ORIGAMI: SYMMETRY AND APLICATIONS IN ARCHITECTURE

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Abstract: This research aimed at studying the geometry of symmetric origami. Examples in architecture and decorative arts were collected and categorized according to their type of symmetry. Connections between origami and architecture were established. As a final product, a manual for architecture students was produced, suggesting the use of origami techniques as a method for exploring the use of three-dimensional symmetries in the design of spatial structures.

Keywords: Origami. Symmetry. Architectural structures.

1. INTRODUCTION

The present research aims at studying the geometry of symmetric *origami* and their applications in architecture. The first phase of this research consisted of a study about the different types of symmetry and their applications in architecture, and the different types of *origami* - in particular those known as *kusudama,* which are based on regular polyhedrons.

For the study of symmetry different approaches were considered, from physics to mathematics and arts. The study resulted in a characterization of bi-dimensional (frieze, wallpaper, cyclic and dihedral) and three-dimensional (crystallographic) symmetry groups. Furthermore, examples of the use of symmetry in architecture and decorative arts in different periods were collected (e.g. Jones, 1986; March & Steadman, 1971). Leonardo da Vinci, for example, developed systematic studies on church plans with central organization, mostly based on the dihedral group, analyzing how chapels and niches could be added without disturbing the cyclic symmetry. Alberti, in his Ten Books, noted that shapes based on circles and hexagons looked more "natural" than the others. In modern architecture there are also many examples of the use of symmetry. Frieze symmetry, for example, is very common in row of houses and other arrangements, where the same cell is repeated recursively. Frank Lloyd Wright, on the other hand, used cyclic symmetry in apartment plans, such as in the Suntop Homes.

Still in the first part of the research, different types of symmetric origami were categorized according to their type of symmetry, resulting in Table 1. We also identified occurrences of architectural structures that are similar to those origami shapes, especially in traditional Islamic architecture and in modern Brazilian architecture. The vaults of the Great Mosque in Cordoba, for example, are based on polyhedrons originated from regular octagons. It was also possible to identify forms that resemble origami in structures designed by Brazilian architects such as Affonso Eduardo Reidy, João Villanova Artigas, and Paulo Mendes da Rocha.

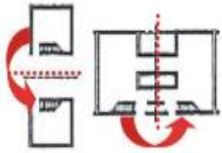
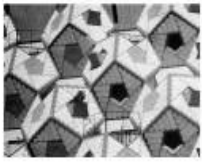
SYMMETRY/ POLYHEDRON	ORIGAMI	EXAMPLE IN ARCHITECTURE
Bilateral (reflection symmetry)		
Bi-dimensional cyclic (rotation symmetry)		 Frank Lloyd Wrhight
Frieze (translation and reflection symmetry)		 celtic frieze
Spatial cyclic (3d rotation symmetry)		 Palácio das Convenções – Anhembi SP
Prismatic (3d translation symmetry)		 Gothic church
Polyhedron *kusudama* (3d symmetry)		 Ramot apartments
Geodesic domes *kusudama* (spherical symmetry)		 geodesic domes

Table 1 – categorization according to the type of symmetry

The modular origami or *kusudama* is characterized by a regular structure. The construction of this type of origami encourages the development of creativity through experiments with colors and textures. It can be seen as a method for exploring the use of three-dimensional symmetries in the design of spatial structures. The study of three-dimensional structures led to a research on regular polyhedron, solids that are mathematically related to *kusudama* through the spatial symmetry.

2. EXPERIMENTS AND MANUAL

Different origami paper shapes were sectioned and used in scale models of buildings as vaults, roofs, walls and slabs, in order to explore and confirm their possible applications in architecture. Different ways to represent buildings were experimented using the origami technique. We selected significant examples from different periods that could be constructed using the origami technique. The manual developed (Fig. 1, 2 and 3) described how to fold paper in order to produce architectural models. The instructions were based on traditional books about Japanese origami (Fig. 4).

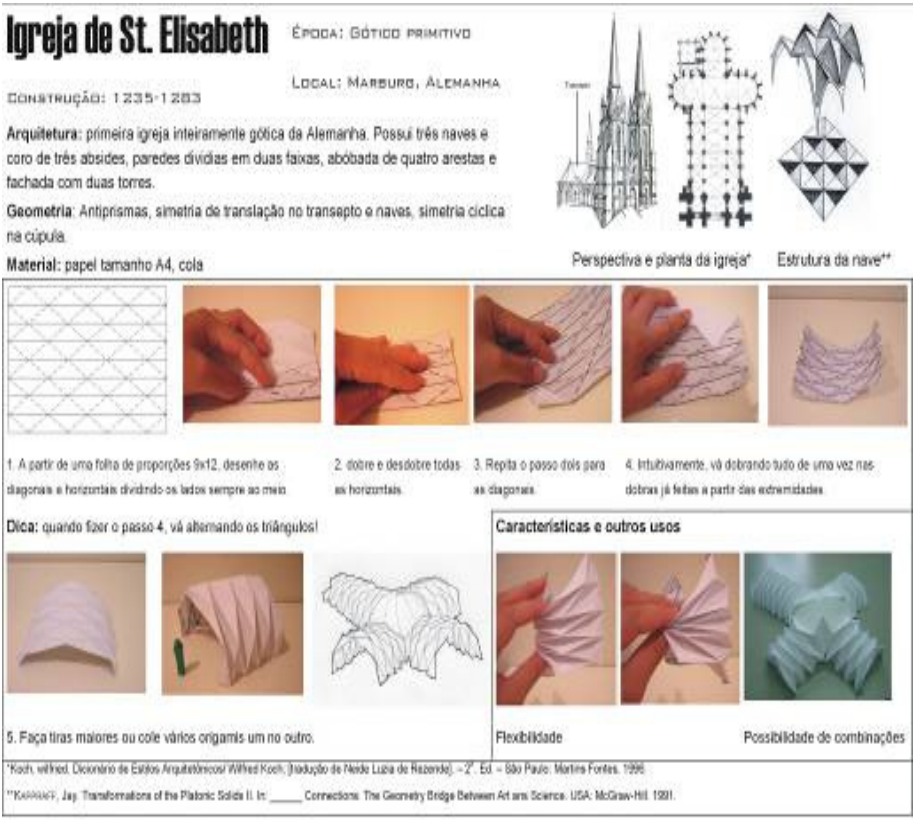


Figure 1 – Manual developed for architecture students (St Elisabeth Cathedral).

Figure 2 – Manual developed for architecture students (Orient Station).

Figure 3 – Manual developed for architecture students (Auditorium).

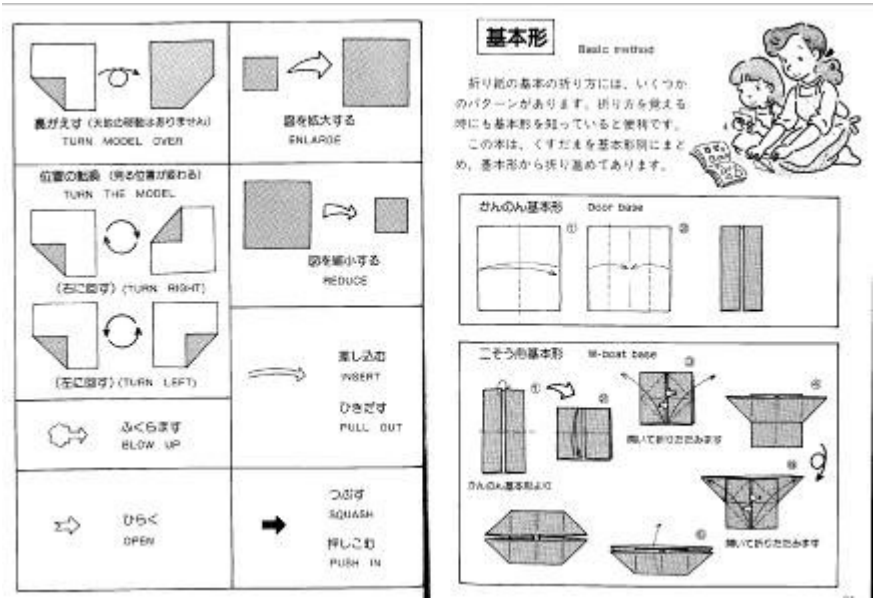


Figure 4 – Traditional origami manual.

The pedagogical issues related to origami are many. While mathematicians study the geometry of origami and use it to develop some mathematical concepts, physicians and engineers research structural applications of the origami - the fold as a structural edge, which gives rigidity without creating excessive weight. Artists and architects explore not only the structural potential, but also the aesthetics aspects of the technique.

To verify the efficiency of the technique, we carried out an experiment with students in the Faculty of Civil Engineering, Architecture and Urban Planning, in the State University of Campinas (fig.5).

Figure 5 – Students working with the origami techniques.

Exercises using origami help to develop a better sense of spatial perception. Students develop the idea of how to turn something bi-dimensional into something three-dimensional, exploring how the modules fit into each other in the case of the *kusudamas*. Many of them are able to set the models faster when they built the models together with other students. They exchanged ideas and thoughts with each other and were able to go further with other kinds of mortises for the same type of modules. The difficulties lie exactly in the mortises. The booklet aims to help giving hints and ideas of how to visualize the many possibilities that the mortises offer.

3. CONCLUSION

The research allowed us to have a more accurate knowledge about origami. We were able to see origami from a mathematical point of view, especially in regards to its symmetry and geometry, aspects that had not been clearly noticed before. The study of symmetry and polyhedrons, as much as the experiments carried out with paper provided the comprehension of bi-dimensional and three-dimensional concepts. It was possible to verify that origami has pedagogical relevant aspects that explore three-dimensional compositions and allow us to make tests not necessarily beginning with a quadrangular shape. As a result, we proposed the use of origami as a method to explore shapes in the design process, which can even lead to the discovery of new forms and construction methods.

More than contributing for the production of scale models, the booklet produced aims at suggesting the use of origami techniques as a method for exploring the use of three-dimensional symmetries in the design of spatial structures. In future works, we expect to explore the structural properties of folded sheet materials with the use of origami techniques.

4. ACKNOWLEDGEMENTS

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