1 DEFENSIVE ARCHITECTURE OF THE MEDITERRANEAN
XV to XVIII Centuries

Pablo RODRÍGUEZ-NAVARRO (Ed.)

DEFENSIVE ARCHITECTURE OF THE MEDITERRANEAN

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Vol. I

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XV TO XVIII CENTURIES

Vol. I

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Comprehensive Methodology for Documenting the Defense Towers of the Valencian Coast (Spain)

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Abstract
For years we have approached the architectural heritage through the traditional drawings, based on data collection taken from sketches and point to point measurements; however, today we can rely on different systems that make necessary to consider not only the phases of the elevation but the methodology to follow, constituting in itself a study that needs to be addressed from the knowledge of advanced data collection techniques. Thus we must analyze what is special about the work and what are our research needs, which will give rise to a list of products to be obtained and will result in a number of plans to scale, photogrammetries, 3D models, pictures and videos. Only then will we obtain the appropriate methodology which may include traditional direct surveys, photogrammetric surveys (2D correction, 3D restitution), 3D laser scans, drones, photographs, spherical panoramic photographs, video, etc.
In the present communication we describe the process followed in determining the methodology that is being carried out in the elevation of a building corpus that presents special characteristics due to the diversity of geographical locations and the dimensions and materials used, as well as its conservation status.

Keywords: digital heritage, coast towers, photogrametry, scanner laser 3D.

1. Introduction

The towers of Spain's eastern coast have a clear historical and architectural identity, but a comprehensive study of them is still pending. The approximations that have been made so far, besides constituting a partial approach, need to be updated at both the content and the use of current scientific methodology so their results do not have the rigor and visibility that advanced technologies are putting within our grasp.

It is precisely with the study of the constructions themselves where we can make further progress in their knowledge, and the best way to more deeply comprehend their relevance is by drawing them. The overall objective of the present work is to provide a methodology for the graphic documentation of this architectural heritage, which addresses all the existent problems in the different constructions, so that we are able to generate the metadata and three-dimensional models of the watch and defense towers of the Valencian coast for their interpretation and effective worth.

Our proposal includes a global study which allows us to have a comprehensive view of what truly was of such great strategic military importance. This way, methodology will be applied not only to existing towers, but also to the ones which no longer remain, making hypothetical virtual reconstructions from documentary sources, projects, photographs and archaeological remains.

For this study, we propose using the most advanced technical means available in the area of graphical representation, employing a flexible methodology as appropriate, trying to simplify processes and optimize resources while maintaining maximum reliability and quality of results. This system will enable to obtain photo-realistic two- and three-dimensional models with the incorporation of complete data, becoming a documental source not only for the present research but also for future ones, providing a body of work with accurate and reliable models with which to work from any location using the current means of dissemination. In addition, these same results can be adapted for use in the cultural field aimed at the general public.

2. Previous documentation

The distinctive features of each of the towers in regards to their conservation status, geographical location (either in plains, mountains or along cliffs), access to them and their external and internal shape, will determine a specific methodology for optimum results. Therefore, prior to the first visit we have to gather all the information possible in order to capitalize our onsite visits.

The basic pre-visit information needed is established in the following items:

- Location: town and access to the tower.
- Cartographic map of the area.
- Ownership: public or private. Permissions needed.
- Contact with local technicians: archaeologist, architect, engineer,...
- In case of current occupation, contact managers; Tourist Office, dealership,...
- Access to the interior of the tower. If it is possible to access to the interior we must determine if it is opened or we have to request its opening.

3. Photo and first sketches

We always bring a camera to our first visit to any of these towers and basic tools for first freehand notes, which will consist of the main measurements. For the realization of the photographs we must proceed very orderly, taking notes in a schematic sketch, numbering the pictures taken in the exterior, interior by floors, cover, etc, so that later on we find no difficulty in identification.

On this visit, the methodology or methodologies for the graphic elevation will be decided, and we should dedicate the observation of towers mainly to the determination of the following:

- Location:
    - On plain or mountain.
    - Exempt or within a urban área.
    - Visible or not around its entire perimeter.
- Form:
    - Polygonal.
    - Rounded.
- Flown elements. Shape.
- Dimensions:
    - Height.
    - Number of floors.
    - Number of rooms per floor.
- Stairway:
    - Size.
    - Shape.
- Cover; accessible or not.
- Has movable objects inside.
- Has annexed buildings.
- Presence of vegetation.
- Other features.

4. Topographic support

The topographic support is reduced to obtaining the coordinates (x, y, z) of the targets, needed to locate a specific spatial position and be able to scale the model. To obtain the coordinates of targets, we employ a IS model Topcon topographical station, capable of measuring distances to a maximum length of 3,000 m. with an accuracy of ± (2 mm. + 2 ppm. x D *) m.s.e. by prism measurement.

The methodology carried out in the elevation is based on the generation of a closed polygonal mesh around the tower, in which vertices we have located the basis of the topographic survey measurements. The method used in establishing this closed polygon will allow us to minimize possible measurement errors and to compensate where appropriate. For the interior, we establish an itinerary that attached to the outer polygon will constitute the support mesh.

To create this support mesh we must establish an absolute coordinates system to which refer the positions of the rest of bases and targets. So we start from an estimated position for the first base, to which we have assigned the coordinates (1000, 2000, 100) and from a relative orientation with respect to a fixed point in the tower. Taking the first position as the origin, and by measuring angles and distances, the station will give us the position of the following measurement bases that, provided we keep the axes of measurement oriented, will be given in the same absolute system above mentioned. At the same time the supporting mesh has been generated, the positions of the different targets located at fixed points on the ground have been measured by the radiation method. By working directly with an absolute and oriented coordinates system, we avoid having to make further calculations.

5. 2D photogrammetry. Rectification

Rectification remains the most simple and economical system to obtain scale drawings of flat or substantially flat vertical surfaces. In our case, we find towers of square or polygonal plant in which we can apply this method.

To ensure reliable and accurate completion, we must procure the successful accomplishment of:

- The photographic shot.

- Obtaining the coordinates of at least four points.

- The correct calibration of our camera.

Precautions when taking photographs start by having our standpoint as perpendicular as possible to the object; in case of projecting elements (such as a machicolated balcony) we should take two or more photos for the correction, so that we can cover the entire surface.

As for obtaining coordinates, we will try to work with targets and identify morphological points at those inaccessible points. All these points will be identifiable from the place where the photo shoot is done.

Regarding the camera calibration, we must exercise caution during this process and maintain the focal length calibrated to take the shots to be rectified.

Fig. 1- Photogrammetric elevation of the Burriana Tower (Castellón) using a rectification system. A- West elevation. B- South elevation. C- East elevation. D- North elevation. (Graphic elaboration: R. Atzeni, V. Naldini, P. Rodríguez-Navarro).

6. 3D photogrammetry. Photomodeling

In recent years, photomodeling advances have been remarkable, mainly due to the development of new algorithms that have facilitated the production of three-dimensional models using the method called SfM (Structure from Motion).

This method is based on the use of conventional images, made in principle with any camera, from any point of view, but keeping with the maxim that all parts of the model are visible at least from two different points of view.

In models with textures of uniform tones, such as clear skies, glass or polished surfaces, artifacts appear due to the inability to identify homologous points precisely. We mainly encounter this problem when shooting the towers against the sky and, although it can be avoided with the use of masks, the process is very laborious.

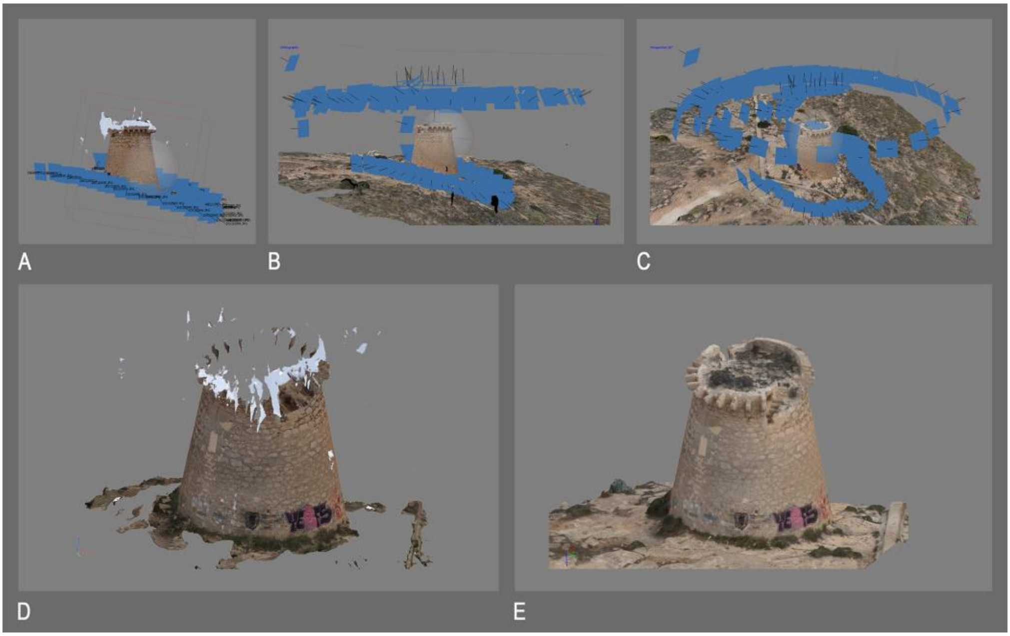

Fig. 2- Photogrammetric elevation of the Escaletes Tower (Santa Pola, Alicante) by SfM photomodeling A- Process by taking photographs from the ground. B- Process by incorporation of photographs taken by the drone. C- Perspective showing the sequence and connection of the terrestrial and aerial images, where we can appreciate the three sets integrated by the ground ring, aerial ring, and the cover area. D- 3D model from terrestrial photographs, made without masks or post processing, where the absence of the cover, the aberrations of the tower's coronation and artifacts due to the sky can be seen. E- Same model including aerial photographs. The absence of artifacts and complete restitution of the model is observed, including the cover and surroundings. (Graphic elaboration: P. Rodríguez-Navarro).

When working with this type of software, the first thing that needs to be done is the alignment of the pictures that will be used to rebuild the model. This is done automatically and includes calibration and correction of all images based on their EXIF data. The procedure is based on the use of each pixel of the image as a point, looking for homologous points in all the pictures and thereby the relative positions of each camera.

The set of camera positions, along with the pictures themselves, are used for the next phase which is the construction of the model's geometry, ie, the construction of a 3D polygon mesh defining the model's surface.

Finally, we can automatically create the photorealistic texture for the 3D model where to get the orthographic views.

However, this system poses some difficulties we should solve by implementing alternative methodologies. These problems are:

- Access around the entire perimeter of the tower to take pictures.

- Access to the cover and flown elements to be photographed.

- Need to mask all the photographs capturing the sky

- High difficulty or impossibility of photographing interiors (due to lighting problems) and constricted spaces (such as narrow staircases).

7. UAV (drone)

Using a drone for shooting the photographs solves the first two accessibility problems listed above. Aerial photographs allow us the freedom of movement needed to take pictures from every point of view that we deem necessary, including areas that cannot be accessed otherwise. Furthermore, if we use the same camera for a terrestrial photographic sequence, we can proceed to do photomodeling without masking the sky, solving the third problem above mentioned.

For this Project we used two drones manufactured by Dronetools, a quadcopter (quad) and an octocopter (octo). There are two fundamental differences between them:

- The quad is handled by a single operator who acts both as pilot and camera operator; while the octo requires a pilot and a camera operator, who will make use of his own command to operate the camera.

- The quad has a lower elevation capacity, so it carries a lighter camera.

The camera used in the quad is the Sony RX100 II, with a 20.2 MP resolution, a 13.2 x 8.8 mm. CMOS sensor and Zeiss F1.8 lens with 28-100 mm focal length. (Equivalent 35 mm.). The camera used in the octo is the Sony α7R octo, with a 36.4 MP resolution, full frame CMOS sensor and ZEISS f4 lens with a 24-70 mm focal length.

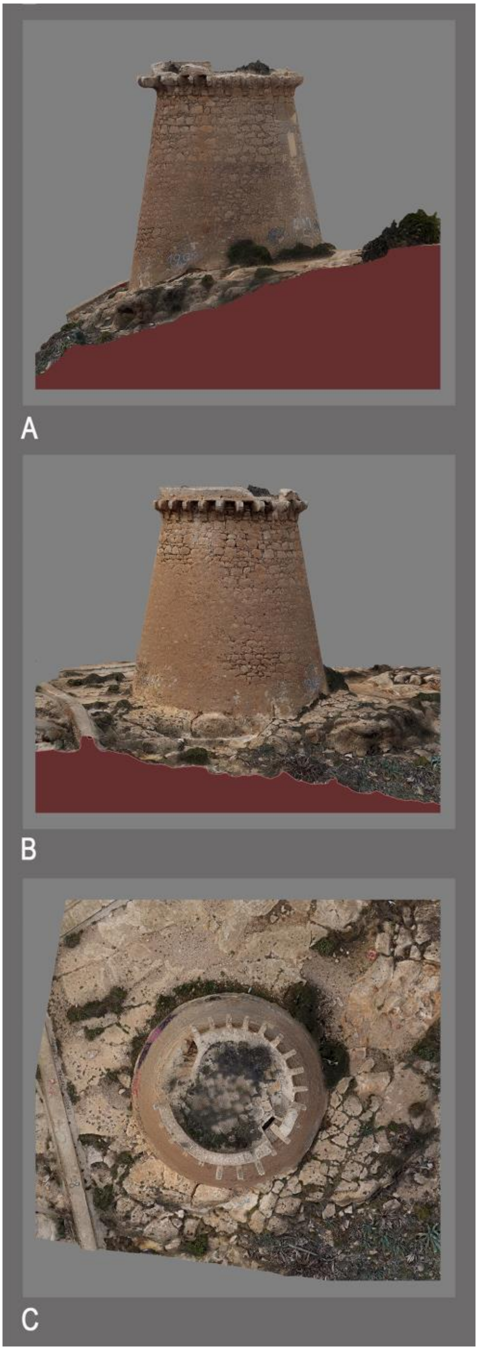

Fig. 3- Photogrammetric elevation by SfM of the Escaletes Tower (Santa Pola, Alicante). A- East elevation. B- South elevation. C- Plant. (Graphic elaboration: P. Rodríguez-Navarro).

The choice of camera is given by the distance from which the shot is made since it is advisable, in order to achieve a good result, trying to capture as much of the object as possible. Thus, with larger towers featuring annexed constructions, the drone shoots from a further distance and a higher resolution camera is used.

8. Scanner laser survey

For more complex structures, the use of 3D laser-scanning technology is necessary, solving the problem posed by photomodeling of interiors, whether for lighting reasons or for a question of space and complexity. For this work we have chosen to scan all the towers that have a complex inner space and / or narrow staircases, mostly curved or spiral.

Scanning is much more laborious, both for data acquisition and subsequent processing (registration of clouds, mesh, surfaces, textures,...), but ensures correct data acquisition under any circumstances. In our case we used a ZF 5006h Zoller + Fröhlich GmbH phase-shift variation scanner, with a maximum effective distance of 79 m. and a measuring speed of more than a million pixels / sec.

The software chosen to manage the point clouds has been V9 Leica Cyclone, by Leica Geosystems, which continues to be the most capable software to manage dense point clouds. In addition, this version has advanced significantly to include reports that cover registration accuracy, error statistics and histograms for each target and/or cloud constrain. In addition, we have used the Autodesk ReCap 360 Ultimate software with very good results in terms of automatic registration, exportation of files to be read with other software (such as Cyclone), and compatibility with CAD and BIM formats.

9. Conclusions

The study and determination of a methodology is fundamental to approach any research project. In addition, in our case, taking the architectural elevation as a fundamental means for the analysis and study of a building corpus, it is

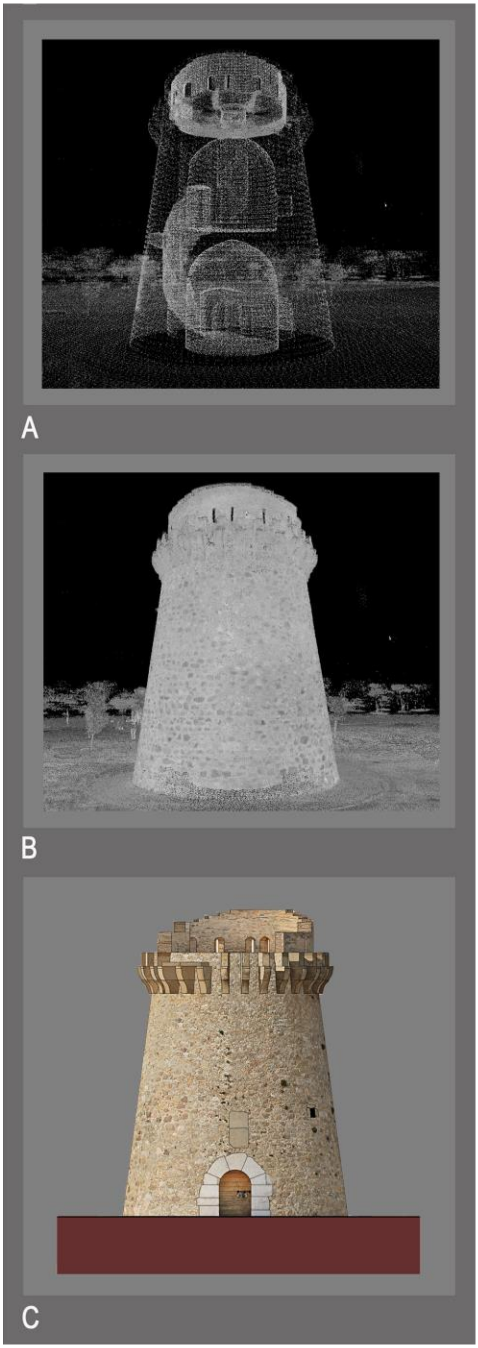

Fig. 4- Elevation of the Piles Tower (Valencia) by 3D laser-scanning technology. A- Inner-outer point cloud. B- Exterior. C- Textured model. (Graphic elaboration: G. Verdiani, R. Atzeni, V. Naldini, P. Rodríguez-Navarro).

even more important since the casuistry of each of the towers can be completely different.

We started with the necessary preliminary inspection that led us to adapt the methodology used in each case, for each tower, ending up with a combination of various technologies that are being incorporated to the project.

Furthermore, we have added historiographical archived information which, in many cases, has helped us to understand and complete the data required for the thorough understanding of these constructions. With all this we will be in a position to disseminate the results at the two levels contemplated in the project: a scientific level, with complete data and high-resolution models; and for the general public, with lighter models manageable by smartphones or tablets, with the selection of the necessary data for its understanding.

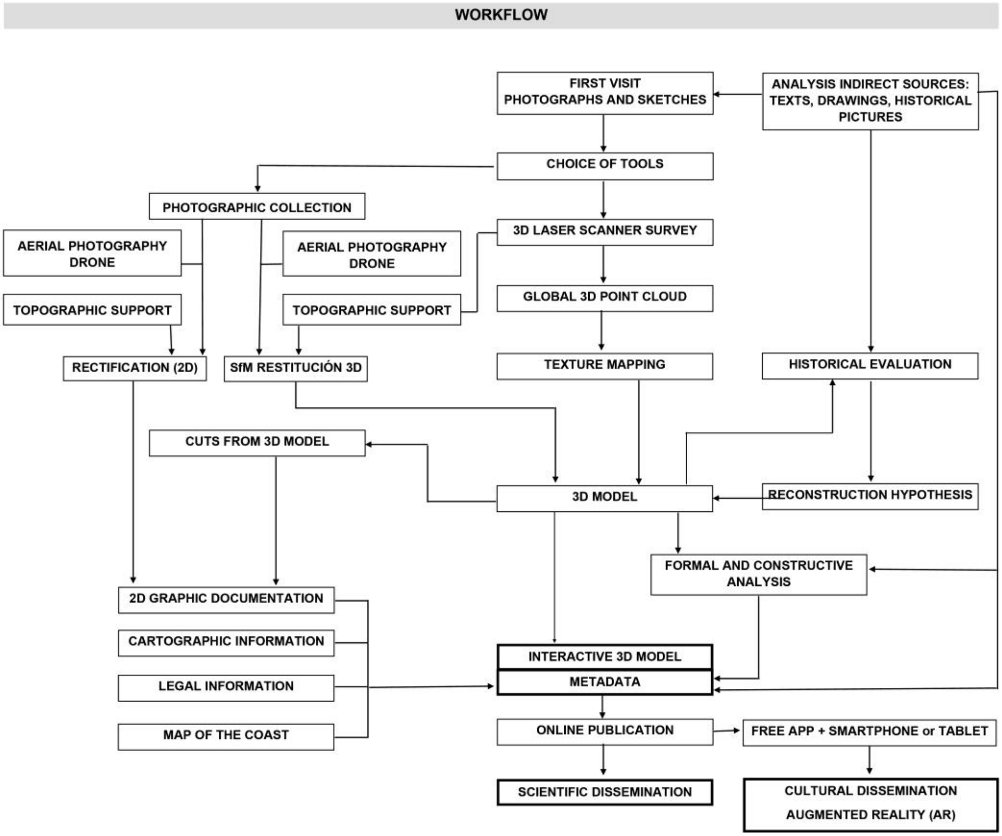

Fig. 5- Workflow.

Note

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