
Dimensioni	
Lunghezza	9.9840
Area	24.530 m²
Volume	16.672 m³
Dati identità	
Immagine	
Commenti	
Contrassegno	
Fasi	

Guida alle proprietà — Applica

Fare clic per selezionare, premere TAB per alternare, CTRL per aggiungere e MAIUSC per deselezionare.

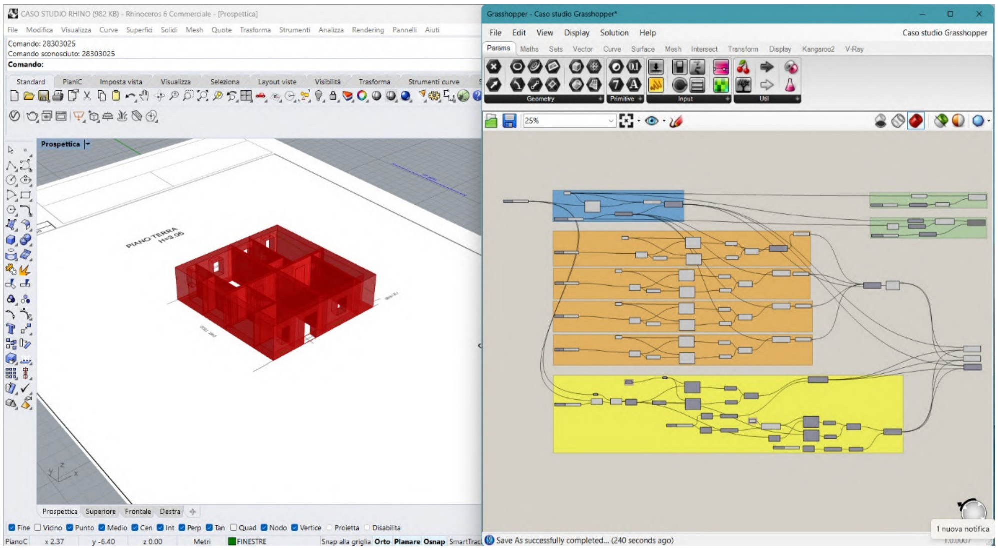
Fig. 5

Autodesk Revit Software screenshot with sectioned 3D view of the obtained BIM (manual method)

Semi-Automatic Method

To apply the semi-automatic method in the case study, the cadastral plans were first imported into Rhinoceros and scaled using a special tool. Next, the building representative curves were created, i.e. the input elements for the construction of the modelling algorithm in Grasshopper. The curves, to be subdivided into external walls, internal walls, doors and fixtures, had to be drawn in the centre of the elements on the cadastral basis using different levels. The Grasshopper plugin was then opened and the algorithm for parameterization of the objects was constructed. The first step involved the digitization of the external walls. The curves of the internal walls were then reconstructed, diversified according to the different thicknesses, followed by the reconstruction of the openings (doors and windows), and finally of the floors.

The realized implementation is shown in **Fig. 6**, where an excerpt of the modelling algorithm constructed in Grasshopper is reported. The algorithms for modelling the different components are indicated in light blue for the external walls, in orange for the internal walls, in yellow for the openings and in green for the floors. Using the same algorithm just described, it was possible to build the upper floor; therefore, it is necessary to implement a further task in order to join the several information.



Comando: 28303025
Comando sconosciuto: 28303025
Comando:

Save As successfully completed... (240 seconds ago)

Fig. 6

Grasshopper modelling algorithm with virtualization of the model in Rhinoceros referred to the ground floor

Once the algorithm was built and applied to the case study building (for each floor of the building, varying the initial input curves and modifying the sliders) the thickness and height of the walls and the size of the openings were modified. The virtual model created through the "Baking" command (see **Fig. 6**) was handled within Rhinoceros. The resulting model, consisting of multiple surfaces divided into components, was finally exported and imported into Revit, through the following steps:

- the external walls component was selected and the export selection tool was used to create a ACIS.sat format file (a 3-D model saved in Spatial's ACIS solid modeling format which stores 3-D geometry information in a standard text file format);
- within a new Revit file, the plan view of the building floor level exported from Rhinoceros (exterior walls) was opened and the ACIS file was inserted using the tool "CAD Import", thus obtaining the automatic positioning of the objects, from source to source;
- the imported object was assigned the material type (from the Manage menu under Object Styles and under Imported Objects) selecting the material from the library window;
- the above export and import process was then replicated for each building component (internal walls, openings and floors) for the complete conversion of the Grasshopper generated model to the BIM.

AI-based Method

AI-based automatic recognition enables the automatic creation of a BIM model. There are currently different software and online systems that allow the creation of planimetries with artificial intelligence, such as "geo for all", "planner", etc. In this work, the Acca BimAI software developed by the Italian ACCA software company was used.

Table 1

Parameters used in AI software for automatic object recognition

Automatic recognition parameters	Values entered m)
Maximum length of an opening	5.00
Max. wall thickness	0.65
Minimum aperture length	0.30
Min. wall thickness	0.20
Default door height	2.10
Predefined slab thickness	0.20
Default wall height	2.50
Default window height	1.20
Default sub-window	0.80

Thanks to a special tool available in the software, the parameters for automatic recognition and the subsequent modelling phase were input, as shown in Table 1.

The UsbimAI software was able to recognize almost all the elements on the plan in almost all of the plans. The wall partitions do not present any anomalies or distortions with respect to the planimetric layout. Further tests and attempts were made with different masonry thicknesses and shapes. They showed substantial anomalies in the recognition of curved masonry, unlike classic straight lines. Indeed, in this specific case, the AI software tried to segment the walls by dividing the masonry into smaller linear masonry walls. While the recognition of windows and doors was often incorrect, in several cases doors and windows are confused or even not recognized.

Overall, the three- dimensional models created automatically are of good quality considering the speed the system uses to transform the data of a simple image into a BIM model (Fig. 7).

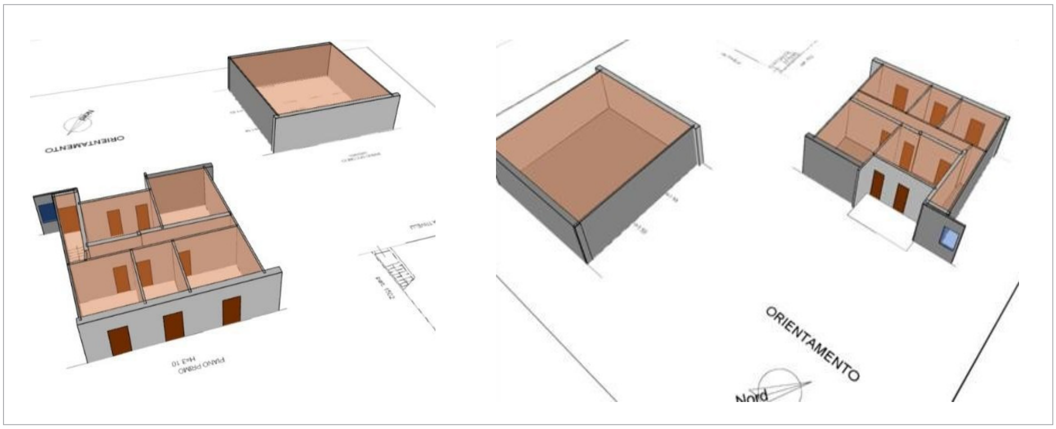


Fig. 7

Axonometric views of the model generated by the AI software

In fact, following the above procedure and entering and varying the input data, the BIM is generated in a few seconds entirely over the web platform, without the use of software and using the power of the Personal Computer to a minimum. The resulting model is complete and can be quickly managed through other tools that allow the user to better set up the families and refine the BIM project.

The evaluation of the classification of walls, windows and doors objects was carried out using the performance indices of Eqs. (1), (2) and (3) and are reported in Table 2.

To assess the performance of the AI-based model when the plan type changes, the model was applied to a larger dataset. More specifically, a dataset of 22 floor plans was considered, 14 of reinforced concrete and 8 of masonry buildings. This application to a larger dataset allowed the procedure to be generalized and validated. Performance indices were computed for each of the identified classes, as reported in Table 3.

Table 2

Performance index values obtained in the case study

	Precision (%)	Recall (%)	Overall Accuracy (%)
walls	100	100	100
windows	71	83	88
doors	44	44	60

Table 3

Performance index values of AI-based model calculated on further 22 plans

	Precision (%)	Recall (%)	Overall Accuracy (%)
walls	87	94	95
windows	74	50	60
doors	68	45	57

Results

Starting from the cadastral data, manual modelling provided a reliable and controllable model, where all modelling and construction processes of the building's characterizing elements take place within a single software. The semi-automatic method, on the other hand, allows all extrusions to be obtained quickly, as the constructed algorithm can be easily applied to any plan by simply changing the initial input curves. Moreover, this method is particularly effective in modelling complex architectural elements, such as curved surfaces, thanks to the modelling versatility achieved by combining Rhinoceros with Grasshopper. Conversely, in the application of this method, starting from a cadastral base which does not provide detailed information, one is limited to the modelling of the main elements of the building, without any further details. Otherwise, this operation would require additional modelling, which in Revit is accelerated thanks to the use of families (e.g. doors, windows, railings, etc.). In other words, Revit, with its libraries of Families, gives the possibility to quickly insert detailed objects such as doors, windows and railings. These families are not available in Rhinoceros and must be created by the user. As for the AI-based method, considering the different types of floor plans of the case study, encouraging results were obtained for the recognition of masonry buildings. Problems in the automatic identification of objects were found for all categories of openings (doors and windows).

In the construction of the BIM model of the entire building, it is necessary to point out an additional problem since the software works for individual floor plans. Thus, to create a single model, it is necessary to assemble the different BIMs for the different floor plans. An interesting aspect concerns the time required to create three-dimensional models. While it is possible to create a BIM model in a few seconds, the model is rather schematic and requires user interaction for a suitable implementation in the BIM environment. A further limitation of the automatic implementation method is the inability to recognize curved surfaces, in contrast to the manual and semi-automatic methods. In conclusion, in the application of all the methods, the greatest limitation in the construction of the BIM derives from the cadastral dataset that lacks information required to build a model completely faithful to reality.

Both the cadastral plans and the data acquired by Docfa procedure do not report any data on the type and thickness of the floor slabs, the height of the openings (doors and windows), the type and size of the stair risers, the type and size of the foundations, the type of roofing (wood, concrete) and in case of inaccessibility of the same, its shape and the slope of any pitches. Comparison of the three methods considered in terms of quality, metric accuracy, processing speed and handling of complex surfaces is carried out using the performance parameters proposed in Pepe et al., 2022. The evaluation for the three models are reported in **Table 4**, where the value of 1 star indicates very low performance while 5 stars indicate top performance.

It is clear from **Table 4** that the different methods used present different qualitative and time-related aspects of BIM implementation. While the AI-based method produces a BIM model very quickly, the manual and semi-automatic methods produce models that are more reliable and representative of the actual plans.

Table 4

Comparison of the three modelling methods

	Detail of objects	Metrics precision of model	Speed	Management of complex surfaces
Manual	★★★★	★★★★	★★★	★★★
Semi- Automatic	★★★	★★★★	★★★★	★★★★
AI-based	★	★★	★★★★★	★

Conclusions and Future Prospects

Three methodologies are identified and described in the paper for the creation of BIM models from cadastral plans: a manual one, a semi-automatic one and an automatic AI-based methodology. For each method, the advantages and disadvantages were analysed. For example, the semi-automatic method and the manual method resulted in accurate models, but the time required to create the BIM was significant. The AI-based method, on the other hand, lead to a BIM very quickly, but the accuracy of object recognition was questionable, particularly for windows and doors. In fact, while the OA of the walls found in the various plans taken into consideration was 95%, decidedly lower values (around 60%) emerged in the recognition of windows and doors. It is necessary to add more stringent parameters in AI-based software to facilitate the recognition of objects automatically and this approach and this approach becomes inaccurate when the geometry of the elements is curvilinear. Furthermore, since in AI-based software the parameterization takes place for individual plans (and thus floor level), additional manual editing is required to assemble the different plans and make sure that they match. Therefore, an optimal approach might not be a single methodology, but rather their integration in different forms depending on the building geometries. In other words, the initial construction of the model in the AI environment and subsequent editing in semi-automatic or manual methods could be useful. In general, the manual method made it possible to obtain a more detailed model of the structure under consideration from the same information. Moreover, both the Rhinoceros/Grasshopper and AI-based methods do not allow modeling of critical elements, such as roofing which should be developed anyway with the help of an operator and not modelled automatically.

BIM obtained from 2D floor plans is particularly useful, not only in the cadastral environment for the 3D identification of interior spaces, but also as a tool for the integration of information in buildings that are not directly accessible. Indeed, especially in historical centres, cadastral plans could be the only information available for the characterization of buildings and the creating of a BIM. However, to date cadastral information is used primarily to estimate the property value and aspects and the property fiscal income and do not provide the elements for the structural, technological, and architectural characterization of buildings. Therefore, it is desirable in the future to include additional information in the cadastral data regarding the location and type of structural elements (load bearing walls, columns, and beams), the type of architectural and technological elements (wall type, stairs, roofing, size, and type of opening). In fact, the creation of a BIM model would allow the different Agencies that manage planimetric information (cadastre, municipality, etc.) to use the same unified building dataset, thus reducing search times and making data accessibility easier. On the one hand, today's technology allows the creation of realistic and interactive models that are easily consultable, on the other different Agencies often continue to work independently with little or no sharing of their needs. It is therefore desirable to create single, unique BIM models that can be shared by different Agencies. To achieve this goal, it is central to first digitize the real estate stock according to a standard BIM-based approach. This involves creating a platform where users can build and update the BIM of the building under consideration. Each information manager (cadastre, municipality, etc.) can have access to unique, consistent, effective, and realistic BIM and evaluate and approve (or not) the proposed model.

Acknowledgements

The study presented in this article was partially funded by the Project GENESIS: SEISMIC RISK MANAGEMENT FOR THE TOURISTIC VALORISATION OF THE HISTORICAL CENTERS OF SOUTHERN ITALY. PON MIUR "Research and Innovation" 2014 - 2020 and FSC. D.D. 13/07/2017 n. 1735. Industrial research and experimental development projects in the 12 Smart Specialization areas. Specialization area: Cultural Heritage. Project Code ARS01_00883. The opinions and conclusions presented by the authors do not necessarily reflect those of the funding agency. In addition, we want to thanks the reviewers for their careful reading of the manuscript and their constructive remarks.

References

Andrianesi, D. E., & Dimopoulou, E. (2020). an integrated BIM-GIS platform for representing and visualising 3d cadastral data. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 6, 3-11. https://doi.org/10.5194/isprs-annals-VI-4-W1-2020-3-2020

Atazadeh, B.; Kalantari, M.; Rajabifard, A.; Ho, S.; Ngo, T. Building information modelling for high-rise land administration. Trans. GIS, 2017, 21, 91-113. https://doi.org/10.1111/tgis.12199

Atazadeh, B., Halalkhor Mirkalaei, L., Olfat, H., Rajabifard, A., & Shojaei, D. (2021). Integration of cadastral survey data into building information models. Geo-spatial Information Science, 24(3), 387-402. https://doi.org/10.1080/10095020.2021.1937336

Bieda, A., Bydłosz, J., Warchoł, A., & Balawejder, M. (2020). Historical underground structures as 3D cadastral objects. Remote Sensing, 12(10), 1547. https://doi.org/10.3390/rs12101547

Bruni, E. (1893). The new Italian cadastre. (Vol. 137). U. Hoepli.

Chen, Y., Zhang, Y., Xiao, B., & Li, H. (2022). A framework for the elderly first aid system by integrating vision-based fall detection and BIM-based indoor rescue routing. Advanced Engineering Informatics, 54, 101766. https://doi.org/10.1016/j.aei.2022.101766

Costantino, D., Pepe, M., & Restuccia, A. G. (2023). Scan-to-HBIM for conservation and preservation of cultural heritage buildings: The case study of San Nicola in Montedoro church (Italy). Applied Geomatics, 15(3), 607-621. https://doi.org/10.1007/s12518-021-00359-2

Costantino, D., Grimaldi, A., & Pepe, M. (2022). 3D Modelling of buldings and urban areas using Grasshopper and Rhinocersos. Geographia technica, 17(1). https://doi.org/10.21163/GT_2022.171.13

El-Mekawy, M., Paasch, J. M., & Paulsson, J. (2014). Integration of 3D cadastre, 3D property formation and BIM in Sweden. In 4th International Workshop on 3D Cadastres, 9-11 November 2014, Dubai, United Arab Emirates (pp. 17-34).

FIG joint commission 3 and 7 Working Group on 3D Cadastres. In Proceedings of the International Workshop on '3D Cadastres', Delft, The Netherlands, 28-30 November 2001; Available online: www.gdmc.nl/3D-Cadastres/workshop2001/ (accessed on 23 March 2020).

Hajji, R., Yaagoubi, R., Meliana, I., Laafou, I., & Gholabzouri, A. E. (2021). Development of an integrated BIM-3D GIS approach for 3D cadastre in Morocco. ISPRS International Journal of Geo- Information, 10(5), 351. https://doi.org/10.3390/ijgi10050351

Heidari, A., Peyvastehgar, Y., & Amanzadegan, M. (2023). A systematic review of the BIM in construction: from smart building management to interoperability of BIM & AI. Architectural Science Review, 1-18. https://doi.org/10.1080/00038628.2023.2243247

Janečka, K. (2019). Standardization supporting future smart cities-a case of BIM/GIS and 3D cadastre. GeoScape, 13(2), 106-113. https://doi.org/10.2478/geosc-2019-0010

Kang, T. (2023). Scan to BIM Mapping Process Description for Building Representation in 3D GIS. Applied Sciences, 13(17), 9986. https://doi.org/10.3390/app13179986

Miller, N., & Stasiuk, D. (2017). A novel mesh-based workflow for complex geometry in BIM. ACADIA 2017: Disciplines & Disruption, 404-413. https://doi.org/10.52842/conf.acadia.2017.404

Oosterom, P.; Stoter, J.; Ploeger, H.; Thompson, R.; Karki, S. (2011). World-wide inventory of the status of 3D Cadastres in 2010 and expectations for 2014. In Proceedings of the FIG Working Week, Bridging the Gap between Cultures, Marrakech, Morocco, 18-22 May 2011.

Oksana, M., & Tatyana, S. (2019). Specifics of utilities design using information modeling. Architecture and Engineering, 4(3), 13-21. https://doi.org/10.23968/2500-0055-2019-4-3-13-21

Pedrinis, F., & Gesquière, G. (2017). Reconstructing 3D Building Models with the 2D Cadastre for Semantic Enhancement. Advances in 3D Geoinformation, 119-135. https://doi.org/10.1007/978-3-319-25691-7_7

Pepe, M., & Parente, C. (2018). Burned area recognition by change detection analysis using images derived from Sentinel-2 satellite: The case study of Sorrento Peninsula, Italy. Journal of Applied Engineering Science, 16(2). https://doi.org/10.5937/jaes16-17249

Pepe, M., Costantino, D., Crocetto, N., & Restuccia Garofalo, A. (2019). 3D modeling of roman bridge by the integration of terrestrial and UAV photogrammetric survey for structural analysis purpose. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, 42, 249-255. https://doi.org/10.5194/isprs-archives-XLII-2-W17-249-2019

Pepe, M., Alfio, V. S., Costantino, D., & Herban, S. (2022). Rapid and Accurate Production of 3D Point Cloud via Latest-Generation Sensors in the Field of Cultural Heritage: A Comparison between SLAM and Spherical Videogrammetry. Heritage, 5(3), 1910-1928. https://doi.org/10.3390/heritage5030099

Pizarro, P. N., Hitschfeld, N., Sipiran, I., & Saavedra, J. M. (2022). Automatic floor plan analysis and recognition. Automation in Construction, 140, 104348. https://doi.org/10.1016/j.autcon.2022.104348

Rajabifard, A., Atazadeh, B., & Kalantari, M. (2019). BIM and urban land administration. CRC Press.

Scricco, F. (2016) Cadastre and territorial government: From the first surveys to GIS. In Proceedings of the 3rd International Balkans Conference on Challenges of Civil Engineering, Tirana, Albania, 19-21 May 2016; pp. 19-21.

Sun, J., Mi, S., Olsson, P. O., Paulsson, J., & Harrie, L. (2019). Utilizing BIM and GIS for Representation and Visualization of 3D Cadastre. ISPRS International journal of geo-information, 8(11), 503. https://doi.org/10.3390/ijgi8110503

Waas, L. (2022). Review of BIM-Based Software in Architectural Design: Graphisoft Archicad VS Autodesk Revit. Journal of Artificial Intelligence in Architecture, 1(2), 14-22. https://doi.org/10.24002/jarina.v1i2.6016

Yekeen, S. T., Balogun, A. L., & Yusof, K. B. W. (2020). A novel deep learning instance segmentation model for automated marine oil spill detection. ISPRS Journal of Photogrammetry and Remote Sensing, 167, 190-200. https://doi.org/10.1016/j.isprsjprs.2020.07.011

Zeybek, M. (2021). Classification of UAV point clouds by random forest machine learning algorithm. Turkish Journal of Engineering, 5(2), 48-57. https://doi.org/10.31127/tuje.669566

About the Authors

MASSIMILIANO PEPE

Associate Professor of Geomatics

University "G. d'Annunzio" of Chieti-Pescara
Department InGeo,
Viale Pindaro 42, 65127,
Pescara, Italy

Main research area

Geomatics, HBIM, Cadastre

Address

massimiliano.pepe@unich.it

FEDERICA FRANCESCA TANA

Scholarship holder in Geomatics

University "G. d'Annunzio" of Chieti-Pescara,
Department InGeo,
65127, Pescara, Italy

Main research area

BIM, Cadastre

Address

tanafederica@gmail.com

DONATO PALUMBO

Scholarship holder in Geomatics

University "G. d'Annunzio" of Chieti-Pescara,
Department InGeo,
65127, Pescara, Italy

Main research area

3D survey and modeling, BIM, Cadastre

Address

archi.palumbo@gmail.com

ENRICO SPACONE

Full professor of Structural Engineering

University "G. d'Annunzio" of Chieti-Pescara,
Department InGeo,
65127, Pescara, Italy

Main research area

Reinforced Concrete Structural Analysis Earthquake, Engineering Structural Dynamics, Finite Element Modeling and Analysis

Address

enrico.spacone@unich.it