MANAGEMENT PROPERTIES AND PROCEDURES IN THE INFORMATION MODEL OF THE HISTORIC BUILDING HBIM ON BUILDING FACADES

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ABSTRACT:

Historic Building Information Modelling (HBIM) has become the ideal tool for professionals studying building conservation and restoration. The BIM model allows one to identify structural deformations following three-dimensionally resolved models. In addition, this methodology is specifically designed to register parametric construction models, as an information manager by adding semantic components to the model, including information on the different transformations of the historical artefact, and allowing continuous progress in the building's life cycle. In this work, graphic information and data related to conservation projects are compiled that allow a management of all the documentation integrated in the same Project, from all the disciplinary fields related to the heritage conservation and rehabilitation process. Specifically, from the geometric identification and the restoration documents, it is intended to develop an experimental application where both terrestrial laser scanning records and the use of image processing routines can allow automatic operations to monitor alterations in façades, in order to subsequent control by conservation experts. For this, a building with certain characteristics has been chosen, such as the Miguel de Mañara palace in the city of Seville. A building that has a main façade of 43.30 metres in length by 6.75 metres in height and, in which its façade rotates in an angled guideline to adapt to the urban planning of the time. The analysis is based on the applicability of two segmentation algorithms and the construction of the multilayer enclosure model where the different stratigraphies of the results obtained are exposed.

1. INTRODUCTION

Historic Building Information Modeling (HBIM) has become the best tool designed to adapt to the activities of a restoration project. This methodology is specifically designed to register parametric construction models, as an information manager by adding semantic components to the model, includinginformation on the different transformations of the historical artifact, and allowing continuous progress in the building life cycle. Despite the traditional CAD models where the representation is only geometric, this methodology as an information manager acquires a greater role in rehabilitation projects. More than a decade ago, HBIM was defined as a new modeling system for historical structures (Murphy et al., 2009) and where massive data acquisition techniques play a primary and essential role in capturing the real geometry of the elements thatmake up the structure. facade of a historic building. In some buildings, the geometric forms present very complexarchitectural details, as in the case study presented in this article. These 3D surveys can lead to an evaluation of the surface degradation and deterioration of the exterior elements.In the field of practice, by comparing the cloud of points with the digital parametric construction models, it will be possible to determine a qualitative and quantitative evaluation of the advanced state of degradation of the materials. On the other hand, in the selection of the set of points that determines the scanning of the epidermis of the building, it is necessary to lookfor classification procedures of the artifacts, where through segmentation algorithms it can be determined, which elements are susceptible to modeling and which ones. not. The possibility of these composition elements being integrated into a digital library is also known, as a systematic way of capturing and registering architectural elements as intelligent (Sakellaris et al., 2022). The incorporation of the data set extracted from the point cloud by means of massive data acquisition techniques such as photogrammetry or LIDAR techniques in the BIM environment allows greater completeness in the representation of 3D models (Moyano et al., 2021). The data from the point sets thatwe call attributes provide metric accuracy, information about the reflectivity and texture of materials, and colorimetric aspects. There is a compositional structure of elements that must be studied when proposing a model of a façade. Modulating complex structures includes recognizing that there are artifact elements that, due to their geometric properties, require an adaptation mechanism through meshes generated by software other than BIM. Also recognize that the constructions of the walls are executed with theoretical modeling, in which the cloud of points inserted in the model can determine the variations of the discrepancies of the collapse of the old walls, these variations can be shown both in section and in elevation. Another component is the integration of the damage

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detected in the heritage and that can be represented in the digital model itself. (Garcia-Gago et al., 2022) structured the capabilities of HBIM by integrating two essential features; the geometric and the materials and proposed the integration of the information about the damage to a building in an information model of historic buildings. In this order of ideas, a systematic approach is proposed where the geometric components, texture, semantic segmentation, and semantic components of the model are shown, and the semantic implementation of the study of the façade. For this, the façade of the Miguel de Mañara Palace, one of the most representative historical buildings of 17th century Sevillian architecture, will be taken as a case study. Today the building houses an institutional headquarters and the works carried out have made it possible to recover the entire decoration of the façade carried out in the year 1767. The methodology that will be carried out includes all the processes of geometric characterization, semantic characterization and insertion of the study component of the diagnosis of the building.

The objective of this research is to propose a methodology through a chain of tools as an integral procedure for the study and analysis of the pathologies of the façade of a historic building. Here, three basic aspects are analyzed. The geometric characterization of the complex elements that form a facade. The characterization of the materials and the different types of historical coatings, colors, pigments, textures, etc. and aspects of diagnostic recognition and finally the semantic characterization of the properties in a 3D digital reconstruction model. Some procedures have been developed in other investigations, although at a comprehensive level they have not been perfected.

2. MATERIAL AND METHOD

The Miguel de Mañara palace is a building that has a main façade of 43.30 meters in length by 6.75 meters in height. The surface of the building is not completely flat, but presents an angle of 30º. The dimensions that these buildings sometimes cover present the problem of accessibility in terms of the applicability of mass data acquisition techniques. For terrestrial acquisition, the complexity of some elements can cause false registrations and occlusions. Therefore, since no sensor can by itself obtain a complete information record in the reconstruction of cultural objects (Xu et al., 2016), it is necessary for the recording and capture of the point cloud to use two systems, the Terrestrial Laser Scanning (TLS) and the Unmanned Aerial Vehicles (UAV). Both techniques are going to be developed to provide complete coverage of points in the different elements of the façade. With the advent of new geomatic technologies such as the personal laser scanner (PLS), the capture of data in the measurements of architectural spaces is simplified (Moyano et al., 2022) and among these equipment is the BLK360, with a kg in weight using waveform scanning (WFD) technology with a maximum scan speed of 360,000 points/second. It has three HDR digital cameras with colour sensor and fixed focal length (single image 2592 x 1944 pixels, 60° × 45° (vx hz), full-dome scanning of 30 images and automatic gap rectification, 150 Mpx, 360° × 300°), as well as an infrared thermal camera (160 x 120 pixel single image, 71° × 56° (vxhz), 10-image full-dome scan, 360° × 70°), all four included in the kit . For the case study and to cover the entire surface of 43.30 metres in length, five scans were developed that were coupled, in a post-processing in LEICA Cyclone REGISTER 360 software (Geosystems, 2018), obtaining an optimal report. of the records made in the field work. In the case of monitoring for photogrammetry processing, a high-tech DJI Air2S unmanned aerial vehicle weighing 0.6 kg was used. The UAV has a 1" 12 MP CMOS sensor. The equivalent focal length of the camera lens is 35mm, with an aperture of f/2.8 and a field angle of 83º. The size of the RGB image is 4000 x 3000 pixels. The drone is equipped with a global navigation satellite positioning system (GNSS) taking the constellations: GPS+GLONASS+Galileo. In the flight plan, the photographs were taken at a distance of 3 metres from the façade plane and with an overlap of 80%. For the processing, the Agisoft Metashape software (Agisoft PhotoScan software., 2019) was used, which produced a dense point cloud in a 3D coordinate system in the representation of the entire façade. A second data output allowed one to obtain both a mesh of triangles and the generation of orthophotos that will later be used in the model.

Studies on the integration of photogrammetry and complementary terrestrial data capture tools are numerous in the scientific literature. For the study of heritage documentation, the two technologies interact to cover possible occlusions generated by the records. An important part is the zenithal record that covers the flat surface of buildings, and among the studies is (Chatzistamatis et al., 2018) where the fusion of the two sets of points is evaluated, aligned by means of the ICP algorithm. The integration of terrestrial and aerial data to obtain a geospatial database is one of the most significant facts and becoming the scientific objective for the Historic Building Information Model (HBIM) environment (Klapa and Gawronek, 2022) and every study emphasises the consistency between both technologies. The alignment between both sets of points highlights the difficulty with which they have coupling Figure 1.

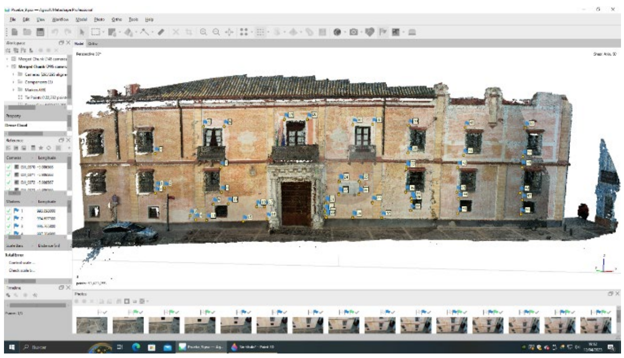

Figure 1. Point cloud obtained from the alignment of UAV and TLS acquisitions about the "Palacio Miguel de Mañara's façade".

3. THE GEOMETRY OF THE FAÇADE AND ANALYSIS OF THE MATERIALS.

Current technologies for documentation of cultural heritage, such as computer vision, photogrammetry, and new terrestrial laser scanning tools and the use of 3D modelling platforms with semantic information, open up a new spectrum of applications in conservation policy. The evaluation of the geometry constitutes an intrinsic value to know to what degree the objects that are part of a facade are altered. Although there are very advanced techniques in the area of thermography to detect humidity problems for the purpose of controlling characteristics and pathologies in buildings (Fino et al., 2019), in photogrammetry, you can observe the colour changes in the facing. Holistic documentation constitutes one of the essential steps in the detection of alterations in the façade (Adamopoulos et al., 2021). Durability problems in coatings are an important factor determining the characteristics of the material properties. And in recent years, different approaches to thematic mapping have been tested, according to specific intervention themes (Delpozzo et al., 2022), although this work develops the original maps from CAD

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contour drawings from orthophotos. Our vision is to develop the characterisation of the materials and mapping analysis directly from the point cloud that has been obtained from the TLS or the SfM and that are inserted into the BIM environment through procedures already described by Moyano et al. (Moyano et al., 2021b). Yes, it will be necessary to have and analyse the parameters that arise, since the unstructured and non-flat nature of the point cloud makes surfaces key modelling instruments in this facet (Morel et al., 2018). Of course, the point cloud must be free from noise and occlusions generated by both the TLS and the UAV. The implicit reconstruction of façade surfaces is the process of the best fit function of the input data to the output data of parametric modelling. Provide a roadmap where the durability of materials such as stone or coating materials such as mortar and other materials is considered through the information provided by data acquisition techniques where the set of points can determine important aspects. Specifically, from the geometric identification and the restoration documents, it is intended to develop an experimental application where both the TLS records and the use of image processing routines can allow automatic operations to monitor façade alterations, in order to subsequent control by conservation experts.

In the field of architectural restoration, point-cloud segmentation for the characterisation of material defects is still little explored. On the other hand, the study of the application of regional growth algorithms for façade areas or surfaces has been extensively studied, among which we find Vo et al. (Vo et al., 2015) with a voxelization work for data simplification and (Biosca and Lerma, 2008) for the identification of flat structures. But the study of alterations is closely linked to the attributes provided by the cloud of points obtained either through TLS records or image-processing routines, and here the parameters have to do with atmospheric contamination or the biological activity that can influence both stone aspects (Armesto-gonzález et al., 2010) and other materials. Some years ago Bruno et al. (Bruno et al., 2017) emphasised the evaluation and performance study of entering data from visual inspections and diagnostics in historic buildings and transferring those data to a historic building information model. Later work by the same University continued with studies of identification and quantification of the physical alterations that affect the masonry. (Galantucci and Fatiguso, 2019) created an easy-to-use prototype for users to obtain information on cracks or loss of material.

4. WORK PROCESS OF CLASSIFICATION OF POINTS FOR HBIM

4.1. Segmentation by Colour Classification

The semantic segmentation of a set of architectural element record points is an analysis process applying identification algorithms to later generate different regions with homogeneous properties and characteristics. Drzewiecki et al. (Drzewiecki et al., 2022) enunciated the four methods for classifying and segmenting a cloud of points. The first are the methods based on line segments, attributes and definition of geometric shapes. The third ones are those based on the 3D Hough transform, and finally the region growth algorithm. The segmentation can have a set of points that can be the point cloud itself from the most common TLS or SfM records, but it can also be carried out through meshes. For an understanding of the structure of the detection of material alterations in a façade, we must refer to the work of the research group of the Polytechnic of Bari. Galantucci et al. (Galantucci and Fatiguso, 2019) proposed a classification approach based on digital photogrammetry to detect cracks and features caused by material loss. These alterations are identified using false colour maps and morphological filters. Musicico et al. (Musicco et al., 2021) proposed a colorimetric segmentation based on a 3D point cloud. Among the grouping methods used, they have preferred the hierarchical order, using the HSV colour space as the most consistent. But this is not always the case in other works such as (Howland et al., 2022) the Kastrouli space for a selection of points per colour with tolerance parameters of 15 and channels of red, green, blue, hue, saturation, and value. Starting from this line, where some results of obtaining segmentation can be lowered to classify the different tonalities, in this work we have used the set of points obtained from Image-Based Modeling (IBM). Agisoft Metashape, which has a colour classifier based on the use of RGB images. To carry out this selection, in the first place, an experiment of incoming data sets was carried out, where the robustness of the method was established. From the façade as a whole, a pre-selection of fourteen samples is carried out among the different regions that make up the façade. The darkest colour fringe is obtained with the RGB values and can be determined in the graph of Figure 2 a).

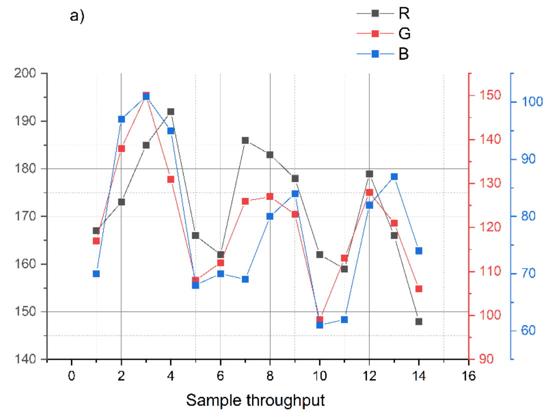

Figure 2 a). The darkest color range obtained with the RGB values 170.122.77 as segmentation filter.

Once the standard deviation and mean of the values taken, the input sample value is reached with 170.122.77. The chromatic is defined by the software itself as a transformer of the properties of the HSV parameters. The second data entry is obtained in the same way for the lighter regions where and according to the set of samples selected and determined in the graph of Figure 2 b), the value of the mean sample taken as segmentation filter is 137.147 .110.

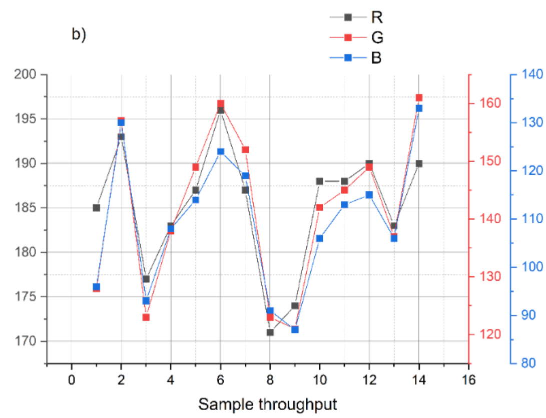

Figure 2 b). RGB values of the clearer segmented regions according to the combination of selected and determined samples (average RGB value for segmentation filter is 137.147.110).

The described method results in two classification models, in which the darkest parts are established as regions, that is, those that suffer alterations due to humidity or temperature properties and that alter the chromatic aspect of the mortars that imitate the nature of bricks, as can be seen in the photograph of the SfM point cloud Figure 3.

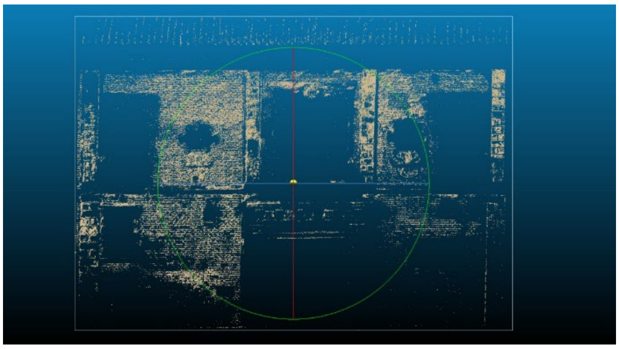

Figure 3. Classification region of darker areas

Once the data output of the two models is obtained, the data set is exported in.ply format to the CloudCompare software to detect changes in the surface regions. The process involves sectoring into regions and seeing those regions that overlap between the two models.

Once the second model with the clearest aspect is obtained Figure 4, the experts will determine the coincident regions and those regions that are truly classifying to delimit and take the established model to BIM.

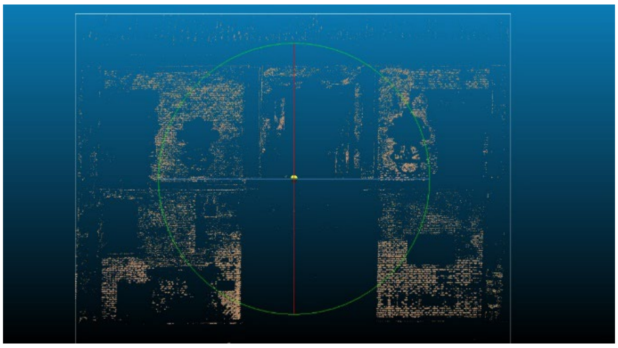

Figure 4. Classification region of lighter areas

The classification model must be validated by experts, differentiating the colour tones that belong to the false masonry and the coverings that imitate the brickwork Figure 5.

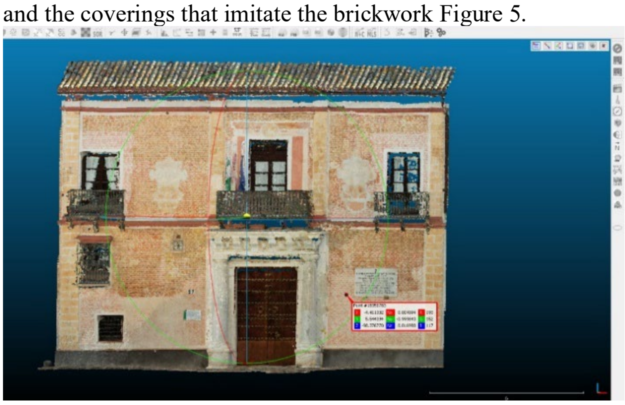

Figure 5. Photogrammetry of the UAV inserted in CloudCompare to establish the characteristics of the colour attributes

4.2. Segmentation by wall classification

The main problem facing the segmentation of walls and floors is that the project itself, when it is in the point-cloud phase, must be embedded in a georeferenced coordinate system, both the TLS and photogrammetry point clouds. The UAV made must contain the same point of origin to be aligned. These problems have already been formulated in other heritage works (Rocha et al., 2020) (Shao et al., 2019) where the best alignment starts with a manual adjustment, followed by an automatic adjustment (Moyano et al., 2023). Despite the potential that terrestrial scans currently have, they pose serious problems in terms of photographic quality, which, on the other hand, are solved by scanning from images. On the other hand, when a correct alignment is performed between the two sets of points in Figure 6, the alignment data may be admissible, as is the case for the portal of the Palace of Miguel de Mañara, where the adjustment between both point clouds had a mean error of best fit of 0.04517 metres and with a standard deviation of 0.07228 metres.

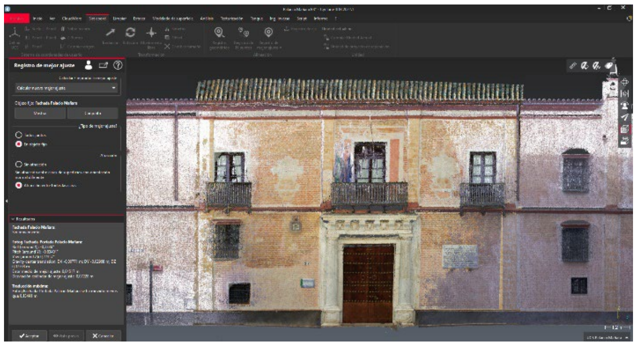

Figure 6. Alignment between the AUV point cloud and the TLS in Cyclone Registre 360

The alignment between the photogrammetry does not prevent a mismatch of fine details between the two sets of points. Variations in the measurements or differences in the control points can have significant repercussions in the overlap of both results. Taking the TLS as a reference in this case, we find small variations that are appreciable in Figure 7.

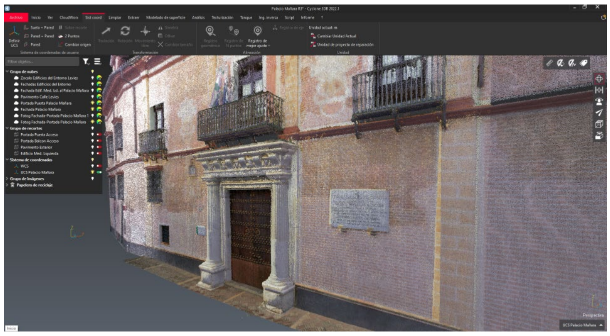

Figure 7. Perspective of coupling between both results. The mismatch can be seen in the vertical protrusion to the right of the cover.

Cyclone REGISTER 360 software uses the RTC360 Visual Inertia System (VIS) to place the collected data into coordinate values, thus utilising efficient self-registration for the user (Adebiyet et al., 2022). Among the different algorithms available to Cyclone 3DR is the detection of walls and floors in a sector, using the limit frame, which was applied for the case study to detect the exterior pavement of Levies Street, thus allowing segmenting and discriminating the set of points around the Miguel de Mañara Palace Figure 8. The parameters defined in the first sample test were established with a smoothing of 0.01013 metres and a maximum angular tolerance of 10º. The data approximate the results of possible collapses in the vertical walls and significant deviations from the roof planes.

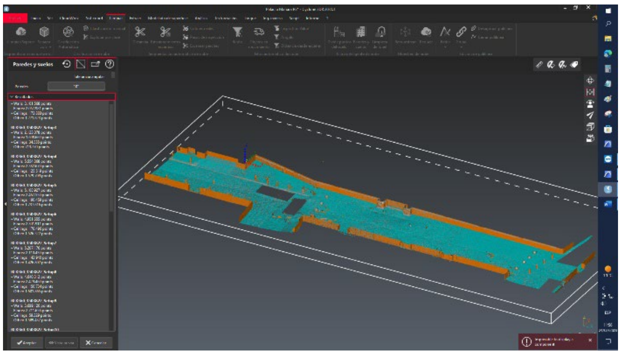

Figure 8. Segmentation of floors and walls

Cyclone 3DR's automatic floor and ceiling classification algorithm will be an effective classification method for subsequent modelling processes in the HBIM project, where all fractions will be exported in specific point sets. The point classifier will be in the hands of the BIM operator who will export the work to the BIM environment using Grafisoft's ArchiCAD software. The format used in this case is e57 files. When the point cloud is exported to the BIM platform, the software itself converts each set of points into an lcf Libraries. Therefore, the software does not obtain parametric objects developed in GDL programming (from an architectural, construction, or decoration system provided by a manufacturer and that they usually provide for the AECO sector), but rather they are grouped as point container objects that will be managed in a library manager using LCF files. Each of the points sets will act in a unique way without the option of modifying their parameters, Figure 9. The import of the point cloud to BIM is based on segmenting the range cloud and transforming it through the BIM digital platform, into an object that will later be enriched with its semantic data, introducing specific properties derived from the process of auscultation, dating, cataloguing, conservation and restoration (Moyano et al., 2021a).

Figure 9. Image of the exterior of the Miguel de Mañara Palace, with the six active point clouds (TLS)

4.3. Building Information Modelling and Façade Layering

The integration of the wall study from field analysis of geomatics and geospatial technology is little known, although the studies have focused their efforts on working from the BIM platform itself, as is the case study of the stratigraphic analysis of the walls of the old prison. from the University of Seville (Nieto Julián and Moyano Campos, 2014). Sectorization was carried out using the shape tool to outline the stratigraphic units. Recent studies on semantic discretization (Nieto-Julián et al., 2022) for the purpose of identifying and classifying the stratigraphy in historic buildings allow for automatic classification of ashlars using algorithms with Python. It is about bringing synergy in the field of Information Modelling of the historic building closer to pathologies, classification of injuries and deterioration, also taking into account the environmental impact that certain facades with historical value may present. From the point of view of restoration experts, the first information that must be available is the existence of restoration projects for the building's façade. Make a catalogue of historical photographs and know the scope of the entire restoration process. The insertion of all this data into a BIM model is essential to know its historical value. Next, the data entry is structured by means of a network, guiding axes of the structure and establishing the floor levels. Before proceeding to the modelling using the parametric objects of known geometry, the matrix of entities must be developed and later arrive at the classification. The construction of the parametric objects in front of the cloud of points will determine the possible deformations that the walls have, as is the case in Figure 10.

Figure 10. Elevation and floor plan of the Facade of the Miguel de Mañara Palace, superimposing the cloud of points with the parametric wall (red) in its theoretical position (0º collapse).

The theoretical wall of earth-coloured is integrated into the point cloud and will show the differences in the deformations of the two faces. Using the theoretical plane, the analysis of the deviations can be determined if we make multiple cross sections, which would give us the exact deformation in each plane (y,x), See Figure 11, with 23.7 centimetres of collapse in the direction of the public road that has the analysed façade wall (section S142, out of a total of S175 every 25 cm along the façade).

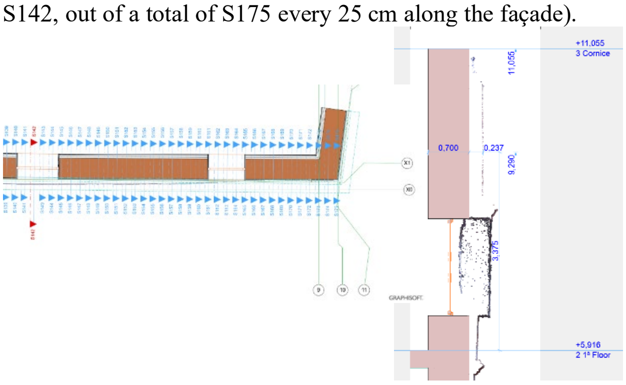

Figure 11. Theoretical wall overlay (in section S142) with 0º

plumb with respect to the vertical vector and the wall obtained through the terrestrial laser scanner.

For the representation in a BIM model faithful to the original stratigraphy of the façade, a wall composed of multiple layers has been developed, where in the composition the different layers of the cladding appear together with the core (brick factory). From the outermost face there are type composition materials: fresh paint on lime, fine stucco mortar, fine lime rendering mortar, coarse lime rendering mortar, and brickwork. From the inside, there is a sheet of brick with little thermal mass that is separated from the structural bulk by an unventilated chamber, to support the interior mortar lining and its paint. In the parametric modelling process, having multilayer walls allows a classification of all elements with a characteristic identification ID, Figure 12. Using the ID identifier allows grouping elements in the lists made for each participatory discipline in a restoration, with the possibility of being catalogued for future actions of BIM work such as labelling in the planimetry or the classification output in.ifc formats. Nowadays, before proceeding with the modelling of a parametric object, it is necessary to establish what the Level of Development (LOD) of the project can be and, on the other hand, to know the components of a classification system. Firstly, to group and organise the structural elements of the façade and secondly, those materials that will determine the coating. According to the BIM Classification Systems guide (BuildingSMART Spain, 2022) there are two types of sets of elements, those that have to do with their shape, that is, morphological classification, and those that have to do with their meaning, semantic classification.

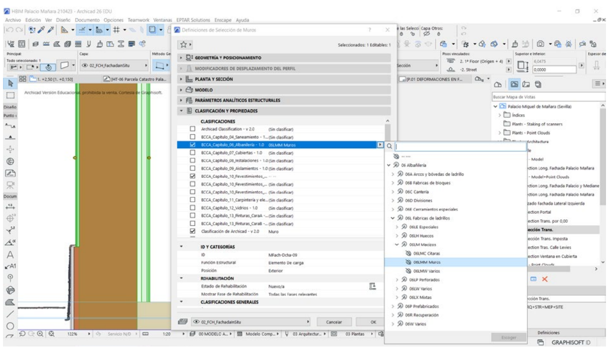

Figure 12. Qualification of the façade wall according to the Bank of Andalusia -BCCA-, in various categories: Wall Structure, Interior and exterior coatings, Final finish.

In this case study, a stratigraphy classification is made according to the Bank of Construction Costs of Andalusia (BCCA), which allows for identification and correlation between ID and headings of economic costs of the construction bank. But, in addition, very recently, the Railway Innovation Hub has published SCFclass V2 (Railway Innovation Hub, 2023), a new version of the BIM classification specialised in the railway field, with the aim of establishing a new, more ambitious technological context for the management of all types of assets. This ranking database is very comprehensive across the board. Once the segmentation by lesion areas has been carried out, each of the specific properties is defined in the HBIM project and later the tables and diagrams of specific properties of the elements identified on the façade are created. In the case of the façade, any parametric element of the HBIM model can be semantically classified from the edited element's own definitions window, choosing the appropriate items from the available options, even with a multiple assignment Figure 13.
In the case of the segregated sector with the original sgraffito coating, it is identified with an ID OR-2 Figure 14, as it belongs to an Original Canvas, with an assignment among those available of a base type: Semi-ironed Stucco/Stucco / Ironed / Ironed and Waxing / Fresco Painting. In this divergent direction towards a digital information model where very defined elements of restoration projects are inserted, both BIM operators and specialists in the conservation of architectural heritage have to intervene. Hence, such important researchers in the field of restoration (Fatiguso et al., 2017) understand the spatial and functional configuration resulting from a process of continuous evolution that includes social, economic, and cultural aspects. And all of them must act through a multidisciplinary vision.

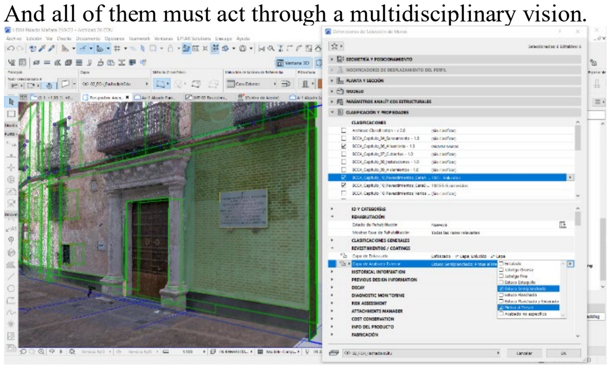

Figure 13. Choice of the specific properties created in the Coatings/Revestimientos category for a typical historical architecture in Seville.

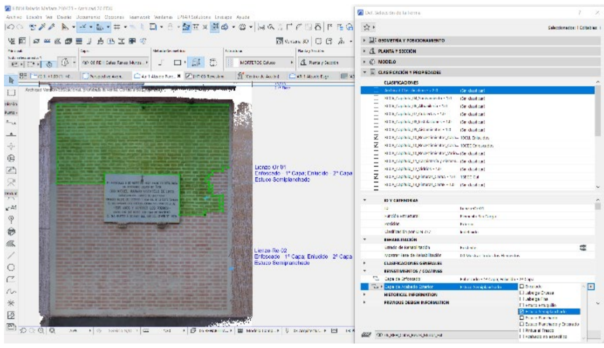

Figure 14. Discriminated sector of the façade wall with the incorporation of the semantic property of the coating, original sgraffito with Stucco-type exterior finish

5. DISCUSSION

The modern techniques currently used for data acquisition and its use in 3D digitisation allow the control of deformations and alterations of the facades. It is a true monitoring system that provides efficiency on the conservation system in the installation of canvases that embellish the structure of the urban space.
The analysis of the study presented shows two fields of experimentation in the classification of cloud of points of affected areas with lesions or alterations. In the first analysis, an algorithm based on colour classification is taken through the study of photogrammetry. In Figure 2 a and b the classification parameters can be determined by means of the RGB attributes and in Figure 2 b) the similarity of the correspondence of the obtained values can be determined. Subsequently, the classification is analysed by experts to determine the degree of nature of the alterations. In the second data output, a segmentation is carried out using Cyclone 3DR software that allows classifying between floor plans and walls, to determine specific plans and structure the information model of the historic

building.
To follow up the three-dimensional analysis, taking the segmented plans to BIM and showing the cloud of points with the theoretical wall makes it possible to detect discrepancies of the order of 27 centimetres in a collapse towards the outside. These discrepancies between the theoretical model are very significant, and experts will determine if they are attributable to the passage of time or, on the contrary, important foundation settlements can occur.
In a restoration project, it is essential to know and consider all the actions and interventions carried out previously, valuable information that is part of the previous study. Well, these data constitute a first parameter, called "Number of restoration interventions", with the aim of obtaining, for each constructive element (in our specific case, the different layers of coatings), how many actions have been carried out. For this, it is necessary to enter the specific data after its analysis by the specialist and manage the parameter through an interactive window to be able to mark it in the element. The parametric model of the HBIM project will be updated semantically and accurately, so the effectiveness and solvency of the graphic and semantic data make the methodology highly suitable for conservation and restoration work.

6. CONCLUSIONS

The approach developed in this work allows us to know the different tools of the Scan-to-BIM process and its applicability in the spaces of the analysis of the architecture of archaeology. Every study process is not exempt from obstacles and difficulties that researchers must state in order to be an echo of the work developed; therefore, one of the difficulties that we find in the use of two different but complementary technologies is the alignment of the cloud of points of the photogrammetry from the UAV as well as from the TLS and that in future works we will address with greater precision. On the other hand, the selection of samples and the lack of material of geometric elements could be detected by means of other algorithms, knowing in this case their nature. The advantage of comparing Scan to BIM procedures and being applied in the information model of the Historic building allows associating a three-dimensional idea to the experimental work that is produced and, on the contrary, moving away from the applicability of the model itself, observing without the analysis is effective. or on the contrary it is disposable. The advantage of this systematic method is that it allows a rapid assessment of the alterations compared to traditional survey techniques.

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