

Laura Carlevaris, Graziano Mario Valenti

edited by

DIGITAL & DOCUMENTATION

Reading and Communicating Cultural Heritage

Volume 3



PROSPETTIVEMULTIPLE
STUDI DI INGEGNERIA
ARCHITETTURA E ARTE

Laura Carlevaris, Graziano Mario Valenti

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DIGITAL & DOCUMENTATION

Reading and Communicating Cultural Heritage

Volume 3

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The scientific responsible for the organization of the event is Prof. Graziano Mario Valenti, Sapienza University of Rome.

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METHODS AND INSTRUMENTS FOR OBSERVATION, DATA ACQUISITION AND MULTIDIMENSIONAL ANALYSIS: THE PASSING OF TIME IN THE DOCUMENTATION OF CULTURAL HERITAGE

FRANCESCA PORFIRI

Abstract

The intervention focuses on the process of normalisation and integration of a system of data (gathered over a period of time and part of a much broader research project) regarding the Arch of Titus in Rome, in particular an accurate qualitative acquisition system and its comparison with quantitative-mass data. The objective of the research and this contribution – an integral part of the research – is to create a multiple, integrated, descriptive model. The assessment and synchronic and diachronic comparison, based on the time variable, was performed using a topographical survey, i.e., an accurate element of 'comparison and reassurance' with previous surveys. Data systemisation allows for transversal critical interpretation of a case study that has undergone important changes over the years; the interpretation highlights the importance of scientifically verifying accrued data, given the huge mass of data acquired so far in the field of architectural survey.

L'intervento proposto è incentrato sul processo di normalizzazione e integrazione di un sistema di dati, raccolti nel tempo all'interno di un ampio progetto di ricerca, riguardante l'Arco di Tito a Roma; si focalizza in particolare sul sistema di acquisizione a livello qualitativo e puntuale e del confronto di esso con il dato quantitativo-massivo. L'obiettivo di tale ricerca e di questo contributo, che si inserisce al suo interno, è quello di creare un unico modello descrittivo, multiplo e integrato. La valutazione e il confronto sincronico e diacronico, declinato secondo la variabile temporale, viene eseguito in particolare attraverso il rilievo topografico, elemento puntuale di "confronto e conforto" con i rilievi precedenti. Mettendo a sistema i dati raccolti si propone una lettura critica trasversale, applicata ad un caso studio testimone di importanti cambiamenti nel corso del tempo, capace di mettere in luce ad oggi l'importanza della verifica scientifica del dato, a fronte di un'ingente acquisizione di esso nel campo del rilievo architettonico.

Introduction

A complex architectural object that has undergone important changes over the years needs to be studied, understood and then illustrated in all its parts so as to highlight and substantiate its tangible and intangible memory. With the passing of time an architectural work evolves seamlessly; it undergoes important changes or imperceptible alterations to its morphology and material essence and is defined not only by its spatial coordinates or intrinsic materials, but also by the way it changes over the years, something that makes it unique and completes its narration. As a result, two different interpretations are required: one synchronic, the other diachronic. The first deals with a reality linked to the knowledge available at a specific moment in time, a reality in which all aspects are considered as a system

governed by precise laws regarding function; instead, the latter considers the evolution of all the phenomena studied as an ensemble in order to identify precise laws regarding change. Based on these two interpretations, the objective of any study is to transfer knowledge of the object in question to future generations by providing accurate documentation, interpretation and management of the data acquired thanks to an integrated approach. In this case, the joint participation of several players – architects, archaeologists, historians and restorers – plays a key role. In the last fifty years digital instruments have become commonplace in the analysis and acquisition of cultural heritage, especially in the field of architectural survey and communication of its findings. Although this is common knowledge within the scientific community, it is also possible to provide further experimental input by applying this





Fig. 1 - The Arch of Titus, located in the Archaeological Park of the Colosseum.

Fig. 2 - Three historical representations of the main phases of the Arch of Titus: left, Giovanni Battista Piranesi, historical view of 1755-1765; middle, Gaspard Vanvitelli, 18th century view; right, the view after restoration of Luigi Rossini in 1836.

knowledge to a specific case study. This will involve weaving a sort of invisible web in order to create patterns that can scientifically and ontologically reconnect the elements of the work in question. After all, its true essence can only be identified by monitoring existing geometries and thus revive lost geometries – a task achieved through accurate data acquisition.

An Integrated Knowledge-gathering Model for the Arch of Titus

Three main temporal phases characterise the old monument down through the centuries:

- its construction in 81 A.D. by Emperor Domitian to celebrate the heroic acts of Emperor Titus;
- its incorporation into the fortifications of the Frangipani in the Middle Ages; although the arch lost part of its unitary identity, it also led to its partial conservation;
- finally, its anastylosis restoration by Stern and later Valadier between 1817 and 1824.³

The monument was in a dreadful state prior to restoration [Jonsson 1986, pp. 99-117]; although several elements of its old structure were missing, the barrel vault was still in place, as were the bas-reliefs, the half-columns and entablature, parts of the frieze, and the commemorative epigraph on the attic. The vaulted room inside the attic has been there since antiquity, probably to reduce the weight of the arch. When Valadier restored the monument, he deliberately chose to simplify the architectural order as regards the decorative motifs and use of materials, for example by replacing marble with travertine (fig. 2). The current quadrilateral morphology of the free-standing monument includes a base, a monumental attic, a central arch with a barrel vault, and side columns with composite capitals. The original coffered surface of the vault is still in place, as are the bas-reliefs on the inner walls of the vertical supports; they represent the conquest of Jerusalem by Titus and his triumphal entry into the city. The morphology of the

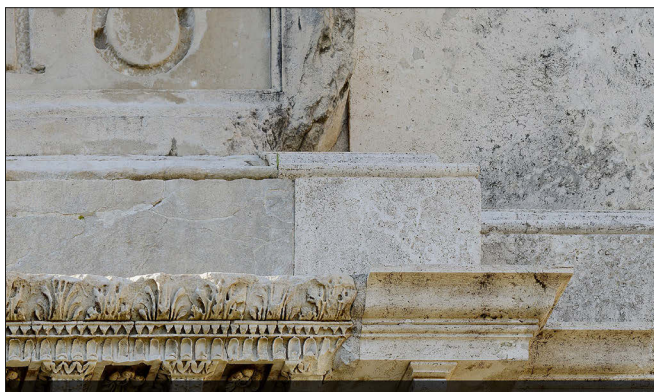


Fig. 3 - The process of simplification of the architectural order in the decorative motifs and in the use of materials.

Fig. 4 - The planimetric representation of the georeferenced topographical survey.

Fig. 5 - The topographical fiducial markers overlayed to the mass acquired data and to the very high-resolution image.

arch remained intact after restoration since only the decorative details had been simplified, making the new parts easy to recognise compared to the original elements (fig. 3). The correct methodological approach in any study, in this case that of the Arch of Titus, which underwent important changes over the years, requires a multifaceted and well-structured survey campaign, one that highlights several of its elements and peculiarities.

The campaign involved the complex integration of the following phases:

- 3D laser scanner survey;
- photographic acquisition and IBM-SfM restitution, terrestrial digital photogrammetry and aerial photogrammetry;
- acquisition of gigapixel orthophotos;
- experimental acquisition involving sample testing;
- georeferenced topographical survey (linked to the Roman Forum-Palatine GPS network).

The initial phase of the study involved massive and, to a certain extent, objective acquisition, automatically acquired using a 3D laser scanner and digital aerial and terrestrial photogrammetry. This provided a huge amount of data that was crucial when constructing the texturised numerical model of the monument. The ensuing use of gigapixel images provided further refinement of the documentation regarding the studied surfaces which could then be illustrated on a 1:1 scale. The second phase entailed using a topographical survey in order to achieve non-automatic subjective acquisition; in fact the operator critically chose which points to link on the monument, thus retaining control over the points during the ensuing phases. This required the establishment of a hierarchy of the elements that make up the object and a semantic structuration of its parts. The massive data had to be combined with the accurate topographical data in order to orient and control the surveyed data; the goal





Fig. 6 - The topographical survey of the monument performed in the nineties by Professor Alessandro Sartor.

Fig. 7 - The comparison between the two topographical surveys after the re-collimation process of the same fiducial markers.

was to find a univocal orientation from amongst the acquisition methods, but it also helped to define the geometric and ideal representation of the monument. This enabled data systemisation and a comparison between the aforementioned data acquisition methods; the objective was to produce a solid, reliable integrated system. After the data has been normalised – one of the

primary goals of the research – it will be inserted into a multiple, integrated model – a HBIM model – containing both the geometric data (from the numerical model) and informative data. This type of structure makes it possible to specify the ontology of each element and the system of relations between the parts, based on an absolute reference hierarchy.



Topographical Survey, a Critical Comparison

The objective of this contribution was to validate the acquired data and perform a synchronic and diachronic comparison using a georeferenced topographical survey⁴ (fig. 4). This involved pre-emptively performing a critical selection of certain key points, based on very precise criteria: monitoring the 'state of health' of the monument over the years, and studying the partition of the elements of the arch. These points were collimated to establish the univocal direction of the clouds, but

also to manage the data from the mass acquisition systems. At any time in the future, the key points that were identified and measured can be compared in order to verify possible transformations and adjustments of the arch; they can also help in the development of the ideal and geometric representation of the monument. This provided greater control over the study of the architectural order, the mouldings, and their semantic study. It involved creating a system of fiducial markers as a further element to test the mass acquired data (fig. 5). An accurate survey to reconnect and retest all the

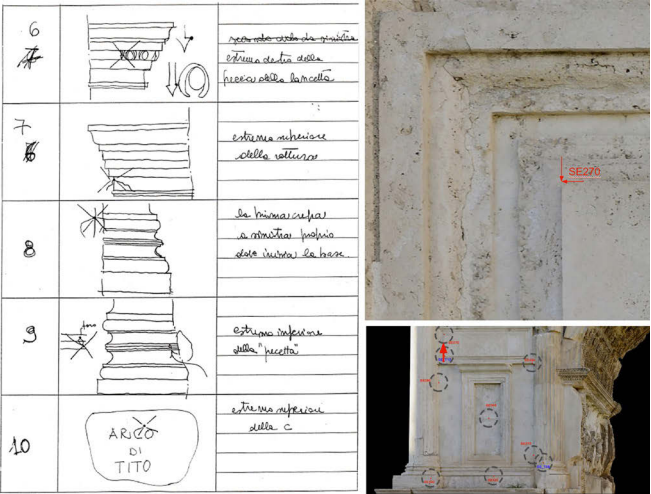
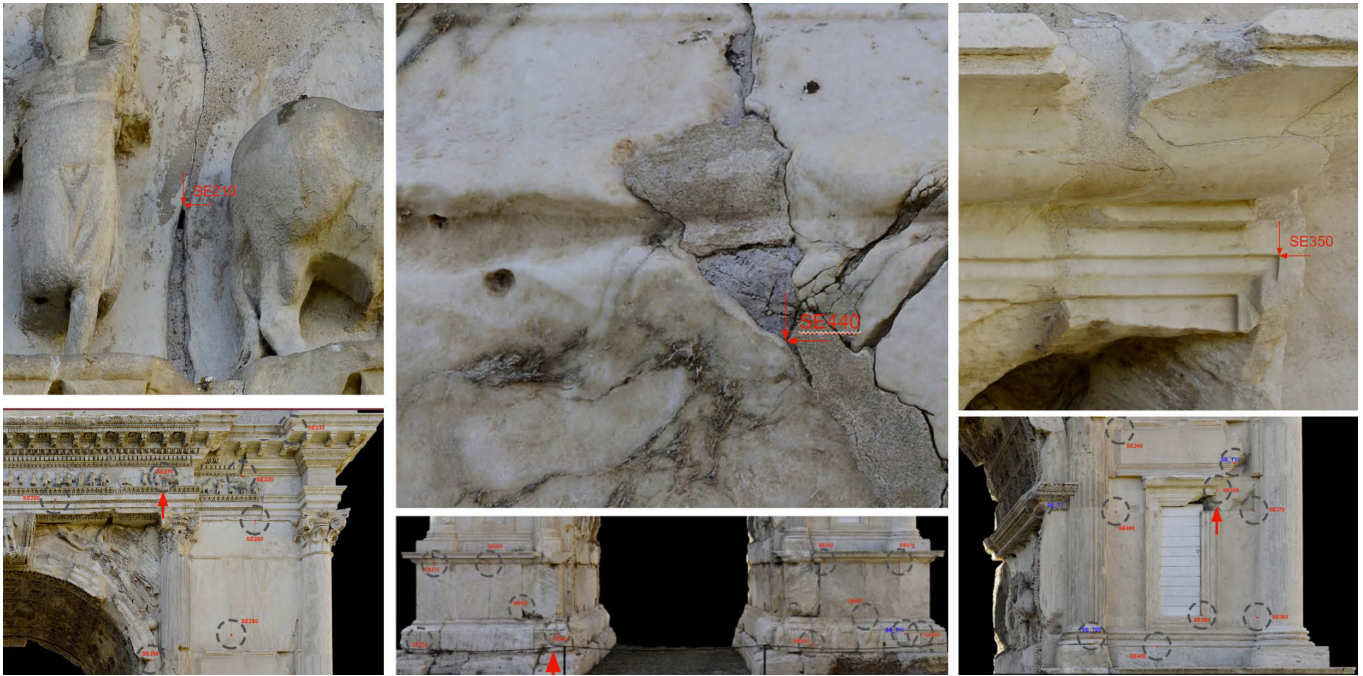


Fig. 8 - The comparison between the two monographies of the points.

Fig. 9 - The calculation of the average deviation between the two surveys, in 1993 and in 2020.

Fig. 10 - The monographies of the points in the contemporary survey: the points are selected in the very high-resolution image.

	1993			Dist 1993	2020			Dist 2020	Differenza 1993-2020
Codice	x	y	z		x	y	z		
1	3,3029	-16,3759	9,4142	8,783	6266,5961	3027,7385	40,945	8,791	-0,008
7	10,1145	-17,5867	4,003	6,465	6259,8523	3029,3149	35,53	6,474	-0,009
8	3,9837	-16,9075	2,0673	6,817	6265,7615	3027,5164	33,592	6,826	-0,009
9	10,7916	-17,2531	1,9626	3,684	6259,3576	3029,8784	33,491	3,696	-0,012
10	13,3322	-16,993	-0,6929	12,781	6257,1228	3031,1327	30,828	12,798	-0,017
12	1,703	-17,0415	4,6095	11,250	6267,8034	3026,4933	36,137	11,264	-0,013
13	12,9332	-17,7104	4,6067	8,845	6257,2059	3030,3091	36,139	8,854	-0,009
14	13,0624	-17,2204	13,4374	10,590	6257,2767	3030,8169	44,978	10,611	-0,021
Codice	x	y	z		x	y	z		
7	10,1145	-17,5867	4,003	8,451	6259,8523	3029,3149	35,53	8,459	-0,008
12	1,703	-17,0415	4,6095	17,736	6267,8034	3026,4933	36,137		
Codice	x	y	z		x	y	z		
10	13,3322	-16,993	-0,6929	9,748	6257,1228	3031,1327	30,828	9,764	-0,017
8	3,9837	-16,9075	2,0673	17,493	6265,7615	3027,5164	33,592		



data, thereby providing reassurance re the monument's state of health, at least dimensionally. The comparative analysis between the current topographical survey of the monument and the one performed in the nineties by Prof. Alessandro Sartor turned out to be extremely interesting since it helped in the observation and definition of the micro-variations that had occurred in the last thirty years. The material gathered during this survey included eleven, 10 x 15 cm photographic plates of the south-east elevation of the monument (fig. 6). The points collimated and inserted in Sartor's campaign handbook in turn became part of the current survey project, making comparison possible after re-collimation (fig. 7). The two monographies of the points were compared; the former manually drafted

in 1993 (the year Sartor performed the survey) using preparatory sketches of the details, the latter based on the gigapixel images acquired during the current survey campaign. In the handwritten monograph the point was codified, represented and described, while in the contemporary survey it was identified directly on the very high-resolution image (fig. 8).

After an initial on-site inspection, it was clear that no micro-variations of the selected points had taken place. This theory was tested by superimposing the two surveys after roto-translation and calculation of the average deviation between the two. An average error of roughly 1 cm is present on the coordinates x,y,z ; this is acceptable considering the years that have passed between the two surveys (fig. 9).

It is important to emphasise the critical points regarding the two surveys:

- interpretation of the selected points. The handwritten monograph cannot be univocally and objectively interpreted because the selected point was difficult to identify and had to be interpreted at the operator;
- instrumental inconsistency due to different topographical acquisition methods. In 1993 the topographical survey used forward intersection; every point was collimated from a pair of stations and even the angles were calculated. Today we use the polar coordinates method and the point is collimated using a single station;
- variation in the climate and temperature during the two surveys. On 6th March 1993 the temperature was 12°, while on 1st October 2020 the average temperature was roughly 23°, a difference of 11° which would justify reasonable deformation in the marble or Roman concrete.

The topographical points were connected to the Roman Forum-Palatine GPS network after identification of the points (V24 and V26) using a monographic technical sheet of the point with its FUR coordinates. These geographical monographs help to identify the GPS point of the Forum network as well as establish the point thanks to a photograph, a CAD drawing, and a brief description of its location. Interpretation of the point is again subjective; the surveyor's skills can influence the recognisability of the point which may in turn lead to an error.

Therefore, using the gigapixel image to objectively locate the point ensures safe transmission of the surveyed data over a period of time. To draft the current monographs a decision was taken to adopt a two-step approach: initial identification of the point in a generic abacus, divided according to the elevation of the monument and semantic group (e.g., attic, arch, base, etc.), followed by a

detailed localisation of the point, on an almost 1:1 scale. The points selected on the monument belong to two groups: the first level involved the architectural partition of the monument, while the second level involved its material characteristics (fig. 10).

Conclusions

In this case the topographical survey was an opportunity for discussion which, together with the mass acquisition of data, made it possible to put together more information about the project. It also ensured greater accuracy in the study of the mouldings and allowed for a critical interpretation of the semantic study of said mouldings (proportioning of their elements); this was performed by critically comparing the two surveys. Clearly this involved updating a procedure that is already well-structured and has been used at length in the field of architectural survey. Once again, an accurate qualitative survey, rather than a quantitative survey, is confirmed as being the most up-to-date tool used in general testing and in the integration and normalisation of heterogeneous data from points clouds surveys (3D laser scanner or Image-Based Modelling). It is a solid element used to combine the massive data that is collected and helps in its normalisation. It is also a reliable, reassuring tool to compare past and present measurements when trying to accurately verify changes to the monument, thus highlighting the importance of time in all the processes documenting our existing heritage. Even the interoperability of the players involved in the study of an object temporarily becomes 'transversal'; it adds a semantic potential to the reconstruction of the model by inserting a new piece of the puzzle based on the management of survey data over a period of time.

Notes

1. The research on the Arch of Titus is entitled: *Experimental knowledge-gathering models for integrated survey and digital representation: the case study of the Arch of Titus in the Archaeological Park of the Colosseum*; scientific director, prof. Graziano Mario Valenti. The research was jointly performed by the Department of History, Drawing and Restoration of Architecture, Sapienza University of Rome and the Archaeological Park of the Colosseum; special thanks to Federica Rinaldi.
2. The survey campaign, performed at different moments in time, by all members of the research group, began in 2019 and ended with the topographical survey performed in September-October 2020.
3. Related to the bibliographical sources on the subject of Stern-Valadier restoration, the following must be mentioned: Valadier 1822; Valadier 1828; Valadier 1833; Brües 1958; Marconi 1964; Casiello 1973; Debenedetti 1979, Pfanner 1983.
4. On this subject, it is necessary to quote from Docci, Maestri 2009.

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