The Church of St. George in the Kyrenia Castle in the North of the Island of Cyprus: Bringing out the Shape of Architecture

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The contribution focuses on the digital documentation of St. George's church, dating to the Early Byzantine Period, close to the Roman fortress of Kyrenia in the north of the island of Cyprus. In medieval times the Kyrenia castle became a focal point in the defense of Cyprus, being increasingly fortified, first in the Crusader period, then by the Venetians and the Ottomans, when it has incorporated within its defensive structures the church of St George of which today only the central dome covering is perceived from the outside.

A digital survey campaign was carried out, integrating the morphological data coming from laser scanners with the texture of photogrammetry, so to be able to study the church and its architectural features; the textured 3D model was used both as a three-dimensional space fruition system through digital platforms, and as an informative base necessary for the graphic restitution of technical architectural drawings to build-up cognitive analyzes.

The adoption of a three-dimensional model is useful to understand the distributional complexity of the architectural volumes that hide the Church of St George. It is beneficial for the visitor in the context of virtual museums, and appropriate to obtain traditional 2d drawings as a base to analyze the construction techniques for a stratigraphic-evolutionary study of the building that, together with a careful analysis of historical sources, allows to understand the development phases of the church in relationship with the enlargement of the castle's defensive structures.

Key words:
Digital Survey, Kyrenia Castle, North of the island of Cyprus, St. George's Church.

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KYRENIA CASTLE AND THE ST. GEORGE CHURCH: HISTORICAL FRAMEWORK[1]

The island of Cyprus, thanks to its natural resources and its strategic position at the crossroads of three continents (Africa, Asia and Europe), has been exposed to different cultural influences. It has been conquered by several civilizations which have dominated the eastern Mediterranean area in different periods: it turns its own history very rich. The island was settled by Mycenaean Greeks and it was subsequently occupied by Assyrians, Egyptians and Persians, the Arab caliphates for a short period, the French Lusignan dynasty and the Venetians, which were followed by Ottomans between 1571 and 1878 [Mirbagheri 2009].

Kyrenia (*Girne* in Turkish) is the main town of the homonymous district, and it is situated on the north coast of Cyprus, between the ancient cities of Lapethos and Macaria, about 30 km from the capital Nicosia. In the middle Byzantine and in later sources, the city and the port are mentioned [Papacostas 1995]. Wilbrand of Oldenburg, bishop of Paderborn and of Utrecht, by attending the orders of Otto IV, Holy Roman Emperor, to prepare the Fifth Crusade to the Holy Land, writes down in 1211 the *Itinerarium terrae sanctae*, important historical source on the crusades and crusader castles, where he describes *Schernis* as "civitas parva, sed munita, castrum habens in se muratum et turritum": a small town well-fortified which has a castle with walls and towers. The description underlines the two key elements – the harbor and the castle – which are strictly linked to the history of the place, dating back to the Prehistoric period.

[1] The chapter "Kyrenia Castle and the St. George Church: Historical Framework" has been written by Rolando Volzone; the chapter "The Digital Survey Campaign for the Analysis of the St. George Church in Girne" has been written by Federico Cioli; the chapters "The Problems in the Survey and Different Methodological Approaches" and "Archaeological and Interpretive Analysis" have been written by Matteo Bigongiari.

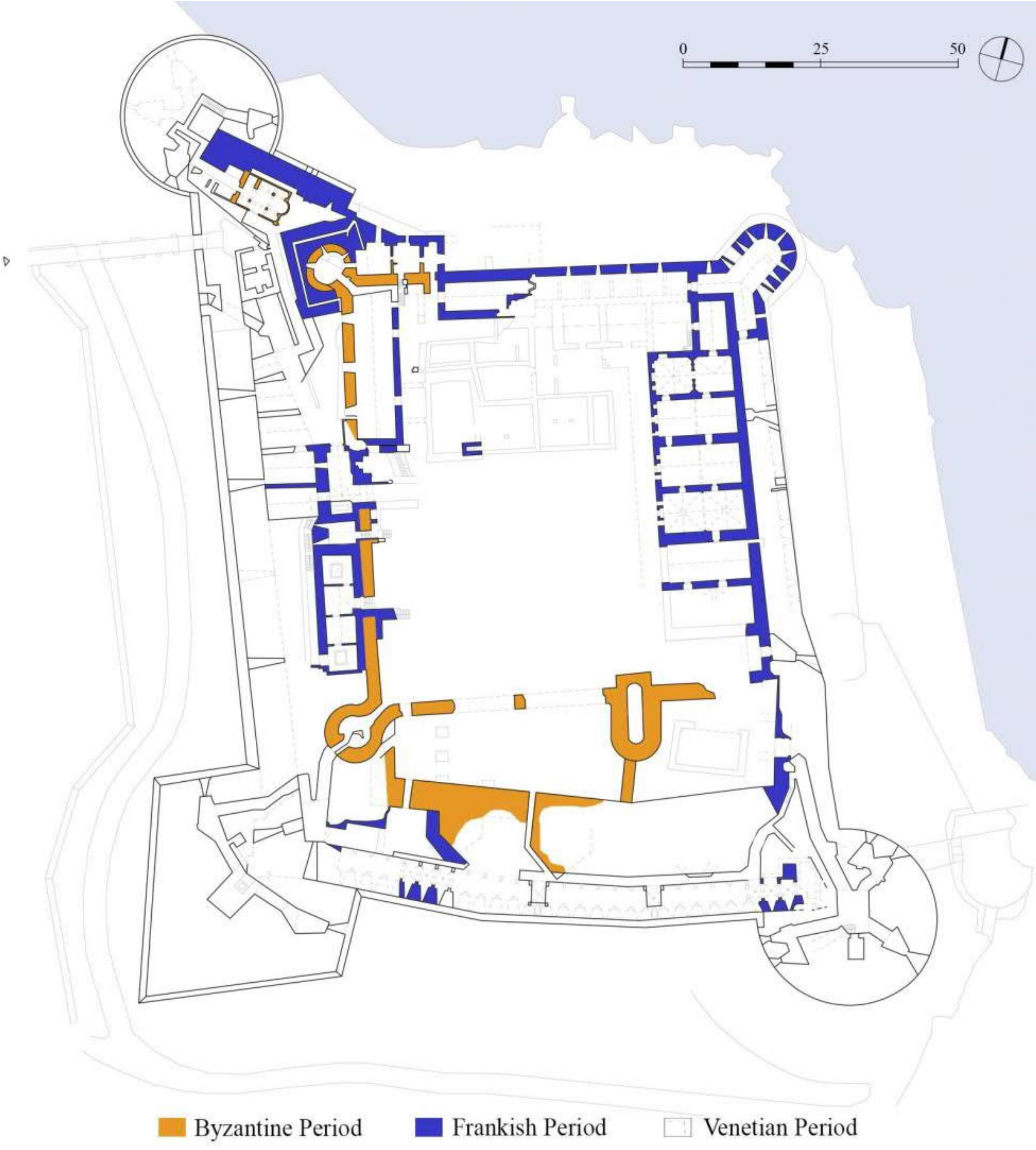

Fig. 1. Kyrenia Castle and its alteration along the centuries

The Kyrenia castle is located at the east end of the harbor. The exact date of construction of the castle is unknown. Explorations, carried out in the castle area, reveal traces of the Hellenistic and Roman Period. The original castle was built in the 7th century A.D. by the Byzantines with the purpose of defending Kyrenia against Arab raids. The remains of the castle are the result of its alterations in different periods (Fig. 1): Byzantine Period (330-1191), whose fortifications were generally built to accommodate armored knights and archers [Camiz et al. 2016]; Lusignan Period (1192-1489), the French Catholic dynasty whose major contribution to the island's architectural landscape was the importation of the French ecclesiastical styles of the 13th and 14th centuries [Given 2005]; Venetian Period (1489 - 1570), at which time Kyrenia was reconstructed, mostly when gunpowder – for cannons and general artillery – came to the use, and these main weapons were adopted for the war [Dreghon 1985], and high curtain walls with numerous openings as gun ports were built. The conquerors employed various techniques to modify existing previous parts or to build stronger ones of the castle, to protect themselves from attacks [Camiz et al. 2016]. What we see today is mostly a consequence of reconstructions and additions made by the Venetians, who built over a crusader fortification from 1540 to 1544. The castle was altered; thicker and higher walls were built, with more and stronger battlements and deeper ditches and moats. Part of the original 7th century Byzantine castle is still evident in the west and south sides; its medieval remains are in adulterated conditions: the original plan was a rectangle large court surrounded by ranges of buildings against the four curtain walls. At each angle there were large square towers, of which that on the north-east angle was planned diagonally to the rest [Jeffery 1918]. It was during this period that important monasteries and churches were built, many of which still exist. It is important to underline that the term Byzantine, as used in the eastern Mediterranean, corresponds to the late Roman period (330-1100). It began when the Roman Empire split up into two halves, the first one at east, centered at Constantinople, and the second one at west, with Rome as the center [Dreghon 1985].

Fig. 2. The Chapel of St. George: interior view

The best example for this period is the Byzantine church or chapel, later known as St. George of the Donjon, dating from about 1150 A.D. From the castle gate, by crossing the fortified Venetians wall, through a narrow vaulted corridor, it is possible to reach the church (Fig. 2). The door left to the tunnel opens to the rooms where the church servants spent their daily lives. De Mas Latrie [1874] publishes the will (1406) of Lady Pinadeben of Ferrara, widow of Anthony of Ferrara, who mentioned the “chapele de Sainct Jorge du Donjon” [Enlart and Hunt 1987]; the German classical archeologist Ross [1852] mentions the “Capelle mit vier Marmorsäulen” (the chapel with four marble columns); in 1865, the architect Edmond Duthoit, who accompanied the Count Melchior de Vogüé in a scientific mission in Cyprus, describes

> *"une petite chapelle sur plan byzantin avec coupole au centre. Les colonnes AA' sont en marbre blanc avec chapiteaux antiques"*

(a little chapel with a byzantine plan and a dome in the middle, with two columns A and A' the ones near the apse, in marble whit ancient capitals) [Bonato 2001].

Fig. 3. Exterior (on the left) and interior (on the right) view of the dome

The chapel is located at the foot of the north-west tower. This tower has a square outline and ~~has~~ inside a stone staircase which snake figures decorating the interior walls. During the time of the Byzantines and the Lusignans, the Chapel of St. George was outside the castle perimeter, and, it was enclosed when the Venetians extended the defenses with new fortified walls (Fig. 1), according to the plan of the 13th century castle made by Jeffery [1933]. It has a cross-in-square layout, with a central dome supported by four columns, and the apse east-oriented. This main semi-circular apse is flanked by inscribed apses where, according to Papageorgiu [1965], traces of fresco decorations were preserved. It is also the case of the church of Christ Antiphonitis, remarkable for the frescoes on the walls and on the pillars [Jeffery 1918]. The structure of the Saint George Chapel was built in ashlar masonry, and is nowadays the unique surviving example of the four-column type in Cyprus. The columns and capitals are made of white marble, probably coming from an important building of the second century, as are the *crustae* of the floor, with remains of *opus sectile* paving, dating between the late 11th and the early 12th century [Megaw 1974]. According to Jeffery [1918], the chapel was used as a burial during the late medieval period: the sepulchral memorials in village churches – imitating the ones in town churches – were common until the end of the 16th century. In the Venetian period, the original dome was removed, the church was utilized as a passage to the north-west tower and the narthex was filled with masonry. Amongst these, there is an interesting gravestone of the 16th century with the usual form of shield containing the inscription "QUI IACET ALUISE DEMEDICI DA BEEGAMO CHEEE", mentioned in the will of Donna Pienadabene of Ferrara. The scarped rock on which the church stands was the site of the north-west corner tower, which is still evident. It is at the intersection point of the western curtain wall with the line of a northern one, still visible at several places. This north-west corner tower, second only in importance to the round tower must, from the shape of the rock foundation, have been rectangular in trace, unusual at that period, but giving better flanking fire along the west curtain wall.

A brick dome was erected subsequently – between 1910 and 1930 – after years with a roofless church [Enlart and Hunt 1987, Gunnis 1936], and the north-west column was replaced by a wall. In 1938, the filling behind the apse and the west part was removed, revealing the narthex. In the early 1950s the wall in the place of the lost north-west column was replaced by a column brought from Nicosia and a capital from the castle precinct [Papacostas 2015]. The modern brick dome was replaced by a stone dome with eight recessed windows (Fig. 3).

It was presumably inspired by the domes at Church of Christ Antiphonitis (Christ who responds) and Panagia Theotokos Church (Fig. 4). The first one was built in the 12th century, and it is located at 1.5 km south-west of Kalograia in the Kyrenia district; its dome – nowadays with an irregular shape, due to damages occurred during the Cyprus earthquake of 1222 – has twelve windows, built in regular courses of good ashlar masonry, and it is supported by eight columns – the only surviving example of this type in Cyprus. The second one, as suggested by the architecture and style of fresco decoration, is dated of the early 12th century, and it is located in Trikomo, a town in north-eastern Mesaoria in Famagusta district; its dome drum was built in isodomic courses of good ashlar masonry with twelve arched and recessed windows.

Fig. 4. On the left side: Church of Christ Antiphonitis, August 2016, © Gerhard Huber; on the right side: Panagia Theotokos Church

The church of St. George was one of the most significant spaces, due to the particular features of this building, which shows the historical phases of its evolution and lies into the defensive wall, being placed between the Venetian wall of the 16th century and the medieval wall of the 14th century [Dreghorn 1985]. Nowadays, only the central dome covering is perceived from the outside, and, in order to bring out the shape of the architecture, it was necessary to start a digital survey campaign. It is necessary to analyze the construction techniques for a stratigraphic-evolutionary study of the building that, together with a careful analysis of historical sources, allows understanding the development phases of the church in relationship with the enlargement of the castle's defensive structures, particularly its interaction with the north-west tower.

THE DIGITAL SURVEY CAMPAIGN FOR THE ANALYSIS OF THE ST. GEORGE CHURCH IN GIRNE

The study of the volumes and of the architectural features of the St. George Church required a digital survey campaign that integrates the morphological data coming from laser scanners with the information on the characteristics of the materials acquired through the use of “Structure from Motion” (SfM) methodologies. The most distinguishing feature of this building is to be encompassed into the city’s defensive walls, maintaining two of the original facades: this makes it more difficult to survey and clearly redraw the “image” of this architecture.

Between the 6th and the 13th of May 2018, the workshop “Reading and Designing the Kyrenia Castle” took place in Girne American University in Cyprus. The workshop was planned thanks to a collaboration between the Girne American University (Department of Interior Architecture), the Department of Architecture of the University of Florence and the Department of Interior Architecture of Özyeğin University. The workshop involved fifty-six students of the three universities, which were divided into groups in order to cover the design and digital survey topics under the guidance of their tutors. The main topic was focused on the Archeological Museum inside the Castle, which needs a new distribution scheme for the interior rooms. The digital survey conducted using range based and image based instrumentation, produced 360 laser scans, 1900 aerial pictures, 30.000 terrestrial pictures, and low altitude pictures acquired using a telescopic photographic system 3DEYE (Fig. 5) [Camiz et al. 2018]. Despite the attention given to the Ancient Shipwreck Museum area, the digital survey involved also several parts of the Castle, of which the Church of St. George was one of the most significant.

Fig. 5. Representative picture of the digital survey campaign carried out with a laser scanner Z+F IMAGER 5006h

In order to understand the architectural morphology, it was necessary to elaborate an accurate plan of analysis and acquisition of metric and qualitative data. The analysis of the historical evolution of the Church of St. George is closely connected with the one of the castle. The understanding of the phases of construction of the building offers a new insight on the history of the architectural complex and of the whole city. The acquired data are a testimony of the current condition of the church and provide the documentation for in-depth analyzes. This allows us to describe the physical features, the characteristics of the materials and the conservation status of the single element of the architectural structure.

The integrated digital survey generated a quantity of data that required a discretization in the post production-phases, in order to provide useful and understandable drawings. The process of building the morphological textured 3D model starts with the planning of the survey and the establishment of a descriptive model. An IMAGER 5006h laser scanner by Z+F was used for data acquisition. The instrument was placed inside the 9x9 chessboard scheme deriving from the layout of the church, where a dome standing on four columns surmounts the central part. A dark corridor connects the church with the entrance of the castle, permitting the constitution of an overall model, which includes the upper path to the bastion from which the dome and the roof stand out. The survey of the Church of St. George required the specific acquisition of 16 scans, nine of which inside the building; two on the doorstep in order to connect the inside part with the corridor and with the exterior, while seven scans were used to restore the image of the external fronts. It has to be considered that the church is an integral part of the fortress and therefore the upper rooms and the dome were acquired and connected to the polygonal path of scans of the castle of Kyrenia. The lack of a topographic survey demanded an *in situ* registration and verification. The shaping of an overall polygon and of a partial polygonal was necessary to quantify the error in the readings [Bigongiari 2017a].

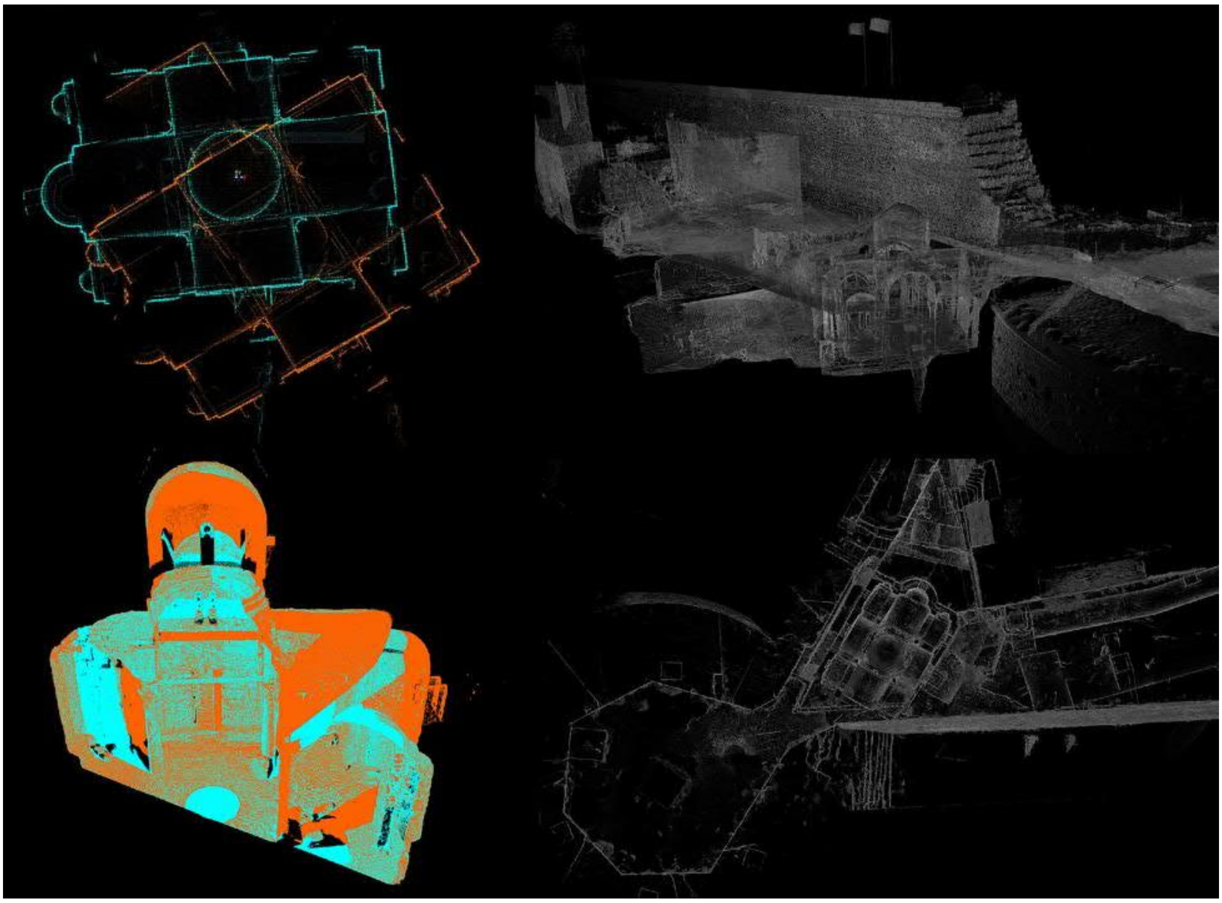

Fig. 6. On the left, procedures for the registration of the point cloud using the visual alignment. On the right: perspective view and general plan of the overall model of the church and the environment

The registration of single point clouds and the verification of data reliability is a fundamental phase that brings together the work *in situ* with the subsequent post-production phases. It is fundamental during the acquisition phase to provide the necessary superimpositions required for recording the data. The registration starts from the assumption that the scans use the same polar reference system. Through the rigid rotation of the clouds by using a visual alignment, the scans were recorded via cloud constraint, allowing to survey without using the black and white targets (Fig. 6).

Fig. 7. Two examples of pictures acquired with two different exposures

The SfM survey [De Luca 2011] was carried out using instruments with high resolution sensors and correction processes of the single shot. The purpose of the photogrammetric survey was to export the ortho-images of the facades, useful for the understanding of the masonry and its evolution. Thus, a detailed acquisition of the individual elements was not carried out, despite an overall relief that returned the architecture in its entirety. The survey was conducted during closing hours of the castle. Therefore, the short time available for the SfM acquisition required a planning that produced 193 photos for the exteriors and 125 for the interiors, following the checkerboard acquisition scheme used in the laser-scanner survey. In particular, the interior of the church was acquired with a Nikon D800e placed on a tripod, using a remote control for remote shooting and the self-timer in order to minimize vibrations, giving the possibility to increase shutter speed. The acquisition required the preparation of the environment, through the use of spot lights set at strategic points in order to give a uniform and constant lighting throughout the survey phase. In fact, the main problem was the strong contrast of light between internal and external parts of the Church and between the space below the dome and the rest of the indoor environment. The impossibility of fully compensating these variations required shots on various exposures that were then elaborated in order to create a single homogeneous photo (Fig. 2). The establishment of a photogrammetric 3D model has served to extrapolate the ortho-images, useful for restoring the image of the masonry apparatus. On the outside, the impossibility of maintaining a constant distance from the object led to the creation of a model of greater detail in the south-west part in spite of the north-east one. The morphological complexity of this architecture, incorporated into the castle walls, which can be joined by a poorly lit corridor and surrounded by narrow passages, did not provide the necessary overlapping points to be able to join the two models (Fig. 3). Despite the use of specific targets positioned at the opening on the north wall, it was not possible to combine the model of the exterior with that of the interior, which was then integrated with the point cloud obtained by the laser-scanner survey in order to establish an overall model. The new approaches to surveying, aimed at the acquisition of 3D data, partly facilitate the documentation process, but require careful processing to move from the three-dimensionality and completeness of the point cloud to the two-dimensionality and schematization of the drawings. The graphic rendering phase started from the management of laser scans using the *Cyclone software*[2], and then proceeding through a vectorization of the point cloud in the CAD environment.

2 https://leica-geosystems.com/en-gb/products/laser-scanners/software/leica-cyclone

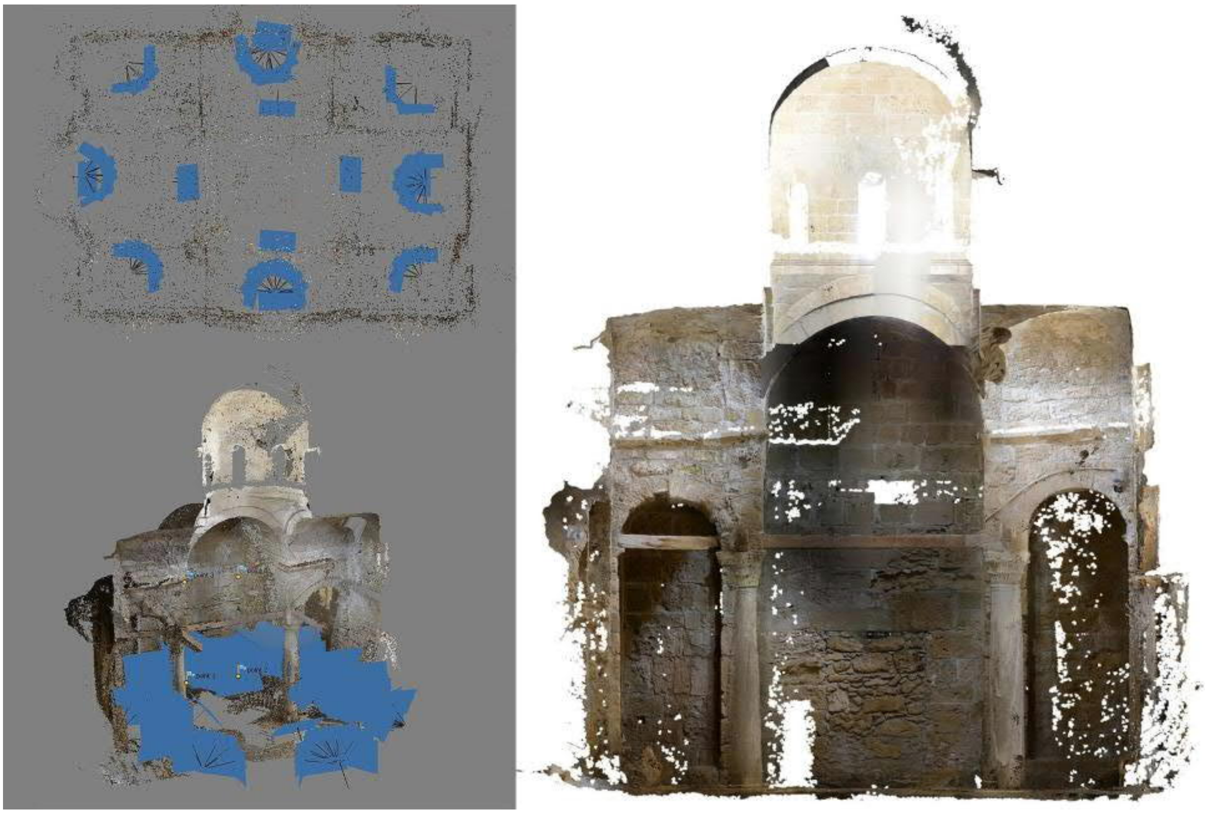

Fig. 8. The interior of the Church of St. George has been modelled using 125 high-resolution pictures. The model obtained by the SfM processing testify the presence of lacks and problems connected with the homogeneity of the texture.

The high resolution of the scans guaranteed to export detailed ortho-images from which it was possible to analyze, with the help of the ortho-images, the masonry and its evolutionary phases. The exported, oriented and scaled ortho-images, provided the basis of the drawings, through which it was possible to redraw the point cloud by tracing the main elements through closed polylines. Later the representation was deepened, characterizing the design of details and more specific signs, thanks to the integration of the information contained in the photographs. The drawings are in 1:100 scale, concerning the plant and the environmental sections, useful for the understanding of the relationship between the architecture and the castle. Then, plans, elevations, and sections in 1:50 scale have been realized, in order to facilitate the reading of the Church and serve as support for the study of the historical evolution of the building (Fig. 5). The integrated model is a database of implementable information, useful to understand and transmit knowledge regarding the architecture of the Church. In fact, in addition to the documentary potential of the survey, it aims to develop promotional tools, according to the overall idea of reorganizing the Kyrenia castle museum complex [Bianchini et al. 2018]. One of the aims of the workshop was in fact to develop a project for the redistribution of museum environments around the central courtyard of the castle. The Girne Fortress is a focal point of the city and of the harbor area and it has a great tourist potential. In order to be fully exploited according to the criteria of a cultural and sustainable tourism it requires an overall reorganization of the museum itinerary inside it. The data is therefore a knowledge base and a planning tool for a consistent development of the system, which takes into consideration all of its components, in a single path that reflects the essence and history of the place. The cognitive studies carried out in the church of St. George conclude in a series of images and models that can be used with VR and AR technologies to make it easier for guests to understand the complex building they visit. [Bertocci et al. 2018].

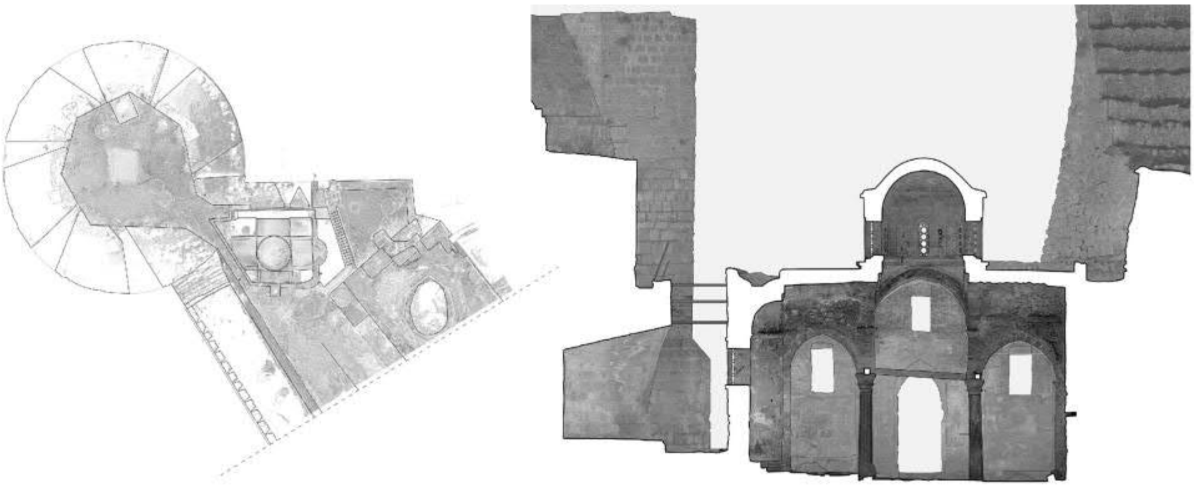

Fig. 9. General plan and detailed section of the Church of St. George with the support of the ortho-image derived by the point cloud of the laser scanner survey.

THE PROBLEMS IN THE SURVEY AND DIFFERENT METHODOLOGICAL APPROACHES

Since its first applications in the field of architectural surveying, the degree of innovation that SfM applications could bring to the disciplines of representation was evident: the possibility of creating three-dimensional models on which to apply highly reliable textures has greatly improved the descriptive capacity of both digital models and two-dimensional drawings. The need to have photographic ortho-mosaics is due to the demand to create a database of 2D graphic drawings useful to map the different types of analysis, from archaeological to material to the identification of decays. Up to that moment this requirement had nevertheless been satisfied through the use of photogrammetry software, calibrating the frames on the basis of the ortho-images from the point clouds [Pancani 2015], while for the realization of three-dimensional photorealistic models, useful graphic communication tools especially if they are intended for non-technical subjects, very simplified models were used on which to apply the textures of the various faces of the building starting from the ortho-mosaics of the facades [Bertocci et al. 2014].

Photomodeling has considerably modified the methodological procedures for the realization of ortho-mosaics and digital models. From the survey point of view, however, it immediately became clear how the models obtained from the frames were not comparable, as regards the metric reliability, with the point clouds obtained by laser scanners: at first, we tried to contain the problem by using, in support of the models obtained from the photographs, points taken with more reliable instruments such as total stations [Gaiani 2015]. Recent software developments permitted to have lower metric errors and the ability to build models from large-scale photo datasets, things that were difficult until a few years ago.

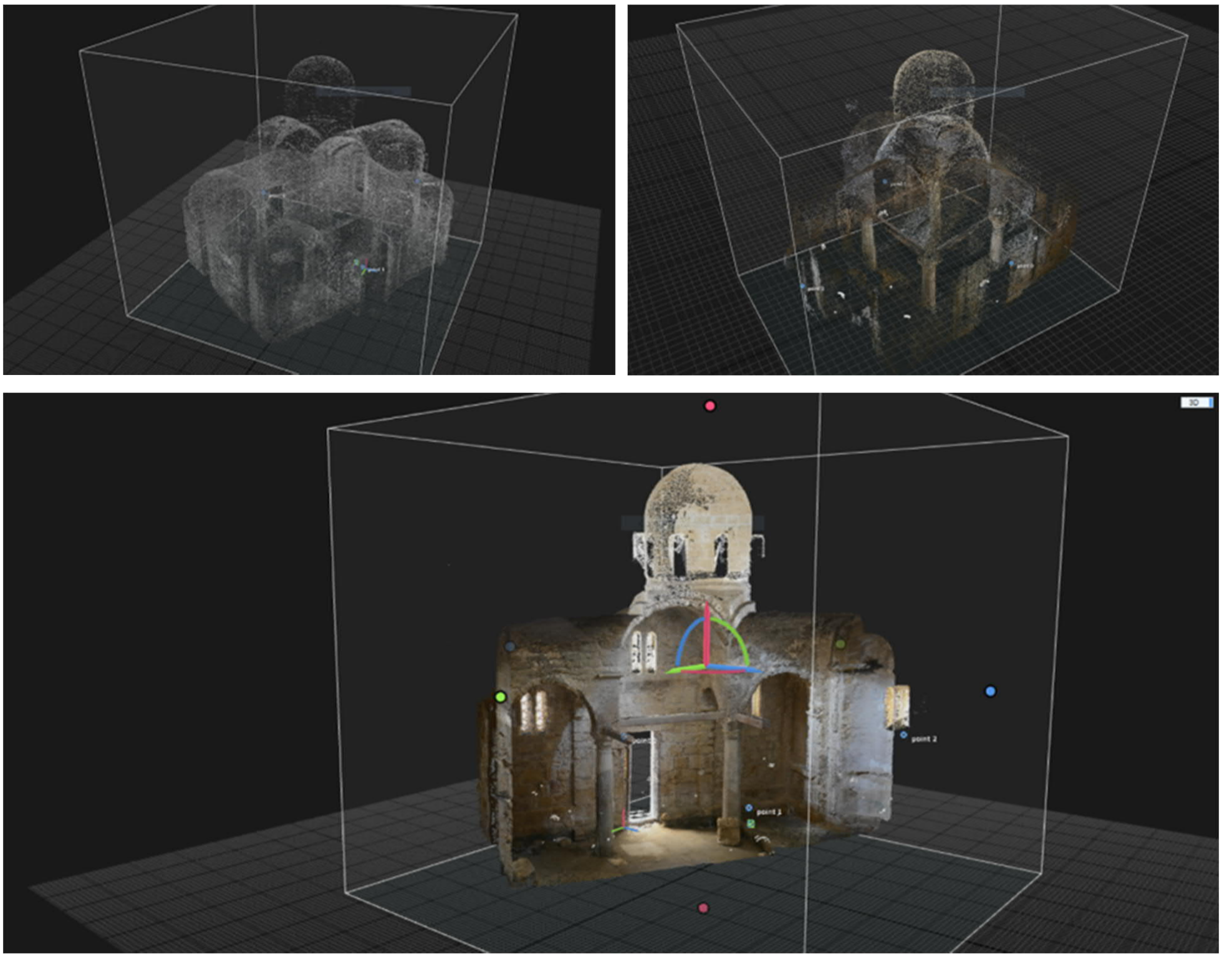

Fig. 10. 3D model obtained from the laser scans alignment (top left) and from the photographs (top right); the result is a complete 3d textured model that can be sectioned to realize orthophotos. (bottom)

The main reliability problem affecting photomodeling consists in its measurement mode: the frame comes from a passive acquisition method, that is, the camera sensor is impressed by light, doing nothing else but remaining exposed to it. Precisely for this reason it is not possible to determine the error that a survey can achieve before seeing the result obtained; this is decidedly different than the laser scanner survey, where the instrument sensor emits a light signal that is checked in order to test the results in the laboratory from which the technical data sheets of the instruments are made.

The success of a 3D photographic survey does not really depend only on the morphology of the building, the acquisition method of the photograms and the materials that form the architecture, but also on the lighting conditions of the object, both artificial and natural. These problems mainly lead to cause different effects: if on the one hand they cannot recreate a uniformly balanced colored texture on the other they can cause morphological errors due to the misinterpretation of badly lit surfaces (whether they are unduly underexposed or burned). It is possible to limit these errors in post-production by modifying some parameters of the frames, which is possible only if the shots have been made in .raw format, otherwise the pixel changes lead to obvious errors: in this way shadows and burns are attenuated and the white balance of the photographs can be uniformed among them, but inevitably the realization of a much heavier archive results.

Fig. 11. High resolution image from the3D textured model obtained combining laser scans and photographs

In the case study of the church inside the Girne fortress many of these problems have been found, especially within the church: the interior lighting condition is totally devoid of artificial light points, and is strongly influenced by the architectural typology, characterized by narrow and long windows that cause a strong overexposure of the areas near the window-frame; at the same time, the development of the fortification that has incorporated the religious building has led to a total absence of direct lighting from many of its openings, leaving the south and west sides of the building completely blind; finally, the central dome, illuminated from all sides, causes an area very much overexposed with respect to all the surrounding bays.

The photographs taken to create a three-dimensional model, have suffered from these problems and in fact in the development of the 3D model through the software *Agisoft Photoscan v.1.4.0*[3] have been highlighted significant morphological inaccuracies; mainly the errors are due to the lack of general lighting in the church, which obliged to make acquisitions with very slow shutter speeds and to use the tripod to avoid the shake-out effect, and to the presence of areas overexposed around the windows. The result of automatic alignment has highlighted these problems in several ways: the dense cloud point created in fact presented a lot of digital noise, in fact the sections of the cloud of points were not threadlike, but the software, due to the difficulty of correctly placing the points in space, returned very thick sections; moreover, due to the problems of overexposure many of the surfaces have not been correctly reconstructed: in this case they showed themselves with evident lacunose portions, due to the bad recognition of points, similar to when trying to reconstruct a plastered wall almost completely homogeneous from the color point of view.

An unsuccessful model would have resulted in a great loss of reliability and information; to solve the gaps within the model it was decided to use a different software *reality capture*[4] that allows to manage the data of the laser scans simultaneously with the photographic data. The program imports both the data of the scans, previously filtered and recorded (with the Leica *Cyclone software*), and the frames, afterwards and it tries to automatically align the data with each other; this is possible because laser data can be assimilated to frames, each scan can be considered as a panoramic view that is decomposed into a cube (6 frames) [Bigongiari 2017b]. If the pixel images of the scans and photographs are not automatically recognized, the alignment between the models can also be done through the registration with homologous points. The union between the two acquisition systems leads to great improvements: the three-dimensional reconstruction of a mesh model is not only based on the points calculated from the photographs, but mainly bases its morphology on the points coming from point clouds from the laser scanner and

[3] https://www.agisoft.com
4 https://www.capturingreality.com

integrates the missing data with the data coming from the photographic cameras. Obviously the laser scanner survey of the interior of the church did not suffer from lighting problems and this allowed to obtain a complete model; the correct overlapping of the two acquisition methods, assisted by control points (with an error of less than 1 px), allowed to realize a complete and textured model of the church, which can be sectioned and used to recreate high resolution ortho-mosaics.

ARCHAEOLOGICAL AND INTERPRETIVE ANALYSIS

Fig. 12. Final drawing of a 2D section of the church with the ortophoto taken from the 3D model, where it is possible to see the crusades pointed arches.

The survey was functional in this case to set the first considerations on the history and on the evolution of the building. Analyzing the walls it is in fact possible to advance hypotheses of phases of the construction periods; for scientific and methodological rigor, today we try to extract, for exposed walls no longer protected by plasters, the distinctive features of the masonry discontinuities (stratigraphic units) [Brogiolo and Cagnana 2012]; by relating the various stratigraphic units in relation to each other within the building, it is therefore possible to hypothesize the chronology of the interventions, relating to the historical sources.

In the specific case of the church of Saint John the contribution added by the survey leads to the identification of the evident reconstructions; it is still necessary to deepen these initial considerations with an in-depth archaeological analysis that supports and verifies what we saw in the first campaign inside the church.

The architectural typology is consistent with the Byzantine cult buildings: the central plan layout, oriented with the main apse to the east, fits perfectly into the scheme; the presence on the sides of the apse of two niches with small hemispherical caps, in the walls, one on the right and one on the left, symbolizes the *diaconicon* and the *prothesis*, two fundamental elements for the Orthodox liturgy (often in the larger religious buildings we find two rooms or sacristies at the sides of the central apse).

The plan of the church has been preserved over time, what has changed is the surrounding of the building following the changes in the fortification: in a first period in fact the church was outside the defensive perimeter, probably on the road access from the inhabited village to the castle. With the advent of the Lusignani, a crusading dynasty that held the lands of Jerusalem, the church of St. John remained at the service of the local population of the Greek rite, while probably a second church of the Latin rite existed inside the castle of Lusignani, identified by some in the vaulted hall, which ends in the corner tower at the intersection of the newly constructed wings, which presents a singular "Y" shape. The church has probably kept orthodox rites, which is why the Byzantine features are so evident today.

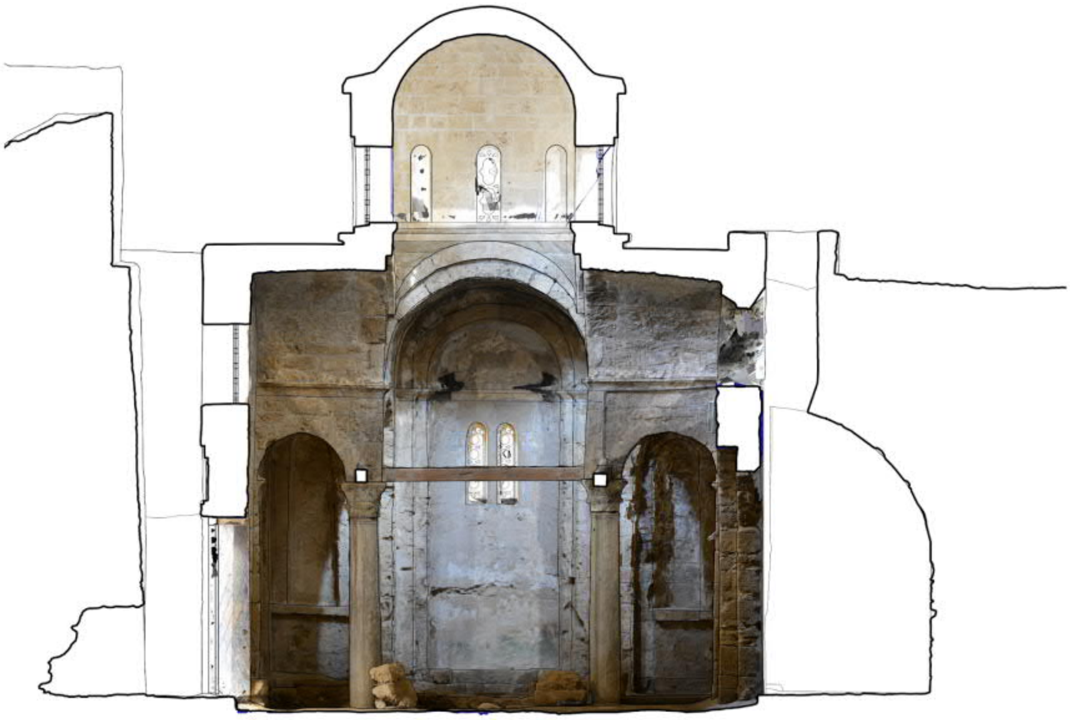

Fig. 13. Final drawing of a 2D section of the church with the ortophoto taken from the 3D model

The columns on which the arches are set are probably reused from a previous building; the capitals are also of spoliation and are of the late Corinthian order (after the 4th century?); one cannot certainly ascribe the origin of shafts and capitals to the same building: from what emerges from the drawings one of these does not coincide perfectly with the shaft on which it is laid. From plans and historical sources it is evident that a column was embedded in a wall, or was perhaps missing; the recent restorations do not allow us to understand the possible replacement of the column; evident traces of changes appear in the round arch that crosses the aisle, and probably from the wrong positioning of the tie rod. The entrance on the main façade of the church, which has not been digitally detected, remains today inside the circular tower that defends the fortress. The four columns are all bare, resting directly on the ground; this may be due to a subsequent modification that has led to the raising of the paving level; this solution can be considered a foresight in anticipation of seismic events, thus reducing the unsupported length of the vertical element; the same thing was found in other buildings occupied by the crusaders during that period: in particular the research group of LS3D (Landscape Survey and Design Laboratory), a joint laboratory between the University of Florence and Pavia, in 2014 took care of the digital survey of the Basilica of the Nativity in Bethlehem [Bertocci 2016]; the building was taken by the Crusaders who modified its layout to adapt it to its defensive needs; among the changes implemented, the paving was raised, an intervention that was not linked to the liturgical need to hide the Roman mosaic floors to avoid trampling on the sacred representations but for structural needs in a strongly seismic area. Surely the builders were aware of the problems caused by earthquakes as evidenced by the use of rods to contain the thrusts of the central dome: even if the wooden chains seem to be recent (it is not possible that the wood remains so well preserved) it is evident how the church has undergone strong earthquakes or structural sagging, and is especially visible from the inclination of the chains, which are not horizontal at all; in the same way the cornices that run around the aisles, interrupting in key of the arches except where there is the curve of the apsidal basin, have been affected by this movement and are not perfectly leveled.

You can easily notice the changes in the springer of some arches: the originals of the Byzantine period are round-shaped and because of the width of the spans are higher in the central and lower in the lateral ones; the south side of the central nave presents instead pointed arches, probably modified in the Crusader period, which are more slender than the others; on the same side also the openings have been modified and have pointed arches; this is particularly evident in the central opening, since the Venetians built the new wing of the fortification which incorporates the Byzantine church. The north side has an opening similar to the original type of architrave that is not in discontinuity with the walls and is visible on the west side, despite being walled. In this sense it is worth highlighting how the traces of openings on the walls were probably windows at first.

Lastly, the central dome has been recently built on pre-existing structures with evident changes, above all as regards the tholobate and the lower cornices, which have considerably cleaner and preserved walls, even with a lighter color than the rest of the church.

CONCLUSIONS

The results of the work presented here made it possible to realize the first digital survey of the church of St. George. The research has allowed us to recreate a database of information that combines both the morphological data acquired by the laser scanner and the material-photographic data in a three-dimensional work space; the three-dimensional datum has been traced to two-dimensional drawings that describe all the surfaces of the building: thanks to these data it was possible to understand the forms of architecture and advance archaeological hypotheses consistent with the stratigraphy of the walls on the evolution of the church.

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