IPIRANGADIGITAL: 3D DOCUMENTATION ACTIVITIES FOR CONSERVATION AND AWARENESS INCREASING OF CULTURAL HERITAGE IN BRAZIL

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KEY WORDS: Digital Documentation, Cultural Heritage Awareness, Point cloud processing, Ipiranga Museum, Smart Cultural Heritage

ABSTRACT:

By promoting awareness at several levels in collaboration with Italian organizations like the Circolo Italiano and the General Consulate of Italy in São Paulo as well as local partners (USP university and SP Municipality), this project seeks to value the local identity of a significant place for Brazil in terms of culture and distinctiveness. The collaboration's results included the dissemination of historical research and the digital documentation of buildings (carried out through the Scan-to-BIM process), which were intended to be pivotal events in the site's cultural rehabilitation. In order to prevent significant portions of a nation's history from being forgotten by the populace, historical recollections were thus encouraged. The purpose of this contribution is to use digital technologies to highlight the history of the most important area for the Brazil's Independence, which is situated in São Paulo on the banks of the Ipiranga stream, in the location where Dom Pedro I would have declared Brazil's independence from the United Kingdom of Portugal, Brazil, and the Algarves on September 7, 1822.
The primary tasks established by the project's partners were the dissemination activities. They attempted to value the cultural characteristics of the location, dealing with both the preservation of memories and long-term preservation of the monuments while always staying within the bounds of reliable science. The information gathered was subsequently put together in an online platform (in Portuguese language) that could explain the major outcomes and next steps to a larger audience (local population).

1. INTRODUCTION

1.1 Research Framework

DIAPReM laboratory (Development of Integrated Automatic Procedures for Restoration of Monuments) at the University of Ferrara has been involved in training activities with the University of São Paulo for more than five years (Balzani et al., 2019). The outcome of this ongoing international exchange is the dissemination of an integrated multidisciplinary and multiscale approach that enables the implementation, exploration, and enhancement of the findings of the research activity developed on the cultural heritage in Brazil (Balzani et al., 2017). In the framework of this cooperation network, since 2017, three main digital documentation activities have been carried out involving some of the most iconic buildings for the Brazilian Independence (1822): the *Ipiranga Museum* (1895), the *Independence Monument* (1922) and the *Idependence Park* with its small building called *Casa do Grito* (1884). The final output was a huge 3D point cloud database which is probably among the biggest cultural heritage digital archives in South America (Figure 1) with more than 250 billion registered coordinates within a total area of 850 meters by 200 meters. The achieved main goals of this activity were to provide an affordable dataset that can be used now for restoration/conservation purposes and, at the same time, to increase the awareness towards the history of this areas through the technology also in the public by means of the web site www.ipirangadigital.org.

1.2 Archival research

The first task of the study was the archival research, which was carried out using conventional techniques that have been well documented in wide literature (Moore et al. 2016, Godfrey 2011, Timothy 2012), and that was based on three different types of sources:
- Written (books, letters and local historical newspaper),
- Oral (interviews and public discussions),
- Iconographic (pictures, paintings, sculptural objects available at the Ipiranga National Museum).
The studies were conducted in collaboration with the São Paulo Municipality's Department of Cultural Heritage (Nucleo de Monumentos e Obras Artsticas, NMOA), which was essential for gaining access to libraries and public archives. Additionally, the colleagues from the USP Department of Architecture and Urban Planning were able to locate additional sources of investigation by utilizing their local network of researchers. The information acquired made it possible to identify each stage of the area's growth, significant interventions, and the motivations behind them.

1.3 The digitized areas

Along the riverside of Ipiranga Dom Pedro I proclaimed Independence on the 7th of September 1822. Since then, the area became the symbolic place of the Brazilian Independence (Barro & Bacello, 1979).

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The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-2-2023
29th CIPA Symposium "Documenting, Understanding, Preserving Cultural Heritage:
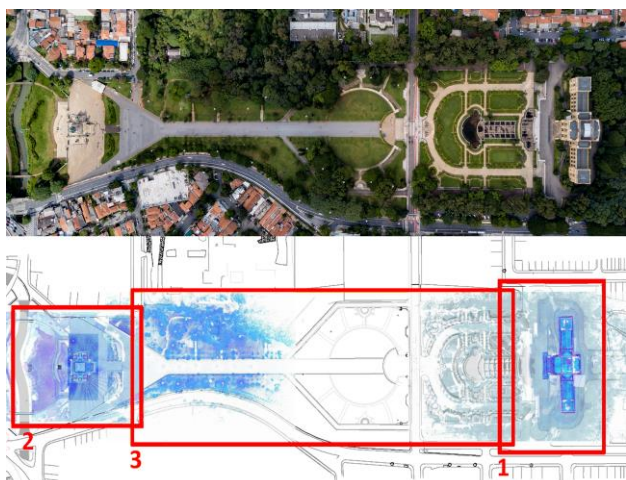Humanities and Digital Technologies for Shaping the Future", 25–30 June 2023, Florence, Italy

Figure 1. The 3D digital documentation campaign: 1_Museu do Ipiranga 2017, 2_Monumento à Independência do Brasil 2018 and 3_Parque da Independência / Casa do Grito 2022 (Pictures area= 850m by 200m).

Discussions on the construction of a monument in the neighbourhood brought, in 1881, the government to resort to lotteries to raise money for the project. Finally, the project of the Italian architect Tommaso Gaudenzio Bezzi was chosen, and the works began in 1885, under the supervision of the master builder, also Italian, Luigi Pucci. It was completed with the border garden, designed by the Belgian Arsène Puttemans in 1907 and inaugurated in 1908 (Fonseca, 2005). On the other side of the Ipiranga Park, a few years after the inauguration of the Ipiranga Museum, it was built the Independence Monument (International competition in 1917). The project by sculptor Ettore Ximenes and architect Manfredo Manfredi was selected and it was inaugurated in 1922, during the celebrations of the Centenary of Independence (Salmoni & Debenedetti, 1981). Since then the Ipiranga park became the venue where the independence from Portugal is celebrated and remembered.

2. THREE SCANNING CAMPAIGNS, A WHOLE DATASET

2.1 The digitization of the area

One of the most important places in the history of the State of São Paulo Independence is the monumental and urban complex, which is the focus of the integrated 3D survey and HBIM modelling approach described. The project combines goals of valorising and understanding various narratives related to the Cultural Heritage under consideration with objectives of memory preservation, restoration and adaptation efforts, accessibility, and security of the structures and urban areas (Balzani et al., 2020).
Furthermore, due to functional adaptation requirements over time, both the *Monumento à Independência* and the *Museo Do Ipiranga* have changed. Therefore, engineers and architects were the main target audience for the integrated digital documentation of the state of the art of sites to provide technicians with digital memory and digital tools to manage the historical places and their modifications over time (Bianchini et al., 2018). The digital survey protocols that were put into place were meant to provide, at the same time, adequate documentation support to represent the technical, figurative, as well as literary and historical context, related, for instance, to the multi-layer interpretation of the monument.

The developed 3D survey campaign is implemented to assess the accuracy of the digital data in relation to the associated two- and three-dimensional techniques of representation as well as the integrated digital information system (Georgopoulos, 2017). The use of the topographic survey in conjunction with the Terrestrial Laser Scanner (TLS) survey pursues several goals, including the verification and control of the geometric and morphological characteristics, from the urban-architectural scale to the detailed scale, with a view toward the accessibility and usability of the database developed and the subsequent implementations, also carried out using a variety of survey instruments and techniques.
The further segmentation of the models aims to enable database accessibility, usability in Scan-to-BIM procedures, and eventually visualization in integrated digital platforms for communication. Additionally, the development of the comprehensive database has then made it possible to start initiatives for the transfer of technology and training for local technicians. In fact, technicians from the H+F Arquitetos studio, which won the open competition for the Museo do Ipiranga restoration, participated in a course in Italy in 2018 that was organized by the DIAPReM Laboratory and TekneHub of the University of Ferrara. The course concentrated on using the three-dimensional database to verify the different stages of the project and construction site, considering also the potentials of damages detections and degradation identification (Gonçalves, 2017).

2.2 3D survey of Ipiranga Museum and BIM Model (2017)

In 2017 the Museu do Ipiranga was digitally documented by laser scanner based on topographic net (Leica P40+TCRP 1203) to create an accurate georeferenced point cloud database.
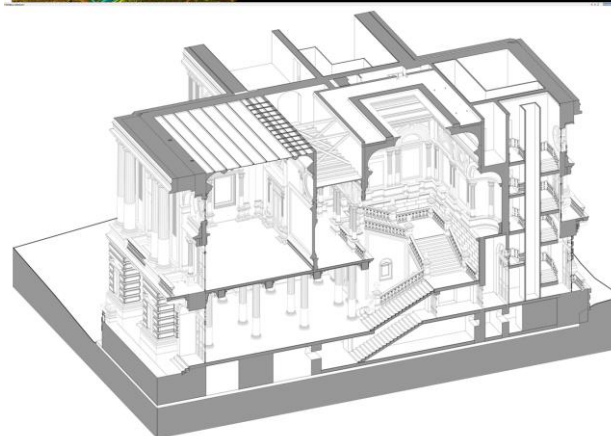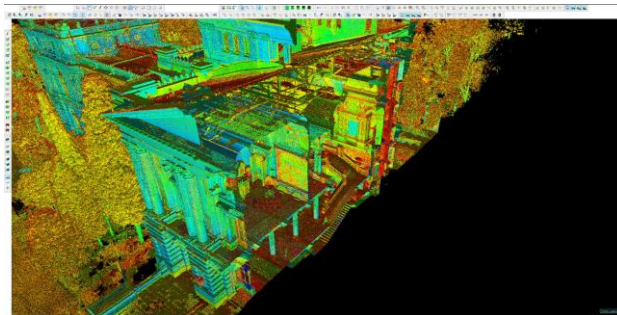

Figure 2. The Scan-to-BIM process by digital data of the Ipiranga Museum (Leica Cyclone® and Autodesk Revit® Software).

This was intended to assist the restoration process (completed in 2022) and offer a HBIM model of the Museum. The survey

The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-2-2023
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Humanities and Digital Technologies for Shaping the Future", 25–30 June 2023, Florence, Italy

campaign was carried out with the goal of recording the building's whole layout by a representation detail up to a scale of 1:20 (Figure 2).

The restored museum opened in 2022: the conservation projects was based on this 3D dataset used by the Z+F architectural practice to optimize the adopted solutions and to verify every decision by an accurate check through point cloud enquiring.

2.3 3D survey of Independence Monument and BIM Model (2019)

Beside the 3D survey (Leica P20+TCRP 1203), on the Monument were also applied Building Information Modeling tools (Figure 3) based on Scan-to-BIM approach, considering the knowledge requirements for data representation and visualization throughout the project phase, as well as the later requirements for knowledge, management, usage, and improvement by multidisciplinary teams (Parrinello et al., 2019). Furthermore it must be considered that a powerful strategy to boost learning capacity is through the emotional effect of a narrative form of dissemination, especially for historical and cultural contexts (Dickey 2006).
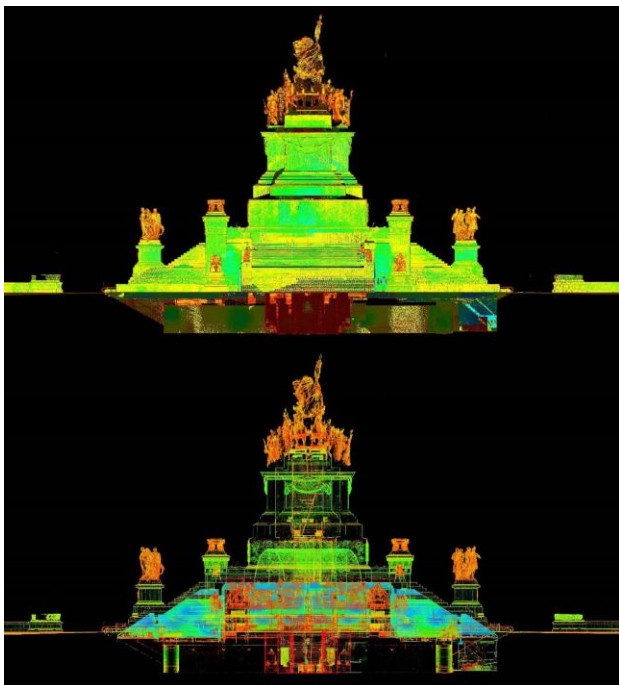

Figure 3. Cross sections of the dense database of the Independence Monument in São Paulo with different layout of visualization.

2.4 Digital survey of Ipiranga Park (2022)

In 2022 the third step of the documentation activity (Leica C10+Leica BLK+TCRP 1203) was completed joining the previous database with the results of the scanning campaign of the Independence Park.

Topographic net played a crucial role at this stage considering the ground morphology and the vegetation on the site.

The only way to pass on to future generations both the monument and the cultural heritage it protects is through ongoing talks, writings, seminars, technology transfer events, and preservation efforts.
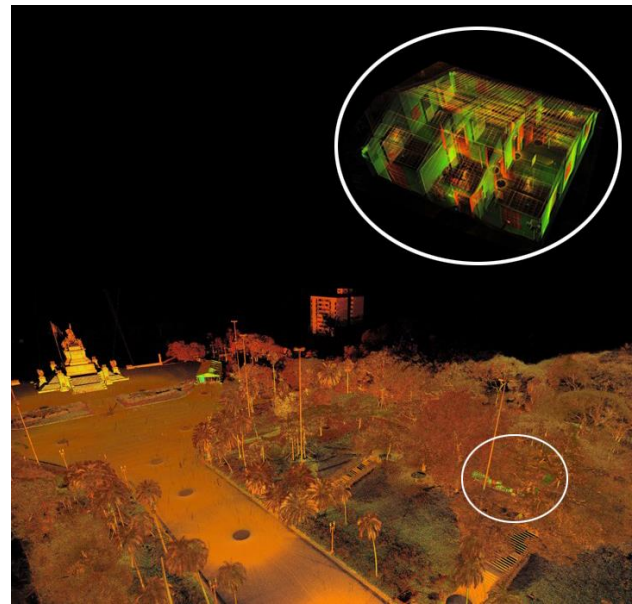

Figure 4. Digitization of the park area (3rd step of the whole laser scanning campaign) with special attention paid at the small traditional house built on 19th century.

Moreover, the small house called "Casa do Grito", was also digitized with a denser point cloud in order to allow future investigation on this 19th century building (Figure 4). This building, part of the complex, during the 80s was the object of archaeological research and underwent restoration work that sought to correct the excesses of previous interventions. In 2007, it underwent a new stage of restoration and conservation, and was re-inaugurated on 7th September 2008. The full point cloud could now improve the activities to foster the enhancement of this built heritage and its preservation.

3. DATA REGISTRATION

3.1 Data integration

The approach of integrating digital terrestrial survey methodologies and tools has been the focus of the work, which aims to create databases and 3D models that are trustworthy and implementable throughout time (Weinmann, 2016).

The use of topographic survey in conjunction with surveying with TLS technology and the available 3D data through the platform GeoSampa (Figure 5) allowed the researchers to implement the existing database (Tommasi et al., 2019).

GeoSampa is a portal coordinated by the Municipal Secretariat for Urbanism and Licensing (SMUL) which follows the guidelines of the Strategic Master Plan (PDE).

It gathers georeferenced data on more than 350 layers relevant to the city of São Paulo, such as zoning, public transportation network, libraries, schools and parks, geotechnical maps and data on population among others, including land parcelling data (De Lima et al. 2017).

The charge for sending the data to be made available on the GeoSampa portal is the responsibility of each of the municipal departments, also involving SEL, which in 2015 implemented the Geoprocessing and Georeferencing Technical Group - GGEO in order to organise the sharing of data from the entire collection relating to land parcelling.

In 2021, the portal broke a record and logged more than 2.6 million accesses.
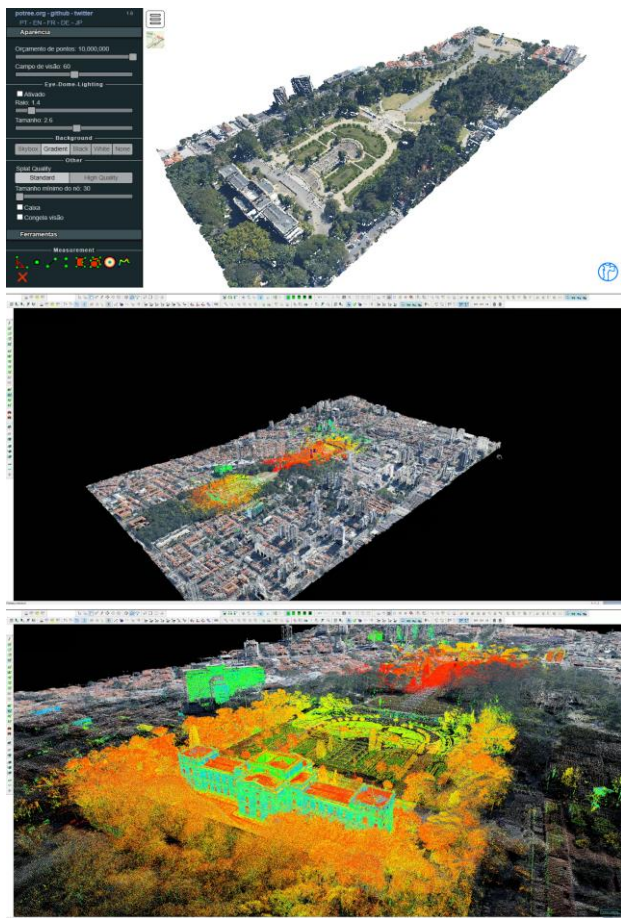
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Figure 5. The joining process of the whole point cloud database and the local GeoSampa platform (top image) shows the feasibility of the integration of the two sources of data by Leica Cyclone® software.

GeoSampa has been recently upgraded with the features linked also to cultural heritage. From this new feature, the user of the digital map of the city can check where are located the public facilities that pay tribute to national and international personalities, besides consulting their biographies.
Information about protected assets, art works and monuments in public spaces and even records of places which served as stages of repression or resistance due to the military dictatorship were already available.
In addition, the digital map user had the opportunity to consult the complete archaeological heritage of the municipality.

4. DATA IMPLEMENTATION

4.1 Between LOD, LOG. and LOI

In the context of Building Information Modeling (BIM) and, specifically, Historic Building Information Modeling (HBIM), the concepts of LOD (Level of Development), LOI (Level of Information), and LOG (Level of Geometry) are crucial for determining the level of precision of the 3D models created (Brumana et al., 2018). For the models created for the Ipiranga Museum and the adjacent Independence Monument, both unique buildings, it was chosen to develop digital models with high geometric precision and simplified informational content.

Defining a LOD can be challenging, especially for models of complex historical buildings where it is not possible to achieve the necessary informational detail. However, based on the Italian regulation 11337, the reference LOD corresponds to an LOD F, which is equivalent to an LOD 350.
To further specify the precision of the HBIM models created is necessary use the LOG. The LOG can be considered as an additional specification of the LOD, related solely to the geometric aspect of the model but it is necessary to use in historic buildings because it is very difficult to model the geometries in 3D due to the decorations or complex shapes.
So, the reference LOG is relatively high, as all interior detail and decorative elements have been created in the museum, while outside the monument, all statues have been created as families. The decision to focus more on the LOG than the LOI (Di Giuda et al., 2017) is driven by two main factors: the availability of very accurate and definitive base data, obtained through laser surveying, on which to base the modeling; and the need to have the elements in place to insert information, thinking HBIM models that could be containers and then populated with the information.

4.2 Museuo do Ipiranga

The HBIM model developed for the *Museu do Ipiranga*, given its considerable size, was thought as an integrated model that includes both structural and architectural aspects, ensuring a comprehensive and coherent analysis of the entire building. However, within this project, the MEP systems discipline was not considered, focusing instead on the analysis of the architectural discipline of the BIM model (Osello et al., 2018).
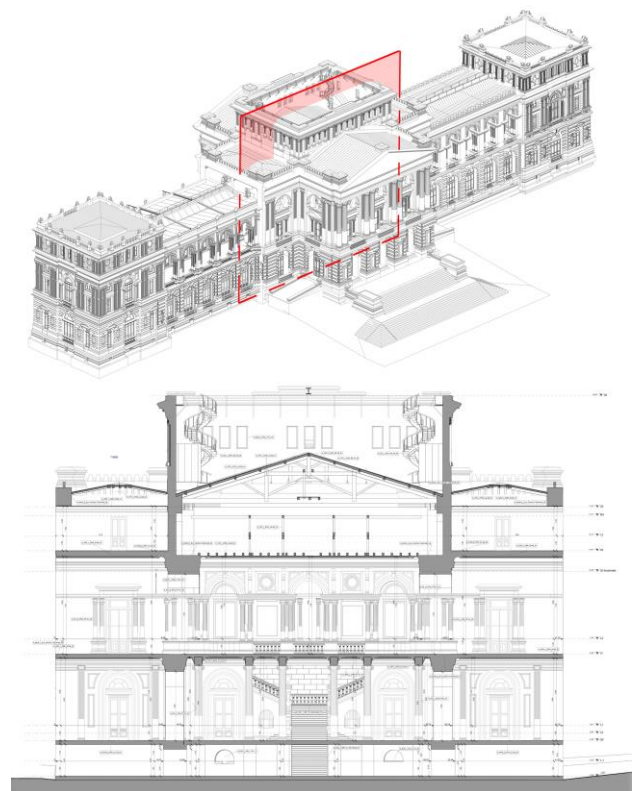

Figure 6. HBIM Model of Ipiranga Museum and section extracted from it (Revit® software).

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To guarantee high accuracy in such a large model, it was decided to divide it into five sections, the two towers at the ends, the two galleries on the right and left, and the central part. The division was necessary for various reasons, including the management of the starting data, as the point clouds resulting from an accurate external survey had a very high computational weight, and the simplification of management, allowing to open and focus on a single portion of the building.

The five models are all georeferenced and can be combined into a single coordination file, allowing the visualization of the sections building together (Figure 6).

The creation of the BIM model was based on point clouds, and to simplify its management, the software used was Autodesk Revit. The modeling procedure was:

-Generation of a specific template and a Recap point cloud. The template contains the basic information needed to create the five common models.
-Definition of the starting levels common to all files, making the project more easily manageable avoiding collaborative commands.
-Creation of the main volumes using system families such as walls, floors, and roofs, defining their type and thicknesses,
-modeling of stairs and vertical connecting elements,
-and finally the creation of loadable families such as windows, doors, beams, decorations, and other essential components for understanding the building (Chiabrando et al., 2016).

In these projects the modeling of the individual portions was carried out by different people at the same time, using separate georeferenced clouds, without the use of particular worksets or tools.

The informative data in the project include the materials assigned as instances to individual components and the insertion of "spaces" for the definition of areas within the project. Furthermore, all components have been named according to a naming convention, created through an Excel spreadsheet, which defines the family name, the type name, and the type mark.

4.3 *Monumento a Indipendencia do Brasil*

Creating a BIM model of a monument presents several challenges. BIM models software are thought for the construction of new buildings, and software does not always manage the complexity of the object.

Although, with difficulty, it is possible to adapt the software for HBIM models, it is important to consider that some simplifications have been necessary.

There are two main considerations to understanding the HBIM model: the monument features numerous decorative elements, such as statues, which are not easily modeled through BIM modeling programs; and a significant part of the monument is underground, so even if the historical data was available, it was not possible to model all elements.

Taking these considerations into account and counting the smaller size of the monument compared to the *Museu do Ipiranga* model it was possible to use a different approach.

It was chosen LOD F, which corresponds to a LOD 350. Three models were generated for the project: an architectural model, a structural model and a coordination model that allows the visualization of the two ARC and STR models together. The division was necessary for the analysis and understanding the architectural and structural part of the monument and for the management of the statues present in the monument.
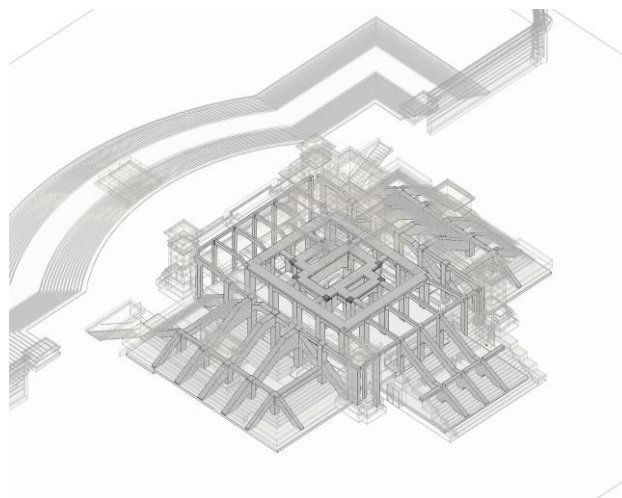

Figure 7. The structural BIM model of the Independence Monument (Revit® software).

The STR model produced for the monument includes all load-bearing structures, such as walls, vaults, floors, and roofs. These were modelled starting from the point cloud obtained from the laser scanner survey, removing the decorative component and isolating the structural part of the building, often through critical analysis or historical data (Figure 7).

Figure 8. Portion of the ARC BIM model where the sculptural ensemble (grey) was inserted by mesh of the objects, subsequently exported as .dxf files and then imported into Revit.

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The ARC model, on the other hand, is composed exclusively of architectural and decorative elements that perfectly overlap the load-bearing structure of the building. In this model, many complex elements are present, such as thrones, statues, and others, which cannot be replicated with simple modeling as used in BIM projects.

To solve this problem, meshes have been made from the survey data. Recent advances of gaming engines focus on and allow for an excellent visualisation of mesh data. Aforementioned data sources can be converted into mesh objects and imported in BIM model (Vincke, 2019).

Using a Meshlab algorithm, it was possible to generate a highly accurate mesh of the objects, subsequently exported as .dxf files and then imported into individual Revit families (.rfa) using a generic model template assigned to the element proxy category (Figure 8).

The families were then labelled according to a naming convention and imported into the correct position within the architectural Revit project.

Thanks to this methodology, it was possible to import complex objects, increasing the project's LOG, and being loadable families, it is possible to add new parameters and implement the reference LOI information. Although this procedure makes the model heavier from a computational point of view, it contributes to completing the project and enhances the understanding of the entire monument.

5. RESULTS AND FUTURE STEPS

One of the main results was the optimization of a survey protocol (Di Giulio et al., 2017) that is based on more than 20 years of experience in the digital documentation of cultural heritage and that enables the geometric and angular control necessary to achieve the required level of accuracy while also optimizing the redundancy of the digital data quality. An integrated topographical method was consequently selected over a morphological approach, which is now more popular due to the increased applicability of terrestrial laser scanner technology.

The survey protocol (Maietti et al., 2021) required the development of a first-level topographic network, second and third-level target networks, normalization, and registration of the overall point cloud model to manage angular accuracy and elevation deformations, and segmentation of the overall data model by areas related to the purposes of the surveys.

Furthermore, the website www.ipirangadigital.org launched on the 200th anniversary of the Brazilian independence in 2022 (conceived in Portugues language to reach the widest public coverage) is still growing in terms of graphics and information and it will be a digital place of knowledge and learning possibly also through playful digital activities. Undoubtedly, the field of digital storytelling has drawn a new line of inquiry into cultural heritage. The interactivity is the most distinctive component that the digital era has added to narrative structure, even though there were a few examples of interactive narration that existed before it became popular, such as interactive novels, role-playing games, etc. (Goodson et al., 2010).

The buildings built to celebrate the Brazilian Independence from Portugal demands to be conserved but it is its intangible dimension that needs special care.

The history of the place should be told taking into account the assumption that the story's events actually live between the narrative dimension and the reality dimension, inside the user's knowledge environment and culture (Miller, 2014).

The effort to release all digital information via the website Ipirangadigital.org intends to raise awareness among the populace about some plot elements that extend beyond the parameters of the novel.

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