

Marco Ceccarelli · Michela Cigola
Giuseppe Recinto *Editors*

New Activities for Cultural Heritage

Proceedings of the International
Conference HeritageBot 2017

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Preface

The organization of this International Workshop HeritageBot 2017 on the multi-disciplinary activities for Cultural Heritage is the main dissemination activity of the project HeritageBot that is developed at University of Cassino and South Latium with funding from the Latium Regional Government.

HeritageBot is a research project with multi-disciplinary contents that is finalized to develop a wireless robotic platform equipped with suitable sensors with mobility by locomotion and small flight for monitoring operations and intervention in Cultural Heritage frames. The multi-disciplinary structure of the project is characterized by the synergic activity of four different laboratory unit partners from Architecture, Robotics, Entrepreneurship, and Finance, respectively, and plans for design and research activities with technical and non-technical aspects. The design of the HeritageBot platform is expected to produce innovation that can lead to practical implementations with market challenges thanks to merging engineering issues with entrepreneurship interests for Cultural Heritage needs.

After the review process, 26 papers by authors representing 10 different countries were accepted for publication in the proceedings of HeritageBot 2017. One glance at the table of contents is enough to see that we succeeded in bringing together an interesting group of people with a stimulating variety of subjects as due to the multi-disciplinary needs in modern activities in Cultural Heritage frames. We are very satisfied with this result, and we thank the authors for their valuable contributions and for the efforts in submitting in time the final versions of the papers.

This book is meant for researchers, graduate students, historians, architects, restoration operators, engineers, and all others with an interest in Cultural Heritage frames. We believe that it can inspire and motivate them in developing challenging new systems and strategies for activities in Cultural Heritage frames.

We would like to express our sincere gratitude to the colleagues, who helped us in the review process giving also suitable suggestions to improve the papers with desired visionary views.

We also thank the University of Cassino and South Latium for hosting the conference event.

June 2017

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Michela Cigola
Giuseppe Recinto

Introduction

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Heritage is our legacy from the past as appreciated today for cultural background and cultural evolution that is valuable to pass on to future generations.

The United Nations Educational, Scientific and Cultural Organization (UNESCO) seeks to encourage the identification, protection, and preservation of cultural and natural heritage sites around the world with outstanding value for humanity.

Cultural Heritage includes tangible culture (such as buildings, monuments, landscapes, books, works of art, and artifacts), intangible culture (such as folklore, music, traditions, language, and knowledge), and natural heritage (including culturally significant landscapes, and biodiversity).

Keeping Cultural Heritage from the present for the future is connected with actions such as identification, analysis, preservation, and restoration, with specific technical meaning. Each of these areas of intervention includes not only technical actions and expertise but also requires cultural evaluations in respect of the concept of Cultural Heritage. Preservation, restoration, and valorization of Cultural Heritage can be also understood as a complexity of activities in a very wide range of disciplines, whose aim is to identify, evaluate, and preserve past achievements for the benefit of next generations in having memory of the past and inspiration from them for future enhancements and appreciation of current results.

Mechanical devices are frequently used in particularly difficult situations and different contexts, where unmanned operability is requested such as inspections of contaminated sites, inaccessible places, buildings with a collapse risk. Therefore, the possibility of using specific surveying instruments associated with self-propelled robotic systems opens up new opportunities of particular interest for the procedures of analysis and investigation in the rich Cultural Heritage frames, and in particular in Architectonical and Archaeological goods.

The use of remote-controlled robotic devices offer a huge potential in terms of possible increase of efficiency and time in operation, and application, experimentation and research in architecture and archaeology. The combination of Robotics

and Cultural Heritage has the potential to increase the awareness and the knowledge when environments are substantially inaccessible because of logistical or security reasons. In order to preserve the objects of study, the technical specifications (weigh and dimensions) of a robotic platform may be a good solution to ensure the preservation of the historical objects by suitable actions ensuring also knowledge acquisition on the Cultural Heritage aspects.

In addition, the sensors currently in use for the investigations and surveys of historical sites and products offer huge possibilities since their capabilities and reduced sizes can permit efficient new operation and even simplification of the historians' investigations. In fact, sensors of digital type, that are suitable for acquisition of digital data, allow to integrate digital information within a single working platform.

Since the beginning of the 60s, a series of influential changes gave the possibility of new surveying methodologies to finally arrive at experiments with 3D virtual models of today in the field of saving and preserving Cultural Heritage, in particular Architectonical and Archaeological Heritage.

In the first decades of the twenty-first century, the methodology of laser scanner surveying reached its full development. This methodology allows to build very accurate 3D models of Architectonical and/or Archaeological Heritage with the objective to preserve or valorize them.

After this period, a new surveying methodology was used, the so-called photomodeling. Through this methodology, using specially developed software, it is possible to obtain high-definition 3D models with some images taken by digital camera device. The comparison between laser scanner survey and photomodeling survey has proven that the two procedures are comparable in terms of accuracy.

Given the considerable difference in weight between a laser scanner and a digital machine, the above vision technology for Cultural Heritage makes robotic platforms with some more attraction since they will make possible to enlarge the range of reach of those visual investigations because of the mobility not only in unreachable places.

The research project HeritageBot, that is founded within the FILAS program of Latium Region in Italy, is carried out by the Department of Economics and Law of the University of Cassino and South Latium with researchers from DART (Laboratory of Documentation, Analysis, Survey and Technique of Architecture and Territory), LARM (Laboratory of Robotics and Mechatronics), IMPRENDILAB (Laboratory for Entrepreneurship), and FINLAB (Laboratory for Finance) laboratories.

HeritageBot is a research project with multi-disciplinary contents that is finalized to develop a wireless robotic platform equipped with suitable sensors with mobility by locomotion and short flight for monitoring operations and interventions in Cultural Heritage frames. The project activity is planned on technological developments of new patents in robotic field for market implementation and professional application in Cultural Heritage frames through additional service operations (industrial-like, cultural aims, educational, etc.). Expected applications as service operations in Cultural Heritage frames can be considered as:

The survey/knowledge of unsafe products

The survey/investigation of not accessible areas by preventing deterioration of the environments

The visual inspection with remote interface

The survey and investigation of Cultural Heritage goods with action of analysis and restoration avoiding hazardous conditions and accidents

The monitoring of Cultural Heritage goods and sites with remote interface

The characteristics of the project activity and platform design are based on the multi-disciplinary structure of the project with four different laboratory unit partners from Architectural Heritage (DART), Robotics (LARM), Entrepreneurship (IMPREDILAB), and Finance (FINLAB), respectively, and the plans for design and research activities are expected with technical and non-technical aspects. Common interests of the teams are planned in developing and exploiting robotic platforms servicing in Cultural Heritage frames from the very different perspectives as from technological aspects up to entrepreneurship success of implementable solutions of the designed platform and project itself.

Different expertise views are expected to be integrated in both the research activities and expected design results. Entrepreneurship aspects and exploitations are investigated also looking at the potential users. Financial implications are considered with business plan evaluations and legal aspects. In addition, the acceptance of the project outputs is tested with feedbacks for potential fruiters both as a user and as a public of Cultural Heritage visitors.

One other important aspect of the project is related to the dissemination toward a wide public including fruiters of Cultural Heritage sites and technological transfer also by attracting, defining, and forming new figures of professionals so that a prototype, although developed with the limited resource of the project, is planned for demo purposes with the specific features of low-cost solution and user-oriented operation capabilities.

An investigation on Cultural Heritage goods of Architectural or Archaeological nature is aimed to achieve deep knowledge of the products with possibility of both analysis and intervention to fully understand the historical value and preserve it properly. This requires a synergic integration of technical actions with cultural studies that have been considered as requirements and goals of the development of the HeritageBot robotic platform.

In fact, the requirements for the HeritageBot robotic platform for servicing in Cultural Heritage frames have been identified in:

- capability of data acquisition with autonomous or supervision action, even with on-board storage capacity, in environments also of difficult access
- capability of small interventions for checking or collecting small pieces from the environment by using the small arm or other devices to be installed on the platform on demand
- capability of investigations with different instruments (e.g., color-photogram analysis, radiography) that can be equipped for specific purposes on demand for identification of the status of the environments/objects

- modularity of the robotic platform for mobility capacity in walking and small flight with suitable space available for equipment and instruments to be installed on-board on demand
- operation of the platform at skill reach of the users by using joystick or easy programming teach pendant
- cost of the platform at budget level of potential users for both high-performance needs or limited capabilities by using the modular design
- design novelty for technological transfer that can be attractive for existing users and companies but also for stimulating new entrepreneurships.

The demonstrative prototype is equipped with basic instrumentation for monitoring purposes such as a high-resolution digital camera, a lidar vision scanner sensor, an infrared camera, and an integrated lighting system as a first important implementation of the emerging vision developments in surveying and analysis of Cultural Heritage sites.

Detailed specifications have been defined for HeritageBot robot platform by considering specific features and constraints given by experts of architectural survey of Cultural Heritage goods. Accordingly, HeritageBot design has been conceived with a modular structure that can provide specific features and equipment as depending on the specific application and functionalities that are requested by the users. Three main modules have been designed, namely for operating the system, its small flight, and its locomotion. The first module hosts the control and operation architecture (including batteries and communication hardware) as well as the specific sensors and instrumentation that are needed by the users. The second module is a quadcopter-like system that allows a short flight for avoiding obstacles and for increasing payload/stability capacity. The third module is based on a multi-leg mobile robot.

A demonstrative prototype of HeritageBot platform has been built at LARM as a proof-of-concept device, whose overall cost has been limited by the project budget. Commercial components have been selected for the control and operation hardware, batteries, propellers, actuators, and cables and connectors. Main frames of modules have been made by using 3D printing that are available in LARM laboratory. The overall size of the prototype is contained in a box of $50 \times 50 \times 50$ cm with a weight of 5.0 Kg including batteries for an operation duration of 2 hours.

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Sedile Dominova in Sorrento: Survey and Analysis of a Complex Architecture

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Abstract. The topic discussed here is the study of an ancient aristocratic *Sedile* of the 14th century, the *Sedile Dominova* in Sorrento, and the elements that subsequently joined the architectural organism, such as the precious dome made by coloured roof tiles and perspective frescoed paintings on the inside. Through the use of integrated techniques for architectural survey, it was possible to perform two-dimensional and three-dimensional morphological analysis on the current state of the artefact, emphasizing the peculiarities, anomalies and structural beddings both in elevation and plan [1].

Keywords: Architectural representation · 3D laser scanning · Drone · Integrated survey · Illusionary perspective

1 Investigations on the Morphological Structure and the New Survey

Sedile Dominova, between via San Cesareo – the major decumanus of the Roman era – and via Giuliani in Sorrento, is the only aristocratic *Sedile* almost fully preserved in Campania. Built in the second half of the 14th century, it has two imposing arches in piperno, a local volcanic stone overlooking the two above-mentioned streets. In correspondence to the *Sedile* in via San Cesareo, in which historically there were the most valuable patrician houses and the *Sedile di Porta* – the first of the city of Sorrento – broadened a square, which today still exists but it is of reduced dimensions, known as the “Schizzariello” for the presence of a fountain now moved from its original position. The *Sedili* hosted the meetings of the noble families who governed the city; originally, the *Sedile di Porta* was the only one, after, due to internal division within the assembly, the *Sedile Dominova* (*Domus Nova*) was built. The location and the morphology of the *Sedili* as they were in the eighteenth-century age, can be observed in the cartography of the eighteenth century [2] and from their paintings, in particular the Theodore Duclère’s canvas of 1861 shows the *Sedile* in relation to the fountain and also how today it is free only on two sides, close to other buildings that have changed over time. The formal structure of the *Sedile* is variously heterogeneous: it is characterized by a sort of “stylistic discontinuity” [3] that makes difficult the understanding of a clear and defined

architectural figure. It runs between polystylar pillars, which support the intrados of the framed arches and the denticulated cornices of the formal structure, similar to the styles of Neapolitan Renaissance noble palaces. Moving into the twilighted arches in piperno, it is striking to note the perspective paintings of the two closed internal walls, carried out in the eighteenth century. From the union between the real context and the painting, there is an expansion of space that is projected externally towards two real and two imaginary arches. The room inside, unique room, was delegated to secret meetings and the preservation of acts and public documents. It still retains some marble columns, while other elements were transported to the Correale Museum. The outer covering of the seventeenth century dome with yellow, green and white roof tiles, echoes the typical shades of the region. The cognitive documentation of the *Sedile*, based on a new survey presented in this paper, conducted with integrated acquisitions [4] - laser scanning, photography, drone - and on the analysis of painted perspectives, has enabled to provide a first step towards a consistent knowledge of the structure, in its peculiarities and uniqueness. The survey was set on a system of scans conducted in topographic mode, therefore, on a polygon of topographic stations connected, materialized on the ground, outside and inside the building, and in altitude [5], Fig. 1. The survey of the dome has required an integration of information carried out with the use of the drone – as it will be specified later on – because it has been impossible to acquire it entirely by the 3D scans.



Fig. 1. *Sedile Dominova* geometric survey, the plan with the 3D scans positioned.

The acquired data showed the morphological complexity of the *Sedile*. Some features not highlighted by the previous metric measurements, although accurate and well-read [6], show, in a nutshell, an angle variance in layout walls, which occurs slightly

rhomboid, and a decentralization of the dome from the load-bearing walls. Metrological analysis allowed us to identify the measure unit used for the structure, the Neapolitan *palm* – equal to 0.2645 m – and to relate the architectural space with the one painted, Fig. 2.

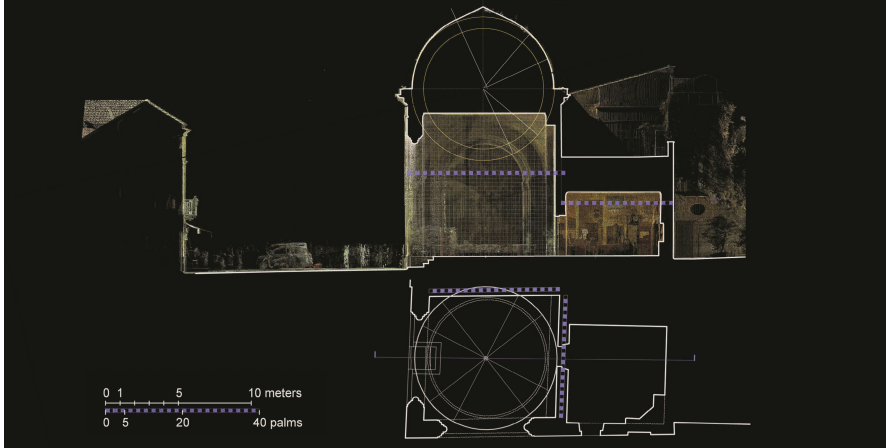


Fig. 2. *Sedile Dominova*, the plan and the section with the Neapolitan *palms* grid.

2 The Illusionary Perspective Analysis

The perspective frescoes of the eighteenth century belonging to the *Sedile*, placed along the two inner sides of the loggia, are attributable to Carlo Amalfi or an artist trained at his school [7], although it is thought to have undergone some alterations during the years. The current state of preservation of the frescoed surfaces shows the major lacks in the lower part, there are also several bandage applications, or “velinatura” for the support and the protection of the paintings, Fig. 3. The decorative painting project showed frescoes also on the inner surface of the dome, but their bad conservative state has necessitated the application of a drop cloth [8] (even painted) that prevents the view. Leaving aside for the moment the material and tangible aspect, has been addressed the study of the two quadrature works, regulated by a rigid perspective framework. The two walls have a similar subject: a row of arches in succession, placed on twin-supports formed by corinthian columns and pilasters. The reading levels are different: in the foreground there is an arch which introduces the architectural space, a filter between reality and illusion; then follow in succession three arches with columns and pilasters; later on new perspective views open, on a side we find a circular exedra, while on the other side there is a new building set in an angular view.

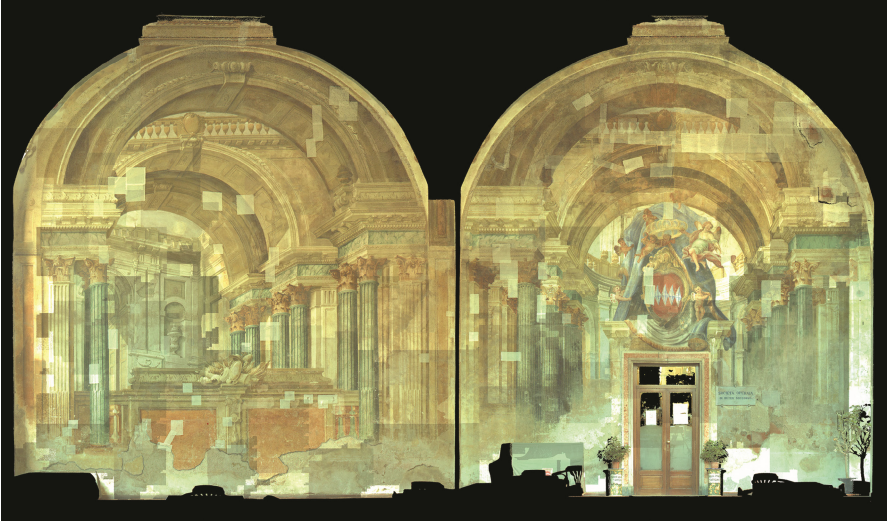


Fig. 3. The frescoed walls elevations from 3D scanner laser orthographic view.

The front wall has a symmetrical composition placed in axis with the longitudinal path of the room, thus causing an immediate illusory spatial extension along this direction; while the side wall respect to the entrance shows an asymmetrical composition but more rhythmic and, in some ways, more fascinating. The elements represented, with regard to the succession of arches, seem to be the same, although viewed from two different angles: the first is a central and axial projection, the other is accidental and highly decentralized. In the front wall there is a circular exedra, flooded with a light from above; the composition appears interrupted by a large coat of arms that prevents the complete understanding of the backwaters elements. In the side wall, instead, there is what can be defined as a “bibienesco [9] artifice”, a theatrical scenic expedient, which allows the viewer to imagine the continuation of the space into a perceptual and emotional involvement between real and illusionary space. In a geometric analysis of a quadrature, it is essential to identify the key elements of the perspective construction: the vanishing point, the horizon line and the straight line of the track. Once identified these elements, it is necessary to understand how they were proportionate to the other parts between them, assuming in this case that the unit of measurement used was that local unit, i.e. the Neapolitan *palm* (equal to 0.2645 m). The front wall is thirty-two palms in length, while the side is thirty-four, both measured in height about thirty-five palms, Fig. 4. The main perspective elements recur in both paintings: the three circumferences, that define the three arches in succession, have a radius of ten - eight - six point five palms, therefore, are harmonically proportionate to each other; the height of the two vanishing points, and then the horizon line is equal to six point five palms from the ground (about 1.70 m, the height of the human eye). In these painted surfaces the use of light strongly accentuates the spatial separation between what is depicted in the foreground and what is painted in the background.

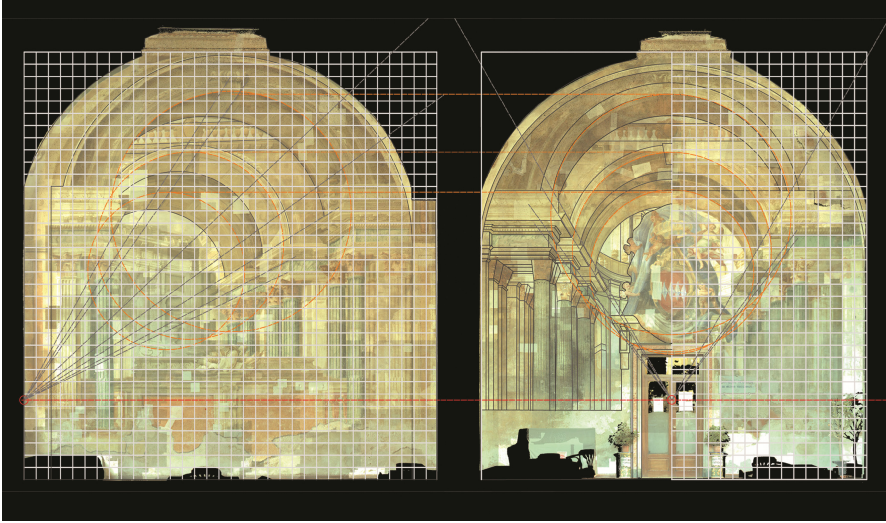


Fig. 4. The perspective construction of the painted walls, with Neapolitan palms grid.

3 The 3D Model and the Dome

The particular position of the *Sedile* has not allowed the complete acquisition of the whole structure using only terrestrial laser scanning, so it is thought to detect non-visible parts from the instrumentation station points and then, in order to fill the gaps present in the set of points acquired and to obtain a more complete representation of the complexity, to use the digital photogrammetric method or photo-modeling. On several occasions have been acquired different datasets of images from the ground and from the *UAV (unmanned aerial vehicle)*. In particular, the use of this technology has allowed the three-dimensional reconstruction of the dome, and some details of the balustrade, Fig. 5. In this context, the upholstery represents a particular construction type, usually identifiable in religious buildings, covered with polychrome roof tiles defined “*riggiolo*”, laid out with a fish scale pattern, coloured in yellow, green and white, forming rhomboid drawings caged by eight ribs coated by yellow trapezoidal roof tiles.

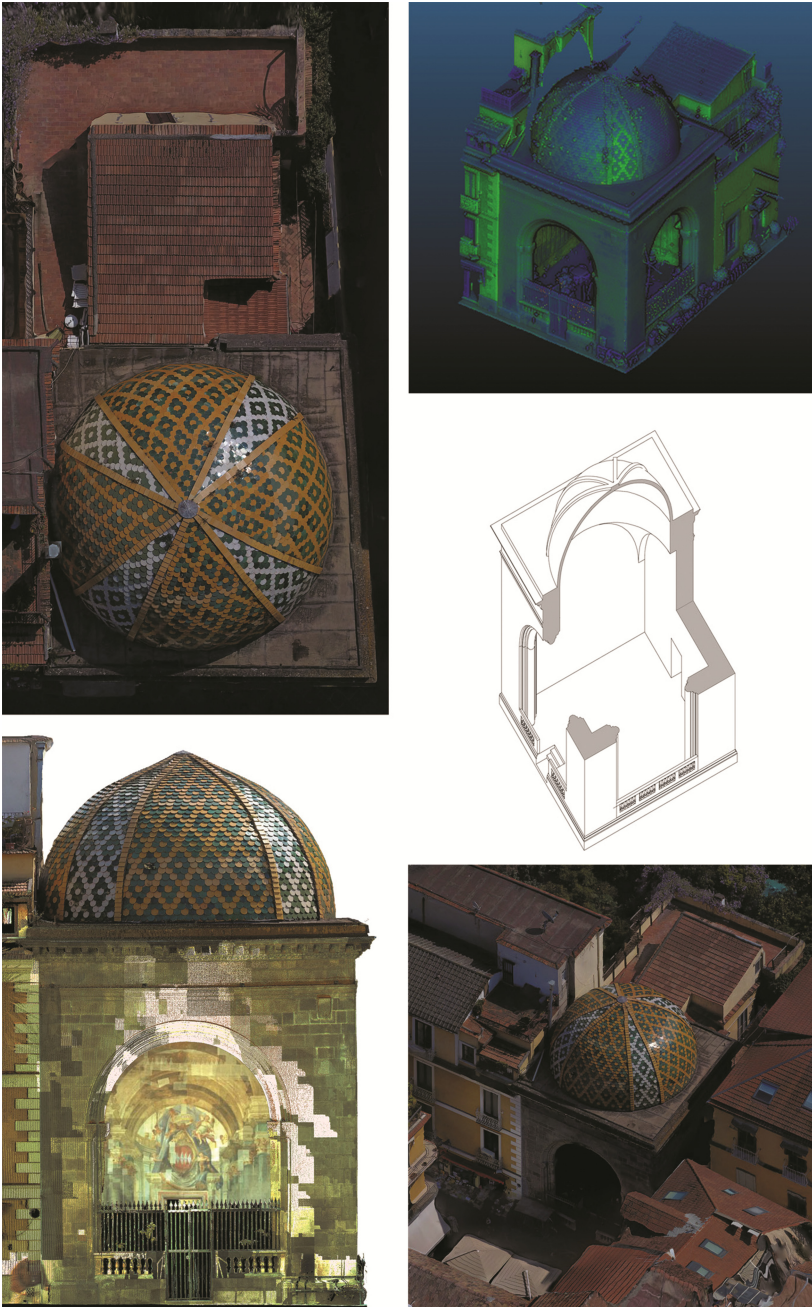


Fig. 5. On the left column orthophoto images of the *Sedile* and its dome (from *Agisoft Photoscan*), on the right column axonometric views (from *Cloudcompare*, *3D CAD* and *Photoscan*).

In the tambour are still visible the heraldic insignia of the noble families that were part of the *Sedile*. The dome rests on a tambour which is invisible from the outside because it is contained in the bezel width, while inside it is clearly discernible and rests on pendentives that accentuate the perspective views of solid walls. On the two free elevations, at the top right of the one facing “Schizzariello” square and on the top left of the one facing via Padre Reginaldo Giuliani, are embossed two shields of the fourteenth century, in one there are Angevin lilies and, in the other, the coat of arms of the city of Sorrento with five diamonds. The small size of the building, the complexity and the texture of the site that encompasses two sides of the building, are an excellent field for experimentation and the application of advanced techniques and technologies through no-contact survey procedures have produced metric data of different accuracy, but of the same consistency, sets of points that have been recorded appropriately after processed to obtain a single three-dimensional model of the *Sedile*. The photographic acquisition required a preliminary recovery project based on a mapping of the areas of interest for the creation of a flight plan via *waypoints*, calculating the setting of the path, the number of shots, and the value of *ground resolution* (GSD), a determining factor for the proportion of optimum flight altitude within the town to get a ground resolution of at least 1 cm/pixel.

The integration of different types of survey highlighted the formal qualities of an artifact that hardly can be recognized walking San Cesareo street. In fact the *Sedile Dominova*, essentially unaltered in its original configuration, shows elements from the architecture of the fifteenth century buildings, identifiable elements with a prism building, with piperno colour variations, with round arches and the crowning moldings. These define a particular architectural structure that marks not only the space that collects, but also the space of the square that it marks.

4 Referencing

- [1] Although the article was jointly written by the authors, Gaia Lisa Tacchi focused more on the paragraph entitled 1 *Investigations on the morphological structure and the new survey*, Francesca Porfiri curated in-depth the paragraph 2 *The illusionary perspective analysis*, while Raffaele Catuogno the paragraph 3 *The 3D model and the dome*.
- [2] Guastafierro, pp. 74–78.
- [3] Pane R., Sorrento e la costa, Edizioni scientifiche italiane, Napoli, (1955).
- [4] We take this opportunity to thank the laboratories *mLAB Monitoring Laboratory Tecnologie per il monitoraggio dell'ambiente costruito*, scientific director prof. Valeria D'Ambrosio, DiARC Università di Napoli Federico II – *Drone Dji Phantom 4*, responsible and manager of SAPR arch. Marco Facchini – and the *LIRALab Laboratorio di Innovazione per il Rilevamento, la Rappresentazione e l'Analisi dell'Architettura*, director prof. Carlo Inglese, DSDRA Sapienza Università di Roma – *Leica ScanStation C10* – for making equipment and expertise available for us.

- [5] Almost all the scans have a general character, carried out with a medium *probe* of 10mt for a *sample spacing* of 10×10 mm: are able to identify the morphology of the building in its peculiar characteristics. A 3D laser scanning has been made for painted environment, with a *sample spacing* of 5×5 mm, unique, to avoid the impact of errors - even the smallest - to return on the frescoes.
- [6] Pane, p. 101; Dell'Aquila, p.159.
- [7] Guastafierro, pp. 80–81; Dell'Aquila, p. 162.
- [8] The drop cloth was positioned in 2013.
- [9] The word “bibienesco” comes from the “Bibiena” dynasty: architects and stage designers working during the 18th century, very famous for their unique skills.
- [10] By following the painter's *modus operandi*, it is possible to guess where the vanishing point was collocated, and where the viewer was supposed to be standing in order to be struck by the breathtaking sight of the illusory scene.

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