METHODOLOGICAL ASPECTS OF ARCHITECTURAL DOCUMENTATION

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Abstract: *This paper discusses the methodological approach that is being developed in the state of Bahia in Brazil since 2003, in architectural and urban sites documentation, using extensive digital technologies. Bahia has a vast territory with important architectural ensembles ranging from the sixteenth century to present day. As part of this heritage is constructed of raw earth and wood, it is very sensitive to various deleterious agents. It is therefore critical document this collection that is under threats. To conduct those activities diverse digital technologies that could be used in documentation process are being experimented. The task is being developed as an academic research, with few financial resources, by scholarship students and some volunteers. Several technologies are tested ranging from the simplest to the more sophisticated ones, used in the main stages of the documentation project, as follows: work overall planning, data acquisition, processing and management and ultimately, to control and evaluate the work. The activities that motivated this paper are being conducted in the cities of Rio de Contas and Lençóis in the Chapada Diamantina, located at 420 km and 750 km from Salvador respectively, in Cachoeira city at Recôncavo Baiano area, 120 km from Salvador, the capital of Bahia state, and at Pelourinho neighbourhood, located in the historic capital. Part of the material produced can be consulted in the website: <www.lcad.ufba.br>.*

1. THE CONTEXT OF ARCHITECTURAL DOCUMENTATION

This paper presents the methodological approach that is being developed since 2003, by LCAD - the Laboratory of Computer Graphics Applied to Architecture and Urbanism at the Architecture School of the Universidade Federal da Bahia through their work for document the architectural heritage in the Bahia state, in Brazil, using digital technologies [1].

The vast architectural collection stands out as one of the main aspects of the rich cultural heritage of Brazil, with important colonial assemblies, such as the ones found in the states of Bahia and Minas Gerais and the city of Parati in Rio de Janeiro, among others. Heritages that alongside the modernist Brasilia, have symbolic values and represent a significant educational potential.

The state of Bahia contributes especially to the advance of that legacy, for its valuable historical heritage, arts and culture, one of Brazil's richest. Inside this huge collection, we highlight urban centers and its architecture, incorporating significant collections of movable and integrated goods of utmost importance for the history of Luso-Brazilian art. Most notably, Bahia has a set of preserved urban nuclei that encompasses five centuries of history of the New World, representing the various political moments, the economic and social changes that shaped the country, like the first possession and conquest of territory - represented by sets Porto Seguro, Santa Cruz de Cabrália, Salvador and Trancoso, The Sugar Cane and Tobacco Cycle - Cachoeira, São Felix and Maragogipe; the Gold Cycle, in the eighteenth century - Jacobina and Rio de Contas; The Diamond Cycle in the nineteenth century - Lençóis, Mucugê and Igatu [2,3].

Geographically, these settlements cover coastal areas of Recôncavo and the Chapada Diamantina. However, this important asset - as indeed the whole of Brazil - is under continuous threat due factors such as urban sprawl and land speculation, the socio cultural changes and new values resulting from them, and subject to degradation and all kinds of accidents. Despite the importance and fragility of this collection, most of it are in state of disrepair or lack of specific care, that impairs its preservation.

Over the last decades, many conservation actions have been implemented (legal protection, recovery and restoration works), but none of them have resulted in effective conservation of such property, whether by insufficiency of human and financial resources, either by the lack of a strategic planning policy that articulates the various social actors through democratic participation. Maybe, much of the population did not recognize the importance of this heritage.

The project of architectural documentation of historical sites and monuments can be understood as a complex process of systematic and comprehensive planning, acquisition, processing, indexing, storage, retrieval, dissemination and delivery of data and information about single buildings or sets of them, including graphical and non-graphical information and metadata for various uses.

Besides the more obvious applications in conservation and restoration of the buildings, the architectural documentation plays a vital role in preserving the memory of this heritage. This is a highly relevant aspect, given the impossibility of the physical preservation of all significant samples. There are several reasons for this, from the simple effect of time and weather, to more serious and dangerous causes such as heavy rains and floods, fires, earthquakes, neglect, abandonment and vandalism, among others. In Brazil, this is particularly worrying considering that except for few examples; most buildings from the colonial period were composed of raw earth and wood, materials that are completely destroyed by water and fire.

As explained, by their nature and extent, the documentation of architectural heritage in Brazil is a strategic issue and involves a great effort for its accomplish. The actions proposed aim to safeguard these monuments.

As a result of the documentation project, it is generated a huge multimedia database containing information of buildings such as photographs, photographic panoramas, rectified photographs, orthophotos, technical drawings, various types of 3D geometric models, including point clouds, and other kind of data such as videos, audio tapes, interviews, reports, pictures and historical texts, among others.

All steps in this process involve the comprehensive and intensive use of digital technologies. Thus, the methodology proposed comprehends five main parts summarized here:

- The overall planning stage, that consider all aspects of the work and the objective conditions for it, as well as the financial support and other resources;
- Data acquisition and field work, when the primary or raw data are captured from *in situ* studies or compiled from secondary sources, which also involves some other technologies;
- Data processing and analysis, including handling or manipulation, when the data (primary or secondary) collected are processed to generate the desired products or information and their metadata;
- Management of data including indexing, storage, retrieval, data security, access, dissemination and publication of the data and information produced for concerned public and, finally,
- Control and documentation of the project, in which should be analyzed in the various aspects involved in the project's implementation, as well as the assessment procedures used, and product quality grades, and also indicators of income, essential to assist in the planning of future works.

This set of phases represents a scientific methodological approach for a documentation project in order to achieve best results and the best practices. So, in the development of these activities it is required a set of digital technologies in every related step.

2. GLOBAL PLANNING

Every documentation project should be initiated by the global planning of the work, from the earliest stages comprising one or more of three main focuses, namely:

The focus of the contractor, usually a public agency that hires and establishes the work to be done, in their qualitative and quantitative aspects, being the main elements of this stage the edict and the terms of reference of the work. Complementary to this approach there is the focus of the performer, usually a private company that holds possession of these documents, prepare a thorough and detailed work plan in order to achieve the same under conditions of price, quality and deadlines established. Finally, in a different approach from the previous two, we can establish the so-called academic approach, adopted in academic studies that involve teaching, research and extension, which covers some issues of the two approaches mentioned above. However, there are specific features, which particularize the research done in Brazilian universities: few technical and financial resources available, undefined scopes and terms, and the absence of a contractor who establishes the general context for the work to be performed. This paper adresses all these aspects.

Thus, the scope of the architectural documentation project includes the general characterization of the work being undertaken in their quantitative and qualitative aspects, considering the study of the physical site, the purpose of the surveys, the specification of products to be obtained, data and media formats and execution schedule.

Thus, before the actual start of field work it is necessary a careful inspection of the physical site where the architectural documentation project will be developed with the purpose of checking the actual conditions for carrying out all activities involving the recognition and demarcation of the project physical area, counting the buildings to be surveyed, as well as verification of the specific conditions of each of them. Moreover, it is necessary identify additional resources to perform the work, such as scaffolding, for example. Also, related to the physical site, there is the need to obtaining prior authorization from the authorities and owners to carry out the survey, and the evaluation of climatic conditions, so that work should not be paralyzed by bad weather.

The clear definition of the work purpose is crucial for the development of products to be obtained, and the technologies to be used in the different phases of the documentation project. The products could be as varied as possible, since the traditional technical drawings for cadastral survey made by hand or through more sophisticated resources such as photogrammetry. The kind of product to be achieved depends crucially on the needs and aims of the project, along with the technologies to be employed. A particularly interesting record of the monuments is through three-dimensional numerical representations, such as geometric models of edges, surfaces, solids or even point clouds. When the technologies are employed to survey the three-dimensional data, usually two-dimensional products such as technical drawings, orthophotos, rectified photos and mosaics are obtained from the processing of primary data. So, depending on the work purpose, other technologies could be employed for the surveying of monuments, such as the photographic panoramas, photographs and videos, extremely useful and important to capture the general aspects of the works, such as context and temporality.

Depending on the survey purpose and phase of project documentation several technologies will be employed in the survey field, in data processing in laboratories, storage, publication and dissemination of information produced. It should, therefore be assessed the resources available for the work, considering the financial, human and technological aspects, so that the expected results can be produced within the requirements of time, cost and quality.

Finally, control mechanisms should be designed to follow work execution, whether from the standpoint of quality assurance of products, time schedule and financial resources available. It is also necessary to establish productivity and quality indicators to assess the work from a scientific bias, in order to provide experience and reliability to conduct similar projects. This allows a careful evaluation of the methodologies and technologies that are employed, a particularly important issue considering the technological evolution. Nowadays, the technological and methodological approaches are practically new in each survey, thing that did not happen until the 1980s. This generates a degree of uncertainty for the results, since each experience is unique.

3. DATA ACQUISITION

Undoubtedly, the evolution of digital technologies have profoundly impacted the documentation of cultural heritage. And one of the steps that have undergone major transformation was perhaps the stage of primary

field data collection, given the diversity and potential of the technological apparatus that was developed, and is available at increasingly affordable prices.

The traditional method of surveying buildings using direct measurement with sketches remains extremely important and useful for its simplicity and low-cost tools such as tape measures, plumb-lines and levels. Nowadays, this method can be enhanced by the use of measurement instruments based on digital microelectronics such as digital tape measures, laser levels, goniometers and plumb-bobs. These tools increase the accuracy of the survey and reduce the time required to perform the measurement. Thus, this method is still valid and popular for buildings with simple shapes (with few polyhedric faces), without many ornaments and small, especially in relation to height. Buildings with complex floor plans, with many non-right angles, always represent a problem for the survey, due the difficulty for measuring and controlling the deformation of these angles without the aid of topographic instruments. Another limitation of this method are great height buildings, due the need of scaffolding, expensive and time consuming to assemble, besides the risk of accidents that they always represent.

A way to address the deficiencies pointed out for the direct measurement is using, whenever necessary, topography to determine points of difficult access in the surveys, as well as for measuring angles in irregular shapes with the aid of a closed topographic polygonal, to allow compensation for errors and ensure the accuracy of linear and angular dimensions. Moreover, the topography is a method for calculating the coordinates of points that are inaccessible to direct measurement. Although it was a good solution, by directly measuring the association with topographical methods, the process of determining the coordinates of the point of surveying instruments was too laborious which was a complicating factor for its use, when many points were needed to be determined. With the automatization of surveying instruments, determining the coordinates of points, distances and angles has been greatly simplified as the calculations and notes are made by the technological apparatus.

Although the combined use of these two techniques performs very well, and solves most problems, special situations and new requirements imposed the development of new technologies and surveying techniques that were only possible through the digital electronics. As an example of particular situations, we can mention buildings with non-polygonal shapes and complex ornamentations in their exterior or interior. As new demands there is the need for three-dimensional representation of the monuments at the computing environment.

Also another technological possibility for use in documentation of sites is the GNSS - *Global Navigation Satellite System*, the best known and most popular segment is the GPS - *Global Positioning System*, maintained by the U.S. government. Although it may have an important application in particular cases, in most cases this technology comes with a secondary role, providing the georeference of sites and monuments. Considering this, we will refrain from further considerations.

Another "classic" and well known technique used in the survey of buildings is the Photogrammetry, which went through several phases of development: graphic, analog, analytic, and digital. The Digital Photogrammetry broke the paradigms of Photogrammetry in its other previous stages involving the use of extremely expensive and specialized equipment, and skilled workforce (photogrammetrists). These characteristics have made the use of these techniques inexpressive in Brazil for purposes of architectural documentation so far. The advent of digital photogrammetry allowed a significant simplification of the procedures, reducing the need for specialized labor, so the process can be used by architects and engineers. At the same time, the financial resources necessary to purchase equipments such as precision cameras and specific programs and computers are often smaller than the investment required previously.

So, "classical" Photogrammetry solved the problem of registration of complex shapes using stereoscopy and representation through the use of isovalue curves, while the digital photogrammetry allowed the generation of different types of geometric models, besides the traditional photogrammetric products such as orthophotos, rectified photos, mosaics, and technical drawings. However, photogrammetry still has some problems, especially regarding the taking of photography, whether on account of obstructions on the object to be surveyed, inadequate visuals, or alternatively, the difficulty in photographing the top of very high buildings.

In recent decades, *3D laser scanning* appears and is optimized with its great versatility for capturing any type of shape and amazing speed of data acquisition. This technology produces detailed geometric models in

point clouds, realistic or false color. Although the *3D laser scanning* technology raises the surveying of buildings to another level, the costs for its use in architectural documentation are still prohibitive in Brazil. In addition, there is the need of processing a huge amount of points, which will be discussed in the next section. The primary products produced by this type of technology are the geometric models of points and surfaces, as well as orthophotos. Other products are possible processing of primary data. The great advantage of this technique is the speed of data capture in the field, and the possibility of working in the dark, if it is not necessary the capture of the surface texture of the object [4].

Finally, constitutes the state of the art in building survey, the production of point clouds from photographic methods using techniques of Photogrammetry, Pattern Recognition, Image Processing and Computer Vision [5]. These techniques have been called Dense Stereo Matching [6] or photo-based Scanning [7], or Dense Surface Model - DSM [8].

Although they have significantly lower prices than *3D laser scanning*, this technology is still under development. The output of the geometric point models still requires too much processing and the models are still left with many gaps. The experiments known in architectural documentation present only partial models [9]. However for reasons pointed before, the technology is promising and should produce more significant results in the near future. Its main advantages are low cost compared to laser scanning and reduced working time in the field. The technology has been successfully used in the production of models of small objects like statuary.

Besides the technologies previously mentioned employed in the capture of data to produce technical documentation to be used for purposes of conservation and restoration projects, or even for filing as safeguard, there are other digital technologies that have great potential to represent the building, its surroundings and the temporal context in flexible and versatile ways for other types of application, namely the photographic panoramas, videos and movies and audio testimonials.

4. DATA PROCESSING

In architectural documentation, the data processing stage is basically the transformation of raw data gathered in field into the desired end products. Another advantage of digital technologies is the possibility to generate several products from the primary data collected, depend on processing quantity, using automated, semi-automatic or manual methods. These processes involve various types of tools and use of skilled labor and depend primarily on the type of technology and products to be generated. However, additional care should be taken since the capture of the primary data determines the final result, then emphasizing the importance of the overall planning of the work. We discuss below the main aspects of digital technologies used to produce data within the aimed products´ generation processes.

In surveys conducted using direct measurement or topographical methods, data processing is done through CAD tools like geometric design editors or modelers. In these cases, the process is manual, interactive, time-consuming and subject to misinterpretation. Boards of technical drawings or geometric models for online viewing on the *web* are the final results. Moreover, these models can be used to generate other products such as 3D animations and overviews using techniques of image synthesis or studies using numerical simulations.

When data acquisition is done by Photogrammetry, data processing consists in processing the photos and other data gathered in the field through the restitution models implemented in software algorithms, aiming to generate products of photogrammetric restitution, like orthophotos, rectified photos, mosaics, technical drawings, wireframe or surface geometric models. These models can be represented with the object original textures, in false color or shaded. The difficulties lie in the photogrammetric methods of data processing phase. While these methods are very accurate, powerful and versatile, the data processing is still done through interactive methods where the operator's experience and accuracy are essential. Efforts are being made for process automation, but the generation of useful finished products still requires much human labor.

When 3D Laser Scanning is used, data treatment consists initially in record of various point clouds (partial models) to obtain the complete model. Based on this model, operations of segmentation, filtering and sorting are carried out to generate geometric models of surfaces, orthophotos, technical drawings and various other products. Through photogrammetric techniques and image processing it is possible to associate the coordinates of captured points to their true color by resampling the point cloud on high-resolution

photographs taken from angles very close to those used for capture of point clouds. The main difficulty of this survey technique is exactly the processing of point cloud, due the size of files and the amount of processing needed, which requires robust machines and skilled labor. However, the technology is evolving rapidly.

In the surveying technologies that involve the acquisition of point clouds from photographs, known as Dense Stereo Matching, Photo-based Scanning, or Dense Surface Model, the process for obtaining this geometric model is carried out almost automatically after reported to the processing system the parameters to be used in the operation. After obtaining this basic point cloud model the derivatives are generated, as surface or solids models, technical drawings and orthophotos. However, these second generation products still require much specialized human labor.

All these mentioned technologies have significant application in architectural documentation, although they might be more suitable and effective in specific situations. The studies and experiments done so far and the results indicate that a single technology is not sufficiently versatile and efficient to serve all ranges of existing applications. Thus, the technology to be used during both data acquisition and processing will depend on many factors such as characteristics of the application, implementation deadlines, technological, human and financial resources, besides the team experience.

At least, discuss the later stages in compiling the data, the development of applications that use the information produced, by both the vastness of the possibilities, as the diversity and sophistication of available technologies are beyond the scope of this paper, considering the space to discuss them in a minimally adequate manner.

5. DATA MANAGEMENT

Regardless of immediate applications that led to the execution of the survey, once data is produced, it needs to be indexed, stored and preserved for later use. And to ensure that these data can be used effectively they must be disclosed, published and retrieved. That closes the cycle that encompasses planning, gathering, processing, indexing, storage, publication, dissemination, retrieval and use of data and information on buildings and architectural ensembles. Information which in turn will influence the conservation and interventions on these sites by generating a new cycle of documentation, to be repeated indefinitely throughout the lifetime of the building and sometimes even after their destruction.

The set of operations which includes indexing, storage, preservation, publication, dissemination and retrieval, performed on the multimedia database and its metadata, is called data and information management. This set of operations, perhaps the most complex, given the amount of different types of knowledge needed, technologies and professionals involved in its planning and execution, as discussed below.

Profesionals of Information Science will contribute to the knowledge for identifying (nomenclature), index and store documents and metadata in order to facilitate the retrieval of these documents and their use. This involves the definition of keywords, descriptors, rules for document classification and nomenclature of the same, and the establishment of flows to query, update, maintenance, access restriction, and other types of operations applied to documents contained in the database.

The Computer Science professionals will act in design and implementation of a multimedia database able to promote the use, maintenance, integrity, security and efficiency of operations conducted by users on the database with specifications set, even in the final stage or intermediate stages of the process. So, there are established business rules, requirements for information integrity, the hierarchy of data access, transactions and access records, and all other control that are necessary and sufficient to ensure efficient use of the system.

Moreover, other professionals such as web designers, webmasters and others would act in the web interface between the multimedia database and end users, providing appropriate conditions for online access and queries to the various types of information stored. In order to achieve this, it is necessary to make use of various types of viewers and *plugins* that allow different media and data storage formats visualization, besides traditional resources for web interfaces for database applications implementation.

Although this idea is particularly attractive, the construction of a large database to contain and maintain multimedia data of the architectural heritage, there are some issues that need to be better thought out to ensure data access in the future. More than the physical security of data, a problem overcome by technical *backup* and data security, it is necessary assures that the data could be read in the future. The velocity of technological evolution, diversity of media, file formats and their versions, and the obsolescence of programs and devices for reading and writing that occurred in recent past shows that the guarantees to preserve compatibility are far from being a solved issue.

6. CONTROL AND META-DOCUMENTATION

As a final step of the proposed and used methodology, there is the control and documentation of the processes, so called meta-documentation, which involves the production of partial reports and final reports.

It is essential do a critical evaluation of products and processes in order to produce qualitative and quantitative performance indicators of activities and generated products, which could guide new documentation projects planning and implementation. Moreover, they should validate the use of those technologies in practical applications in specific areas.

At this stage, a particularly useful control mechanisms is the generation of thematic maps for monitoring work progress implemented through GIS tool, which allows the spatialization of the work in case of many units to be surveyed or very large or complex buildings. Such maps can be converted into illustrated spatial schedules.

7. CONCLUSIONS

This work aims to divulgate the perceptions accumulated in conducting a series of scholarly works in order to discuss and refine them with other experts participation, contributing to the improvement work methodologies as well to the diffusion of scientific knowledge.

As explained here, the documentation process for architectural and urban sites, by the amount of variables involved and resources allocated is a complex and multidisciplinary activity, involving traditional disciplines such as architecture, design, survey methods, history and art history and strongly combining digital microelectronics, computer science and information science, involving significant technological, financial and human resources.

Finally, we must assure that in the eagerness to produce extensive documentation, poorly understood and poorly drafted, one does not lose the focus of the problem, i.e., instead of further efforts for monuments physical preservation, these efforts should be divided for the preservation and re-working in digital media. Therefore, it is research institutions and groups´ responsibility to find solutions and produce specifications for use and creation of applications and file formats that can ensure the preservation of digitalized heritage. These are open questions that need to be addressed soon.

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9. REFERENCES

[1] AMORIM, A. L.: Documenting architectural heritage in Bahia – Brazil, using digital technologies. Proceedings of CIPA 2007, Athens, September 2007.

[2] BAHIA, Inventário de proteção do acervo cultural da Bahia. Monumentos do município de Salvador. v. 1. Salvador, 1975.

[3] BAHIA, Inventário de proteção do acervo cultural da Bahia. Monumentos e sítios da Serra Geral e Chapada Diamantina. v. 4. Salvador, 1980.

[4] AMORIM, A. L., CHUDAK, D.: Patrimônio Histórico Digital: documentação do Pelourinho, Salvador – Ba, com tecnologia 3D laser scanning. Proceedings of SIGRADI 2005, Lima, November 2005.

[5] SCHARSTEIN, D., SZELISKI, R.: A Taxonomy and Evaluation of Dense Two-Frame Stereo Correspondence Algorithms. International Journal of Computer Vision 2002, 47(1/2/3), 7–42.
[6] HULLO, J. F., et al.: Photogrammetry and Dense Stereo Matching Approach Applied to the Documentation of the Cultural Heritage Site of Kilwa (Saudi Arabia). Proceedings of CIPA 2009, Kyoto, October 2009.
[7] WALFORD, Alan.: A new way to 3D scan: photo-based scanning saves time and money, http://www.photomodeler.com/downloads/ ScanningWhitePaper.pdf, 2010-10-10.
[8] HUTTON, T, et al.: Dense Surface Point Distribution Models of the Human Face. Ieee Journal 2001, 153-160.
[9] LIMA, J. F. S., et al.: Levantamento da portada das igrejas de São Francisco e do Rosário com nuvens de pontos. Proceedings of Arq.Doc 2010, Salvador, December 2010.