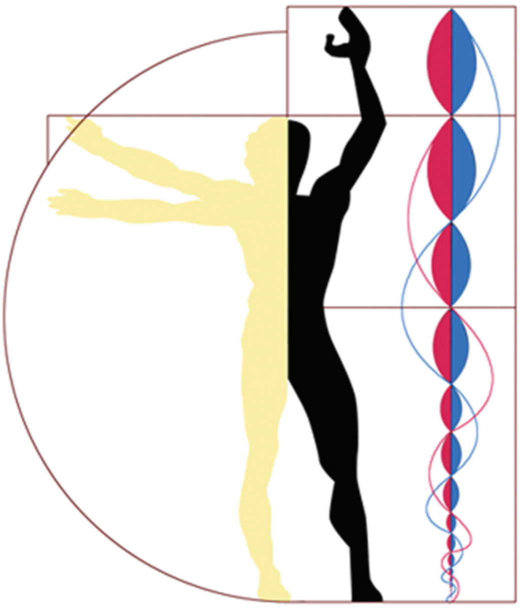
Fabbrica della Conoscenza

XIII Forum Internazionale di Studi

Le Vie dei Mercanti

Carmine Gambardella



HERITAGE and TECHNOLOGY

Mind Knowledge Experience

La Scuola di Pitagora editrice

Fabbrica della Conoscenza numero 56
Collana fondata e diretta da Carmine Gambardella

Fabbrica della Conoscenza
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Carmine Gambardella

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REGIONE CAMPANIA

Progetto CAMPUS Pompei

Il Progetto “Ecoturismo urbano per la fruizione sostenibile dei Beni Culturali in Campania”, in attuazione degli Obiettivi Operativi 2.1 e 2.2 del Programma Operativo FESR Campania 2007/2013 per la realizzazione e/o il potenziamento, nel territorio della regione, di forti concentrazioni di competenze scientifico tecnologiche, di alto potenziale innovativo, intende favorire la concentrazione di competenze scientifico-tecnologiche finalizzata a rafforzare la competitività dei sistemi locali e delle filiere produttive regionali non solo nei settori dei servizi associati al turismo e beni culturali ma anche in settori ad altissima tecnologia che possano rappresentare una svolta tecnologica e culturale all’approccio innovativo per lo Sviluppo sostenibile in aree ad altissima vocazione turistica.

Conference topics:

Heritage
Tangible and intangible dimensions
History
Culture
Collective Identity
Memory
Documentation
Management
Communication for Cultural Heritage
Architecture
Surveying
Representation
Modelling
Data Integration
Technology Platforms
Analysis
Diagnosis and Monitoring Techniques
Conservation
Restoration
Protection
Safety
Resilience
Transformation Projects
Technologies
Materials
Cultural landscapes
Territorial Surveying
Landscape Projects
Environmental Monitoring
Government of the Territory
Sustainable Development

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XIII Forum Internazionale di Studi

Aversa | Capri
11 - 12 - 13 June 2015

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Peer review

Scholars has been invited to submit researches on theoretical and methodological aspects related to Heritage and Technology, and show real applications and experiences carried out on this themes.
Based on blind peer review, abstracts has been accepted, conditionally accepted, or rejected.
Authors of accepted and conditionally accepted papers has been invited to submit full papers. These has been again peer-reviewed and selected for the oral session and publication, or only for the publication in the conference proceedings.

Conference report

357 abstracts received from:

Albania, Argentina, Australia, Benin, Brazil, Bulgaria, Canada, Croatia, Egypt, France, Greece, Iraq, Israel, Italy, Japan, Latvia, Malta, Mexico, Norway, Poland, Portugal, P.R. China, Russia, Slovakia, Spain, Turkey, United Kingdom, USA.

More than 500 authors involved.

291 papers published.

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Preface

The theme of the thirteenth Forum "Le Vie dei Mercanti" aims to investigate the complex relationship that develops between technological innovation, knowledge, enjoyment and protection of cultural heritage and the landscape. This leads to the need for an international multidisciplinary comparison in order to explore the questions and issues that are being debated not only in academia, but also among those who govern, manage and control Public Administrations, Institutions and businesses.
The subtitle specifies the macro areas: Mind, intended as both speculative thought as well as the preparation of a methodological process; the subject who investigates, establishes an inescapable destiny with the object analyzed at different scales of analysis, from the architectural structure and design, to the infrastructure and the landscape; Knowledge, as the historicizing of the state of the art reached by the disciplinary skills, integrated with those of material culture, humus generative of innovation for the formation of a human capital that continues to grow; Experience, the representation and sharing of results obtained with good practices, exemplary and paradigmatic, as patrimonial value for humanity to achieve a better quality of life and places created working with Art.
The conference is open to multidisciplinary experiences on one or more of the proposed themes. Scholars are invited to present research on either the theoretical and methodological aspects or concrete applications carried out on these issues.

Carmine Gambardella

HERITAGE and TECHNOLOGY
MIND KNOWLEDGE EXPERIENCE
XIII International Forum Le Vie dei Mercanti
Aversa, Capri 11-12-13 June 2015

Multisensor and multiscale surveying into Pompeii's archeological site. Three case studies.

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Abstract
Within the wider Campus Project, this study focuses on the definition of the geometric multiscale layer, essential for the planning of the multidimensional research activities on the Pompeii area and on archaeological site, particularly. The orography between the Vesuvius and the Castellammare Gulf, and the morphological complexity of the ancient and contemporary cities of Pompeii, guided the application of remote sensing multiple sensors (photo and LIDAR), from the satellite altitude to the architectural scale. From the larger study being developed, this paper focuses on the archaeological site and critically compares the technical and scientific different phases of the integrated digital survey applied to three case studies - the Amphitheater, the Villa of the Mysteries and the Tower of Mercury - which are emblematic for construction and excavation dating, for historical and artistic importance, for material composition, for architectural morphology.

Keywords: LIDAR, 3D Modelling, Amphitheater, Villa of the Mysteries, Tower of Mercury.

1. Introduction (Carmine Gambardella)

The "Campus" Project, in implementation of the 2.1 and 2.2 Operational Objectives of the "Programma Operativo FESR Campania 2007/2013", was to promote the concentration of scientific and technological skills in strategic fields through the synergistic interaction and integration between the Research and Industrial worlds. Within the Tourism and Cultural Heritage, this Project titled "Urban Ecotourism for the sustainable use of the Cultural Heritage in Campania" is aimed to the local systems' strengthening in own field and also in high-tech one, that could be a technological and cultural turning point to the innovative approach for the sustainable Development in high tourist vocation areas.
In particular, the Program's objectives are prosecuted through the multisectoral development of industrial and experimental research, although the scientific expertise involved in the Project appear to be interested only on the field of Cultural Heritage. The achievement of these objectives needs multidimensional expertise according to the complexity of the approach planned for this topic, while focusing on Cultural Heritage and Tourism. The knowledge and project activity in the territory of Pompeii was carried out in a metropolitan scale, through multicreteri@ analysis of type implementable and interchangeable. The technology platform that integrates data both for the aims of this study and to continue the research is a handy support to public decision-makers and private actors. The knowledge activities, in fact, require a humanistic, historical and managerial knowledge particular and specific, in addition to specific knowledge about processes/products with high technological content in this Project, in order to promote specific research programs.
To enhance virtuous practices in cultural heritage and tourism management in Campania Region, the program of activities proposed aims to develop three platforms integrated each other:
- Connected Urban Environment Heritage (CUEH): application of a handheld, as well as being an information tool for tourists, statistically analyzes the paths and calculations required by users becoming a tool for the improvement of infrastructure and information.
- Heritage-Link Environment Program (HELP): a model of recovery of traditions and environmental efficiency, we will collect and rationalize the information contained in the historical archives about the historical buildings of the city of Pompei. An innovative and technological system not only for maintenance, and

restoration of historic buildings but also for the definition of new criteria and procedures for the construction of "Heritage buildings", public buildings (museums, institutions, etc.), tourist reception and private ones (hotels, accommodation, parking areas etc.) with improved energy efficiency and reduced environmental impact.
- Multisensory Virtual Simulation (SiSMuV): a platform that will advance the project outline architectural structures and environments with less invasive in the area and greatest positive impact on the population.
The project involves the Research Center BENECON Scarl and industrial partners, enterprises in the cultural heritage and tourism fields, environmental monitoring, sensors and new materials. In particular, the study and experimentation area within the Project Campus affects the city of Pompeii, for significant interest from the point of view of tourism development and the impact of the same flow of tourists in the area. The Project has also extended the study area to the coastal strip between Vesuvius and Portici and Castellammare di Stabia, also providing for this test and the integrated use of different remote sensing technologies within the technology platform "Cloud Data and Monitoring Knowledge ".

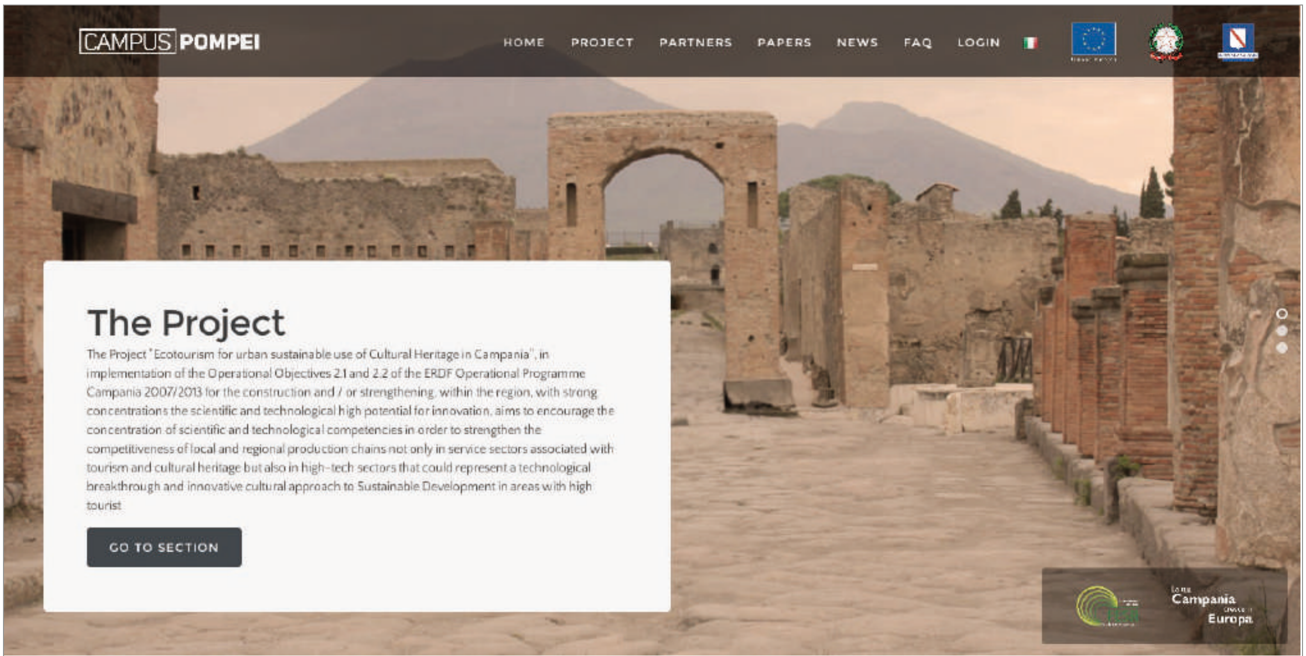

Fig. 1: Campus Pompei Project, web site homepage.

Within the wider "Campus" Project, this study focuses on the definition of the geometric multiscale layer, essential for the planning of the multidimensional research activities in the Pompeii area and in archaeological particularly.
Preliminary knowledge of the City and archaeological site is a fundamental premise in order to test the integrated use of the remote sensing survey techniques and tools and to develop a methodology that can be exported to other contexts. The method applied to the City of Pompeii aimed to the creation of the "Data Cloud and Monitoring Knowledge" technological platform that collects and integrates all the analysis and the data acquired and processed on the City, thanks to the use of airborne and terrestrial survey equipments.
In according to the scientific Protocol coordinating this research, the satellite acquisitions, the aerophotogrammetric scans, hyperspectral and thermal surveys, terrestrial and airborne LIDAR scans, as well as three-dimensional processing (meshing and rational) from the urban scale to the architectural detail were carried out on the territory of Pompeii. It is a multiscale methodological and technological approach, aimed at the processing of a discrete model with variable resolution, in close relation with the morphological complexity of the natural or anthropogenic objects. In particular, today the satellite survey return images with very high spatial resolution (one meter or less) in the ranges of the visible and near infrared; the LIDAR scanning by Leica ALS50II is necessary to develop the DEM (cm 25 ground resolution) for the ortho-projection of aerophotogrammetric, hyper-spectral and thermal images, subsequently acquirable. Given the importance of this data, in addition, the research team planned the LIDAR calibration flight on the same area, in order to manage a dual geometric check between the 3D laser scans - performed at different altitudes by standard procedures - and the Ground Control Point already put and measured. The LIDAR point cloud model was also used as geometric macro-mesh for the Mobile Mapping surveying; the aerophotogrammetric scanning by Leica ADS40 allowed the processing of the stereo-photogrammetric model of Pompei, particularly detailed thanks to the technological characteristics. The integration with DEM optimised the data ortho-rectification, and consequently the outcome 3D model allowed a precise and detailed characterisation

of the territory. Inside the archaeological area, especially, the LIDAR data texturing allowed to classify more carefully those parts where the ruins were covered with weeds and the geometrical data was automatically classified not well.

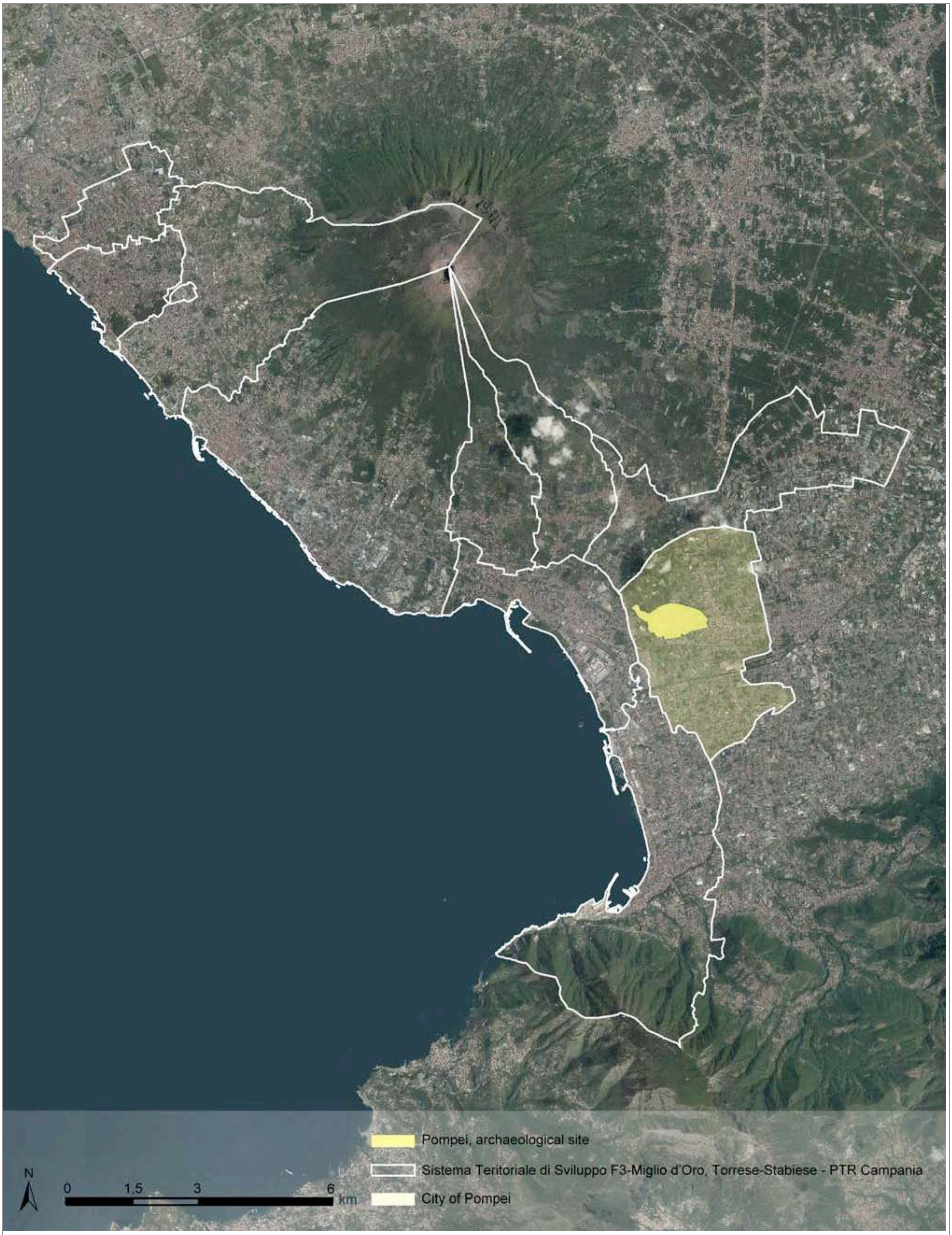

Fig. 2: Area of interest of Campus Pompei Project from Pompeii to Vesuvius coastline.

The theming in the visible and tangible characteristics of the city was completed with the invisible and intangible ones, possible thanks to the development of hyper-spectral and thermal imaging.

Fig. 3: Three case studies into Pompeii's boundary.

These scans were performed respectively by Itres CASI-1500 and TABI-320 sensors, installed on a military aircraft of the Italian Guardia di Finanza, under a collaboration agreement for remote sensing in Italian territory and abroad. In order to control the geometric quality of the data acquired by airborne and terrestrial platforms, the research team installed a permanent GNSS station (ETRF2000 φ:40°45'12.4156" λ:14°29'38.1878" h:79.206 m) connected to the regional geodetic network, in turn calculated by the national one of the Istituto Geografico Militare, at Florence. The multi-scale link between airborne and terrestrial surveys was carried out through the integrated processing of LIDAR and Mobile Mapping data. The point cloud model of the territory acquired from aerial platform with LIDAR sensor Leica ALS50II, texturised with infrared digital ortho-photos and RGB geo-referenced by Leica ADS40 digital aerial camera, has become the digital macrotexture for the point cloud model and digital images acquired by terrestrial 3D laser scanning static and dynamic.
Referring to the terrestrial investigation, the urban and architectural survey has interested the urban screens, situated along the streets that cross the square overlooked by the Sanctuary of Our Lady of the Holy Rosary, adjacent to the archaeological site. The buildings on both sides from 'Villa of the Mysteries' Street to 'Bartolo Longo' Square were also scanned by Mobile Mapping system that involved both the urban facades as well as the road.

Fig. 4: Pompeii data cloud and monitoring knowledge, conceptual framework and iconographic synthesis of the multiscale and multidimensional investigations.

The applications of 3D laser scanning survey, which integrated the acquired data by mobile mapping system, were carried out at the Hospice of the Daughters of the Sacred Heart, interesting building for rational architectural drawing and for the location in relation to the entrance to the excavations in the area of 'Amphitheatre. Inside the excavations, the Tower of Mercury, the Villa of the Mysteries and the amphitheater were the subject of integrated digital survey by applying 3D laser scanning sensors, GNSS topographic and close-range photogrammetric by drone.
The methodological variations developed by the authors for the integrated digital survey of the three case studies of the Amphitheatre, the Villa of the Mysteries and the Tower of Mercury highlight the importance of scientific Protocol.

2. A comparison among three digital surveying projects in the archaeological site of Pompeii (Pasquale Argenziano)

The integrated digital approach to the architectural remote sensing is becoming a standard practice as documented in the scientific literature, although it is usually confused with 3D laser scanning use. In fact in various fields, as customary or a trend, the 3D laser scanner is always used for the architectural surveying, or cultural heritage documentation, regardless of the reasons, the morphology, the scale, the materiality of the object. The morphological data capture through the 3D laser scanner is only one of the possible actions of the digital integrated approach: to realise a georeferenced topographical network, to which connect at least the position of the 2D target used for the scans orientation, is certainly an essential step of the surveying project's setting; to complete the scans' gaps (evaluable only at the end of the first processing) by the digital photogrammetric close-range technique, is an interesting and innovative integration, still being tested. In addition to the metrical and visible dimensions, the data capture that enrich the architectural diagnostic can range from spectrophotometric and thermal characterisation of surfaces to that sonic ones to check the structures and their materials.

The dimensional and morphological integration can instead continue changing the distance between sensor and object, according to a multi-scalar approach which is another paradigm featuring new technologies in architectural and terrestrial surveying. The practice of close-range photogrammetry by UAV adds to the LIDAR or aero-photogrammetric data capture - widely established and used: it is a promising technique in the lower middle economical segment which is still being developed and tested; and it is emerging in recent years, especially for the novelty of the aircraft rather than to the validity of the data acquirable. The comparison of three survey projects in the archaeological site of Pompeii is an opportunity for a fruitful discussion of critical approaches experienced - certainly no completeness presumption - trying to put the focus on the results and the progress on the issues addressed.

Established the expected outcome that is the realisation of a multi-scale digital model of each building from which deriving the geometric, structural, conservative and fruition characterisations, the planning the integrated digital survey was first characterised by three factors: the buildings' size, their plan-altitude articulation, the relevant environment.

The choice and knowledge of sensors, accessories, hardware and software integrated in the many activities on site and in the laboratory are added to the spatial aspects. The choice and knowledge of sensors, accessories, hardware and software integrated in the many activities on site and in the laboratory are added to the spatial aspects: the network topography is made with the Trimble VX S6 Total Station, which provides technologically high standards of precision; georeferencing of topographical landmarks is acquired by Trimble R5700 sensitive GPS constellation; the photogrammetric are made with Nikon D70 respectively calibrated to different software version tested in 'educational' as an opportunity for critical evaluation and comparison; the 3D laser scanner is the Faro CAM2 Focus 3D X330, which can be properly defined as a multi sensor platform multi-sensor integrating compass, inclinometer, a RGB photographic camera (70 Mpx) and laser sensor with a scan range variable between 0,6 and 330 meters, and a relative accuracy variable between 2 and 200 mm, depending on the scan settings.

Fig. 5: Pompeii, the Tower of Mercury seen from the town center.

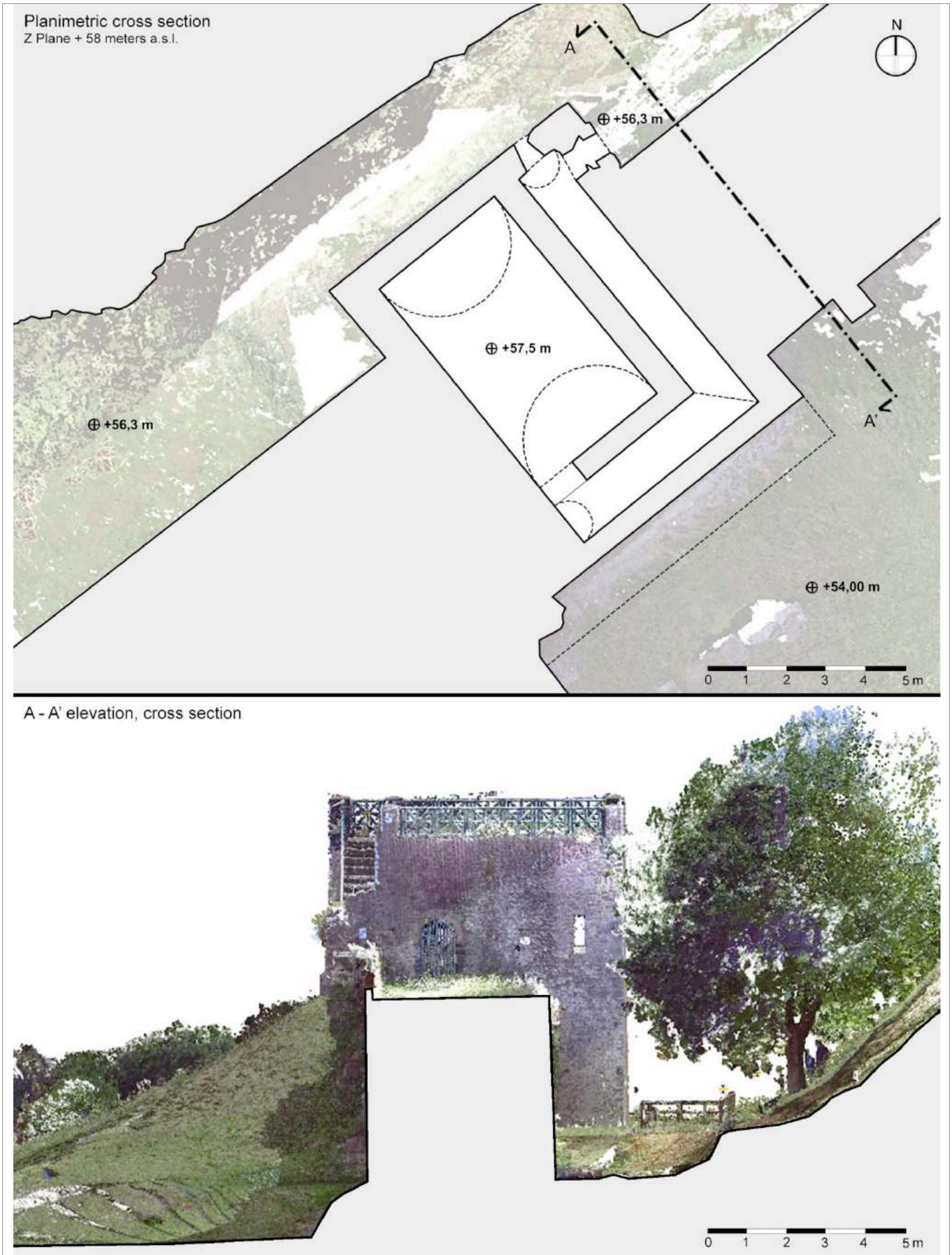

Fig. 6: Pompeii, Tower of Mercury. The 2d graphics of the tower were obtained through sections made on polygonal surface; redundant points were eliminated to check geometric inconsistencies that were in the mesh. The model has almost always gaps created by shadows. Four horizontal planes were drawn to realize plans at different altitude level. The sections had been useful to understands planimetric configuration of tower. The figure shows plan of 58 meter above sea level that is the ground floor. (Drawing by L. Abate, 2015).

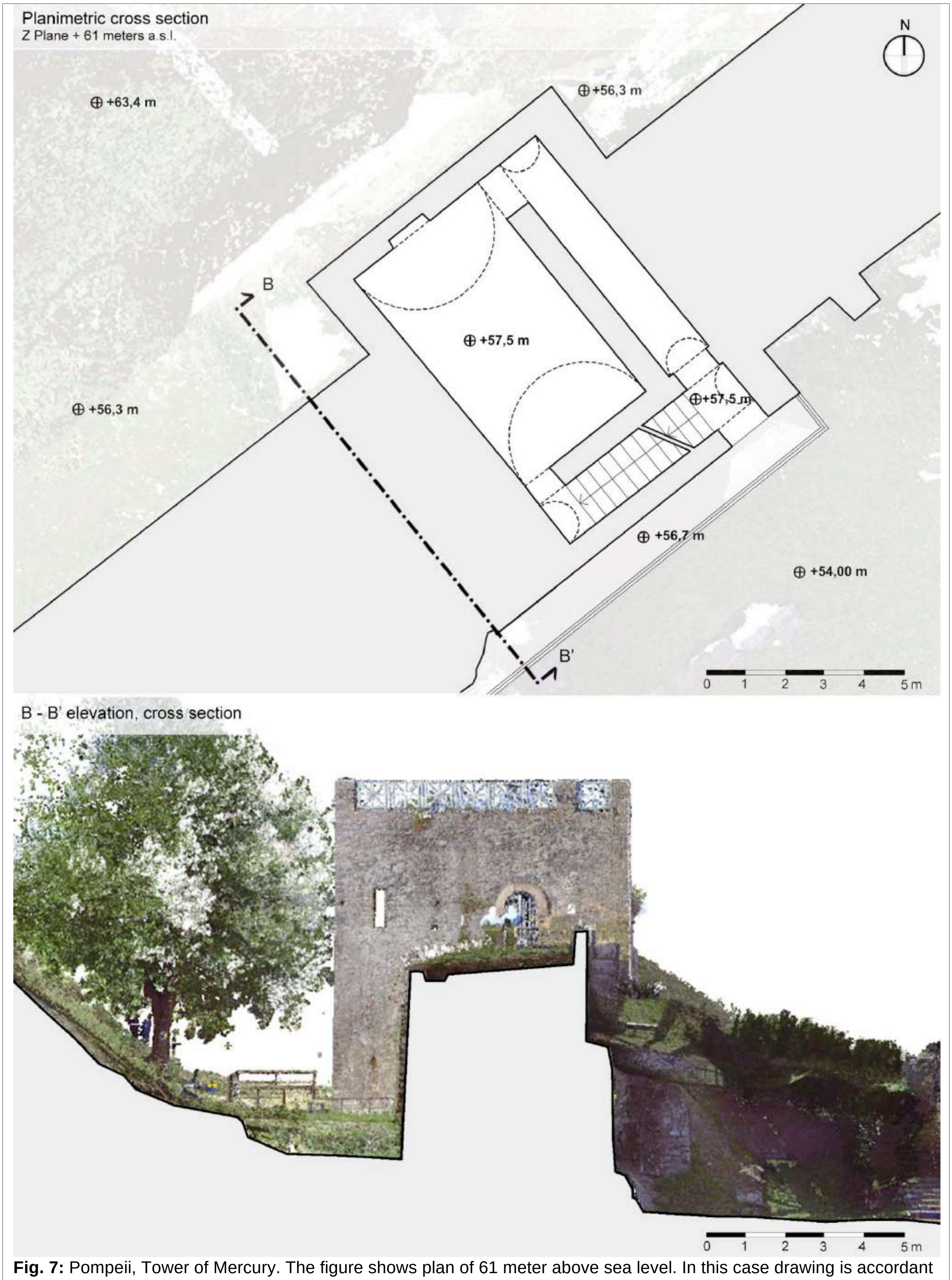

Fig. 7: Pompeii, Tower of Mercury. The figure shows plan of 61 meter above sea level. In this case drawing is accordant to UNI 936. (Drawing by V. Cirillo, 2016).

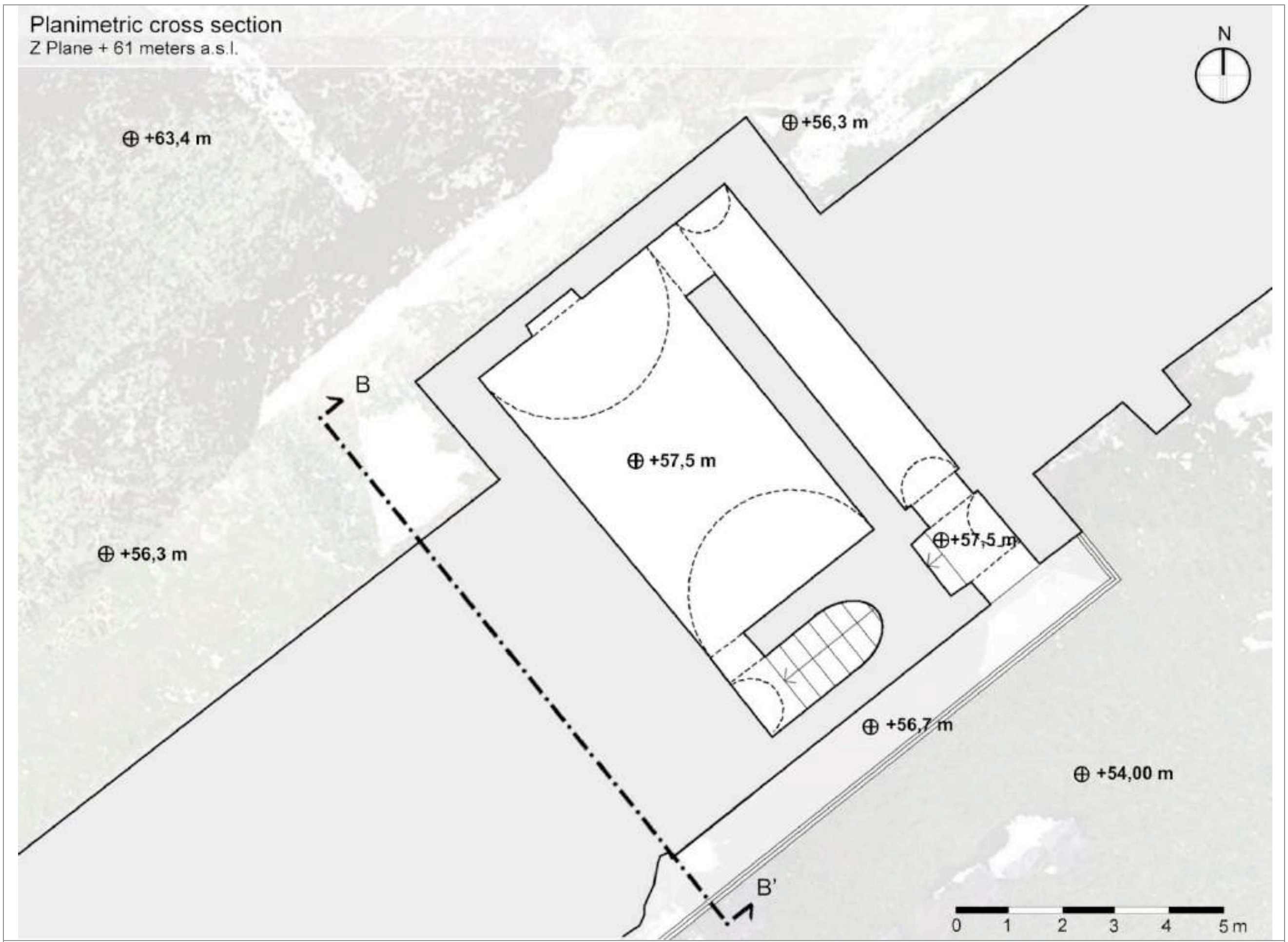

Fig. 8: Pompeii, Tower of Mercury. Some graphic signs are not visible in the orthogonal projection of the cloud like vault drawn with a dashed line. In all figures, we had to re-draw graphics according to UNI 936. In this case the work of re-drawn has concerned the representation of stairs. This is the result without the work of re-drawn. In 3D geometry the drawing is correct but it is understandable and don't respect the standards of the legislation. (Drawing by V. Cirillo, 2016).

The latter characteristics - reported by the manufacturer - have been tested and verified before the activities in the site, in order to optimise the acquisitions sequence in relation to the plan-altimetric buildings set up and consequently the spatial distribution of the 2D and 3D targets, chosen for the scan orientation.

The test results have shown that the accuracy of measurement decreases linearly with respect increasing distance between the sensor and the scanned surface, regardless of the resolution set to the sensor. This data concerning obviously affects the accuracy on semi-automatic recognition of the barycentre of the target (2D or 3D) into the dedicated software Faro Scene, with a quantitative difference between the same operation performed on point clouds processed with only the reflectance data or with the addition of RGB images taken with the built-in camera.

The choice of the resolution of each scanning will affect, also to the subsequent steps of alignment of the point cloud models or meshing ones. The enhancement of the hardware performance of the 3D laser scanner allows to capture millimetric point clouds (as in the cases under review) and generates, consequently, a 'bottleneck' in the performance of the hardware workstation processing and the intrinsic characteristics to proprietary software or third-party ones, which must be integrated throughout the processing chain.

So, a last factor to be considered during the survey planning is the relationship among the sensor resolution, the expected accuracy of the point clouds, the GB size of each raw files and model processing ones.

In contrast to the analogical or analytical approach (direct and instrumental), in which the drawing representation scale affected just the first measuring phase on site, the integrated digital approach shifts the choice of model representation scales to post-processing during the meshing or 'rational' models generation.

As described in the next paragraph, the density of the triangular mesh or the graphic detail of architectural vector profiles is directly related to the expected scaling of the 2D or 3D drawings, with further implications in the relationship among the graphic models' density, the hardware workstations' power and the algorithmic features of CAD modelling softwares.

The Tower of Mercury is a stocky parallelepiped (approximately 8 meters on each side by 13 meters high), placed in the city walls, from which exceeds in both sides, approximately 2 meters. Among the first urban elements brought to light, the building was restored in stages over the years, and today it looks altogether intact, with walls without plaster, and has no architectural elements or decorations.
Observed the morphological factors and evaluated the technological ones, the survey project was divided into two data capturing steps on site, performed by three researchers in two days.
The first step, focusing the building outside, provided a continuous sequence of scans, which starting from the outside area went around the building to the east leaping over the walls towards the the urban side, then coming into the tower through the gangway built on the facade in the last century. The second step, dedicated to the tower's interior, provided a continuous scans' sequence, which starting from the bottom room, followed the architectural path through the corridors and the stairways, up to the flat roof.
The relative alignment of the two scanning projects was assured by 31 2D target, also checked by 25 tie points, which were neatly arranged in the outer areas and inner spaces of the building, with a focus in the shared areas between the two projects' paths, identified the three significant portions of 'building (ground level, the wall pick and the floor covering).
The scan scheduling according to a sequential path is justified by the sensor's technological characteristics, and its operability in the alignment scans' software. Starting from the first scan, the sensor stores the data of the compass, the inclinometer, and the GPS receiver (outdoor) incorporated therein; these data are used synergistically with relative coordinates of the homologous targets, picked semi-automatically in several scans.
The point clouds' alignment is then calculated with respect to the sensor position when shooting 3D capturing, and the homologous targets' position. This processing feature therefore integrates the traditional topographic approach to the more recent 3D laser scanning technique, adding an upper check error level to the sensors feature.
The integration and mutual adjustments of the data from embedded sensors into the scanner, and the targets' coordinates, however, are able to control and mitigate the errors can be focused in the exclusive use of the first or second ones. The calculation of the model global position through the embedded GPS sensor, and the negligible error of the clouds alignment led to excluding the option to realise a georeferenced topographic network.
From the complete point cloud model, consisting of 515 million points, it was subsequently developed a mesh model from which were extracted the two-dimensional drawings, illustrating this paper.

The digital integrated surveying project of Villa of the Mysteries, as expected, was much more detailed and complex, and despite the detailed preliminary planning, it was in progress adapted to optimise the activities in relation to contingent problems.
The scanning resolutions and the expected accuracies were chosen in relation to the architectural peculiarities, and the historical and artistic decorations of every single room in the Villa, giving more importance to the realisation of the geometrical data-base rather than the optimisation of the 3D modelling process.
It was opted for the realisation of a discrete model with high accuracy, postponing the solution of the hardware/software management post-processing problems, to the filtering data stage. The organisation in 5 macro scanning projects was instead determined according to the wide planimetric extension and to the complex plan-setting of the 70 Villa's rooms. The global alignment of the projects was instead assured by the georeferenced topographic network, against which were calculated the xyz positions of several 2D targets for each macro-project.
The rooms' spatial setting and the decorations quality prevented the massive use of 2D targets, choosing instead spherical, although they can not be determined in relation to the topographic network, they ensure high speeding setting up in the scanning site, and then the optimisation during the scan alignment software process, in the laboratory.
In the complexity of the laser scanning activities, the use of 2D and 3D targets differs substantially: while 2D targets shall be bound to the scan scenario during the data capturing time, especially if several of them are to be determined respect to the topographic network, the spherical target can be gradually moved, when they go out from the optimum scanning radius, and may be so relocated in subsequent areas in the same scan scenario. According to this operating practice, it can scan buildings as complex as the Villa of the Mysteries with only six spherical target; a greater number of these, would only serve to further speed data capturing in site.
As tested in the previous case study, in each macro-scanning project it was followed an ordered scan sequence taking care to overlap the last scan on the first one, or to detect in the last scan position some targets saved in the first one. This in order to optimise the operations of scans compensation, integrating data of the embedded sensors with the global targets' coordinates.
The scans sequence from the generale floor of the Villa guaranteed the morphological data capturing of the intrados of the rooms. Therefore, the model would have been lacking the covers' extrados, although the

perimeter embankments to Villa had allowed scanning of emerging external positions. To complete the Villa's nadir morphology was finally planned the photogrammetric shooting from an UAV platform, whose data were bound to the complete point cloud model by the coordinates of some targets laid on horizontal surfaces, related to the topographical network.
The complete point cloud model of the Villa is composed of 7 billion points, 9 people are still working on its mesh model, after 12 days of activities on site (from July to September 2014). The two-dimensional drawings illustrating this paper are projected and optimised from the complete mesh model.

The Tower looks like a small and compact volume; the Villa is an ordered extension of rooms connected and distributed on one level; Amphitheatre, finally, is a large concave building, walkable along concentric paths, on three significant levels at least.
In years of experience by the team coordinated by prof. Carmine Gambardella, the Amphitheatre of Pompeii is the most complex challenge of digital integrated survey. The obvious issues relating to the size and the morphological characteristics of the building in addition to the restrictions imposed by the Soprintendenza of Pompeii: capturing instrumental data in six days and do not use adhesives targets to archaeological surfaces.
The solution was structured: to divide the building into homogeneous architectural sectors, corresponding to the same macro-scanning projects; to use two laser scanners Faro CAM2 and one total station, with a team of 12 surveyors, divided into homogeneous groups according to acquisition activities.
Following the capture mode already tried and tested, the team working with the Faro 330 sensor mostly worked in the open areas, leveraging the power of the laser beam propagation up at least 200 meters with good quality; the other team, working with the Faro CAM2 Focus 3D X130 sensor, worked in the lower underground level and the ima cavea sector. The open areas of the ima cavea were selected to overlap the point cloud models captured along six days, with two Faro sensors.
Not being able to use fixed targets in the Amphitheatre scenario, they were used 30 spherical targets, positioned on cylindrical or prismatic bases to better lay them to horizontal surfaces. Assessed the overall size of the Amphitheater, the technological characteristics of the two Faro sensors, the various accuracies reached by them, it was tested spherical targets of 3 different sizes (respectively 14, 25 and 50 cm in diameter) in order to optimise the semi-automatic targets detecting by the software even at great distances from the sensor.
Following the same principle of spatial dislocation, already experienced in the Villa of the Mysteries, the spheres were placed in about 300 positions to guide each other 275 scans. In order to solve the inability to measure the coordinates of the spherical targets' center, it was materialised a topographic network georeferenced with respect to which were measured the coordinates xyz of a large number of target areas in 2D placed underground, at the Bourbon substructures. The UAV photogrammetric sensor, just used in the Villa of the Mysteries, finally solved the shadow cones of the scans in the coverage areas of the Amphitheatre's apical ring.

Fig. 9: Pompeii, the Tower of Mercury seen from the upper side of the city wall.

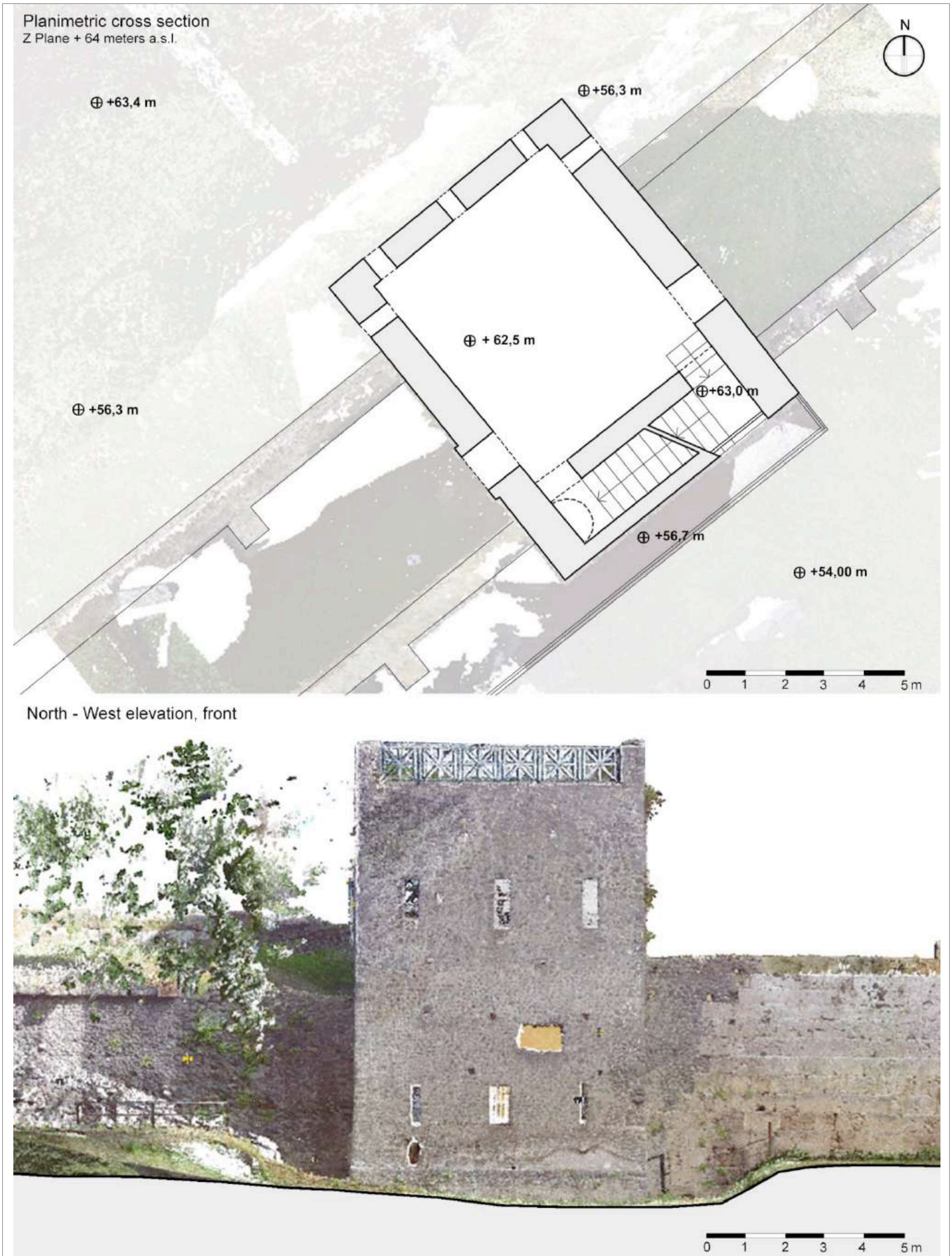

Fig. 10: Pompeii, Tower of Mercury. The figure shows the planimetric cross section at 61 m above sea level. Also in this case we had to draw the correct orthogonal projection of the architectural building. The most important element are the stairs. The result is accordant to UNI 936. (Drawing by L. Abate, 2015).

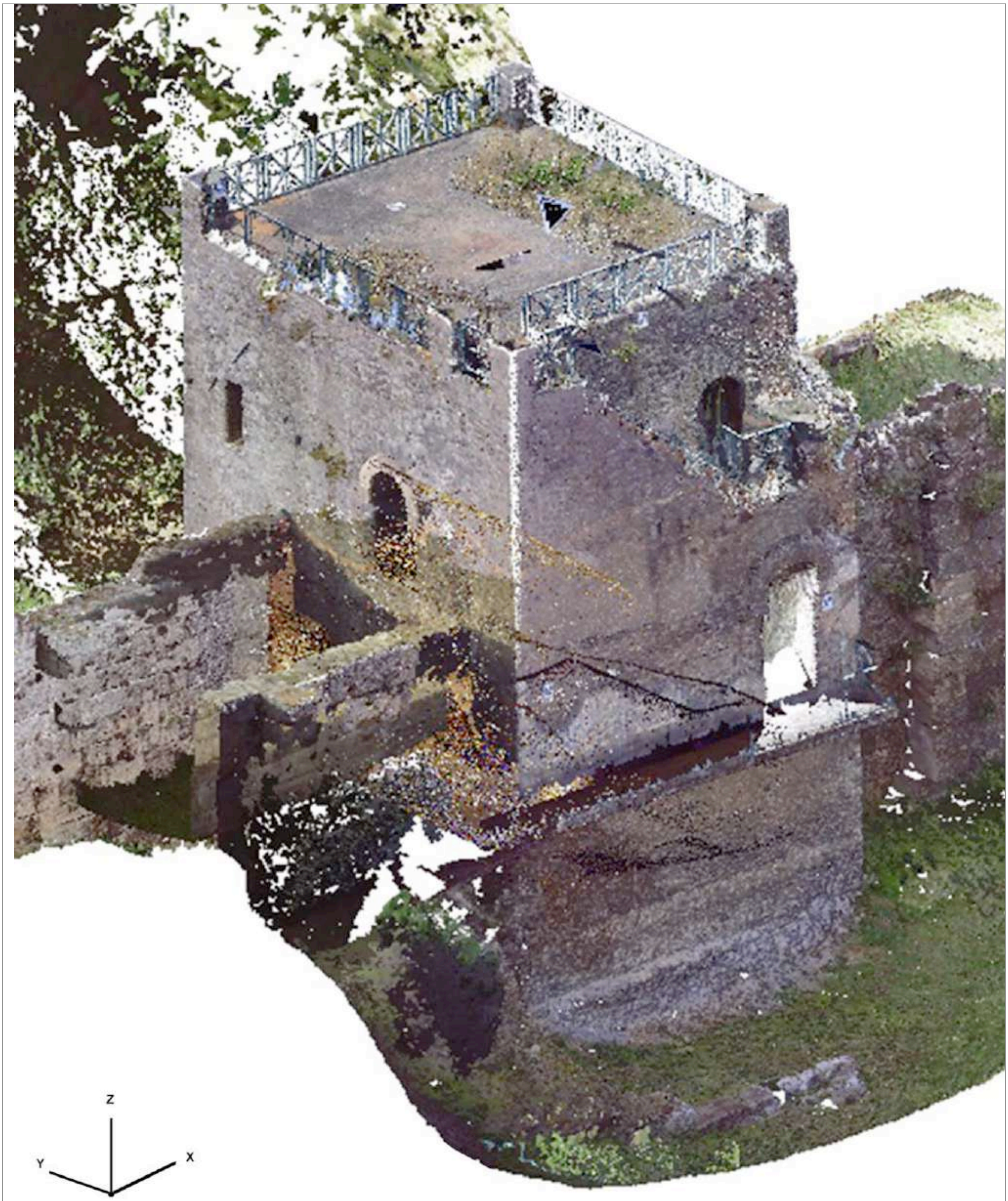

Fig. 11: Pompeii, Tower of Mercury. A detail of axonometric cross section. (Drawing by V. Cirillo, 2015).

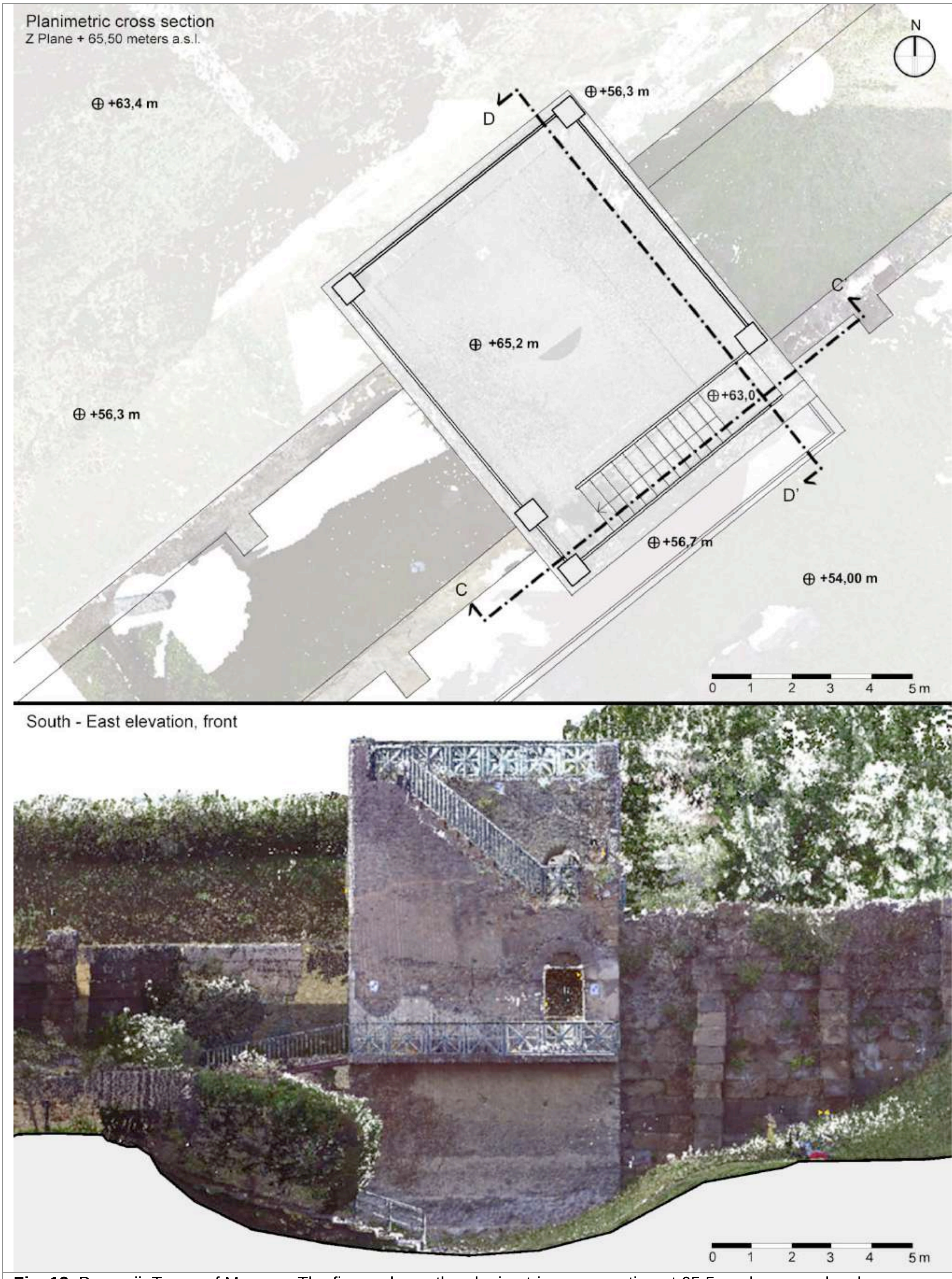

Fig. 12: Pompeii, Tower of Mercury. The figure shows the planimetric cross section at 65,5 m above sea level.
Metal element reflect the laser beam so produce noise in the representation of tower. We had to clean the cloud points and re-draw the plan accordant to UNI 936. (Drawing by R. Parente, 2015).

Fig. 13: Pompeii, Tower of Mercury. The cross section of this figure are useful to understand the vertical structure of tower. The section planes were drawn along the scale in two different direction. Also in this case the drawing has been standardized in accordance to the UNI 936. (Drawing by R. Parente, 2015).

Fig. 14: Pompeii, Tower of Mercury. This figurers show two axonometries view that are unequivocal in the communication of the architecture. Through an isometric cross-section it is possible to understand the depth of the architecture. (Drawing by L. Abate, 2015).

At the time of this paper, the scans' alignment processing is still in progress. The problems highlighted concern the simultaneous management of an high amount of data, such as to distress the workstations specifically assembled for this point clouds processing. The mesh processing being planned is aimed at the best compromise between 'rational' modelling of the architectural elements, and the meshing of the green and dirt areas, inside and outside. These issues are discussed in the subsequent contributions.

3. The architectural mesh modelling. Critical insights about three case studies in the archaeological site of Pompeii (Alessandra Avella)

In application to Architecture and in particular to the architectures surveyed in the archaeological site of Pompeii, these notes focus on theoretical and practical implications of the process of interpretation of data acquired with laser scanning technology for three-dimensional modeling. The morphological discretization of the 'point cloud' model in mesh or 'rational' surfaces is critical operation specific to the Drawing of Architecture.

The integrated digital survey performed on the three case studies of the Amphitheater, the Villa of the Mysteries and the Tower of Mercury, is part of a wider research being developed on the Pompeii area, with a focus on the archaeological site. This research has involved synergistically different scientific and technological competencies within the “Campus” Project.

This study presents a double opportunity: in general, to validate the multiscale technological and methodological approach in according to the Scientific Protocol coordinating this research, already tested with positive results in technical and investigative activities carried out by these authors on comparable case studies; to think about the different methodological interpretations of the three-dimensional modeling of Architecture and Cultural Heritage between discrete and continuous, shifting the focus from the urban scale to the architectural detail.

The integrated approach to geometric measurement of the architectures, subject of these notes, is part of the research field of the Geomatics applied to the study of the Cultural Heritage. In this regard it should be noted that until a few years ago the survey was carried out with the systems used in the two previous centuries. From the debate of the 80s on the direct or indirect survey of the monuments, which welcomed with great suspicion the photogrammetric technique dedicated to this aim, we are witnessing today a real invasion of technological innovation in the field of the archeology and the Cultural Heritage in general.

New digital surveying technologies based on measurement for the three-dimensional modeling applied in the archaeological field allow the representation of complex objects and places, such as archaeological sites and the buildings that characterize them through a digital model; this combines the visual capabilities of the images, usually employed for the documentation, and the precision of the survey: the three-dimensional model of any architecture of historic and artistic interest so developed is both a support for the 3D visualization of architectural heritage, and for the its metric evaluation through the geometric data-base. Current geomatic technologies, therefore, provide interesting instruments of survey: when used appropriately they open new possibilities of knowledge and documentation of cultural heritage, and guide the fruition, cataloguing and valorisation of this preciousness heritage.

A confirmation of the documentary value of multiscale models, especially in relation to cultural heritage, this study describes the methods and techniques adopted to create 3D models for the representation of the architecture that were selected appropriately in the archaeological site of Pompeii. The archaeological site of Pompeii and the architecture within it are, at the same time, a witness of great historical and archaeological value and an ideal opportunity to explore the integration of advanced survey by indirect methods. The extension of the archaeological site, its long cultural sequence, together with the multitude and variety of architectural and archaeological objects make Pompeii an extraordinary and unique complex to be investigated with rigorous methods. The survey of an archaeological heritage, in fact, makes it necessary to intervene with an instrument and a methodology which do not affect the state of its conservation while allowing the documentation of the status quo before the execution of any restoration: frequently the digital survey guarantees the virtual preservation of all that remains of the past as the only evidence of the cultural heritage, sometimes 'crystallising' in the date of the acquisitions what no longer exists or has been transformed at the end of human intervention or natural calamities.

The Amphitheater, the Villa of the Mysteries and the Tower of Mercury - which are emblematic for construction and excavation dating, for historical and artistic importance, for material composition, for architectural morphology in the wide typological repertoire of Pompeii - have been subjected to the integrated digital survey aimed at the geometric and morphological characterization of each architecture. As fully described in the previous section, the digital survey integrates four different acquisitions: 3D laser scanning, GPS and traditional topographic survey, high-resolution photographic mapping, digital photogrammetry techniques. The laser technology digitally acquired three architectures as 3D point clouds; to complement the data acquired by the GNSS sensor integrated in the same laser scanner, a topographic network of each survey was planned and carried out with total station and GPS system and the relative/absolute orientation of different 3D scans and the georeferencing in the IGMGPS95 national geodetic system was performed; the shady areas were integrated with photogrammetric techniques where it was not possible to access them with the laser; the terrestrial surveys was integrated with close-range photogrammetry by drone in the high and inaccessible areas of the buildings, as the roofs. The product of the acquisitions is a point cloud model in real scale of the actual and continuous object coloured with RGB values of images taken by high-resolution digital camera integrated in 3D laser sensor. This digital geometric representation of the object is discrete and tending to continuous: the higher the resolution set to acquire the more is dense the point cloud and then the detail of the representation. Having the morphology of an object through scanning laser, orientation and mapping of point clouds does not mean having finished its survey: the acquisition phase must necessarily follow the critical processing of numerous three-dimensional data acquired; this must be controlled according to the Drawing of Architecture practices.

Fig. 15: Pompeii, Villa of the Mysteries. The figure shows the merge of 265 scans made for the survey of Villa of the Mysteries. The 2d graphics were obtained through sections made on polygonal surface (mesh); redundant points were eliminated to check geometric inconsistencies that were in the mesh. The model has almost always gaps created by shadows. In particular you can notice shadow cones represented by white circles in the figure, they are the position of the laser scanner in different phase of scanning. The figure is useful only for a visualization of Villa of the Mysteries, it is not a drawing accordance to UNI 936. (Drawing by R. Parente, 2015).

As it is common knowledge to our scientific community, the problem of Representation of Architecture is no longer about acquisition phase, that is automatic through laser technology, but rather about processing and

then of 'rational' modeling through the selection of the set of software most appropriate among those made available by the most recent technologies. The orthogonal representations (plan, elevation, axonometric) of the surveyed object, obtained by central projection and parallel projection of the 3D point cloud model, can not be counted among the 'traditional' drawings in the Drawing of Architecture, but rather considered the visualizations characterized by an effective synthesis of dimensional and quality data, completely comparable to orthophoto regarding the metric reliability. In this regard, it should be noted that the orthophotos processed by the point cloud model and integrated with colorimetric dimension through photographic images were affected inevitably by the character of discontinuity that is specific to point cloud model. This discontinuity in orthorectification phase of the photographic images involves the loss of the colorimetric information in correspondence to the lack of points in the discrete model, specifically in the so-called shadow areas. Differently, the orthophotos processed by the corresponding mesh model do not have these limits thanks to the very nature of the continuity of this model; this continuity makes it more adapted to orthorectification of photographic images.
The representation of the conventional 2D and 3D models of the Drawing of Architecture requires, in the more advanced approach of the three-dimensional scanning as in the traditional survey, the critical processing of the considerable amount of three-dimensional data acquired indiscriminately while scanning laser through the geometric discretization (meshing and rational) of the point cloud model: the continuous geometric or mathematical model is processed from the three-dimensional discrete model to extract the 2D and 3D graphics of the real object specific to the Drawing of Architecture.
Digital modeling can be done through two different geometric operations: the meshing and geometric discretization that allow, with different modalities, to interpolate the points of the point cloud model directly into 3D space in order to convert them into geometric elements of higher level: mainly surfaces and solids.
By the meshing of the raw point cloud, a digital model is constructed through the semi-automatic extraction of a surface model with triangular mesh, which is the result of the interpolation of the points of the point cloud model. The distribution of the triangles, conditioned by the step taken in the scanning process, is almost homogeneous. Therefore a plane surface is described with the same density of triangles of a complex surface; this generates a surface model that overly detailed surfaces that have simple geometry, and at the same inappropriate for description of complex surfaces.
By the geometrical discretization, the point cloud model is sectioned along parallel planes to the tern of Cartesian planes associated with the point cloud itself. The discretization of the points cloud through significant plans allows the identification and the determination of the generative geometries of the architecture. The 'rational' discretization obviously involves a slight loss of definition, because it could easily be argued that the surfaces of a manufactured does not correspond exactly to the corresponding geometric surface; this type of objection can of course extend to the physical reality, because we know that notions of plan or straight are abstractions and simplifications that we use to interpret and represent the built.
Based on the experiences published in the literature, it should be noted that in terrestrial laser scanning applications have not yet established rules that can uniquely lead the construction of a geometric model to extract the traditional representations of the object of the survey.
According to these considerations and in application to the three architectures subject of these notes, the author describes some critical reflections that emerged during construction of 3D geometric models emphasizing the need to consider from time to time the operation of geometric modeling to be applied with regard to the particular case studies and to the different complexities of each.
Based on the experience, consolidated in similar applications or being developed in the case of this study, the author sets some guidelines that may be useful to the identification of a protocol for the geometric modeling. The selection of most appropriate methods of modeling is addressed by the following parameters principally: the specificity of the architectural object subjected to the survey, the nominal scale of representation and the aim of the survey.
The specificity of the architectural object is a function of the morphological articulation, of the dating of construction and excavation, of the stratigraphical and material composition, as well as the presence of conservation and restoration, with special attention to their date and type.
The nominal scale of representation influences the simplifications to be carried out on the discrete model through the selection and the activation of the geometric information specific to different nominal scales in order to represent the architecture with different levels of detail.
The aim of the survey is an interesting parameter particularly urging us to reflect upon the selective extraction of data from three-dimensional discrete data-base in relation to the processing of a three-dimensional model aimed to geometric representation of the Architecture as the main instrument of analysis or aimed to its photorealistic visualization.
In the first case the mesh model, obtained by successive approximations of the geometric discrete model, is produced in relation to the different analysis that various experts and professionals can perform on the original architecture. The geometric approximation, therefore, is constantly monitored and evaluated according to: the specific requirements of each operator (architect, archaeologist, engineer, restorer, historical); the software parameters of exchanging data specific to each type of investigation, the observance

of the most common techniques of architectural representation and geometric modeling that are more fit for the specific sector of architectural diagnosis.

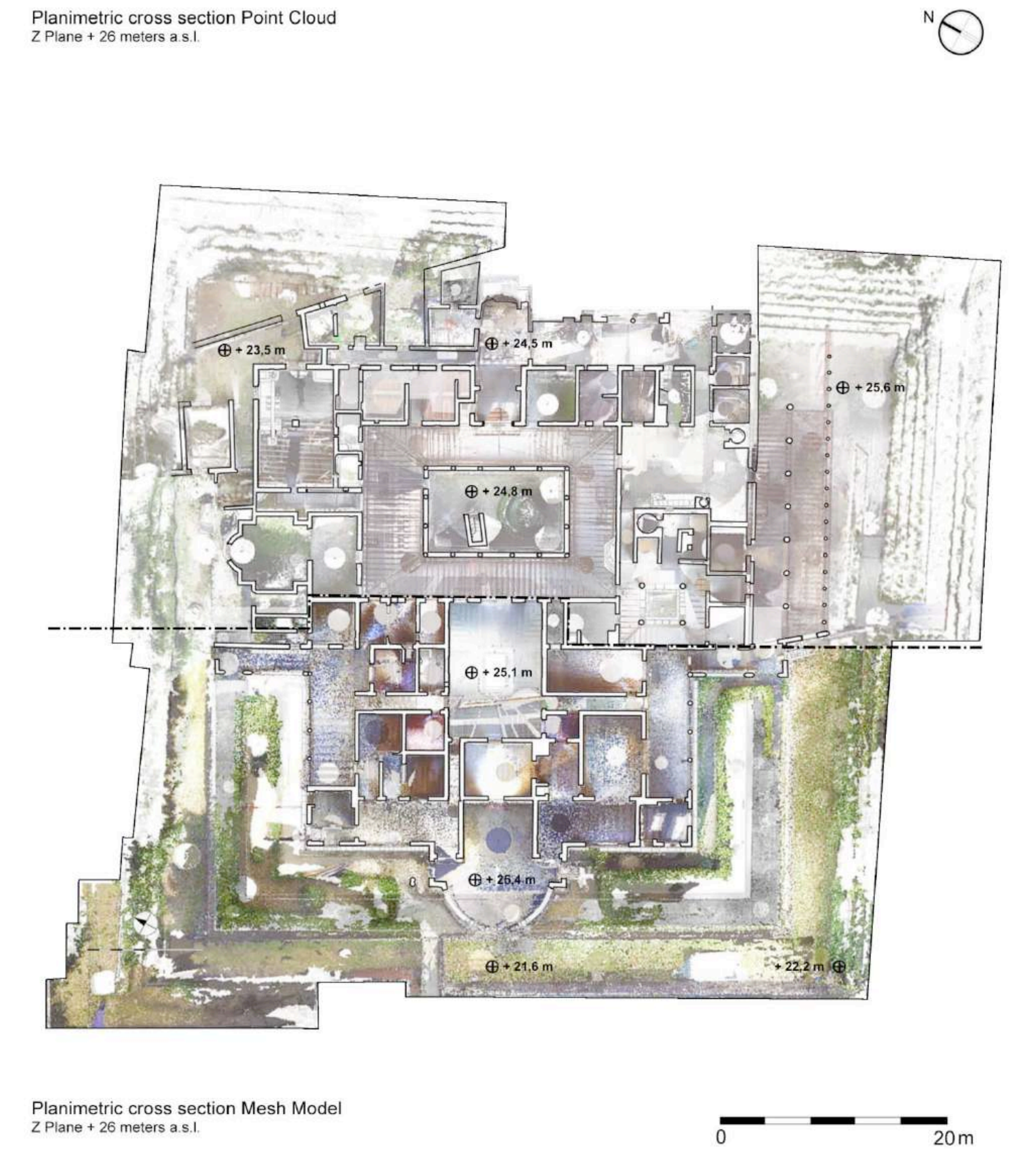

Fig. 16: Pompeii, Villa of the Mysteries. In the figure there is the planimetric cross section and Mesh Model. This plan has been obtained by the discretization of the polygon mesh of Villa of the Mysteries. Some graphic signs are not visible in the orthogonal projection of the cloud like thickness of wall. In all figure, we had to re-draw graphics according to UNI 936. In this case the work of re-drawn has concerned the representation of wall. It is necessary to make understandable the drawing. (Drawing by V. Cirillo, 2015).

It is known that the most widespread processing software used in fields of research different from that of the survey, are unable to organize large quantity of data produced in 3D modeling phase; frequently this limit is exceeded with the adaptation to the potential of the software recipient of the 3D model; in some cases limit the phase of geometric modeling of 3D data is deleted and replaced with the simplification of the point cloud

model to the detriment of geometric three-dimensional information acquired. Therefore, the discretization and the simplification of the data acquired must be carried out carefully, in a continuous return not only to the Manuals of the Treaties of Architecture but also to information that we intend to give to allow the different specialized studies, through the interpretation of the raw data.
In the second case, however, the three-dimensional models mapped with high-resolution photorealistic images, have an even stronger link with the computer graphics for the virtual visualization of architecture. This latter, aimed to facilitate the perception pseudo three-dimensional of a site or historical-archaeological resource through the two-dimensionality of a monitor, desktop or handheld, does not require the accurate metric correspondence between physical object and numerical model in the process of geometric modeling. This simplification process of the 3D model should be into crisis if the simplified model was enjoyed through augmented reality devices. By using of these devices the complexity of the real, in turn, putting into crisis also the not simplified mesh model.
According to these guidelines, the 3D model mapped with photorealistic textures and/or with those produced as a result of specific analysis is the result of the right balance all of these factors; it is to support specific analysis that can be performed; it is the result of the optimization of the whole process of survey (acquisition/modeling/representation/visualization) from input to output in relation to the aim of the survey.
Disregarding in this study the modeling topic aimed at photorealistic visualization of the Architecture, although this topic is interesting in the field of Cultural Heritage, we describe the first geometric-spatial analysis performed on the Amphitheater, the Villa of the Mysteries and the Tower of Mercury for the construction of three-dimensional geometric models. It is necessary to emphasize that these geometric-space analysis needed to a continuous return to classical texts to inspect the materials and manufacturing techniques that are specific of the Roman Architecture; these techniques are almost all detectable in buildings of Pompeii. This is true if considering that the unique system of historical and archaeological heritages make Pompeii a privileged observatory of the Roman Architecture. The tragic eruption of Vesuvius, in fact, suddenly interrupting the daily life of the city of Pompeii, has left houses, furniture, everyday objects almost unchanged. These materials, which are signs of inestimable value, show how they built and lived in a provincial town that is an extraordinary insight of truth, while not presenting specific characteristics. In general, in each architecture, the architectural surfaces by the clear geometric connotation were distinct by constructive and/or decorative elements for which prevails the plasticity of forms. The first one were processed with a geometric reduction of the surfaces through a process of 'rational' discretization of the point cloud: each flat surface, spherical or cylindrical has been assimilated to a single geometric element that best approximates the corresponding portion of the point cloud. The geometric modeling through ‘rational’ discretization was brought within the scheme 'object - geometrical model'; the second one, however, was modeled starting directly from the set of 3D acquired data through the meshing of the raw point cloud. The mesh 3D model, that is obtained by interpolation of the points of the point cloud model, is 'like' the scanned object and, like this, it has an irrational geometry. Where the density of triangles (conditioned by the step taken in the process of scanning) is inadequate to describe in detail the complex surfaces with a plastic development of the forms, a various processing of fragmentation and densification of the triangles was performed through the use of appropriate software tools. In particular, the operations of densification performed in proximity of the variations of inflection of architectural surfaces allow optimizing the density of the triangles. In this way the triangles are more developed and sparse on large surfaces, while considerably increase in number and density in proximity of the edges in order to accommodate the morphology. The result is the topological configuration that best approximates the real surface of the surveyed object.
From the general to the particular in the Villa of the Mysteries the results of critical evaluations that were conducted on the procedures of geometric modeling has highlighted the need to differentiate the original roman architecture and the contemporary restoration. For the restoration works, in fact, prevalently in reinforced concrete dating back to World War II, it was decided to perform the ‘rational’ discretization of the raw point cloud model, obtaining the 'geometrical model', then a 'scale model' and finally its 'representation'. Differently, the modeling of structural elements and/or decorative (wall and floor coverings) specific to Roman architecture was performed after recognizing the techniques and building materials. Some examples can better illustrate this point. The preliminary acknowledgment of modular architectural elements allowed to apply, during the processing step, the constructive rule of each element through the development of the profiles-section, reducing the complexity of the model in relation to the number of data required for its representation without substantial losses of 3D information. Just think: the columns made of campanian tuff; the roof with shingles (*tegulae*) made of terracotta and tiles (*embrices*) that have simple and recognizable structures because they are made according to the norms dictated by Vitruvius; the canals in stone in ‘peristyle’ to collect rain water; the arches and vaults. The Romans attained construction technique of arches and vaults with high level both in form and materials. As part of vast selection of Pompeii, this technique is still recognizable within the entrance arch of the northern *vomitorium* of the Amphitheatre. These examples do not want to be exhaustive, but only illustrative of the interesting and complex repertoire of architectural elements that can be modeled geometrically according to 'rational' discretization for the structural characteristics and/or materials.

Fig. 17: Villa of the Mysteries. The figure Pompeii, show front section and cross section. In this case the work of re-drawn has concerned the rapresentation of wall. It is necessary to make understandable the drawing. (Drawing by L. Abate, 2015).

Fig. 18: Pompeii, Villa of the Mysteries. The figure shows two different cross section. The section on the mesh show only the intrados of Villa of the Mysteries. We have to integrate this representation with data of APR survey.
This photogrammetric data will allow to drawn the configuration of Villa of the Mysteries. (Drawing by R. Parente, 2015).

Fig. 19: Pompeii, Villa of the Mysteries. This figure shows axonometries view that is unequivocal in the communication of the architecture. Through an isometric cros-sectiion it is possible to understand the depth of the architecture. (Drawing by R. Parente, 2015).

The systematic application of this approach has allowed the progress of the construction and management of the 3D model of each survey, still being worked out.
As a comment to the images accompanying this paper and as support for methodological decisions largely motivated describes the conditions that oriented the geometric modeling of the Room of the great Dionysian painting which, unearthed in 1910, it is named 'Villa of the Mysteries'. In this Room, the roof built in a recent restoration was modeled by ‘rational’ profiling; the vertical elements, namely the walls decorated with frescoes, open to two possible modeling mode according to the type of three-dimensional representation to be obtained: if the photorealistic 3D model must represent the stratigraphic composition of the wall that has been frescoed with techniques of Roman wall painting, highlighting the different levels of preparation of the wall surface in correspondence of the detachment, then you run the meshing of architectural surfaces through operations of parcellation and of densification of the triangles at the edges in order to observe the morphology. The mesh modeling can be integrated in 3D space with the data of the characterizations specific to the structural diagnostic of the architecture, which always belong to the field of instrumental actions of integrated digital survey conducted by our research team.
If, however, the construction of three-dimensional model is aimed prevalently at the 3D representation for the virtual visualization and documentation of the Dionysian Painting, then it is possible to represent a photorealistic model of the Room through the creation of mesh with rational discretization of the numerical model and the mapping of the flat surfaces with photographic images acquired during the scan.
It is known to the scientific community that the images taken by cameras integrated into laser sensors have a resolution far lower than of digital photos taken from the latest measurement instruments. Reference is made to the Trimble V10 sensor, for example, that have a panoramic camera that can acquire panoramic images quickly and with a high level of detail thanks to 12 cameras with 12 calibrated sensors from which the 3D metric information can be extract through the use of specific software. The option of integrating the Trimble V10 sensor with a GPS system allows georeferencing metric and chromatic data scanned. This acquisition process was tested in the Room of the Mysteries and the verification of the results is still in progress.
In the case of the Tower XI, more usually known as the Tower of the Street of Mercury, geometric modeling depends primarily on its material composition. The Tower, located between Herculaneum Gate and Vesuvius Gate at the end of the Street of Mercury in Regio VI, is in ‘*opus incertum*’ with small stones of lava and tuff linked with mortar and covered with plaster. Its construction dates back to the last phase of construction of the fortifications of Pompeii in the first century BC. These fortifications were reinforced with strong towers placed into the thickness of the double curtain of the fortification wall. Tower XI, that protrudes slightly on the outside and inside fortification wall to be astride the parapet and to dominate with the third floor the parts of the wall between the towers, has a quadrangular structure (9,50 m x 7,60 m), as required by military technique, with two vaulted superimposed, connected by an interior staircase and surmounted by a terrace equipped with battlements, now destroyed. The meshing of the Tower produced a mesh model with irrational although continuous geometry that best approximates the irrational morphology of the inner and outer surfaces made entirely of stone. If the three-dimensional representation of the Tower should be supportive to specialized analysis, it will prefer the geometric operations that are more appropriate in relation to the type of investigation.
The processing still in progress of the 3D geometric model of the Roman Amphitheatre is more complex, although it is one of the best-preserved amphitheatres. The large dimensions of the Architecture, the vast selection of materials and construction techniques of Roman Architecture present therein, a particularly complex and interesting plant morphologically, spatially and typologically, make it an emblematic case study to explore and testing the measurement techniques through laser scanning technology.
The laser scanner data were the starting point to deal the complex problem of identifying the geometrical drawing underlying of the architectural form of the Amphitheater; difficulties that required a careful geometric study, for which reference is made to the next paragraph. From the laser scanner data we have processed the mesh model, elaborated in part by rational profiling and in part by the meshing of the point cloud. The integration of the terrestrial surveys with airborne surveys by LIDAR sensor (Leica ALS) and photogrammetric camera (ADS40 sensor) and with close-range photogrammetry by drone, was useful for modeling and the representation of the ground (arena), of the roofs and of the extended horizontal surfaces.
In according to the operational procedures described herein, the construction in comparison of geometric models of the Roman Amphitheatre, the Villa of the Mysteries and the Tower of Mercury allowed: to examine the construction techniques specific to the Roman architecture; to tackle some of the most common problems related to its representation; in the end, to collect a records of mesh or rational modeling of the architecture enough exhaustive through the analysis of three case studies emblematic.
The geometric models, still being processed, represent every single architecture with a level of detail consistent with the aims of the survey, guaranteeing in each case the geometric, constructive and formal congruence of each 3D model with the information acquired through integrated digital survey.

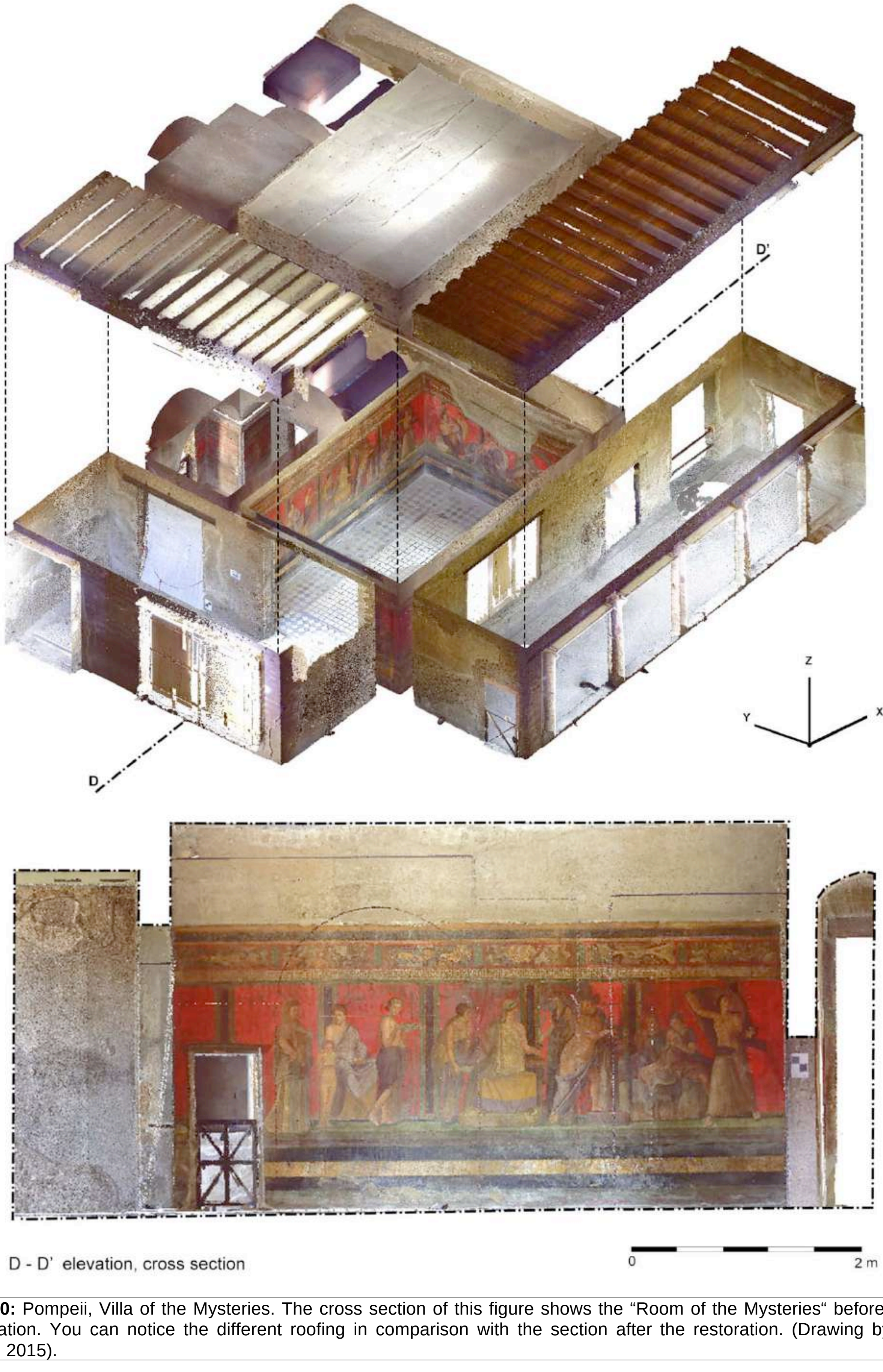

Fig. 20: Pompeii, Villa of the Mysteries. The cross section of this figure shows the "Room of the Mysteries" before the restoration. You can notice the different roofing in comparison with the section after the restoration. (Drawing by V. Cirillo, 2015).

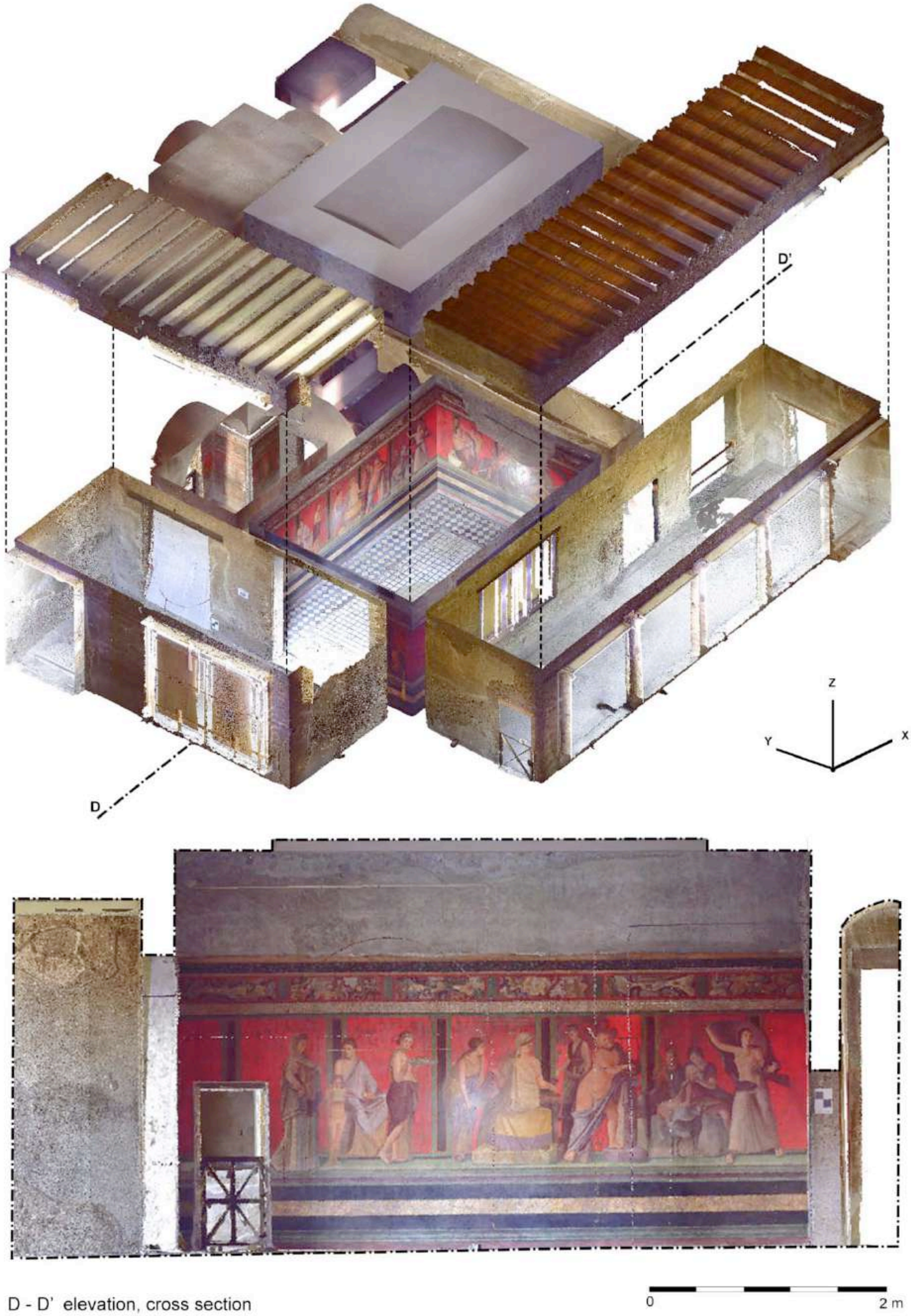

Fig. 21: Pompeii, Villa of the Mysteries. In this figure there is the “Room of the Mysteries” after restoration. The colour of fresco is brighter than before the restoration. (Drawing by V. Cirillo, 2015).

4. Using 3D point cloud model for geometric consideration about complex archaeological buildings (Nicola Pisacane)

These paper want to offer considerations regarding the restitution of digital models acquired by 3D laser scanner. In particular, on it will outline some possible considerations to be made in the modeling from point cloud for the transformation of a discrete model into a continuous one. The survey activities carried out on some buildings from the archaeological site of Pompeii offer, for their different spatial configuration, material consistency, transformations during the time, a panorama sufficiently wide to be able to trace a method implementable and extensible to other contexts, archaeological or not. The approach to buildings with different shapes -the 'Mercurio' tower, the 'Villa of the Mysteries' and the Amphitheatre - led to the start of considerations and methodological experimentation for the redrawing of three-dimensional point cloud through acquisitions. In particular, this contribution will emphasize the difference between the methodological approach if the case studies modeling through flat geometries or equivalent, compared to those with complex spatial articulations for which the analysis of the shape represents the first step in the establishment of the redrawing method. In the specific case study in question, it is interesting to clarify the approach that we are having in finding a better modeling of the Amphitheatre of Pompeii. This approach is not limited to mere geometric restitution but also a comparison with the construction techniques, the events and restorations have occurred over the centuries. Well we know that especially in the case of archaeological buildings is necessary to investigate and study changes and additions occurred in order to understand the difference in shape and structure. The approach and method that is being conducted aims to deviate from experiences in other contexts and described in the scientific literature on the subject. Specifically, the approach is trying not to limit the study of internal and external shape of the building to the simple form derived from planar projections but deepening their knowledge through a study of the formal complexity of the cultural heritage.

The literature concerning the surveys of Roman amphitheatres alternates some hypotheses about elliptical or oval plan shape. Scholars and experiences, also chronologically different, have led to different results on the actual trend in plant amphitheatres. An issue that has always been analyzed in relation to the possibility to realize at that time of the plan tracking –of the ellipse or of the oval- and then the skills and equipment available to Roman 'gromatici' for execution of these works. There is no doubt that the study and the survey, in particular, of this type of architecture is performed in reference to the construction techniques as well as the implementation phases of the works themselves and the spatial relationship between the work and its context. Amphitheatres in the specific case were realized through the construction of the outer wall from which then came the construction of the internal parts of the auditorium. Plan tracking of the external shape was dependent by the tracing of the geometry of successive internal parts. In fact, the tracking of the ellipse is much more laborious although operationally, especially for large curves, presents problems similar to those of the oval. The oval has however the advantage of being able to simply describe concentric curves (substantial problem for the bleachers amphitheater) as well as a simplification in the preparation of ashlars stone that constitute the structure.

But the consideration of the plan shape greatly limits the possible considerations useful for redrawing the discrete model: it is equally important to understand, learn and investigate the complex geometry of the auditorium, the direction of the stairs crossing and reaching the different parts of the theater space, such as the shape of the corridor below the auditorium itself: an integrated study of the different parts of the same amphitheater in function of the same use it had. Then we can not separate from the study of the slope of the auditorium in relation to the visibility inside the different parts of the theater, as you can not study the trend of the tiers according to the problems of cutting of stones and other materials used for the construction.

The approach used has first verified the plan shape and then extend the considerations to the spatial geometry of the auditorium. The first verification was the application of Pascal's theorem to the inner perimeter of the upper wall and that of separation between the auditorium and arena. Recall that the Pascal's theorem verifies the curves obtained from the flat section of the cones through the relationship between six points of the same curve through the alignment of three points inside and outside the same curve. Pascal's theorem is a fundamental result that is part of the theory of conics. Blaise Pascal (1623-1662) published it under the name of 'mystical hexagram' theorem in "Saggio sulle coniche" he wrote at the age of sixteen. The theorem can now enunciate thus: "If a plane hexagon ABCDEF is inscribed in a conical, then the three pairs of opposite sides AB-DE, BC-EF, CD-FA meet in three aligned points ". The theorem also occurred to the sides of the triangle between them intertwined. Verification and application of the theorem is performed on plan sections of the horizontal mesh generated from point clouds. Therefore, the audit was conducted on points and then actually detected with considerable accuracy, due to the high precision required when scanning. The test, performed on two pairs of six points for the two sections made -share perimeter wall, and the inside portion of the wall of separation between 'arena' and 'cavea'- verified with a minimum margin of error of the elliptical amphitheater. The above test should be checked but with the identification of major and minor axes of the ellipse and the gap size between the theoretical curve and the real one.

Fig. 22: Pompeii, Villa of the Mysteries. A panoramic view of the east side.

Fig. 23: Pompeii, Villa of the Mysteries. A instant view during the capturing laser data.

Fig. 24: Pompeii, Villa of the Mysteries. A detail of axonometric cross section. On the right, the room of the Mysteries. (Drawing by L. Abate, 2015).

Fig. 25: Pompeii, Villa of the Mysteries. A instant view during the capturing laser data in the room of the Mysteries.

Fig. 26: Pompeii, Amphitheatre. A instant view of the *cavea* during the capturing laser data. In the scenario there are many white spherical targets.

The correct identification of the axes would be possible through pairs of conjugate diameters always identified through the Pascal's theorem itself.
But the attention to the geometry of the amphitheater of Pompeii, as already mentioned, must not be limited to the study of its plan, but the spatial configuration of the surfaces that describe the spaces. Indeed checks plan will mainly determine the curve that describes the real performance with less error and how this same curve turns into model space through the creation of surfaces of different complexity. Just in case, think the influence that this information determines the trend of bleachers and on their radially and their disposal than the performance of the perimeter of the amphitheater. Different, in fact, it is the tracking mode of a perpendicular line to an elliptical wall, than to an oval one. In the first case the curvature varies at each point, in the second is constant for the individual arcs of circumference that determine the final shape.
This trend involves variations of the surface detected by the steps of the auditorium, as occurs on digital model must verify the direction in which the slope of the auditorium is constant. Direction of the slope constitute the generating of theoretical inner surface that define a good chance a cone, from which sections define direction connecting the various parts of the theater as well as the ways in which various stone elements were designed, cut and built. The operation of surface definition of the auditorium will be the analysis of the innovation development of the mesh from point cloud guaranteeing an even more thorough than those available through only plane sections with vertical or horizontal position.
The above considerations want to be a first approach to the analysis of complex geometries directly on the 3D model that can be in the case of some buildings the opportunity to develop and elaborate in the best way the discrete point cloud model from which generate the continuous model. A modality that can optimize the use of laser scanner systems for survey of buildings and a critical use of software for processing and modeling, also for the construction of structural models, assumptions of restoration and design. These outcomes, subject to the continuation of the Project 'Campus' research, will be announced in the future.

Fig. 27: Pompeii, Amphitheatre. A instant view of the upper walkway during the capturing laser data. In the scenario there are many white spherical targets.

Fig. 28: Pompeii, Amphitheatre. A instant view of the perimetrical arches during the capturing laser data. In the scenario there are many white spherical targets.

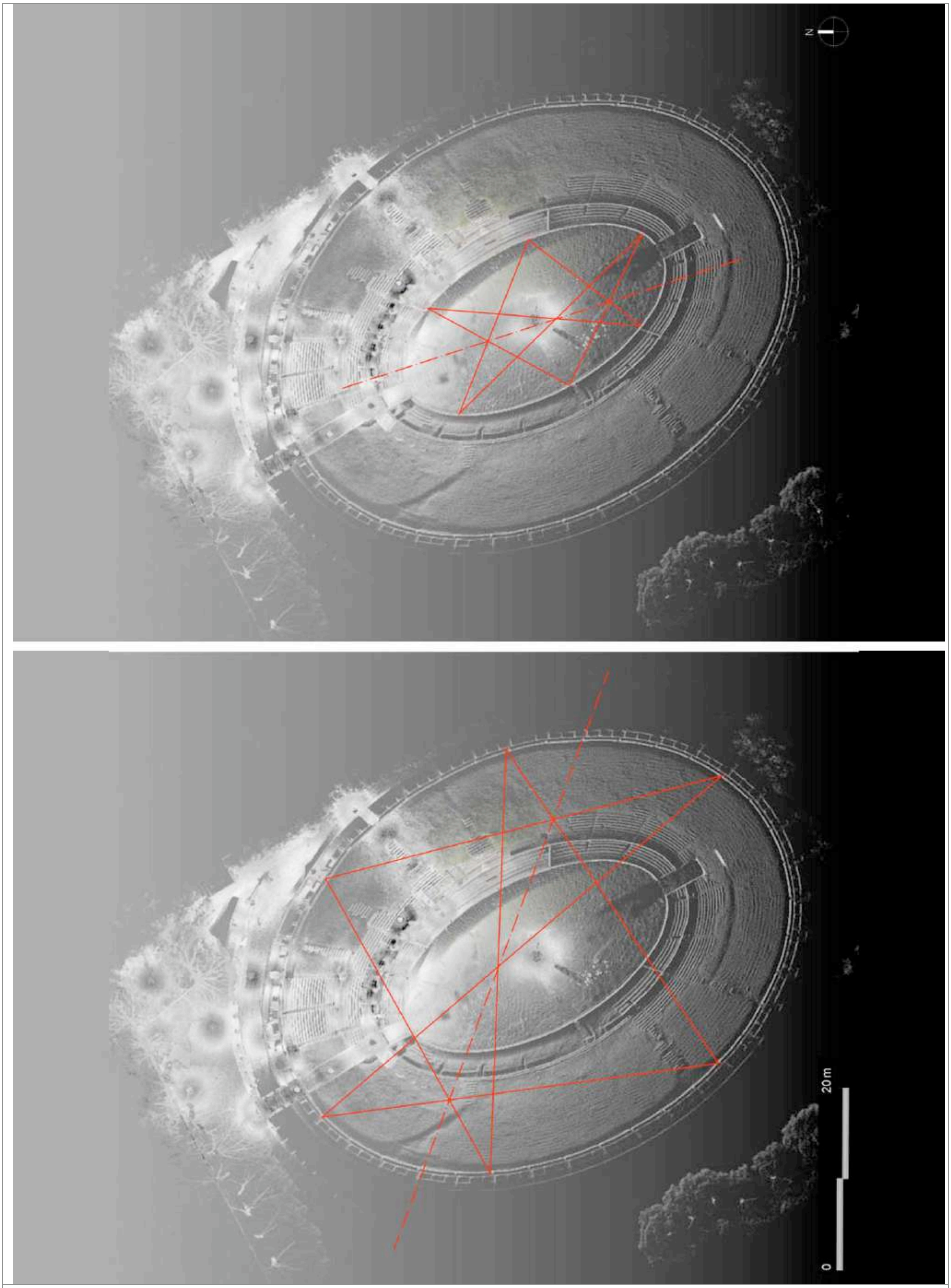

Fig. 29: Pompeii Amphitheatre: geometric preliminary check of the geometry of the inner profile of the perimeter wall and the profile of the wall of the arena through the application of Pascal's theorem in plan sections of the mesh model generated from 3D laser scanner acquisitions. (Drawing by N. Pisacane, 2015).

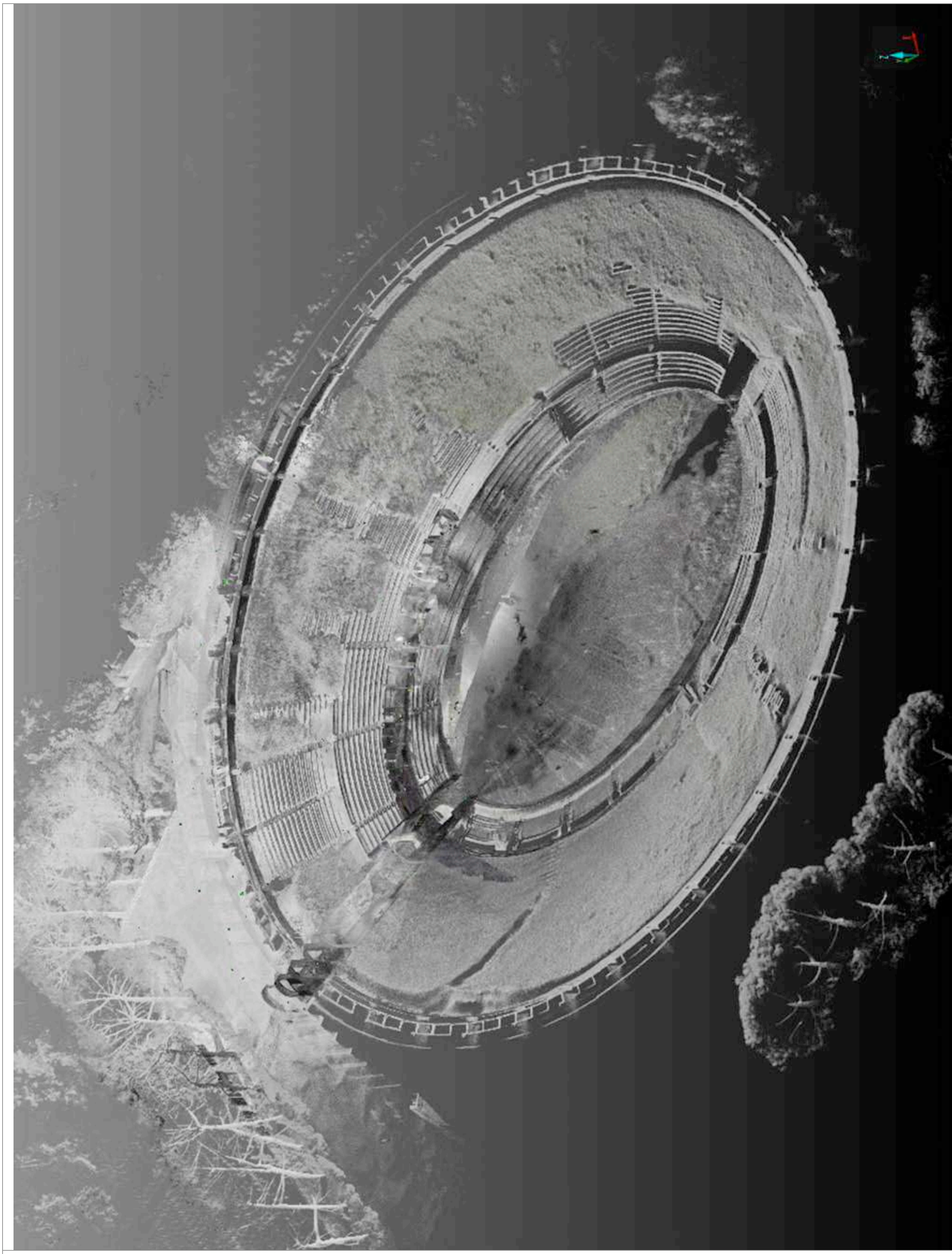

Fig. 30: Pompeii, Amphitheater. Point cloud model, axonometric view from south-eastern. (Drawing by V. Cirillo).

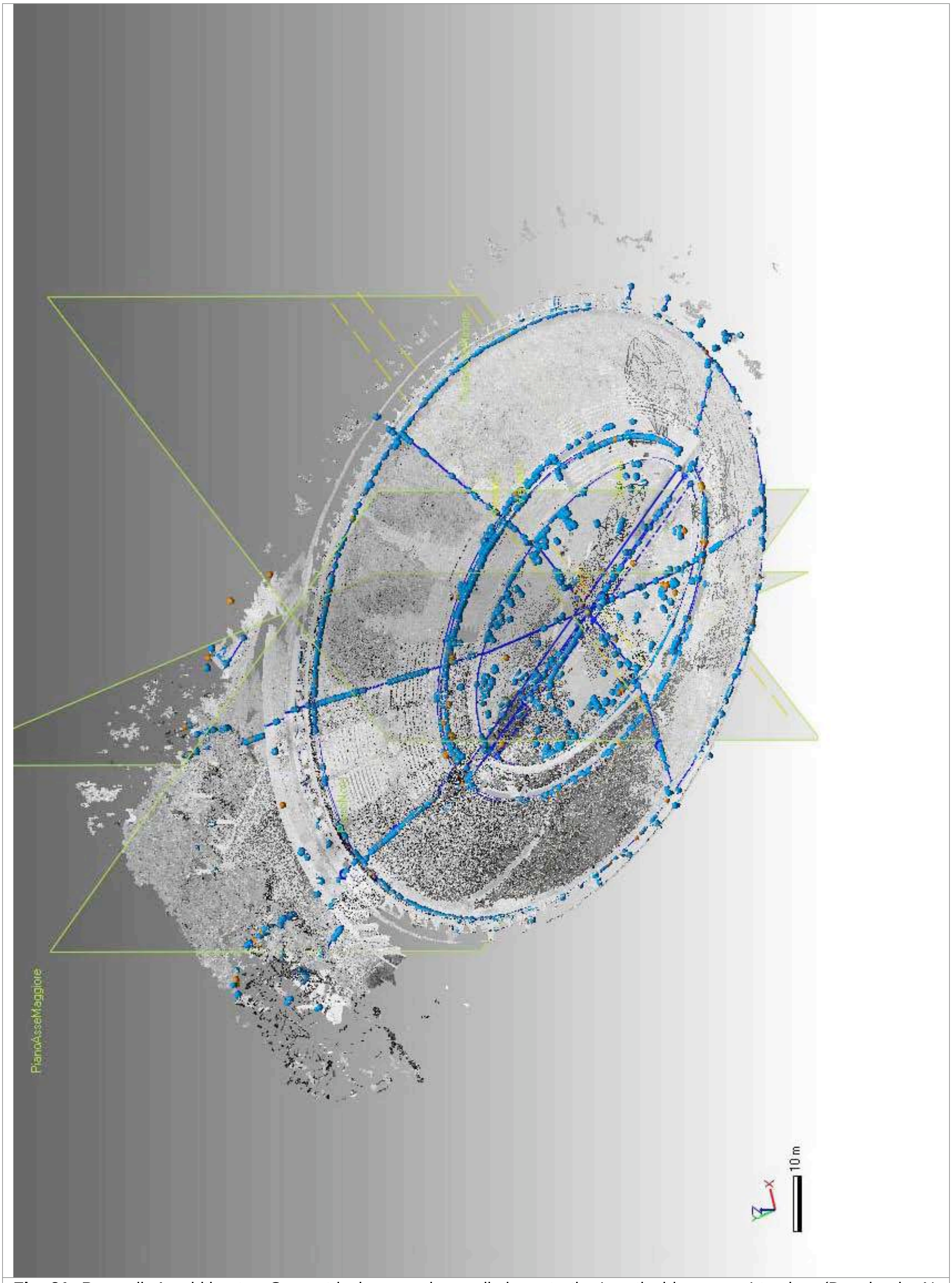

Fig. 31: Pompeii, Amphitheatre. Geometrical processing preliminary to the 'mystical hexagram' tracing. (Drawing by N. Pisacane, 2015).

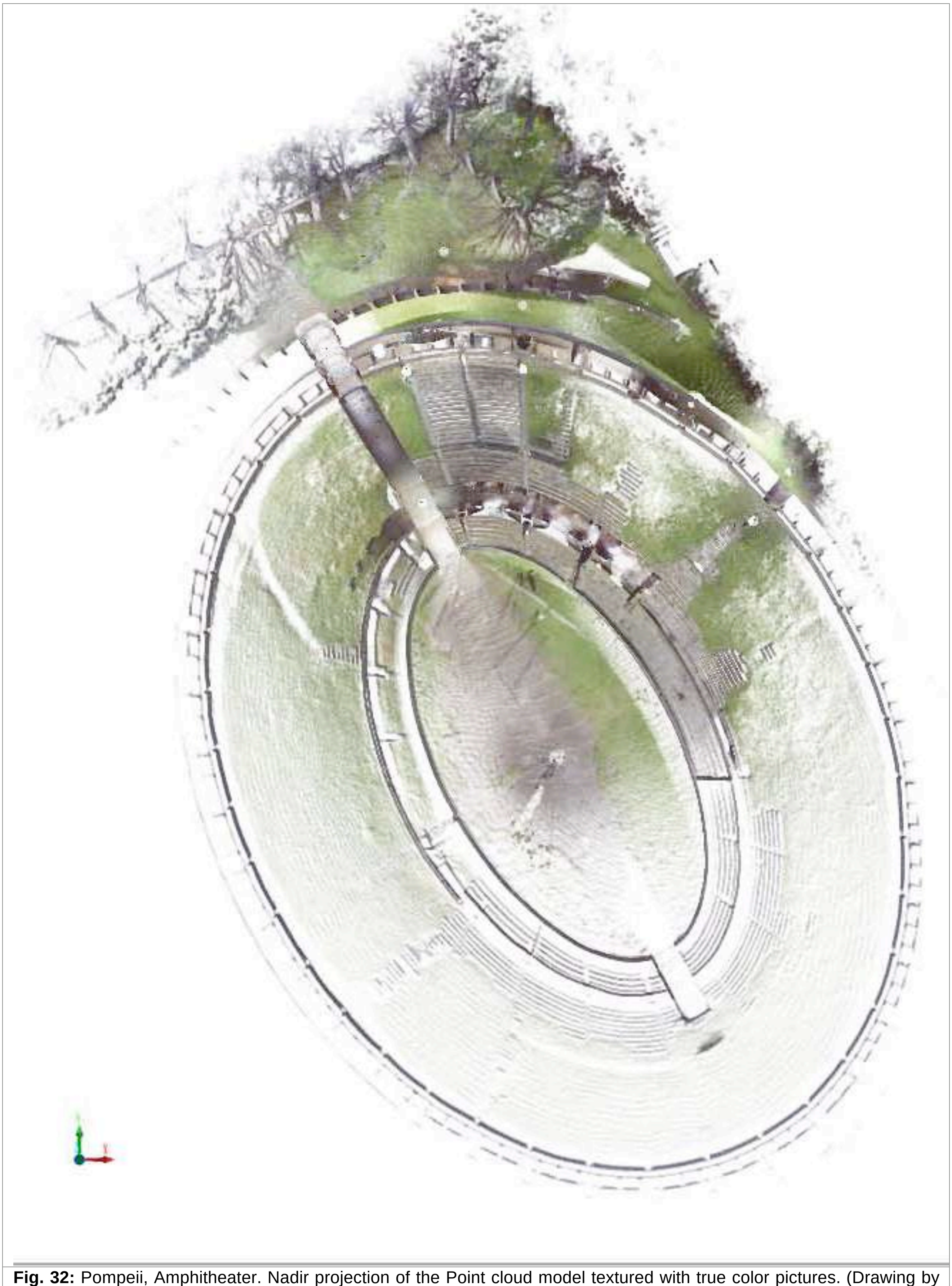

Fig. 32: Pompeii, Amphitheater. Nadir projection of the Point cloud model textured with true color pictures. (Drawing by V. Cirillo, 2015).

Fig. 33: Pompeii, Amphitheater. Point cloud model, axonometric view of the north-western side. (Drawing by R. Parente, 2015).

Fig. 33: Pompeii, Amphitheater. Point cloud model, axonometric view of the north-western side. (Drawing by R. Parente, 2015).

Fig. 34: Pompeii, Amphitheater. Point cloud model, perspective view of the *cavea* from the bottom *arena* to the upper ring. (Drawing by L. Abate, 2015).

5. Conclusions

Photographic and 3D laser scanner remote sensing activities described, with particular reference to the archaeological area of Pompeii, fully in line with the relationship between heritage and technology main topic of this forum, are totally recorded in a technology platform that collects and processes georeferenced data carried out by the activities on the study area of this research.

The GIS platform, which at the conclusion of the research will be accessible from the web, is structured in thematic layers from which integration can envisage scenarios for development and protection for environment and for cultural heritage. The system still allows, in continuous and dynamic updating of data collected in the different layers representing a tool for the management of a wide and complex site.

The chance to view and explore existing buildings, covered by the survey and modeling activities described, and hypothesis of urban land modification, will provide users with a powerful tool both for decision-making than for the sustainable use of the cultural heritage.

Bibliographical References

[1] GUIDI, Gabriele. BERALDIN J.A.. A*cquisizione 3D e modellazione poligonale. Dall'oggetto fisico al suo calco digitale.* Milano: Edizioni Poli.Design, 2004.

[2] GUERRA, Francesco. BALLETTI, Caterina. ADAMI Aandrea. *3D multiresolution representations in archaeological sites*, in Proceedings of CIPA 2005 - XX International Symposium "International cooperation to save the word's cultural heritage". Torino, 2005.

[3] ADAM, Jean Pierre. *L'arte di costruire presso i Romani*. Milano: Ed. Longanesi, 2008.

[4] GAMBARDELLA, Carmine. *Atlante di Pompei*. Napoli: La Scuola di Pitagora Editrice, 2012.

[5] AGNELLO, Fabrizio. *Un metodo per il rilievo e la modellazione digitale di superfici non razionali in manufatti antichi*, in E-ARCOM, maggio 2004, pp. 6-11.

[6] AVELLA, Alessandra. *La modellazione tridimensionale attraverso la discretizzazione geometrica 'razionale' delle forme nel disegno di architettura. Il caso studio dell'architettura cimiteriale a Napoli*, in GAMBARDELLA, Carmine. GIORDANO, Paolo. *CAMPANIA WORLD HERITAGE PROPERTIES Ancknoledged lands [material and immaterial] and Unknown fragments [built and natural]*. Napoli: La Scuola di Pitagora Editrice, 2015.

[7] ARGENZIANO, Pasquale. *Il Laser Scanning dell'architettura: database geometrico e "fonte documentaria" di discretizzazione critica. Il caso studio dell'architettura cimiteriale a Napoli*, in GAMBARDELLA, Carmine. GIORDANO, Paolo. *CAMPANIA WORLD HERITAGE PROPERTIES Ancknoledged lands [material and immaterial] and Unknown fragments [built and natural].* Napoli: La Scuola di Pitagora Editrice, 2015.

[8] *Il Colosseo. Studi e Ricerche*, in "Disegnare. Idee Immagini", nn.18-19/1999.

[9] WILSON JONES, Mark. *Designing Amphitheatres*, in "Mitteilungen des Deutschen Archäologischen Instituts", Römische Abteilung, n.100/1993.

[10] MIGLIARI, Riccardo. *Ellissi e ovali. Epilogo di un conflitto*, in "Palladio" n.16/1995.

[11] SALATI, Rosanna. *La geometria degli anfiteatri romani. Verifica delle ipotesi di tracciamento applicate ai più antichi esempi presenti in area campana*. Edizioni Accademiche Italiane, 2014.

[12] ZERLENGA, Ornella. *La «forma ovata» in architettura. Rappresentazione geometrica*. Napoli: Cuen, 1997.

Credits

The surveying activities described in this paper were coordinated by Professor Carmine Gambardella.

The laser scanning capturing on the Tower of Mercury were carried out by Pasquale Argenziano, Alessandra Avella, Paola D'Auria, Dario Martimucci; its point clouds and meshing models were carried out by Luciana Abate, Vincenzo Cirillo, Rosaria Parente. The digital integrated surveying on the Villa of the Mysteries were

carried out by Pasquale Argenziano, Alessandra Avella, Carlo Alberto Bozzi, Vincenzo Cirillo, Eduardo Fiorillo, Piero Lusuardi, Donato Marcantonio, Dario Martimucci, Rosaria Parente; its point clouds and meshing models were carried out by Pasquale Argenziano, Alessandra Avella, Luciana Abate, Vincenzo Cirillo, Rosaria Parente, Nicola Pisacane.
The digital integrated surveying on the Amphitheatre were carried out by Luciana Abate, Pasquale Argenziano, Alessandra Avella, Carlo Alberto Bozzi, Vincenzo Cirillo, Ciro Ferrandes, Eduardo Fiorillo, Piero Lusuardi, Carmine Maffei, Dario Martimucci, Rosaria Parente, Nicola Pisacane, Pasquale Pizzini; its point clouds and meshing models are still carrying out by Pasquale Argenziano, Alessandra Avella, Luciana Abate, Vincenzo Cirillo, Rosaria Parente, Nicola Pisacane.

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Fig. 35: Pompeii, Amphitheater. A instant view of the elliptical tunnel during the capturing laser data.