Origami art and its effect on the creative process enriching the design of glass sculpture for architecture

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Abstract:

Origami: It is (the art of folding paper), and the word is derived from the Japanese culture, where this art uses many techniques of paper folding, resulting in different shapes and designs, starting from flat shapes through to stereoscopic vacuum shapes and ending with complex shapes.

Paper is a fragile material, but when its parts are cut and folded, it gives us a new product with different qualities in terms of durability of construction, shape and form, and because of these qualities we used cutting and folding paper to teach important lessons about the nature of construction in design education since 1925, which made that topic an important focus in enrichment of the creative process of designing artwork. Therefore, the research was interested in shedding light on this method of art to find modern and fast methods of forming and placing design ideas within a methodology of thinking that the student adheres to in forming glass sculptural works for the architectural space, through: the use of paper slides (folding, bending and twisting), hollowing out in geometric shapes and shaping with the application of processes of repetition and contrast...etc… The study was applied to a group of students, for one group using those methods of forming to demonstrate the effect of origami art in enriching the creative process of designing glass sculpture for architecture.

The research problem appeared in:

● The need to enrich the students' creative process system in developing design ideas for designing glass sculpture works for the architectural space with modern and fast methods of modeling and forming prototypes.

The research aimed at:

Developing a proposed methodology for designing glass sculpture works for interior architecture by making use of the rules of origami art so that it can be used and applied to enrich the students' creative process system.

The importance of the research:

● Discovering modern and fast methods of building and forming educational models for designing glass sculpture for architecture.

● Enriching students' creative process in developing design ideas within the proposed scientific thinking methodology for designing glass sculpture for interior architecture by making use of the origami art rules.

Hypothesis:

● By analyzing the methodology of building and forming origami art, we can benefit from it and apply it in designing prototypes to enrich the creative process of students in developing design ideas for some of the sculptural works of the architectural space.

DOI: 10.21608/MJAF.2021.55923.2151

Search limits:

● The research determines the study of ways to benefit from the rules of origami art to develop a proposed methodology for designing (two-dimensional) glass sculpture works for interior architecture and its application to enrich the students' creative process system.

Research philosophy and methodology: The research follows the approach (analytical - applied) by studying the following basic axes:

First - an analytical study: It was based on a study:

Origami art (concept - historical development)

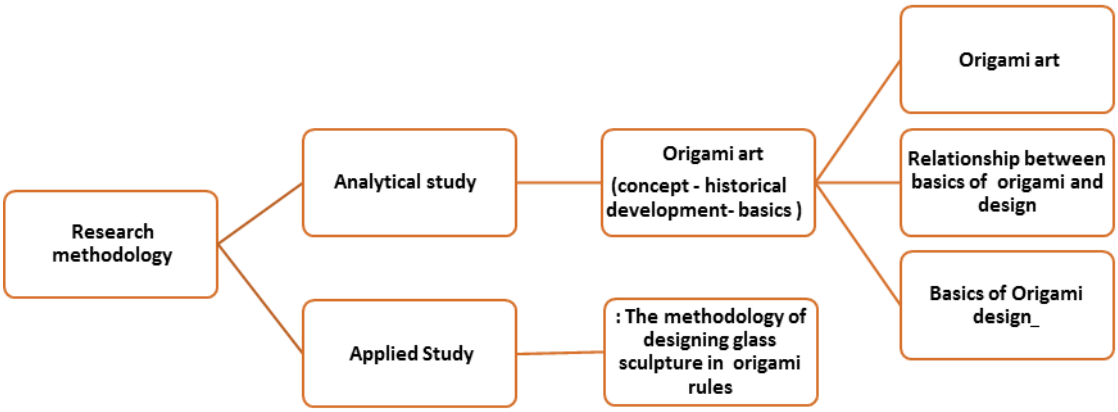
Origami design basics and methods.

- A proposed methodology for designing glass sculpture for architecture in light of the origami rules.

Second - An Applied Study: Applied to the students of the third year glass department, and it relied on (enriching the students' creative process in developing design ideas within the proposed scientific thinking methodology for designing glass sculpture for interior architecture by making use of the origami art rules).

Key words:

Origami Art, Glass sculpture, creative, principals



Research philosophy and methodology

Introduction:

When searching for and developing innovation for students, we go towards what is new and easy to shape to contribute to the widening horizon of students. With the development of architectural thought, we find that both architecture and origami art have potential relationships and links between both disciplines, when thinking that both involve building forms with scientific limitations related to mathematical logic and mathematical operations. Origami art is a multi-disciplinary approach to mathematical, architectural and structural aspects (especially for folded structures), which helps to understand how paper folding is used as a means of solving structural and aesthetic problems. In this context, origami provides a rich source of inspiration and to gain cognitive experience in formations and shape creation, which works as an effective tool in the innovative development of designers and architects to craft three-dimensional

sculptural shapes, especially complex ones through new methods of building in the process of designing architectural sculpting.

First: Origami art (concept - historical development- basics)

1- Origami art:

Origami is a Japanese word, which combines the verb (ori) which means (folds) and the word (kami) which means paper. This art appeared in the seventh century AD and was used in rituals and religious beliefs by folding pieces of paper rectangular or square shape for entertainment and decoration, such as misho and ochu butterflies in the noble ceremonies, but for this time there is no evidence of the existence of origami. But after the quantitative production of paper during the Edo era, origami origins began to increase significantly. It is worth mentioning that Muslim merchants and sailors played an important role in transporting (folding the paper); Andalusian Arabs were the ones who developed the engineering aspects of origami and introduced engineering forms to it. It is noticed that until the nineteenth century AD there is no knowledge in Europe of folding paper except for a few glimpses; until the idea of kindergarten appeared in Europe, which was founded by German Friedrich Froebel and children practiced folding papers until the kindergarten reached Japan, and paper folding is considered Japanese and the arrival of paper folding during the kindergarten was a success for them. It is believed that the modern term for folding paper in origami came from a kindergarten, where the word origami corresponds to the German word papier flatten, which means folding paper. Although paper is a fragile material, but when it is cut and folded it is strong and from the experiences gained from experiments with slices of paper or metal, or related raw materials, we find it related to all design activities, because of these characteristics, use of paper pieces and folds to teach important lessons about the nature of construction in design education since 1925. Until it was popularly taught in design and art schools, one of the famous examples is the designer Joseph Albers, the famous designer in the Bauhaus movement who was fascinated by the properties of materials and their potentials when they are formed, and he encouraged his students to design by folding and cutting paper in courses for the Bauhaus in 1930. The figure (1) Illustrates one of Joseph Albert's works. Josef famous work was based on folding an individual piece of paper, and in 1981 Masahiro Chatani called it origami architecture and then in 2006 it was the title of the cover book of Kirigami by Ramin Razani[1].

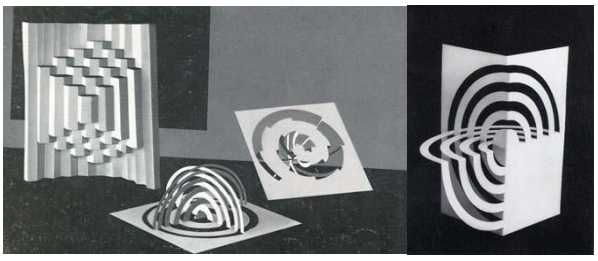


Fig1: show examples of Joseph Albert's students works.

2- Relationship between basics of origami and design

The concept of origami may diverge from the fundamentals of design…. The principles of design are the tools, which are used to format the elements of design. Formal or semi-formal origami forms are constituted by considering the principles such as repetition, gradation, and radiation, which are obtained through the rules of symmetry and isometric, but by studying and

analyzing we find that there is a strong and close relationship in the essence of both directions, each of which depends on mathematical logic and repetition, gradient and symmetry processes and their effective impact in developing the innovative process of the design process, as shown in fig 2.

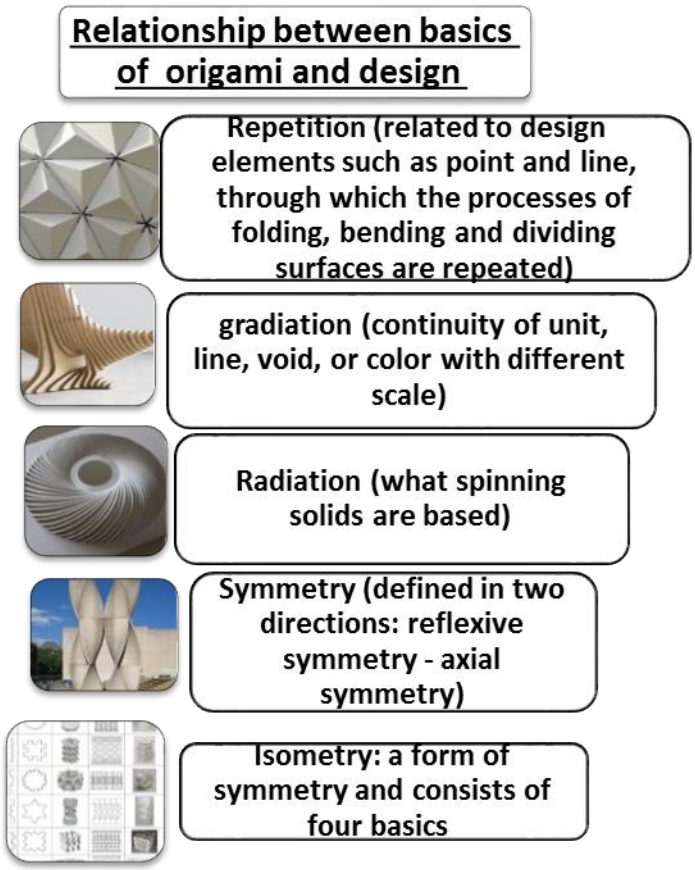


Fig:2 Relationship between basics of origami and design

3- Basics of Origami design:

Origami design: Origami is a group of flat surfaces in a system, so it is based on a group of (surfaces, and systems). We find that the plane plays an important role in the formation, whether to create stable structures or dynamic movement of surfaces that integrate parts into a non-total form that is Symmetric. Origami design is a three-dimensional design that can be obtained through two-dimensional form. Three-dimensional design requires the ability to fully visualize or imagine the shape mentally and its changes in all directions, as well as explore the effect of mass, the nature of different materials, and the relationship of spaces and depth, the design of origami also requires decisions that the designer takes of how to build the model to be taken.

Those systems on which origami are based differ according to the context or goal through which the origami is formed, but they are all related to the nature of the formation of the surface, which in turn depends on the processes of folding and unfolding. Fig 3, shows the basics of origami design.

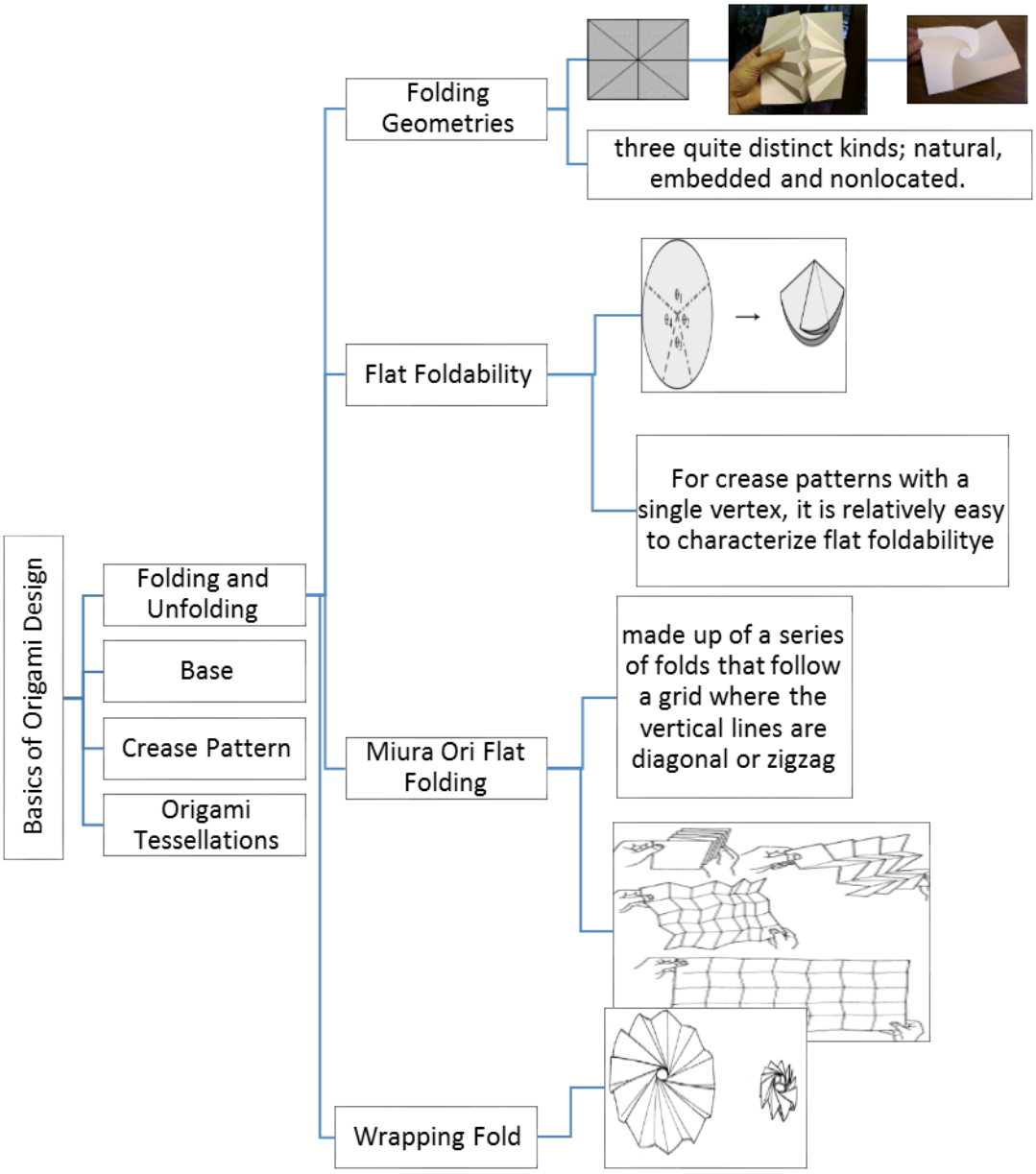


Fig: 3 Basics of Origami Design

There are different types of origami and various classifications, some of which depend on the folding technique or the result of the folding process, the source of the technology, or the classification of the origami structure according to the number of paper slides used in the formation, and they are either using one slice in the formation deployable (Transformable) Planar Structures or using more than one slice. From a paper informing or construction, which is called (modular structures), some of these types will be discussed:

1- Folding Geometries:

Origami is no longer just a work of beautiful shapes of objects and figures. Since 1980 mathematicians began drawing folding laws, converting words and concepts into algebraic rules and principles of computational geometry that have been widely applied in the design of origami. Origami design is defined as the formation of a two-dimensional piece into a specific shape with desired characteristics by cutting and folding.

It is based on mathematical calculations in designing the folds, and from it, many products have been developed in various fields, starting from designing movable metal roofs, designing airbags in cars, and various furniture units and tools that are based on mathematically calculating loads and designing the folds with engineering logic.

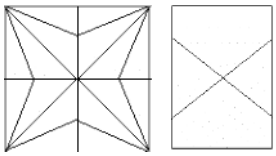


Fig4: Natural folding geometry in square shape.

- **Embedded folding geometry**

Another form of geometric folding in origami through which it is possible to obtain various curves and curved surfaces. Among the most famous artists who made curves on paper and folded them to form curved surfaces are (Polly Verity, Philip Chapman-Bell, and Fernando Sierra)

By folding operations to form curved surfaces, it is possible to move from a flat surface to an open curved surface to a completely closed curved surface. We can achieve this in two ways, the first of which is through a curve-fold tessellation.
Or a straight line folding, but the fold-lines are straight. It is shown in figure5.

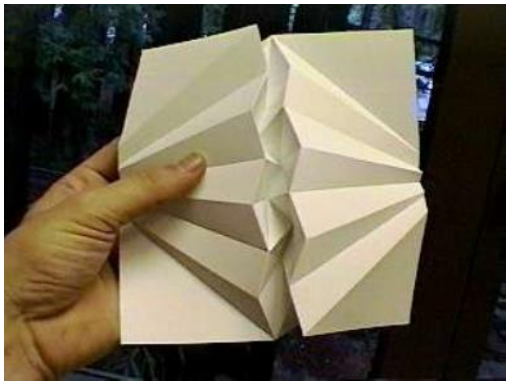


Fig5: straight line folding

2- Flat Foldability

Flat folding' means folding '*n*' dimensional origami form into the plane, and so the paper must necessarily touch itself. In the case of a flat folding, the flat folded state is called as flat origami. Flat-foldability is the property of a design that can be folded into a single plane with a thickness determined by the material, Fig6 shows flat folding crease pattern.[2] To design an origami model, it is necessary to determine the crease pattern that will dictate the folds necessary to achieve the desired 3D form.

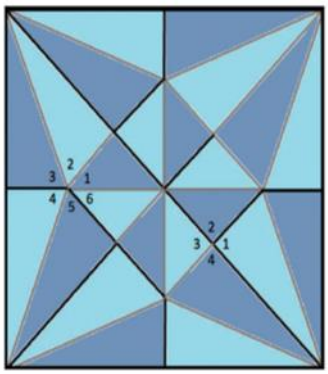


Fig 6: flat folding crease pattern

3- Miura Ori Flat Folding Technique:

The **Miura-Ori fold** is a flat-folding technique that greatly reduces and compresses a sheet of paper through a tessellated crease pattern made of repeating parallelograms. Although the fold is fairly advanced and engineered, it is only comprised of alternating mountain and valley folds[3]. Miura Ori Technique is made up of a series of folds that follow a grid where the vertical lines are diagonal or zigzag. The horizontal folds are straight with alternating valley and **a** mountain fold given by the zigzag. The vertical lines that come in zigzag fold as mountain or valley all the way across. Using the same system in a straight fold grid, the transmission of the movement is irregular and jams the system.[4]

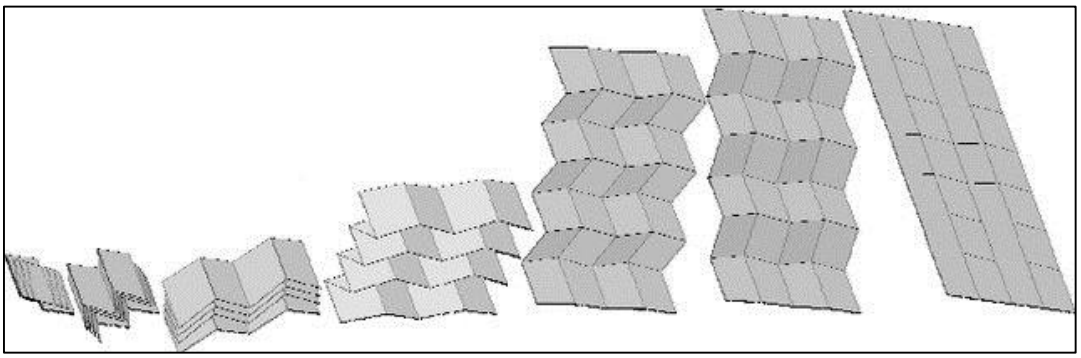


Figure7: The single mechanism of the Miura-Ori fold (several steps of the unfolding process, from left to right, from the flat folded state to the flat unfolded state.[5]

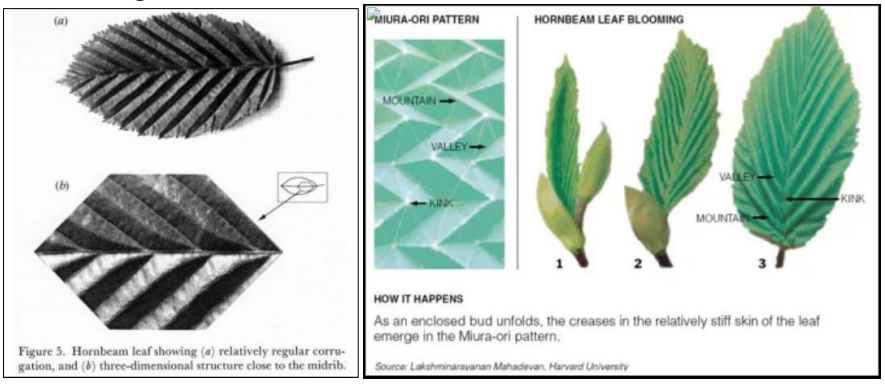
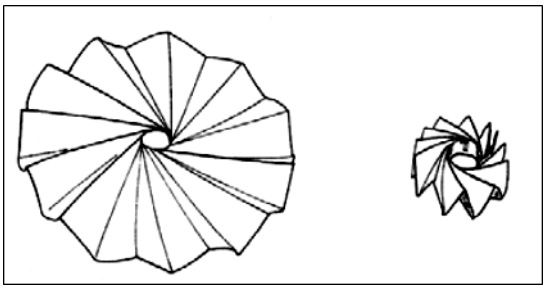
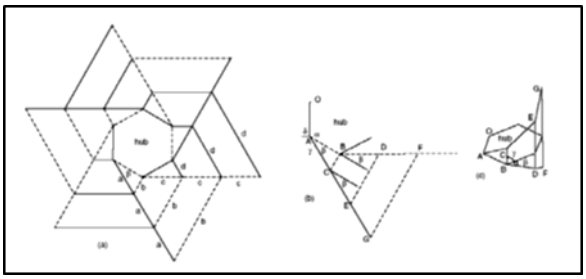


Fig8: The Miura-Ori fold

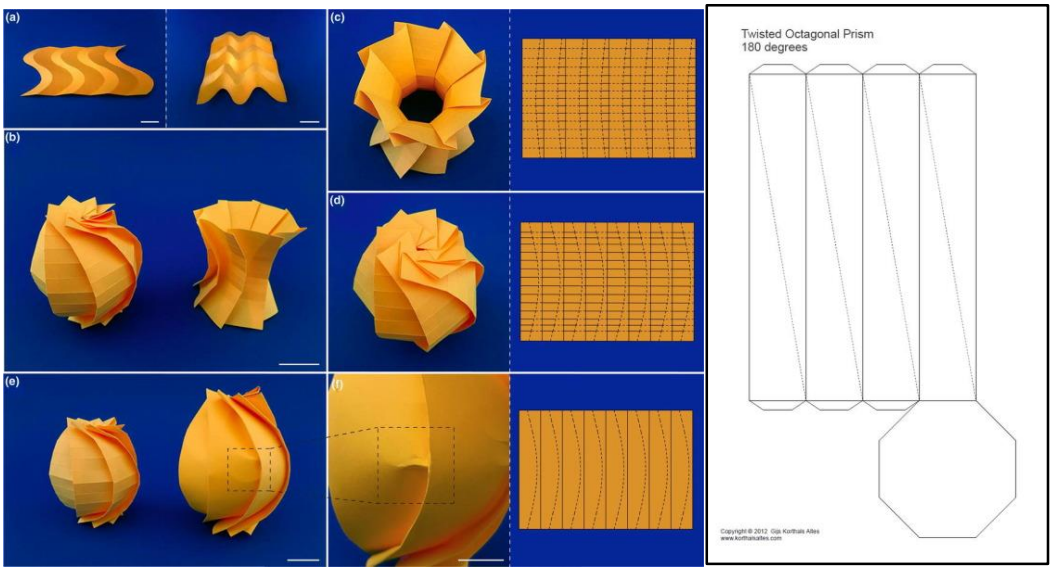
4- Wrapping Fold:

Wrap fold is a different way to wrap a flat, thin medium. Instead of folded flat, it is wrapped around a central circular axis as shown in the figure (9) (a,b,c) and in which it is wrapped around a center, whether a point, a circle or a square ....





(a) (b)



(c)

Fig9: Wrapping Fold around a central circle ,a square and prismatic hub

5- Helically Triangulated Cylinder:

They consist of a number of triangular panels arranged in a helical pattern on a cylinder; when folding the cylinders, they are packaged as a compact stack of plates.

Three simple designs are shown below in figure (10) . These cylinders all fold down to the flat polygons shown underneath each cylinder. However, the concept is much more general than these simple cylinders show. There is a very wide range of possible designs, which have different folding properties.[6]

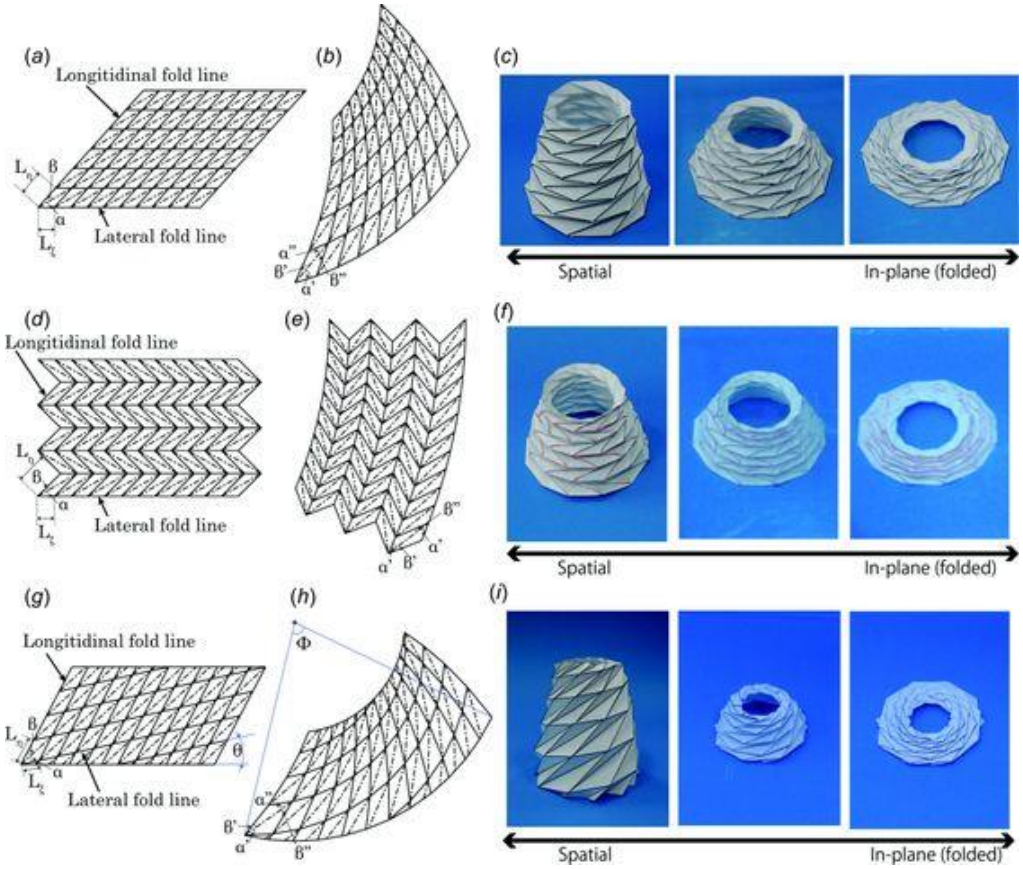


Fig 10: Three simple designs arranged in a helical pattern on a cylinder

Here we investigate the axial compressibility of origami cylinders, i.e., cylindrical structures folded from rectangular sheets of paper. We prove, using geometric arguments that a general fold pattern only allows for a finite number of {isometric} cylindrical embedding. Therefore, compressibility of such structures requires either stretching the material or deforming the folds. Our result considerably restricts the space of constructions that must be searched when designing new types of origami-based rigid-foldable deployable structures and materials

Modular origami: "

In origami, the word ‘module’ implies the units that are repeatedly attached in order to construct complex forms. These units have simple structures, which are either all identical or formed in sets of different complementary units.

It relies on a repetition of a simple construction standard unit that combines to form more complex shapes. They are completely consistent at work or repeated in a specific pattern and are carried out in several stages using the system of multiple slides where each unit is designed and folded separately and standardly and then they are assembled by another modular unit, meaning that they are divided into surface design units and units to link them.[7]The degree of complexity of the unit varies from its design to a vicious to a flat surface, **as shown in figure (11)** to overlap together forming a more complex shape.

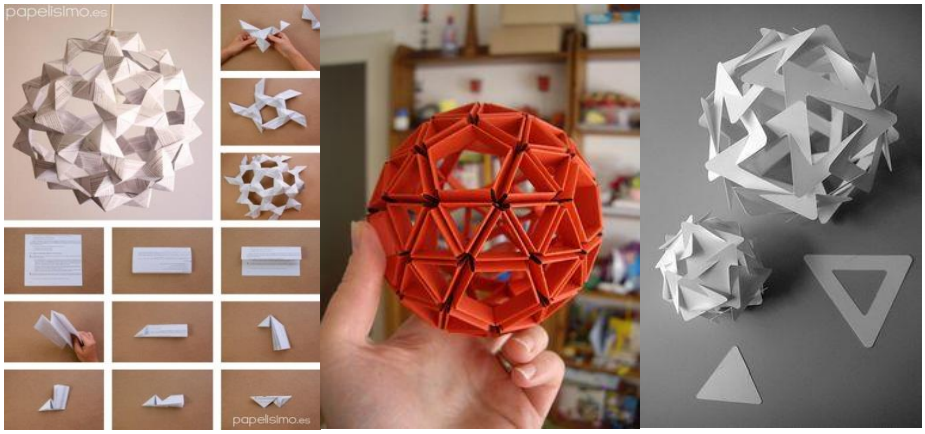


Fig 11: overlap flat surface together to forming a more complex shape.

Modular origami is classified into four main categories: 1- general organic pattern, 2- the business cards cube, 3- polyhedron model, 4- the waved polyhedral pattern. As shown in figure (12) origami module classification.

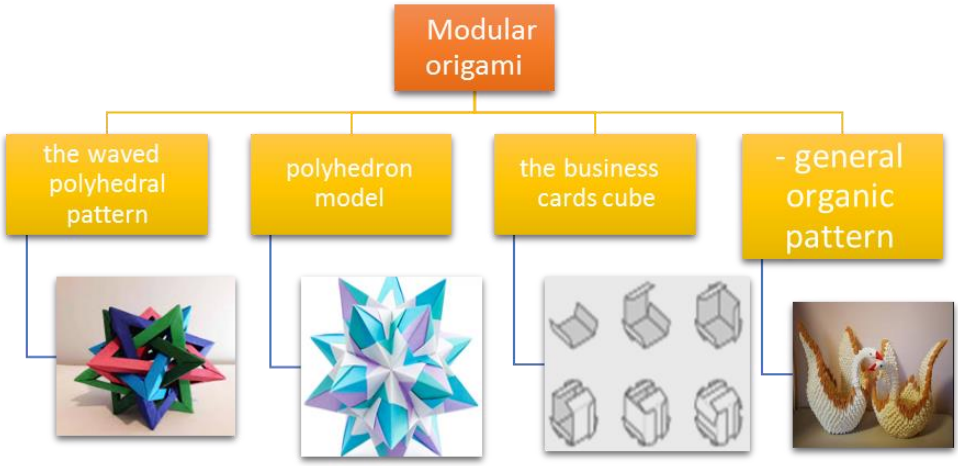
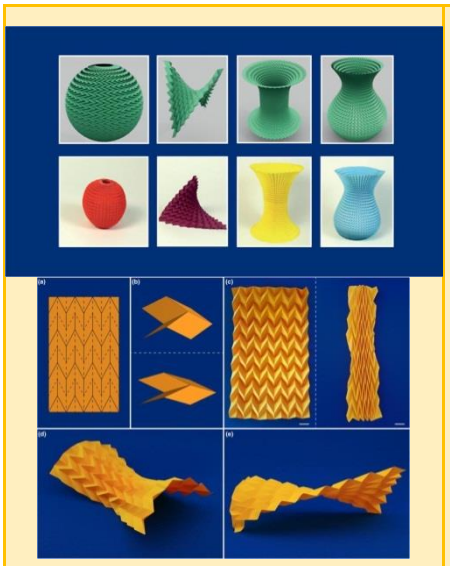


Figure12: origami module classification.

Table (1) shows a comparison of the characteristics and fields used for each technique or method of origami art.

Illustration	fields	Characteristics	Method
	**Design of movable metal roofs, airbags in cars and furniture units**	**based on mathematical calculations in designing the folds**	**Mathematic origami"**
	**Interior design as tables ,chairs**	**Change the angles to achieve a variety of surfaces and levels**	**Flat Foldability**

	The design of **awnings,** and **movable roofs** in what is known as **kinetic architecture, cladding units** for **architectural facade**	Compressibility, rigidity and increased structural integrity	**Miura Ori Technique:**
 	**Formation of three-dimensional rotating round models**	-wrapped around a central circular axis -Axial-symmetrical shape - This method is also related to the basics of design and the property of radiation equilibrium.	**Wrapping Fold**
	**It is used in water pumps, deployable structures and collapsible materials**	**Axial compression of cylinders**	**Helically Triangulated Cylinder**
 	-Formation of 3D organic shape models. -Forming polyhedral 3D models. -Associated with modeling many industrial products.	A repetition of a simple, modular structure that combines to form more complex shapes.	**Modular origami**

Second: The methodology of designing glass sculpture in origami rules

Origami design methods and techniques have varied and their applications have varied, so the research deals with choosing some of the methods that may be required for sculpting glassworks of architectural spaces. This may help in the development of the innovative process among the designers of glass sculpture (application on students of the third year - glass department).

• After analyzing and extrapolating some of the methods and rules for origami art, it was possible to classify these methods into two and three dimensions through which students can raise the skill level and accuracy of measurement and get used to teamwork and patience when carrying out work while obtaining some innovative forms that are difficult to imagine with traditional design practices.

- **APPLICATIONS:**

The study was concerned with understanding and studying the methods and fundamentals of design in origami to move it to product design processes, which range from simulation to the adaptation of methods to suit materials to abstraction and inspiration.

An origami-based design is a design that has a link to origami. Origami-based designs can be arranged on a fidelity continuum that can be divided into three regions: origami-applied, origami-adapted, and origami-inspired.

These regions define classifications of origami-based design that fall along the fidelity continuum ranging from direct to abstract applications of origami to the design.

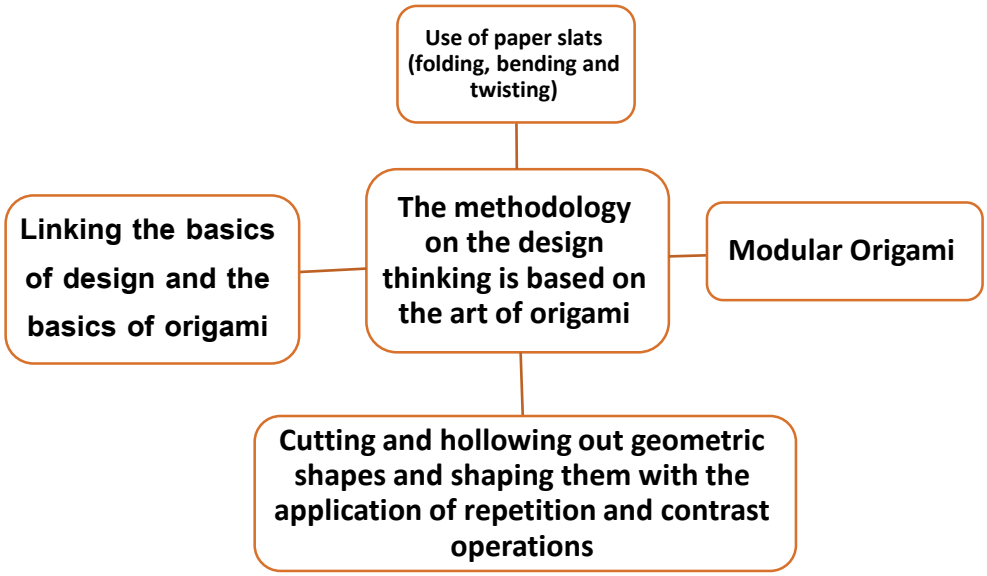
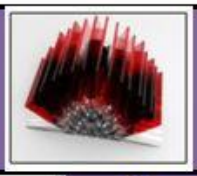


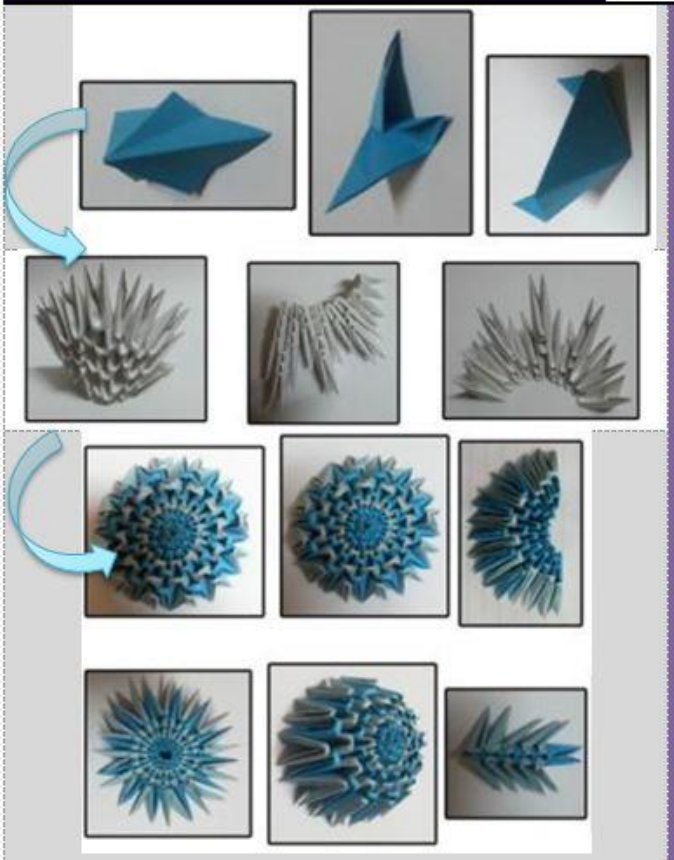
Fig13: **methodology on the design origami**

1. First application:

It was a model of students' work using the organic pattern of origami units to formulate a model of a glass sculpture based on the method of combining the units.

First application:
Glass Sculpture for landscape





- **Origami technique :**

Depend on the modular origami method, that was used The polyhedral modular origami pattern

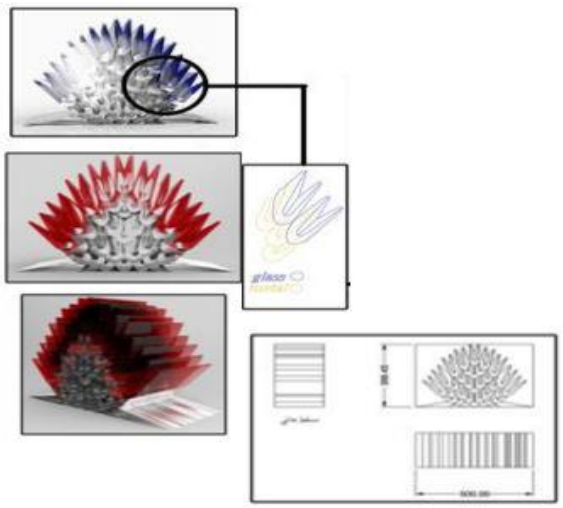
- **Time of application :**

Academic year 2015-2016

- **Type of process:**

Repeating units and overlapping them together to formulate an assembly composition using origami units, through which they form a model for an industrial formable product.

- Then, the glass designer is translating the paper molding and replacing the techniques and materials from the paper material to the glass material, taking into account the characteristics of the glass material, the production methods, the installation and the means of protection.

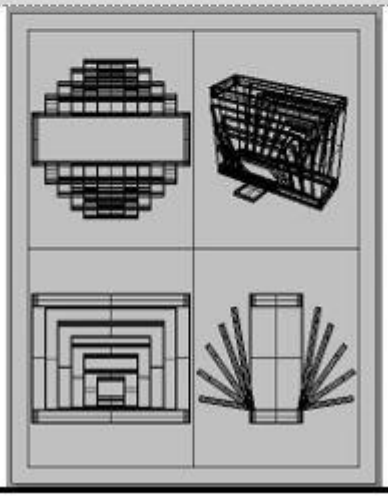
	Illustration
	The design idea relied on one of the solutions •Using graduated glass slides and fixing them in the metal structure by sticking with ultraviolet rays, as in the illustration. •Or to form glass pieces by the method of casting each piece proportional to the part installed in it to obtain the gradient as the proposed design. The default dimension of the sculpture as a whole is 350 * 500 cm The length of one glass slide is 200 * 350 cm, with a thickness of 2 cm. •The slats are fixed by adhesive and metal fittings bonding to the metal frame of each bundle of glass slides or glass block.

second application:

- **Origami technique** :Cutting **and discharging in geometric shapes and forming in them with the application of repetition operations with the addition of the movement element (opening and closing)، which achieves formal and functional change**
- **Time of application:**

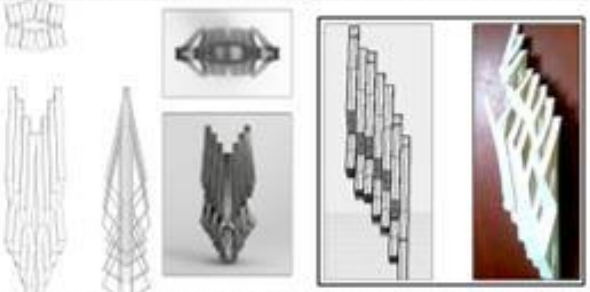
Academic year 2015-2016

- **Type of process:**



third application:

- **Origami technique** : folding Inspiration from the folds of the top and bottom to form the standard unit in which the artwork is formed
- **Time of application:** **Academic year 2015-2016**



- **Initial stages of the design idea with engineering projections**

The difference in shape according to the different formulation of the parts and the relationship between them

Conclusion:

The research has reached the following results:

- There is a correlation between the art of origami and the basics of design, which in turn develops the innovative ability and artistic sense of the student.
- The multiplicity of origami design methods, the ease and flexibility of forming from (deletion - cutting - folding) operations that increase the student's awareness of mass and void and the ergonomic requirements of design.
- Ease of preparing prototypes to understand the formal and volumetric values of the sculptural work in the surrounding architectural space.
- The use of the folding grid and the folded form of paper instead of the prototypes styles. This represents a different way of thinking than the designer used to display the idea, and this in turn reveals a difference in the formal aspects of the design idea.
- Origami excites other modalities of learning. It has been shown to improve spatial visualization skills using hands-on learning.

Research recommendations:

- Benefits and advantages of teaching some of the origami methods as a tool for designing and testing the proposed design ideas, especially in the fields of industrial and architectural design.
- The use of origami in the implementation of the prototypes of design proposals**.**

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