3D SURVEY FOR TECHNOLOGY TRANSFER: LARGO DA MEMORIA IN SÃO PAULO, BRAZIL

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ABSTRACT:

With the broadening of the concept of Cultural Heritage - which now, in addition to great monuments, also includes urban cores, landscapes and intangible manifestations - the possibilities for heritage conservation actions have also expanded. Nowadays, in a globalised world immersed in technologies that are evolving with astonishing rapidity, precisely technological innovation can be an important ally for the enhancement of historic public spaces.
On the occasion of the bicentenary of the placement of the existing obelisk in the "Largo da Memória" public space (in the centre of São Paulo), a three-dimensional survey pilot project was carried out in cooperation with local municipality. One of the objectives of this project was to develop an example of "good practices" for the conservation of urban space and a possible benchmark for the use of digital data by local technicians avoiding expansive software and hardware solutions. Thus, the three-dimensional survey of the area helped to evaluate the effectiveness of the optimisation of the integrated procedure, taking into consideration the importance of the public space of the Largo, at the intersection of Xavier de Toledo and Quirino de Andrade streets. Technology transfer actions played an important role within the whole process, enabling further evaluations for the conservation of the place by local authorities.

1. INTRODUCTION

1.1 Research overview

Nowadays, digital technologies and ICT tools applied to heritage buildings and sites provide an incredible opportunity to encourage both economic growth and knowledge. One of the first steps in this direction is to promote human networking and the exchange of experiences and skills amongst different groups and communities (Ronchi, 2008). The last two-decades technological development has led to the practical application of digital tools for the preservation and enhancement of urban districts and small open spaces.
Today, it is clear that the architectural surveying of large urban environments requires the design of multi-scale and multi-level support, capable of incorporating the knowledge of different experts. A multi-scale approach is necessary for supporting cartographic urban and architectural data structures, involving syntactic analysis related to morphological aspects. Furthermore, 3D techniques in 3D GIS – including 3D data collection, 3D data model, 3D data management and visualization – have been applied in fields such as urban planning and virtual city (Ying et al., 2012).
3D digital survey of urban environments can be performed applying different technologies and procedures, with different accuracies according to specific aims; beyond the different technologies that can be used, for the documentation of historical urban spaces - which have undergone transformations over time - it is essential to apply a critical approach that answers specific research questions and, above all, to adopt a replicable methodology capable of forming new skills that combine direct knowledge with the great potential that 3D documentation can offer.
Cultural significance, interpretation and classification of spatial qualities in 3D survey datasets (De Marco and Pettineo, 2022) of historical urban areas are essential to support "memory" documentation for preservation, knowledge processes and enhancement and conservation strategies, in addition to perform monitoring of changes in urban features and spaces.
The current emergency scenarios due to climate change and other events that put urban environments and cultural heritage at risk (Maietti, 2022) are also to be considered to make the best use of the digital survey technologies available today.
In this framework, the key factor seems to be the training of heritage managers, users and stakeholders, focusing activities on capacity-building programmes able to conceive real technological transfer, from young architecture and engineering students (future professionals) to researchers and international academics (Novello et al., 2011), up to administrators and government agencies.
One of the main requirements in the field of heritage documentation is indeed the interdisciplinary collaboration and the integrated application of digital technologies, allowing teams of researchers, professionals, curators, government experts and students to exchange skills and expertise, fostering the training of local emerging professionals in adopting these techniques to make documentation more accurate, reliable and sustainable (Reina Ortiz et al., 2021).
Among the research projects carried out worldwide in different countries, it is possible to highlight this proposed training activity in São Paulo's metropolitan region. Here, the DIAPReM centre (Development of Integrated Automatic Procedures for Restoration of Monuments) of the University of Ferrara in cooperation with the local Municipality and Mackenzie Presbyterian University – was asked to digitally document a peculiar public space, witness of the fast growth of the city: the Largo da Memória (Figures 1, 2 and 3).
The aim of the paper is to present the digitisation of a historical space that is highly representative of the urban development of São Paulo with the aim of technology transfer and progress of knowledge and assessment of this urban area. The overall goal goes beyond the 3D survey of a urban site, addressing the importance of training and capacity building in the use of digital data and technological capabilities, promoting innovation in

heritage assessment and conservation and empowering people and businesses to make the most of digital data.

Figure 1. View of Largo da Memória, a space built on the site previously known as "Piques", a triangular-shaped ravine that served as the entrance and exit of the city of São Paulo for the troopers who transported goods.

Figure 2. Largo da Memória photographed from the other side.

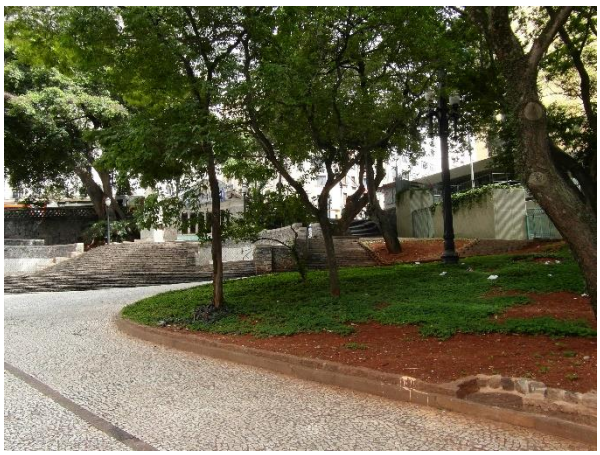

Figure 3. To the sides, green spaces surround the Largo da Memória.

1.2 The case study

Until the middle of the 19th century, the city of São Paulo did not resemble the metropolis it is today. It was the entry into the west of the country and a resting place for traders who travelled between the coast and the interior. Largo da Memória’s origin is related to such paths.

In 1814, an obelisk was built in the region of the current Largo (the Pyramid of Piques, currently the obelisk of Memory), which marked one of the boundaries of the new city, in the confluence of two important roads – the slopes of Piques and Sete de Abril (Figures 4, 5, 6 and 7). This place was a landmark for the commercial troops arriving or departing from São Paulo.

From 1870, with the arrival of the railroad to the city, the Largo lost its role, being forgotten until 1922. In this year, the centenary of Brazil's independence was celebrated, a moment marked by several works to beautify the city. One of these works was the enhancement of the old obelisk, considered the oldest monument in São Paulo.

The project by architect Victor Dubugras redesigned the area, creating spaces for passage and permanence in the unevenness existing there.

The project considered the relocation of the monument next to a fountain and an exedra with a tiled panel. An old vasca existing on the site for feeding pack animals was the inspiration for the fountain, while the built set is related to the neo-colonial movement of Brazilian architecture.

Also, the proximity to one of the main libraries in the city made the place become a meeting point in the central region. Years later, in the 1970s, the Largo was once again forgotten: the construction of a subway station nearby, with escalators, caused the flow that existed on the stairs to migrate, bringing degradation to the site. Despite this degradation, it was in this same decade, in 1975, that the site was officially recognized as cultural heritage by the state council for the preservation of cultural heritage (CONDEPHAAT), for its historical and urban values.

Figure 4. Map of the city of São Paulo in 1881. Archive: SEP-GESP, Instituto Geográfico e Cartográfico.

Figure 5. 1881 map detail showing the location of the Largo da Memória in blue. Archive: SEP-GESP, Instituto Geográfico e Cartográfico.

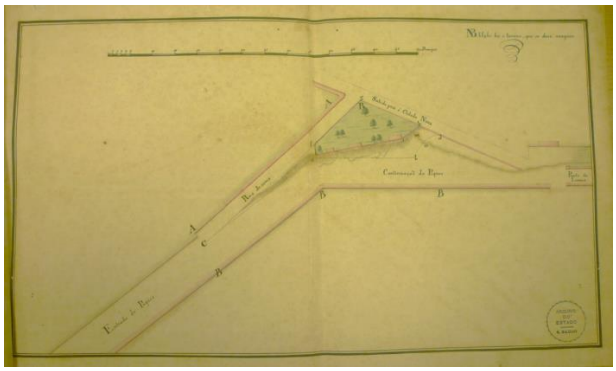

Figure 6. Project for Largo da Memória. Daniel Pedro Muller. Archive: Arquivo Publico do Estado de São Paulo.

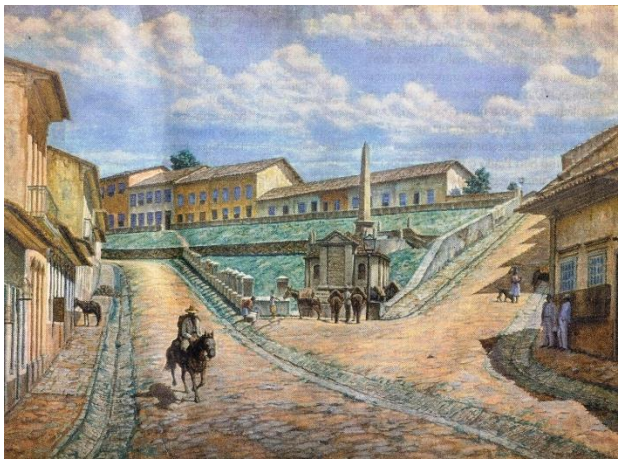

Figure 7. Largo da Memória in a XIX century representation. Archive: Museu Paulista.

A new moment of recovery took place in the early 2000s. In the midst of several projects that sought the rehabilitation of the central region, one of them restored the tiled panel in 2005 (Oliveira & Matsuy, 2013), starting a new period of its enhancement. These actions culminated in 2014, within celebrations for the bicentenary of the Obelisk. At that time, there was an ongoing project in the city to recover existing fountains in the central region, including Largo da Memória (Huelsen & Graglia, 2016). Within such celebrations, the project presented in this article was carried out.

2. RELATED WORKS

2.1 State of the Art

This investigation, using operative tools applied to the project, is aimed at giving a clear picture of the current possibilities offered by technologies for the conservation and enhancement of urban sites involving the skills upgrade of local stakeholders. Since the 2000s, the 3D technological support to the field of urban planning has improved the knowledge and analyses on public spaces.

Through the work of several research centres, mainly located in the US and Europe, operational methodologies involving 3D geometric models and virtual representations of the urban layout have been developed. The creation of 3D models of cultural heritage and archaeological objects and sites in their current state requires a robust methodology able to capture and digitally model the fine geometric and appearance details of such sites (Remondino, 2011; Bakula et al., 2019). This approach can effectively set up a wide range of interdisciplinary analyses (Figure 2) related to the preservation of sites and architectural structures built within their boundaries (Zlota et al., 2014). It is also important to highlight the necessary adjustment of North American and European methodologies to different local realities, especially in the Global South (Cuperschimid et al., 2019).

Numerous studies and research have been undertaken in the field of digital surveying at an urban scale, both to manage large-scale aspects (such as environmental and infrastructural ones) and to document historical centres transformations with the aim of knowledge and conservation through 3D models to visualize, assess and manage different data for different purposes (La Russa et al., 2021).

In the field of technology transfer, an additional essential issue is related to the possibility to deal with low cost technologies, allowing training that does not require a large initial investment in tools and software, but is based on accessible methodologies to train first and foremost a critical approach to digital surveying (Morena et al., 2020).

Today, there is a need to speed up digitization processes, at a global scale, also to respond to possible risk of loss, natural disasters and anthropic damages. A reference in this direction is the action promoted by the European Commission called “Common European data space for cultural heritage” and aimed at accelerating the digitisation of cultural heritage assets to protect and preserve those at risk, and boost their reuse in domains such as education, sustainable tourism and cultural creative sectors (European Commission, 2021). The Commission encourage to digitise by 2030 all monuments and sites that are at risk of degradation and half of those highly frequented by tourists.

This recommendation will contribute to the objectives of the Digital Decade by fostering a secure and sustainable digital infrastructure, digital skills and uptake of technologies by businesses, in particular SMEs. The Digital Decade policy programme aims at different levels of digitisation in different areas, including the improvement of skills.

To reach the digital targets and objectives, the European Commission will accelerate and facilitate the launch of multi-country projects, large-scale projects that no single Member State could develop on its own, promoting a human-centred digital agenda on the global stage and promoting alignment with EU standards.

Launching the European Data Space programme, the Commissioner for Internal Market, Thierry Breton, said: “We owe the preservation of our European cultural heritage to future generations. This requires building and deploying our own

technological capabilities, empowering people and businesses to enjoy and make the most of this heritage. We must take advantage of the opportunities brought by artificial intelligence, data, and extended reality. The European data space for cultural heritage will promote creation and innovation within the cultural heritage sector, and beyond, in education, tourism, and cultural and creative sectors".

The creation of awareness of heritage values in urban environments and the training as one of the most important means to understand how digital technologies can be used to assess conservations needs are among the topics faced in the Policy Guidance for Heritage and Development Actors (Labadi et al., 2021) by ICOMOS - International Council on Monuments and Sites, to demonstrate the potential for harnessing heritage to assist in achieving sustainable development and address the United Nations Sustainable Development Goals (SDGs). Moreover, nowadays digitization processes are at the centre of several studies related to issues such as the lack of resources, non recognition of the value by local people or authorities, both in developed and developing countries, to be faced thanks to online geo-crowd sourcing systems (Dhonju et al., 2018) or integrated services platforms (Apollonio et al., 2019; Tommasi et al., 2019).

3. APPLIED METHODOLOGY

3.1 Digital documentation: tools and methods

Since 1997, DIAPReM centre at Ferrara University's Architecture Department has been conducting research actions on protocols and methodologies for digitizing cultural heritage. The centre is also involved in education and concentrates its efforts on capacity-building initiatives that enable actual technical transfer among various stakeholders, including young students of engineering and architecture (future professionals), researchers, and international academics. Some of the research centre's global initiatives have been carried out in Brazil, with a focus on the metropolitan area of São Paulo. Among these the Largo da Memória is the most remarkable public area analysed, a place that has witnessed the city's rapid growth. The DIAPReM center was invited to digitally document this space (Figure 8) in collaboration with the Faculdade de Arquitetura e Urbanismo of the Mackenzie Presbyterian University and the local Municipality.

The survey was developed using a Leica C10 Laser Scanner (Lidar technology) splitting the data capturing phase into 46 scan stations, the data were recorded in a point cloud form, and the database of the area identified for the pilot project (Figure 9) was provided in *.imp version compatible with Cyclone 8.0.3 and *.PTS interchange format to be used with open-access systems such as CloudCompare, a 3D point cloud (and triangular mesh) processing software.

3D documentation activity	
3D survey equipment	Laser Scanner Leica C10
Topographic equipment	Leica Total Station TS06 plus 2"
Number of 3D scan stations	46
Point cloud coordinates	570.105.364
Local stakeholders trained	DPH Prefeitura de São Paulo (SP), Universidade Presbiteriana Mackenzie (SP), Estúdio Sarasá (SP)

Table 1: Documentation data.

Particular attention was paid to the documentation of the pavement layout and its state of conservation, as well as the anthropic degradation present on the surfaces of the monument (Rolim et al., 2016). Furthermore, besides the geometric-morphological investigation, a photographic survey was also carried out of the public space as a whole, the street furniture and decorative features (as well as the main morphologies of deterioration) to record the general state of conservation.

The technology transfer process was only partially focused on the mere technical issues. The survey was developed mainly with the aim of sharing a methodological approach, which, at a training level, went beyond the application of the specific tools used to document the Largo da Memória.

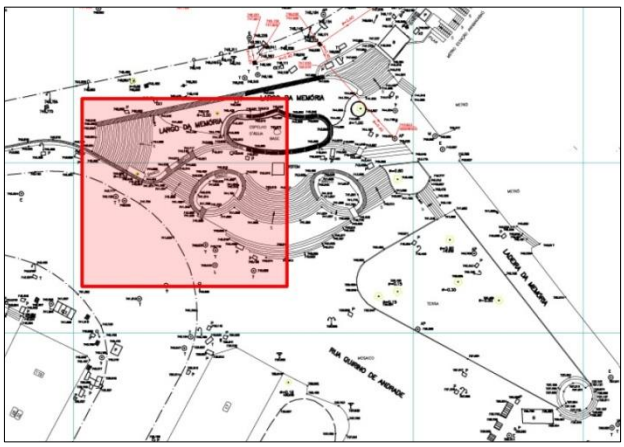

Figure 8. Survey area of the pilot project for Largo da Memória.

In this specific survey, terrestrial laser scanning and photographic survey allowed to achieve a sufficient dataset to start training the staff from the São Paulo Municipality and Mackenzie Presbyterian University to data achievement and management (Figure 10), and mainly to train to the meaning of collecting digital data strongly related to heritage significances and to the main final output required by the survey.

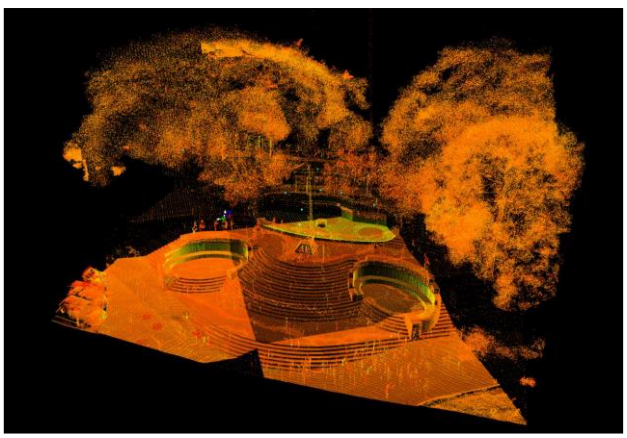

Figure 9. View of the point cloud model of "Largo da Memória" public space.

In general, the best way to approach a survey at a urban scale (merging different levels of detail and accuracies according to the specific features of the context) is to integrate different sensors and image-based techniques (Chiabrando et al., 2019).

Numerous uses can be found for gathering 3D data in the subject of preserving urban and heritage assets, and it can be combined with other technologies to increase information about a city or location in general (Brusaporci, 2015). In terms of acquisition speed, data accuracy within the appropriate working range, portability and ease of use, and interface flexibility, the main surveying technical tools (3D laser scanner combined with total stations and digital cameras) are continuously upgraded (Docci et al., 2011). A level of information and technical knowledge sufficient to absorb the true potential of use is not always supported by the degree of innovation that the industry gives to the professional market.
Numerous research institutions have been creating software and techniques that have been optimized for this objective. These instruments facilitate and lower the cost of technological transfers from the producing sector to the construction network (professional engineers, service providers, ministries, local governments, and building and restoration firms). Professionals and academics are currently dealing with challenges linked to the cost-effective generation, administration, and use of 3D data when balancing innovation and documentation tactics (Lualdi, 2011).

Figure 10. Axonometric section focused on the analysis of the different levels of urban space, and their morphological and altimetric relationship.

3.2 Urban scale digitization: toward data integration

Working with various software at a multi-level approach is essential inside the framework of urban areas digitization. The point cloud must first be used more effectively. It may be viewed, explored, sliced, and measured straight from it, and it can output 3D, 2D, and raster data (Figure9). On the other hand, using the conventional working procedure, the point cloud imported into CAD software can be utilized to extract 2Dprofiles and then produce the 3D model (Tommasi et al., 2016) with BIM software that can generate 3D objects and parametric entities to obtain a more semantic database (Di Giulio et al., 2017).
The great information density of morphological data is made possible by 3D laser scanner survey technology. The "geometric memory" of a public place can be studied for research purposes or utilized as the foundation for conservation and restoration projects when these data are organized in a database throughout time.
In order to establish a technique for the documenting of the urban area prior to the restoration and conservation interventions, a pilot project of a three-dimensional survey of the urban space of Largo da Memória was completed.
The three-dimensional survey of the urban space will make it possible to evaluate the technological effectiveness of the integrated procedure given the overall survey of public spaces in the city (Rossato, 2022).
Utilizing project-specific operational techniques, the investigation sought to provide a clear picture of the current opportunities presented by technologies for the preservation and enhancement of urban areas. Since the 1990s, public space knowledge and analyses have improved thanks to technological help in the field of urban planning.
Operational approaches using 3D geometric models and virtual representations of the urban layout have been established via the efforts of various research centres, primarily based in the US and Europe.

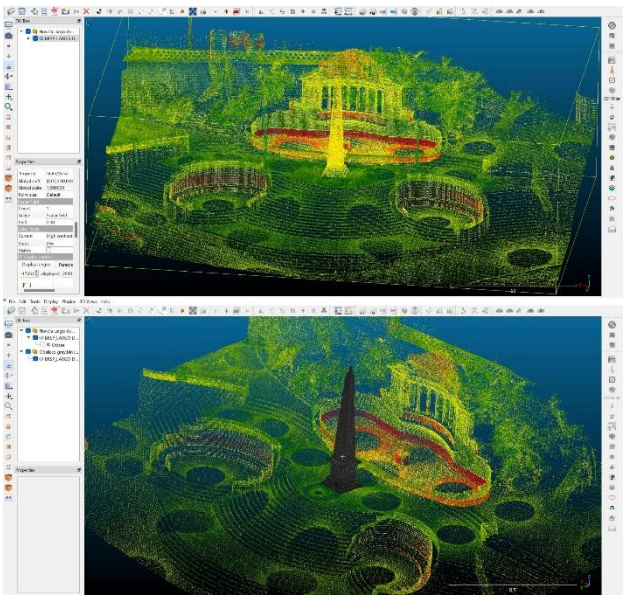

Figure 11. Training session on the use and exploration of digital data by CloudCompare software.

A GIS system might incorporate the digital survey of Largo da Memória and the computer-aided drawings to support initiatives for the preservation and restoration of the urban space in relation to the surrounding environment and geographic region.
Many GIS applications, including the creation of 3D building models as a crucial component of 3D city models, the detection of vegetation in urban areas, the terrain and object modeling for flood simulations, and the extraction of roof and facade surfaces for solar potential analyses, benefit from the integration of original 3D point clouds (Jochem et al., 2011).
A general 3D GIS standard is called the Feature Geometry Model. It supports three-dimensional coordinates and object classes for three-dimensional bodies, three-dimensional topologies, and three-dimensional surfaces.
While 2D raster and vector data in geodatabase systems have established and standardized models and structures, the integration of original 3D point clouds is still not specified or standardized.

At the moment several associations and research centres are focused on establishing standards and requirements for interoperability in the use of 3D point clouds.
Furthermore, processing original 3D point clouds is not a typical GIS operation; instead, it is primarily carried out using specialized point cloud, laser scanning, digital photogrammetry, and/or 3D modeling tools. A extremely flexible piece of open source point cloud software like CloudCompare does not offer a programming or database interface, for instance.
Anyway there are numerous instances of how point clouds can be used to great advantage in GIS applications, therefore the integration of large 3D point clouds as features in geodatabases is certainly feasible. Based on their proximity in 2D and 3D, point clouds and typical GIS elements can communicate useful information. By controlling point clouds in spatial databases, even general engineering projects (which aren't always related to traditional GIS applications) can be optimized. Workflows benefit from a combined storage and analysis of large 3D point clouds with other project data for a more effective urban project management (Meyer and Brunn, 2019).
The direction is to achieve digital interactive maps, 3D digital cultural heritage models, and linked open data, exploiting the high potential of web-GIS (Nishanbaev et al., 2021).

4. RESULTS

The digital survey of Largo da Memória and the computer-aided generated drawings could now be integrated into a GIS system to support projects for the restoration and conservation of the urban space with the environment and geographical area. Nevertheless, this laser-based surveying provides 3D support where traditional techniques can be incorporated.
Global merging does not fill all the details for professional requirements and must be completed with contributions of other research fields and applications in a multi-disciplinary approach (Finat et al., 2005).
A global model of Largo da Memória could aid tools for restoration and conservation planning, as well as for architectural and urban management with divulgation purposes.
From this idea, the survey worked as a starting point for discussions within the Municipal Heritage agency, regarding not only the survey itself. It was also considered how partnerships held in the process could contribute in the long term to that heritage conservation. The main challenge is to achieve continuity in the technology transfer started by the partnership, within local technology and human resources realities (Figures 11 and 12).
The pilot project was considered an example of good practices for the preservation of urban spaces. Four years after the work carried out in Largo da Memória, another similar initiative was carried out in Parque da Independência (Caldana Jr et al., 2021), with the same actors involved.
The Municipality remains struggling with the challenge of lack of infrastructure (both hardware and software) to systematically implement the laser scan technology. However, it continues to qualify its staff on the use of this technology, contributing to a more effective dialogue between public authorities and professionals who already incorporated 3D survey technology in their activities.
Beyond difficulty of access to equipment and resources to enable the management of databases with large storage capacity, there is also the requirement to establish conservation parameters and guidelines. A path that continues to be followed by public authorities in Brazil is the establishment of partnerships with civil society, particularly with universities, in order to enable better management of the cultural heritage present there.

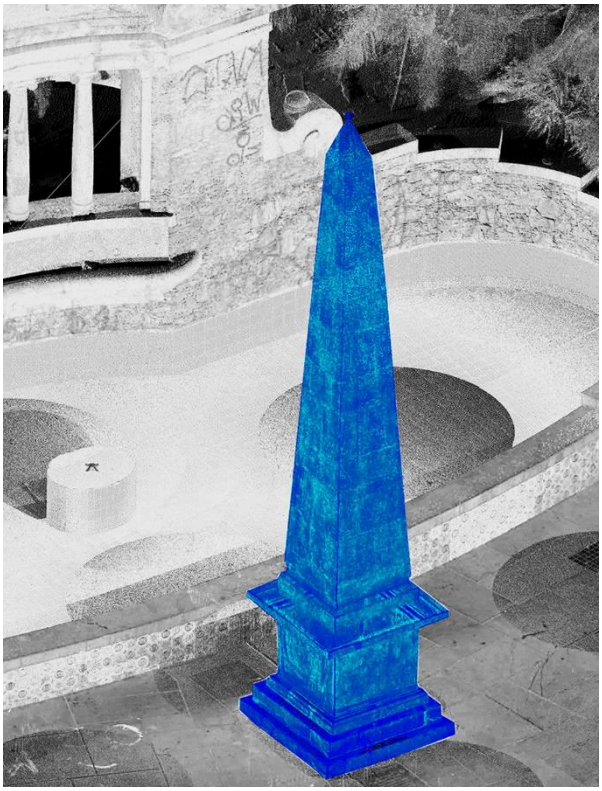

Figure 12. Example developed during training session for morphological segmentation of the point cloud of “Largo da Memória” by CloudCompare.

5. CONCLUSIONS

During the last two decades, private companies in cooperation with universities and research institutes have been testing instruments and techniques for acquiring 3D data, on various scales and degrees of accuracy, on architecture and urban spaces.
This approach is finally happening also in Brazil, a country where these techniques were habitually applied mainly on oil drilling sector. The sharing of experience such as the Largo da Memória 3D survey could improve - and expand - the use of these methodologies also in most diverse urban contexts (both at small and large scale) and preserve the memory (and the souls) of cities and districts.
Moreover, the Covid-19 pandemic crisis has highly stressed the need to improve digitization, at different levels, showing that invest in digital services and infrastructures as well as in training and capacity building for digital skills in the heritage sector is crucial.
Heritage organizations must be prepared to facilitate the sharing of cultural heritage assets and values through digital and on-line means (Europa Nostra, 2020).
While tangible heritage has been affected by the decrease of tourists and visitors (with a resulting negative economic impact), a positive impact was associated with technological and scientific opportunities for the digitization and transmission of knowledge (Kono et al., 2020), stressing once again the importance of be trained about the use of digital data.

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