THE LASER SCANNER FOR ARCHAEOLOGICAL SURVEY: "LE TERME DELL'INDIRIZZO" IN CATANIA

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ABSTRACT

3D laser scanner technology, joining precision and versatility, assures survey's high quality and working time's optimization. Nowadays, this is the most advanced methodology to document, monitor and diagnose buildings which are difficult to survey for their articulated formal-geometric shape, unfavorable logistic and environment conditions. Thanks to its peculiarities, this methodology has great potentialities in archaeological survey, not yet explored; whereas traditional systems have more difficulties and limits.
The aim of the present essay is to verify laser scanner's potentialities in surveying the so called “Terme dell'Indirizzo”, an organism of great interest for its spatial complexity and the substantial integrity's conditions of its ten rooms.
The use of a high precision technology instrument, capable of providing great number of information (total cloud of approximately 24 million points) supported by suitable softwares, allows to realize the whole building's three-dimensional model by assembling single scansions into one reference system. The possibility of exploring the object's spatiality and of studying the three-dimensional model through several scales of detail has represented the first step for choosing the following suitable elaborations: extracting plans, prospects, profiles and sections at different heights and in appropriate parts of the model; turning the discreet model (cloud points) into a continuous one; projecting the photographic image on the mesh model in order to acquire material and pathology's information. The high precision of the analyses carried out has been the basis to undertake the subsequent critical researches in order to recognize potential modular matrices by using the ancient unit of measure (roman foot); to interpret the geometry of some complex rooms such as the *Calidarium*, presenting an octagonal plan covered by a dome vault; to formulate hypothesis about historical stratification, ruines and modifications occurred throughout the centuries.

1. INTRODUCTION

3D laser scanner technology, joining precision and versatility, assures survey's high quality and working time's optimization. Nowadays, it is an irreplaceable research's instrument to document, monitor, know, and, consequently, safeguard Cultural Heritage.
3D scanning points clouds elaboration permits to obtain three-dimensional digital models of artistic objects. It also allows the creation of databases and virtual museums, the digital restoration and the real models' reconstruction through 3D laser prototyping.
Nowadays, in spite of fast technical progress, the application of laser scanner technology to artistic heritage's knowledge and preservation takes place only in theoretic researches.
Moreover, this method actually allows to monitor and to diagnose architectonic organisms difficult to survey for their articulated geometric-formal shape and for unfavorable logistic and environmental conditions. Thanks to its peculiarities, this methodology has great potentialities in archaeological survey, not yet explored; whereas traditional systems present more difficulties and limits.
The present essay deals with the so called roman *Terme dell'Indirizzo* survey, located in Currò Square, in the heart of Catania's historical centre. The building probably dates back to the late imperial age and is part of S. Maria dell'Indirizzo convent structure.
Only ten rooms covered by original vaults and lava ashlar walls with a cement mortar core still remain of the original *Thermae*. The best characterized parts of the building are the *Calidarium*,

Figure 1. Western view of the Thermal complex

Figure 2. Southern view of the Thermal complex

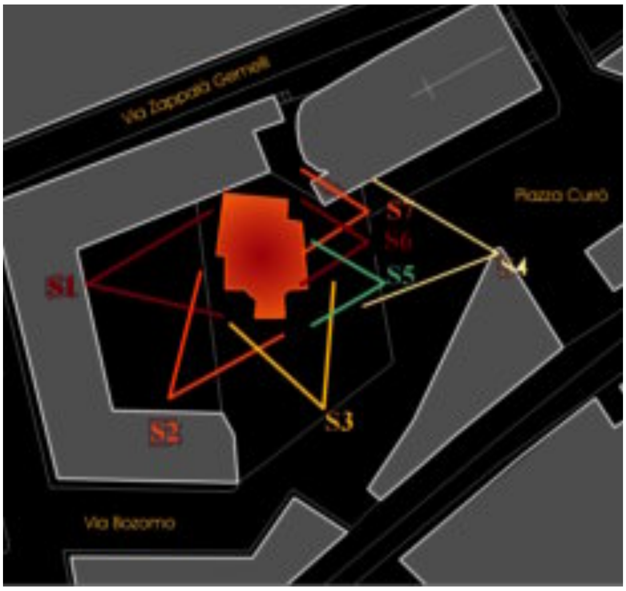

Figure 3. External scan project

Figure4. Internal rooms scan project

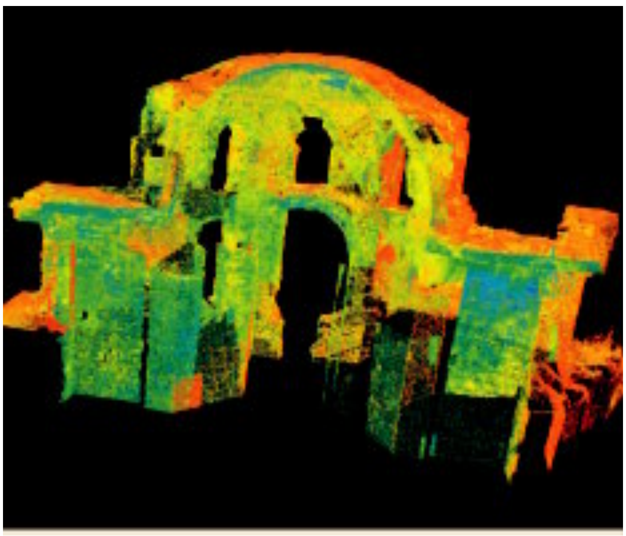

Figure 5. View of the *Calidarum* complete 3d model in RGB color

an octagonal room with a hemispheric dome in squared lava stones, the furnaces, built in bricks with small terra-cotta pillars, and the marble bathroom.

2. DATA ACQUISITION AND PROCESSING

The first step was to plan the survey's project in relation with the place and the object's peculiarities and the instrument's features. The used scanner Leica Cyrax 2500 is suitable for studying great dimension's buildings: indeed, it allows shot's fields up to 100-150 m, with a scansion field equal to 40° x 40°, a range of accuracy of about 4 mm and an angular precision equal to 60 microrad.

In order to obtain a partial scanning overlay fundamental to the following elaborations, during outside surveying it was necessary to perform eight scansions in seven stations.

The station positions were chosen along the external perimeter of the building at different levels in order to cover the whole thermal complex, laterally and from the top, and to integrate lacking data due to shadow zones.

A mesh of station points planned to survey some internal rooms (*Calidarium*, *Tepidarium*, and *Laconicum*), allowed both general scansions and detailed ones, the last one in correspondence of complex or significant architectonic elements.

The building's shape and its spatial articulation have raised two problems during survey's execution: the choice of instrument orientation depending on intrinsic rooms' shape; the limited scansion field which did not let survey all the space from a single station. So that it was required to carry out multiple scansions and to locate well recognizable reference points in order to handle, without uncertainties and lacking areas, the following scansions assembling.

In particular, to survey the *Tepidarium* rectangular shape it was necessary to put the scanner along the plan longitudinal dimension, while to survey the *Laconicum* quadrangular shape it was necessary to turn it towards the sidewalls, for a total of six stations and ten scansions.

The *Calidarium* has an octagonal plan covered by a semispherical dome. In order to produce a complete survey minimizing the number of stations and obtaining a good data's quality, the wall-s's shots have been carried out radially, along octagon edges by executing two scansions (towards the bottom and the top) for each station, with a total of 8 stations and 16 scansions; moreover a detailed scan, barycentric and hyposcopic, has been carried out for surveying the dome's surface.

After metrical data acquisition the following step was to obtain the whole model (inside and outside rooms) of the thermal complex by assembling single scans and referring them to one reference system.

Usually, single scans alignment and registration take place in two different ways: manually or through the identification of reflecting targets acquired by the scanner during the surveying phase and topographically surveyed.

In this case, the impossibility to apply the targets on the handmade item, working without using topographical survey, has required, during alignment and registration step a vaste amount of work in homologous points collimation (adding constraints). More difficulties have occurred, during inner room alignment, because of the absence of remarkable points such as doors and windows edges, or element's detail (capitals, cornices, etc) dealing with a squared stone masonry.

However, the high density of the acquired points, giving almost a real detail (scan stepwidth equal to 5 mm), have facilitated

Figure 6. Outside view of the complete 3d model

Figure 7. Detailed view of the points cloud

collimation work .
Operatively, in order to obtain a better error compensation, it has been employed the polygonal method, whereas possible, hooking each scan to the previous and to the following one both in horizontal and in vertical direction.
Calculus parameters (subsampling percentage, iteration number, max search distance) has been optimized in order to reduce at least scan aligment error which on average was about 7/8 mm and in some cases it was inferior to scan stepwidth.

3. 3D VIRTUAL MODEL ANALYSIS

The whole three-dimensional model of the thermal complex, formed by the union of 34 scans for a total of 24.000.000 surveyed points, is a copy of the real object, an accurate and reliable documentation, which allows its analysis and control, as well as its measurement and the evaluation of the dimensional features of all surveyed parts.
Furthermore, it provides the basis for the development of traditional (extracting plans, front views, sections in each point and according to the led study) and three-dimensional (meshes, orthophoto) elaborations, with the advantage, in this case, of being immediately perceived and understood even by not expert people.
In a first elaboration step different horizontal and vertical profiles have been extracted in order to delineate, in a traditional manner, the geometrical conformation of the thermal complex.
We used Cloudworks (by Leica geosystem), a software which operates in CAD environment allowing to easily manage cloud

Figure 8. Vertical section along the plane passing through one of the octagonal plan’s diagonals

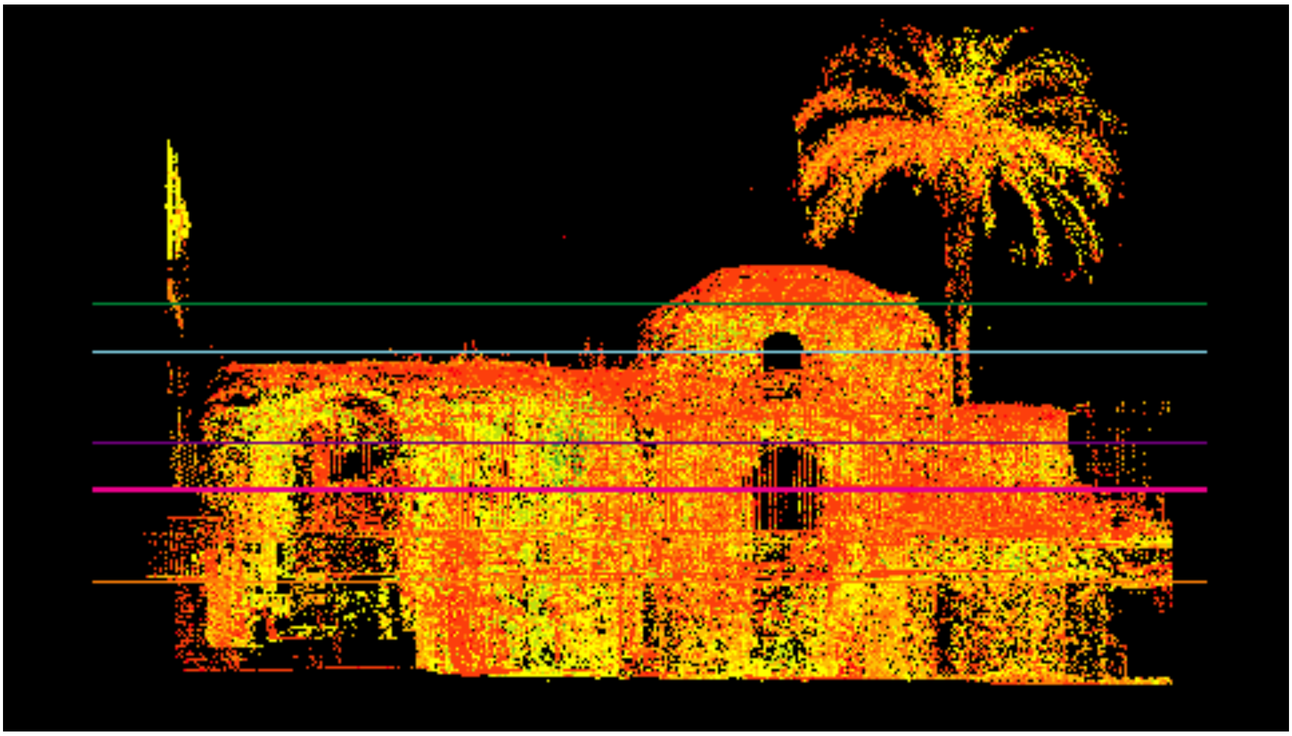

Figure 9. Different horizontal crossing planes at different levels

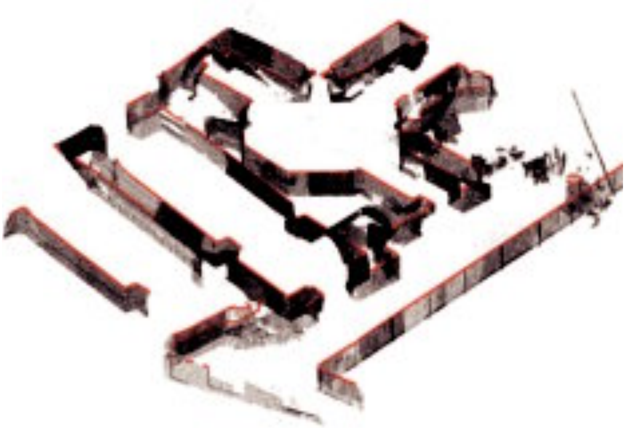

Figure 10. Horizontal section at 5.50 m level

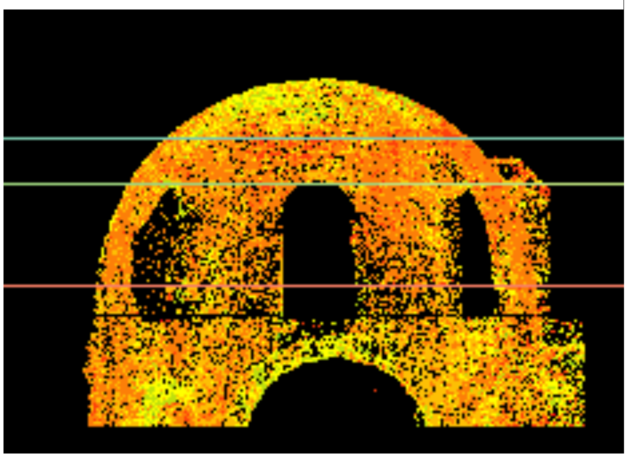

Figure 12. Different horizontal crossing planes on dome point's cloud at different levels

Figure 11. Horizontal section at 6.60 m level

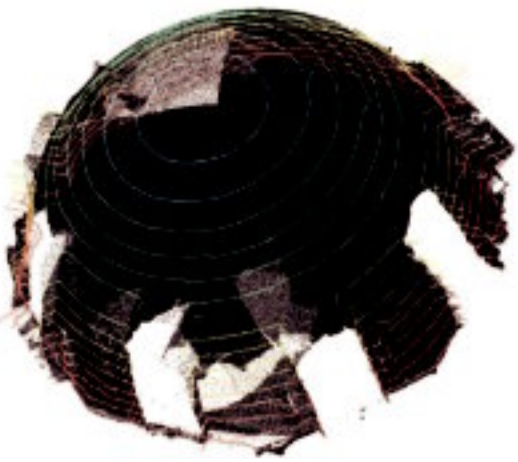

Figure 13. Contour lines overlapped on dome point's cloud

points visualization and to extract profiles through planes defined by the operator.
In particular, 7 section-profiles with horizontal planes have been carried out in order to obtain the plans at different levels and 3 vertical section-profiles through the most significant planes.
The *Calidarium* octagonal room and its relative dome geometry have been closely examined.
The vertical section along the plane passing through one of the octagon's diagonals proved to be fundamental to study the dome: as a matter of fact, it was possible to recognize the passing from the octagonal to the circular plan shape. Moreover, in order to study dome's geometrical shape, the relative point's cloud part has been sectioned by 14 horizontal planes placed at a stepwidth equal to 20 cm, obtaining at first a contour lines drawing.
Furthermore, working in CAD environment it was possible to measure the horizontal displacement due to cracks.
Studying complex buildings - above all archaeological ones - with the traditional instruments of survey could be extremely onerous, sometimes not exhaustive. Archaeological objects' geometries are often strongly irregular, discontinuous, incomplete and these peculiarities make more difficult to locate the target elements required for a geometric survey and to choose the two-dimensional drawings that as well as possible document the complex spatiality of the object.
Furthermore, the archaeological survey requires to analyse the material features of every element of the fair-face stone walls and eventual discontinuities and decays.
In studying the thermal construction placed in Catania, an important step was the passage from the cloud points - that constitute a discreet model of the real object - to a three-dimensional continuous model, obtained from the triangulation of closer points of single clouds and the subsequent union of the same.
The used software, Reconstructor by Inn.tec. srl, allowed to select in a critical way the parameters that control the dimensions of the triangular meshes and to diversify them in different parts of the same model. The aim was to obtain simplified surfaces without losing the details of every lava stone's material conformation.
The method has concurred to explore the Thermae's complex inner and outer spatiality, choosing different points of view and the best kind of mesh's visualization (wireframe, flat or textured), according to the analysis to be carried out. It has also concurred to study - by different scales - the single constructive details and to calculate areas and distances in every portion of the three-dimensional model.
The acquisition of material, chromatic and degraded data has been obtained through the projection of the photographic images on respective point clouds, collimating several well distributed and visible equivalent points and the successive application of the projected images on the continuous mesh model, in order to take the best advantage from the high resolution of photos.
The chance of re-projecting the textured model on suitable plans, obtaining metrically precise orthophotos, is finally considered an effective instrument to integrate - with material and constructive information - the still irreplaceable two-dimensional traditional drawings, such as plans, prospects and sections.

4. CONCLUSIONS

The high precision of the carried out analyses is essential for a both quantitative and qualitative correct knowledge of the building. It's the main start to undertake future critical researches, in order to recognize potential modular matrices using the ancient unit of measure (the roman foot) and to explain the geometry of some complex rooms such as the *Calidarium* presenting an octagonal plan covered by a dome vault. Thanks to these high precision analyses it is possible to formulate hypothesis about historical stratification, ruins and modifications occurred throughout the centuries.
Using periodically 3D laser scanner to document every element of the archaeological construction, allows to monitor the building during time, keeping cost and time acceptable. This technology could be a powerful instrument to safeguard the rich archaeological heritage in areas, like Sicily, where the problem gets to serious and pressing questions.

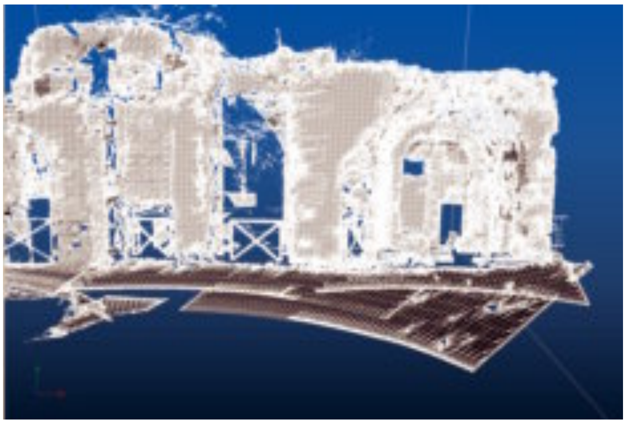

Figure 14. Eastern view of outside wireframe model

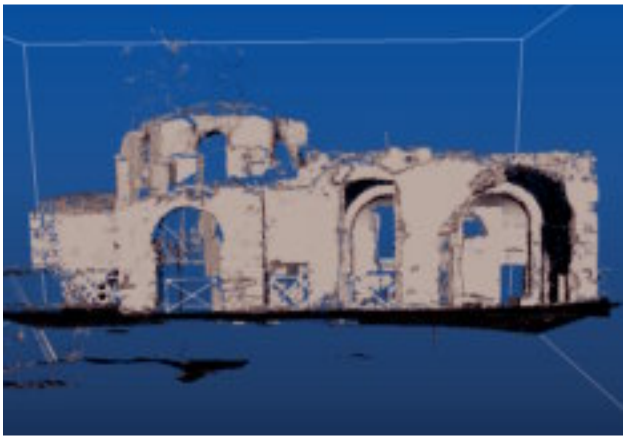

Figure 15. Eastern view of ouside flat model

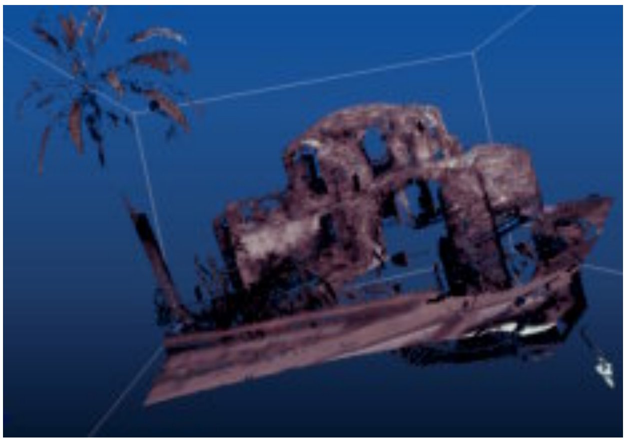

Figure 16. Eastern view of ouside textured model

Figure 17. *Calidarium* textured model

Figure 18. *Calidarium* textured model detail

Figure 19. Eastern view of the outside textured model

Figure 20. Detail of ouside textured model

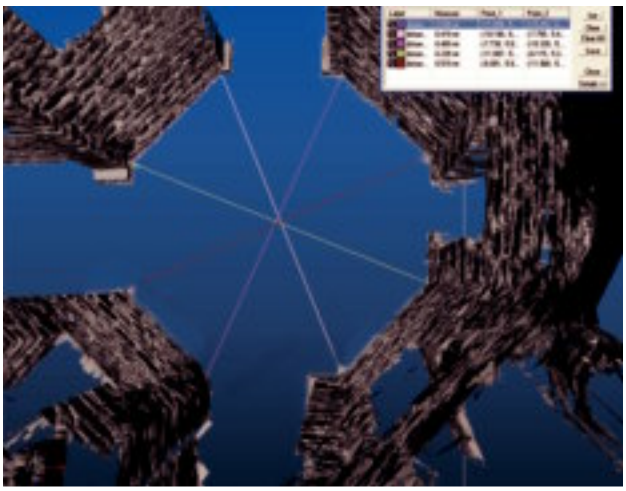

Figure 21. *Calidarium* plan diagonal distance computing

Figure 22. *Calidarium* dome hyposcopic orthophoto