QUALITY TOOLS FOR IMPROVING A SYSTEM OF DOCUMENTATION FROM CULTURAL HERITAGE OF HABANA (CUBA)

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Keywords. : Cultural heritage; photogrammetry; structure from motion; La Habana; Cuba.

1. Introduction

"Structure from motion" system's technology allows real scene's reconstruction starting from pictures and some basics measurements, used for scaling. Photo-modeling applied to architectural goods represent an awesome solution to document the state of existing buildings, being able to provide technicians of every necessary tool to later develop an information database which could be considered the basis for structured electronic information's managing process. The Cuba's concerned assignment under examination introduces photo-modeling techniques' applied to complex cases in medium and large scale, leading to a wide comprehension of such techniques' potentials and importance in architectural and urbanistic fields. Over a limited amount of time 59 buildings' facades and decks, 2 fountains and 2 monuments afferent to five squares in Havana's historical city center were surveyed: *Plaza de Armas*, *Plaza Vieja*, *Plaza San Francisco*, *Plaza de la Catedral* and *Plaza del Cristo* (Figure 1).

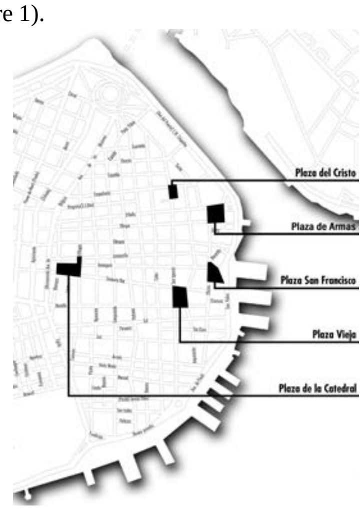

Figure 1. Plan of La Habana Vieja.

30.000 m^2 of floorings and as many vertical surfaces were analyzed overall. The application of this method on such a large scale, an urban scale, for which the laser scanner is normally used, certainly presents a novelty in the field of the celerimetric survey. It is the first case study on these large scale. A very interesting topic for the Oficina del Historiador de Ciudad de la Habana, a Cuban public body, that oversees the architectural and cultural heritage of the city. The Oficina was established in 1938 to protect the old Havana. The restoration of the historic area was developed by Dr. Eusebio Leal Spengler, who was elected as the Historiador de la Ciudad de La Habana in 1967 and is currently the highest authority for the complete restoration of the historic centre. Such historic centre was declared a World Heritage Site by UNESCO in 1982. The Oficina is the engine of many initiatives taking place in Havana. It could be called Sovereignty, with the aim of safeguarding the national identity through the research, the promotion and the development of culture.

2. Survey methodology

The problem of acquiring a multitude of data is very much felt in Italy as in other European countries of great tradition as there is the need for 3D modeling of the immense historical and architectural heritage existing with practical, fast and low cost methods compared to traditional methods. For this reason the academic debate throughout Europe on this subject is wide. The five squares of Havana were classified according to their realization and according to their main characteristics: the surface, the perimeter and the number of buildings, and the peculiar elements that have determined and conditioned the type of survey according to the Freedom of movement for picking points and obstacles. Medium and large-scale surveys of parts of the city, in fact, generate a large amount of data and information that needs to be processed at a later time and normally at distant places from where the survey was performed, in this case study, thousands of miles overseas. Operationally, data acquisition doesn't require trained personnel or specialists in architectural history, since it is sufficient to follow precise protocols and technical rules, while for the realization of the model it is important that the operator is well prepared on this matter in order to acquire data with a critical sense and consistently with architectural canons. Therefore the required compendium does not depend on the importance of the buildings but on the work phase that is taking place. The important operation was carried out according to an accurate work program, a precise choice of instrumentation and gripping modes was made. These modes follow applicable rules on a case-by-case basis, but it is not always possible to comply with objective physical impediments to the view. The three combined or integrated techniques are: parallel or multiple axes shot, converging axis shot, and panoramic shot (cylindrical, spherical or partial). The fronts of the buildings were photographed using the technique of parallel axis shot as well (Figure 2, Figure 3).

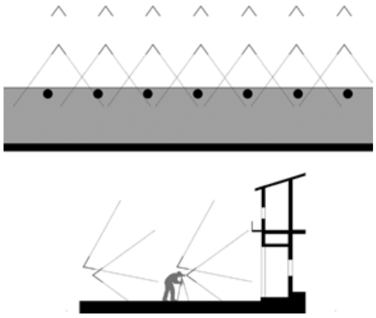

Figure 2. The parallel axis technique.

Figure 3. Photo shoot - parallel axis technique.

This technique involves a multiple photos shot, moving in parallel to the front of the building and taking pictures with a frame that overlaps at least 25% the previous frame (similar to the classic photogrammetry). This method allowed to process the design of the front through the photo-rectifier technique and was actually ideal to determine the weaving of the surfaces. In this case, the shot was taken with the camera in portrait position to take advantage from the maximum resolution of the camera.
The convergent axis shot (Figure 4, Figure 5), specific for photo-modelling, was used for the shot of the fronts of the building. In this case the camera was placed in portrait (vertical) or landscape (horizontal) position, depending on the size of the object. It consists of turning around the building in a semicircle way, aiming at the centre of gravity of the front. It was not always possible to frame the entire front with one shot as desired, so we ended up by taking photos of portions of the building. The photos were usually taken turning in semicircle at 30° intervals (5 clicks per semicircle). The buildings that have some parts geometrically different required a deeper study, like the columns, the pavements and the ceilings of the arcades which were photographed with the technique of spherical panoramic shots. The technique of cylindrical shot (Figure 6, Figure 7) was used for the shot of exterior spaces with a central composition like cloisters, courts and in particular squares. It captures images from a central point, and from that point it starts making with the camera a round angle. The shots we used were selected with an overlapping of the images of about 25%, so that we could choose the most appropriate image between the camera in the portrait and the panoramic mode. Particular attention was also given to the survey of the porches because of their shape, that required the combination of these techniques and the necessity of a very large number of photographic shots. In order to obtain a correct calibration of the cameras, we made sure that during the shot there were at least eight characteristic points that could be easily identified on the photos.

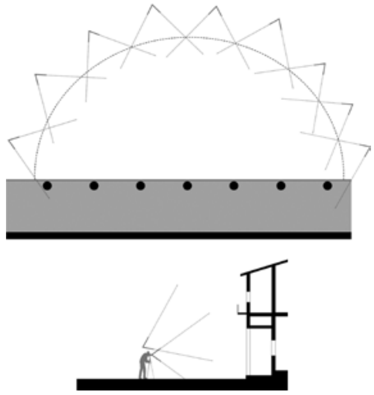

Figure 4. The convergent axis shot.

Figure 5. Photo shoot - convergent axis shot.

This is just discontinuity, recognizable on shape (like edges) or surface weaving (like pores in materials). Finally, the correct calibration of the cameras was not difficult to verify thanks to the condition of the complexity and irregularity of the fronts and the materials. Each group of taken images was then associated with the measurements of some reference sizes in the three dimensions (widths, heights, depths), that are necessary to scale the model and to control the correctness of the graphic rendition. The measurements were previously carried out in excess by using traditional measuring tools like: metric tape, rigid meter and laser meter. This last one is particularly useful for measuring heights. The fronts required a measurement of general widths and heights among the characteristic points identified and written down on free hand drawn eidotype. Widths and heights of the main openings (doors and windows) were as usual measured, too. The measurements of the main parts of the elements that constitute the pavements and the parameters or wall coverings were also taken into account. All measurements were taken and written down with the precision of half a centimetre. Further additional difficulties were the strategic choice of shooting to define arcades, complex elements with a big amount of components and details, for the orientation of the fronts in every direction, arches, floors and ceilings.

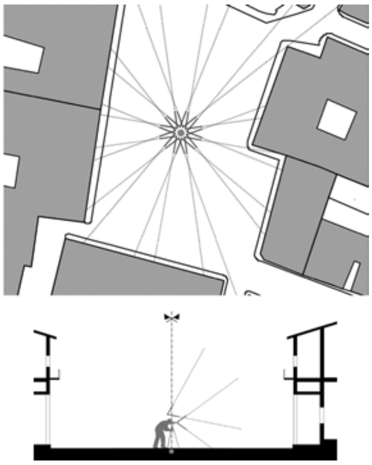
Figure 6. The technique of cylindrical shot.


Figure 7. Photo shoot - technique of cylindrical shot.

The survey of those constituents required a big number of pictures and the combined use of the already mentioned three techniques. In the particular case of the five squares, due to the complexity of the works, all these techniques have been used. Once the settings to be used for the camera were decided, the photo taking campaign proceeded according to the methods already studied at the table; these methods follow applicable rules on a case-by-case basis but that it is not always possible to comply with objective physical impediments to the visual (Figure 8).


Figure 8. Fixed or mobile obstacles.

In particular, in the five squares photographed there were several critical issues: some common, such as being able to photograph entire fronts of buildings avoiding fixed or mobile obstacles such as vegetation, urban furniture, temporary installations such as boxes and street markets, vehicles, people and cars -occlusions generated by the articulation of the volumes (see balconies, porticoes and other façade articulations). Obstacles can generally be overcome by approaching the object, which leads to greater complexity in the operations and a greater amount of photographic shots. The final work consisted in rendering with commercial hardware technologies and dedicated software, in particular Agisoft Photoscan, all the information recollected in order to create a substantial information unit. To evaluate the accuracy of the method we proceeded to compare the result with the direct metric measurements obtaining the calculation of the error.

3. Managing information

After the survey and the photographic campaign, we proceeded with the data processing through a personal computer with quite good hardware performances. So that if there are many photos it is able to limit the time of loading:

- –Processor: AMD Athlon (tm) X4860K Quad Core Processor 3.7 Ghz;
- –GPU: NVIDIA GeForce GTX 960;
- –RAM: 32Gb;
- –SSD: 500 Gb;
- –Operating System: Windows 7 (64 bit).

There are various processing programs available on the market about the photo-rectifier, about the structure from motion and 2D and 3D graphics. The following software was selected for the realization of this study:

- –Perspective Rectifier (2D photo rectifier);
- –Agisoft PhotoScan Professional (for 3D SFM);
- –AutoCAD Autodesk (for graphic re-processing).

For this research we chose to use third-party software, not open source, we were not interested in the comparison between software because already addressed in previous works (see *I portici di Bologna. Architettura, modelli 3D e ricerche tecnologiche, a cura di M. Gaiani, Bononia University*). Regarding the problems faced during the data analysis the most important problem was that of processing times. In this case, it was interesting to evaluate the processing time of the information technology with respect to the time required for pure relief with a mid-range hardware. From the histogram you can see the ratio in terms of time needed to develop all the phases, with these data you can estimate times and costs of the entire work (Figure 9). Starting from the photographic images acquisition, structure from motion techniques' purpose is to generate a tridimensional model by the principle of photogrammetrical survey. To resume, the examined subject images' acquisition is carried out at first by applying all the previously described shooting techniques, afterward a dedicated software will position those picture in space to make them interact between each other achieving a tridimensional cloud of points thanks to its prospects algorithms.

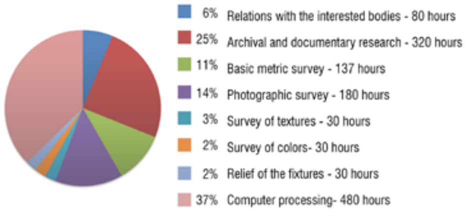

Figure 9. Histogram of the times for carrying out the work.

Right after inserting the images on the software, the passage of points' lining has to be executed in order to achieve a spare cloud, which a subsequent elaboration will transform into a dense cloud. This cloud is later converted into a "mesh", that is to say a "net" made of polygons obtained by the interpolation of all the points. This network is basically composed by three elements: vertexes, edges and sides. It can be seen as a sort of empty volume that lacks of thickness, of which sides are some superficial "veils". The achieved "mesh" is correlated to colors known data, thus textured. Agisoft Photoscan, among the others is the selected software designed to execute this significant research on Havana's squares: it operates by automatically recognizing homogeneous points in pictures through artificial sights informatics algorithms. Thanks to photos alignment prospective algorithms, it aligns all the pictures with each other producing the forementioned cloud of points (sparse cloud). Once the entire set is aligned and the mistake distributed, it gives a denser cloud of points through stereophotogrammatical classic formulas. By interpoling every dense cloud points it then restitute a tridimensional surface (mesh building) on which pictures are screened and mixed to generate the complete texture building. The last steps of this work are: model scaling, and model and texture exporting. Once concluded the survey and photographic footage, we eventually proceeded with data elaboration using the computer. During post-production phase it was thus possible to make the picture clearer through anti-noise filters, balancing whites and correcting chromes thanks to colorchecker and colors profile applications, for which raw format pictures seems to be better than the jpeg format. Photo editing programs were also used to improve pictures by erasing people or superficial defects which didn't have to appear in the final texture. To exclude some part of the pictures during computing it is actually enough to apply Agisoft masking functions. The software is indicated for material analysis precisely because it gives the possibility to act on singular pictures. Is there to add that to achieve a mesh lacking artifacts it was mandatory to operate with points of cloud's critical cleaning after every single calculation. It appeared essential to pay particular attention during those operations in order to avoid erroneously erasing useful points, and at the same time to eliminate as much mistakes as possible. With Agisoft it was also possible to correct the mesh with holes closures and chunks joins, although for more precise works it is recommended the usage of dedicated softwares like MeshFix or MeshLab. Once corrected the geometry, textures had to be verified. In the first place it is suggested to calculate the texture without masking functions, because Agisoft tends to exclude automatically some disturbing elements like pedestrians or cars. In some cases artifacts and unconnected elements appeared anyway so that we acted in two different ways: exporting the jpeg texture and adjust it with a photo-editing software to successively re-apply it on the 3D model (best way), or working directly on Agisoft covering disturbing elements and re-calculating the texture again. The scaling model was finally reached by bounding it on some basics points with known spatial coordinates. To achieve better results we could align the Agisoft model with a scanner laser made clouds of points, or even complete station instrumental survey or direct survey. We employed the last one because even though results appears to be less precise, they can be considered acceptable for the aim (Figure 10).

Figure 10. Building in Plaza de la Catedral: SFM.

Technological development of the last two, three decades has profoundly changed the process of knowledge. While considering indispensable the contribution of the scholar at each stage of cognition, it has become evident that the new instruments have transformed surveying operations into semi-automatic procedures capable of gathering millions of points at a low uncertainty level. A fundamental aspect of the study, after years of consistent use of low cost acquisition instruments as a photographic camera, is to test the detail level possible to achieve in terms of metric accuracy as well as metric, chromatic and surface information[1] to document some different urban context. The study of analyzed subject demonstrated that cognition of architectural and urban scale does not end with identifying its geometric and morphological characteristics, but has to be based on a selective and specialized reading of various aspects. Collecting, interpreting and disseminating a large amount of information helps to define a system we can use to understand our Cultural Heritage. The system has to be based on scientific process used to achieve a dual objective: to document acquisition using a heterogeneous set of data and metadata to guarantee repeatability and to ensure data quality during data capture and processing of 2D and 3D models. Some images are given below as an example of the work carried out for all five squares (Figure 11).

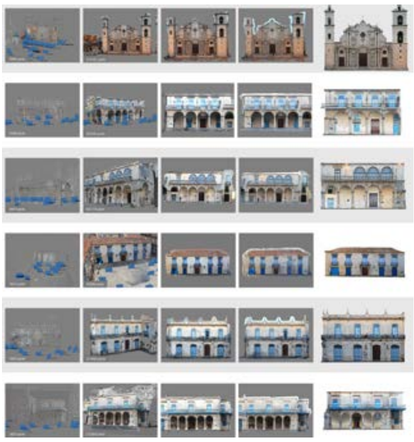

Figure 11. Buildings in Plaza de la Catedral: SFM.

Today there exist integrable methodologies of surveying which ensure surveys of entire cities in a few days taking advantage of photographic acquisition. In this manner models obtained either the most important historical artifacts or entire built-up areas can be obtained at no time at all and at the necessary scale. In the digital age, the concept of model is based on digital techniques now present in all architectural representation tools, techniques which have also invaded the field of architectural survey. 2D and 3D models give the possibility to have static and dynamic representation that allows us to move elaborations in a transitive manner around freely and shift from outside to inside the object. Now the concept of models is refined and updated giving more possibilities to study objects thanks to the complex and absolute interactivity between the real object (point clouds and photographs) and virtual system of 2D and 3D digital models. The use of these models would make it possible to work with more extensive knowledge when securing artifacts of Cultural Heritage. Acting upon more extensive knowledge reduces the costs and in some cases shorten the time necessary to carry out the intervention. 3D models prove to be indispensable for preventions, and for the process of cognizing. Historical architecture documented through the survey with 3D models can always be subjected to analysis or conservation and preservation intervention. It is precisely on the basis of this conception – which considers knowledge and prevention to be the most efficient and long-distance instrument – that we ought to work with our methodologies with the certainty that we can contribute significantly towards our country.

Endnotes

1.The comparison between high cost and low cost survey instruments is possible because they give analogous result in terms of models (numerical model) and edit operation to construct mesh models. Infact, since some years, SFM allows to get analogous results of 3D laser scanner by supporting just the cost of a simple camera.

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Summary:

The new technologies solved some of the problems of surveying, for example, accelerating data collecting, yielding graphic models less subject to interpretation and more adequately corresponding to reality, or offering the possibility to reproduce the graphic models many times with the view to sharing it with other researchers and scholars. The technology developed in the last twenty years makes it possible to obtain millions of points almost automatically in ever-shorter spans of time.

The great advantage of the innovative technologies is that they make it possible to create models of objects characterized by a density of metric and geometric information that no traditional surveying method can yield.　This new technologies constitute an useful and flexible tool to restitute a great part of scientific documentation on Cultural Heritage.

This paper precisely presents the City of La Havana (Cuba): a series of buildings overlooking the five main squares located in its historic center have been taken into consideration.

The process of surveying is conducted with a set of techniques. The acquired data are observable, empirical and measurable with the uncertainty level stated a priori and strictly controlled. Moreover, they can be archived and shared, and thus can be assessed autonomously. Also, all the procedures applied are replicable and therefore it is possible to acquire new sets of information for making comparisons. The SFM technique was applied to the Cuban case study; Structure from motion technique is a digital technology able to generate three-dimensional clouds of points departing from simple raster images. Today, digital technologies at our disposal impose the necessity to analyze in depth hardware and software that work together at all the stages of surveying (acquisition, elaboration, modelling and – obviously – CAD drawing). On the one hand, it is precisely this equipment that allows one to acquire points quickly and without difficulties relative to the volume of the object and the detail level (it is possible to survey artifacts of great dimensions and geometrically complex). On the other hand, the representation of surfaces acquired cannot be said to be so direct. The more relevant the complexity of the object, the more operations are necessary while difficulty level requisite for its representation soars. That is precisely why we are wary of the equipment which executes the whole process fully automatically in favor of semi-automatic processes which allow the operator to intervene in order to select the material, taking into account his knowledge of history and geometry, and to decide which surfaces will be the best for reconstructing the model with the greatest fidelity to reality. Each digital model has to be assigned a scale reference in close relationship with its geometric and perceptual characteristics. We consider it worthwhile to ponder the way in which the information has to be acquired in reference to the enormous possibilities opened up by digital technologies of surveying and representation.