Applications of Laser Scan and drone aerial survey in museums

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ABSTRACT: This study introduces some concepts and several applications of 3D Laser Scan (3DLS) for the survey of monuments, museum pieces, and sculptures, aiming at obtaining models, virtual models, films, virtual exhibitions, and resin models. In some cases, laser scan is complemented by drone aerial surveys, which lies within the field currently known as virtual reality or augmented reality.

KEYWORDS: Electronic model. 3D Laser Scan. Drone surveys. Virtual reality. Augmented reality.

RESUMO: O presente trabalho apresenta alguns conceitos e diversas aplicações da tecnologia Laser Scan 3D (LS3D) para o levantamento de monumentos, peças de museu e esculturas, visando a obtenção de modelos, maquetes virtuais, filmes, exposições virtuais e maquetes em resina. Complementa-se, em alguns casos, com os levantamentos aerofotogramétricos com drone e situa-se na área que vem sendo conhecida como realidade virtual ou realidade aumentada.

PALAVRAS-CHAVE: Maquete eletrônica. Laser Scan 3D. Levantamentos com drone. Realidade virtual. Realidade aumentada.

INTRODUCTION

3. Cf. Gonçales (2019).

Documenting, cataloging and generating copies of museum collections, especially in the case of 3D objects, requires measurements to be performed on the object to obtain its dimensions. Performing these measurements without touching the objects is safer and creates better conditions for preservation of the piece. Obtaining replicas also helps in preserving the original piece and allows tactile experience in some cases. Technologies known as 3D Laser Scanner (3DLS) use laser sources to perform remote and contactless measurements, provides digital information about the object and enable documentation and creation of electronic and physical models (through 3D printing), and digital reconstruction of pieces that have been damaged for some problem, such as pieces broken into parts.

In some applications such as topographic and architectural surveys of buildings and monuments, unmanned aerial vehicle photogrammetry (UAV), popularly known as drone, is a good complement to this technology.

This study provides essential information to understand the technology used and several examples of how to use this methodology based on the authors' experience.[3]

OVERVIEW OF STUDIES IN THE FIELD

Close-range photogrammetry has been used to model and build replicas of museum pieces and objects for many decades (since the 1960s). Several revitalized methods were enhanced by computerized numerical control machines (CNC) and computer-aided manufacturing (CAM), which allowed turning objects into several materials, but the major development was Terrestrial Laser Scanning.

When searching the applications of this technology, it is mostly used in the various branches of engineering: civil construction, topography, refinery, mining, naval engineering, mechanical engineering, among others. Many recent studies focus on productivity, cost-benefit improvement, and decreased teams.

In mechanical engineering, there are many applications in the field of vehicle body, engines, and parts. By derivation, applications emerged in other fields that also require 3D scanning of parts for various purposes: computational modeling, building of models, creation of replicas, construction of prostheses in medicine, among others.

4. Cf. Xiao; Furukawa (2014).

5. Cf. Wachowiak; Karas (2009).

6. Cf. Clough (2013).

7. Cf. Ball State University (2019).

In Humanities, the number of studies and publications is still scarce. Some examples are found in the area of Archeology, in reconstruction of historical ruins, survey of buildings as a base or for restoration project. Information are written in the form of case studies, provided by equipment manufacturers or dealers.

In Architecture, it is used for architectural survey, interior modeling, and Building Information Model (BIM), among others. From this point, it becomes easier to start interior reconstruction of museums and create virtual exhibitions. Scanning pieces of the collection to compose the exhibition is also necessary. In Xiao and Furukawa, [4] an example of this assertion can be observed. Their article focuses on the efficiency of computational algorithms of 3D view creation, specifically in the algorithm called inverse constructive solid geometry, describes the use of this technique at the Metropolitam Museum of Art and aims to recreate interior scenes (*indoor*) and to combine good resolution photos with architectural surveys using 3DLS for photorealistic effect. It also develops a visualization system that allows easily going from the overview (museum plant) to the view of a room and its objects, with fast magnification and detail reduction (zoom control) processes. The work is useful to know the potential of this type of application.

Wachowiak and Karas[5] make a small review of the current status of 3D image capturing in the field of cultural heritage and methods of object duplication, through specific high-tech, high-resolution equipment (submillimeter precision) that applies to objects with high-dimensional complexity and shapes, and, consequently has a high cost, being much more expensive than 3DLS. It is equivalent to laboratory equipment and applies to relatively small objects such as skulls, statuettes, plates, and not to buildings, archeological ruins, and larger sculptures. In our field, exploring the potential of equipment that are also aimed at large objects, whose cost or loan is relatively affordable and whose precision is sufficient, is important.

In the last decade, some museums and universities started research on concrete fields, as pointed out below.

The Smithsonian Institution published an interesting book on the topic: *Clough*.[6] This work, focused on principles and master ideas, also reports, albeit in a generic way, the efforts of this institution to employ various technologies to make its collections and programs available to the general public. This study is a good overview of this effort of the museum, without detailing methods, equipment and processes, due to the nature of the study and its target public.

The Ball State University, in Indiana (USA), has been working on three-dimensional sculpture survey. The *website* of this university[7] contains basic information on the project to model sculptures using handheld scanner, which is ongoing. In the future, these models will be made available in a 3D virtual reality environment that will allow the visiting user to view these sculptures using special glasses, including a model of the context in which they are placed.

The Shuler Museum of Paleontology in Dallas (Texas) uses laser scan for reconstitution of archeological skeletons, as reported on its website.[8] This is one of the three technological areas of the museum, which has a portable 3DLS for submetric objects. No further details are provided, but the information they are searching in this area are interesting for a possible contact. The study by Kuzminsky and Gardiner, in the same area of Paleontology,[9]points out the potential of 3DLS in this field, focusing on the study of skeletons and the creation of models as a form of preservation and research tool, replacing the original. ***

The Science Museum of London, in partnership with a scanning laboratory, develops virtual gallery works such as the Ship Gallery, focusing on scanning objects as a knowledge resource. In its website,[10] it offers examples of applications using only common color photographs, and the technologies for creating the three-dimensional object, including point cloud, are classic and digital photogrammetry, which also use drone technology.

In turn, the Smithsonian Institution has a program to create virtual models of skeletons and other objects. The main accomplishment is the creation of replicas of statues using 3D modeling and printing, instead of the traditional rubber molding and casting techniques. A concrete replica of Thomas Jefferson's bronze statue was made for a temporary exhibition at another museum. The original sculpture was not removed from its original place, where it is continuously exposed.[11] A specialized company was hired to make the copy, to which the point cloud generated by a very high-resolution 3D scanner was sent. The statue, due to its natural size, was printed in four parts (joined below), in a thermoplastic material that combines strength and durability. Finally, the whole work was painted in a bronze color, and the junction of the parts cannot be perceived.

The Fitzwilliam Museum, in Cambridge, England, also performs 3D modeling of works of art belonging to its collection. They hired a specialized company that has specific equipment for small objects, typically smaller than 50 cm.[12] The purpose is to reproduce faithful replicas of its ten most precious small objects using jesmonite (a combination of plaster and acrylic resin), in large quantities, for sale in the museum shop. They are pieces from the ancient Rome and Egypt, Han dynasty dogs, and a

8. Cf. Shuler Museum of... (2019).

9. Cf. Kuzminsky; Gardiner (2012).

10. Cf. McKenzie (2019).

11. Cf. Smithsonian Institution (2019).

12. Cf. Fitzwilliam Museum (2019).

13. Cf. Melbourne University (2019).

Renaissance sculpture. It is a high-precision process, which is compatible with the policy of this museum and could be used by others.

The University of Melbourne also has an object modeling program focused on 3D printing.[13] Scanners with portable tripod and one handheld scanner are used, with 0.5 mm resolution for medium-sized objects such as busts and small furniture. They include a tutorial and several videos to help the user on the website. It is a relatively inexpensive and easy-to-use solution.

The academic environment is also awakening to the application of drones to cultural heritage. As an example, a magazine (*Drones*, 2019) has just issued the call for papers for a special issue on the use of drone in cultural heritage.

As a balance of this information, it seems to us that there are reports of applications, and all of them are valid: creation of virtual reality for viewing of pieces and visits to museums, creation of three-dimensional models such as replicas of skeletons, busts, sculptures and all types of objects, including museum souvenirs, for sale to the public.

The finding is that the experience of dealers and service providers (through promotional brochures) and university research information available on the internet provide few details about the experiments and limitations and difficulties found, unlike what is done in this study, which presents the technology to nonspecialists. This study also differs from most cases presented because it also deals with experiences with large objects: archeological ruins, large monuments and buildings listed as historic property, in addition to models, videos and other products, pioneering the integration of data from 3DLS and drone aerial survey.

3D LASER SCAN EQUIPMENT: OPERATING PRINCIPLES

3DLS equipment can be defined as laser radiation devices that allow obtaining and recording three-dimensional coordinates of objects of interest, which can be summarized in the concept of a dense point cloud belonging to the object to be surveyed. The equipment can be classified according to the size and application into two groups: tripod or handheld scanners.

Figure 1 shows the scheme of a tripod scanner. The measurement of the distance ρ and of the α and θ angles allows obtaining, by mathematical calculations, the coordinates x, y, z in relation to the origin of the Cartesian system (origin located on the optical axis of the equipment). Some models even collect around 1,000,000 points per second with a range of about 80 meters, while others collect up to 200,000 points per second, with a range that can reach a few kilometers. Other devices aim to collect data from objects at shorter distances, e.g. vehicles, busts, museum pieces, art objects, and other small ones. Their capacities are similar to those of the aforementioned devices regarding their collection rate and point density to model the entire object. The final mesh spacing that will represent the object can also be specified, depending on the dimensions of the details to be surveyed, such as the capital of a Corinthian column.

The data processing stage, that is, the manipulation of this dense point cloud, requires equipment (computers) with great memory capacity and high calculation speed. The reader who wants to know more details and deepen into the operating principles of the abovementioned equipment and of working methods can see Cintra and Gonçales.[14]

An image of an equipment in operation can be seen in Figure 2.

Only what is in the sensor field of view is collected and, in the case of a three-dimensional object, the equipment should be positioned in other collection stations, around the object. This operation is repeated until information from all parts is collected. Figures 3 and 4 exemplify this operation.

In the example shown in Figure 3, the collection equipment was positioned at four different points to generate a complete point cloud of all objects, giving complementary views to form the whole. By collecting only information from objects that are visible to the optical system of the equipment, shadow areas or gaps are generated in each collection station, and data become unavailable in these locations. The correct positioning of the collection points allows forming a complete point cloud, without shadow areas. This process of joining partial clouds is called a record, because it registers in the same coordinate system. Each station generates a local coordinate system. Figure 4 shows a perspective of the final cloud of the points registered, gathering the data collected, shown in the four viewpoints in Figure 3.

Recording the point clouds of several stations in only one station depends on the identification of homologous points, that is, easily identifiable elements that appear and are recognized in consecutive point clouds (corners, edges and others). This can be done or complemented by placing targets in regions that are common to both scenes. In turn, data calculation and recording is made through mathematical transformations in the coordinates. More details about this process can be seen in Gonçales.[15]

14. Cf. Cintra; Gonçales (2017).

15. Cf. Gonçales (2007).

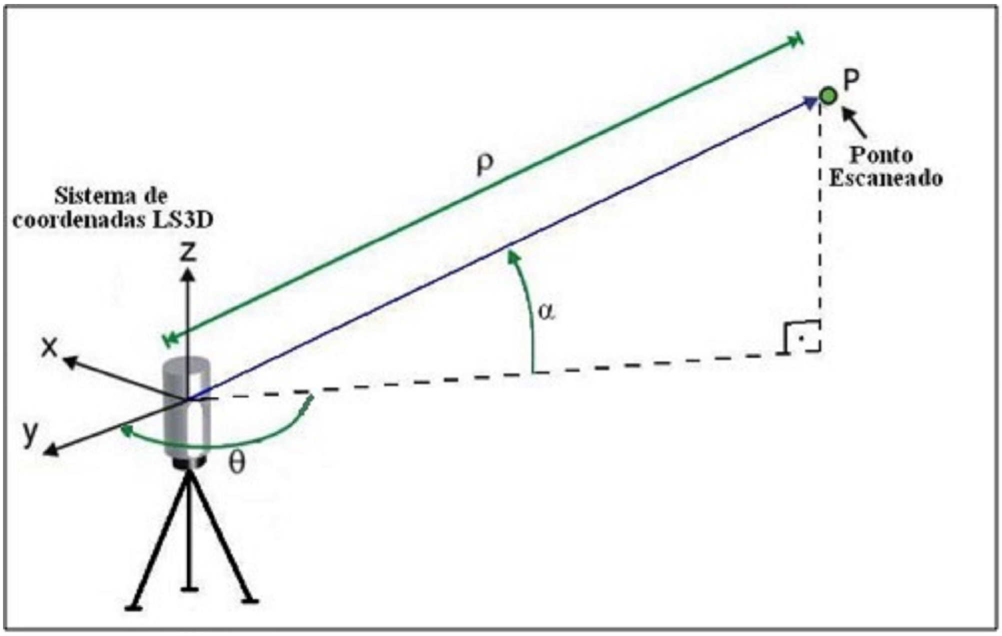

Figure 1 - Perspective scheme of the 3DLS observations. Adapted from Gordon & Lichti, 2004.

Figure 2 – Trimble TX8 3DLS, which was used to carry out several experiments for this study.

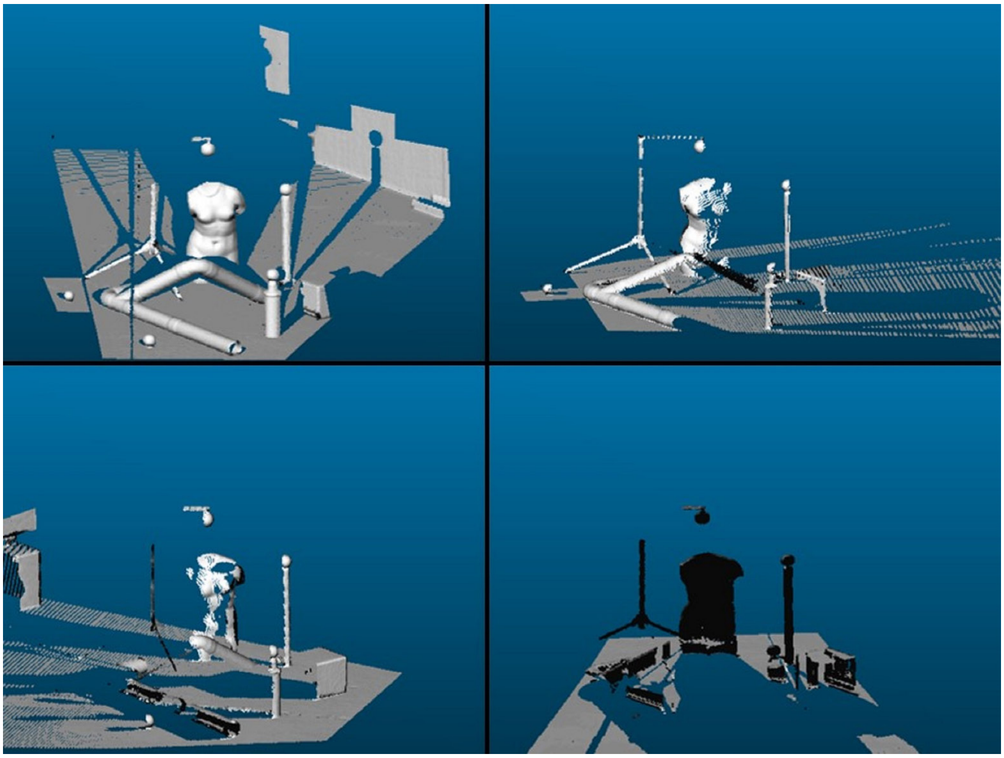

Figure 3 - Data collection from four different locations or viewpoints. Source: Gonçales (2007).

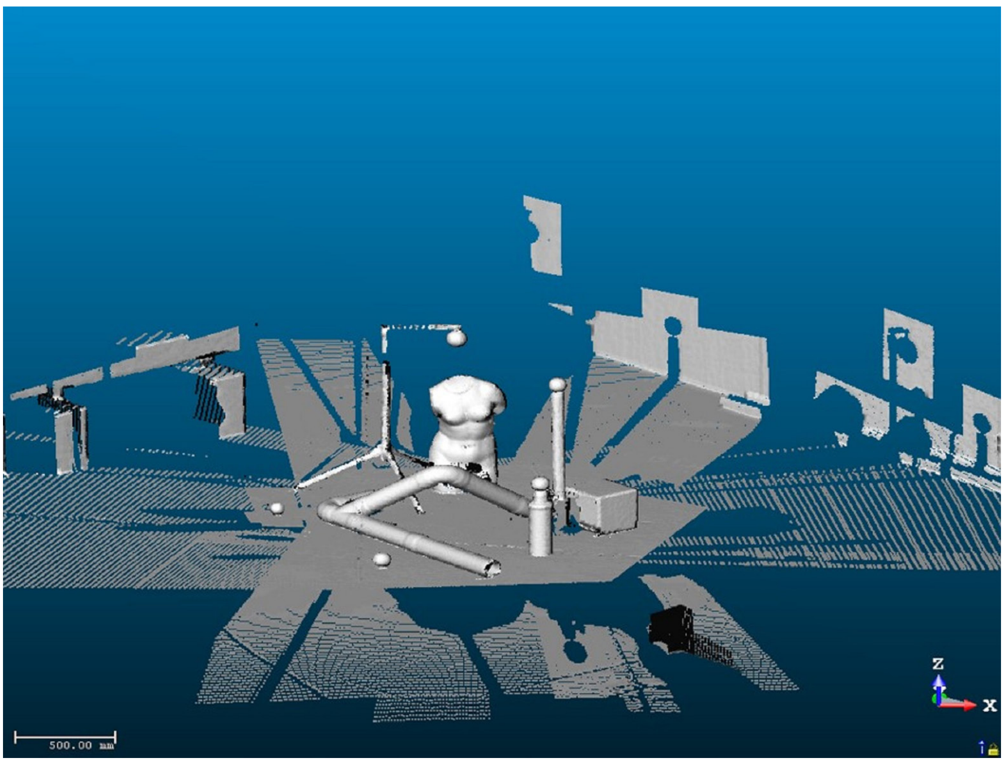

Figure 4 - Complete image, with all data registered. Source: Gonçales (2007).

Data processing requires a specific program, usually associated with the equipment that produced the data, but converting the files to a standard exchange format is almost always possible – which is called interoperability. The user is required to be qualified to use this program, which has a certain complexity. Initially, a quality control of the data should be performed to verify: whether all objects of interest were scanned; the existence of shadows complicating data interpretation; whether the size or opening of the mesh, associated with point densities in the survey, is compatible with the level of detail required; if the data was recorded successfully.

In engineering, the first example is that of a water pipeline measuring 2,000 m long and 11.4 m in diameter, dug in the rock. Its inner part was scanned throughout about 40 collection points, 50 m far from one another. In Figure 5, a screenshot shows the consolidated point cloud and the pipeline axis in yellow.

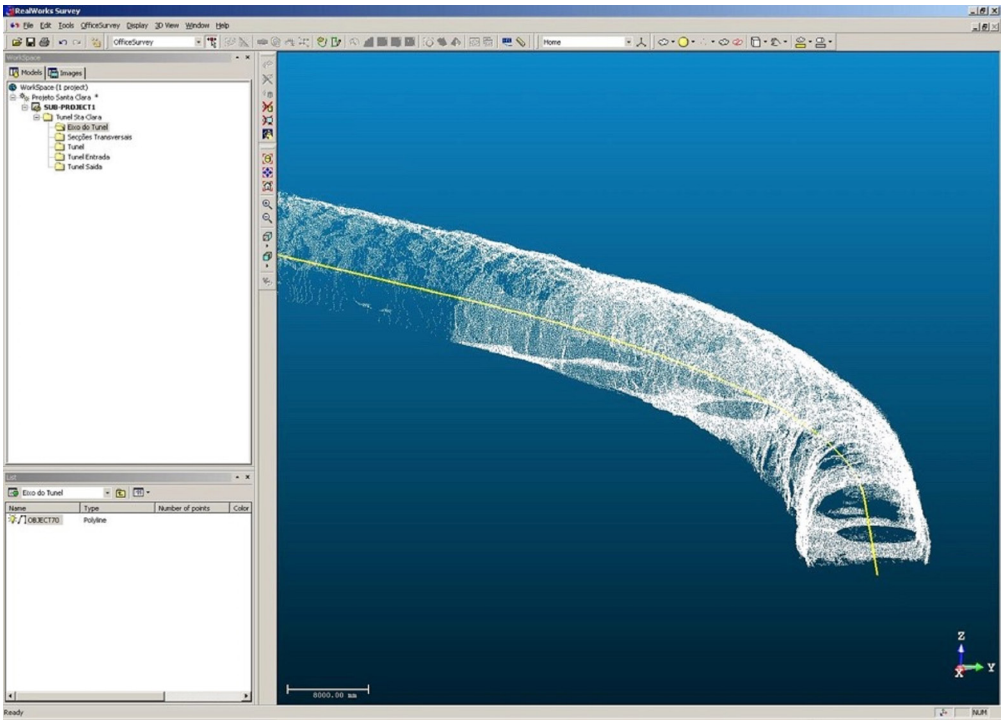

Figure 5 – General point cloud of a pipeline and its axis.

Handheld scanner is another type of equipment, as shown in Figure 6. This type of equipment was created to overcome some of the main difficulties of tripod equipment. Its advantage when compared with the latter is that it does not need to be installed on the ground in a fixed position, because the equipment works in the operator's hand.

Following the principle of scanning the entire piece, the operator should aim the equipment at the piece and perform a full scanning to collect data from several angles.

Figure 6 – Trimble DPI-8 handheld scanner. Photograph by the authors.

On the display, which is a normal tablet, yellow points appear in the points already surveyed. When there is enough sample to reproduce the piece, according to calculations, these points become green colored. The measurement finishes when the entire piece is green.

Figure 7 shows, through a photograph, the scanning process. Figure 8 shows the screen of the equipment during operation. A common tablet, according to the user's choice, must be attached to the equipment.

In addition to facilitating fieldwork, processing is greatly simplified: the images are correlated automatically by an internal program of the equipment (*firmware*), as the part is scanned. At the end, a 3D model of the piece and its surroundings is obtained. Figure 9 shows an example. The intention was to scan an 18th-century mortar that appears in the center of the image. However, due to the process, other contiguous pieces were captured, including a pillar of the building, with a black and a yellow belt.

Figure 7 - Operation of the equipment to scan the piece in the foreground. Photograph by the authors.

Figure 8 – Screen of the device, during operation, showing what will be imaged. Photograph by the authors

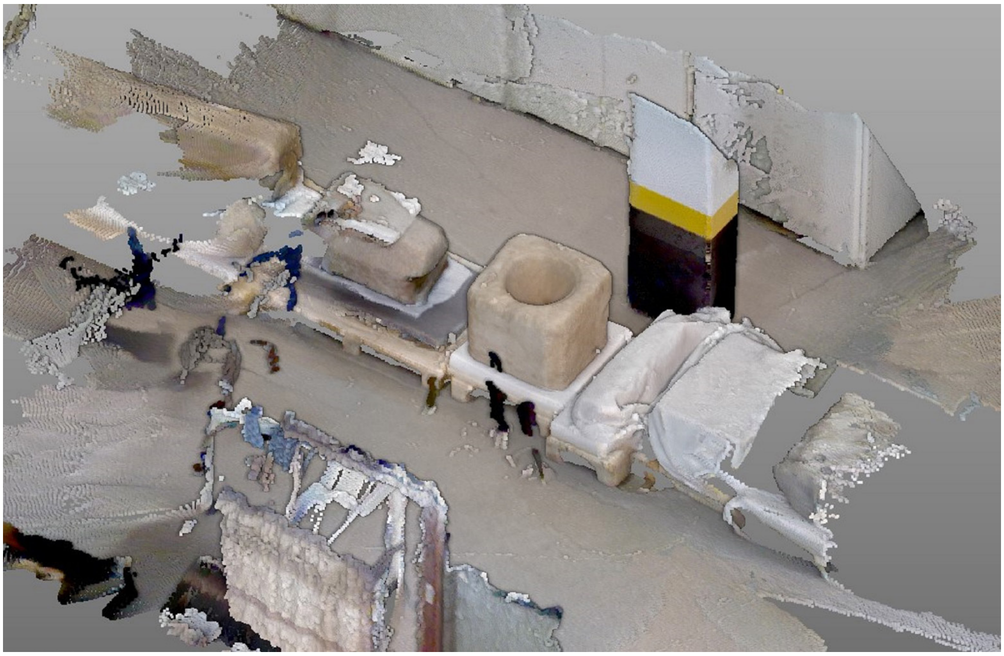

Figure 9 - Result of the scanning of a mortar in the center. Photograph by the authors.

Figure 10 – Cropped point cloud showing only the mortar. Photograph by the authors.

For the final result (Figure 10), one must crop the unimportant parts, resulting in the object of interest, under a wooden support and a white fabric on the base. As it is a 3D image, choosing the angle from which we wanted to view the piece was necessary. We chose one angle that allowed us to view two faces and a portion of its inner part.

The technology applies to almost all opaque solid materials or objects and may have problems in highly reflective objects, such as water or mirror.

Comparing the tripod scanner with the manual device, although the latter is less accurate, it allows hard-to-reach points to be surveyed, as it does not depend on fixed tripod and can be easily handled to survey inaccessible regions. The result is always a point cloud of the surveyed object as a whole, which can be manipulated and generate the most different products, as further detailed in this article.

ELECTRONIC MODELS

The point clouds generated compose an electronic model. Figure 11 shows the 3D model of the water pipeline, which enables identifying and measuring undesirable roughness, above a certain limit, as a red circle indicates. One can also automatically draw cross-sections, calculate areas, volumes, and other indicators.

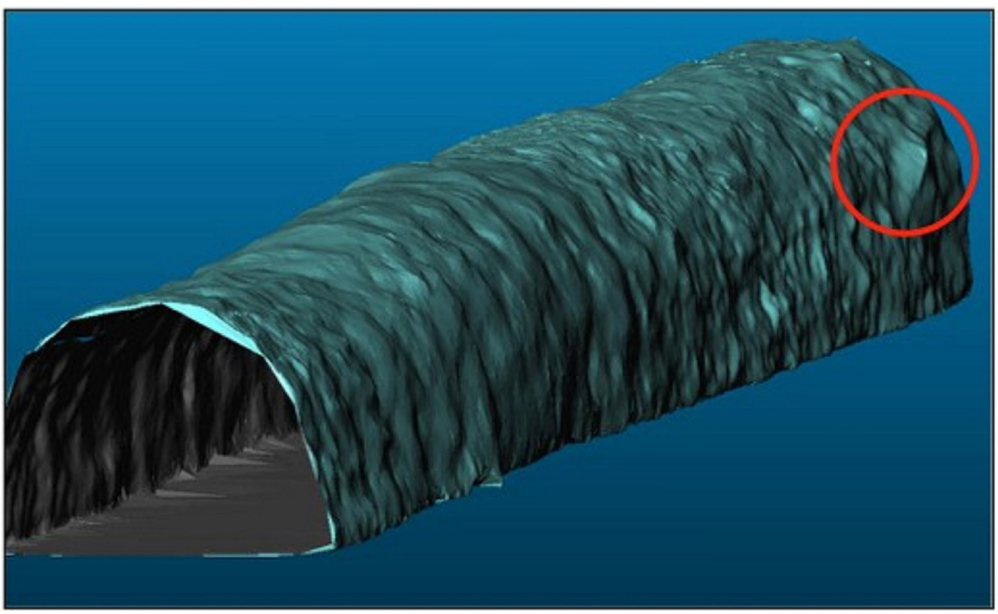

Figure 11 – 3D model of a water pipeline allowing analysis and quantifications.

However, the Terrestrial 3DLS has a limitation in large works and buildings: in many cases, the roof or ceiling of the building cannot be scanned. In the case of the pipeline, the entire ceiling (inner part) is visible to the scanning, but in many other cases, such as in buildings, only side walls are visible for terrain scanning. To complement and form a hybrid model, another technology should be used, such as drone aerial survey, as explained later.

Logically, in the case of handheld scanners on relatively small objects, complementing drone survey is not necessary.

COMPARISON BETWEEN ELECTRONIC AND PHYSICAL MODEL

Electronic models can be compared with physical or conventional models. For this purpose, some items can be analyzed. The conventional one is more expensive and its building takes longer time, but the advantage is that it is already a 3D object, which can be viewed from all angles, if conveniently assembled. This is the case of the model of the city of São Paulo at Museu Paulista or that of the city of Jerusalem at the Israel Museum. In addition, the conventional model allows choosing the materials of which it will be composed.

The electronic model has to be viewed on a computer or television, and its size limited to the dimensions of the display. Although it provides the feeling of 3D and can be viewed from any angle, through appropriate commands, it is a flat representation of a three-dimensional object, in reality. Therefore, in Computer Graphics, its denomination is 2 $^{1/2}$ D image. The production of videos is an additional resource. The result looks like a drone footage, but, in reality, it is a simulation. A path is defined on the model through points with horizontal and vertical coordinates, and the program interpolates diverse points along this path. Then, various frames that will compose the film are created by making calculations on the model. Thus, flights are easily simulated and improved, and music, subtitles, credits and other images can be added. As it is well known, images and animations powerfully draw attention nowadays.

A resin model can be made based on an electronic model. For large objects, such as a building, and thinking on a large scale, there is a size limitation, imposed by 3D printers. One can print by parts and even design the fitting parts (male and female), which is also a very convenient solution for transportation. For example, the building of Museu Paulista, measuring about 150 m, could be modeled on a 1:100

16. Cf. Andrade (2003).

17. Cf. Piteri; Rodrigues (2011).

scale, generating a 1.5 m model to be printed in three parts measuring 0.5 m. Currently, no color 3D printer is available, thus requiring manual painting after printing. Therefore, the physical model is still an advantageous process for large sizes.

DRONE AERIAL SURVEY AND ITS PRODUCTS

Drones are increasingly popular and numerous models from different manufacturers are launched annually. These devices can fly to great heights (in Brazil, the legislation does not allow flights above 120 m) and collect high-definition images.

Conventional and drone aerial survey are very similar. It has a satellite positioning system (GNSS, generic name that includes GPS and other systems) on board and a photographic camera, as well as other auxiliary sensors. It can be operated manually via remote control, or pre-programmed, through a mobile application. The user plans the flight by marking the area of interest on a cartographic product (a Google image, for example), and the program calculates the flight tracks and longitudinal and cross-sectional overlays to cover the entire area and capture the image of each region in at least two photos, thus allowing stereoscopy and 3D view, as in the traditional process. Flight programming is transmitted (via radio) to the drone, which runs the scheduled flight and returns to the starting point.

GPS provides camera position at the time of each shot, which is called supported flight. By correlating images and other pattern recognition and computer vision techniques, the program identifies common points in neighboring photos, on the same flight range and on the side, and can calculate the altitudes of each point of the object, forming a digital model of the field and its buildings and trees. For more details on photogrammetry, see Andrade[16] and on computer vision, Piteri and Rodrigues.[17]

Figure 12 shows the scheme of the pre-programmed flight.

Several products can be obtained from these input data. The first are the individual photos, corrected from the distortions caused by relief (orthophoto or rectified photo). A photomosaic of the region, or a unique photography, corrected from distortions, can be obtained by putting several photos together. Another product is the electronic models, whose appearance is very similar to that of models produced with 3DLS. Its advantage is that it also represents the ceiling of buildings. The electronic model produces videos that simulate flights, as in the case of 3DLS. However, metric precision is ten times lower, as the practice shows.

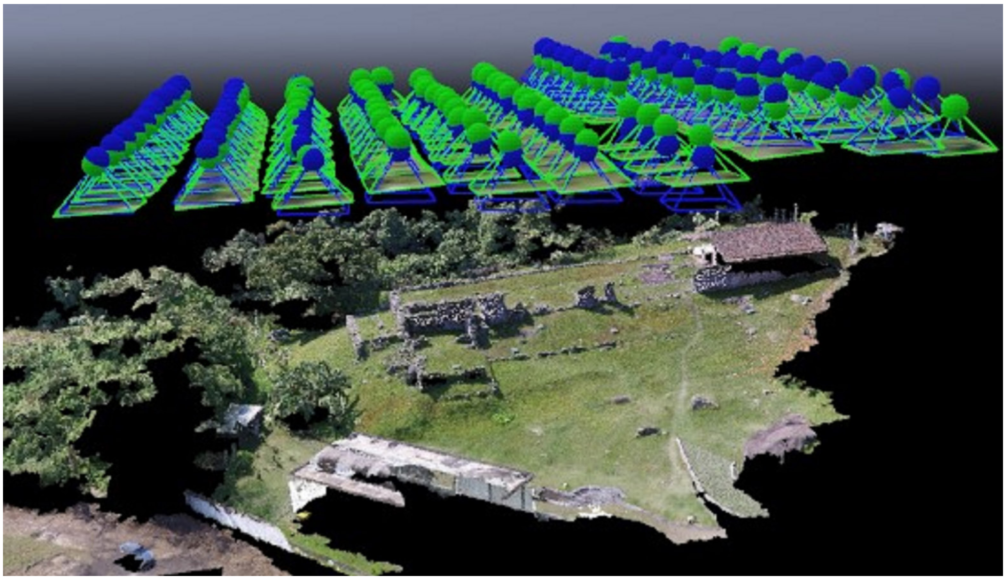

Figure 12 – Scheme of the pre-programmed flight. The associated small balls and tetrahedrons, in blue and green, show the position in which each photograph will be taken.

The operation and application of the equipment, whose cost is lower compared with that of other technologies, is quite simple, and the processing is very automated, in such a way that this technology has substituted the conventional technique in many small extension surveys. The prices of the devices vary: rotor drones (quadcopters and similar devices cost about US$ 2,000) have battery life that lasts about 30 minutes and a relatively limited range. When the power falls below a certain level (15%), it returns and automatically lands at its starting point. Fixed-wing drones (which cost about U$ 70,000 or more) reach higher speed, autonomy and range, being used for major surveys. Devices fall, are lost and, if recovered, total loss occurs due to the fall.

The system is not simply a toy and has been rapidly improved. The program issues a very complete report, similar to that of the conventional air survey, through which experts can assess the internal or relative precision of the elements represented in orthophotos with good absolute precision, i.e. based on a reference coordinate system (latitude and longitude). The next improvement underway, which is very promising, is the use of the DGPS method, i.e. differential GPS, which should greatly increase precision and, in the medium term, replace the terrestrial laser in several applications.

In Brazil, studies have assessed the representative and dimensional quality of products created using this technology. Currently, dimensional precision is still unsatisfactory, so that talking about integration and complementarity of technologies is

18. Cf. Gonçales (2019).

19. Escola Politécnica da... (2016?).

preferable to thinking about competition at this moment. For this purpose, 3DLS is used to achieve dimensional precision for the entire cloud, and drone images complement inaccessible regions. Drone data are integrated and corrected by laser data.

Direct measurements of the terrain dimensions (e.g. track width or urban lot dimensions) and their comparison with those of orthophotos provide a first simple assessment for the users, investigating whether its application meets the requirements. We successfully applied it.

EXAMPLES OF APPLICATIONS OF MODELS AND VIDEOS

An example of application is the survey of the sculpture *Monumento a Minerva* by Denise Milan at USP, in São Paulo, representing a temple and the helmet of the Greek goddess (Pallas Athena). Figure 13 shows a perspective of this monument obtained from the point cloud generated using 3DLS, and Figure 14 shows another perspective, using drone aerial survey, to which the flight plan overlapped. This was the first experiment to show the precision of 3DLS is about ten times better than that of the drone and that drone, in its turn, covers regions that are not visible and not surveyed when using 3DLS; hence the convenience of integrating the two technologies.[18]

The second example was the survey project of *Monumento Nacional Ruínas do Engenho São Jorge dos Erasmos*, in Santos, belonging to USP. The two technologies were integrated. The image of Figure 15 was produced from the electronic model.

A video, available at <https://bit.ly/2OJpxi2>[19], was produced from this electronic model.

The third example, in a project funded by *Associação Amigos da Poli*, is a survey of the Ipiranga brook, aiming at studies on depollution, in the sample stretch that goes from Rua Coronel Diogo to its mouth in Tamanduateí. There were 338 photos, one digital model, one orthomosaic (mosaic of photos rectified to the orthogonal and uninclined position, of which a stretch is shown in Figure 16), one point cloud, two videos (one produced using the point cloud, and the other using the electronic model), and several technical reports.

Another project, associated with this one, was the survey of Parque da Independência, where the Ipiranga Museum is located. Similar products were generated, with more than 1,000 photos. Figure 17 shows a picture of part of this building and the front yard. From the model, an artistic video representing an overflight of the park was also produced. Figure 18 shows the point cloud of the façade of the museum obtained using 3DLS from a single station.

Figure 13 – Point Cloud of the 3DLS of *Monumento a Minerva*, near the Civil Engineering building, at *Escola Politécnica* of the University of São Paulo, SP.

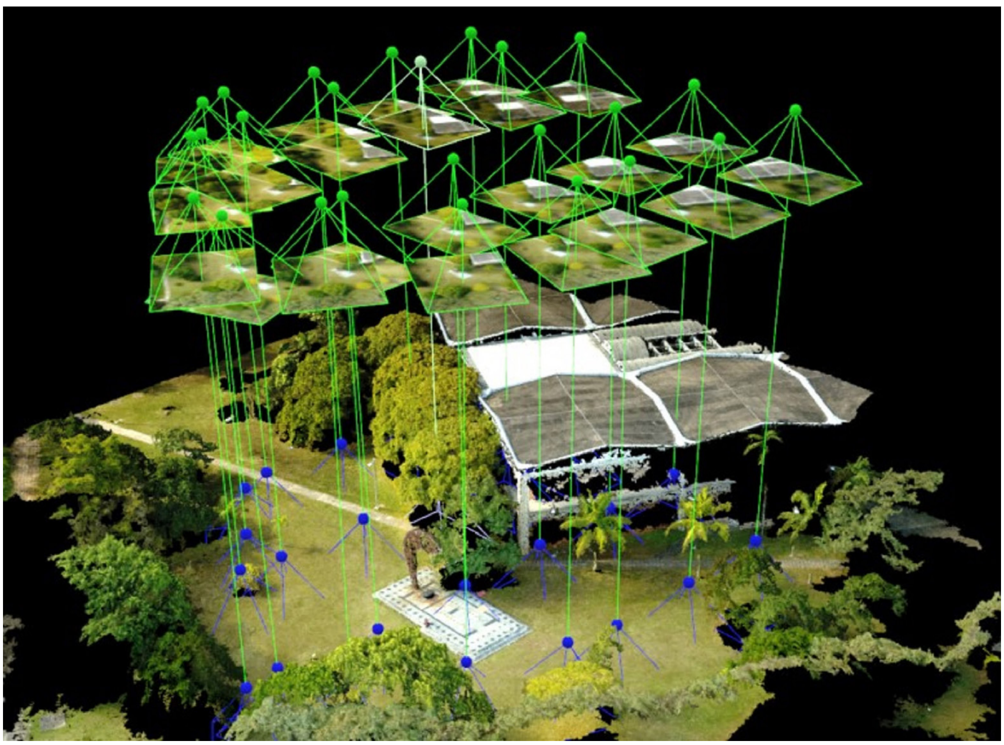

Figure 14 – Model obtained using drone, showing the flight plan.

Figure 15 – Perspective of *Monumento Nacional Ruínas do Engenho São Jorge dos Erasmos*, produced from the electronic model (drone aerial survey).

Figure 16 – Stretch of the orthomosaic of the Ipiranga brook, in Parque da Independência.

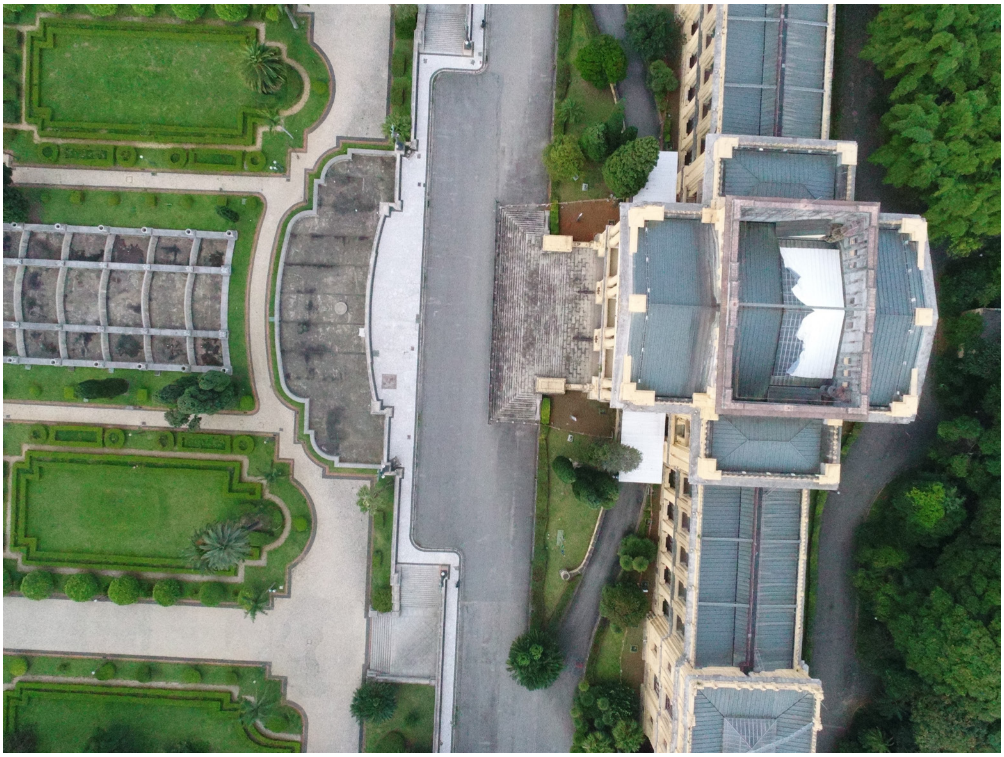

Figure 17 – Partial aerial photo, taken by a drone, of the building-monument and the front garden. Photograph by the authors.

Figure 18 – Point cloud of the façade of Museu Paulista, in Ipiranga.

In turn, Figure 19 shows the model produced by aerial survey.

Figure 19 – Electronic model of the building-monument of Museu Paulista, generated by drone aerial survey.

EXAMPLES OF PHYSICAL MODEL, VIRTUAL EXHIBITION AND ACCESSIBILITY

In another experiment, several pieces from the lithic collection of Museu Paulista were scanned, using a handheld scanner.

The cropped parts constitute a set of three-dimensional models that can be used, for example, in virtual exhibitions. They can be individually designed on large screens, rotating to show the various angles, or together, by creating a virtual exhibition in which the visitor browses the environment. One can scan and model, or even create, a typical room and distribute the pieces in a certain sequence of locations simulating the route, with their respective identification and meaning. That is, simulations during the planning and production of the museum exhibitions are also possible. Each of the pieces may be associated with a two-dimensional barcode (*QR code*) that refers to further information. Figure 20 shows several pieces, in which the user can evaluate their potential to compose an exhibition.

Figure 20 – Scanned pieces to compose a virtual exhibition. Clockwise, from the upper left corner: Baptismal font of Itanhaém; Holy water font of Pátio do Colégio; Marco de sesmaria; Lintel of the Matriz de São Vicente (fragment). Objects from the collection of Museu Paulista

Assessing the work using handheld scanner, in this first experience with the results shown in Figure 20, one observes that they can be improved, increasing the number of points for a better view of the inscriptions, for example. In Figure 21, the scanned image of an object (Tombstone of Afonso Sardinha) is compared with its photograph. The tripod scanner is expected to be more sensitive for these inscriptions, because it can get closer to the object (minimum distance of up to 60 cm), scan at a higher point density (lower spacing in the representation mesh) and provide greater depth precision. These results are partial and improvement in the results with the use of handheld scanner is expected, considering its numerous advantages in the fieldwork stage.

In this regard, it is interesting to note that this limitation is perceived worldwide and reported indirectly. For example, Johns Hopkins University develops the Digital Hammurabi project, which scans cuneiform writing plaques to create replicas in numerous materials, aiming at study and preservation, reducing the need to access the original. For this purpose, a specific equipment was developed and built, which is not based on laser technology. Despite being expensive, this alternative can be used for pieces with inscriptions, in case the results of the conventional processes in the studies we are conducting are unsatisfactory. In turn, Indiana University together with the Polytechnic University of Milan developed a project to scan 1,250 ancient sculptures. The technology, for points where the drone cannot be used, was based on photo shoots from several angles and on an image treatment process similar to that used in the drone methodology, which is an adaptation of the traditional photogrammetry. In a few cases, laser technology was used. Details can be seen in Malik and Guidi.

Obtaining better images is not only a matter of readability of the inscriptions for researchers, but also a way to help the general public and the visually impaired people in reading such inscriptions. Given that the face of the tombstone is planned, it can be treated by identifying the points below that average mark and painting them in red in the digital model, which would also be displayed on a digital screen, near the physical piece. A full-size resin model (20 x 40 x 60 cm can also be prepared) can also be created, painting the letters in red; and a complementary plaque, in which the sentences are reproduced, letter by letter, and in words, when applicable. This model can be tactile, to be felt by all publics, including by visually impaired people, being complemented with the same statements in Braille.

Using this technology, one can produce sensory models of architectural elements of the building, for educational purposes: palmettes, rosettes, Corinthian capitals, among others. Our investigations also go in this direction.

Figure 21 – Tombstone of Afonso Sardinha. On the left side, image taken by handheld scanner; on the right, photo taken by mobile phone. Objects from the collection of Museu Paulista

FINAL CONSIDERATIONS

This study, through a series of examples, showed the potential and limitations of these two technologies for the production of individual images, rectified mosaics, electronic models, films, virtual exhibitions and resin models, for educational and accessibility purposes.

The few international articles found and analyzed do not include either the integration of technologies or this range of applications, in the fields of museums, large sculptures, and historical buildings.

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