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Geometric and Parametric Modeling to Identify the Characteristics of Niemeyer's V Columns

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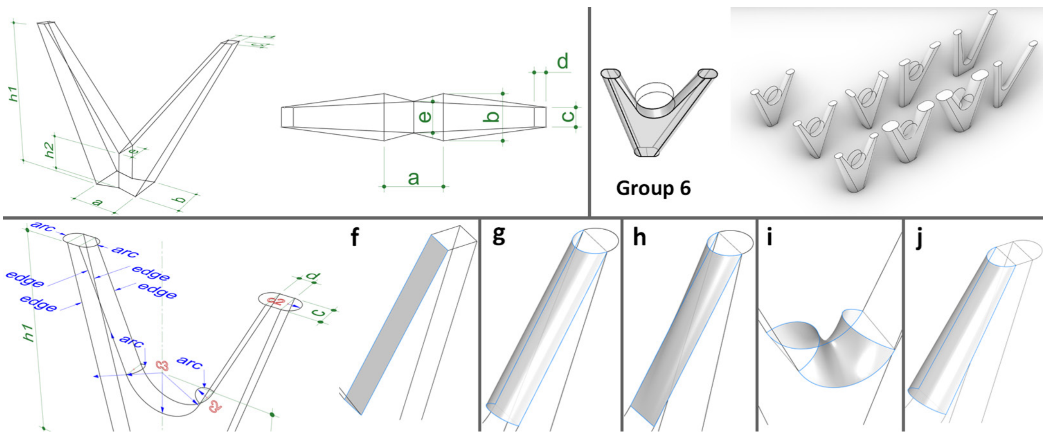
Abstract

The reinforced concrete structure allowed an effective renovation of the building elements' geometry definition within the framework of modern architecture. The architect Oscar Niemeyer's innovative contribution in this regard was to generate a set of columns, which not only transmit the building's load to the ground but also provide 'visual' lightness to this constructive element. The architect created new forms of columns – 'V', 'W', 'Y' – to demonstrate his creativity regarding this element in the context of modern architecture in his time. The 'V' column appears in Niemeyer's work in the early 1950s. However, until now there is no study related to the geometric characteristics of his V columns. The methodological procedures adopted were distributed in four phases: 1. Survey of projects in Oscar Niemeyer Foundation that contain 'V' columns; 2. Identification of its most relevant geometric characteristics; 3. Analysis of columns 'V' by geometric modeling to identify the parameters that make up each type; 4. Parametric modeling to combine parameters and to generate a set of variations. Classification by groups of columns with similar characteristics and Discussion on the results obtained. The research proved that Niemeyer retrieved previously applied knowledge and reused it in a new design situation. The original contribution of this paper is to identify and classify the geometric characteristics of Niemeyer's 'V' columns.

Keywords
Algorithm, Design Process, Modeling, Parametric Modeling, Parameter



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Introduction

The reinforced concrete structure allowed an effective renovation of the building elements' geometry definition within the framework of modern architecture. Among the architect Oscar Niemeyer's innovative contribution in this regard was to generate a set of columns, which not only transmit the building's load to the ground but also provide 'visual' lightness to this constructive element.
The columns of buildings with more than two floors designed by Niemeyer have innovative geometry. The columns shapes that stand out are 'V', 'W', or 'Y'. The design of these columns demonstrates the lightness in transmitting the entire weight of the building to the ground. In higher buildings, the reduction in the number of columns on the ground floor is achieved through 'V', 'W' and 'Y' columns, and they were widely used in buildings in the '50s. The architect's *oeuvre* has been studied by many researchers [Papadaki 1951; Petit 1995; Dulio 2007; Philippou 2008; Pagliano 2011]. However, so far there is no specialized and systematic research on the geometry of the curvilinear columns, nor the identification and classification of 'V' type columns.
We identified three arguments used by the architect [Niemeyer 1975; Niemeyer 1978; Niemeyer 1998; Niemeyer 2000]. Initially, these shapes are justified as an alternative to the excess of rectilinear columns in buildings that reach the ground floor, causing excessive repetition, allowing the architect to reduce the number of columns by converging two columns of a building in one, but with larger dimensions. The second use is to intensify the overhang effect in buildings with a recessed ground floor by having the 'V' columns carry the load transition toward one end near the ground floor. The third use is to sustain marquees, providing structural support with greater lightness and graciousness.
As results from Florio's and partners studies [Florio, Tagliari 2020; Florio et al 2019; Florio et al 2017] is possible to affirm that Niemeyer explored different geometries along his career. In this paper we relate the research that explored geometric and parametric modeling of 'V' columns designed by Oscar Niemeyer. We investigated how Niemeyer retrieved previously applied knowledge and reused it in a new design situation. To prove this hypothesis, it was necessary to identify the columns in their projects, as well as parametrically generate a set of columns from the parameters identified in the architect's drawings. So, we adopted the concept defined by Rivka Oxman, denominated "refinement and adaptation" [Oxman, 1992]. Refinement is a cognitive process based on 'generic' design, while adaptation is another cognitive process in which a 'prior design' is adapted into another during a situated act. Refinement is linked to a schema; it is diagrammatic and, therefore, flexible enough to produce derivations. Thus, the architect produces an initial diagrammatic and abstract schema based on his tacit (implicit) knowledge to condense his previous knowledge and store it in his long-term memory.

Methodology

Phase 1: i. Gathering of data at the ON Foundation and in books and periodicals on the work of the architect; ii. Research on newspapers containing interviews and testimonies of the architect.
Phase 2: iii. Gathering drawings, iv: Analyses and identification of the most relevant geometric characteristics of each column.
Phase 3: v. Identify the parameters and variations; vi. Geometric modeling of the columns.
Phase 4: vii. Parametric modeling; viii. Generate the columns; ix. Classification by groups; x. Discussion on the results obtained.
During the steps of phases 1 and 2, we produced an historical and theorical material about the columns in Niemeyer's oeuvre. In this paper we have to put forward only the synthesis of the main steps of phases 3 and 4.

Research and Results

Characteristics of the geometry of the 'V' columns

During the geometric modeling it was possible clarify each parameter adopted by the architect to define his 'V' columns. Unfortunately, the information collected about his projects is not enough, and occasionally inaccurate. As a result, we decided to assume some decisions from the drawings provided by Niemeyer Foundation and consulted books published about his buildings and projects.

Geometric modeling is time consuming, particularly when different kinds of surfaces. Initially we decided to model the width of the base and the top supports with the same dimensions, as the objective was to understand the geometric characteristics.

Since the beginning we noticed that the geometry of the base and the top were restricted to square, rectangle, circle, oblong, and rectangle with fillet corners. We soon realized that there was a set of surfaces derived from boundary edges: 1. only straight lines; 2. only straight line and arc; 3. only arcs (fig. 1).

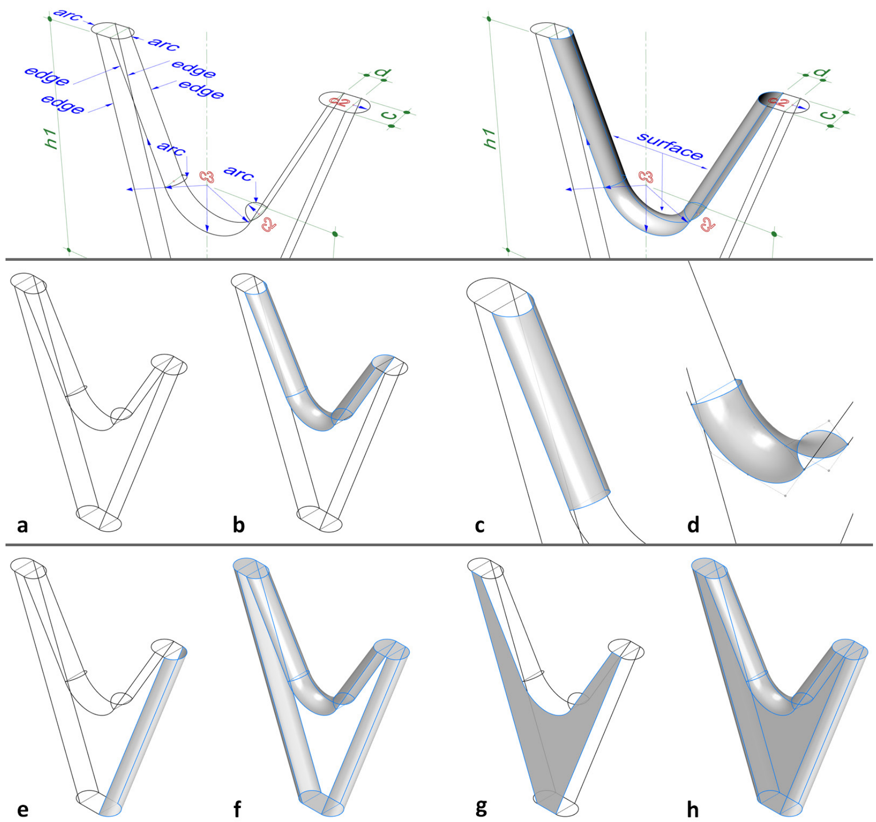

Fig. 1. Steps of geometric modeling of a V column. Graphic elaboration by the author.

Naturally we observed that the set of generated surfaces were well known: planar; semi-cylinder; developable ruled surface; torus; conoid; polygon; double curvature (fig. 2).

In this Phase, we concluded that:

- There are five types of boundary edges (both at the bottom of the column and at the 2 upper supports) (fig. 3 top): a. square; b. rectangle; c. circle; d. oblong (2 arcs in opposite sides connected by lines); e. rectangle with fillet corners.
- There are seven types of surfaces (fig. 3 bottom): f. planar; g. semi-cylinder; h. developable ruled surface; i. torus section; j. conoid; k. polygon; m. double curvature.
- The arcs are semicircles.
- The center of V column is defined by two kinds of edges: a. lines; or b. arcs.
- Asymmetrical V columns have a vertical part and an inclined part.
- In large buildings, the area at the bottom of the column is greater than the area at the top.

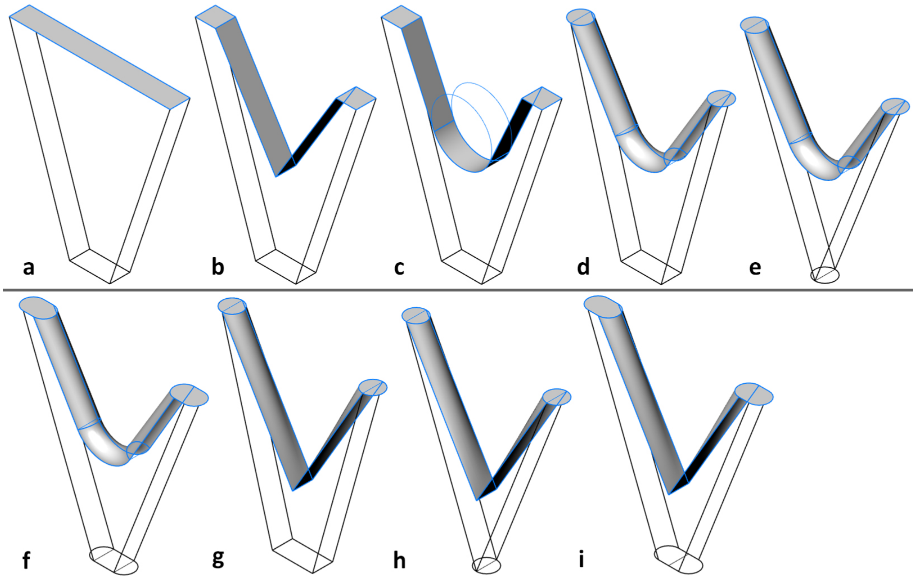

Fig. 2. Geometric modeling of a set of V columns. Graphic elaboration by the author.

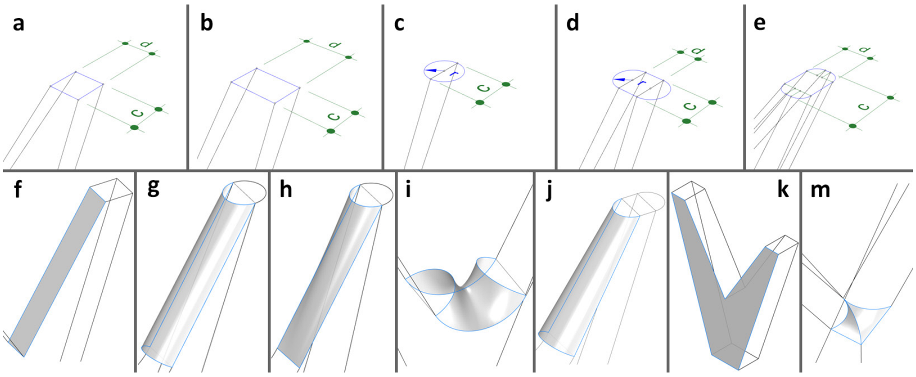

Fig. 3. Five types of boundary edges, both at the bottom of the column and at the upper supports (top). Seven types of surfaces (bottom). Graphic elaboration by the author.

Steps of the construction of the algorithm

With the intention of classifying by types and, later, by groups, during the next Phase the columns were parametrically modeled, in order to obtain the possible variations between the parameters.

According to Robert Woodbury, "an algorithm is a finite procedure, written in a fixed symbolic vocabulary, governed by precise instructions, moving in discrete steps" [Woodbury 2010, p. 34]. Consequently we organized the discrete steps sequence based on vertex, lines, and surfaces definition (fig. 4). Furthermore, based on the previous experience during geometric modeling, the steps of parametric modeling was: 1. Location of the column base support vertices; 2. Location of the height of the 'V' concavity; 3. Definition of boundary edge variations for squares, rectangles, circles, oblongs, rectangles with rounded corners and trapezoids; 4. Drawing of the edges that delineate the faces of each type of column; 5. Drawing of the surfaces that make up the faces of each type of column; 6. Joining the surfaces to form the solid.

The algorithm produced gathers the parameters identified during geometric modeling. This starting point was fundamental for understanding the real geometric characteristics – five types of contour edges and seven types of surfaces – in order to facilitate the organization of the sequence of steps of the created algorithm.

The defined parameters were: 1. Length and width of the base; 2. Length and width of the top; 3. Height of the top support; 4. Distance between upper supports; 5. Five types of base boundary edges; 6. Five types of top boundary edges; 7. Rotation 90° of base or top boundary edges; 8. Seven types of surfaces; 9. Width of the concavity; 10. Height of concavity V; 11. Axis displacement to generate symmetry or asymmetry (fig. 5).

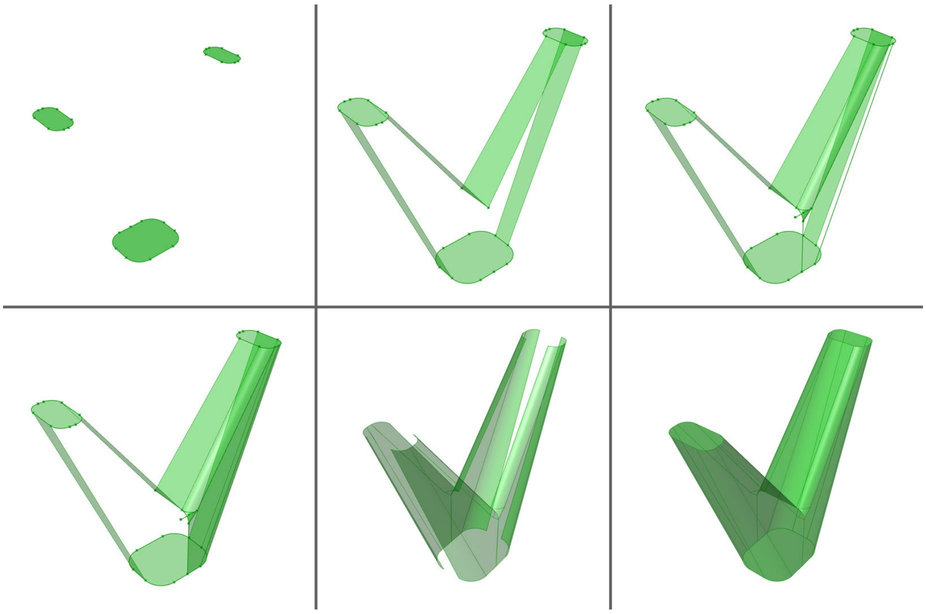

Fig. 4. Drawing surfaces by parametric modeling. Graphic elaboration by the author.

In fig. 5.1 the algorithm can switch the column design to a monolithic trapezoidal shape, it can generate columns consisting only of straight lines but with a pronounced cut, or it can consist of straight lines but with curves at the center.
In fig. 5.2 the algorithm can change the width and length dimensions of the bottom and top, generating square or rectangular boundary edges. In fig. 5.3 the algorithm manipulates the trapezoidal shape of the basis.
In fig. 5.4 the algorithm can transform the bottom and top boundary edges into circles or oblongs. In fig. 5.5, you can operate with boundary edges with rounded corners, with 90° rotation of the base and top.
The parametric modeling enabled the generation of new columns from combinations of parameters. Thus, the parametric modeling was able to combine the identified parameters with greater agility, in order to make us understand the lexicon of possibilities operating this type of column. In fig. 6, produced by parametric modeling, we see how valuable the process of combining parameters is to generate unexpected 'V' columns shapes.

Classification by types and by groups
In this phase, we identified that the 'V' columns were made up of different geometries: a) only by straight lines; b) only by circumferences; c) only by semi circumferences and straight lines connected to semi circumferences at both ends (oval); or yet; d) hybrids between the three previous ones. Thus, after parametric modeling, we identified and classified the columns into seven groups.
The first group comprises the 'V' columns consisting only of straight lines, constituting monolithic trapezoids. The dimensional variations at the base and top of the column confer a greater or lesser perception of robustness or lightness. In addition, because they are 'closed', they are visually heavier. This is the type of column found in the Itatiaia Building in Campinas (1953).
The second group comprises the 'V' columns consisting only of straight lines but with a pronounced cut. The columns of the Hansa building in Berlin (1955) and the Getulio Vargas Foundation (1955) are of this type. Interestingly, these columns were combined with each other in certain projects, such as the Clube 500 (1953), with the hybridization of 'V' columns positioned together but inverted side by side.
The 'V' columns of the third group are made up of straight lines but with curves at the center. Therefore, the curvilinear surface occurs only between the two side supports. In the California Gallery (1951), the center curve is more pronounced, and the corners are slightly rounded. However, when the width of the central support is different from the upper supports, there are ruled surfaces on the front and rear faces of the columns.

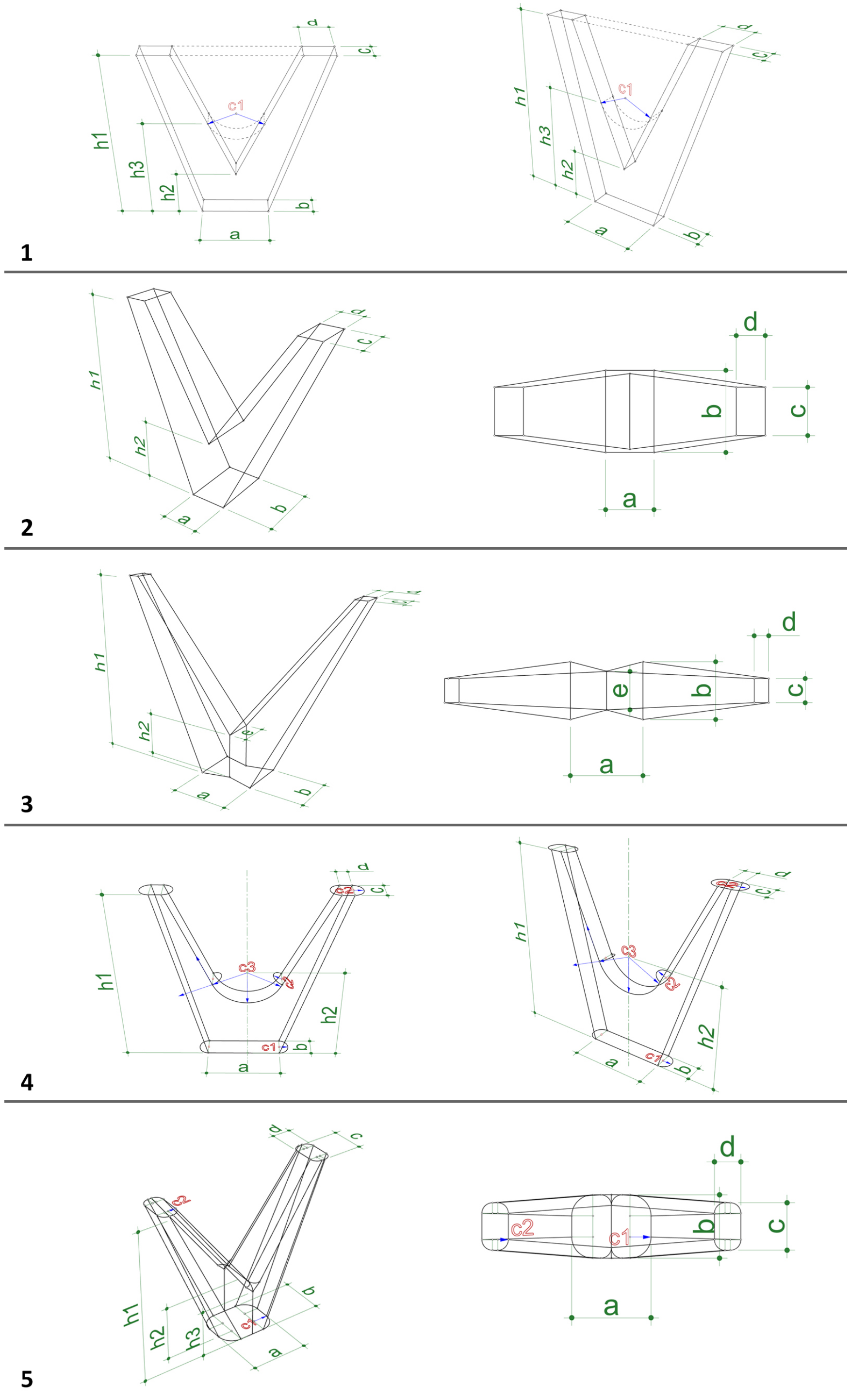

Fig. 5. Parameters of parametric modeling. Graphic elaboration by the author.

The 'V' columns of the fourth group are more complex, combining upper circular supports with rectangles in the lower central support since the four faces (front and side) are composed of ruled surfaces, which interpolate circumference arches with straight lines.
The 'V' columns with circular or oval bases, and circular or oval upper supports, constitute the fifth group. Like the columns of the fourth group, the four faces (front and side) are made up of even more complex ruled surfaces. The columns of Palácio da Agricultura (1953) (present-day Museum of Contemporary Art of USP) are of this type.
The sixth group comprises the 'V' columns with central, lower, and upper support, consisting of semi circumferences at the ends, connected to straight lines, generating oval shapes. Addition-

ally, the 'V' surfaces in the center can be of the same section as the upper supports or formed by interpolating semi circumferences and straight lines. The internal 'V' columns of Palácio das Nações in Ibirapuera Park (present-day Afro Brasil Museum) (1953) are of this type.
In all six groups described above, there are symmetries and asymmetries in some options regarding the column axis.
Finally, we underlined that there are 'V' columns with hybrid geometries, i.e. straight lines with circumferences or semi circumferences. The columns of the Lagoa Hospital (1952) in Rio de Janeiro and the external columns of Palácio dos Estados and Palácio das Nações in Ibirapuera Park (1953) are of this type.

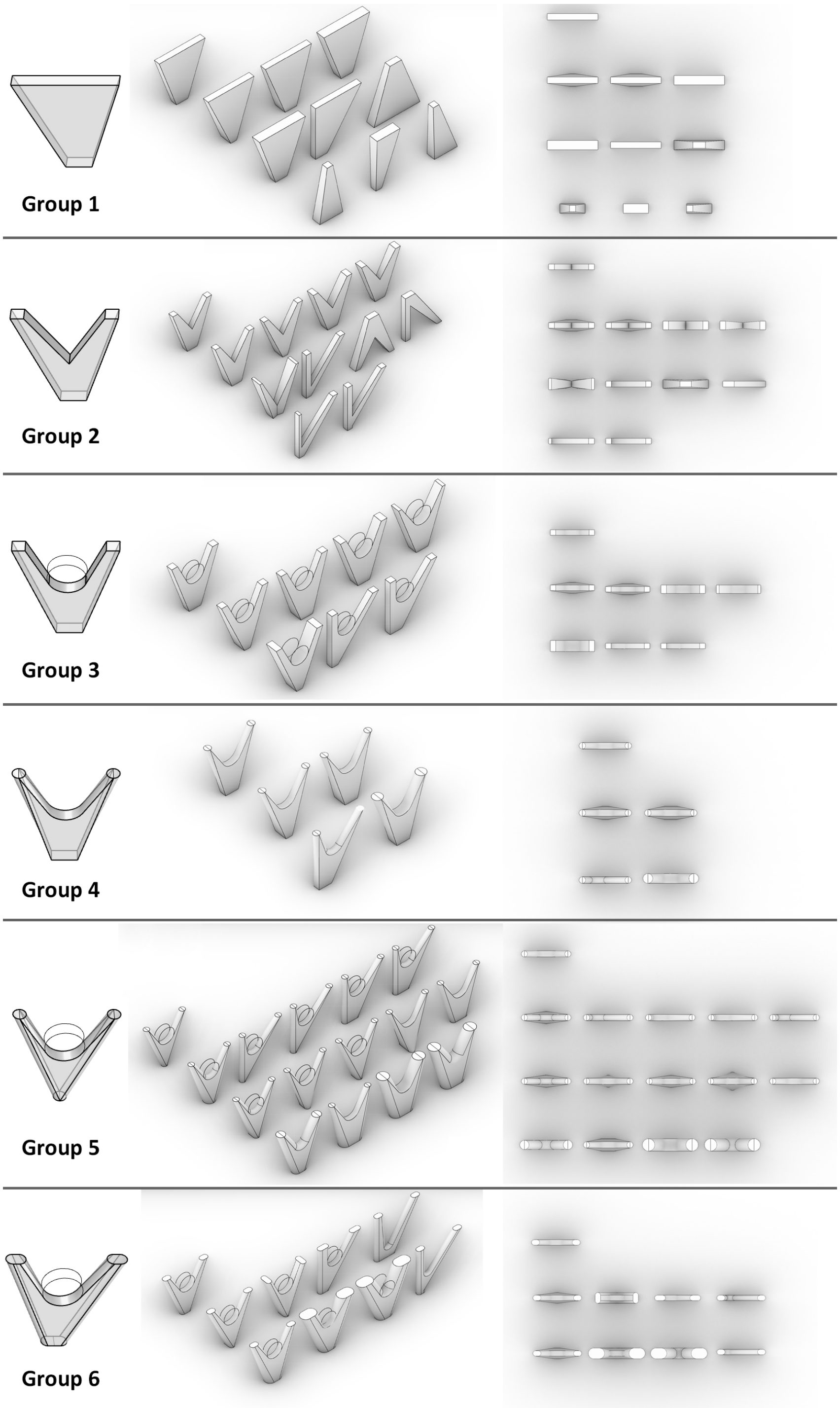

Fig. 6. Classification the generated columns by groups. Graphic elaboration by the author.

Discussion

Analyzing buildings designed by renowned architects always requires much attention to detail. At first glance, the 'V' columns designed by Oscar Niemeyer seem to have a simple geometry, which is repeated in each project. But the most surprising fact we discovered is that the architect created many geometric combinations to define the shape of the 'V' columns. As a result, a more rigorous investigation allowed us to identify subtleties and innovations in his innovative column.
In fact, only during the geometric modeling was it possible to identify the real implicit characteristics in the columns designed by the architect Oscar Niemeyer. Even though the geometric modeling enabled the initial understanding of the geometric characteristics of the columns, the parametric modeling enabled the generation of multiple combinations of parameters identified. On other words, although geometric modeling is able to precisely define the position of vertices, lines and surfaces of each type of column in space, parametric modeling was able to interpolate the identified parameters with greater agility, in order to make us understand the lexicon of possibilities operating this type of column. Therefore, it was feasible to explore both types of modeling in a complementary way, in order to allow the classification of columns by groups.

- Contrary to what authors claim in previous research, there are variations in the geometry of the V-shaped columns in Oscar Niemeyer's projects and works.
- There are five types of boundary edges and seven types of surfaces.
- As matter of fact, the V columns are defined by different geometric characteristics: a) only by straight lines; b) only by circumferences; c) only by semi circumferences and straight lines connected to semi circumferences at both ends (oval); or yet; d) hybrids between the three previous ones.

The research proved that, in fact, Niemeyer retrieved previously applied knowledge and reused it in a new design situation. To prove this hypothesis, we explored parametric modeling to generate a set of columns from the parameters identified in the architect's drawings. In fig. 6, produced by parametric modeling, we see the successive transformations that occurred in the processes of refining a schema and adapting ideas preceding each new design.
As a characteristic of experienced architects, Niemeyer recovers previously applied knowledge and reuses it in a new design situation revealing the concept of refinement and adaptation. This latent, stored knowledge is recovered during the elaboration of another design to adapt to a new design circumstance.

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