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CREATING 3D-DATABASE FROM IMAGES AS TOOL FOR RECORDING BUILDINGS, IN CITIES WITH NATURAL DESASTER HAZARD

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Preparing for natural disasters is vital for mitigating harm and loss of important cultural sites. In Cuba, this rigorous planning informed by years of experience has focused on the recuperation phase after a disaster or storm. Governmental agencies plan rehabilitation and reconstruction projects in the short, medium, and long term. Accurate models are essential for planning these recovery projects. Photogrammetry represents a novel way to create these models at a potentially city-wide scale. Images taken with conventional cameras are used for object measurement to create digital 3D models of buildings, which will be stored in an architectural database. Important cultural and historic sites were used as initial case studies for the creation of models through photogrammetry. These catalogs will facilitate the maintenance and assessment of these important sites and help to plan future reconstruction plans after a natural disaster. Photogrammetric corrections cause minimal graphic distortion to provide accurate metrics of geometric and decorative information. Examples of these techniques in other Latin American cities will also be discussed.

Keywords: Photogrammetry, Digital, Model, Dimensioning, Blueprints.

1 INTRODUCTION

1.1 Initial Situation

To protect the economy and human life Cuba has established a succession of phases to counterattack the meteorological effects in the country. The Cuban Civil Defense gathers today more than 45 years of experience planning with anticipation how to face tropical storms and hurricanes. Planning is based on a rigorous phase definition appointing responsible parts and supplies. According to this methodology, the introductions of these phases answer to certain parameters before they are put in place, this allows certain flexibility depending upon the level of danger for each.

The Recovery Phase, last of the four phases starts when the danger has passed in one or more territories. The characteristics of the threatened region are taken in account in all cases, the influence zone, wind intensity, rainfall and the storm translation speed. It must also consider the previous weather conditions that favor or worsen the situation, and therefore, influence the water table and the filling of the dams.

Although these phases are comprehensive in themselves, there are preventive measures that mitigate hurricane effects, including the flood areas, the pruning of dangerous trees and the cleaning of storm water drains. The technical status and maintenance of reservoirs, the evacuation roads, the determination of the damages that have occurred; making the reconstruction process as efficient as possible, and trying to re-build everything with same architectural identity and historic lines that previously had. Same situation can be found in many cities in Latin America with a great deal of historic structures constantly threatened by natural disasters.

1.2 Problem Definition

After the occurrence of a natural disaster, actions must be taken to rebuild homes, buildings of all types and monuments, based on a process to identify the different pathologies, quantify damages and reconstructing. Maintaining the identity traces, their culture, customs and traditions reflected in the architectural values of their homes, this happens in every hurricane season and many resources are invested in the reconstruction of buildings destroyed by one cause or another. In Latin American and Caribbean Counties, the usage of state-of-the-art technologies for monument conservation is relatively low and, in most cases, they go through an initial stage of organization and institutional strengthening. However, the synergy that could result from the integration of regional experiences around a specific problem would have repercussions, not only on the strengthening of current capacities on the subject, but also in facilitating effective access to specialized information to support the decision-making processes that take place in governments. Today, photogrammetry is little used in Latin America as a tool to preserve national historical heritage, due to the high cost of the equipment it requires and also the little knowledge about this technology among other reasons, despite the fact that all the countries that conform this continent have a great architectural-archaeological wealth, which encourages tourism and reinforces the need to introduce science and technology in order to preserve it for generations to come, with the active participation of its whole society.

2 STATE OF THE ART

Computers opened the possibility of perfection, documents ceased to be the only work tool of historians, architects, and archaeologists, and digital architectural photogrammetry allowed to improve the process of identifying an object or ancient building for later conservation. The need for extremely precise data was evidenced to perform comparative analysis in dimensional information, the goal is to measure as accurately as the instruments allow, and often these instruments are not within the reach of professionals on this field. Architectural photogrammetry is an excellent tool for since it allows to know dimensions with a millimeter accuracy. This, integrated with a database, will enable conservation actions (maintenance, restoration, reconstruction, remodeling) with greater precision.

These technologies began to take shape in the world in the mid-90s, a movement led by developed countries such as USA, Germany, United Kingdom, among others. Early 2000 is when Latin American and Caribbean region began to insert themselves in these initiatives, generally oriented to the introduction of these technologies from the theoretical point of view. University of Holguín, "Oscar Lucero Moya", from the Construction Management Research line, began in 2006 approaching this technology by initiating joint investigations on Photogrammetry, Remote Sensory and Geoprocessing Laboratory of the Federal University of Santa Catarina in Florianopolis (LabFSG), Brazil. In 2009, coordinating the international network REFADC of the Ibero-American Program of Science and Technology for Development (CYTED), called: "Ibero-American Network for the Application of Digital Architectural Photogrammetry and GIS for the

Conservation of the Historical, Cultural and Archaeological Heritage of Cities for a Sustainable Tourism Management ", with the participation of 7 countries: Cuba, Spain, Portugal, Brazil, Guatemala, Mexico, Ecuador. To this date, the catalog of the city of Cuenca in Ecuador, led by the University of Azuay, has begun through the General Deanship of Investigations. The city of Mérida in Yucatán, Mexico, with a project of CINVESTAV, "Unidad Merida", some archaeological sites such as Ixinché in Guatemala, with a project from the San Carlos University of Guatemala (Zucatelli 2009).

With the support of the Civil Defense of Cuba, the catalog of Cuban cities (Trinidad, Santiago de Cuba, Holguin, Havana City) was initiated to be used in the recovery phase after natural disasters, specifically tropical storms, which is the most common meteorological phenomenon in the Caribbean. The project integrates knowledge and experiences in the use of the photogrammetric technique, creating a detailed documentation of the built heritage of Cuban cities and providing the results for conservation of the heritage of Cuba and other parts of Latin America.

3 STATE OF RESEARCH

After the occurrence of a natural disaster, the Recovery Phase will be established, directed by the Disaster Management Centers, to start rehabilitation actions, which includes the medical care to the victims and the restoration of vital services: electricity, water, gas, hospitals, food, communications, transportation, as well as the sanitation of communities and restoring operations on roads and airports (Defensa Civil de Cuba 2017). Parallel to those actions, reconstruction will be initiated, which will be solved in the medium or long-term periods, through programs directed by government agencies, based on city catalogs, elaborating 3D databases from two-dimensional images taken with conventional digital cameras.

The real estate catalog of architectural value is supported in its graphic register (drawings, photographs or models) facilitating classification, maintenance, value, recovery etc. Architectural Photogrammetry contributes to this purpose in a special way, applying certain techniques to the photography to equip them with scale (measurement) and to correct the distortions due to perspective. The building description responds to aesthetics, architectural influence and proportion criteria, so that all buildings are represented on the same scale, facilitating the comparison of their details and characteristics. The photos must be arranged in a Cartesian manner, referenced to a system of rectangular coordinates generating orthophotos, description of important details and 3D models also visible in the Google Earth © platform.

4 RESEARCH METHODOLOGY

4.1 Architectural Photogrammetry

Currently, one of the main application areas of non-topographic photogrammetry is architecture, using the term: "Architectural Photogrammetry" through which graphic material is obtained (planes, images, three-dimensional models) that represents in detail the facades of buildings and monuments. Applying this technique, it is possible to register the real situation of objects and save it in databases for later use. Line Drawings can be obtained (at scales 1:20 or 1:50) from pictures, rectified photographs, three-dimensional models, orthophotographs or digital models, with the possibility of integrating them to virtual environments, facilitating tasks of remodeling, recovery and rescue of buildings, aimed at their conservation.

4.2 Creating the Catalog

Based on the work methodology established by the "Ibero-American Network for the Application of Digital Architectural Photogrammetry and GIS for the Conservation of the Historical, Cultural and Archaeological Heritage of Cities for Sustainable Tourism Management", of the Ibero-American Science and Technology Program for Development (CYTED) began the process of taking photographs with the following equipment: Digital Camera, 18 mm Lens, Tripod, Digital Distance Meter, Flexometer and the PhotoModeler 2012 Software.

4.2.1 *Taking the photos*

After the selection of the building, we proceed to take the pictures that are going to be the fundamental base of the process. The camera should be placed on the tripod at specific positions and at the most convenient distance from the building, allowing the camera to focus automatically at the beginning. When the correct focus is achieved, the camera is switched to manual mode and the focal length is set, which is previously established with the camera calibration carried out in PhotoModeler software, it will be used in all the shots (18 mm was used in this case) (Figure 1).

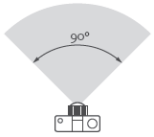

Figure 1. Camera aperture angle (Leão de Amorim and Groetelaars 2004).

On this process is important to consider the following aspects:

- Picture must be performed in a way that the angle between the camera and the model center is 90º, describing a semi-circumference.
- Picture must be taken at daytime and where there will not be shadows projecting onto the building, neglecting this might throw errors on the digitalization process (advisable to take pictures in a cloudy day)
- The minimum number of photos must be 10 and all common points must appear in at least two pictures.
- Reference measurements must be taken to check the scale accuracy.

4.2.2 *Model construction*

PhotoModeler 2012 Software is used to process the pictures, which must be uploaded in a gradual way and the software will recognize them automatically.

4.2.3 *Pictures orientation*

For the photo orientation, points are identified in the dimensions X, Y, Z that way the program has information in the vertical, horizontal and depth axes of the model and it can be located in the space. Once the pictures are oriented with a considerable number of points distributed in a homogeneous manner, the information is processed. The residual error and the proposed software suggestions are observed. A residual error of up to 5 pixels allows you to continue working in an acceptable manner. As the points in the images increase, the residual error decreases, but it must be corrected using the point quality table, which indicates the location of the point with the highest error (Figure 2 and 3).

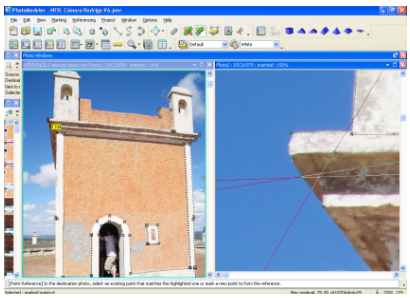

Figure 2. Point reference estimation by PhotoModeler Software in "Loma de la Cruz" Monument, Holguin City, Cuba (Justel 2013).

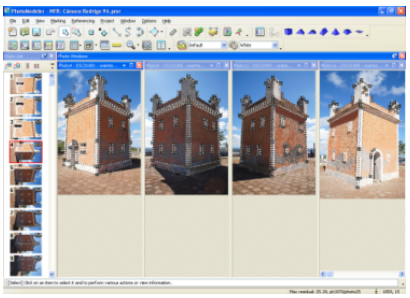

Figure 3. Closing the model (Justel 2013).

Figure 4. Model surface generation through referenced points (Ochoa 2003).

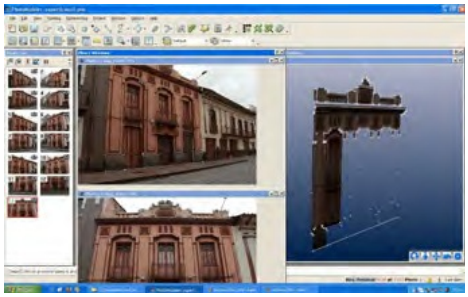

Figure 5. Assigning texture to obtained surfaces (Ochoa 2003).

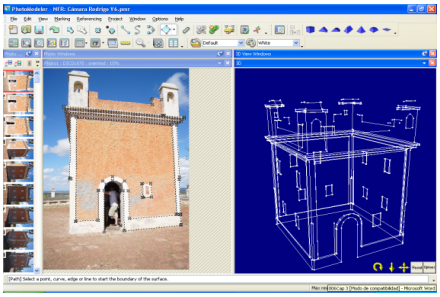

Figure 6. Line view model (Justel 2013).

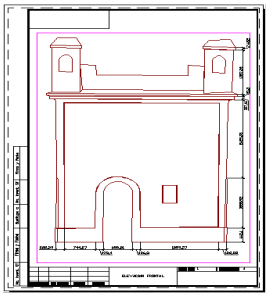

Figure 7. AutoCAD format drawing (Justel 2013).

Each photo must be referenced with the next one, following the established sequence. In the case of constructions that allow it, the last snapshot must be referenced with the first one to close the model.

The next step is to draw the surfaces that conforms the model using the points already referenced in the three-dimensional space (Figure 4).

Once the surfaces have been determined, texture can be assigned to the model. This process can be done automatically or it can be done manually determining textures one by one to be used for specific surfaces (Figure 5).

With the created surfaces the orthophoto is generated and exported to a CAD drawing software (Computer Aided Design), the model is scaled, and its measurements are real and accurate. By working with the visualization tools, the independent faces of the model can be obtained and dimensioned (Figure 6 and 7).

5 RESULTS

Based on the REDFADC proposed methodology, the application of photogrammetry in buildings reconstruction in the city of Holguín, Cuba, made possible the recovery of original projects, analyzed through digital architectural photogrammetry, with three-dimensional geometric quality and the storage of the information in Databases, available for maintaining / recovering the values of the historical patrimony of a nation, after the occurrence of a natural disaster, foreseeing cataloging each epoch, resulting in a faster and precise process (Figure 8).

6 SAMPLES

Figure 8. Orthophoto, digitalization and detail of building facade located at Benigno Malo Street 6-34 in Cuenca, Ecuador (Universidad del Azuay 2003).

7 CONCLUSIONS

The digital architectural photogrammetry turns out to be an excellent tool for cities, in reconstruction after the occurrence of a natural disaster, to carry out actions of maintenance, restoration, reconstruction or remodeling of buildings, since it allows to know the dimensions with millimeter accuracy. Integrated with a database, it will provide better efficiency and accuracy to conservation actions on buildings. In addition to applying a procedure duly documented next to the knowledge and experience acquired by the technical team, plus the instruments and software, constitute a technological solution applicable to different cases and transferable to other institutions and organizations interested in the subject.

References

Defensa Civil de Cuba, *Guía Familiar para la protección ante ciclones tropicales (Para residentes en áreas urbanas),* Cuba, 2017.

Leão de Amorim, A., and Groetelaars, N. J., *Técnicas de restituição fotogramétricas digitais aplicadas à Arquitetura: um estudo de caso,* UFBA, Brazil, 2004.

Ochoa, P., *Fotogrametría Arquitectural: una herramienta para la gestión del patrimonio edificado,* Universidad Verdad N. 60, Universidad del Azuay, Cuenca Ecuador, 2013.

Universidad del Azuay, *El patrimonio edificado de Cuenca*, ISBN 978-9942-13-372-4, 2013.

Justel, A., *Manual de usuarios para el uso del software PhotoModeler NFR versión 6,* Universidad de Holguín Oscar Lucero Moya, Cuba, 2013.

Zucatelli, G. F., *Metodología y evaluación del Software Photomodeler en el uso del levantamiento catastral del patrimonio histórico edificado,* UFSC, Florianópolis, Brazil, 2009.