Letting a Wall Tell its Story: A Low-cost Interactive Proposal for Kyrenia Castle, Cyprus

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"Built Information Modeling" (BIM) is quickly becoming a standard in managing and documenting the built world for development and maintenance, but, when applied, this solution may be time consuming and expensive. The procedure proposed is an entry level alternative to BIM technology in situations with a limited budget and in need of moving towards a more complete BIM solution. In the near future, the BIM approach (based on data interoperability) will be more common and integrated, becoming a new paradigm in design interventions, maintenance plans as well as being easily accessible via VIM (Virtual Information Modeling) tools. This case study focuses on the investigation of the geometric aspects and informative surveys (via 3D laser scanning and photographic acquisition) of the walls of Kyrenia Castle in the island of Cyprus. Evolving from the surveys, a simple procedure has been created to allow the insertion of additional precise information from different means to complement and enrich the geometric modelling, such as types of construction techniques and materials of the walls, colors, static functions, state of conservation and photographs, in order to reach the final aim of the research, which is masonry dating. With this premise it is possible to propose solutions that, starting from digital survey data, can provide rapid and effective information, ensuring results that can be cross-referenced. The use of *Autodesk ReCap*[1] provides the possibility to link photographic images or external links, like references, data, or PDF files, to specific points within the point cloud. The resulting version of the point cloud is compliant with the use of AutoCAD *3D Studio Max*[2] and especially with the integration into *Autodesk Revit*[3]; it may positively influence the construction of a full BIM model, exploiting data gathered and linked to the point cloud for the creation of the general models and associated families.

Key words:
BIM, HBIM, 3D laser scanner, Data collection, Restoration.

CHNT Reference:
Gabriele Farre et al. 2018. Letting a Wall Tell its Story: A Low-cost Interactive Proposal for Kyrenia Castle, Cyprus.

INTRODUCTION

The island of Cyprus has always played an important role in the Mediterranean basin, located in a strategic geographical position: a crucial stop on the way to the Holy Land during the Crusader period; an important commercial crossroad between the East and the West in the 16th century, at the time of the Venetian conquest, and a strategic naval outpost along the Suez Canal in the 19th century, during the British occupation.

Multiple and varied cultures have affected the country, influencing local and traditional building techniques and shaping the language of its architecture. The overlapping of these cultural assortments can be found in the case study of the fortress of Kyrenia (Fig. 1), which, with the mountain castles of St. Ilarion, Buffavento and Kantara, established the northern defensive system of the island between the 6th and 16th century. The city, commanded by mountain defences, offered an umbilical cord in which supplies could flow from the mainland. [Perbellini 1973].

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[1] https://www.autodesk.com/products/recap/overview
[2] https://www.autodesk.it/products/3ds-max/overview
[3] https://www.autodesk.it/products/revit/overview

The purpose of the research is the investigation of the masonry typologies of the fortress, aimed at understanding its historical construction evolution. The result of the analysis has been conceived as precise information used to enrich and complement the knowledge acquired from 3D laser scanning survey elaboration, useful for operators in charge of managing a survey, establishing a preliminary BIM model.

THE CASTLE OF KYRENIA: HISTORICAL INFORMATION

Built next to the ancient port, the hub of social life since ancient times, the castle of Kyrenia dominates the city with its massive scale, overlooking the surrounding historical urban fabric that still preserves its traditional features.

At the time of the first Arab invasions in the 6th century, the Byzantine castle must have appeared in the form of a rectangular enclosure, distinguished by four angular horseshoe-shaped towers, two of which were incorporated into the later Frankish structures. The near Byzantine church of St. George, originally set against the castle, dates back to the 12th century [Enlart 1899; Perbellini 2011].

At the end of the century the island passed into the hands of the French family Lusignan, who enlarged the fortress and built the northern, eastern and western chambers which overlooked the parade ground, the east and south fighting galleries, the north-east donjon and the north-west square tower [Enlart 1899].

In 16th century the island became domain of the Venetian Republic. The construction of the north-west and south-east Venetian circular bastions dates back to this time, as well as the southwest polygonal bastion, punctuated by narrow Italian passages. The Byzantine church of St. George was incorporated into the structure against the north-west bastion and was turned into a crypt when the Italians realized the western ramp to facilitate the transport of cannons to the summit walkway. The southern and eastern fighting galleries were filled with ground, forming massive spur wall reaching the maximum thickness of 22 meters to defend the fortress from cannon shots [Megaw 1964; Perbellini 1973; 2011].

In 1570 Cyprus was conquered by the Ottomans, who turned the fortress into a prison, and remained in their possession until 19th century, when the island fell under the British domain. Gaunt historical sources document these historical moments since the fortress became accessible solely to the military forces. The Frankish northern areas suffered severe alterations and were transformed into detention cells. The outer original curtain wall survives, crowned by a battlement dating back to the 13th century. Numerous internal passages and vents were obstructed [Enlart 1899; Megaw 1964; Perbellini 2011].

The castle passed into the hands of Cyprus Department of Antiquities in 1950 as an important ancient monument. Multiple restoration interventions took place during the next two decades. In 1976 the east chambers became headquarter of the Shipwreck Museum, which is still active today [Megaw 1964; Katzev 1981].

BIM: A NEW PARADIGM FOR THE ANALYSIS, PROTECTION, AND CONSERVATION OF ARCHITECTURAL HERITAGE

BIM is an approach that utilizes 3D digital representation of a database allowing multiple users to read, add or modify 3D or 2D data. The main purpose of this process is to increase the efficiency of workflow, collaboration and interoperability of information in the areas of planning, designing, constructing and management of buildings and infrastructures. Ideally, a BIM process allows collaborators from various fields, from designers to constructors, management and maintenance or demolition crews, to access the necessary data to better inform their work, but this should not necessarily be limited to large-budget projects.

A commonly-believed limitation today is that expensive programmes, such as *Autodesk Revit* or *Graphisoft ArchiCAD*[4], as well as highly-trained professionals in charge of planning the software, are needed to develop BIM components in a design process. However, this complex and costly 3D modelling software is not necessarily required, simply because BIM is a process, not a software.

When applied to the existing building, and the historical ones in particular, the real goal is to comprehend how the BIM can represent a concrete advantage for the study of those artefacts consisting of unique elements made of complex geometry and whose knowledge is often intuitive, while for a new building the very high level of detail

[4] https://www.graphisoft.com/it

guaranteed by industrialization of the components ensures completely reliable data. In this framework, the BIM model describes the form of the object but sacrifices the profound knowledge of the artefact which, even today, is realized only through a complex process of analysis that does not belongs only to the form but also to the changes that its specific components have endured over the years.

Basically, the BIM technology can certainly constitute an advantage in project interventions on existing buildings, but it can also become a significant disadvantage if it leads to an excessive simplification far from a profound knowledge of the building. Analyzing any artefact it is easy to ascertain how it is represents a complex and unique system, substantially unrepeatable. Likewise it is evident how the process of decomposing such a system is still today entrusted to the so-called graphic analysis largely based on traditional design.

A good project approach must be based on the knowledge of the manufactured product developed through qualitative analyses which permit to understand its nature and identify critical issues that arise first as a design and then becoming a matter in the realization phase. Precisely because of this complexity, starting a BIM process from point clouds or digital photogrammetry process to construction of surfaces from their interpolation and rendering, must be considered a necessary step in the evolution of BIM technology, facilitating the exchange of information between operators managing the project [Bianchini et al. 2016].

In this way it is allowed the extension of the BIM process to the phase of digital survey. Laser scanning tools have been employed for the case study to capture data through a less expensive and complex methodology. The use of the software *Autodesk ReCap* allowed the insertion of external data via links to historical documents and references. The insertion of photography has also been used to enrich the information provided by the survey. Purpose of the research is to demonstrate how fields such as heritage preservation, which often suffer of a restricted budget, can also benefit of the attributes of BIM technology, starting from the beginning phase of the survey. [Biagini and Arslan 2018].

3D LASER SCANNER SURVEY

The survey has been conducted employing the digital methodology of laser scanning, which guarantees a highly precise return of the scans performed. The instrumentation used is the laser scanner type Zoller + Fröhlich 5006h. This kind of tool possesses high quality features such as 360° horizontal/ 320° vertical picking range, an accuracy of 2 mm to 10 m distance and standard reflectance. The scans have been performed in high mode, capturing 1 point each 4 mm to 10 m distance, and in medium mode, capturing 1 point each cm to 10 m distance.

The process consists of two phases of which the first is the digital data uptake: taking a distance measurement in every direction, the laser scanner rapidly captures the surface shape of objects, buildings and landscapes, combining multiple surface models obtained from different viewing angles, or the admixing of other known constraints (Fig. 2). The second phase of the process is the digital data elaboration: The result of the acquisition is a set of points scattered in a regular 3D space model (point cloud), generated by polar coordinates and managed by the software automatically through Cartesian coordinates. The final result of the acquisition of digital data has been subsequently elaborated using the software *Autodesk ReCap*, which allows extrapolating plans, sections and elevations of the object, to perform measurements and verify checks. The processed and readable file can be then imported on proper BIM softwares and transformed into a 3D model to obtain architectural and structural designs.

MASONRY ANALYISIS

Construction technique of the masonry, materials, shape, dimensions and assembling of the blocks, denounce the epoch of realization of the architectural artefact, its geographical location, state of conservation and static disruption (Structural integrity analysis; Chemical, physical and biological decay analysis).

Numerous traces left on the surface of the vestments of the fortress, such as beam holes and shelves (Fig. 4), collapsed vault traces, mason' marks impressed on the blocks and placed throughout the castle (Figs. 5-6), all of which provides suggestions about the past architectural conformation.

The masonry fixtures are composed of local stone, a tophaceous limestone in grey or pinkish-blond color. It is possible to identify three macro-categories of masonry typologies, according to the historical period and belonging respectively to the Byzantine phase, Lusignan phase and Venetian phase (Fig. 7).

Byzantine masonries consist of large square blocks of greyish color and of uneven sizes on *opus isodomum* beds; Frankish masonries are much more regular in the vestments, destined to remain exposed as much external as internal chambers. The uncovered sections also denounce the very homogeneous nucleus of the same stone, but with irregular segments, particularly in the late Frankish period. The Venetian paraments differ from the Frankish ones by their smaller size, while the core, given the large thicknesses, is often made up of incoherent material. The Italian engineers plastered only the splices between the blocks, probably due to the considerable extension of the vestments [Perbellini 1997]. A similar system can be found in the defensive walls of Chania, Crete, also under Venetian rule at that time (Figs. 8-9).

THE USE OF *AUTODESK RECAP* TO SUPPLEMENT THE BIM MODEL

The use of the *Autodesk ReCap* software allows the insertion of additional information into the point cloud, such as photographic images and external links concerning the masonry survey, which would otherwise be difficult to identify. This solution provides significant awareness and knowledge of the artefact for the operators managing the digital data, starting from the preliminary phase of the survey and contributing to develop the construction of a full BIM model (Figs. 10-18). In this way it is easier to understand the architectural object from the beginning: the inserted notes and images provide important help to the operators working on the point cloud base who can quickly solve any modelling issue. At the same time, the simple procedure of adding notes over the point cloud in *Autodesk ReCap* allow operating this task even by beginners to this software, like students, volunteers, etc. The enhanced point cloud becomes then a better and more complete documentation tool for any further representation and modelling.

The solution proposed resolves some open questions deriving from the management of the digital survey, such as the deal concerning the operators creating parametric model out of the point clouds, which are often expert in modelling but dispose of a limited direct knowledge of the surveyed architecture. Operators might find the information coming from the simple point cloud tricky and difficult to manage, causing possible misunderstanding and mistakes. Also, in this way the operations of interpretation taken by the BIM operators may slow down the understanding process. A further question concerns the diagnostic analyses fundamental for the understanding of the artefact, which could be hard to interpret directly from the point cloud; not least, the level of details obtained from the point cloud can be very high, but certain characterizations can be difficult to focus on. Adding further information during the survey process could solve this kind of doubts identifying and clarifying the nature of the artefact.

Multiplex benefits increase the efficiency of a full BIM technology, starting from the preliminary survey phase: The interpretation process can be significantly accelerated integrating graphical, textual and photographic elements directly in the point cloud; in this way BIM operators would no longer have to interpret the point cloud only through the geometrical dataset, but supported by multi-competency information. Enhancing the point cloud with metadata and graphical information contributes to ensure a more aware 3D modelling phase that can be used following very simple procedures even by inexperienced operators.

CONCLUSIONS

The incongruity between the project and the survey of the artefact often represents one of the major causes of the delay during the construction phase, increasing times of planned costs. The relationship between BIM and survey needs that the last one permanently becomes the first chain ring in the BIM process, since the subsequent project elaborations depends on its reliability. This aspect should be considered as a primary objective on the impact of the whole process, aimed at simplifying and speeding up the working process, guaranteeing greater protection not least for the entrepreneurial risk. Furthermore, in the “BIM Execution Planning” (BEP) are defined in detail the matrices of the whole supply chain of responsibilities in order to specify the activity of each subject, its relevance, timing and dependence on the times and costs of the construction site. The application of this methodology, vantageous for the design of new buildings, can be equally valid also on existing buildings because its true potential is linked to the definition of a new mode of collective work in which the different professional technicians, clients and users interact in order to limit changes and surprises. Beyond the technical or performance specifications of the software, there must be a change of perspective compared to the past that makes BIM an interesting and probably irreversible process [Bianchini et al. 2016].

The proposed methodology can validate and clarify especially the transition phase between the survey and the subsequent development of the 3D model design. The addition of data included in the point cloud can provide further information to the operators in charge of developing the 3D model, helping them to achieve an easier and quicker comprehension of the survey. Using the software *Autodesk ReCap* it is possible to exploit the digital point cloud survey to form a foundational base where information, texts, photos can be added as additional indications. This alternative method provides lower cost mean for managing sites and structures such as historical contexts, and it can be revealed as essential for fields such as historical preservation and restoration, which are often underfunded and in need of efficient management programs. Future development of cost efficient and simple-to-use programs and methods is also needed to support the research and to ensure the preservation of heritage sites.

FIGURES

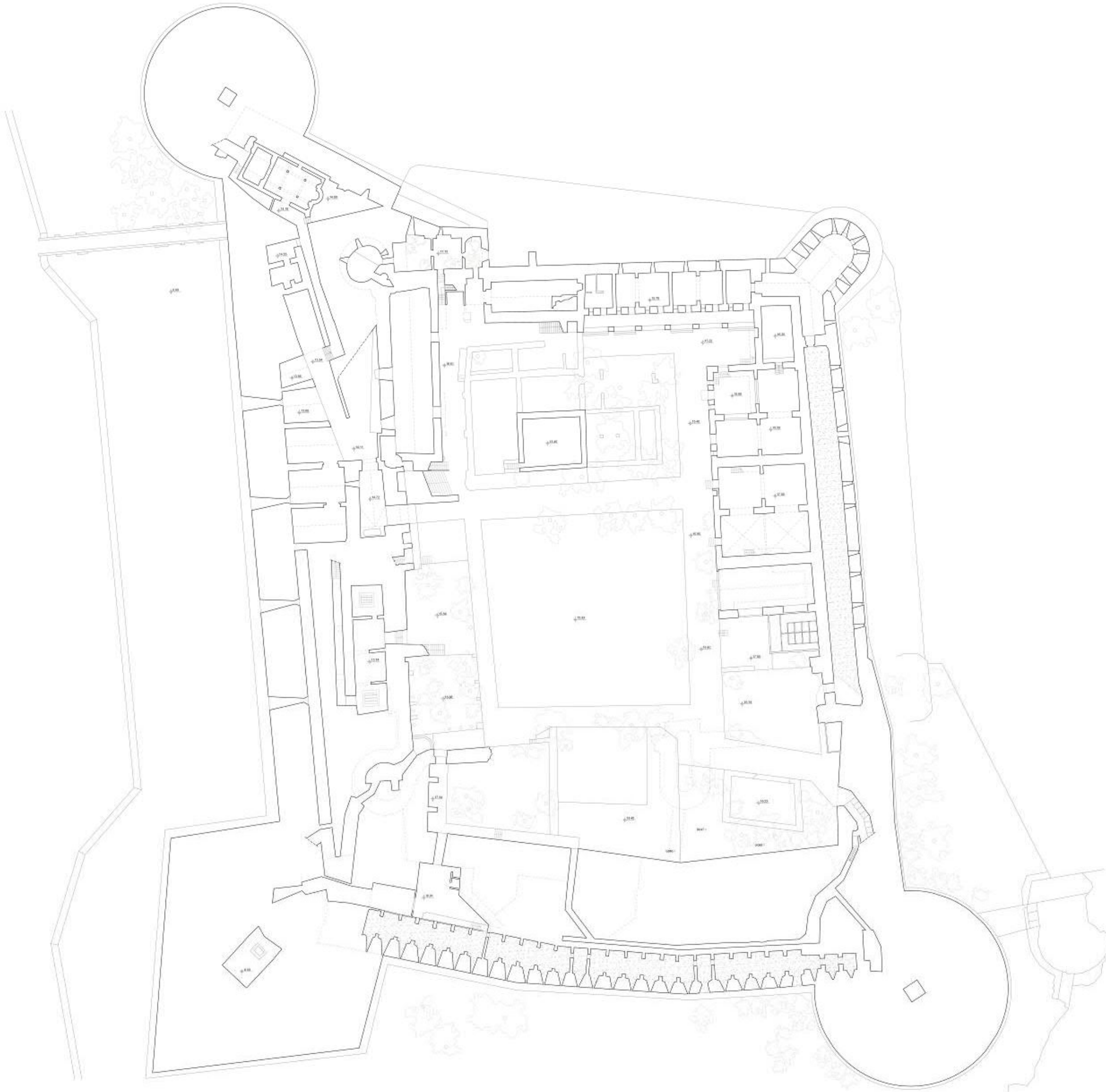

Fig. 1. Plan of the castle of Kyrenia (© E. Valletta)

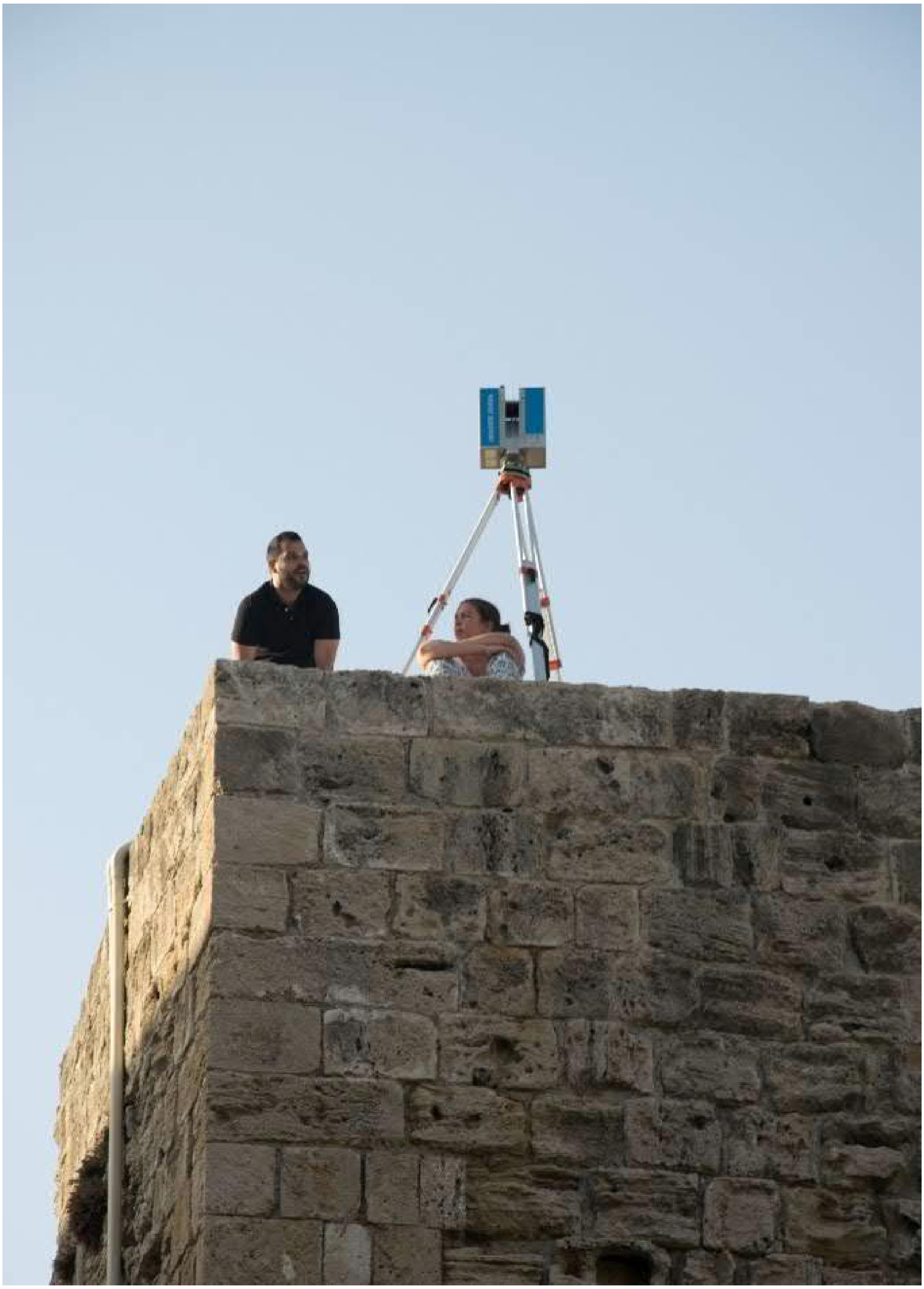

Fig. 2. Laser scanner survey: digital data gathering (© G. Verdiani)

Fig. 3. Laser scanner survey: elaboration of digital data in Autodesk ReCap

Fig. 4. Masonry analysis: balcony shelves on Lusignan masonry testify the past presence of upper storeys (© E. Valletta)

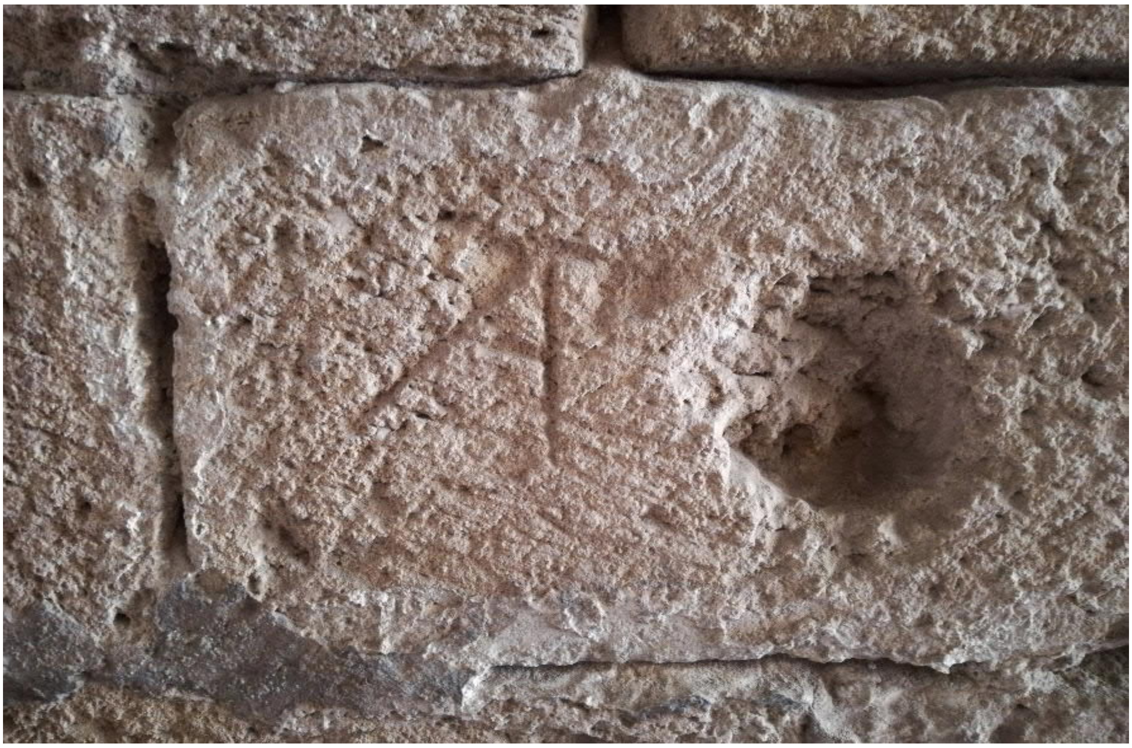

Fig. 5. Masonry analysis: mason's mark impressed on Byzantine masonry (© E. Valletta)

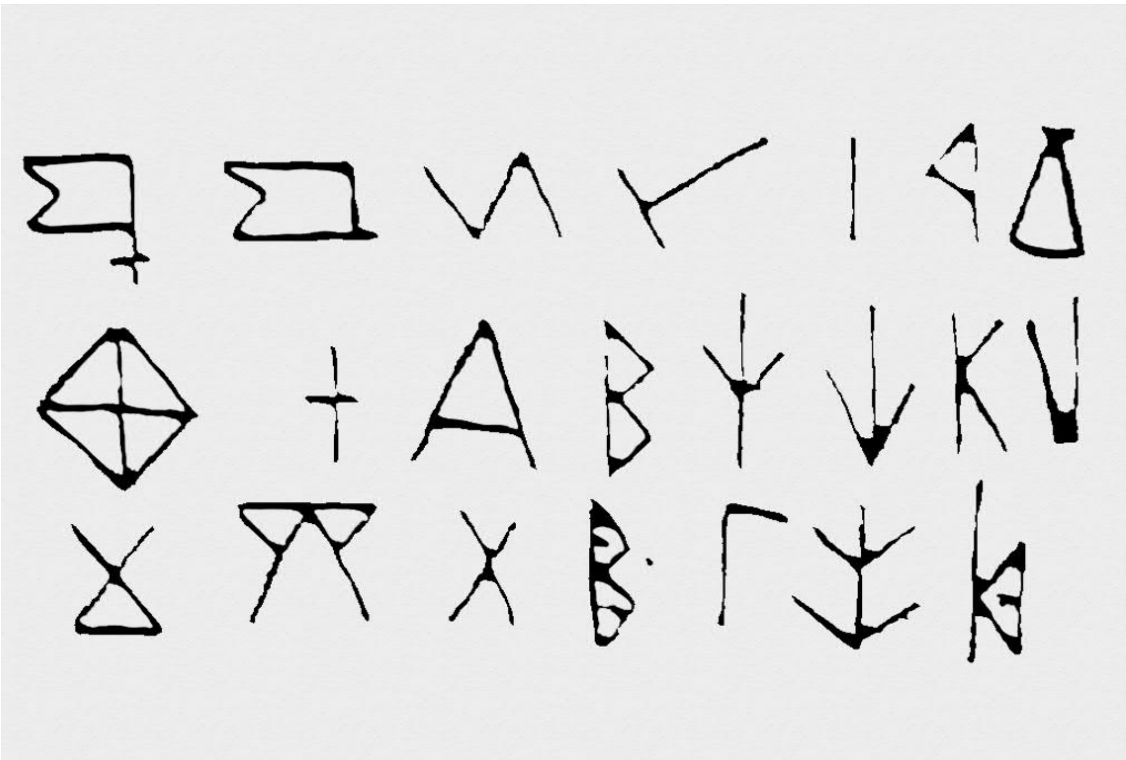

Fig. 6. Masonry Analysis: classification of masons' marks of the castle (© C. Enlart)

Fig. 7. Masonry analysis: St. George Byzantine Church included between Venetian and Lusignan masonry (© E. Valletta)

Fig. 8. Masonry categories in Kyrenia Castle (© E. Valletta)

Fig. 9. Masonry survey of Kyrenia Castle (© E. Valletta)

Fig. 10. Insertion of masonry survey into the point cloud - Byzantine Masonry (330-1191)

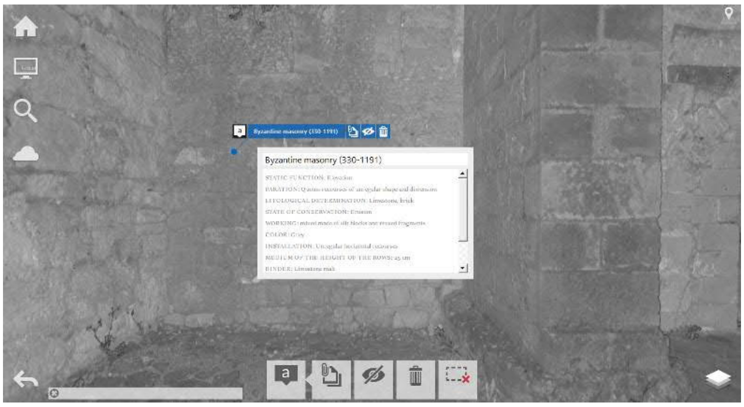

Fig. 11. Insertion of masonry survey into the point cloud - Byzantine Masonry (330-1191)

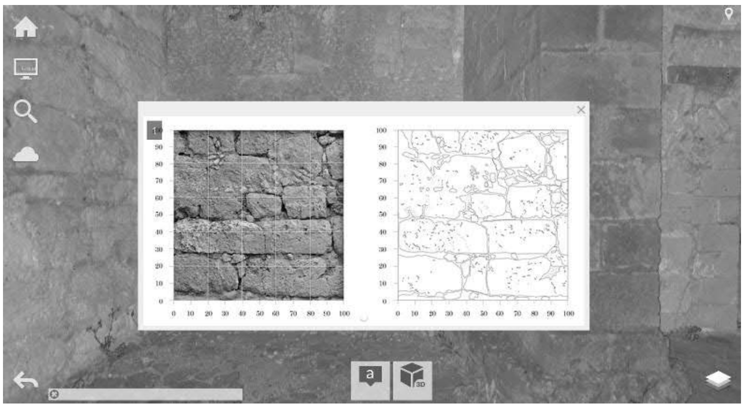

Fig. 12. Insertion of masonry survey into the point cloud - Byzantine Masonry (330-1191)

Fig. 13. Insertion of masonry survey into the point cloud - Lusignan Masonry (1192-1489)

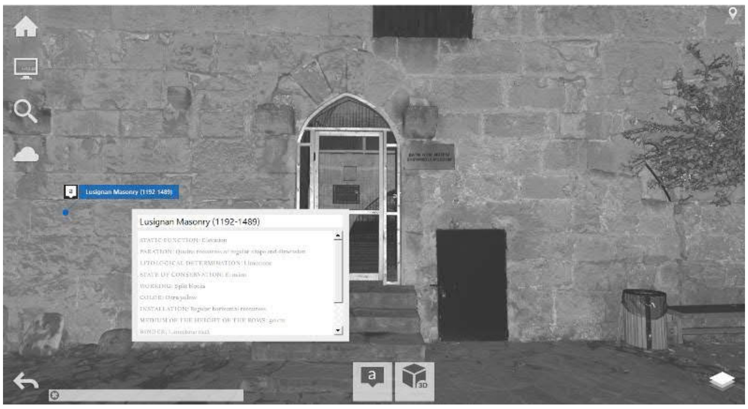

Fig. 14. Insertion of masonry survey into the point cloud - Lusignan Masonry (1192-1489)

Fig. 15. Insertion of masonry survey into the point cloud - Lusignan Masonry (1192-1489)

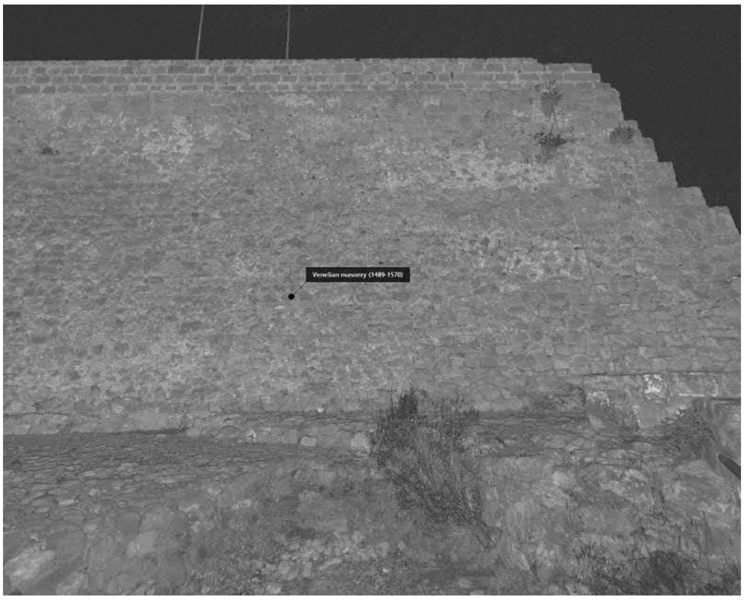

Fig. 16. Insertion of masonry survey into the point cloud - Venetian Masonry (1489-1570)

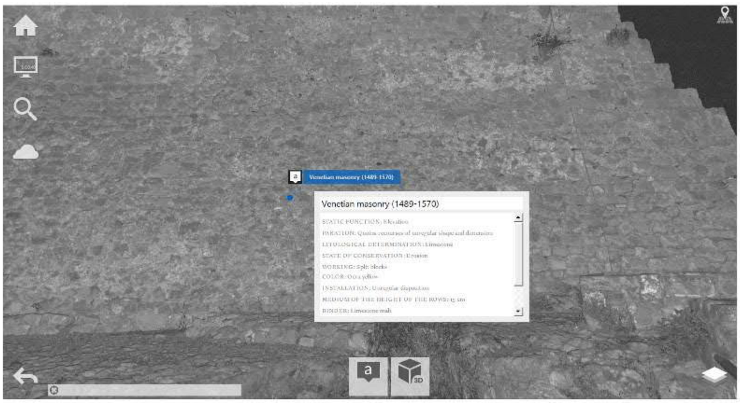

Fig. 17. Insertion of masonry survey into the point cloud - Venetian Masonry (1489-1570)

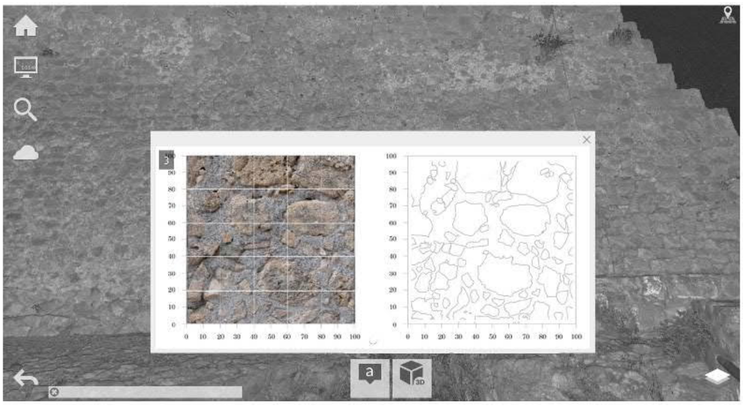

Fig. 18. Insertion of masonry survey into the point cloud - Venetian Masonry (1489-1570)

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Imprint:
Proceedings of the 23rd International Conference on Cultural Heritage and New Technologies 2018.
CHNT 23, 2018 (Vienna 2019). http://www.chnt.at/proceedings-chnt-23/
ISBN 978-3-200-06576-5

Editor/Publisher: Museen der Stadt Wien – Stadtarchäologie
Editorial Team: Wolfgang Börner, Susanne Uhlirz
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