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THE INTERACTION OF KNOWLEDGE AS THOUGH FIELD EXPERIMENTATION OF THE INTEGRATED SURVEY. THE CASE OF SACRISTY OF FRANCESCO SOLIMENA IN THE CHURCH OF SAN PAOLO MAGGIORE IN NAPLES

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Abstract

The use of advanced integrated survey techniques has allowed the acquisition of morphometric and colorimetric information to render three-dimensionally the frescoes by Francesco Solimena in the sacristy of san Paolo Maggiore in Naples. The research has explored different levels of knowledge by applying the necessary integration between consolidated knowledge and innovative technologies: combining innovative aspects of range-based modeling method and image-based modeling method, we created returnable models that can also be questioned remotely. The outcome is a contribution aimed at protection and enhancement of the cultural heritage, favoring conservation and restoration interventions as well as providing a permanent query of data and their complete use.

Keywords

3D laser scanner, range-based, image-based, san Paolo Maggiore, Solimena

1. Introduction

The present paper represents the results of a research work conducted on the architecture and pictorial apparatuses of the sacristy of the church of san Paolo Maggiore in Naples[1].

The interrelated actions of reading and retrieval of data have resorted to advanced techniques of integrated survey that have allowed to acquire morphometric and colorimetric data of the artifact, returning, through high quality processing and detailed control of the data taken, the spatial configuration of the sacristy architecture in a series of projections that, perhaps for the first time, represent the famous frescoes by Francesco Solimena inserted in their three-dimensional dimension.

This documentation, in addition to establishing a field of possible new questions on the work, offers valuable contributions for restoration, management, enhancement and use even remotely with the use of a dedicated web platform.

2. The church of san Paolo Maggiore

"Arrivati nella chiesa di San Paolo vedesi la lagrimosa ruina, cagionata dall'horrendo tremuoto accaduto a' 5 di giugno dell'anno 1688, della più bella et antica macchina ch'havevamo nella nostra città. Machina che era di meraviglia a' forestieri, e di gran decoro alla nostra patria […]" (Celano, 1692)[2].

The architectural 'Machina' of which Celano writes is the majestic Basilica of san Paolo Maggiore, erected on the podium of the temple of the Dioscuri of the first century after Christ[3], between the end of the VIII and the beginning of the IX century.

The church is dedicated to Saint Paul in memory of two important victories against the

[1] This introductory part referring to the church of san Paolo Maggiore, as well as that concerning the sacristy of Solimena, in virtue of the vast and qualified literature existing on these themes is actually an anthological reworking that draws direct reference from the writings of some of these texts.

[2] We refer to the earthquake of 1688 and the effects on the church of san Paolo, defined as the most beautiful and ancient 'machine' of the city of Naples.

[3] "With an emerging position [...] it stood here, with the south-facing front and the underlying square, the Dioscuri temple, [...] built [...] on an older one, as the two construction phases attest, a previous one in ' square work ', and one from the Tiberian era, in' reticulated work" (Cautela, 1994).

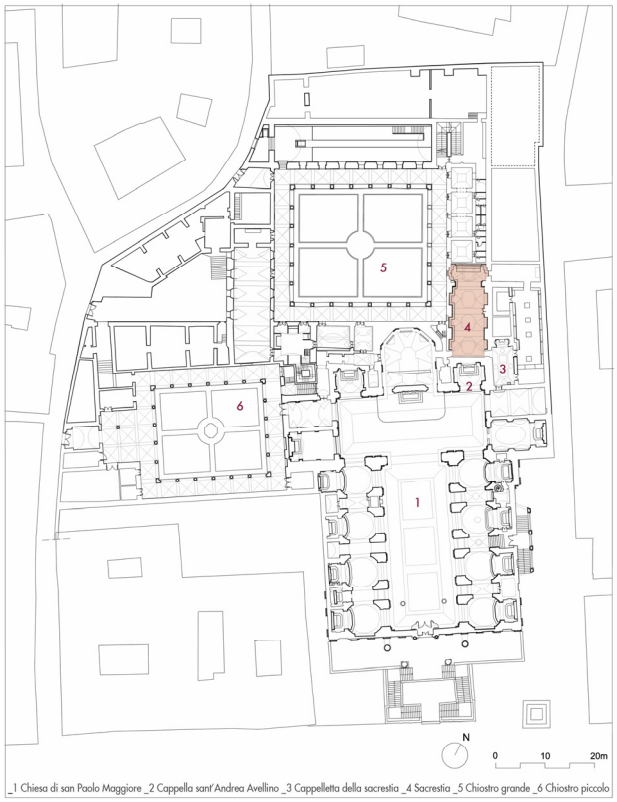

Fig. 1: Plan of san Paolo Maggiore, 2013.

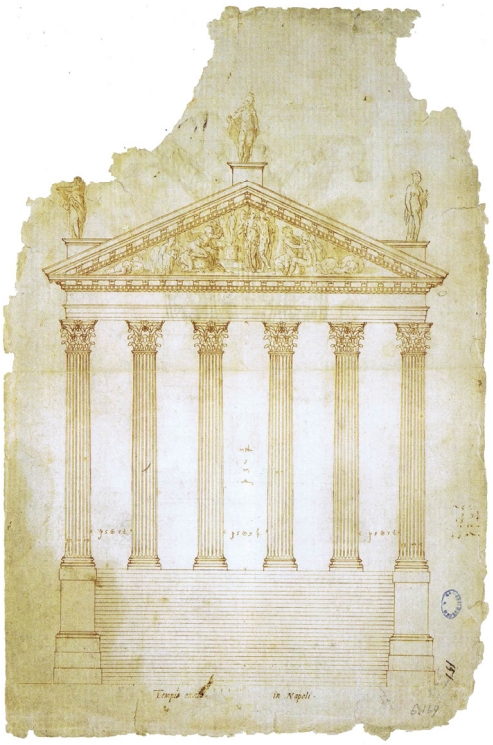

Fig. 2: Andrea Palladio, *Elevation of the Dioscuri temple in Naples* (Stoccolma, National Museum, Harleman Collection THS6169 recto.

Saracens, in 788 and 789, both achieved in days destined for his cult.

"In questo luogo, ne' tempi che Napoli era città greca, fu edificato presso del publico Teatro un famoso tempio a Castore e Polluce […].

Di questo gran tempio […] vi era rimasto il prospetto o vogliam dire l'atrio scoverto, essendo che mostrava di non haver mai sostenuto né volta né travi.

Era questo formato da otto colonne d'ordine corintio scannellate, sei di fronte e due ne' lati delle volte, una per parte. […] Sopra di dette colonne vi si posava un grande architrave con un meraviglioso cornicione, e nel freggio di questo vi stava in greco intagliata ad ampie lettere l'inscrittione […]. Su di questo cornicione erigeasi un gran timpano, similmente incorniciato come sotto, e nel piano di questo, che era in triangolo, vi erano egregiamente scolpite […] figure a mezzo rilievo. (Celano, 1692)[4]. The church, located on the high staircase of the temple[5], divided into three naves with eighteen bare stone columns, completely preserved the pronaos of the temple at the façade, leaving space for a small garden that was later used as a cemetery[6].

The ancient early Christian basilica was granted, by direct intervention of the viceroy Pedro de Toledo, thanks to the intercession of Cardinal Vincenzo Carafa, in 1538, now in a condition of extreme degradation, to the Theatine fathers who arrived in Naples in 1533 with their founder Gaetano Thiene.

Thus began a series of interventions such as restoration work, the insertion of the cemetery in the front garden and the rebuilding of the access stairway and its delimitation.

[4] Here Celano describes the temple of the Dioscuri and the subsequent transformation into an early Christian church dedicated to the apostles Peter and Paul, providing a detailed reading of the architectural elements.

[5] "Until 1576 the access to the ruins of the temple, and from here to the church, took place through a stairway of thirty-six steps that occupied the whole width of the pronaos –about eighteen meters- and dated back to the time of construction of the temple" (Lenzo, 2011; p. 112).

[6] "The temple attracted the attention of illustrious architects such as Giuliano da Sangallo and Palladio and, furthermore, it must have been very well known among the humanists if it could even be plausible the hypothesis that Leon Battista Alberti had borrowed from the Greek inscription on the trabeation in the Tempio malatestiano" (Di Mauro, 1994).

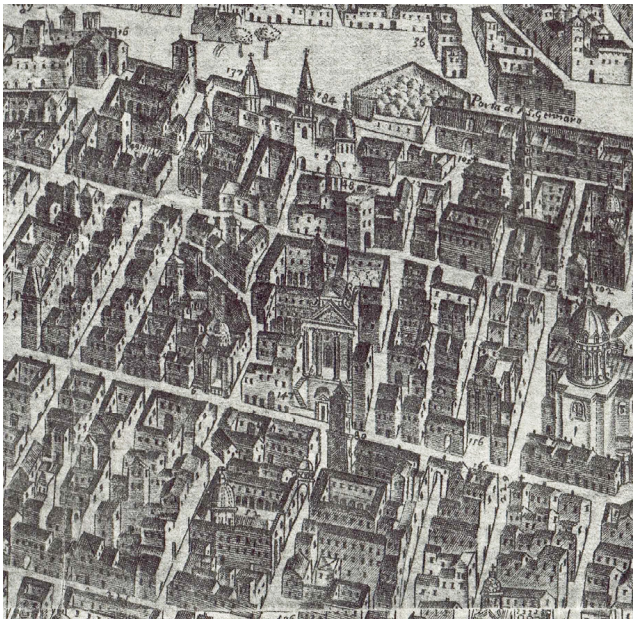

Fig. 3: Alessandro Baratta, *Fidelissimae urbis neapolitana cum omnibus viis accurata et nova delenatio*, 1629. Detail of the convent of san Paolo Maggiore 147.

The Theatine fathers in 1576, in particular, decided to build a new staircase that facilitated the ascent to the temple and at the same time became a new urban element that radically altered both the facade of the church, the street of the Tribunali and the square of the Mercato Vecchio, actually starting the Theatine conquest of the san Paolo *insula*. "The present scale [...] in piperno with marble balusters, was rebuilt in 1715 by Francesco Solimena, but follows the forms of the previous one, although it was made with different materials: in fact [...] for that built in 1576 they had been re-used the marbles of the ancient staircase of the temple of the Dioscuri" (Lenzo, 2011). In 1578 the church was dedicated to the two "Dioscuri" of Christianity the saints Pietro and Paolo and between 1581 and 1603 (Lenzo, 2011) a project of overall reconstruction of the ancient church was started on "[…] disegno del di loro padre don Francesco Grimaldi nell'anno 1591 si vide non solo ridotta nella forma che hoggi sta, ma preziosamente abbellita et arricchita di nobilissima soppellettile che forse non ve n'è pari" (Celano, 1692)[7].

The work preserved the pronaos of the pagan temple whose capitals probably served as a reference for those in the pilasters of the facade of the seventeenth-century church. However the pronaos collapsed ruinously with the earthquake of 1688 almost certainly due to the work of a daring connection wanted by Dionisio Lazzari in 1671 between the ancient structures and those of the modern religious building.

"È da sapersi che nel volersi celebrare la canonizatione […] del beato Caetano i padri vollero abbellire la facciata della chiesa […] et unirla a così maestoso frontispitio. L'architetto ordinò una volta appoggiandola al muro della nova chiesa et al cornicione delle colonne sudette, né curò di ben incatenarla alla muraglia già detta […]. Nella notte delli 24 d'aprile del 1687 fu un gagliardo tremuoto che scosse la volta su detta […]. cadde la volta, e battendo a quattro colonne le fece andar giù con tutta la macchina che vi stava di sopra […]" (Celano, 1692)[8].

Celano reports the presence of four columns in 1692, while some years later, in 1712, it was decided to leave only two with the bases of two others, as it is in its present condition.

The works, following the departure of Francesco Grimaldi for Rome, were continued in 1589 "[...] by Giovan Battista Cavagna to whom we owe the central nave and the façade, damaged by the earthquake of 1688" (Stendardo, 1997).

The façade designed by Cavagna developed on two levels, being the church much taller than the pronaos of the temple, although the upper level was invisible from the street because it was almost completely hidden by the pediment of the temple. However, the current façade is the result of further changes that have taken place since the seventies of the seventeenth century until the late eighteenth century (Lenzo, 2011).

The church, despite its consecration in 1603, was not yet completed and was affected by further work: "[...] between 1626 and 1630, present the architect Giovan Giacomo di Conforto to whom we owe the aisles; in 1635 he was engaged in work by Pietro de Marino. In 1671 the works related to the celebrations for the canonization of the founder St. Gaetano are interested [...] Dionisio Lazzari, Arcangelo Guglielmelli [...]. The façade of the church [...] partially compromised by the earthquake of 1688, was partially modified in

[7] From Celano: it is in fact the attribution of the architectural project of overall reconstruction of the church between 1581 and 1603 to the father Francesco Grimaldi.

[8] In this passage Celano refers to the intervention of transformation of the church and its connection to the frontispiece of the temple with a vault [by the architect Dionisio Lazzari]; the vault, however, was not correctly inserted, from the structural point of view, to the existing wall face, so as to cause the collapse of the vault itself and four columns, following the earthquake of 1688.

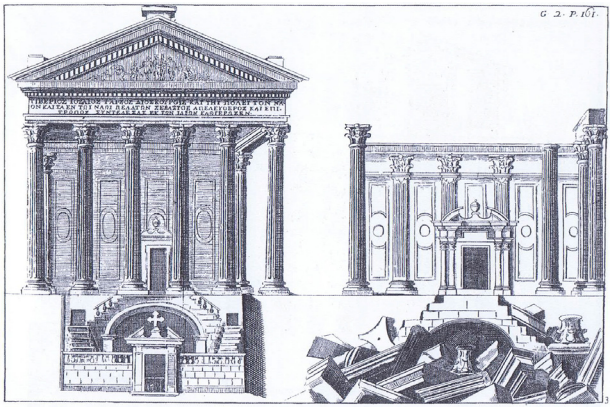

Fig. 4: Arcangelo Guglielmelli, *Elevation of san Paolo Maggiore before and after the earthquake of the 1688* (by Celano, *Notizie del bello*, 1692).

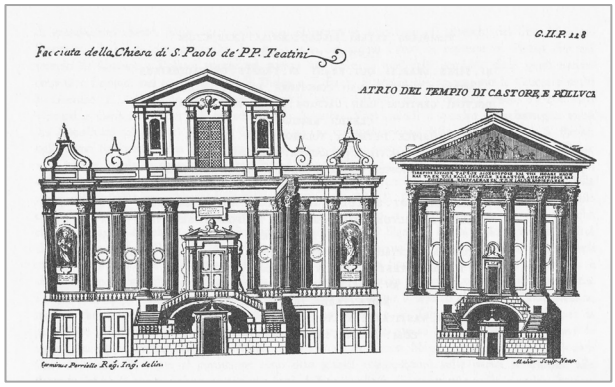

Fig. 5: Andrea Magliar on drawing by Carmine Perriello, *Elevation of san Paolo Maggiore in 1724* (by Celano, *Notizie del bello*, editing 1724).

1773-74 by works executed on a design by Giuseppe Astarita" (Di Mauro, 1994).

The interior has a Latin cross with three naves, with the adoption of the Albertian motif of the rhythmic girder; the central nave and the transept have a lowered pavilion roof, while the aisles are characterized by the presence of chapels vaulted with a succession of elliptical domes.

3. The sacristy of Francesco Solimena

The sacristy is located at the end of one of the side aisles at the chapel of Sant'Andrea Avellino, in a lateral position with respect to the apse and flanked by one side of the large cloister; it is accessed via a small door on the wall to the right of the apse, behind the main altar.

"Nella parte dell'Epistola vi è la porta della sacristia. […] Sta ella dipinta nobilmente a fresco dal nostro Francesco Solimena. Nella cappelletta di detta sacristia vi è una copia ben fatta del quadro, forse dei più belli che fece il gran Rafaello d'Urbino, che stava situato nella chiesa di San Domenico e che poi è stato trasportato altrove" (Celano, 1692)[9].

The construction history of the sacristy is not entirely known. Certainly we know that it was characterized by numerous redefinitions of architectural spaces due to the continuous adaptation with the surrounding buildings (Lenzo, 2011). Certainly the sacristy of san Paolo represents the culmination of the process of stylistic embellishment achieved by Francesco Solimena, a very high level of reached maturity through visual and qualitative rendering to which it had arrived thanks to a careful and wise dosage of the examples of 'doing baroque': from the naturalistic matrix of Giovanni Lanfranco to the coloristic openings of Luca Giordano up to the neo-Venetian riches of Pietro da Cortona, thanks to which the Solimena illuminated the dark plasticism of Mattia Preti.

At the cycle of frescoes Francesco Solimena probably worked already before 1689, the year in which a payment was registered by Don Giovanni Pietro Carafa to complete "the painting of the sacristy of sanPaolo Maggiore" (Wiedman, 1994); in the same year the artist signs the fresco with the scene of the *Conversione di Saul* (san Paolo) and the following, 1690, the fresco with the *Caduta di Simon Mago*.

The choice of subjects that occupy the two small walls of the sacristy (Di Mauro, 2008), was indicated to the painter by the Theatine fathers to celebrate St. Peter and St. Paul. "The iconography of the Conversion of St. Paul follows the description of the event as [...] reported by the "*Atti degli Apostoli*": St. Paul falls from a horse blinded by divine light. The figure of Simon Magus is also introduced in the "*Atti degli Apostoli*", but year the scene of the Caduta di Simon Mago, who tries to give proof of his magic by flying and is knocked down by the presence of san Pietro, [...] is an iconography rather rare" [...]"(Wiedman, 1994). The entire pictorial cycle is attributable to a complex theological program desired by the

[9] Celano writes briefly about the frescoes in the sacristy, praising the work of Solimena and dwells on a copy of a painting by Raffaello placed inside the chapel of the sacristy.

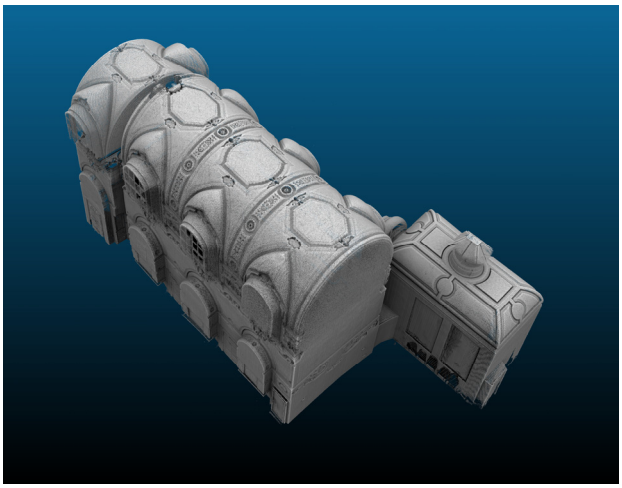

Fig. 6: Reconstruction through elaboration of point cloud of the interior of the sacristy and the chapel of san Paolo Maggiore from TLS point cloud.

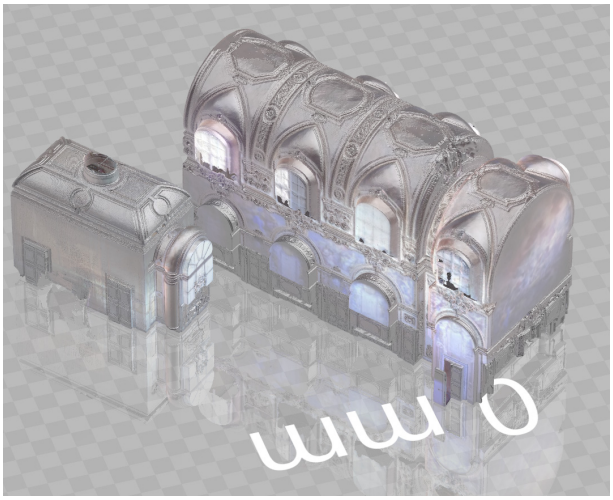

Fig. 7: Reconstruction of the internal space 'in transparency' of the sacristy and the chapel of san Paolo Maggiore from TLS points cloud.

Theatines, in particular by Tommaso Carafa: for the representation of *Virtù* painted in the vault, in compliance with rigorous criteria that could allude to the qualities and merits of the founding fathers, the reference is the *Iconologia* of Cesare Ripa; while for the scenes on the walls and for the images of the founders of the Order the painter makes use of texts of the Theatine fathers, in particular for the portraits of San Gaetano da Thiene, Paolo IV, Bonifacio de Collis and Paolo Conciliariis, Solimena redone at engravings present on the frontispiece of the volume by Giovan Battista del Tufo (Del Tufo, 1609).

In particular, Bologna describes the frescoes by Solimena: "[...] the [...] power of imagination, infused in the most radiant daylight, flows into the great fact of the Sacristy of san Paolo Maggiore, where the poetic possibilities of the master they rise to such a degree, and with such an ability to repent and grow, to let the work of the Giordano (Bologna, 1958) also be discolored, at least for some lines". For these works De 'Dominici between, the other, states that: "[...] similar perfection in painting in fresco has never been seen in the past, and in modern Painters, nor similar beauty of color, nobility of semblants [...] diversity in physiognomies [...]. It is not enough to describe the perfection of these excellent paintings" (De' Dominici, 1742).

A happy reading of the expressive power of the pictorial cycle of the sacristy is, moreover, in the words of Vincenzo Pacelli: "Scholars agree that in the two great scenes on the back walls with the *caduta di Simon Mago*[10] and the *la conversione di Saulo sulla via di Damasco*, sumptuous and magniloquent, full of impetus and passion as rubensian canvases, Solimena realizes a dramatic baroque in the tumult of forms and, instead, moments of widespread lyricism made of levity and chromatic tenderness in the side scenes of the "virtues"[11] in assonance to the most daring inventions of lighter Baroque as it was being made elsewhere by Gaulli, by Father Pozzo or by De Ferrari" (Pacelli, 1994).

As regards the iconographic references contained in the vault and in the side walls, the careful and detailed description of the scenes provided by the Galante is used (as indicated in the caption of Fig. 8) (Galante, 1872).

4. Planning and choice of methodology

The objective of the research activity, as stated above, has aimed at a scrupulous work of collecting data to respond to the need to return rigorous orthographic representations of the constituent parts of the sacristy, the vault, the longitudinal and transverse walls, but at the same

[10] "It should also be noted that the painter depicted himself in the fresco of the Fall of Simon Magus (the character facing us on the extreme right) and that, for the stucco work in the vault, with faces of putti [...] he made use of [...] of the collaboration of the sculptor and silversmith friend Lorenzo Vaccaro, defined significantly by De Dominici [...] «il Solimena della scultura»" (Di Mauro, 20018).

[11] "The main interest obviously inspired the frescoes with the *Virtù* in the pendentives, made known for example also in the prints executed by the drawings of Fragonard" (Wiedman, 1994).

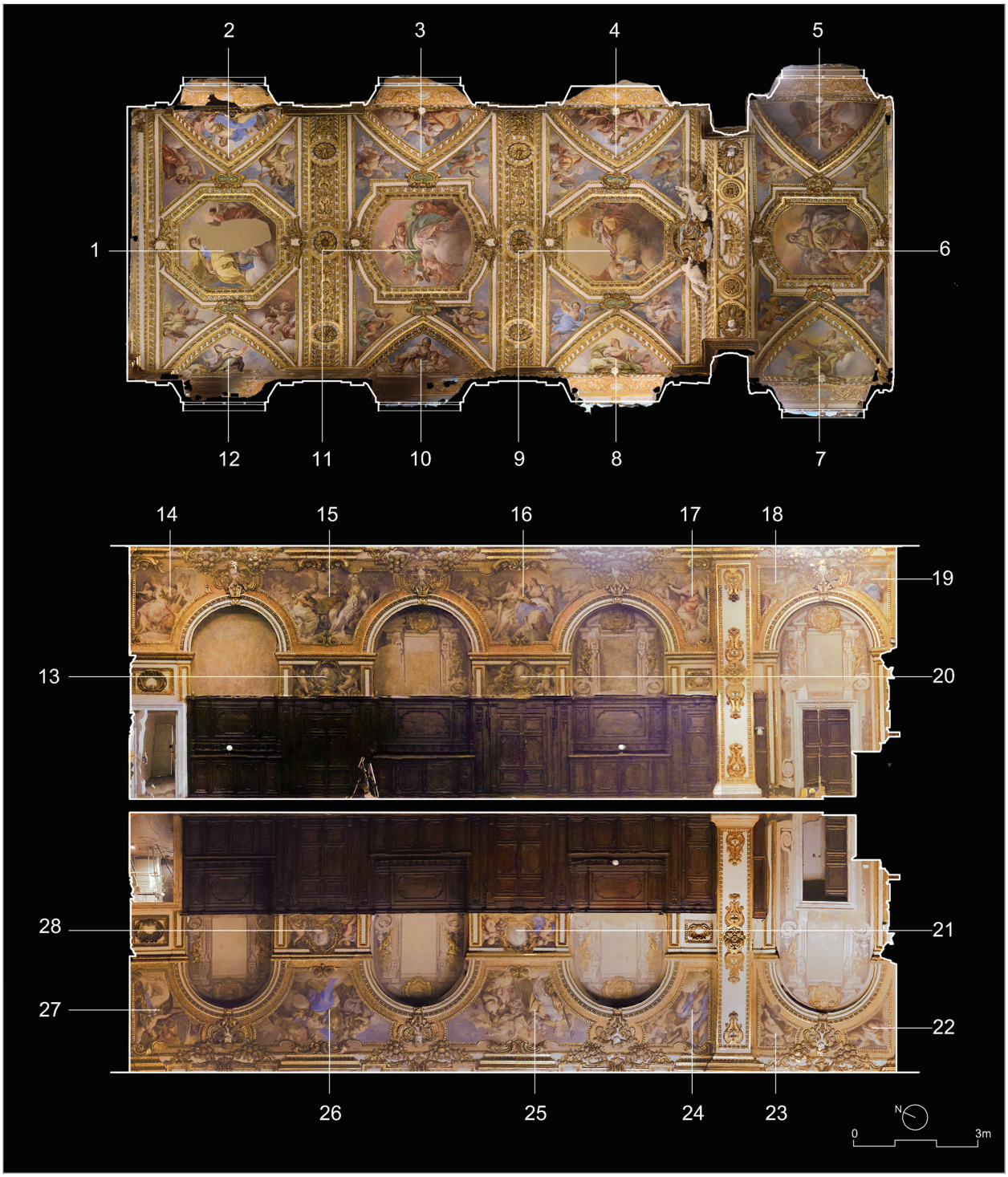

Fig. 8: Sacristy of san Paolo Maggiore, ipografia and elevation with description of the frescos. The vault with two lateral ribs show all the Virtues in good agreement, that is, in the four middle compartments: 1) Temperance; 2) Victory; 3) Purity of Mind; 4) Justice; 5) Meekness; 6) Purity; 7) Meditation; 8) Prayer; 9) Religion; 10) Charity; 11) Worship; 12) Pietà. In the lower part, the portraits of the Teatini founders: 13) S. Gaetano; 20) Paolo IV; 28) Bonifacio de Collis; 21) Paolo Conciliariis. 14) Angel playing viola; 15) 2nd appears to be a symbol of Baptism, that is sitting Religion, and a woman pouring water, and another one raising a mirror; 16) Peace and Justice embraced, and Abundance met; 17) Angel playing a lyre and others with musical cards; 18) Angel with lamp; 19) Angel with censer; 27) Angel playing an organ; 26) The gifts of the Saint appear to be expressed, that is, in the middle woman, who has in the shield Holy Spirit, the Sapienza in the rooster on the crest seems to symbolize the Council and Intelligence, in the book the Science, in the hotel the Fortress; while from behind another woman with a heart and a little dove demonstrating the Pietà, and a third mirroring herself in the shining shield of the first, almost trembling hints at the Timor of God; 25) Faith, Hope and Charity; 24) Angel playing harp; 23) Angel with bucket; 22) Angel with sprinkler.

to provide, perhaps for the first time, the scientific restoration of the Solimena frescoes also in their architectural configuration and spatial perception through the construction of three-dimensional models.

The lighting conditions of the sacristy, the natural light that falls on one side only and the scarce artificial lighting at the time of data collection due to the construction phases, have made the collection of colorimetric data problematic, both for the acquisition of photogrammetric blocks both for the acquisition of spherical images with the 3D laser scanner. Another determining factor in the complexity of the acquisition procedures is to refer to the pronounced plasticity of the interior of the sacristy, which could have generated a series of shaded areas in the clouds of points.

The relevant activity has therefore constituted an interesting application for the integration of different technologies both in the data collection phase and in the post-processing phase. The survey operations were preceded by a series of preliminary site inspections necessary for the design of the various work phases and the determination and identification of the scans to be performed. A draft recovery was prepared for which the operational and environmental factors were taken into account, so as to ensure the maximum coverage of the areas to be surveyed.

These factors, appropriately calibrated, allowed the matching of the processed data, point clouds from photogrammetric modeling and laser that could have affected the quality of the return scanner point clouds. In particular, a GSD (Ground Sample Distance) was chosen to have similar resolutions.

The acquisition of the photogrammetric blocks took place through different high resolution cameras. We proceeded, for the time, to the acquisition of the frames with reflex camera, while for the risers two drones were used, which allowed to bring at height, above the frames of the vault, two rooms with 5K resolution to be able to acquire information that cannot be obtained from the 3D laser scanner. The choices, differentiated also according to the software chosen for the management of the acquired data, were influenced by the context lighting conditions, by the material characteristics of the object to be detected, by the correct snap position and image overlap so that the angle between one grip and the other was not

Fig. 9: Sacristy of san Paolo Maggiore. Elevation from points cloud by photogrammetric modeling. On the left *La caduta di Simon Mago*, on the right *La conversione di Saul (san Paolo).*

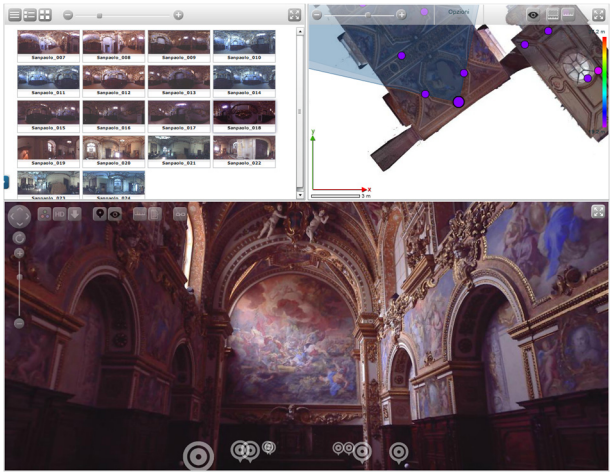

Fig. 10: Sacristy of san Paolo Maggiore. Web interface for navigation and querying in Faro WebShare.

less than 5-10 degrees and the overlap (overlap and sidelap) was about 70% and, finally, from the scale resolution required for the survey.

The different experiences in the use of integrated technologies for the survey and, therefore, for the acquisition of metric and colorimetric data, through the use of technology with active optical sensors have allowed to define the topology of parts of the complex with a speed and an accuracy otherwise unattainable with other instruments or detection techniques.

The data obtained provided a cast that perfectly matched the reality through which to obtain significant amounts of information, thanks to simplified operating methods that greatly reduce acquisition times, even when operating in less than optimal conditions. In order to operate effectively, particular attention was paid to the instrument setting, taking into account the complexity and plasticity of the product and the positioning of the spherical and checkerboard targets, necessary for the union of the point clouds, for which has consistently verified that the same set of targets on consecutive pairs of shots is always visible.

The previous experience in the use of advanced technologies has favored the phases of data collection both as regards the acquisition times, both as regards the reliability and accuracy of the values. The data obtained from the laser scanner scan, in one with the photogrammetric blocks, allowed to return dimensional values, generate orthophotos, elaborate three-dimensional models, extract textures and produce spherical photos.

5. Integrated digital survey

In the complex surveying operations that have accompanied the documentary and historical-architectural study of the precious seventeenth-century space object of this study, the principle of integration has guided the entire process, involving not only the technologies adopted in the acquisition, processing and restitution phases of data, but also their relationship with the interpretative work underlying the entire workflow and condensed in the moment of representation. The necessary integration between consolidated knowledge and information technology has guided the interest and study for the sacristy of the church of san Paolo Maggiore in Naples since the first approaches with the peculiarity of the theme. I was operated by subtracting the theme to the confusion that sees the tools and applications of information technology as a methodological replacement of the interpretative component on which the reliability of each reading of our cultural heritage must be based.

The intent of intercepting appropriate continuity relationships and dialogue between knowledge - theoretical and operational - of traditional type and innovative technologies, while confident in the importance of information technology, it has avoided, for example, the dominant quantitative - excessive mole of data in the process of acquisition and/or processing - confirming the criterion of the interpretative 'reduction' which founds the disciplines of survey and representation and involves, with respect to the infinite components of reality, a necessary "*deficit* of imitation"[12], intrinsic in the 'oriented synthesis' which operates on the object of investigation since the preliminary reading operations.

Starting from these presuppositions of reflection and considering the prevailing historical-artistic slant of the rich and erudite existing bibliography, the contribution intends to deepen the knowledge of the rare space system of the sacristy moving the operative choices within the hi-tech digital survey techniques integrated. Appropriate forms of interaction were experimented between the innovative aspects of the range-based modeling method (lasergrammetric modeling - active optical

[12] "[...] a necessary condition of any kind of imitation is the lack of a portion of reality" (Quatremère de Quincy, 1804).

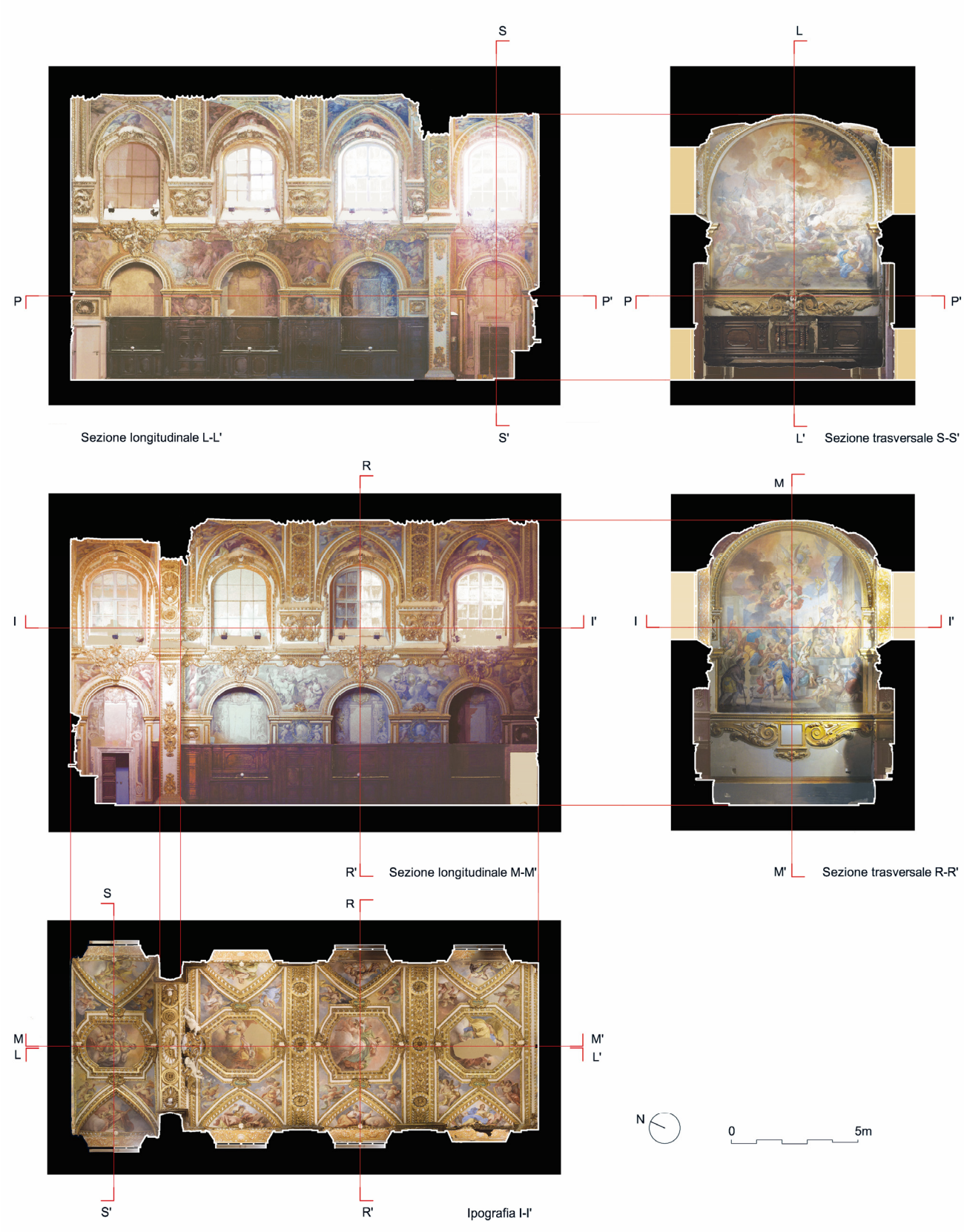

Fig. 11: 'Ipografia' and elevation of sacristy of san Paolo Maggiore, from points cloud of laser scanner.

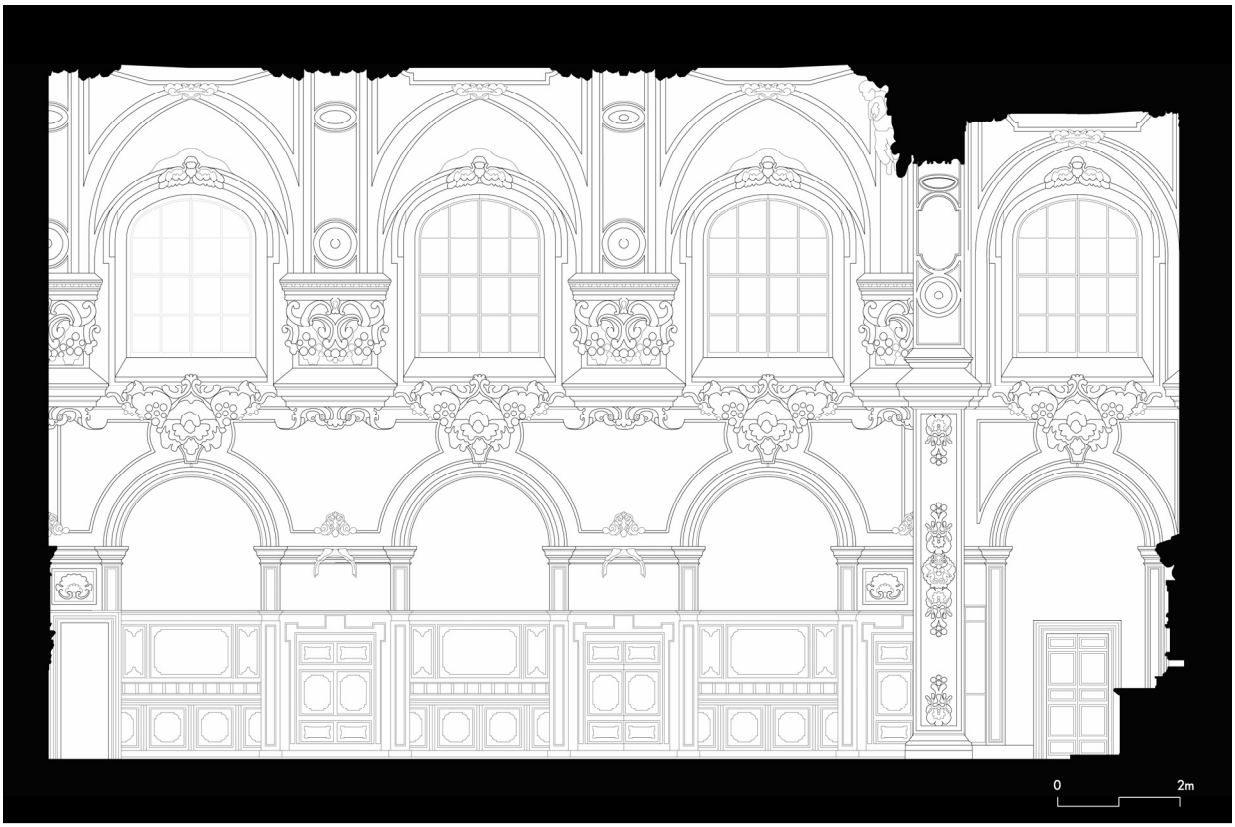

Fig. 12: Sacresty of san Paolo Maggiore. Section L-L'.

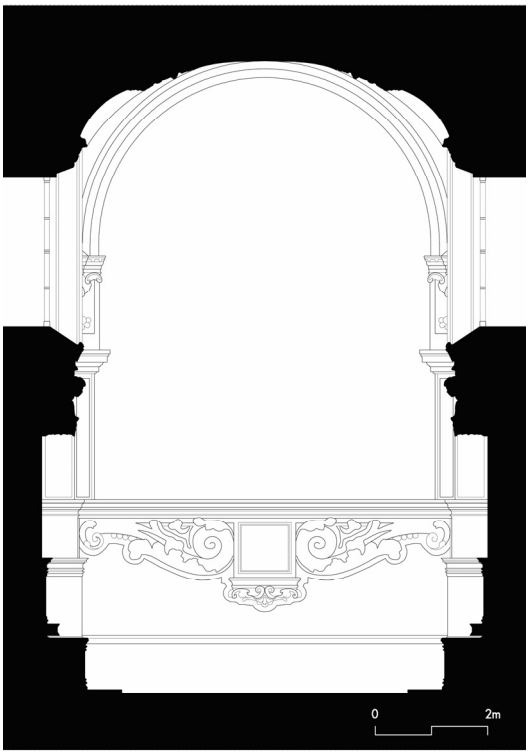

Fig. 13: Sacristy of san Paolo Maggiore. Section S-S'.

instrumentation) and the image-based modeling method (photogrammetric modeling - technique based on passive sensors), whose complementarity, while allowed to inspect the dimensions and geometries of the artifact, it has enabled even more effectively to study the chromatic complexity of matter contained in the rich decorations in gilded stucco, in the elegant wooden cabinets, in the sculptural elements, in the very refined and valuable frescoes.

The synergy between the two methods has founded the interpretative assumptions allowing to reach, beyond the mere descriptive purpose, the knowledge of the consistencies of each element and of the relations between the parts of the artifact that in the representations have taken more clearly form.

The instrumental survey was conducted between 2017 and 2018. The survey plan has studied the specific operations to be performed for both systems and the common ones - for example the preparation of the same network of reference targets - to be prepared for a more effective integration of the data during the return phase and for their cross-checking.

Fig. 14: Sacristy of san Paolo Maggiore.
High resolution detail of the south wall.

The operative synergy has pursued quality objectives, simultaneously looking at the totality and details of the cultural asset, through the union of the results of the overall survey and the deepening of some sculptural elements. For them we have made use of, and in a more focused way, the double acquisition, calibrating the reciprocal potential of the two technologies to direct the results of the research to the construction of an open representative structure of the sacristy.

The aim of the research is therefore not intended to be concluded in the possibility of arriving at an unexceptionable model of the object of study: it is rather proposed to found on an elastic and continuously implementable cognitive structure, open not only to subsequent in-depth analysis and integrations (historical and constructive events, materials, degradation), but also to contain and organise further information, hybrid or latent, that, through sharing actions, go beyond the internal horizon of the sacristy, projecting its meanings and cultural values in the context of the Neapolitan and European heritage.

In the current cultural context, the extension of the consolidated methods of analysis and communication of the real through the use of digital technologies offers unprecedented opportunities for us "to improve public access to cultural heritage assets and allow for their curation and re-use" (European Commission, 2018) (Della Corte, 2019).

One of the main actions that Europe proposes in the field of knowledge and research is to capitalize on technological tools for innovation on cultural heritage, considering that "the innovative technologies, such as virtual or augmented reality, can also enhance people's experiences with cultural heritage, while digital tools such as 3D scanning play a major role in the preservation and restoration of physical heritage assets" (European Commission, 2018).

5.1 Range-based modeling method (lasergram-metric modeling)

The range-based modeling method employs techniques based on active sensors, using, as is known, instruments (laser scanners) that emit electromagnetic signals recorded by a sensor in order to derive a distance measurement (range). Together with the topological data the sensor, for each laser pulse emitted by the scanner, also acquires a reflectance value which allows to distinguish the materials; the combination of sensor and camera data also makes it possible to associate a color with each point detected (Remondino & Zang, 2006).

In the field of range-based instruments, the experience and preliminary reflections on the use of innovative techniques in the survey of architectural and artistic assets have led to the selection of phase-change laser scanner technology, or phaseshift, and to use the FARO Laser Scanner Faro Focus 3D X330 instrument, with integrated digital camera equipped with optical axis coaxial to the laser measurement range.

The technology adopted, now widely used, is based on the instrumental survey of a three-dimensional point grid (cloud) constructed through the recording of even infinitesimal intervals between the points of the object examined. On the availability of accurate metric data, it was therefore possible to "superimpose" an excellent rendering of the chromatic and material qualities of the points (for extension, of the surfaces) gathering very useful informations on the state of conservation of the architectural elements and of the inspected artistic assets.

Effectively, considering the main dimensions of the sacristy space (on the horizontal plane the maximum extensions are 18.50 x 6.70 m, the heights are 7.95 m from the floor to the barrel vault lunette and 11.30 m up to the intrados key line) and the architectural and decorative peculiarities of the asset, by mounting the instrument on a tripod, a scanner resolution has been set such that on a plane placed 10 meters from the emitter two beaten points have a distance of 3 mm.

Even considering that laser scanning is a remote measurement method that does not

involve any direct contact with the detected good, therefore substantially non-invasive, to take greater account of the protection needs of the singular artistic works contained in the sacristy, it was intended to preserve them further, both by calibrating the main acquisition parameters and the distance of the instrument from the surfaces, and minimizing the shooting times and the noise levels emitted by the instrument: a total of 23 scans were carried out - of which 5 in the adjacent chapel of the sacristy - each of the instrumental duration of approximately 14:00 minutes, with dimensions in pixels of 10240x4267, dimensions in MPts (million of points) of 43.7 and quality 3x (480 dpi).

The set resolution value - identified as optimal even in relation to the representation scales foreseen for the restitution was of 1005 MPts, corresponding to a maximum distance between points contiguous of the 3 mm output mesh, for any direction taken on by the radius of the instrument.

In the data processing phase, the single scans were joined together using automatic recognition procedures for the spheres and targets positioned during the operations *in situ*, without the need for any manual registration of scans. This mode, favoured by the substantial regularity of the sacristy's space, which made it possible to optimize the positioning of the references (targets and spheres), guaranteeing full visibility from each station position, has involved particularly fast processing times, avoiding long and less precise manual procedures in the phase of post processing.

The coloring of the morphometric model (point cloud) occurs through the projection from the center of the RGB value of the single pixel of the spherical panorama[13] created by the camera inside the instrument on each acquired point; in this way the three-dimensional and colorimetric characteristics of the space are returned, drawing a high accuracy even on the scale of the rich wall decorations and of barrel vault with lunettes.

The large interactive visualisation enabled by the point cloud highlights the incisiveness of the range-based modeling method by linking this reality-based technique to the reality observed at the time of survey and obtaining on possibilities of understanding and representation very close to direct verification: the singular and scenographic spatiality of the sacristy of the church of San Paolo Maggiore, endowed with a strong immersive power to the direct perception, seems indeed to become even more 'true' and totalizing through the orbitability of the point cloud and the zoom function that allow to exert a sort of remote touch on the surfaces and gain, almost simultaneously, the overall dimension and that of detail of the artifact.

Fig. 15: Sacristy of san Paolo Maggiore. Equirectangular images. At the top, surfaces and reflectance values are displayed; the normal and color display is shown below.

[13] The full-color panoramic images are generated by the scanner by combining 84 photographs that the integrated camera clicks after scanning, for each station position. The Web Share application allows you to explore and measure each overview using specific features.

The laser scanner technology, allowing the rapid elaboration of dynamic digital models of surfaces and complex geometries present, difficult to be examined with traditional topographic instruments, is identified as a technology in itself adequate for the detection of objects of cultural heritage, but more effective if combined with other digital techniques. The present work highlights one of the main complementarity contributions of the photogrammetric method to the laser scanner restitution procedures in the integration of the 'shadow areas' which, given the conformation of the location and the limits of the tripod aid, were closed to the scanner radius but reachable from the aircraft room.

The cutting operations performed on the three-dimensional mesh of points, infinitely sectionable through the clipping box functionality of the Faro Scene software, associated with the production of high-resolution orthophotos, allowed the interpolation of the basic generating profiles for the vectorization of the survey and the processing in a unitary methodical framework of two-dimensional representations.

For some of the predominantly sculptural elements that make up the decorative apparatus of the sacristy, the reading of the profiles was complemented by verifying the contours obtained from the sections of the point cloud through metric interrogation of the spherical panoramas produced by the same range-based modeling, before proceed to the comparison/integration of the results obtained with the surface information obtained from the image-based modeling method.

5.2 Image-based modeling method (photogram-metric modeling)

As already mentioned, since the morphology of the interior of the sacristy, it was necessary to integrate the data acquired with the laser scanner survey, also in consideration of the insufficient lighting inside the environment that does not it has allowed an optimal acquisition of the color deducible from the projection of the equirectangular panoramic obtained with the chamber of the laser scanner. It was therefore decided to merge the data using a low-cost technique, which although less precise than the techniques based on active sensors, allows the parameters relating to the exposure to be controlled and the position of the shot point. Using a topographic base composed of 16 GCPs (Ground Control Points) a useful structure was created to integrate the two surveys.

Fig. 16: Acquisition operations inside the sacristy of san Paolo Maggiore with drone and camera with 5K resolution.

The second technique used is photogrammetric modeling, which through the use of algorithms from *Structure From Motion* (SfM), reconstructs a point cloud composed of coordinates obtained from the epipolar interpolation of pixels with similar characteristics in two frames acquired in succession. We proceeded using high resolution cameras: a 16 megapixel SLR for ground acquisition and two cameras, with 4k and 5k resolution, on drone or, more correctly, SAPR (Remote Piloted Aircraft System). The workflow, from the acquisition of the

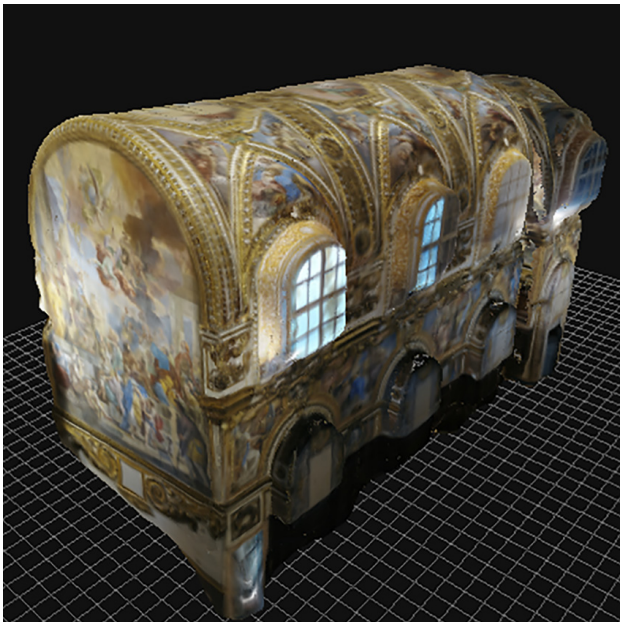

Fig. 17: Reconstruction of the interior space of the sacristy of san Paolo Maggiore through photogrammetric modeling.

photogrammetric blocks to the return of the final product, is divided into four parts: a socket project to establish, depending on the ground sample distance (GSD), the path to be taken by the camera during the shots; the acquisition of frames, from the ground or from a drone; processing of photogrammetric blocks and post-processing through the use of more dedicated software.

A more detailed description of the different steps can make the complexity of the process. The preliminary phase consisted of planning the recovery project, dividing the survey into two parts, the risers and the vault. For the walls, the drone used is a DJI Inspire2, a quadricopter aircraft with variable geometry capable of acquiring images with a 5K resolution camera (5280x3956). An interesting feature of this machine is the presence of a camera combined with two ultrasonic emitters that allow the drone to maintain a safe distance from obstacles and to constantly calculate the position in indoor environments where it is not possible to receive the GPS signal.

To reconstruct the geometry of the vault of the sacristy we proceeded to the acquisition of frames taken at different angles using a Nikon D5300 reflex camera with a 50 mm fixed lens. Before proceeding with the acquisition, 16 control points (GCPs) were identified by marking them with RAD targets (with automatic recognition) which were also used for matching with the point clouds obtained with the laser scanner. These operations were subsequently carried out also for the risers. 200 photographs were acquired for the time, 30 photographs for the small walls and 60 for the long walls. Given the small distance to be covered, the photogrammetric blocks have a resolution such as to allow the software for photogrammetric modeling a GSD (Ground Sample Distance) of 0.876mm / pix.

The second phase consisted in processing the photogrammetric blocks. The software used is Agisoft Photoscan which was replaced during the work by Agisoft Metashape. With the software the frames related to the single mission in chunk were grouped, the markers positioned as control points were recognized in order to have the parts of the model in position at the end of the elaboration. The operations performed by the software are the same as those that can be performed even with open source software, based on the Structure From Motion (SfM) that use algorithms such as SIFT (Scale-invariant feature transform) and SURF

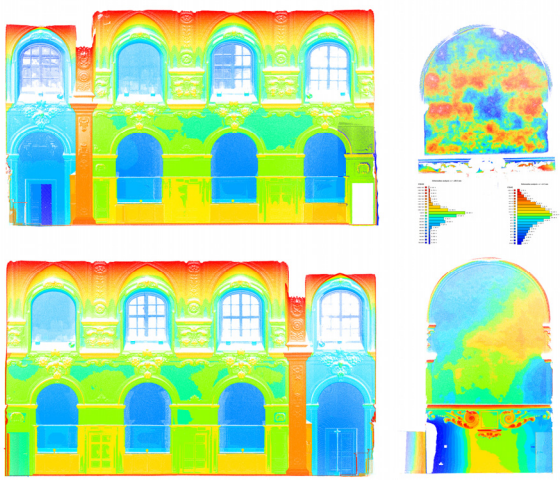

Fig. 18: Sacristy of san Paolo Maggiore. Processing in *LupoScan*. Deformation analysis.

(Speeded Up Robust Features) that extract significant points or tie points, homologous in different frames and identify the parameters of internal and external orientation. The descriptors of each image are used to identify correspondences between pairs of images. Through the triangulation the correspondences allow to determine: the 3D position of the tie points; the three-dimensional position of the camera (position of the gripping center with respect to the object reference system, external orientation); camera geometry (focal length and lens distortion, internal orientation). With the data calculated by triangulation, the software has created a scattered point cloud (sparse point cloud). In the next step the Dense Image Matching (DSM) algorithms build a dense Irregular Network (TIN) a B-Rep (Boundary Representation) model was obtained. The final surface consists of a mesh, the algorithms used to create the surface starting from the point cloud are the Poisson Surface Reconstruction and the Floating Scale Surface Reconstruction (FSSR). The last operation was the texturing of the surface, where the images were orthorectified and projected onto the mesh, returning the colored model.

According to the post-processing of the acquired data, the model is projected onto planes, obtaining orthoprojections that have been used to return two-dimensional graphs such as plant and hypography, elevations and sections, taken from the three-dimensional model; for the evaluation of dimensional sizes and extrapolation of perspective and/or axonometric views, interpretation and dissemination of data, export of the model in a 3D modeling environment for the creation of realistic photoplanes, videos and virtual animations.

Restoration techniques cannot disregard the use of information provided by metric surveys, carried out more and more often through integrated survey techniques. The integrated survey provided, through the correspondence of the acquired data, to describe the three-dimensional geometry of the good through a three-dimensional representation. The analysis was also checked for the verification of the deviations of the surfaces frescoed by a vertical reference wall. This involves using the point cloud using the laser scanner survey, measuring its use with the Luposcan software.

To get a complete picture of the anomalies present in the sacristy that can compromise the preservation of the frescoes and stuccoes, thermographic data have been acquired through the relevant instruments that have to investigate the reflexive and emissive response of the examined surface in different bands of the integrated spectrum, provided auxiliary instructions compared to traditional methods. With the thermographic survey, any small thermal surface anomalies due to a protected discontinuity not visible from the outside, such as inhomogeneity of the materials, humidity of the plasters, were identified during the transient thermal phases.The instrumentation used for the use of the relief is the FLIR camera E40bx model. Peculiar characteristic of the system is the possibility of acquiring data not only in the band of the electromagnetic spectrum corresponding to the thermal infrared but also images in the visible bands. The camera is in fact equipped with two separate optical systems for acquiring the thermal image and the corresponding image in real colors. Thermographic inspection presented a series of images, both in field of thermal infrared and visible frequencies, which showed temperature differences on the surface of the various elements monitored.

6. Dissemination and interaction with model

The use of the model and the interaction with it may in some cases not be a possible operation for several reasons. Having a detailed model of the artifact it was possible to associate it with information accessible both locally and remotely through augmented reality.

The point cloud allowed several analyzes on the existing, making comparisons and queries, also through online fruition having set up an *Apache Tomcat* protocol on the server and the *Faro Webshare* application. The configuration of the web server allows the visualization and interrogation of data and areas and the virtual use of the detected space, through navigation in virtual reality, having archived the different scans with the possibility of accessing them online. This application allows users to interrogate and virtually visit the areas accessible through immersive photos (Panoramic Views) and ensemble maps (Overview Map). It is also possible to perform, in addition to the verification and control procedures, also measurement operations, configuring itself as an archive of information available for further analysis. Alongside the traditional representations in orthogonal projection, new methodologies have been tested for visualization of surveyed data, capable of effectively restoring the complexity of site with the aim of identifying new ways of knowledge and use.

7. Conclusions

The research work conducted in the sacristy of San Paolo Maggiore in Naples has explored different levels of knowledge: from the rich documentary sources to the iconographic apparatuses from which it was possible start a meticulous double reading, data acquisition and representation operation, through the integrated survey. The methodology among the innovative aspects of the range-based modeling method and of the image-based modeling method, through the use of well-established techniques for surveying outdoor applied in the survey of interiors, with the necessary changes to the acquisition pipeline, have allowed us to reach restorative models that represented the architecture of the sacristy and the frescoes of Francesco Solimena in their spatial and configurative dimension, allowing to carry out a careful survey of the morphometric and colorimetric characteristics, which can also be searched remotely, thanks to the *Apache Tomcat* protocol and the *Faro Webshare* application.

The outcome of the research is proposed as a qualified contribution for the protection of the Asset and for its valorisation aimed at encouraging and facilitating conservation and restoration interventions as well as providing a permanent query of the data and their complete use[14].

[14] Riccardo Florio: Paragraphs 1-2-3-4; Teresa Della Corte: paragraphs 5, 5.1; Raffaele Catuogno: paragraphs 5.2, 6.

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