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RECORDING HISTORIC MASONRY BUILDINGS USING PHOTOGRAMMETRY- TWO CASE STUDIES

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Abstract. *The use of conventional and photogrammetric surveys is presented for the recording of two historic masonry buildings in Greece. The first one is a four-storey traditional tobacco warehouse of the late 19th century in Alexandroupoli which has been partially collapsed in 2005 and constituted an extremely dangerous working environment. The second is an old customs house that is located in the old historic town of Nafplio and specifically in front of the central part of the port. It was built around the middle of the 19th century by the well-known Architect Stamatios Kleanthis. The architectural, structural and morphological characteristics along with the pathology of these buildings have been recorded through photogrammetric and conventional topographic surveys. This way, all the necessary information for the structures have been acquired with an appropriate accuracy in order to assist Engineers to choose the proper repairing and strengthening techniques for the renovation and the re-use of these historic buildings. The old tobacco warehouse in Alexandroupoli is planned to be the new Municipal Library, whereas the old customs house in Nafplio will be a museum for cultural exhibitions. The recording procedure used, combines the conventional topographic surveys and the photogrammetric image processing for the formation of all the façades' orthoimages. The orthoimages were used as background information to digitize details of the buildings façades in a CAD environment. The Photomodeler software and the freeware application Hugin has been used to create respectively a detailed 3D model and an interactive panorama file of the buildings.*

1 INTRODUCTION - HISTORICAL REFERENCES AND STRUCTURAL CHARACTERISTICS

1.1 The partially-collapsed building in Alexandroupolis

The building has been first constructed before 1900 in the center of the city of Alexandroupolis by the catholic community to be used as a school. After a major fire that destroyed part of the existing building in 1904, the building has been reconstructed and enlarged to its final shape in 1924 in order to be used as a tobacco warehouse. It was one of the largest, most prestigious and well-constructed buildings of the area and its new usage was the base of the renowned "Companie general de Tabac" (General Tobacco Company), as shown in Figure 1.

The length of the L-shaped plan building is 26.75m, while its width is 12.30m and 10.30m at the northern and the southern side, respectively. The total height of the structure is 12.45 m and it consists of four storeys; a basement, a ground floor, an upper floor and an attic under a gabled roof. The area of a typical floor is approximately 293 m^2 in a building plot of approximately 846 m^2. It has a gabled roof composed by wooden trusses and terracotta tiles forming gables on the façades. The building is a load-bearing masonry structure made of ashlars of regional granite connected with mud mortar. The thickness of the masonry at the basement is almost 60 cm, at the ground floor it becomes 50 cm and finally at the floor and the attic it is only 45 cm. It can be considered as an excellent sample of industrial architecture initially influenced by the urban architecture of the late 19th century. Supplementary features of the examined building are also provided in Ref [1].

Figure 1: Vintage photograph of the building in Alexandoupolis. It was a tobacco warehouse of the corporate named “Compagnie General de Tabac”. At the top of the gable, “1924” is displayed as the year when the building was first used as a tobacco warehouse.

1.2 The customs house in Nafplio

The historic building is situated in Nafplio, a seaport town in the Peloponnese in southern Greece. Nafplio was the first capital of modern Greece, from the start of the Greek War of Independence (also known as the Greek Revolution) in 1821 to 1834. Count Ioannis Kapodistrias, first governor of modern Greece, set foot on the Greek mainland for the first time in Nafplio on 7 January 1828 and made it the official capital of Greece in 1829. Nafplio remained the capital of the state until 1834, when King Otto decided to move the capital to Athens.

The old customs house is located in the old town of Nafplio, and specifically in front of the central part of the port (Figure 2). It was built in 1832 by the architect Stamatios Kleanthis. He is best known for his urban plan of Athens, which he designed in cooperation with Edward Schaubert, and his designs for various public buildings in the same city. It should be mentioned that Kleanthis and Edward Schaubert were students of perhaps the most important German neo-classical architect Karl Friedrich Schinkel [2]. Kleanthis along with the architects Edward Schaubert and G. Luders carried out the plans of many historic buildings of Nafplio at the time that Nafplio was the Seat of State.

Figure 2: Vintage and nowadays views of the western façade of the old customs house taken from Filellinon Square of Nafplio.

The building has been designated by the Minister of Culture as a Historic Monument and as a Work of Art in 1998. From 1999 till today, it is used as a warehouse for the needs of the customs authority.

The main (northern) façade consists of three parts with an arcade supported on pillars (Figure 3). The specific plan recalls the Venetian Arsenal that houses the Nafplio Archeaological Museum in Syntagma (Constitution) Square. Generally the Customs House is simple in design, rectangular, with symmetrical entrances and windows. It creates a sense of balance and harmony, in keeping with the neo-classical movement. The building consists of a ground floor and a small loft (mezzanine) as well as the arcade supported on pillars. The covered surface of the plot is approximately 376 m^2. The area of the ground floor is 322 m^2 (see also the plan view of the building in Figure 4) and the one of the loft 34 m^2.

The future use of the old customs house was decided by the Municipality of Nafplio to be a museum of custom houses as well as a space where cultural exhibitions will take place. For this reason, detailed recording and structural analysis of the building was required.

Figure 3: Northern façade of the old customs house.

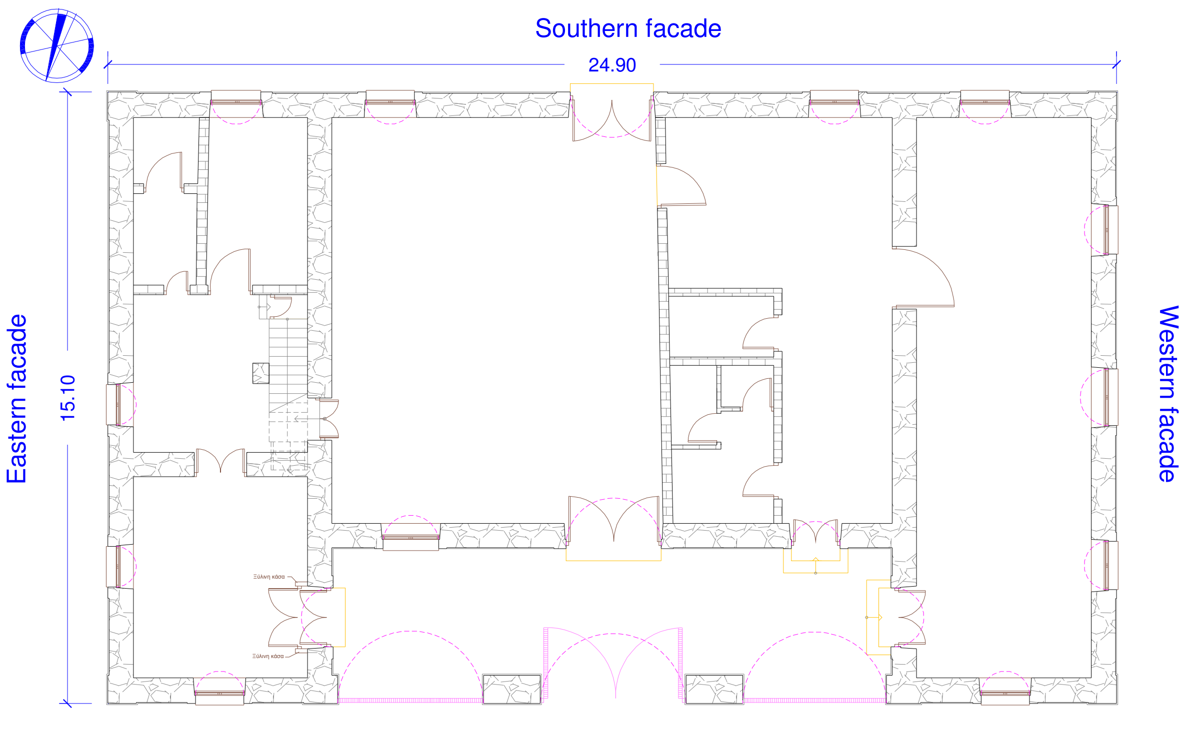

Figure 4: Plan view of the old customs house.

This historic masonry building has a hip roof composed by wooden trusses and byzantine type terracotta tiles. It consists of a ground floor and a small loft (mezzanine) at its north-eastern corner and an arcade supported on pillars at north. The main building materials are stone and wood. Steel only appears in certain architectural elements of the building. In fact it is used at window's metal railings for the protection of the building as well as at arch shaped transom windows recesses. There are two rectangular skylights at the north-eastern corner of the building as well as a circular (bullseye window) at the eastern façade. The main entrance is protected by a metal double-door whereas the two double doors at north and south are wooden. Though the main entry door was supposed to be at the western façade, nowadays there is a window instead of a door. The roof, the floors and the stair that leads to the loft are wooden. The floor of the western room on the ground floor is paved with plastic tiles; the floors of the two central rooms are paved with mosaic.

The foundation of the building is made of bearing masonry and follows the outside perimetric walls of the basement in approximately 95 cm below the ground level whereas the aquifer is 85 cm below the ground level making the foundation soil's characteristics not safe. Due to that fact, one meter below the ground the foundation is probably composed by wooden piles. It should be mentioned that the building was constructed on an embanked section of the coast line.

The thickness of masonry is 60 cm and the height is 6.60 m. The masonry is unreinforced composed of natural stones. The main ingredient of the mortar is clay and its thickness varies from 1 to 3 mm. The walls are covered on the inside as well as on the outside with a rubber coating. The original color of the outside of the walls was a mix of ochre iron with white. The decorative cornices of the windows are composed of solid bricks coated with cement. The pillars that form the arcade at north are covered with carved limestone. Also the four corners of the building are covered from their base to the top with carved limestone resembling four columns. Under the hip roof, there is a stone moulding, quadrant shaped, that covers all the perimeter of the building.

2 PATHOLOGY AND DAMAGES

2.1 Partially-collapsed building in Alexandroupolis

The building sustained severe damages due to (a) its age, the many years of non-use, the total lack of maintenance and the utter forlornness (b) the inappropriate and catastrophic rehabilitation plan which included the total removal of all the interior structural members such as wooden diaphragms, wooden beams and wooden and concrete columns; and (c) the partial-collapse of the eastern and northern wall along with part of the roof in 2005, during the intervention works. Details can also be found in Ref [1].

After the partial-collapse and in order first to support the existing walls and make the working environment safe and second to repair and reconstruct the building, a detailed recording of the existing situation is required. In particular, a thorough recording of the morphology and the pathology of the partially-collapsed building was necessary. The method of photogrammetry was chosen as one of the most appropriate for this recording due to the unsafe and precarious nature of the building, and to the fact that access inside the building and to the upper parts of the masonry walls is hazardous and practically impossible.

2.2 The customs house in Nafplio

The building suffers from damages and wears due to the aging of the materials, to the high humidity due to its seaside location as well as the neglect and lack of maintenance. The damages that are related to the structural system of the building (masonry) are local wears and cracks at the arches of the lintels as well as at certain masonries. Cracks are also observed at the connections of the inner masonries. The majority of the cracks are transversal with rather small to medium width (under 10 mm). Some slight longitudinal cracks (width < 3 mm) are also detected near the windows (lintels and sills). Finally, some carved limestones, without any coating, that cover the pillars of the arcade sustain wears due to aging. Further, as it was expected, all the construction materials of the masonry, natural stones, clay mortars, carved limestone and bricks contain soluble salts, mostly chloroide, because of their exposure to the marine environment according to the results of their examination at the laboratory. A vertical displacement of 14 cm is also observed at the roof (see also Figure 3). This deformation is located mainly at the northern and the southern façade. The wooden elements of the roof (trusses, batters, sheeting) are more or less in a good condition given their age. However certain wooden elements should be replaced due to aging and the lack of maintenance.

3 RECORDING USING PHOTOGRAMMETRY

Concerning the partially-collapsed tobacco warehouse, due to the dangerous conditions of the heavily damaged building, the geometrical details of the structure could not be recorded using common procedures and a rather special refined survey was required. For this reason, photogrammetric image processing is used in order to create the orthoimages of the façades, as background information to digitize details of the buildings in a CAD environment with accuracy of 1 cm [3]. The recording data via photogrammetry consists of rectified images and mosaics of the building and a spherical 3D panorama of the inner of the building. Photomodeler software and the freeware application Hugin has been used to create the detailed 3D model and the interactive panorama file of the building, respectively [4, 5].

The same recording procedure has been also used for the case of the old customs house in Nafplio. The detailed and accurate geometrical shape of the digitized façades of both building provides a rich database of their structural features. Further, all the irregularities of their geometry are detected in detail and can be given as input data to the structural analysis models [6, 7]. Obviously, these data have fundamental importance for the stability assessment of the partially-collapsed warehouse. This way, photogrammetry is used as a refined tool that would help to implement a safe and efficient supporting solution and an integrated rehabilitation procedure of this problematic masonry structure. Further, the interactive spherical panorama has placed virtually the engineer inside the partially-collapsed building, helping him to zoom in the details of the structure without exposing him to the danger of a potential collapse.

The recording through the photogrammetric process was providing the required safety just because its remote sensing nature. All the images were corrected from lens and manufacturing distortions and were calibrated since a common digital camera was used to obtain the complete set of images. The camera used was a Canon dSLR EOS 400D of 10 Mpixel imaging sensor equipped with a accompanied low quality 18-50mm lens. The procedure of the recording was accomplished in the three following described steps; measurements, calibration and photogrammetric processing and digitization.

3.1 Measurements

The capturing of the outer space images of the examined buildings was realized and a set of appropriate control points were measured in a unique rectangular coordinate system. A rough 3D model of the building was created through conventional surveying methodology. An accurate topographic network of ground control points was established in accuracy appropriate to realize in the architectural scale (1:50) all the drawings (sections, façades and top-views and bottom views) of the buildings. The topographic measurements did not include cracks and other important details of the masonries. These were digitized from the rectified images created in a next stage.

For the recording of the buildings, Ground Control Points (GCPs) were measured on the façades and these points were also used to obtain the shape of the construction. A triangulation network, covering the buildings from the outside and its inside, was established. The topographic instrument's stations were installed in the yard, the area around the buildings and on the terrace of neighboring buildings. Only one instrument station was installed inside the partially-collapsed tobacco warehouse for security reasons. From the instrument's stations additional GCPs were measured for the 2D rectification of the façades' images.

3.2 Calibration

In order to obtain the best results two calibration procedures have been applied before the main process of the photogrammetric image processing. Photomodeler's calibration module and a homemade application were used for this reason [4]. The camera calibration module of the commercial application Photomodeler was used to obtain a more precise draft model of the buildings while for the correction of the radial distortion of the images to be rectified, a homemade software application has been used.

Photomodeler's calibration module leads to a solution with an accuracy of 0.45 pixel and the camera's focal distance was estimated at 17.66 mm. The homemade software Calib has been developed using the Open Source Computer Vision Library created by Intel (OpenCV) and has provided similar results [3, 5]. The calibration procedure is using a regular grid (grid of circular points or a printed chessboard) that is supposed to be photographed from different camera positions. The algorithms are identifying the targets of the patterns with sub pixel accuracy and then calculate the exterior orientation parameters of the camera during the image capture and its intrinsic calibration parameters.

Figure 5: Rectified mosaic of images (left) and corresponding digitized façade (right) of the western and the southern façades of the partially-collapsed tobacco warehouse in Alexandroupolis

3.3 Photogrammetric processing and digitization

Special image capturing (vertical image capturing) was realized to create rectified images and orthomosaics of the façades of the examined buildings. In every façade a set of Ground Control Points (GCPs) were measured to obtain the 2D rectification of the images. These GCPs were also connected to the generic 3D coordinate system that is describing the draft 3D model of the building. The connection (transformation and rotation parameters) between the 3D model and the GCPs was used to provide the georeference of every rectified image, mosaic or digitized drawing to the 3D space. The accuracy of the digitization of the images was compatible to the final printout scale (1:50). Additionally, convergent image shooting and the Photomodeler software application were used to obtain a photogrammetric 3D model of the building.

The generated rectified images were created in VeCAD-Photogrammetry [5]. GCPs collected for the 2D rectification of images (radial distortion free) were inserted in the software and simple procedures lead to the desired results. The digitization was accomplished from the rectified images and mosaics after the processing the nearly vertical images of the façades of the buildings (see Figures 5 and 6). Snaps of the interactive spherical panorama are also displayed in Figure 7.

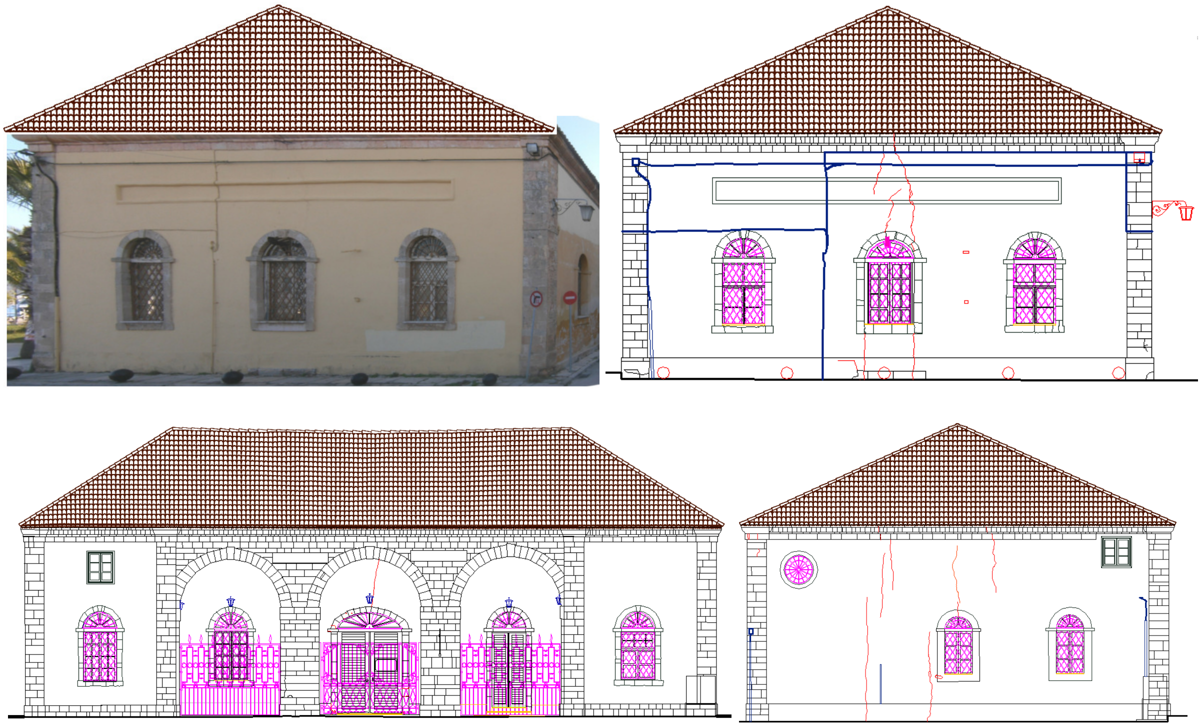

Figure 6: Rectified mosaic of image of the western façade and digitized façades (western, northern and eastern) of the old customs house in Nafplio along with the detected cracking of the masonries.

Figure 7: Snaps of the interactive spherical panorama of the partially-collapsed building in Alexandroupolis.

4 CONCLUSIONS

Application of image rectification to complete 2D drawings of historical buildings has been presented. The conventional 2D drawings have been enriched by the visual information of the geometrically corrected texture images of the masonry structures, thus providing a more comprehensive and understandable representation of the construction, the damages and the materials. The visualization of the examined buildings through the rectified images, mosaics, orthoimages and 2D drawings increased surveying speed and constituted a useful implementation guide.

Additionally, low-cost (Photomodeler), open-source (Hug-in) and home-made software (VeCAD-Photogrammetry [8]) were used to obtain the minimum number of measurements and achieve the desired results and products in the appropriate accuracy (1 cm) for the final (1:50 scale) drawings' reprints. The total budget for the purchase of the specific hardware (camera) and software (Photomodeler), at the time of the project, were under 2,000 €. Taking into account also the reduced time to obtain the measurements on the field and the complete digitization in the office of all the structural details and fractures on the buildings facades, we can conclude that photogrammetry is the most appropriate technique to record in short time with the lowest cost a historic building that is under a renovation process or at risk.

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