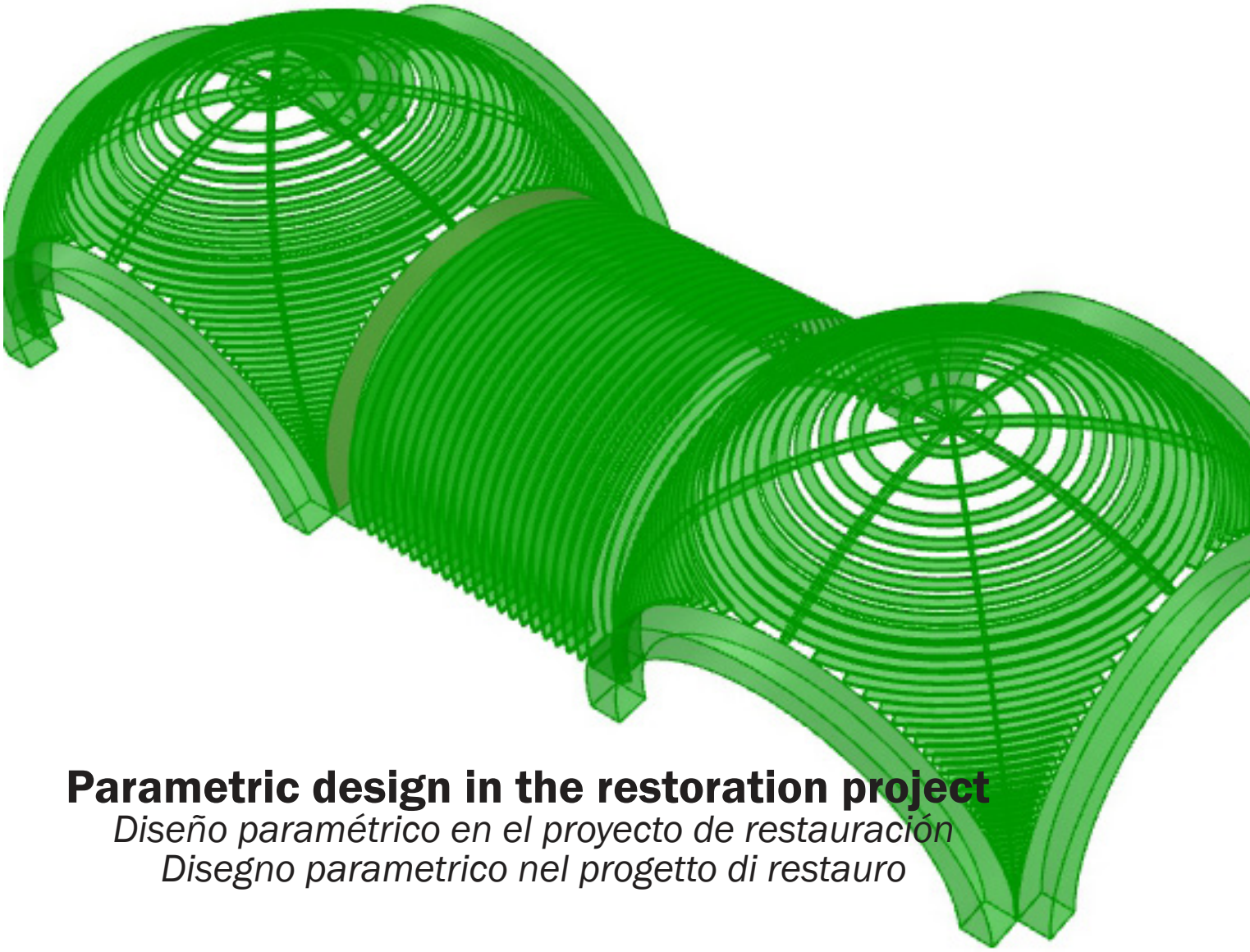
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Parametric design in the restoration project

Diseño paramétrico en el proyecto de restauración

Disegno parametrico nel progetto di restauro

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Abstract

The objective of this article is to present the use of parametric design in the development of restoration projects. Parametric design is a contemporary technique that has influenced diverse disciplines including architecture. It is a design process that consists of establishing the properties of the object through the use of algorithms. Being a useful technique for the deduction of geometric objects, *how can the parametric design be implemented in the restoration project?* Related to the philosophy of restoration, the parametric design can be adapted to the restoration by *analogy* or *contrast*, because it is possible to reproduce in a deductive way the same form of a previously existing object, but in turn, the object can be modified using parameters, achieving the difference between its new part and its original part. It allows to consider safety factors to achieve a stable construction. The reconstruction of the cupola of Ex-Oratory of San Filippo de Neri, located in Bologna, Italy, was analyzed. An algorithm was developed, for represents a similar restoration proposal. For the elaboration of the algorithm it was defined a set of finite variables related to the geometric development of domes, starting from a geometric conceptualization, logical mathematical concepts were used to determine the necessary steps in the generation of the form. This technique can be replicated in the reproduction of forms of architectural elements, using data obtained from historical records such as chronicles, diagrams, sketches and plans, or by geometric deduction from observation and direct recording.

Keywords: design, algorithm, project, restoration, reconstruction.

Resumen

El objetivo de este artículo es presentar el uso del diseño paramétrico en el desarrollo del proyecto de restauración. El diseño paramétrico es una técnica contemporánea que ha influido en diversas disciplinas incluyendo la arquitectura. Es un proceso de diseño que consiste en establecer las propiedades del objeto por medio del uso de algoritmos. Siendo una técnica útil para la deducción de objetos geométricos, ¿cómo puede implementarse el diseño paramétrico en el proyecto de restauración? El diseño paramétrico puede adaptarse a la *restauración por analogía* o *por contraste*, porque es posible reproducir de manera deductiva la misma forma de un objeto antes existente, pero a su vez, se puede modificar por medio de parámetros, logrando la diferencia entre la parte nueva y la original. Esto último, permite considerar factores de seguridad para lograr una construcción estable. Se analizó la reconstrucción de la cúpula del Ex Oratorio de San Filippo de Neri, localizada en Bologna, Italia. Se desarrolló el algoritmo para representar una propuesta similar de restauración. Para formular el algoritmo, se definió el conjunto de variables finitas relacionadas con el desarrollo geométrico de cúpulas. Partiendo de una conceptualización geométrica, se utilizaron conceptos lógicos matemáticos para determinar los pasos necesarios en la generación de la forma. Esta técnica puede replicarse en la reproducción de formas de elementos arquitectónicos, usando datos obtenidos de registros históricos como: crónicas, esquemas, sketches y planos, o bien, por la deducción geométrica desde la observación y registro directo.

Palabras clave: diseño, algoritmo, proyecto, restauración, reconstrucción.

Riassunto

L'obiettivo di questo articolo è presentare l'uso della progettazione parametrica nello sviluppo del progetto di restauro. Il design parametrico è una tecnica contemporanea che ha influenzato diverse discipline, inclusa l'architettura. È un

processo di progettazione che consiste nello stabilire le proprietà dell'oggetto attraverso l'uso di algoritmi. Essendo una tecnica utile per la derivazione di oggetti geometrici, *come la progettazione parametrica può essere implementato nel progetto di restauro?* Correlate alla filosofia della ristorazione, la progettazione parametrica può essere adattato al restauro per *analogia* oppure per *contrasto*, perché è possibile riprodurre deduttivamente la stessa forma esistente oggetto, ma a sua volta, parametri può essere modificato, ottenendo la differenza tra la nuova parte e la parte originale. Quest'ultimo consente di considerare i fattori di sicurezza per ottenere una costruzione stabile. È stata analizzata la ricostruzione della cupola dell'ex Oratorio di San Filippo de Neri, situato a Bologna, in Italia. È stato sviluppato l'algoritmo che rappresenta la stessa proposta di restauro. Si ha fatto la definizione del gruppo di variabili finiti relative allo sviluppo geometrico delle cupole, per la rappresentazione dell´algoritmo. A partire da una concettualizzazione geometrica, sono stati utilizzati concetti matematici logici per determinare i passaggi necessari nella generazione della forma. Questa tecnica può replicare nel riprodurre le forme di elementi architettonici, con i dati ottenuti dai record storici come croniche, diagrammi, schizzi e disegni, oppure, per deduzione dalla constatazione geometrica e la registrazione diretta.

Parole chiave: designo, algoritmo, progetto, restauro, ricostruzione.

Introduction

Design is commonly defined as the set of activities to solve a problem, transforming existing situations into others that are preferred (Taura & Nagai, 2013, p. 09). It is a process that consists in determining the set of features that an object must include, in order to be created to fulfill a function. In architectural context, design is a synonymous of projecting (De Fusco, 2008).

Something is called *parametric*, when it depends on a set of determined variables and assigned data. Conceptually, any methodical design process is a parametric design, because it follows a process in which variables are assigned to determine the result. However, the term *parametric design* is coined to a contemporary design movement, which (a) makes use of digital media to determinate the characteristics of the design object and (b) through of a set of parameters generated and assigned by the designer.

The *parametric design* is the result of the influence that, computational computer techniques and digital media advances have, had in the last decade on the design practices (Oxman, 2017, p. 10). In this process there is a connection between cognitive models and computational processes (Oxman, 1995). This has impacted the *design thinking*[1], changing from the traditional model to *the algorithmic thinking*[2], carrying the representation of the sketches to the use of *design algorithms* (Oxman, 2017, p. 10).

An *algorithm*[3-4] is the set of instructions to perform mathematical operations, designed to get the solution of a given problem (Henrici, 1964/1977, p. 18). In computer science, an algorithm is the set of steps ordered to transform input data into output data (Cormen et al., 2003, p. 05).

The relationship between the algorithm and the

[1] It is a creative approach to problem solving recognized as a valuable route focused on human innovation (von Thienen, et al., 2018, p.13). Design thinking is the set of creative strategies that the designer uses during the design process.
[2] Algorithmic thinking is defined as the set of rules written by a source code, of explicit instructions that initiate digital procedures for the generation of digital forms (Oxman, 2017, p.10).

architectural design is found in the fact that most architectural designs are controlled by guidelines, regulation, or decision rules that can be adopted or not, as well as an algorithm capable to control selected conditions (Österlund, 2010, p. 17).

A design algorithm is the description of a procedure to generate of a parametric model. Parametric modeling is the generation of entities using parameters, which has a number of possibilities for generating and analyzing forms and models (Stavrić, Šiđanin, Tepavčević, 2003, p. 67). The parametric definitions can be used to connect the developed design with manufacturing and to optimize, mainly all, the modeling processes at the architectural scale (p. 67), indicating the characteristics with which it can be reproduced.

This technique has influenced to various design disciplines, including architecture. Algorithms have been used in architecture for more than three decades, in high-tech design trends. The architectural tendencies are known as generative architecture, architectural morphogenesis, complex geometry, parametric design or neo-structuralism, the latter characterized in a manifesto by Oxman and Oxman (2010, pp. 14-23). They also have been used for the reproduction of organic forms by means of triangulated geometries (Biomimicry).

According with this fact, being algorithmic thinking a contemporary design strategy for the generation of architectural forms, the research question is, *how can the parametric design serve in the restoration project?* The aim of this article is to show the use of parametric design in the development of the restoration project. Analyzing how contemporary design can be integrated into the conservation project.

Critical restoration and contemporary architecture

To answer the research question, it is necessary to relate contemporary design with the restoration philosophy. Because, there is a relationship between contemporary architecture and historical architecture. It is necessary first to make reference to *The critical restoration movement*, where design plays an important role in the restoration project. *Critical restoration* was a trend expressed after the Second World War, and was a movement that advocated the conceptual architectural and compositional design treatment (Rivera, 2008, p. 181).

Benedetto Croce, was the philosopher who influenced current restoration. He inspired modern reconstruction in Italy, created a method of aesthetic appreciation that emphasized the attribure of the whole object on the attributes of its details (Jokilehto, 1986, p. 412). But those who developed the proposal were Giulio Argan, Roberto Pane, Renato Bonelli and Cesar Brandi, who proposed the interpretation of the building's artistic values relegating documentary values (Rivera, 2008, p. 196).

Guilio Argan, distinguished between conservative restoration and artistic restoration. The artistic restoration was characterized by a series of operations based on the evaluation of the critical history of the works of art, and its objective was to enhance the aesthetic attributes of the object (Jokilehto, 1985, p. 413). For his part, Roberto Pane, considered that the restoration project should include creative elements, concluding the

[3] The term algorithm comes from algorismus, a Latin translation of the surname of the Persian mathematician Mohammed Al-Khowarizmi, who lived during the ninth century, known for establishing the step by step rules of the operation of addition, subtraction, multiplication and division of decimal numbers (Joyanes, 2008, p.64).
[4] Algorithms have been an essential part of the development of mathematical science, especially numerical analysis, which is the theory of procedures that allow obtaining solutions to mathematical problems with an arbitrary precision in a finite number of steps that can be carried out rationally in mathematical analysis (Cormen et al., 2003, p.17).

work in the best way: restoration as a work of art (Jokilehto, 1985, p. 416). Bonelli, says that any operation and intervention in the monument will be subordinated to the object of reintegration, where the architect has an important role in the restoration project, and to preserve the expressive value of the work, because the intervention must achieve the liberation of its true form (Rivera, 2008, p. 181).

The following aspects from Brandi (1963/1995, p. 16) are highlighted. He points out that: (a) only the matter is restored, because it is consubstantial with the unrepeatable image of the artistic work (p. 16); (b) but the singularity of the work does not consist in its matter, nor in its historicity, but in its artistic condition (p. 17); (c) matter is a manifestation of the masterwork art that can be conceived in form and structure: the structure can be reinforced or replaced, but form is the essence of appearance (pp. 19-20); (d) the masterwork is defined by its unity, as a complete object indivisible in parts (p. 23) here the influence of Benedetto Croce; (e) history not only refers to the first historicity, but also to the second, where the temporization between the two instances represents the dialectic of restoration (p. 17), so the work will be submitted to operate as a stimulus in the present, it will be required to have a topicality (p. 30), and finally, (f) the restoration is a function of the actualization of the masterwork (p. 51). Varagnoli (2017) comments that in two the last points mentioned by Brandi (1963/1995), it leaves open the temporal and spatial dimension of the restoration work, the use of contemporary creativity in the work of restoration, and since then, interventions with contemporary aesthetics in the conservation project have multiplied[5].

The ideas mentioned above, manifest (a) the importance of recovering the aesthetic qualities of the object to be intervened, contained in its form and image; (b) which represent the artistic value, because (c) this is the unique manifestation of the human being that provides the invaluable character to the object, that (d) only exists in the whole work and (e) is possible make a contemporary intervention in the monument. This leads to analyze three aspects, the aesthetics used in the restoration, the artistic activity of the intervention and the conservation of form and image.

The restoration project based on Boito postulates, in the movement of modern restoration, had been carried out under an aesthetic that consisted in the formal differentiation of the old with the new: the contrast. This is also present in the scientific restoration, and is established in the international documents of restoration from the Restoration Charter (1972) to the Venice Charter (1964). The differentiation of the intervention, besides being the easiest way to how which part of the building is the oldest, probably has a relationship with the position of the rational-functionalist movement which valued negatively the historical architecture (Sola-Morales, 1985). With the rupture of this movement, the contrast[6], as an aesthetic category, also ceases to be relevant and becomes a contractual movement. Sola-Morales (1985) indicates that the use of contrast characterizes the sensitivity of the restoration project of the twentieth century, and its psychological key is based on the subjective perceptive satisfaction of the old.

In critical restoration, the contrast of interventions

[5] Brandi (1963/1995) also points out that the development of the figurative capacity of a fragment allows its successive link with other parts of the work.
[6] The contrast is also a heritage of historiography, which emphasizes the differences of the architecture of the past with the architecture of the present (p. 54).



Figure 1. Reconstruction of the church of Santa Clara, Naples. Intervention by contrast. Photography by L. C. Cruz Ramírez, 2017.

is intrinsic in the restoration project, in which contemporary design is integrated with historical architecture. The project of postwar reconstruction of the church of Santa Clara in Naples, product of Roberto Pane's manifesto, the church is reconstructed with a contemporary aesthetic with abstract features alluding to historical architecture form, conserving only the existing medieval Gothic structures (Figure 1). With this the contrast of the shape in a reconstructed building was achieved.

On the other hand, contrast is not the only category of intervention. Sola-Morales (1985), identifies the analogy, opposed to the contrast. It is a proposal of intervention, which is developed from the dominant features in the old building, where the integration was a continuity of the building. The analogy is a way in which the contemporary restoration project is directly related to the historical building and coexists (Varangoli, 2008). However, the analogy is not a new proposal, it has also been present in various intervention projects. The intervention of the outer rings of the Colosseum is an analogous intervention in form and material (Figure 2).



Figure 2. Reconstruction of outer rings of Colosseum (Flavian Amphitheatre), Roma. Photography by L. C. Cruz Ramírez, 2018.

Three influences are fundamental to the approach of the restoration by analogy: Ambrogio Annoni, Cesar Brandi[7] and Giorgio Grassi. Annoni, although based on the rational-functionalist movement, it was believed that the intervention of the building was a particular aspect, not generalizable and that it was defined in the very form of the building. Brandi (1963/1995, p. 16) points out that any intervention will be in each case the only legitimate imperative: each case is a different one (p. 35). In this same line, Grassi, noted that the intervention methodology was provided by the architecture of the same building.

The way to achieve the analogy was also theoretically developed from the same critical restoration, in the typological intervention. Although the typology was a proposal known worldwide by Rossi (1966/1971), it was his teacher Saverio Muratori, who developed the use of typological analysis in reintegration projects in postwar construction (Varagnoli, 2016). Of course, the contributions of Rossi (1966/1971) are highly relevant, because also reflected the artistic dimension of architectural compositional treatment of architecture in historical contexts. The interventions carried out by Carlos Scapa, in Castelvecchio, in Verona (Figure 3), are also representative.



Figure 3. Restoration of Carlo Scarpa in Castelvecchio, Venona. An example of intervention by analogy. Photography by L. C. Cruz Ramírez, 2018.

Finally, the recovery of the idea of the form is presented in the reintegration of the image, proposed by Carbonara (1976), which consists of the conformation of the figure of the object, by means of an intervention using different materials. It seeks the exaltation of the pre-existence, in terms of the figurative quality, of the new, placed at the service of the old, which lies between the historical instance and the brand's aesthetic (Carbonara, 2008, p. 118) (Figure 4).



Figure 4. The Rivoli Castle. Intervention of the reintegration of the image. Photography by L. C. Cruz Ramírez, 2017.

The parametric design can be applied in the restoration project, in the design stage of interventions. This can be related to contrast restoration, analogy and image reintegration tendencies. By means of algorithmic thought, it is possible to reproduce the idea of the form, taking into account the typological analysis of the building, and that can be represented by means of a simplified geometry with the use of parametric design. This is how the intervention project can be adapted to the restoration by analogy, since it is possible to reproduce in a deductive way the

same form of the previously existing object, but at the same time, with its contemporary form and the modification of its parameters, it can be achieved the difference between the new part and the original part.

Method

The parametric design makes use of design algorithms, to represent in an orderly manner the set of steps necessary to obtain a resulting form. Two study variables were considered: (a) the parametric design and (b) the restoration project. The project of restorations looking for recover the form of the building. The parametric design makes use of digital media to determinate the characteristics of the design object through of a set of parameters generated and assigned by the designer.

The use of parametric design at the design stage of interventions begins with (a) the naturalistic observation. If required, (b) the measurement of the parts of the building elements to be integrated. Then (c) goes to the stage of conceptualization: The architectural forms are deduced starting from a geometric conceptualization. The conceptualization of the form is a process in which is determined how physical characteristic of the object can be created from basic flat polygons or basic volumes shape. Next, (d) logical mathematical concepts and algorithmic thinking are used to determine the necessary steps in the digital generation of the form. This is where it can make use of the formal typological analysis of the building, and define the first set of parameters. The logical concepts necessary are the ordered hierarchy of processes for draw, Boolean operations, and transformation geometry operations. The parameters depend of the original form. In this case, the form of the barrel vault depending of the dimension of transversal arcs and masonry webbing; the dome depending of the transversal and lateral arches, the pendentive form and the surface of the dome.

Later, (e) begins to generate a digital simplified geometry. In this process, the parameter of the basic flat or volume geometric shape are assigned to each architectural object. The assignment of values to the design parameters is completely experimental, because in this process is described the way to draw in three dimensions the form of the object that has been deducted with the analysis of form at the “c” and “d” sections previously cited. The experimental manipulations of the geometric values were applied to the parametric design. This was done in a controlled manner, considering volumetric construction processes. Boolean operations are performed on the basic geometry to generate composite geometry. Afterwards, it is projected the final geometry, with the use of other parameters (parameter of geometric transformation), which can create a complex geometry that adapts to the initial shape, achieving a reintegration of the image.

The case of the reconstruction of the dome of the Ex-Oratory San Filippo de Neri, located in Bologna, Italy, was selected as the object of study (Figure 5). The generic procedure mentioned in the previous paragraph was followed. This case is representative, because in this intervention the concept of the reintegration of the image was used, and a restoration by formal analogy. But, in turn, an abstraction of form with contemporary aesthetics is presented. It was defined the

[7] Brandi (1963/1995, p.40) alludes to the intervention by analogy in the intervention of reconstruction, in which she points out that she “tries to reconstitute the work again, to intervene in the creative process in a manner analogous to how the original was produced, tries to recast the old and the new in such a way that they do not distinguish themselves and minimize the interval of time that separates the two moments”.

set of finite variables related to the geometric development of the shape of the domes, and later it was developed the design algorithm that represents this restoration proposal.

Analysis

The Ex-Oratory of San Filippo di Neri, in Bologna, is a building originally completed in 1733 (Seum, 2001). The roof covering, with its vaults and dome, was destroyed after being bombed, in 1944, during the Second World War (Seum, 2001). The intervention carried out in the restoration project consisted in the reconstruction of a system of domes and vaults that were integrated with a wooden structure. The form is analogous to the existing ones. The transversal arches were reconstructed in masonry, similar to the original arcs achieving, in turn, the reintegration of the image of the cover.

The first step, for the parametric design was the recognition of the simplified geometry of the building. The reconstruction of the roof includes the integration of two domes and a vault. Each dome is supported on a pendentive, conformed by two lateral arches and two transversal arches. The geometric development can be described in various ways, the one which was used in this experiment is described below.



Figure 5. Final completion of the intervention project of the roof of the Ex- Oratory of San Filippo de Neri, Bologna. Retrieved from La Fondazione del Monte di Bologna (2018).

The transversal arches of the two pendentive delimit the barrel vault of semicircular form. The domes are formed by two hemispheres, which can be described geometrically as the half-arc surface in revolution. The vault is constructed by means of an extruded arch. The pendentives are constructed by the intersection of two volumes. The first is obtained by subtracting two segments of cylinders cut in the middle of the circumference, forming two vaults that pass through two axes (x, y) of a cube. The second volume is a hemisphere. The pendentive is obtained by inscribing the protruding cube segment in the hemisphere, where the upper vertices of the cube are in contact with the surface of the hemisphere (Figure 6).

On the arcs obtained by the subtraction of the segments of cylinders in the cube, transversal arches and lateral arches are projected. The transversal arch defines one of the ends of the vault that projects to the intersection of the next transversal arch of the next pendentives.

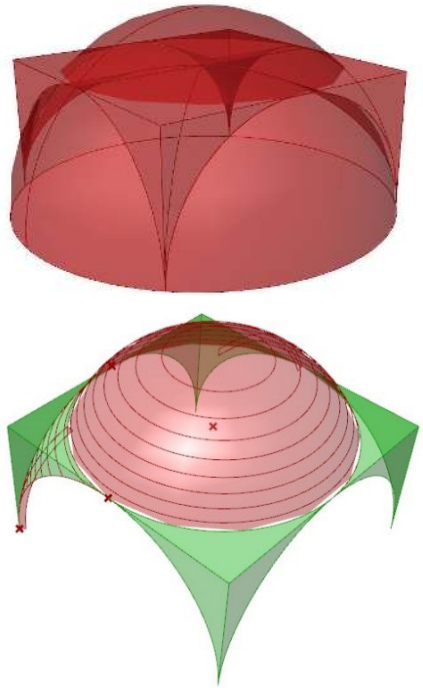


Figure 6. Parametric construction of pendentives and dome by Boolean operation. Made by L. C. Cruz Ramírez, 2018.

Results

The result is the following geometrical elements: two hemispheres for the domes, the two composite figures for the pendentives, and the half cylinder for the vault (Figure 7). This process was parameterized and represented by means of a design algorithm (Figure 8).

On this simplified geometrical model, it was proceeded to project a shape similar to that observed in the Ex- Oratory San Filippo de Neri, Bologna (Figure 9-10). With this in mind, a series of horizontal planes (XY) were intersected on the domes at the top of the development of the pendentive and the dome. On these cutting axes the sections that represent the pieces of wood were projected. In the case of the vault, another series of plans was projected throughout its development, which, similar to the projection of the dome and the pendentives, served as the axis for the projection of the wooden sections.

Conclusions

In this article it was shown that the parametric design can be used in the conservation project, in the design stage of interventions. With the parametric design you can achieve the formal schematic reproduction of the building, which is useful for the presentation of various architectural models and their types. The parametric design makes use of algorithmic design thinking, which is a tool and technique that has been developed with the emergence and proliferation of computational computer techniques and digital media applied to design. For this, design algorithms are used.

The restoration does not negate the integration of contemporary architecture as it has been shown in the analysis of restoration postures. From the movement of critical restoration to the present, with the continuity of this movement, the aesthetic enhancement of the formal essence of the architectural heritage has been sought in

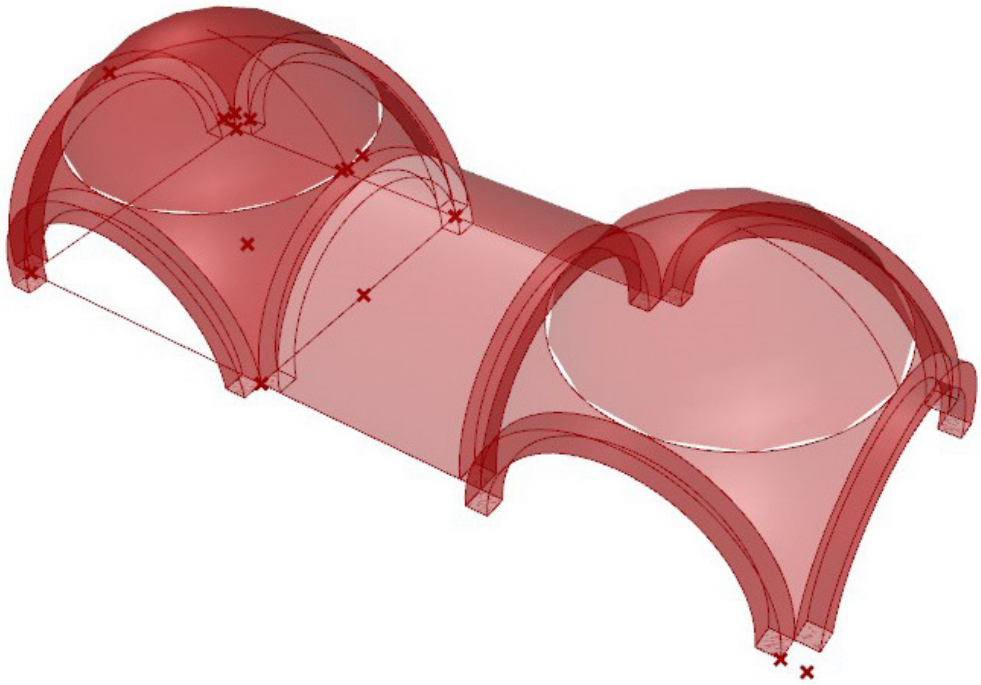
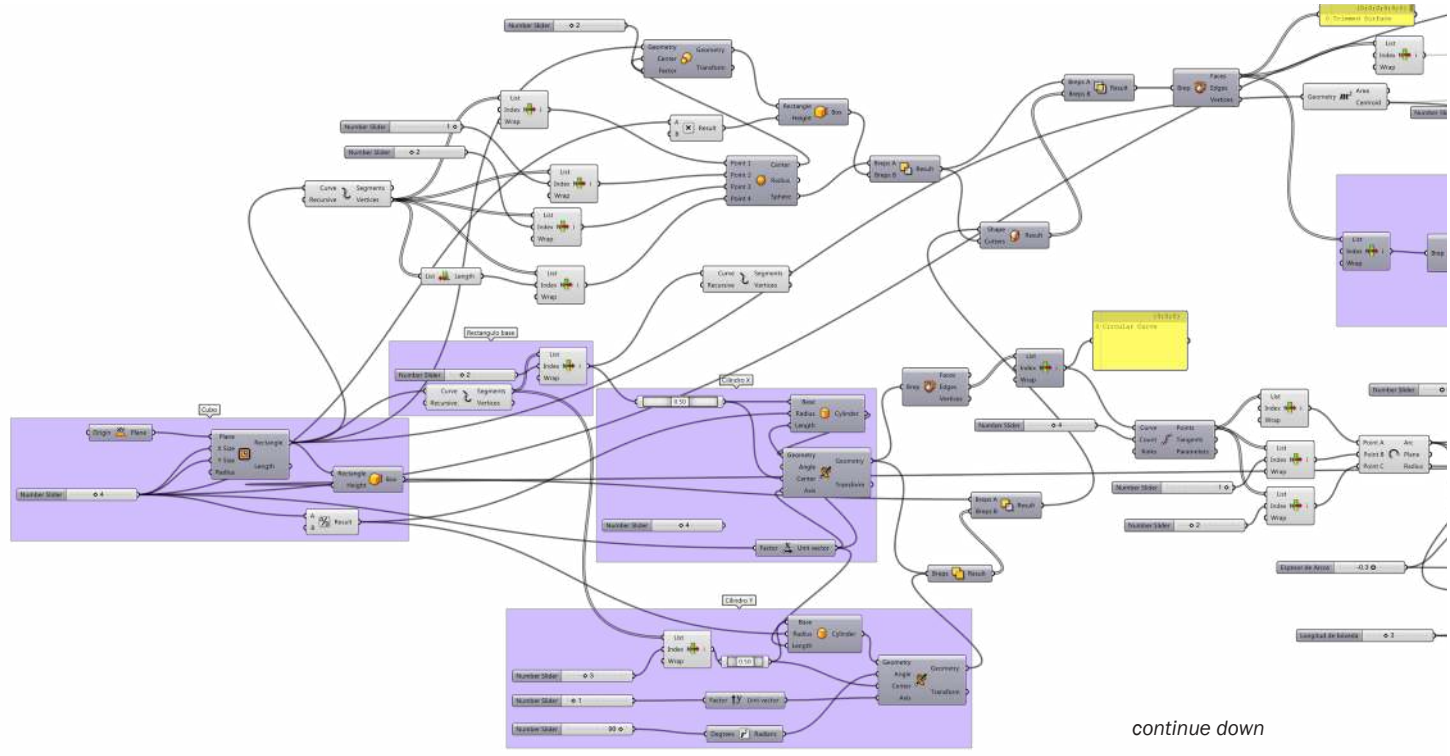
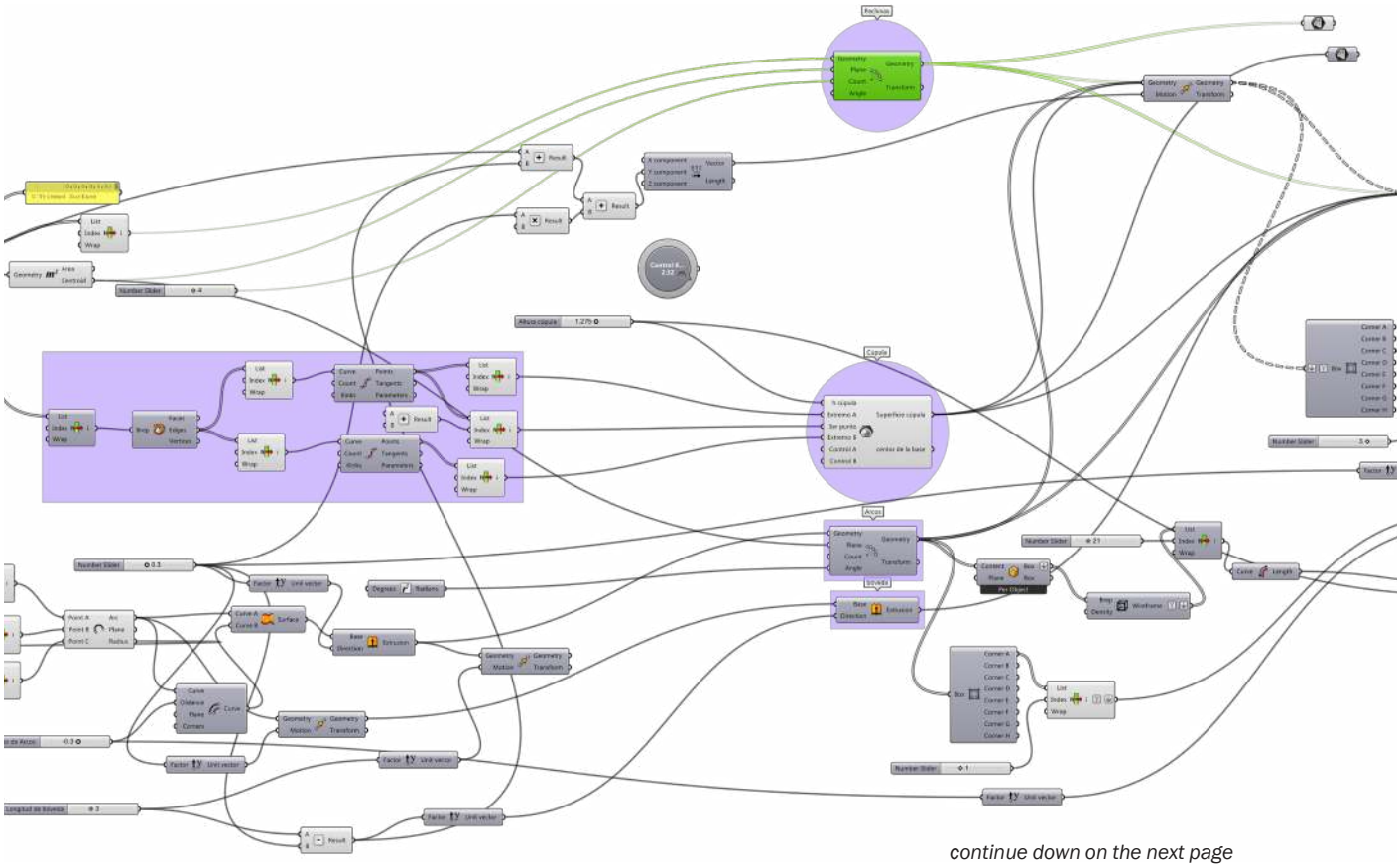


Figure 7. Parametric construction of the simplified geometry of the reconstructed roof. Made by L. C. Cruz Ramírez, 2018.



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Figure 8. Algorithmic model of the vault and domes in the Ex-Oratory of San Filippo de Neri, Bologna, Italy. Developed by L. C. Cruz Ramírez, 2018.

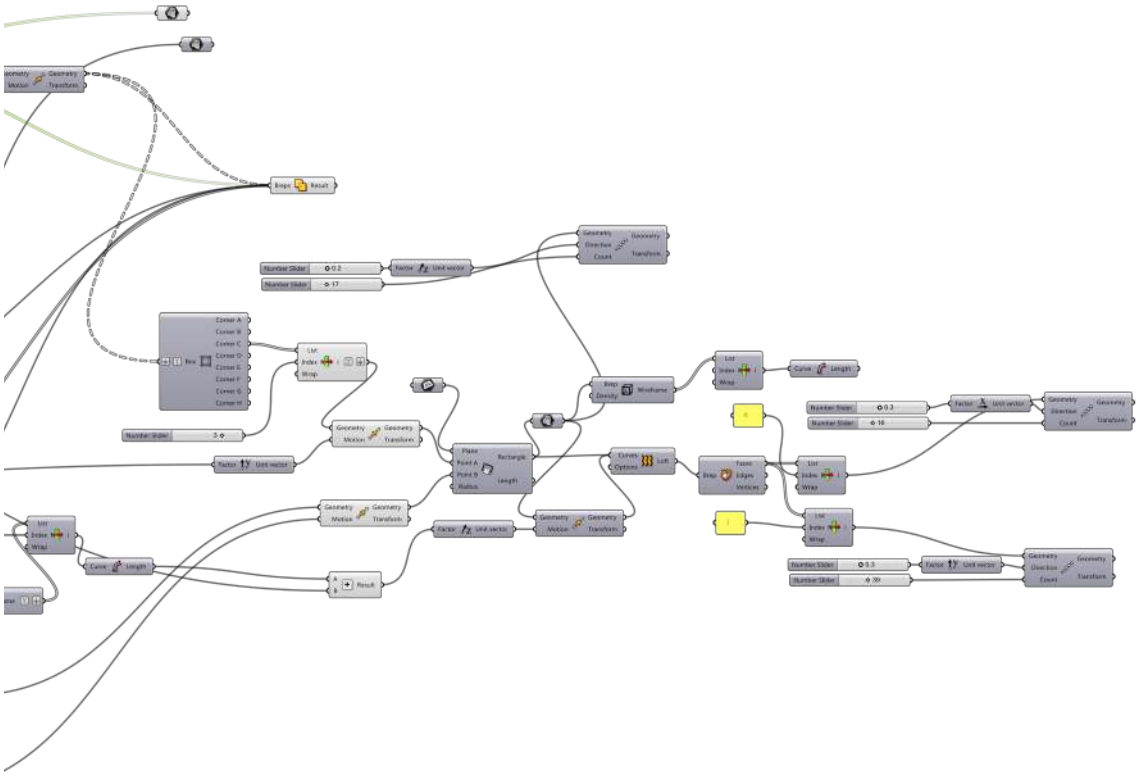


Figure 8. Algorithmic model of the vault and domes in the Ex-Oratory of San Filippo de Neri, Bologna, Italy. Developed by L. C. Cruz Ramírez, 2018.

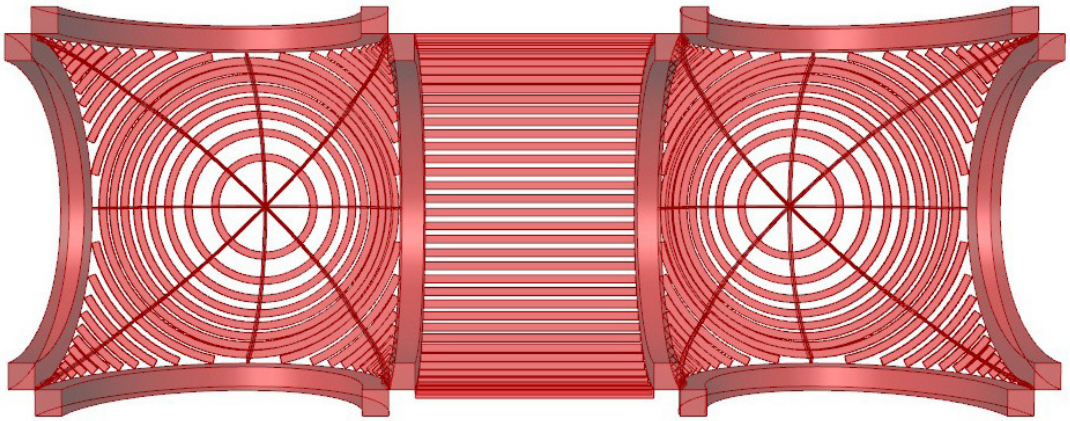


Figure 09. Botton view of parametric projection of the reconstruction of the roof of the Ex-Oratory of San Filippo de Neri, Bologna, Italy. Made by L. C. Cruz Ramírez, 2018.

various ways, which is not limited to material. In this search, several trends have emerged that are widely classified in Carbonara (2013). However, reference has been made to contrast restoration and then restoration by analogy, this latter part from the "contractual" contrast response. Restoration by analogy is the principle on which an intervention project can be developed that relates the form of the patrimonial building and the parametric integration can be developed. In addition, the concept of the reintegration of the image in the parametric design project can be used.

As shown in the example, the algorithmic deductive thinking can project the basic envelopes, from which a significant number of types of complex geometric projections can be obtained later, which become the final form to be integrated. This technique can be replicated in the reproduction of forms of architectural elements, with data obtained from historical records such as

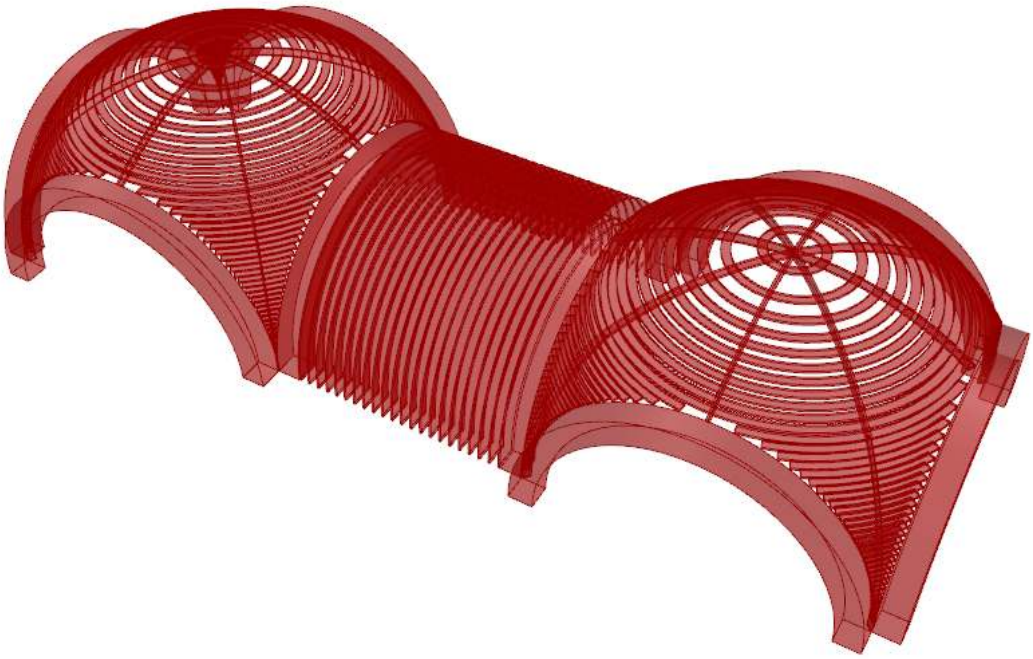


Figure 10. Final parametric projection of the reconstruction of the roof of the Ex-Oratory of San Filippo de Neri, Bologna, Italy. Made by L. C. Cruz Ramírez, 2018.

chronicles, diagrams, sketches and plans, or by geometric deduction from observation and direct recording. It is also possible to take the results to studies of stability and formal optimization.

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Gremium