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Abstract

This article presents research activities conducted on several rooms as part of the extension project of the Grandi Uffizi Museum in Florence (Italy). The research addresses survey methods for monitoring the static performance and evaluating the structural plastic deformations of vaulted systems and architectural elements, mostly subjected to structural reinforcements. In order to achieve positive results, the most appropriate 2D and 3D graphic representation methods have been identified, to enable the realization of detailed, technical documents. Laser scanner survey activities have been executed along with photo-modeling and extensive photographic documentation, crucial for the operations of photogrammetry and photomapping reconstructions. Post-production and data processing steps have produced substantial documentation of graphic materials through the development of floor plans, detailed measurements of series of sections, photomap reconstructions and 3D simulations. The thrust of the innovative research deals with the development of 3D computational models by implementing and refining reverse engineering processes for the simulating the static performance and plastic deformations that overlap the various stages of each investigation. These monitoring techniques have made it possible to determine the effect of the consolidation interventions operated, through a progressive implementation of the point cloud. The opportunity to follow the construction site from 2010 until now has contributed significantly to the enhancement and refinement of these detection and representation techniques, enabling the development of new operational methods with higher metric reliability to support the activities that such a sophisticated construction site as the Grandi Uffizi in Florence represents.

Keywords (separated by '-'): Laser scanner - Reverse engineering - Digital representation - Structural monitoring - Morphological analysis of strain

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Sandro Parrinello and Sara Porzilli

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Fig. 1 Laser scanner survey activities in the museum complex of the Uffizi

Introduction

This contribution presents the key results obtained from digital surveys conducted on several rooms of the Uffizi Museum in Florence (Fig. 1), primarily as a result of the significant rearrangement of the exhibition spaces over the past few years. A detailed structural analysis provides us an understanding of the static situation and allows us to expand the consolidation project whenever necessary.

The research project is carried out in partnership with the institutions (Fig. 2) primarily responsible for the construction works related to the extension of the exhibition areas within the Uffizi Museum.[1] Because of this fruitful collaboration, which started in 2010 and is still active, it has been possible to carry out several analyses and investigations in support of the technicians and specialists involved in the construction work. From a scientific point of view, this experience has enabled the development of important experiments for the advancement of innovative 3D digital survey methods specifically devoted to the structural monitoring of historical architecture. The historical, artistic and architectural context in which this research

[1]The activities were conducted through a specific agreement with the Department of Civil Engineering and Architecture of the University of Pavia. Project Scientific Coordinator: Prof. Arch. Sandro Parrinello. Technical coordinator of the project: PhD Arch. Sara Porzilli. Promoting Institutions for the survey and documentation activities: "CCC Consorzio Cooperative, Costruzioni, Imprese esecutrici CMSA Soc. Cop.", "MiBACT Soprintendenza Belle Arti e Paesaggio per le province di Firenze, Pistoia e Prato" (MiBACT Superintendency of Fine Arts Academy and Landscape for the provinces of Florence, Pistoia and Prato), "Soprintendenza per la Tutela e valorizzazione beni architettonici, paesaggistici, archeologici, storico-artistici ed etnoantropologici per le province di Firenze, Prato e Pistoia" (Superintendence for the Protection and Valorization of architectural, landscape, archaeological, historical, artistic and ethno-anthropological Heritage to the provinces of Florence, Prato and Pistoia).

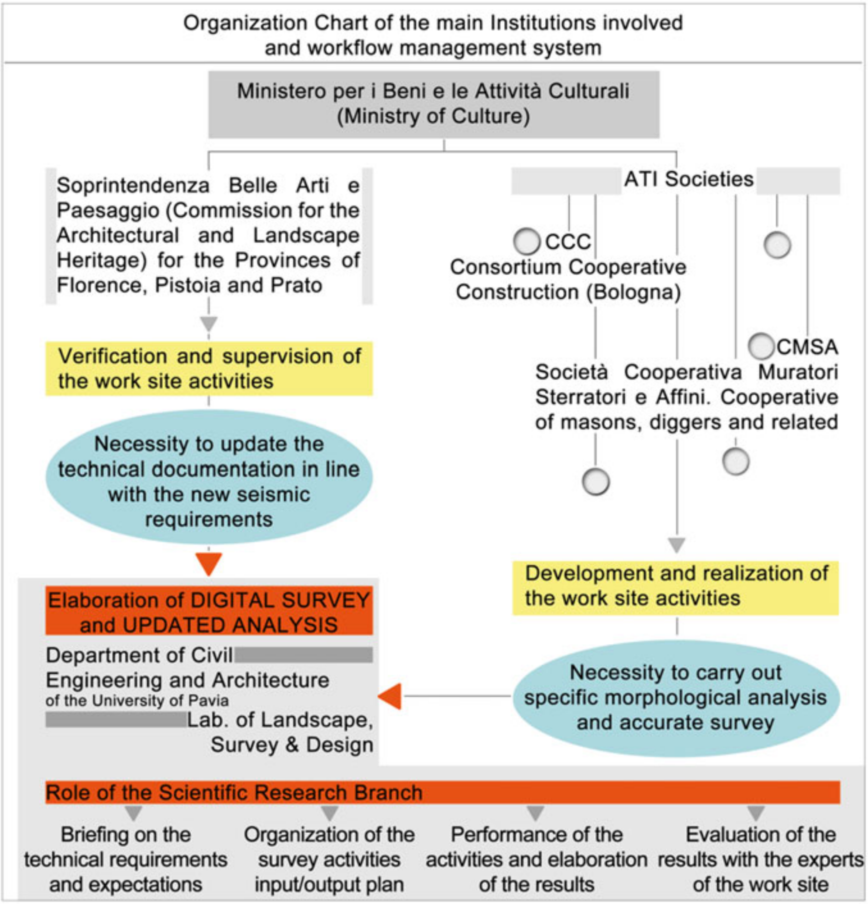

Fig. 2 Scheme showing the institutions primarily involved in the promotion and execution of the process. Survey activities carried out by the research team have produced extensive documentation used by several authorities and for different purposes

has been executed represents a key aspect that has made this such a fascinating and compelling experience, engendering professional passion. The Uffizi Gallery is part of the Italian cultural heritage, not only for its priceless paintings and sculptures, but also for the significance of the building itself, which, together with the city of Florence, is a designated UNESCO World Heritage sites. In this context, monitoring through laser scanner surveys has been carried out with the goal of obtaining detailed morphological analysis with higher metric reliability. This activity has enabled technicians and experts to design more efficient intervention strategies based on detailed documentation. This includes diagnostic analysis, structural inspections of static structures, planning of improved safety measuring activities for each room, restoration and structural consolidation, design of plant facilities, technical corridors and platforms for maintenance and inspection activities.

Research Approach and Development of Operational Methodologies

In order to obtain documentation with high metric reliability, it was necessary to carry out careful planning of all the survey phases (Fig. 3). Due to the complexity of the rooms, as well as their partial accessibility and usability, the survey and photogrammetric data acquisition have relied on reconnoiter surveys and analysis to establish the most strategic locations and methods for instrument placement (Fig. 4).

During the preliminary phase, it was important to define the most appropriate methodologies for achieving the objectives, through the development of operational schemes on which to affix notes and planned on site activities, to identify all the different data typologies obtained and to understand the achievable results.

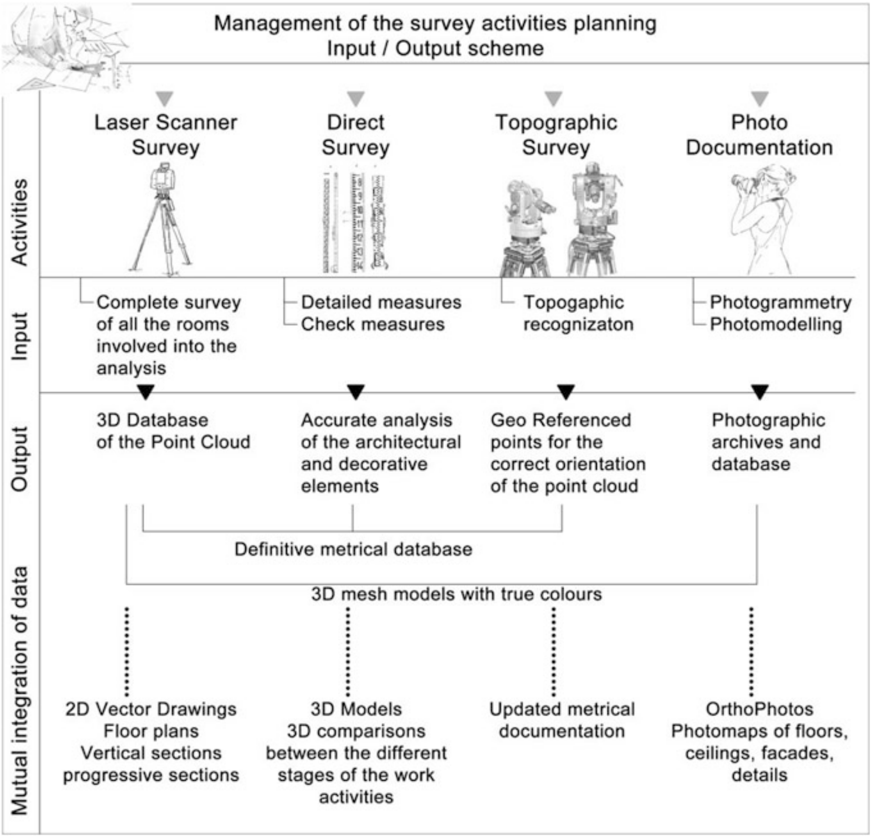

Fig. 3 An integrated research project requires detailed organization of the different activities carried out. By using schemes and diagrams it is possible to develop suitable solutions for achieving the best results from each work operation

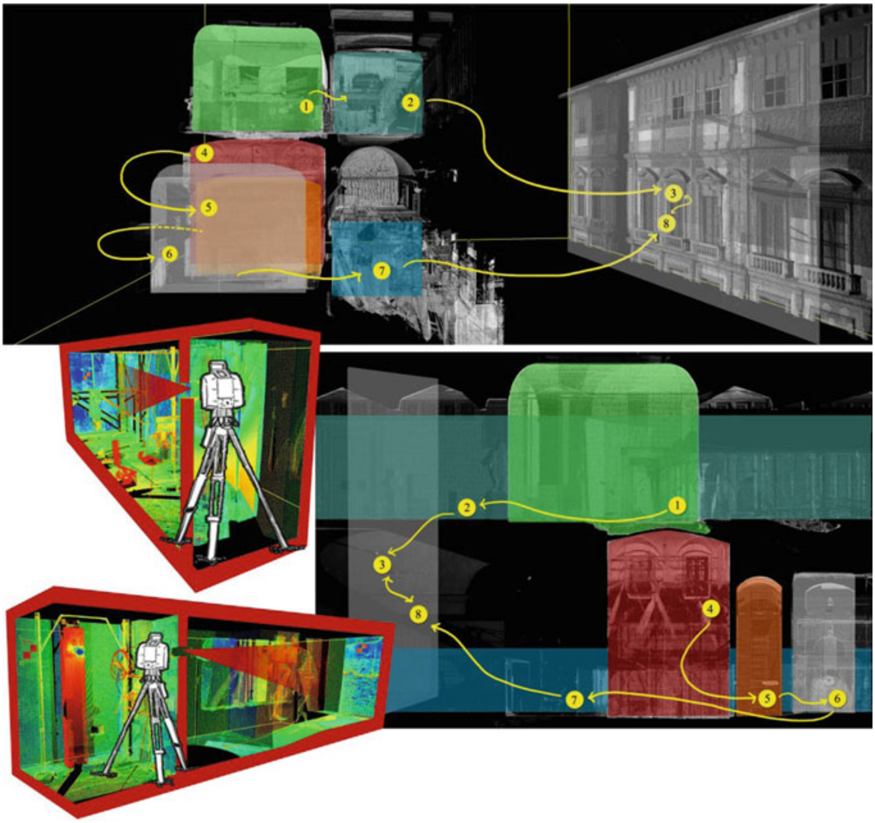

Fig. 4 Laser detection scheme for defining the instrumental path

The second fundamental aspect was the identification of the most appropriate schedule through which to carry out the periodic monitoring scans for obtaining the most relevant data. The elaboration of this information has made it possible to increase the process facilities on the condition of the architectural elements using comparisons and elaborated overlaying data documents.

Analysis and survey activities produce a large volume of updated documentation, characterized by the different data typologies:

- Metric databases (point clouds) obtained from laser scanner survey;
- Vector bidimensional drawings obtained from the elaboration of the point clouds—in particular, general plans, vertical and horizontal sections, progressive sections, comparisons of the data obtained during the different detection phases with dimensioning of the height differences;
- Three-dimensional models obtained through the elaboration of the point clouds with overlapping of the different steps to understand the minimum movements

of the structures and for the static assessment of floors, vaults and wooden structures.

Alongside the technical-operational aspect, this experience has also involved a theoretical and an academic approach for the advancement of the new integrated digital survey systems and for increasing the 2D and 3D post-production methods in order to obtain the newest and most up-to-date procedures for systematic analysis. The fruitful synergy between technicians and professional experts and managers from the university has added value to the research experience, thus increasing our positive results.

The Integrated Survey Project

The most complex aspect of this research has been the ability to perform a laser scanner survey from which all the architectural structures were described completely, obtaining a full survey and investigation of all the extrados and intrados environments and surfaces of all the vaulted rooms, wooden structures, and horizontal and vertical architectural elements (Fig. 5). During the preliminary planning of the survey, it was important to set the laser scanner stations and all the survey activities. The purpose of this phase was not only to identify the best means of understanding the morphological complexity of the building, but also to perform the activity without disruption to the museum. Survey activities covered additional areas around the main survey topic in order to elaborate the triangulation of the points and the closing of polygonal paths, which were necessary steps for the final evaluation and for error compensation (Fig. 6). The survey generated a complete and accurate description in all parts of the masonry floors, the vaulted ceilings, the roofs, the wooden structures with trusses, and the trellis coatings.

Similar to that for the walls and the vertical elements, all aspects of the metric description were complete due to the detection of the architectural elements in their entirety (Fig. 7). The system of laser scanner stations with the polygonal reference used for connecting rooms located on different levels defined a complex structure of relations between the target system and the detected areas (Fig. 8).

Certain rooms of the museum were covered by the investigation so that it was possible to obtain the necessary amount of data for verification of survey correctness and metric reliability. For these reasons, this integrated survey project was initiated, with the use of various detection methods simultaneously, which differed not only in the instruments used but also the results achieved. Three-dimensional laser scanning was the methodology most widely adopted for the detection of the environments under investigation. The laser scans were always carried out at a high resolution in order to simultaneously acquire both the constructive details, deformations and chromatic alterations (deduced from the reflectance value of each different surface), and the targets located at considerable distances (Figs. 9 and 10).

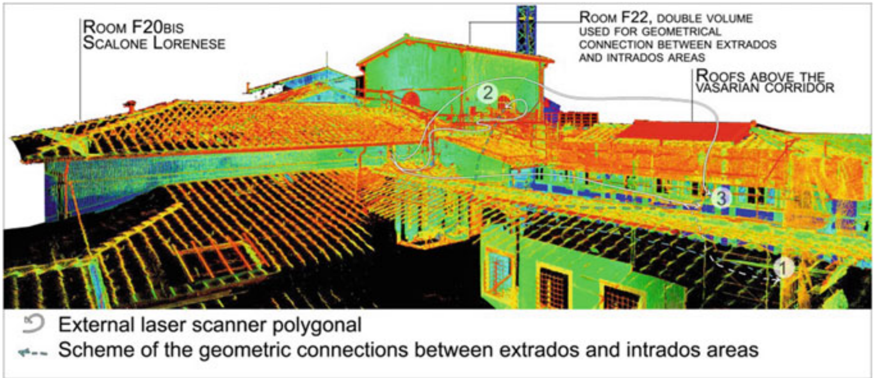

Fig. 5 Graphic representations related to the different types of polygonal designs for the laser scanning survey. The most complex aspect of the survey activities was the need to connect extrados and intrados rooms with the highest metric reliability

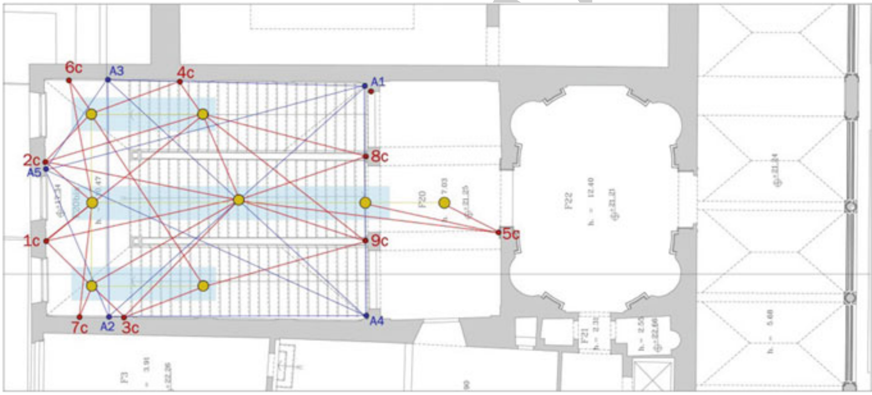

Fig. 6 Reference system with fixed targets for the registration of point clouds

A final aspect, of no less importance, was the ability to manage the instruments (e.g., initiating the scans, monitoring the scanning stages) using wireless remote control. This was particularly important for the management of the scan activities in partially stable environments, such as ladders, scaffoldings and trellis coatings. Oscillation and vibrations produced during instrument installation are detrimental to scan quality. Therefore, under these circumstances, scanning was controlled via a tablet connected to the laser scanner instrument once these disturbances had ceased.

High definition is needed not only to facilitate the redrawing of the architectural elements and = the many decorative elements present, but also to enable a very high level of metric accuracy for measuring the horizontal and vertical bearing structures and their deformations (Fig. 11). For these structures, it facilitated the

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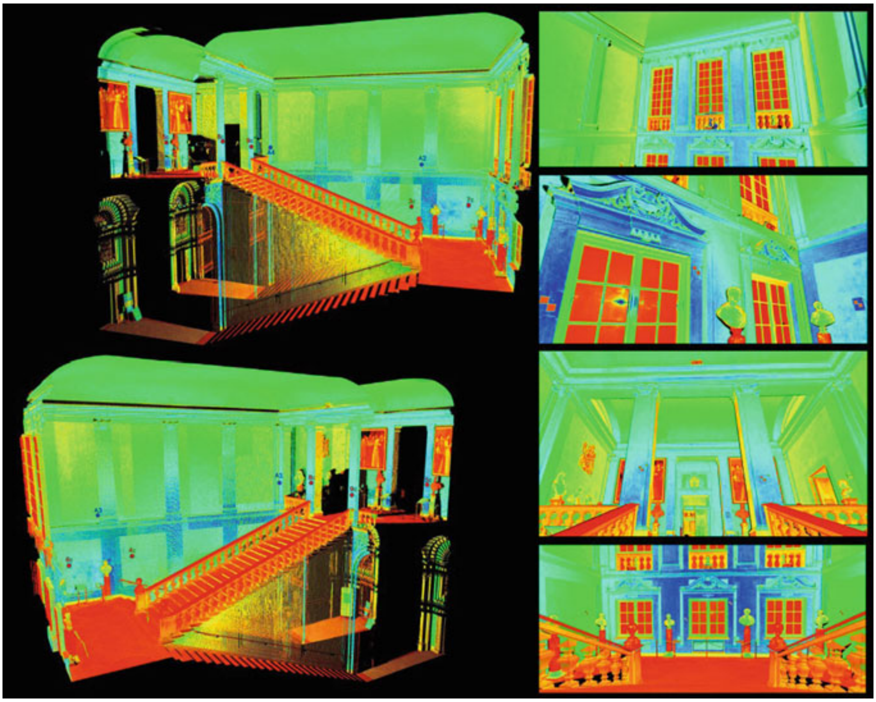

Fig. 7 Views of point clouds of the museum access staircase; the survey was conducted for study of the vault

development of a monitoring system for verification of the stability of complex structures with increased deformations (Figs. 12 and 13).

In some cases, the morphological complexity of the environment required the integration of data obtained from laser scanner survey by performing photo-modeling analysis. From this activity, we developed three-dimensional models of portions of environments investigated directly, thanks to intensive and detailed photographic campaigns using specific software dedicated to this type of function (Fig. 14).

In order to perform periodical monitoring at the worksite, it was vital to place specific “cornerstones points”, consisting of targets strongly anchored to the architectural structures, as this made it possible to report each measurement in the general coordinate system adopted for the whole 3D laser scanner survey (Fig. 15).

Verification of the monitoring was then defined by comparing the three-dimensional databases produced by the laser survey in the same reference system. Each group of points with spatial coordinates belonging to the same acquisition campaign was associated with a specific surface. This made it possible to assess more clearly the detachment or the interpenetration that, within a certain tolerance scheme, appeared between the different models and the original surface of the first

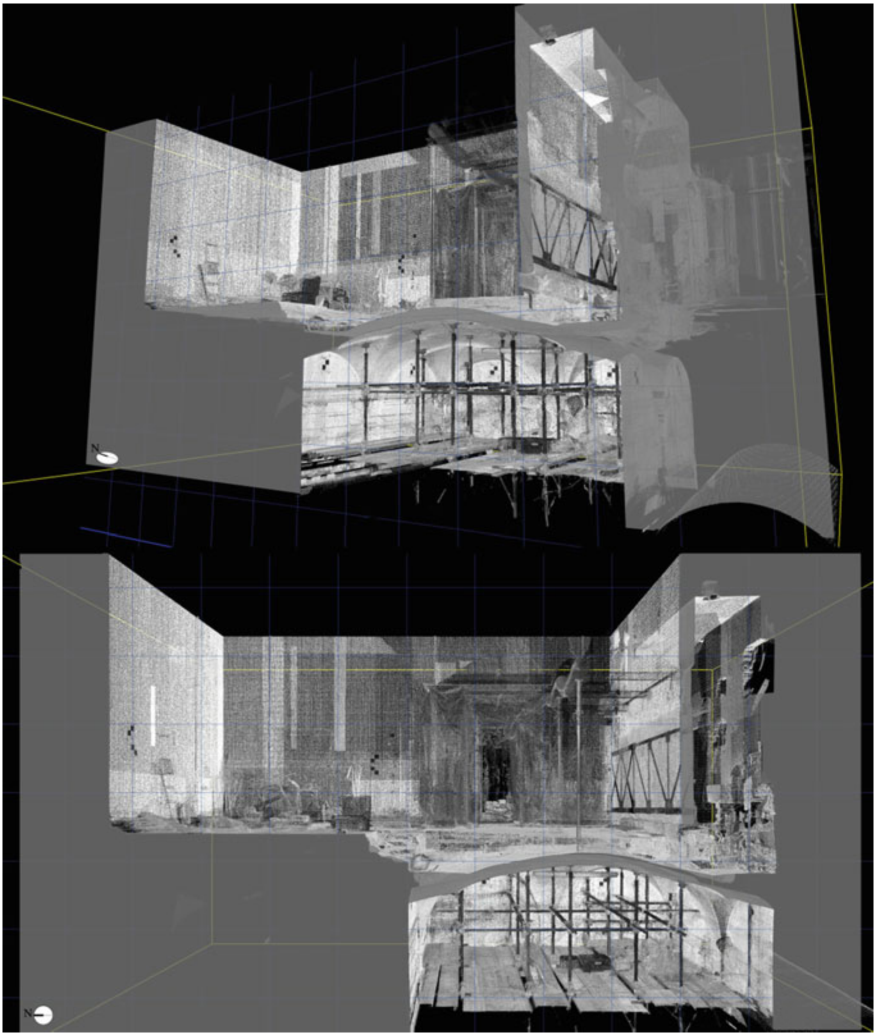

Fig. 8 Section of the point cloud where it is possible to see the cutting action of a wall placed over a vaulted ceiling; the survey was conducted to analyze the micro displacement of the ceiling once relieved of the wall weight

detection. The positioning of the pillars constituted the most delicate phase for all the detected environments. Through this activity, it was possible to validate and define the success of the morphological survey, as it allowed us to execute overlaps and three-dimensional comparisons that otherwise would not have been possible to quantify. The network of points constituted by the system of targets represents the geometric platform on which all the stages of monitoring are fixed, and it gives form to a digital archive of metric information that relates to the same reference

Fig. 9 Surveys carried out in the Botticelli room for the insertion of the new suspended ceiling

system and has the same orientation (UCS). In this experience, different point clouds obtained were progressively overlapped as successive layers, thereby allowing a comparative reading to be conducted entirely within the digital simulation (Figs. 16, 17 and 18). Intensive photographic campaigns were carried out in parallel with the laser scanner survey activities. These followed an operational logic process that generally focused on particular architectural and decorative details. The intensive photographic campaigns were necessary for the realization of the photo plane of walls, floors and ceilings. This activity was also important because it allowed archive documentation of several rooms to be updated during the working phases.

In many instances it was possible to create a photographic historical memory of how rooms and spaces appeared before the redesign assessment, and in other situations, it was possible to document architectural features that are no longer visible. This was the case, for example, with the "Sala della Niobe" (Niobe Room), where the floors were reported as the previous ancient rustic asset characterized by ancient lighting systems and vaults in the masonry, and then after certain fundamental structural engineering interventions, they were again covered by the original restored floor (Figs. 19 and 20).

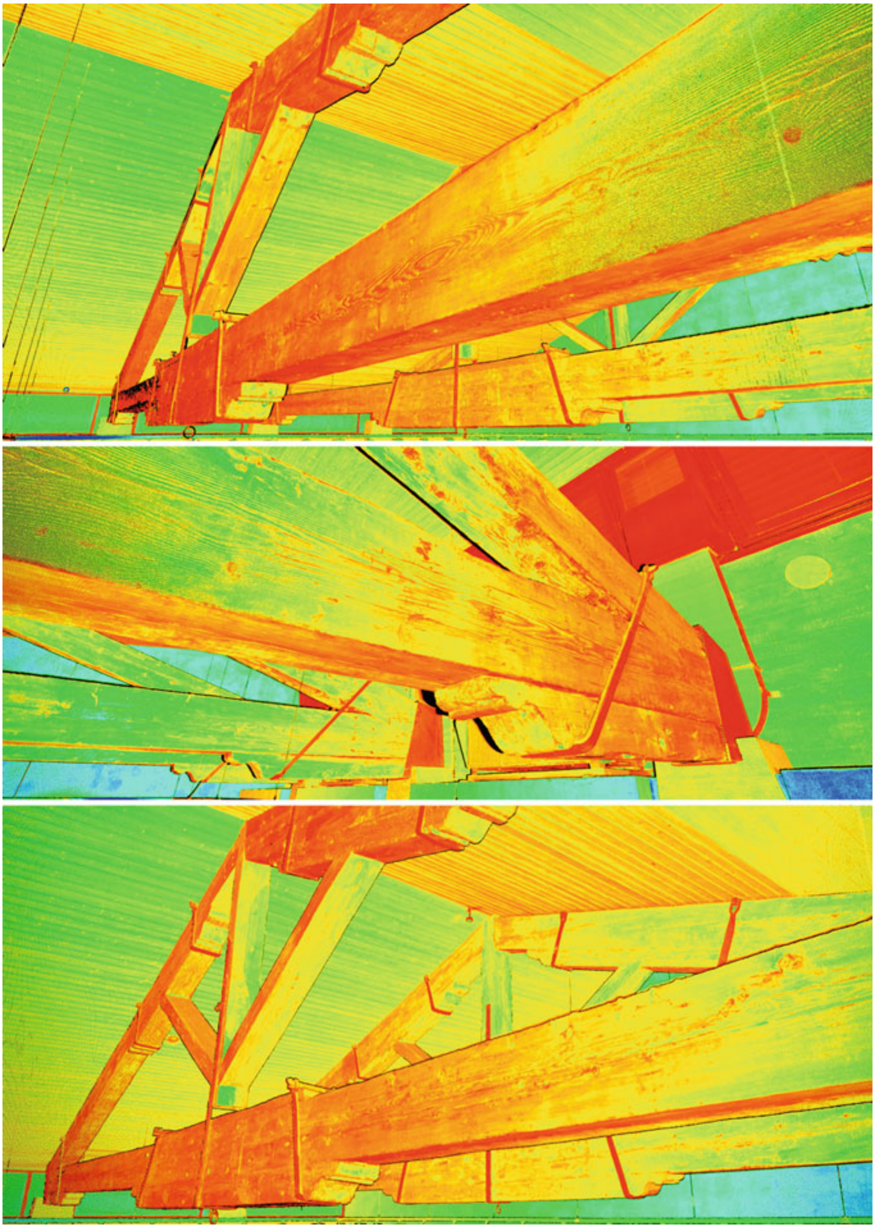

Fig. 10 Detail of the monumental wooden trusses of the Botticelli room

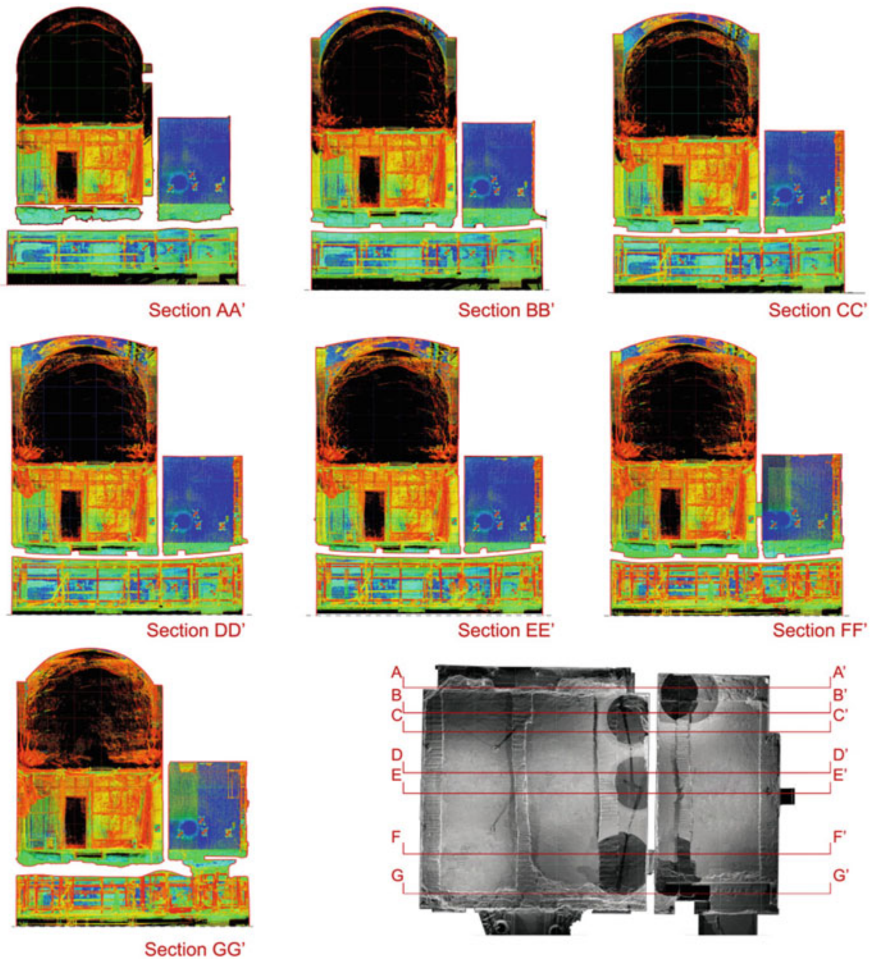

Fig. 11 Analysis of the deformations of a vaulted ceiling due to the weight of a wall

Data Storage Management for the Post-production Phase

Each survey activity has produced a vast amount of data which needed to be carefully scrutinized, evaluated and classified. The laser scanner activities have produced a metric database containing all the partial 3D scans performed (Fig. 21). An essential component of the processing stage was registering[2] and performing all

[2]The "registration" operation represents the technical procedure that enables the combination of different partial point clouds from the same survey activities into one general and complete point cloud. This operation is performed due to the use of common targets surveyed from different scan positions. The specific software can elaborate geometric calculations and algorithms that are aided

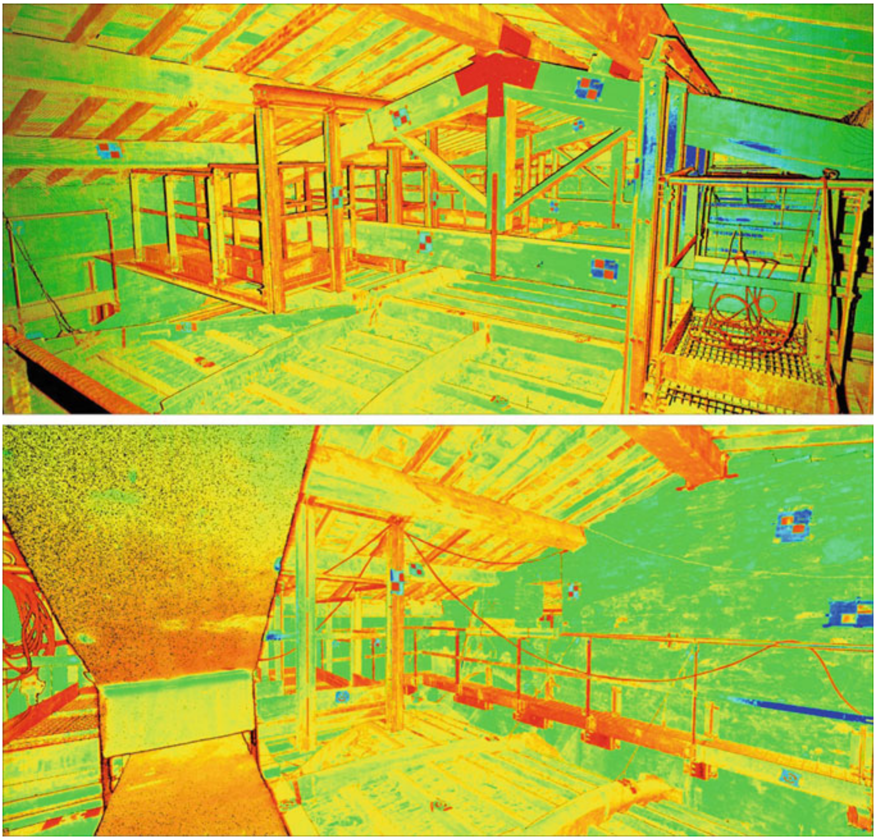

Fig. 12 Point cloud under the roof, above the museum access staircase. It is possible to see the wooden trusses and the top surface of the vault with the wooden structure

tests to verify their reliability. The photographic campaigns are ordered according to an archiving system based on folders marked by reference codes. From this, one can identify each singular architectural element, including the walls, vaults, trusses, staircases and statues (Fig. 22). Due to the use of a code system for storing the information, it is now possible to use the database according to different channels of access that are related to the various operators involved during data processing.

The walls of the documented rooms were defined with respect to their orientation with the cardinal directions N-S-W-E (north, south, west, east). For photo campaigns involving the floors and roofing systems, however, we created descriptive drawings enriched with specific geometric divisions into numbered quadrants. In this way, each individual part is assigned its own related folder. In

by these specific points. Geometric recognition produces a global unique point cloud of the whole survey database.

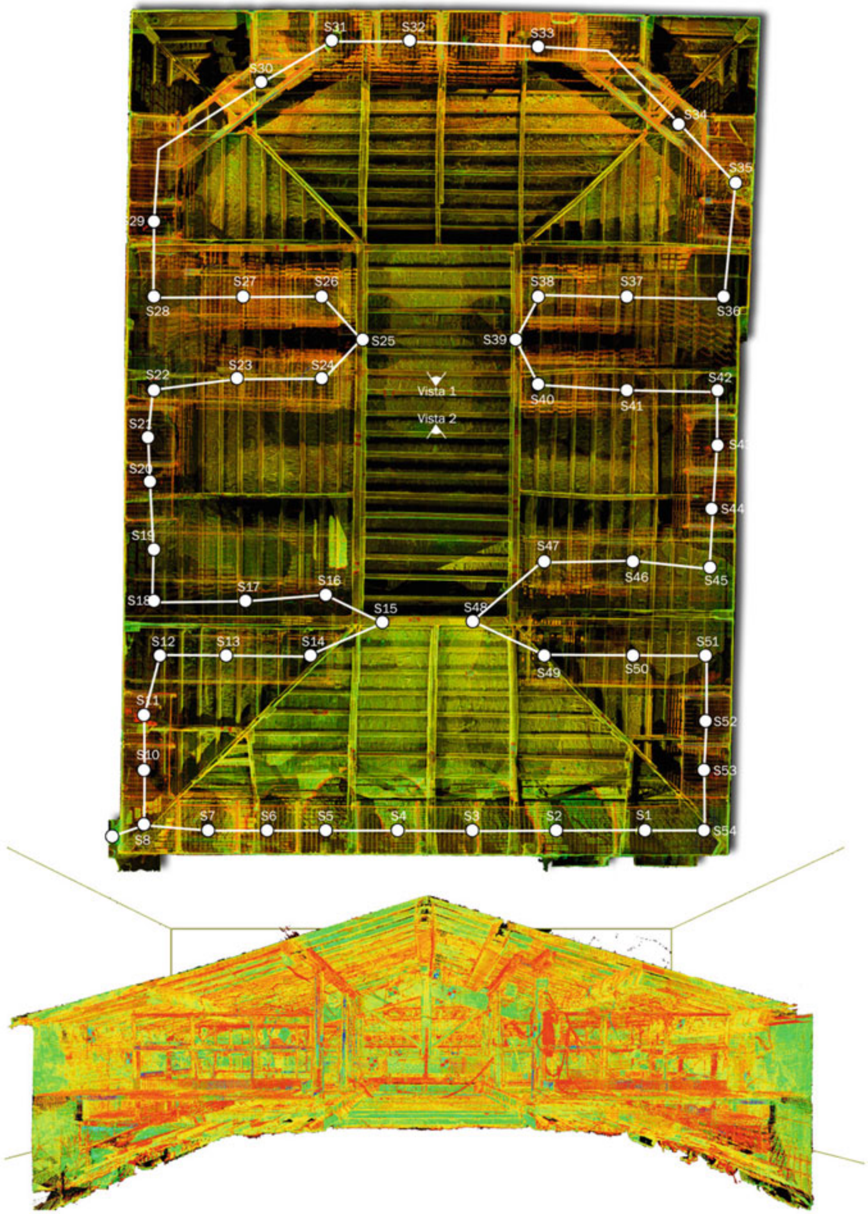

Fig. 13 Path of the laser stations for the survey under the roof, above the museum access staircase

general, all folders of the photo documentation are named with the same codes used for technical drawings or 3D models. Therefore, it is now easy to search for a specific image within a precise section of the architecture documented. To store

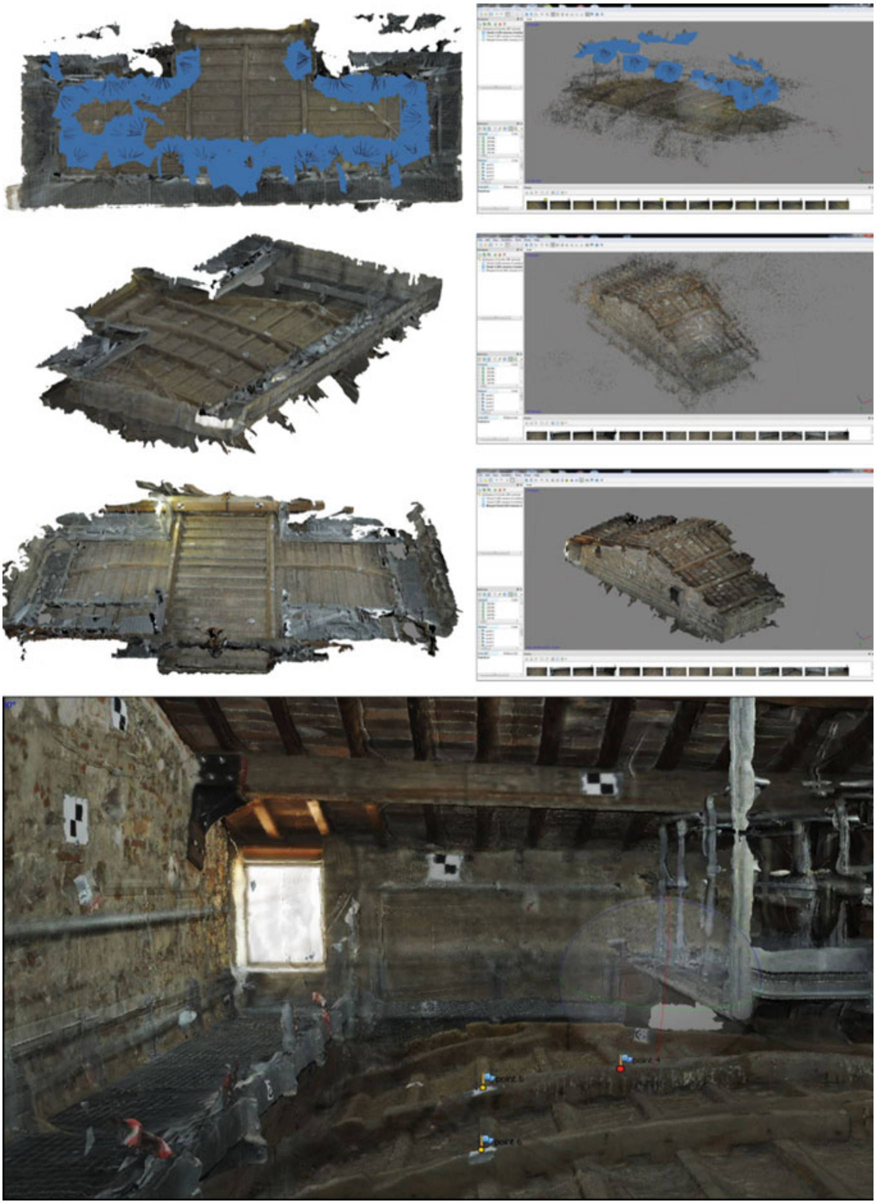

Fig. 14 Photogrammetric survey by PhotoScan software

photos related to the wooden structures, trusses and beams, we have used reference grids where "xi" identifies x-axis and "yi" y-axis. In this way, it was possible to locate precisely each element. For example, an entire truss is identified with an "xi"

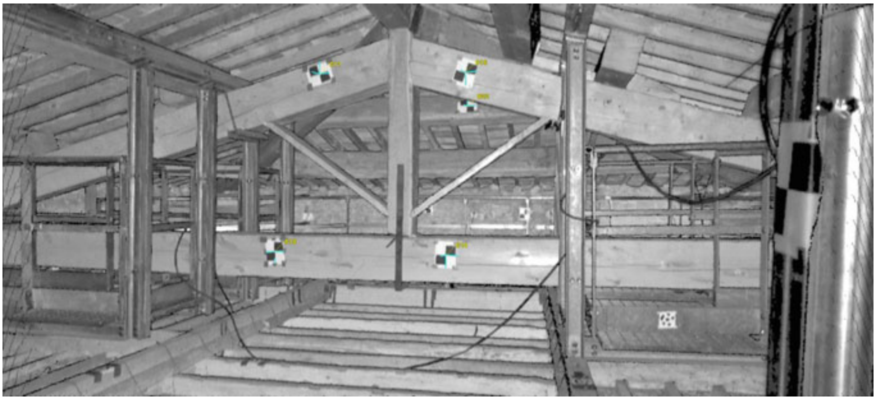

Fig. 15 View of the target system for the registration of the 3D point cloud

or = "yi" code depending on the warping direction, while a node or a joint is assigned an "xiyi" code.

After cataloging the metric information and processing data, it is possible to start the post production step. This step is devoted to the interpretation and representation of data by developing cross-comparisons for critical evaluations, among other techniques.

Computer Data Processing

The registration procedure and the testing elaboration on the point clouds constitute the first critical steps of data processing. Through implementation of the target system explained above, it was possible to merge several partial 3D scans to obtain a complete three-dimensional model of entire rooms and additional spaces. Testing is the final delicate phase, where the level of detail and accuracy of the registration phase are verified and quantified. In this phase, we strategically elaborate certain sections to ensure the absence of erroneous overlapping and roto-translations between partial ScanWorlds.[3] We then assess the level of detail exhibited by all parts of the point cloud in order to define the overall quality of the work done. The same check is performed at the end of the registration process, where complete sections are elaborated in both directions. With the Cyclone software package it is possible to use the "slice" function to obtain section profiles featured on the cutting plane selected. This option gives the surveyor an important digital instrument that enables verification of the quality of the registration process made. The final step is devoted to cleaning the point cloud from all elements of disturbance considered

[3]We define "ScanWorld" as the partial point cloud obtained from a single scan position.

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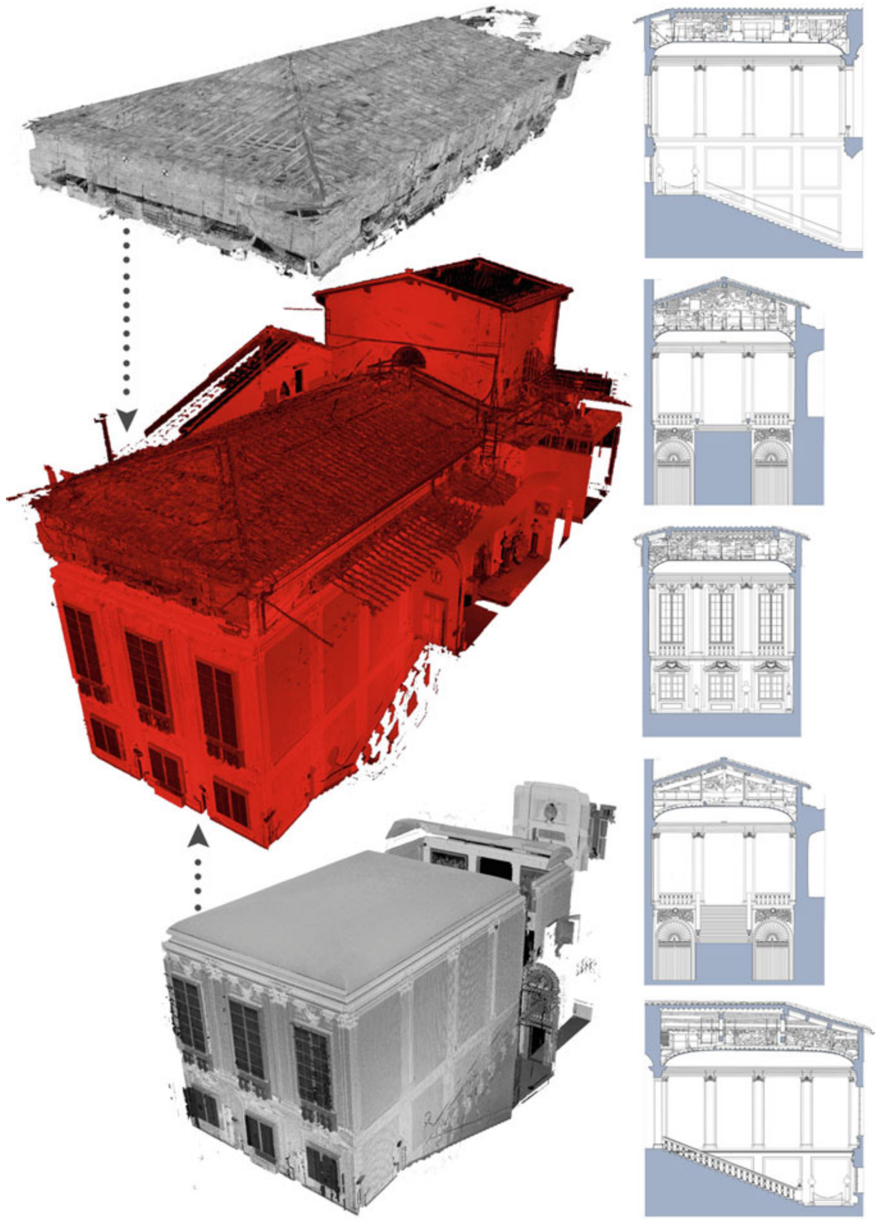

Fig. 16 Union of the extrados and intrados areas in the same reference system

"noise". This "noise" might disrupt measurement, the ability to understand the environment and elaboration of the technical drawings. The "noise" can be bundles or agglomerates of points generated by the instrument during the survey process.

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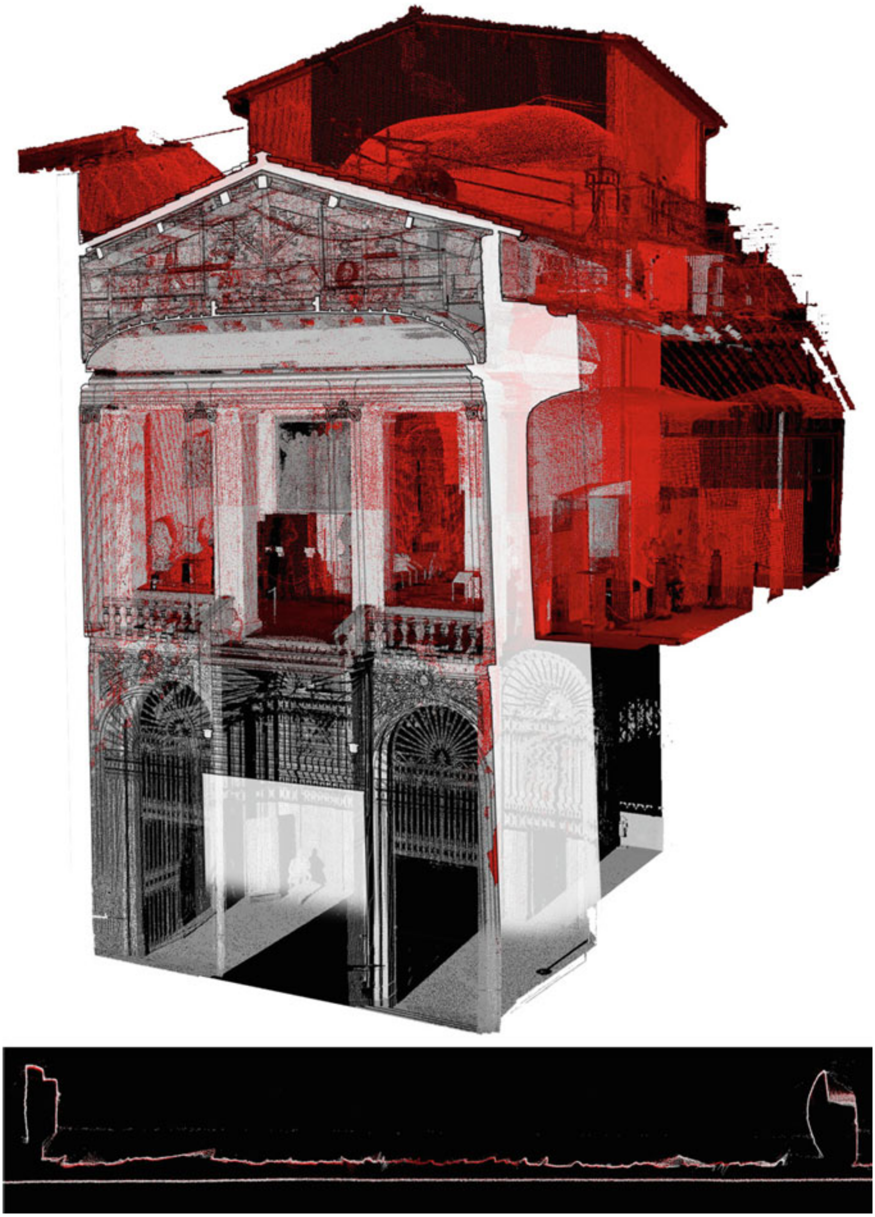

Fig. 17 Section of the staircase for verification of geometrical alignment

The main causes include the presence of surfaces that create reflections; dust in the air; and natural or artificial light that disturbs the pulsed laser light of the scanner, creating agglomerations of points and interference. In addition, operators and

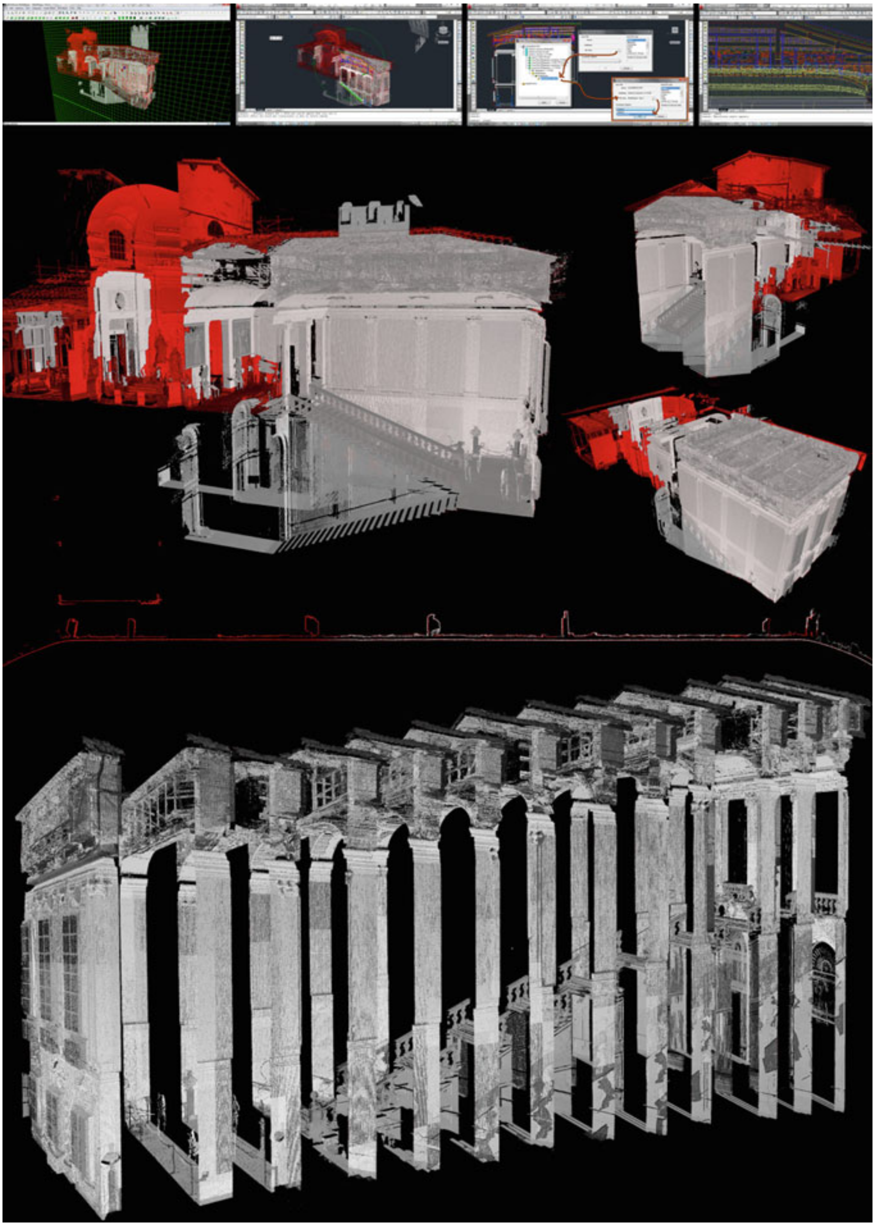

Fig. 18 Point cloud slice of the vault and cross sections

people in general present during the survey activities can create significant deflections. Furniture, supplies, temporary structures, such as scaffolding and platforms related to the construction site, and permanent instruments and equipment

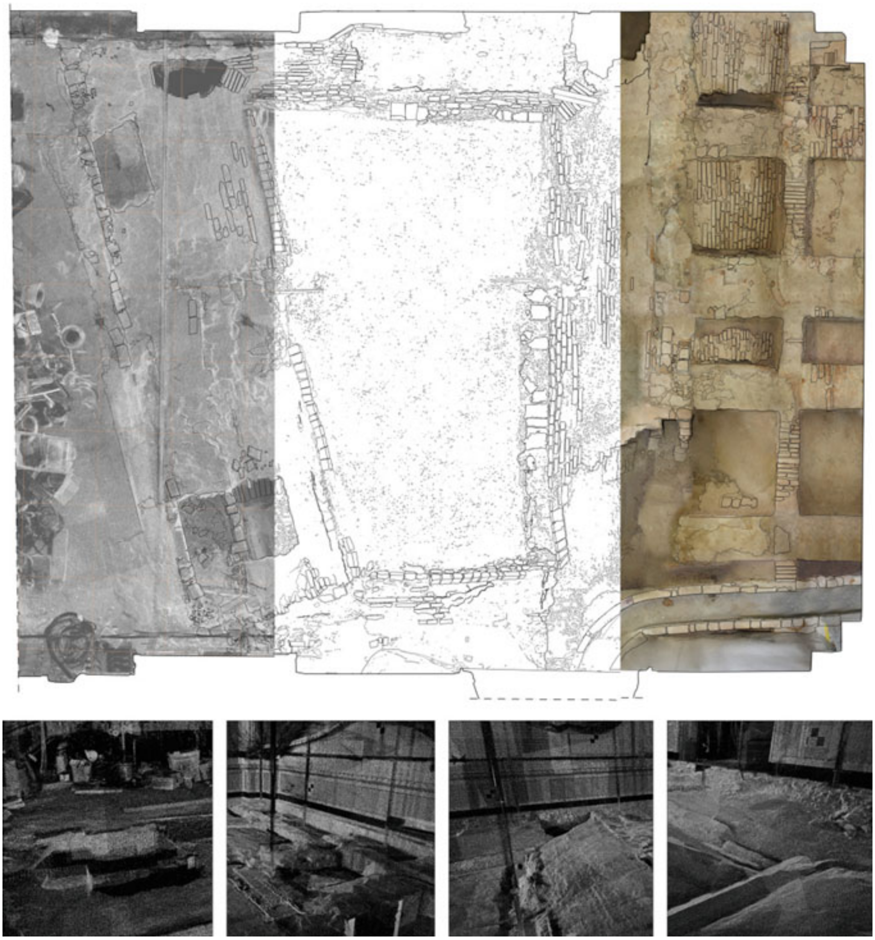

Fig. 19 Details of the graphic restitution: point cloud, wire frame drawing, photomap reconstruction

231 can emerge as disruptive elements. During post-production these disruptive ele-
232 ments are removed from the final point cloud. AQ1

233 ## Interpretation and Representation of Data

234 During the first phase of elaboration of data acquired, we developed all the
235 two-dimensional vector drawings. Specifically, we developed intrados and extrados
236 floor plans with metric dimensions (by using a reference horizontal plane or level
237 previously agreed upon with supervision of works), longitudinal sections, cross

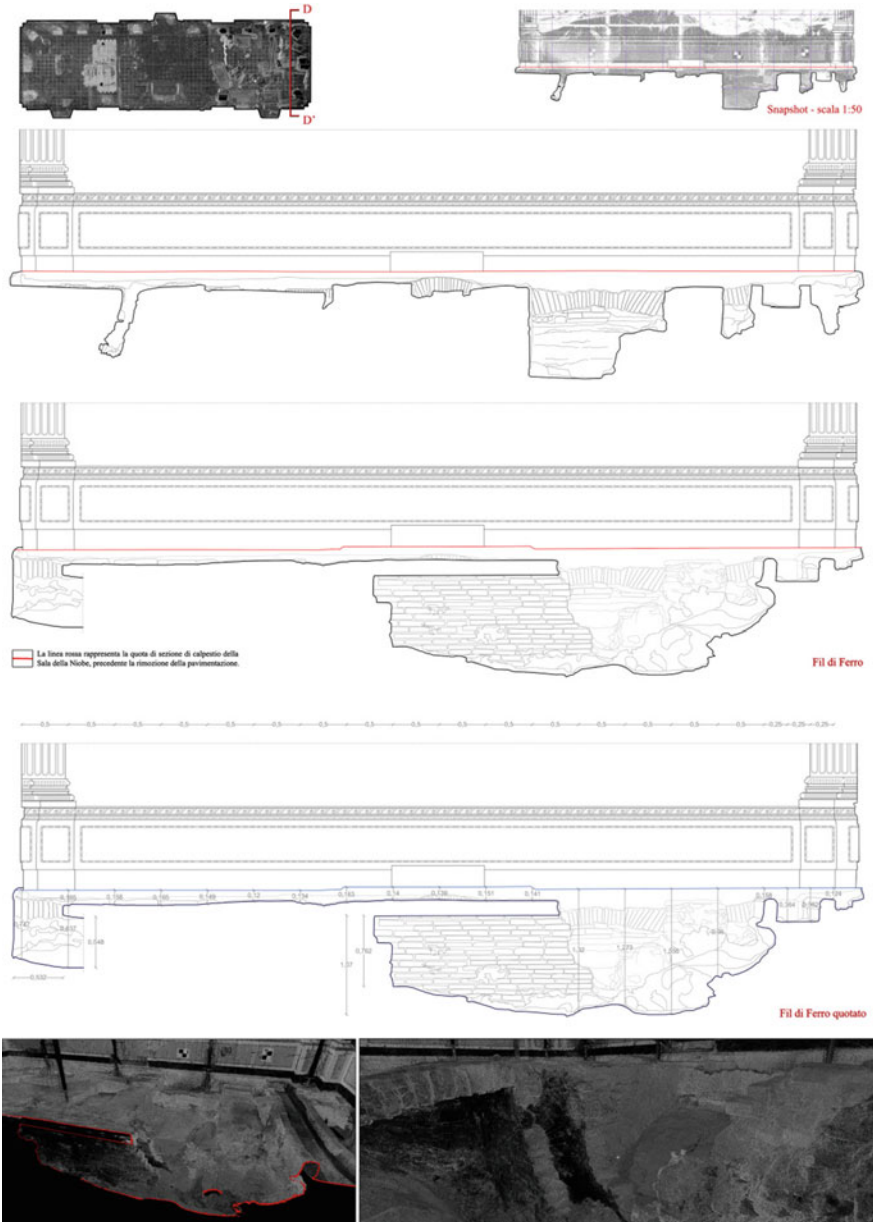

Fig. 20 Detail of the drawing of the excavation under the floor

sections, and progressive sections performed with a minimum constant dimensional interval of 5–10 cm. All CAD drawings were produced with a level of detail equal to the metric scale 1:10–1:5. Following the elaboration of the vector drawings,

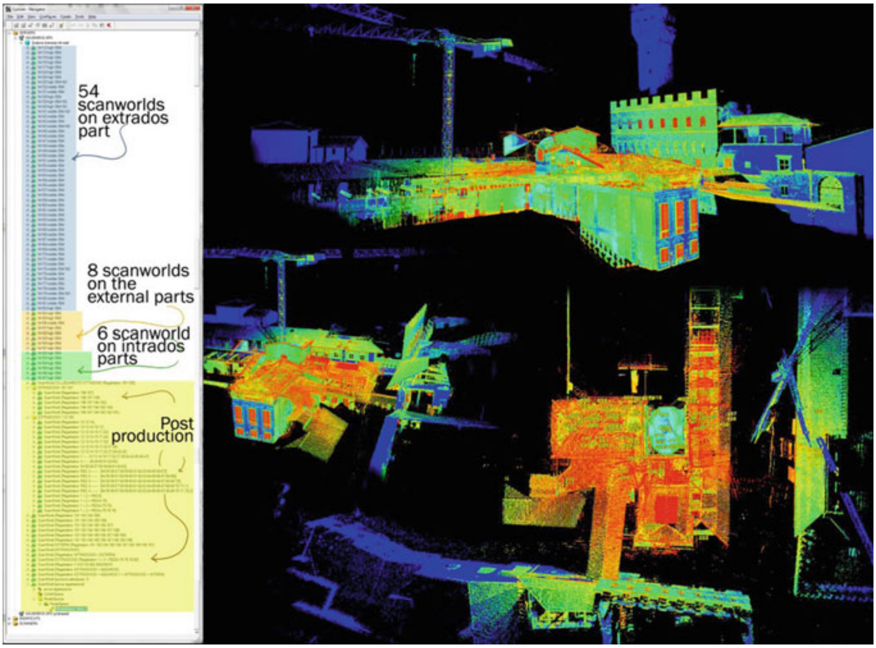

Fig. 21 The database organization of the laser scans uses a large system of reference for the general alignment and a close-range system for the alignment between the individual portions of the building

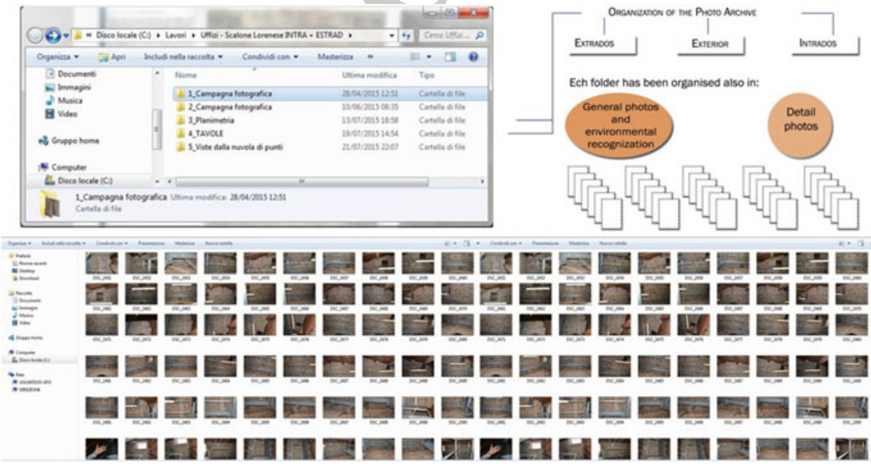

Fig. 22 Organization of the photo documentation

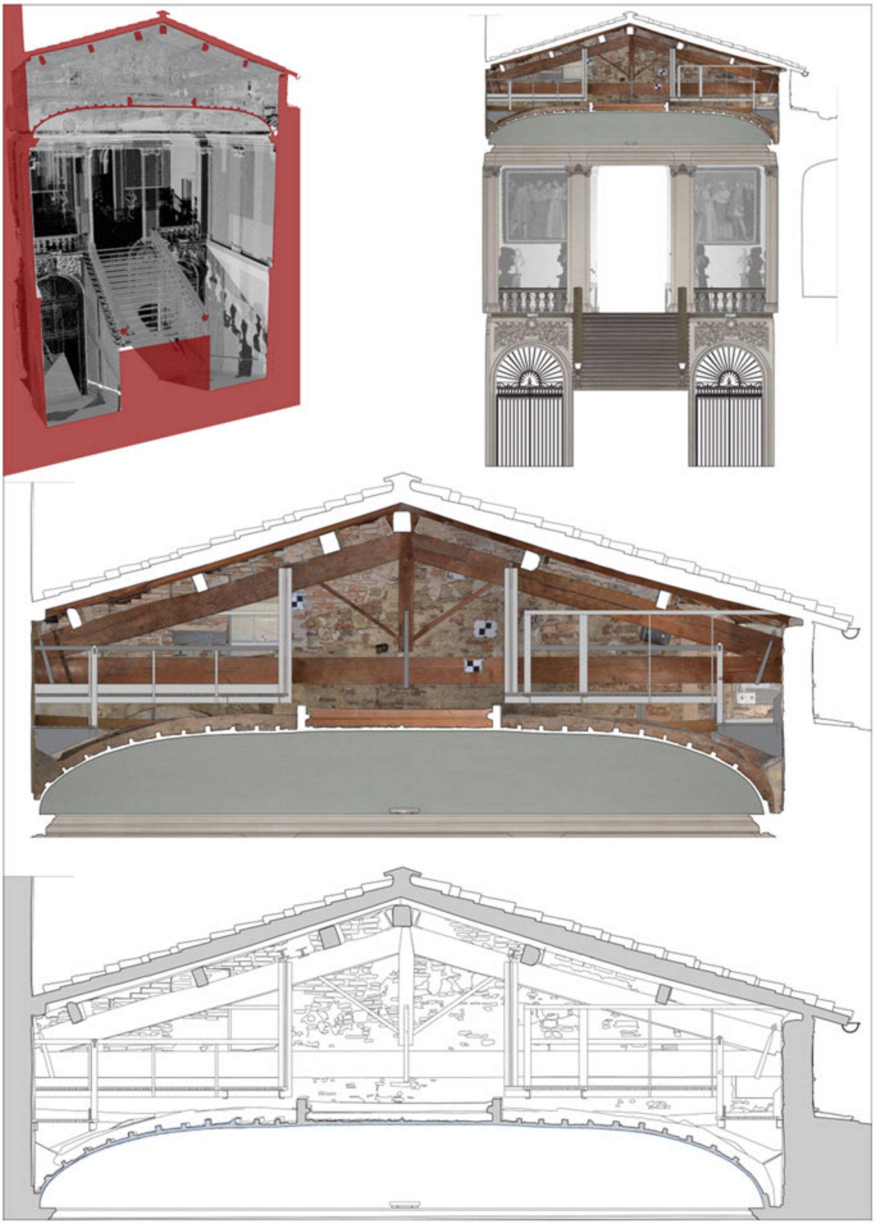

Fig. 23 Comparison between wire frame drawings and photomapping elaborations

241 ortho-photo planes were processed for the representation of each wall and façade.
242 This is necessary in order to obtain material for the realistic description of the rooms
243 and an updated recognition of each surface detected. The processing of ortho-photo

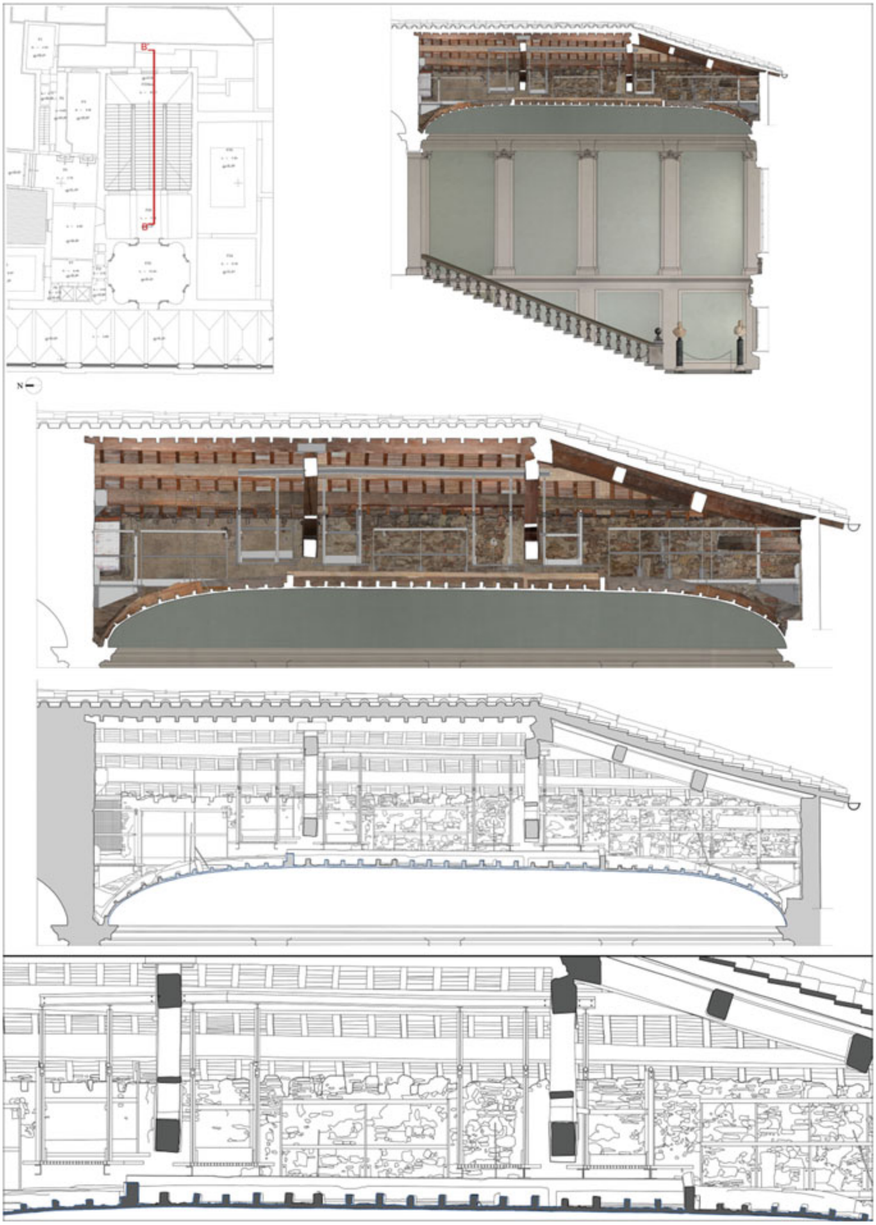

Fig. 24 Comparison between wire frame drawings and photomapping elaborations

planes is a more accurate way to perform the necessary deterioration mapping analysis for restoration and consolidation projects (Figs. 23 and 24).

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Images were acquired at very high resolution in "RAW + JPEG fine" mode in order to manage the balance and color correction during the post-production phase.

The high quality of the photo documentation used for the elaboration of the ortho-photos guaranteed great resolution for graphics printed up to a scale of 1:20–1:10. In some cases, the investigations carried out in the room of the Niobe being exemplary, processing the photo representations of the structurally ancient floor slab structures while the floor and underlying materials were removed presented an interesting opportunity to admire the original floor slab and its complex system of vaults. We have completed a laser scanner survey of this precious and unique architectural feature, and by doing so we have revealed an important descriptive graphic material that would not otherwise be visible without removing the upper structural layers.

Digital Models for the Simulation of Static Assessment and Virtual Applications for the Conclusive Survey Results

Following the development of two-dimensional vector drawings and vectors on CAD software, we proceeded to develop three-dimensional models for each survey phase directly from the point clouds (Fig. 25) using dedicated software capable of transforming the point cloud database in mesh models. This phase involved the most innovative experimentation, and this has made it possible to determine the optimal methods for facilitating the activities of a worksite as complex as the Uffizi Museum. We have documented all operating phases by analyzing the morphology of the structures using virtual simulation during the period concentrated on consolidating works. During the post-production phase, including the practical survey activities, the results were integrated to enhance the level of detail and the metric reliability of the research. For each phase of monitoring and analysis, 3D models were produced directly from the point cloud database. This intricate operation was performed using *Rapidform* software (Fig. 26). This software has several commands and toolbars that enable the necessary corrections to the processed three-dimensional models. These corrections preserve the metric reliability of the point cloud, but at the same time they generate mesh models in which walls, vaults and floors are represented by continuous closed surfaces.

Where the data provided by the point cloud were found to be insufficient, we combined the information with direct measures, either by comparison with the intensive photo documentation or with the support of the photo-modeling activities. After the predetermined phases of monitoring were performed, the individual 3D models related to a single room or a group of rooms, but descriptive of different work phases, were overlapped by use of the same reference system (UCS) to identify potential deviations between surfaces. These deviations are identified by the software through the geometric analysis algorithm by the "deviation parameters" registered along the three directions X, Y and Z.

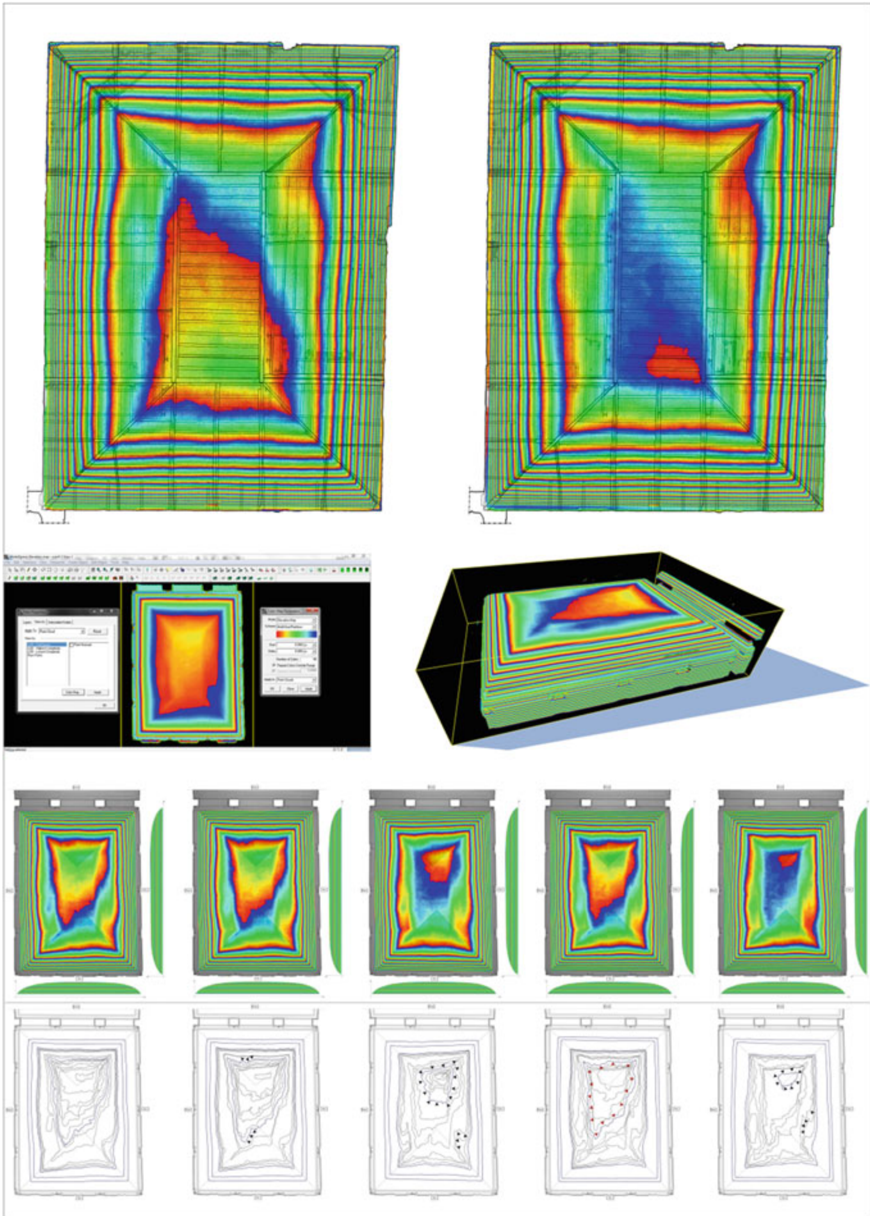

Fig. 25 Elevation map calculated on each point cloud of the studied vault. The geometry of colors shows a deformation and a collapse. Drawings show the results of the five surveys of the vault conducted over two years

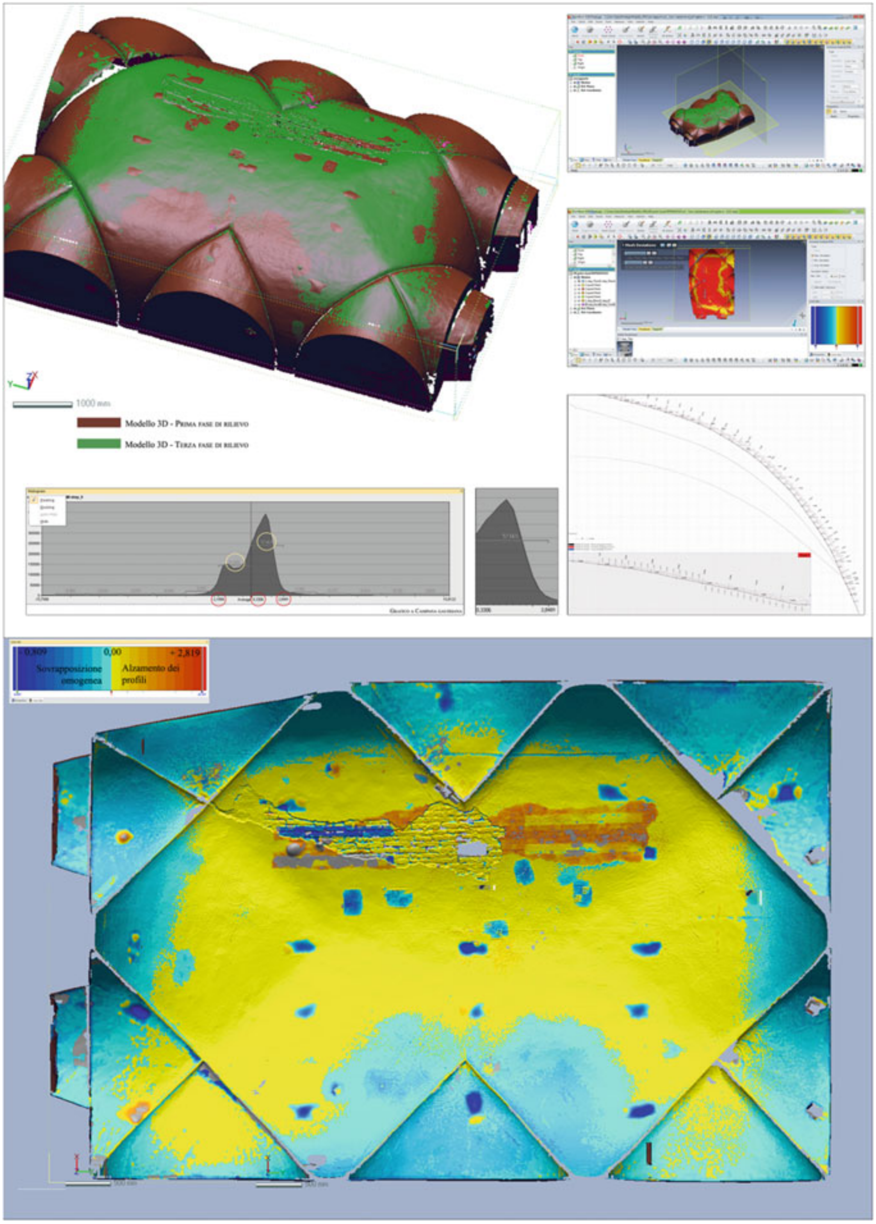

Fig. 26 Mesh model for verification of the most deformed areas through the overlapping of different 3D models

The same surface represented and documented with a different surface development demonstrates that in the period between successive laser scanner campaigns, the structure suffered sensitive movements. The *Rapidform* program and related software can quantify the value of this data element. The level of detail and metric reliability ensures the ability to switch between processing parameters. These parameters include the tolerance for instrumental error exhibited by the laser scanner, and the absolute error verified at the end of the point cloud registration process, during alignment of the partial point clouds. The software not only allows the direct calculation of various deformations of the processed point cloud, but it also offers, during the final synthesis and comparison step, the opportunity to represent this metric information along with statistics obtained through graphics and Gaussian curves.

The results of calculations have identified the maximum deviation measured over the entire three-dimensional model, where the maximum deviation value is defined by the overlapping of different three-dimensional models.

Thanks to these charts and models, it has been extremely easy to share the results with the technicians and experts, and it has had an immediate impact on the critical interpretation of numerical percentages of the dimensional deviations registered. This data has provided engineering managers critical elements to consider when designing the most appropriate intervention strategies.

Conclusions on the Research Experience

This research, which has been under way at the Uffizi Museum since 2010, has contributed significantly to the technical needs of the construction site and to this field of scientific research in general. We have applied technical laser scanner methods in addition to experiments with integrated systems. At the same time, we have tested new software elevating the state of art with respect to the dynamic management of point clouds.

Over the course of the past six years, we have conducted a wide survey on approximately ten rooms, each of which is characterized by unique architectural characteristics, including the morphology and the presence of usable or unusable floor slabs, precious vaulted roofs, and wooden truss systems (as was the case for the Botticelli Room or for the extrados room above the main access of the Scalone Lorenese stairs leading to the Vasari Gallery).

Survey procedures have also identified different intervention strategies for planning and executing the activities based on the location of the rooms studied and the ease or difficulty in accessing the connecting areas. Throughout these studies, we have explored operational methodologies for data acquisition and post-production information handling. This has enabled the exploration of new techniques and has significantly reduced the magnitude of procedural operational errors.

In all point clouds produced and registered by different software programs, a consistently high level of metric reliability was maintained, with minimal dimensional error. This was confirmed via parallel tests carried out by technical engineers at the worksite whose responsibility is monitoring the reinforcements and consolidation solutions introduced in various rooms that we analyzed.

The photographic documentation was expanded, in the case of both orthophoto image processing and the realization of 3D models through photo-modeling activities. The use of professional digital cameras and their associated software in post-production allowed us to obtain highly realistic mapped models that depict the natural colors of the plastered or painted walls of the wooden and masonry structures documented. The photo campaigns have also enabled documentation of areas that are no longer visible. For instance, the floor structure in brick vaults of the Niobe room is presently covered with the original restored floor. The massive structure of wooden trusses present in the Botticelli room defines another example: it is presently hidden by the ceiling system required for placement of the air conditioning designed for the renovated room.

It has been necessary to enhance vector drawings by the use of more suitable graphic tools and to interpret the symbol system to which we transfer the metric information on the two-dimensional drawings. This has increased the readability of comparisons between the same architectural sections that are composed of the sectional profiles related to the different time periods. The investigations have produced transverse and longitudinal sections, with scales of 1:20–1:25, accompanied by detailed drawings with scales of 1:10–1:5 for representation of specific portions with obvious deformations. Along these lines, we have integrated enhanced processing techniques for the progressive sections, and this has made it possible to obtain a series of parallel sections characterized by minimal range. With these kinds of technical drawings it is possible to check on the morphology of the architectural structures in detail. This procedure has given rise to valuable results during analysis of Room F61 and its adjacent rooms. This room was characterized by the presence of a vaulted structural floor which contained a “false wall” that compressed the stability of the vault itself, thereby compromising the static assessment of the whole structure. In this case, the progressive sections have enabled technicians to identify the points at which the wall has further impaired the vaulted structure, as well as parts of the vault that have already started to show signs of structural failure. These technical drawings have made it possible to act quickly on the damaged wall and reinforce the vault at specific points.

In the framework of this research project, the implementation of reverse engineering activities has strengthened the technique of 3D modeling directly from the point cloud. By increasing the potential of the tested software, we have strengthened the operational techniques that allow one to overlap 3D models derived from each phase of the work and elaborate calculations of the deviations for evaluation of the dimensional differences. The integration of different detection techniques has also aided the post-production phase, specifically through the integration of the results from new methods of technical documentation, which is critical for supporting a site as complex as the Uffizi Museum.

In this research project, we have implemented and updated specific documentation for a monumental system, and we have produced analytical methods for the prevention of seismic risk by monitoring the structural conditions of different construction systems. Considering the numerous threats to our cultural heritage today, this represents an invaluable procedure. Digital technologies provide experts a precious opportunity to know and work on the architectural heritage with the delicacy required for preservation of heritage. It is currently essential to improve innovative systems by way of constant experimentation.

Restoration and structural consolidation provide a unique challenge for the scientific field that derives from the infinite complexity of historical architecture. Drawing—especially the architectural drawing germane to this study—remains the main method for governing technology and controlling digital processes which, in the representation of the image, create results arising due to the application of complex and advanced technology, equipment and methods. The representation of vaulted systems, monumental halls, stairways and wooden structures at the Uffizi Museum has given rise to precious updated historical documents. It has been possible to represent the condition of one of the most historical Florentine buildings, a building that constitutes one of the most important contemporary restoration sites in Florence. From an academic point of view, this experience has also led to improved methodologies for the study of historical architecture. This experience should serve as a starting point for further application of three-dimensional data banks for the preservation, management and understanding of architecture.

Credits Sandro Parrinello wrote the introduction and chapters: 1, Research approach and development of operational methodologies; 2.2, Interpretation and representation of data; 3, Conclusions on the research experience.

Sara Porzilli wrote chapters: 1.1, The integrated survey project; 2, Data storage management for the post-production phase; 2.1, Computer data processing; 2.3, Digital models for the simulation of static assessment and virtual applications for the conclusive survey results.

The reference list is limited to main works for further reading and to author’s main experiences. Citation of references has not included in the text since space limits.

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