Parametric Thinking: Recognizing the "Architectural Formulas" in Cultural Built Heritage by Parametric Digital Modelling

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***Abstract* — Parametric digital modeling is today one of the most interesting tools on the international architectural design scene. At the same time it is one of the areas on which architectural criticism debates for some time. The use of parametric methods throughout the whole design process is favored by the rapid evolution of hardware and software devices and the ever-increasing programming capabilities. However, the so-called Parametric Architecture has revealed its existence even before the digital revolution. Parametric Architecture is a definition coined by Luigi Moretti in the '40s. Furthermore, several scholars have found examples of parametric thinking from the origin of the history of Western architecture. The idea of verifying the existence of a "parametric thinking" in the Cultural Built Heritage, recognizing the parameters that could have guided the architectural composition and re-creating their relationships using tools of parametric digital modelling is the focus of the present proposal. It follows, deepens and develops a research carried out on the atria's vaults of several Baroque palaces in Turin.**

***Keywords*— parametric modelling, architectural heritage, complex unitary vaults, architectural survey, descriptive geometry**

I. INTRODUCTION

When, in 2008, Patrick Schumacher launched at the Venice Biennale the Parametricist Manifesto called "Parametricism as Style" [1], the widely antagonistic response by critics, theorists and scholars was not long in coming. Basing on numerous examples found in the architecture of the past, they aimed to demonstrate an ancient origin of the "parametric thinking".

Luigi Moretti emerges as one of the most interesting pioneers with respect to present developments in parametric architecture, both in the design field and in the research on the architecture made by the masters of the past. His wide and complex theoretical contribution dates back to the post-war period and was published in the pages of the journal "Spazio" he founded in 1950 and was director.

In the '40s, in the initial period of his research, he coined the definition Parametric Architecture characterized by geometric inevitability, rigorous concatenation of shapes, and absolute freedom of imagination that can explode in places where the equation does not find its roots determined, and will give it a crystalline splendour [2].

Firstly, the relationship between architectural design and parametric equations was analyzed by Moretti without using computer. However, Moretti understood the importance of using computers due to their ability of self-correcting cyclical series obtaining the probable solutions of the parameters values and their relations [3].

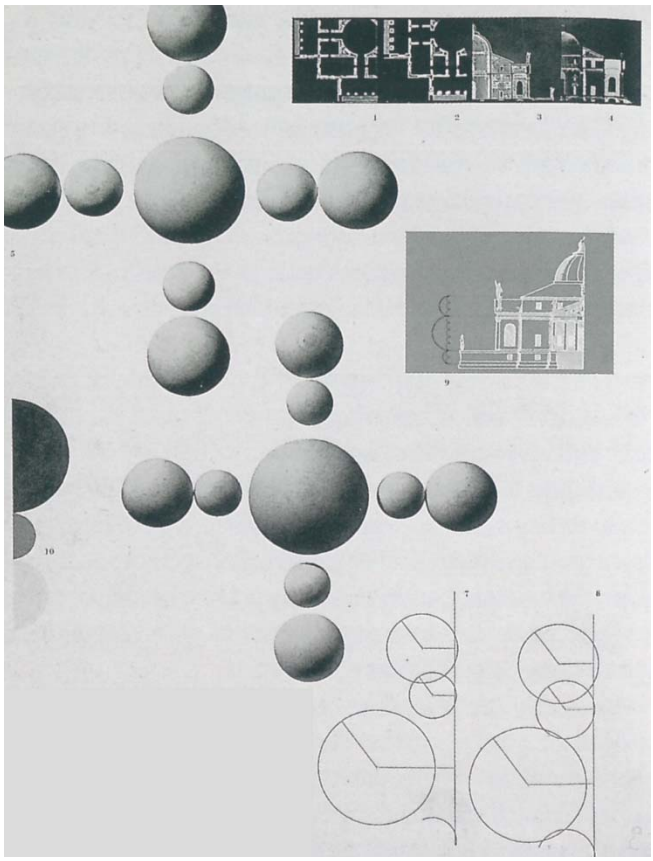

Fig. 1. Luigi Moretti. Parametric analysis of the Palladian Villa “La Rotonda” (From Moretti, 1952-1953).

Collaborating with mathematicians and physicists he developed proposals that merged in the IRMOU's foundation (1957), and in the exhibition "Parametric Architecture" at the XII Triennale di Milano (1960). On this occasion, Moretti exhibited models of stadiums designed and shaped through the statement of 14 parameters using an IBM 610 computer.

The development of Moretti's theoretical thinking was fueled by the study of historical architecture of which he recognized intrinsic parametricity.

In his article "Strutture e sequenze di spazi" [4] Moretti identified, as tools for interpreting the architecture of the past,

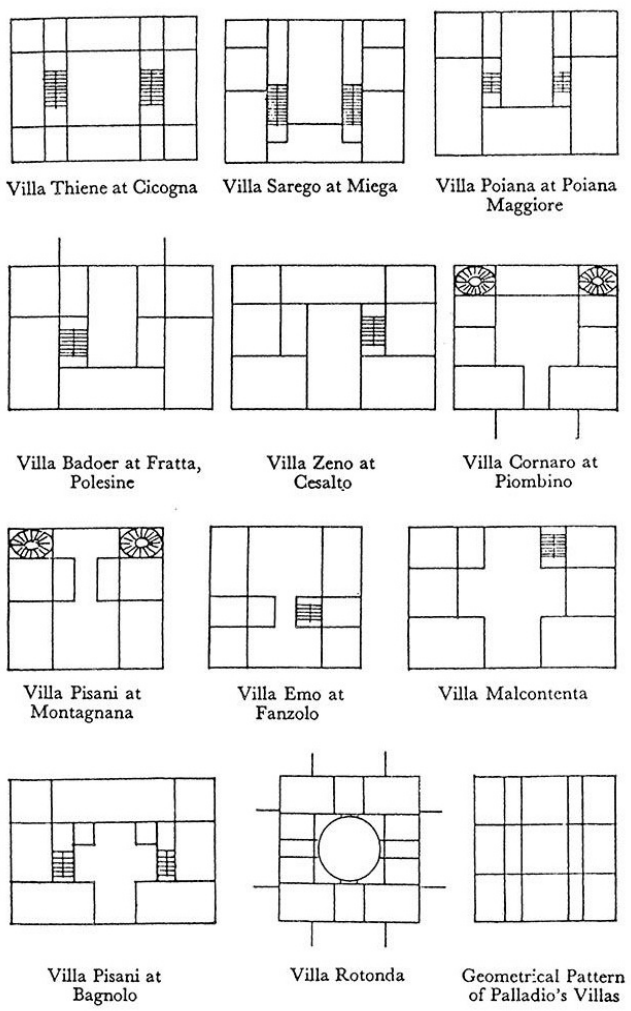

Fig. 2. Rudolf Wittkower. Palladian villas types (From Wittkower, 1949)

four parameters relating to the internal volumes: the geometric shape, the size, the density dependent on light, the "energetic charge". Having fixed these parameters, he examined the sequences of spaces relating them to the differences between the parameters that shape them. The ways in which the internal volumes constituted a spatial concatenation were at the center of his interests [5]. Moretti, after surveying some ancient buildings (Greek temple, Hellenic house, basilicas and Roman baths), focused on Palladian architecture, following the research of Wittkower [6] and deepening the study of the Rotonda, also through drawings and plastic models.

This research line continued with the analysis of the Basilica of San Pietro. Its universality, in Moretti's opinion, derives from the simplicity of its sequences, realized through a composition of singular volumes connected by passage's spaces. Guarinian churches of Casale and Lisbon seem to conclude the reasoning overcoming the sequence of spatial elements in an almost continuous architectural body.

II. State of Art

The parametric thinking was recognized in the architecture of the past by several scholars.

In the '40s Wittkower analyzed the Palladian villas from a parametric point of view [7].

Recently Gage, studying the Greek temples compositional rules, recognizes the use of fractional measures of the column's diameter, taken as a module [8].

Carpo highlighted the parametric thinking in different historic periods and architectural ambits (i.e. the Corinthian capital, the Gothic buildings, and the rules of architectural orders by Vignola and Palladio [9].

Cache found parametric criteria in the De Architectura by Vitruvius (i.e. in the private houses, temples, and stone-throwers [10] [11].

Leopold analyzing the Ulm School of Design educational plan discovered an original design approach: it could be linked to the rule-based or parametric design with digital tools [12].

Steadman established parametric criteria for analyzing the plans of three typologies of nineteenth and first decades of twentieth centuries' residential houses in Cambridge, through DIS (dissection) software [13].

On the contrary, few researches use parametric modelling as a tool for interpreting the built Cultural Heritage. Among them emerges the seminal book An Evolutionary Architecture written by Frazer. He summarized the steps of parametric architecture history [14] and together with Graham scripted a genetic algorithm aimed to generating a population of 100 Tuscan columns [15].

Burry, in charge for the completion of Gaudí's Sagrada Familia, used the parametric tools aiming to understand, interpret, and reproduce part of the incomplete church [16] [17].

Liuti and Pugnale used computational morphogenesis in an original way; indeed they applied this methodology aiming to discover the design poetics, the shaping criteria, and to verify the structural efficiency of Pizzigoni's church of Longuelo [18].

III. Main Focus

The starting point of the research we propose in this paper is the acknowledgment made by Cavallari Murat of the "Planterian formula" (from the name of architect Plantery, working in Turin from early to the mid eighteen century), as a guide for the shaping of unitary vaulted systems in Turin baroque atria [19].

The "Planterian formula" originates from the tradition of late-Renaissance lunette vaults and incorporates the important and new spatial patterns deriving from Guarini's inventions, influencing the architecture of later architects, as Bernardo Vittone (nephew of Plantery) and numerous Turin architects who, although remaining unknown, actively participated in the creation of the new aspect of the eighteenth-century city, especially in the vast areas of remodeling and expansion of the medieval core of the urban fabric. Cavallari Murat identifies and describes masterfully the evolution of this formula in a synoptic table

through which he highlights the relationships between geometry and structure according to the variation – parametric, we could say – of the positions of the structural supports and the consequent amplitude of the lunettes. The result is a "space that presupposes a plurality of points of view, an organization of vision consisting of connected perspectives, such as the cinematographic shot" [20].

Over seventy unitary complex vaults discovered by the authors of the present proposal in the atria of the Baroque palaces in Turin were already the subject of a cataloguing, surveys and interpretive geometric models [21].

In particular, we owe to Cavallari Murat the highlighting of Plantery's work and his central role in the creation of a taste that, from the Thirties of the eighteenth century, could "rely on a series of tested technical formulas and geometries from which it was then easy to extrapolate formal values of aesthetic validity and sure result [...] Systematically cataloguing the combinatorial possibilities of those intersection of vaulted and domed spaces is a practical way of introducing a critical understanding of the value of agreeableness that can become beauty in this theme of shaping"[22].

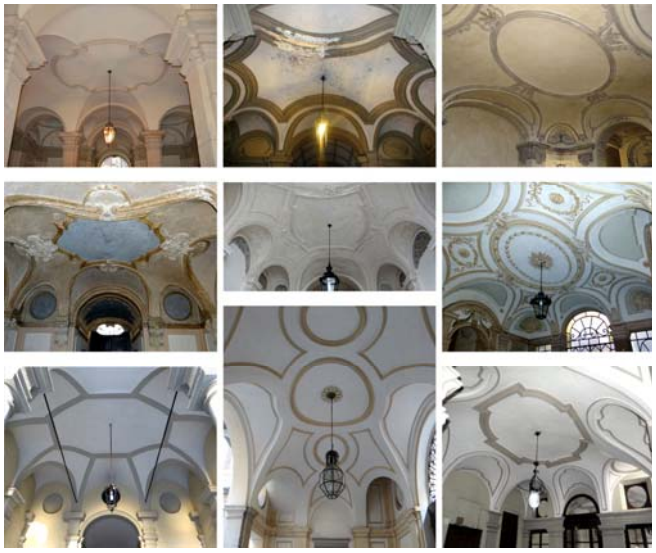

Fig. 3. Planterian vaults in the atria of Baroque Turin (Photo by Marco Vitali)

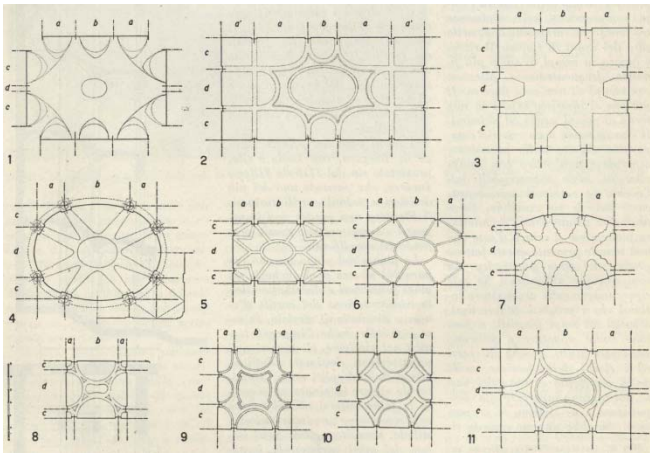

Fig. 4. Augusto Cavallari Murat. The Planterian formula applied to baroque atria and main halls (From Cavallari Murat, 1957)

The current research focuses on the analysis, interpretation and parametric modelling of homogeneous classes of complex vaulted systems, for which the results of some case study will be presented.

These case studies start from applications of parametric modelling on Planterian and star-shaped vaults in Turin [23] [24], and proceed with the development of the work, analysis and discussion of results related to other configurations of vaulted systems, including "a fascioni" vaults.

Among the criteria for the general setting of the parametric model, a specification is required. The idea of creating a parametric model of built architecture is a very ambitious goal, and it is necessary to understand exactly purposes and modes of use. The aim of the work is principally analytical, and it has the following purposes: to extract from the different cases a conceptual existing diagram, which is almost never formalized; to facilitate comparative analysis throughout the different case studies; to study the relationships between the elements that compose complex systems of vaults; to better define the geometric forms that result from the intersections between different surfaces, among others.

One of the challenges that the research takes into consideration is to restrict both the parameters and the generative logics of surfaces to the disciplinary field of Descriptive Geometry. The parameters represent domains of spatial coordinates, relationship rules between geometric elements, solid operations, etc.

A parametric model that accurately represents the survey data would necessarily be very complex since it should take into account not only the geometric compositional aspects of different solutions for different vaulted surfaces, but also construction aspects and irregularities of the building.

In regard to the geometric-compositional matrices, the many characteristics or specific solutions would multiply uncontrollably when describing the examples analysed with a high level of metric precision.

The structural irregularities and the parameters for their description would add to the complexity and should take into account irregularities in the plan, local relative sags of surfaces caused by structural settlement, inaccuracies and/or adjustments made in the construction.

All of this should be openly acknowledged against the objectives that we set: it would make the construction of the model itself enormously unwieldy, it would require the insertion of an excessive number of parameters, and it would make the use of the model challenging for the description of the different cases. Assuming the model is controllable and accessible, its metric accuracy would go against the desire to build a tool that enables agile comparisons between the studied architectures and rapid geometric simulations of objects yet to be studied.

IV. Results and Conclusions

In light of these considerations, it was considered appropriate to limit the number of parameters and sacrifice some of the opportunity to describe a measured surface, which can be described more easily by other instruments and with survey accuracy that requires much more binding measurements. This is done to represent the main spatial quality of architecture under varying parameters. The model is thus aimed at reproducing the theoretical models underlying design concepts while renouncing the chance to consider all the variables of the construction to enable rapid and efficient exploration of the different geometric configurations. Therefore, a simple parametric model should represent the spatial qualities of the various architectures while highlighting similarities and differences.

In a similar manner as it happened within the field of parametric design, parametric technology, which is used for three-dimensional survey of existing architecture, could be intended not only as a technical but also a conceptual resource that permits to reformulate digital reconstruction's problems in a different manner.

An additional consideration must be made about the definition and description of the formal elements used for the construction of system of vaults. In this regard, within the form-making practices, shape-grammar studies represent a consolidated and systematic methodology that can open interesting research developments. Some works, considering entirely the building, refer to notions of type and typology [25] to categorize spaces and objects on the basis of their own structural similarities [26] [27] [28]. In the case of the digital interpretation and re-construction of complex vault systems, it would be more appropriate to refer to continuous surfaces and their grammar and to a relations' syntax that connect them.

These latter considerations, which are related to a Grammatik and syntax structure of vaults, not only had a remarkable influence on the parametric model's construction, but they also offer a valid starting point for the definition of a repeatable methodology that could be used to study several complex vault systems; this aspect could also be one of the most prominent developments of research in this area.

Fig. 5. Parametric models of Planterian vaults in Turin. Synoptic representation of selected cases by the parametric model: plan, elevations and perspective views. (a) Palazzo Saluzzo Paesana, (b) Palazzo Villanis, (c) Palazzo Perucca della Rocchetta. Models: Marco Vitali (From Vitali, 2017)

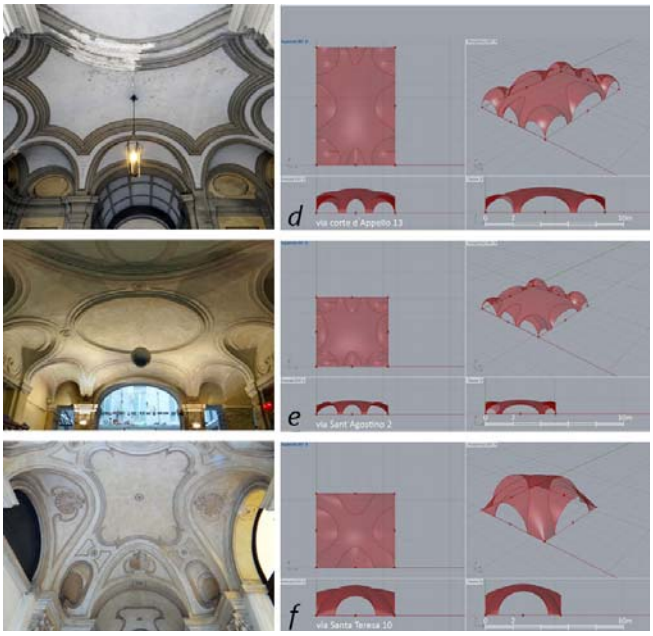

Fig. 6. Parametric models of Planterian vaults in Turin. Synoptic representation of selected cases using the parametric model: plan, elevations and perspective views. (d) building in Via Corte d'appello 13, (e) building in Via Sant'Agostino 2, Palazzo Saluzzo Paesana, , Palazzo Perucca della Rocchetta, (f) Palazzo Riche di Coassolo. Models: Marco Vitali (From Vitali, 2017)

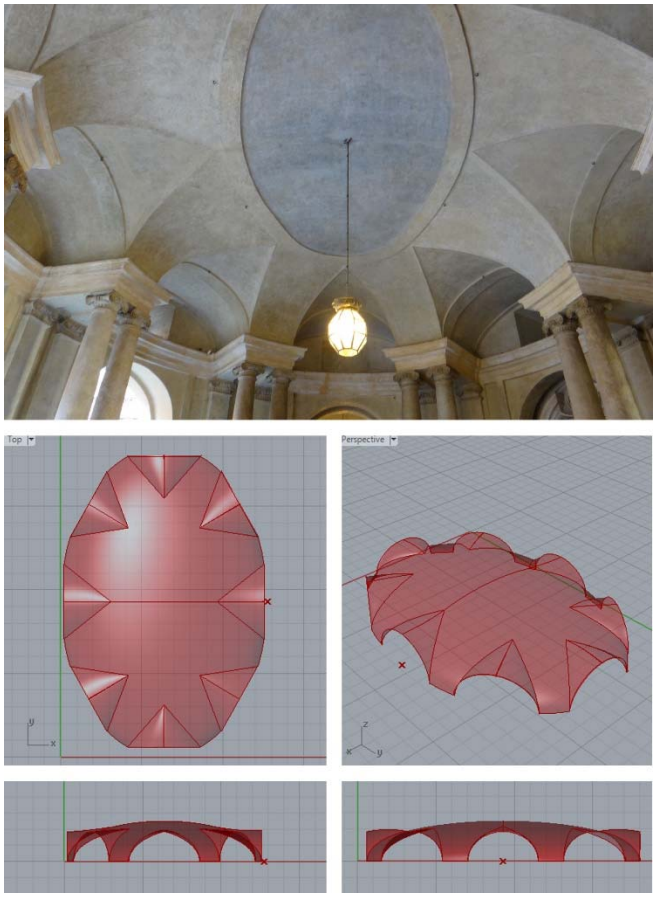

Fig. 7. Parametric model of the geometric configuration of the vault of the atrium of Palazzo Carignano: plan, elevation and perspective

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