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From standard to laser scanning surveying for heritage: some case studies in Enna (Italy)

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Abstract

Current tendency in restoration of cultural heritage cannot neglect a multidisciplinary approach, whereby the research object is simultaneously and synergistically studied by specialists from different sectors. Nowadays, the constant and rapid development of science and technology provides architectural restoration with new tools, which may be very useful in view of a responsible and conscientious conservation perspective of cultural heritage. In this field, characterized by a rich variety of methodological and operational opportunities, *survey* plays a key role. Actually, the continuous improvement of acquisition, processing and graphics rendering techniques, offers an increasing support to the restoration discipline, both in terms of understanding of monuments, than in the evaluation of project choices . The working method, once set on a serial logic (first the surveying then the project) today follows a parallel and coordinated logic in which, also thanks to new BIM technologies, in real time, are simultaneously handled the geometric modelling, the structural and technological analysis and, more generally, all information concerning the whole building characteristics. The use of measuring instruments based on structured light system has also revolutionized the restoration field, because, in addition to ensuring rapid and complete measurability of architectural objects, data processing allows to produce detailed analysis of structural instabilities and degradation processes. This paper intends to document the experience carried out in the framework of the course of Architectural Restoration of the Faculty of Engineering and Architecture of Enna (Italy), in which the standard surveying technique for architectural restoration, has been flanked by an experiment carried out with a laser scanner, combined with a new point cloud tool.

Keywords*: cultural heritage, survey, laser scanning, integration of techniques.*

1 The town of Enna and its sacred architecture

Perched on a hill that rises from the single plain and often hidden by fog, the town of Enna, administrative capital of an Italian province, is located at the heart of Sicily. The *Umbilicus Siciliae* (as was called by Romans, not only for its location, but because it dominated at their meet, the three main roads of the island, whose tracks form the three legs of the *Trinacria*) is still relatively little known and studied if compared with the extent of its historical and artistic treasures (Collura, 2009). City of the Siculi, an ancient Sicilian tribe, and a centre of the pre-Hellenic cult of Demeter and Kore (Persephone), early came under Greek influence. After a brief period of Carthaginian rule (4th century BC) it passed to the Roman domination in which rose to a strategic role in Sicily. Taken by the Saracens in 859, it was elected as the new capital of the island and named *Qasr Yânnah* (Fort of John) until 1087, when the Normans captured the town. The city's name was then converted in the form of Castrogiovanni and so will remain until 1927 when it resumed the name of Enna. During the Norman conquest, Castrogiovanni became an important cultural and political centre of the kingdom. In 1130 Roger II restored the ancient Sicanian fortress, now known as "Castle of Lombardy". After the brief Angevin parenthesis, culminating in the Sicilian Vespers (1282) that lead to the Aragonese conquest of Sicily, Enna rose again. In this period, several monuments were restored and, at the behest of Queen Eleanor, wife of Frederick III of Sicily, the *Cathedral* was founded in 1307.

This magnificent monument has a very complex history, marked by fires, landslides and other static problems that, along with a demonstrated commitment to the formal innovation perpetuated by its different "owners", have redesigned its geometric forms in the medieval times, while respecting the overall spatial characters. Based on three main building phases: an initial one (14th-15th century) to which correspond, at the southern end of the transept, the Gothic walled portal (considered a kind of "Holy door", *porta santa* in Italian and *porta sancta* in Latin), because it was built and opened on the occasion of a special Jubilee) and the three polygonal apses characterized by single-lancet windows and reinforced on the corners by clustered pillars; an intermediate phase (16th century) to which date the rich interior decoration, characterized by interesting figures and Corinthian capitals superbly carved by important artists of the era, as well as a second portal located on the south flank, enriched by a marble bas-relief on the tympanum; and finally the 17th-18th centuries phase when an imposing facade surmounted by a massive campanile that, for its dating, can be considered as a prototype of the towers-facades, realized in the south-east of Sicily at that time, was added (Garofalo, 2007). Other praiseworthy monuments and churches can be found among Enna's streets: the Church of Carmine (Chiesa del Carmine) dating from 18th century, the Church of Santa Maria la Donna Nuova, whose the first nucleus presumably dates from the early 12th century, or even the Church of St. John (Chiesa di San Giovanni), a fine example of Gothic lines with Arabic construction. Another rich testimony of the medieval architecture in Sicily are the towers, initially components of the impressive fortification system of Enna,

latter incorporates into churches as belfries (Boscarino, 1981). This is the case for the Torre del Carmine, characterized by a strange semi-cylindrical lateral protuberance or even for that of St. Thomas (San Tommaso), dating from the 15th century, composed of three orders and characterized by windows framed by an agile full-centered archivolt.

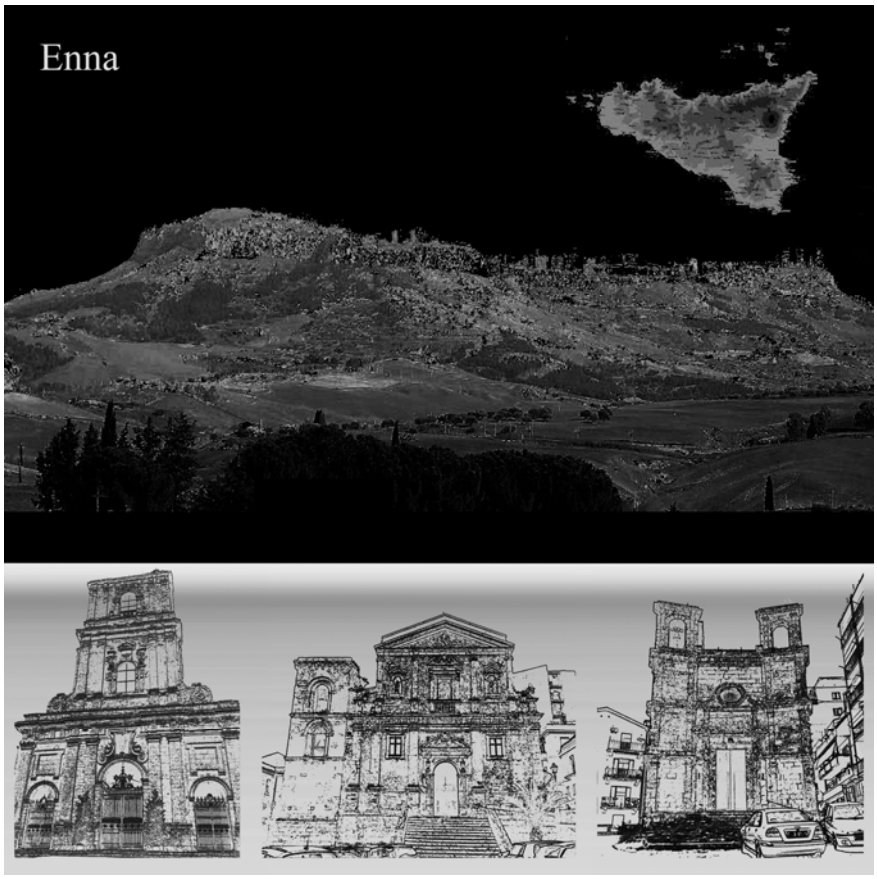

Figure 1: Enna and its cultural heritage.

2 The survey phase: building awareness and understanding as preparatory phase of the restoration project

The main objective of the Architectural Restoration Course of the University of Enna has been to approach the operational aspects and the practice of this matter, that has to be considered not as a summation of interventions but as an unitary project: a wise synthesis of different but usefully linked phases, ranging

from the acquisition of information, to the "faithful and objective" restitution; from the material analysis and characterization until the project proposals, also mediated by conventional and/or unconventional simulations and graphics imaging. Moving from the assumption that any restoration project requires a philosophical approach based on cultural consciousness and from the idea to develop in students that critical attitude towards the various technical and scientific tools, research results and operational achievements that should drive all restoration intervention, the course has intended to conduct an in-depth analysis on the most important ecclesiastical buildings located in Enna, in view of the elaboration of conservation and restoration projects. It has been then followed an analytical process based on the continuous dialogue between the various components of the project and on the evaluation of diagnosis and intervention choices. The course has been also focused on an investigation that begins with the historical/critical awareness of the importance of historical monuments to then deal with their material consistency.

To carry out this exercise, students were directed to monuments offering them the opportunity to conduct a direct survey and to make a philological reading, as well as an analysis of issues related to degradation of materials and the collapse of structures in order to formulate a reasoned intervention proposal. Starting from existing documents and drawings, opportunely revised and reworked, and from a critical review of technical interventions previously made on the churches of their competence, students have re-traced all the relevant phases of the survey and then of the restoration project. The visual analysis of architectural structures, has been followed by the direct acquisition of dimensions and the recognition of geometric features (rules, ratios and proportions) through the use of traditional surveying tools and then by the CAD rendering of metrics data by means of drawings in scale 1:50 (plans, sections and elevations, with trilateration and quotas). Special attention has been devoted to integrate the metric survey with the manual measurements, especially oriented to the description of the decorative system and of the erratic "associated objects" (with particular reference to the architectural orders), as well as with the recognition and the overall systematic description of the cracks occurred, of the humidity and of the deterioration of materials.

Essential support to the graphic survey has been offered by an accurate photographic survey, which has enriched and integrated the information provided by eidotypes and documented the relationship between the monuments and their environment; finally, photorealistic 3D architectural renderings, 3D animations and simulations have enhanced the work, creating interactivity and facilitating the understanding of the spatial organization of the monuments, its position, shape and geometry. These exercises are therefore been identified as the necessary basis support on which to develop any assessment on the state and degradation of the churches, and then to formulate restoration hypothesis. The complexity of the study has, last but not least, suggested the possibility of using these monuments as a test-bed for an experimentation with advanced 3D survey

technologies, based on a new method of data acquisition and processing, carried out in collaboration with the Engineering Faculty of the University of Bergamo.

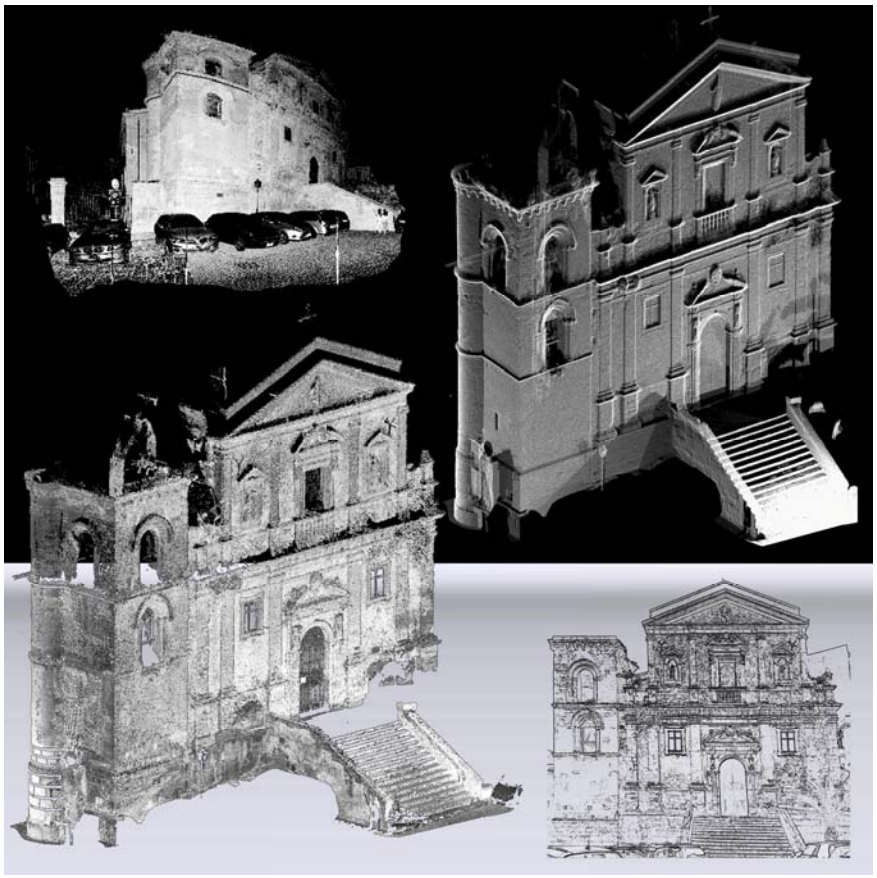

Figure 2: Laser scans of Enna's *Chiesa del Carmine*.

3 The experimentation with the *FARO® Laser Scanner Photon 120* and the *software GEXEL JRC 3D-Reconstructor*

The use of 3D laser scanner systems has profoundly changed and marked the surveying field. If in the past, the metric survey and the graphic restitution system were essentially devoted to obtain a basic document, a kind of canvas on which to set up and then develop further ideas (Docci, 2009), today, the "survey project", is to be considered essentially as a planning phase, a introductory stage to the measurements *in situ*. It 's so that while the traditional technique required the elaboration of an imposing mass of drawings to document plans, elevations

and architectural details of buildings (starting from real sketchbooks on which to note down measurements made, as well as the peculiarities of the buildings themselves and their state of conservation), with the laser scanning this is no longer necessary. The "sketch", for instance, has acquired new function: what had previously served as a rough copy on which to note the information and measurements carried out (the eidotype), now it is not configured as a schematization of plans and elevations, but rather as a spatial reproduction of details. Its function is to capture and recreate the “essence of space”, which will be subsequently detected by laser scanning. The sketch is seen almost like a pictures, purified from all that is superfluous, which aims to direct the operator in the use of laser scanning. Actually, rather than the eidotype elaboration of the object, today it is important to properly plan the survey process. The correct choice of number and location of scan stations, the definition of scans steps and the resolution of scans, are essential elements to obtain a global cloud, able to totally cover the architectures, limiting as much as possible hidden areas (Bartolucci, 2009). Especially for architectural elements characterized by a particularly complex geometry– like as for the monuments concerned by this paper- in this experience it is necessary to take into consideration issues related to the alignment (in jargon, registration) of each scan and the need to contain the error in a tolerance limit of the same order of that of the measurement instrument (at the end of the registration, the scan of a masonry wall should overlap, not to give rise to two different surfaces, placed on plans staggered between them). Traditional targets can be considered by then obsolete and are normally replaced by calibrated spheres, because they do not need to be placed orthogonally to the station: a simplification that in any case would not result in a significant decrease in measuring time, due to the need to always locate the spheres near buildings and in places visible to more stations. For this work it has been therefore preferred a much simpler survey methodology, which does not need the use of a target nor the use of calibrated spheres, but benefits of the combined and integrated utilization of different software.

The digital acquisition of the monuments of Enna has been carried out through the new FARO® Laser Scanner Photon 120, based on the phase shift technology, much faster and more accurate than traditional time-of-flight instruments. The survey projects have been developed by executing several scans at regular intervals along the sides of the churches of most interest (the Cathedral, the Church of Carmine, the Church of Santa Maria la Donna Nuova). Environmental 360° scans" have been conducted, so reducing *in situ* measurement time. The speed of data acquisition and measurement given by this instrument is such as to make it more affordable (in terms of reduction of working time) the acquisition of all of the information and then the cleaning of unnecessary clouds of points, rather than to adjust the scanning angle and the resolution for every single scan. Measurements phase was then followed by refunds and processing of measured data: clouds were first filtered and then pre-aligned by the software *FARO Scene*®, and finally recorded with a new shape control algorithm by the software *GEXEL JRC-3D Reconstructor* (Vassena, Sgrenzaroli, 2007). In order to ensure the best use of the algorithm able to "recognize" between different scans,

homological shapes and forms, it has been observed that the greater accuracy is obtained by choosing a point cloud as reference scan to keep "locked " in space, and rototranslating it on all others. The frequently used practice, instead, prefers to choose as reference scan, the first point cloud and adjust to it the next one: the aligned point cloud is then considered as the new reference scan, and to it, is aligned the following one, so proceedings for all the rest. Although operationally more immediate, this approach involves a high propagation of registration errors, due to the fact that alignment inaccuracies on the first iteration, will be added to those of the second iteration, and to those of third and so on. It is although evident that the first *modus operandi* is not always practicable, because it is necessary to find a station point, sometimes located at a greater distance of the object of study, from which it would possible to see the whole building. It's then clearer the importance to plan in advance the support network, even in view of subsequent data processing operations.

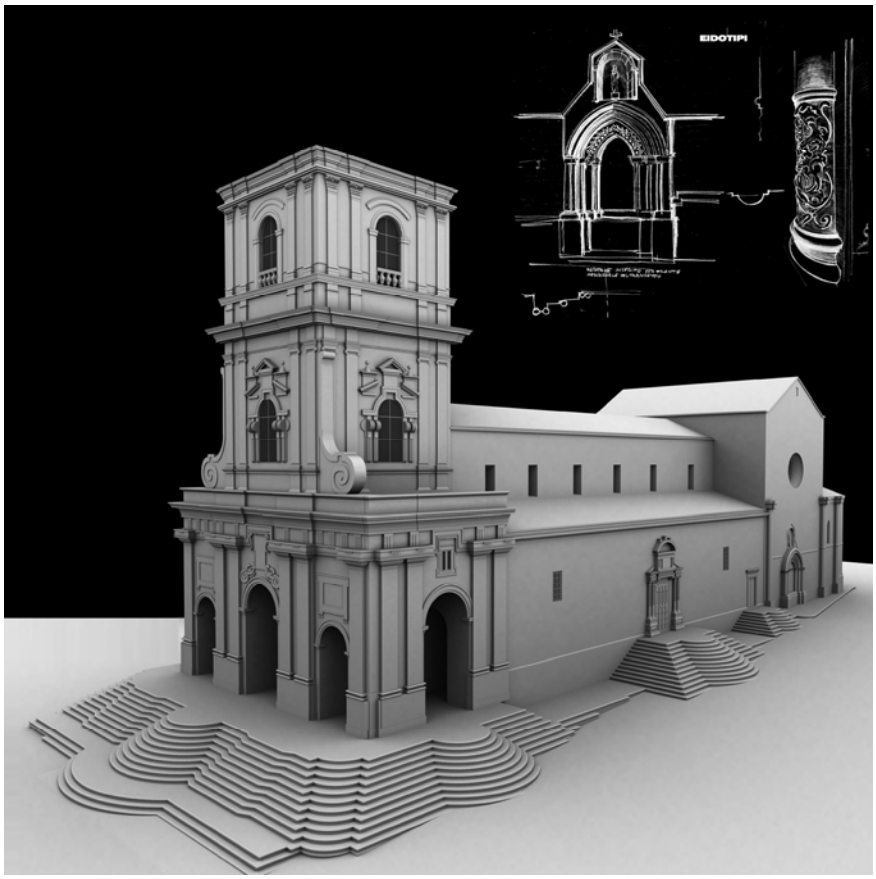

Figure 3: Rendering model of Enna's Cathedral.

4 Conclusion Remarks

The laser scanning technique and its experimentation in the fields of architecture and engineering, is undoubtedly in a process of ongoing developments and updates. Its use in the context of cultural heritage restoration is of great interest and certainly emblematic of the possibilities offered by such instruments, not only in terms of metric data acquisition, but also as concerns the representation and visualization of architectural objects and their contextualization in the territory.

The need to increasingly limit the time devoted to survey operations and other data acquisition activities of architectural objects (generally quite complex from formal and geometric point of view) maintaining, at the same time, a high considerable precision, quality and effectiveness in aesthetic representation needs, has been made necessary the use of such procedures to integrate and support traditional techniques. The data acquisition and processing must however to be carried out on the basis of appropriate methods taking into account the specificities of each survey object.

This work has been conceived on the basis of these criteria and aims at being an example in evaluating the effectiveness of the new survey approach offered by 3D laser scanners, still in a process of continuous experimentation. Despite the recent literature does not often refer to the scan registration without targets, the scientific research is developing new solutions for the scans alignment based on other techniques. The interest is paid back using different software reducing time and detection operations, by means of the acquisition speed of modern scanners that can make it faster – in the phase of data treatment - the deletion of unnecessary parts of the points cloud rather than operate a greater definition of "windows".

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