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"Integrating Creative Architecture and Mathematical genius in Designing Identity-Boosting Buildings " (A Case Study of Designing a Mosque in the Al-Obour city)

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ABSTRACT

Architecture is closely linked to the field of mathematics. Geometric shapes, their laws, and compositions are fundamental aspects of architecture. The geometric drawing of shapes such as squares, rectangles, and circles, while considering the golden ratio in their design, helps achieve the ideal final form of a building.

Furthermore, mathematical analysis of different architectural details leads to an objective interpretation of the beauty of any structure. Therefore, research aims to understand and utilize parametric architecture and generative architecture, which connect mathematics and architecture by employing equations with numerical variables, to create and adapt architectural designs that respect cultural identity. This includes developing innovative scientific methodologies that assist architects in analyzing architectural data, such as symbols and graphical representations from different historical periods, to generate forms that align with the nature of the era while preserving and stimulating cultural identity.

KEYWORDS: Creative Architecture, parametric architecture, mathematics, Algorithm, mosques

دمج الهندسة المعمارية الإبداعية والعبقرية الرياضية في تصميم مباني تعزز الهوية (دراسة حالة تصميم مسجد في مدينة العبور)

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الملخص :

ترتبط الهندسة المعمارية ارتباطا وثيقا بمجال الرياضيات. فنجد الأشكال الهندسية وقوانينها وتكوينها من الأمور الأساسية في الهندسة المعمارية فالرسم الهندسي للأشكال مثل المربعات والمستطيلات والدوائر، مع مراعاة النسبة الذهبية في تصميمها، يساعد في تحقيق الشكل النهائي المثالي للمبنى علاوة على ذلك، فإن التحليل الرياضي للتفاصيل المعمارية المختلفة يؤدي إلى تفسير موضوعي لجمال أي هيكل. ولذلك يهدف البحث إلى فهم واستخدام العمارة البارامترية وعمارة الخوارزميات، التي تربط بين الرياضيات والعمارة من خلال توظيف المعادلات ذات المتغيرات العددية، لإنشاء وتطويع تصاميم

معمارية تراعي الهوية الثقافية. ويتضـــمن ذلك تطوير منهجية علمية مبتكرة تســـاعد المهندســـين المعماريين في تحليل البيانات المعمارية، مثل الرموز والرسوم البيانية من فترات تاريخية مختلفة، لتوليد أشكال تتوافق مع طبيعة العصر مع الحفاظ على الهوية الثقافية وتحفيزها .

الكلمات المفتاحية :العمارة الابداعية ، العمارة البارمترایة ، الرياضيات ، الخوارزميات ، المساجد

1. INTRODUCTION :

The modern architecture is based on considering buildings as abstract forms or masses, removing all historical and decorative references in favor of functional details. This led to the development of free and irregular shapes, with parametric architecture being an example of that. The term "parameters" originated in the field of mathematics, referring to the use of adjustable criteria or variables to manipulate or change the final outcome of a specific equation or system.
(Parametrism) is defined as a new and important style that emerged after modernism. This style focuses on finding suitable measures for various fields, ranging from architectural design to interior design. Parametric design is a concept that emerged with digital systems and their diverse applications, aiming to renew architectural design through a digital computational system based on the concept of information. It relies on computational thinking to create modern and innovative forms, representing a stage of evolution in geometric drawing from a symmetrical system to a digital system. [1].

2.THE MAIN OBJECTIVE OF THE RESEARCH :

Through the application of a design methodology aimed at utilizing parametric design tools and algorithms, the research aims to develop an architectural approach that combines modern techniques with ancient cultural values in order to design buildings that reflect a unique identity and respect the cultural heritage within the context of designing a mosque in Al-Obour city, incorporating architectural elements from Islamic civilization.

3. PARAMETRIC ARCHITECTURES:
This trend is based on using computers to generate form by employing multiple equations with numerical variables, where the shape changes as the values change are shown in **Fig. 1**. The term "parametric" refers to software environments that contain algorithms and mathematical operations, based on engineering principles and mathematical concepts inspired by nature [2].

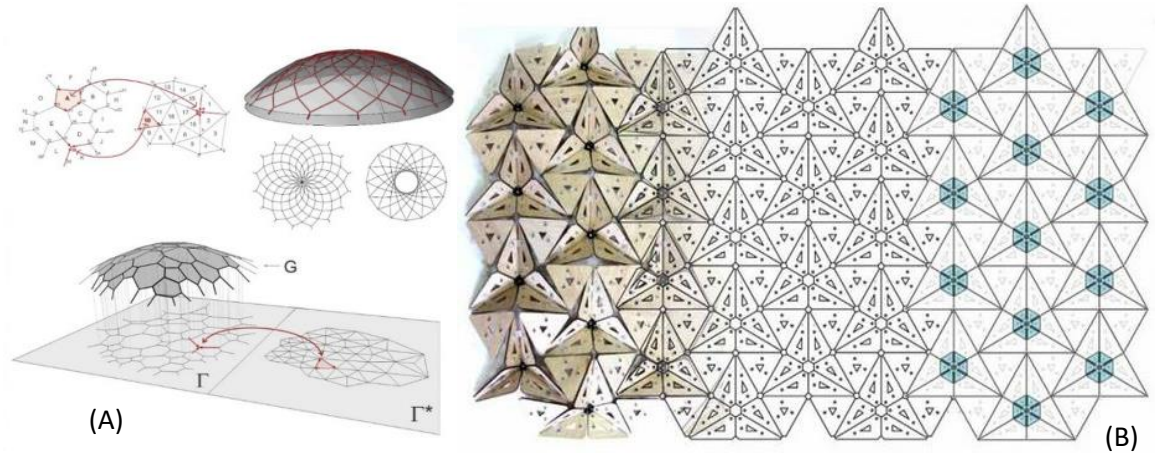


Fig. 1. Parametric Architectures (A) and (B) generate form source [3]

4.1 TYPES OF PARAMETRIC SHAPES

4.1.1 Parametric Ruled Surface :

Surfaces can be created by the movement of a line in space, and curves can also be generated by the movement of a point in space. Furthermore, three-dimensional surfaces can be created as well are shown in **Fig. 2**. [4].

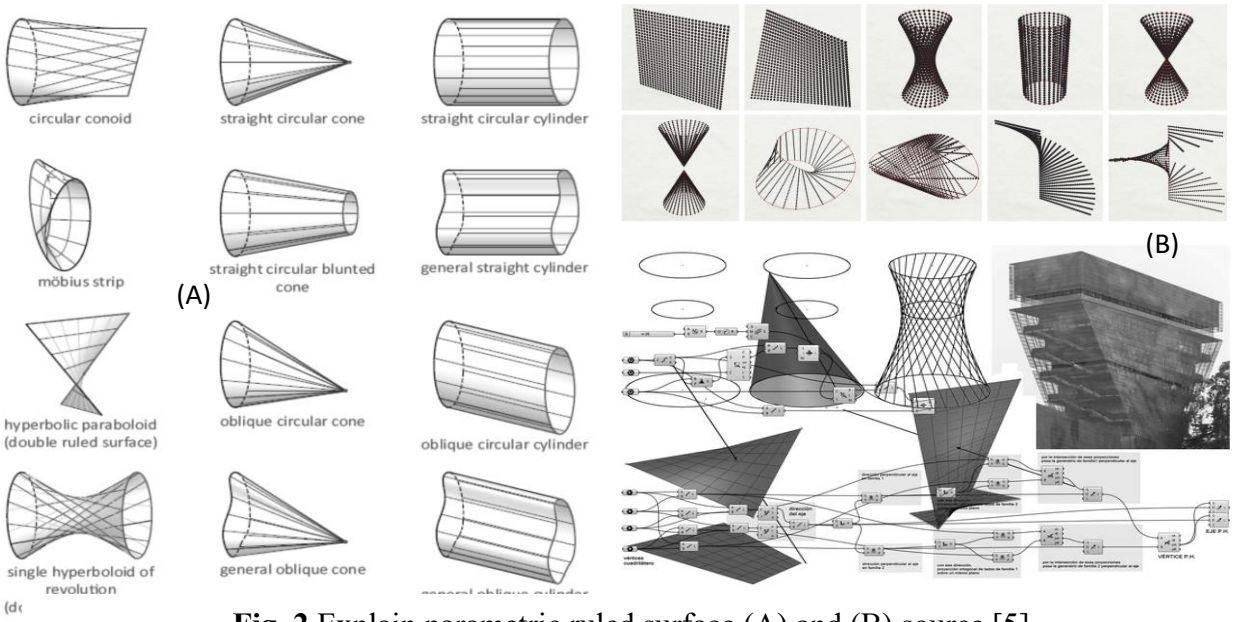


Fig. 2 Explain parametric ruled surface (A) and (B) source [5]

4.1.2 PARAMETRIC CURVES:

There are two types of curves, regular curves and irregular curves." [6].

4.1.2.1 regular curves:

are characterized by an even distribution of points along their length. They have a consistent and smooth shape, where each point on the curve has a specific relationship to its neighboring points. [7].

4.1.2.1.1 Gaussian Curvature:

Curved surfaces can be classified according to their Gaussian curvature are shown in **Fig. 3**.

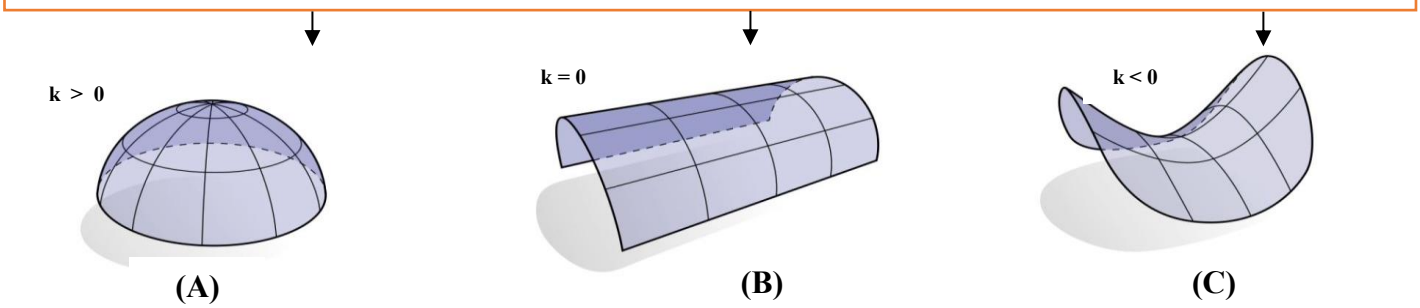
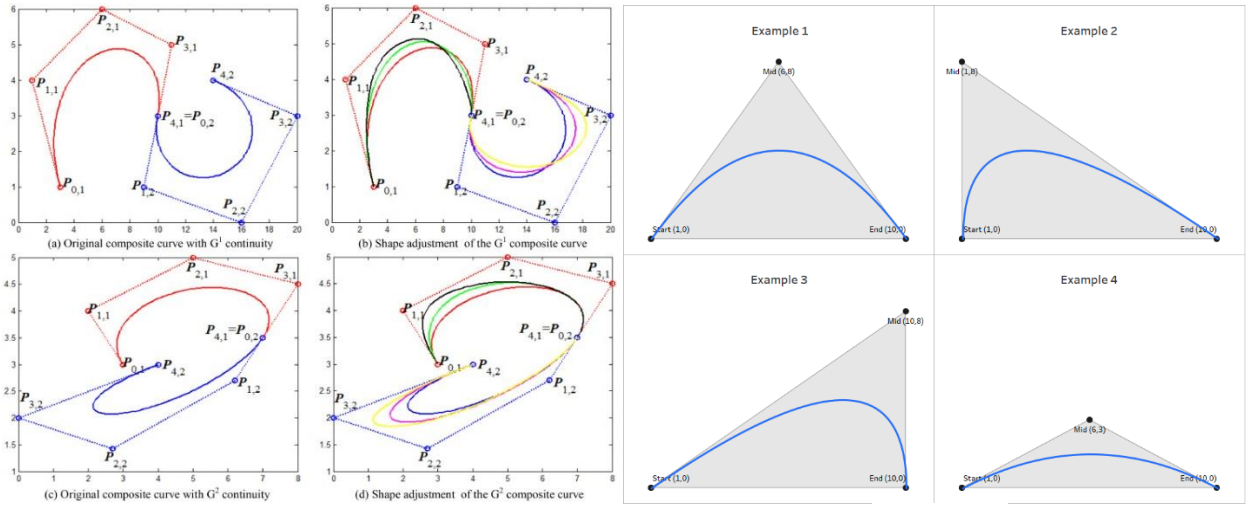


Fig. 3. Explain Gaussian Curvature (A) Surfaces that curve in the same and (B) surfaces that curve in one direction and (C) Surfaces curved in two different directions source [8].

4.1.2.2 IRREGULAR CURVES:

4.1.2.2.1 Bezier curves:

They are curves with irregular shapes and are named after the scientist Pierre Bezier are shown in **Fig. 4**.[9].

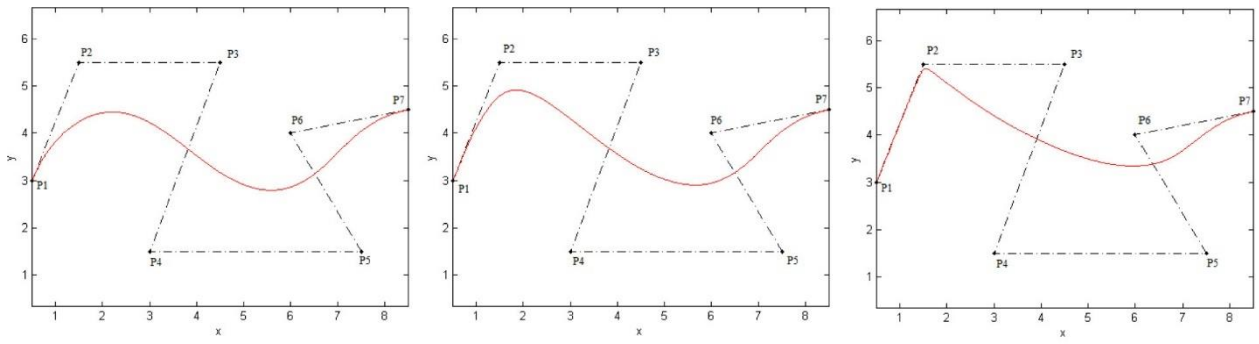


(A) **(B)**

Fig. 4. Explain Bezier curves (A) and (B) Two types source [10]

4.1.3 NURBS CURVES:

NURBS, which stands for Non-Uniform Rational B-Splines, is a mathematical model widely used in computer graphics to generate and represent curves and surfaces. It provides a high degree of accuracy and flexibility in handling them, whether through analytical methods or by creating freeform shapes are shown in **Fig. 5**. [11]



(A) **(B)** **(C)**

Fig. 5. Explain Nurbs Curves (A) The attraction is equal at all points and (B) Increasing the attraction at a point and (C) Reducing the attraction at a point source [12]

4.2. PARAMETRIC SHAPES WITH DISCRETE SURFACES: [9]

4.4.1 Triangular-faced surfaces:

are suitable for architectural forms since their faces are planar, and they consist of triangular faces that meet in a node are shown in **Fig. 6**. [13]

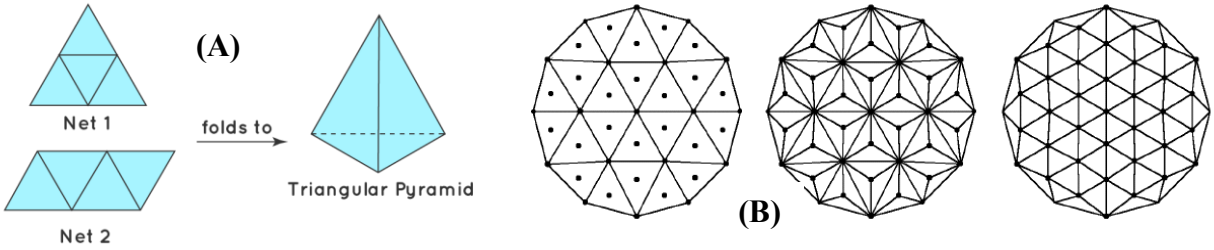


Fig. 6. (A) and (B) Explain Triangular-faced surfaces source [14]

4-2 Quadrilateral-faced surfaces:

They consist of faces in the form of squares or rectangles, and a polyhedral surface can be obtained by rotating a polygon around another are shown in **Fig. 7**. [15]

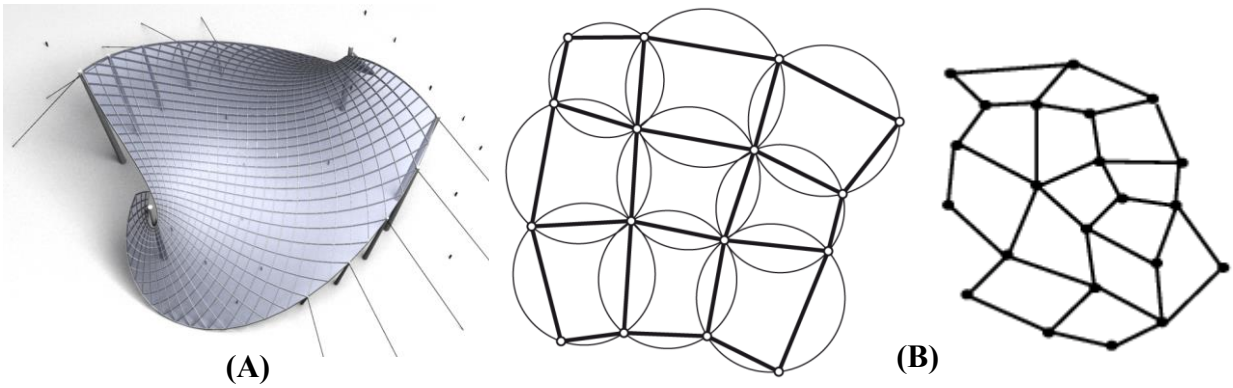


Fig. 7. Explain Quadrilateral-faced surfaces (A) The Final Form after Execution and (B) Stages of Shaping the Form source [16]

4-2 Hexagonal-faced surfaces:

consist of faces in the form of regular or irregular hexagons, and every three hexagons meet at one vertex, helping to cover larger areas are shown in **Fig. 8**. [17]

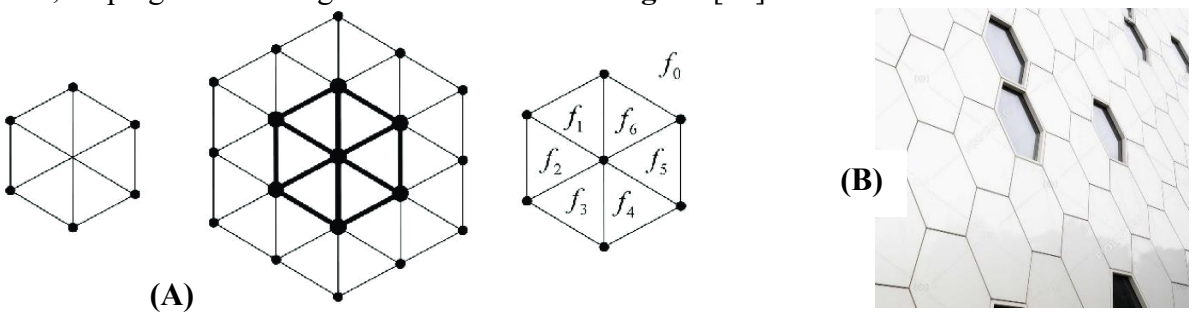
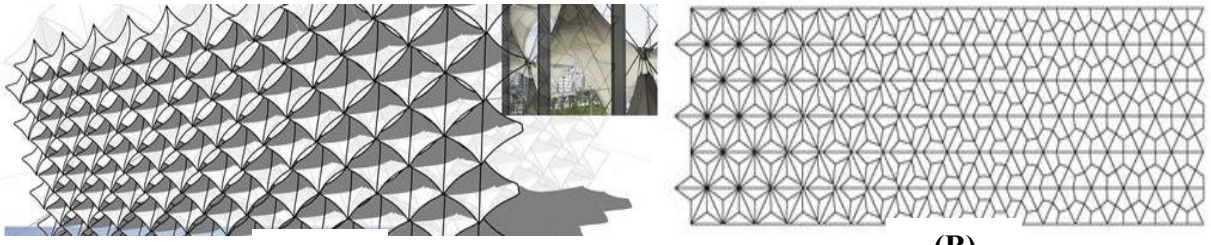


Fig. 8. Explain Hexagonal-faced surfaces (A) Stages of Shaping the Form and (B)The Final Form after Execution source [18]

4.3. Parametric and architectural facades:

The concept of parametric architecture can be used to create different patterns for external facades with a specific geometric division and to generate unconventional designs. Parameters are utilized to achieve flexibility in design and adapt facades according to architectural and environmental requirements are shown in **Fig. 9**. [19]

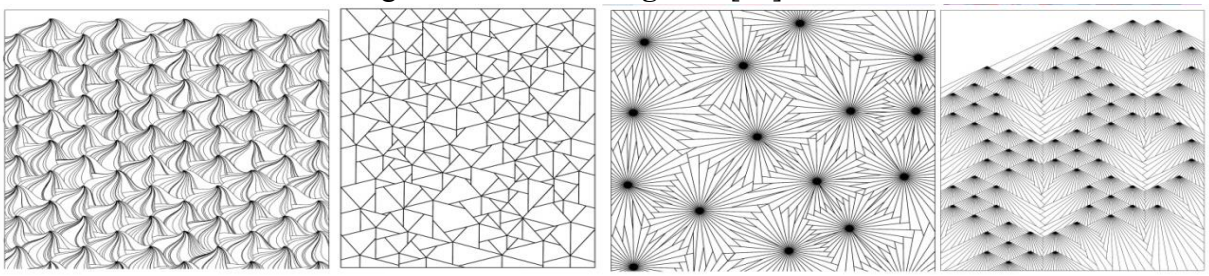


(A) **(B)**

Fig. 9. (A) and (B) Explain example for Parametric and architectural facades source [20]

4.3.1 TESSELLATION PATTERN:

is a pattern of planar shapes where all patterns are formed by the intersection of two shapes but with different distances and angles are shown in **Fig. 10**. [21]

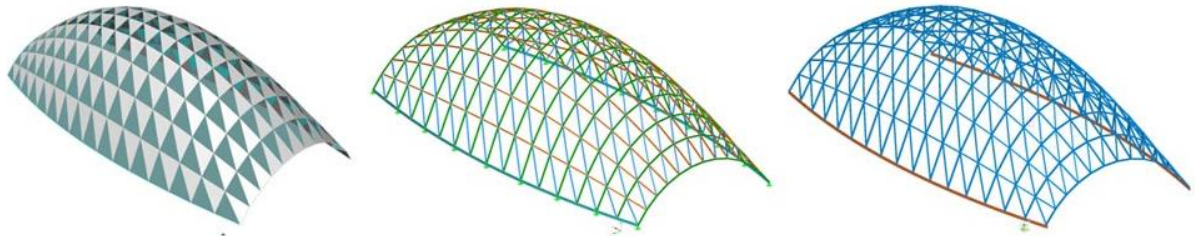


(A) **(B)** **(C)** **(D)**

Fig. 10. (A) and (B) and (C) and (D) Explain different type for tessellation pattern source [22]

5. ALGORITHMS IN ARCHITECTURE:

The use of algorithms in architecture is significant for several reasons. Design can be created using digital processes in two ways: either by using pre-designed software, where the architect only draws the shape, or by writing algorithms using programming languages, which helps the designer think of creating non-predefined designs. The use of algorithms leads to the creation of new forms of buildings that respect the design standards verified by the architect. Algorithmic design can produce more diverse and unexpected designs compared to traditional CAD programs are shown in **Fig. 11**. [23]



(A) **(B)** **(C)**

Fig. 11. Explain Experimenting with Algorithms (A) ARC and (B) FEM and (C) BIM source [24]

5.1. THE TYPES OF ALGORITHMS USED IN ARCHITECTURE:

5.1.1 Voronoi Algorithm:

It is a mathematical principle that relies on dividing a given space into a set of neighboring regions (cells) that are close to each other. Each region is associated with a point inside it, which acts as its center. Considering S as a set of points in the plane (referred to as Voronoi points), each point s in S has a surrounding region V(s) that contains all points closest to s compared to any other point in S. are shown in **Fig. 12**. [25]

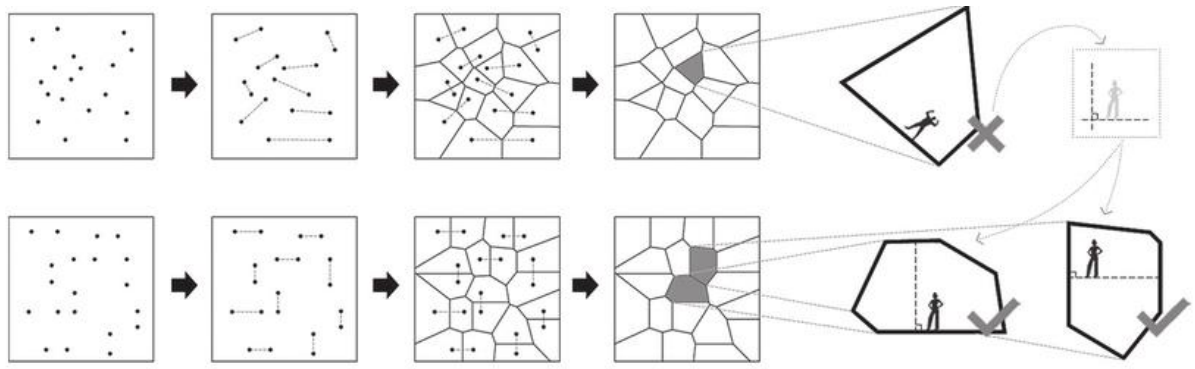


Fig. 12. Explain Voronoi Algorithm source [26]

5.1.2 Fractal Patterns:

These patterns exhibit self-similarity, where smaller parts or motifs repeat at different scales within the overall design are shown in **Fig. 13**. [27]

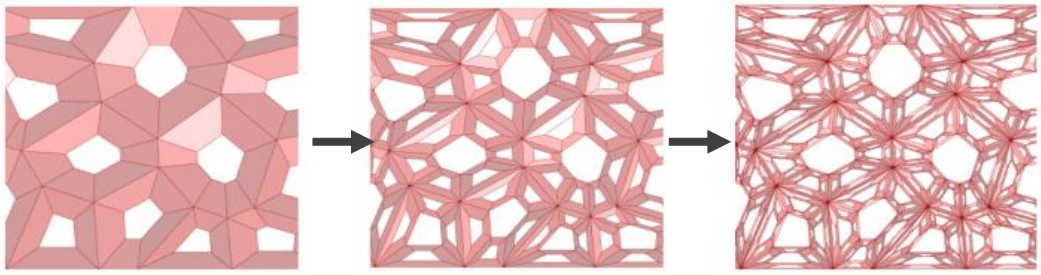


Fig. 13. Explain Fractal Patterns source [28]

5.1.3 Cellular Automata:

These patterns are generated through the application of simple rules to a grid of cells, where each cell's state is determined by its neighbors, resulting in complex and evolving patterns **Fig. 14**. [29]

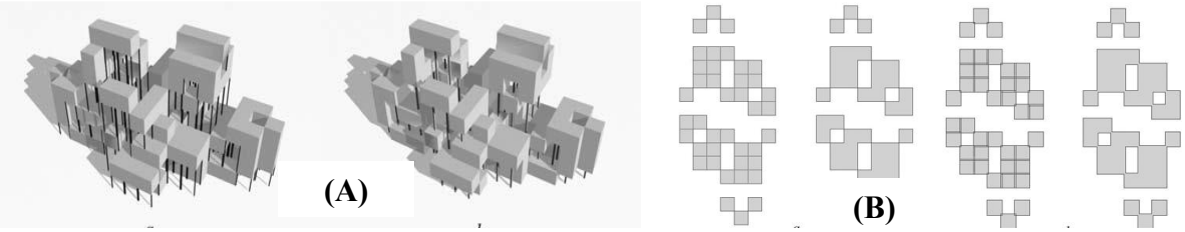


Fig. 14. Explain Cellular Automata (A) The Final Form after Execution (B) Stages of Shaping the Form and source [30]

6- METHODOLOGY FOR INTEGRATING CREATIVE ARCHITECTURE AND MATHEMATICAL GENIUS IN DESIGNING IDENTITY-BOOSTING BUILDINGS:

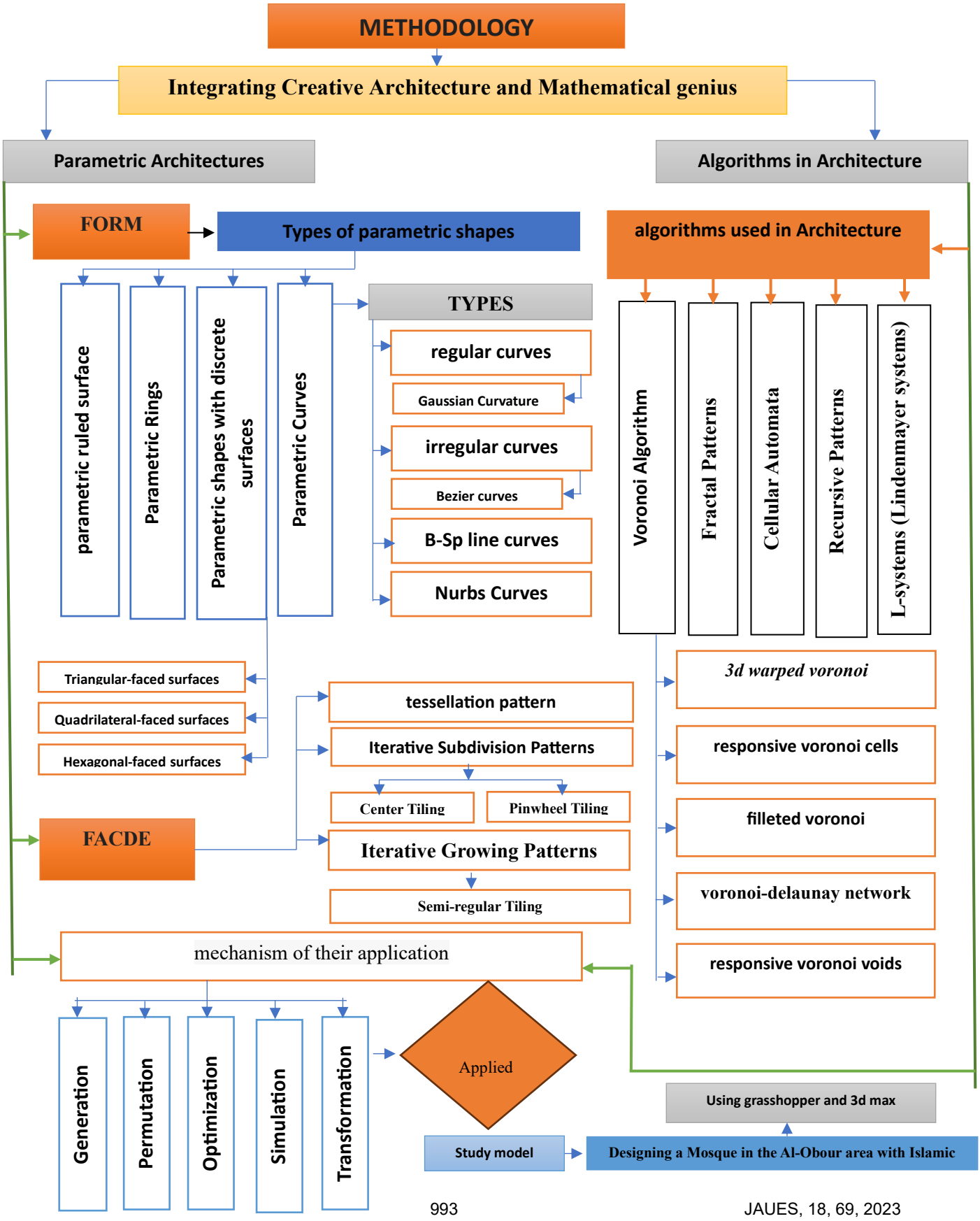


Fig. 15. Methodology source: researcher

6-1 THE EXPERIMENTAL METHOD:

The methodology relies on a main axis, which is the adoption of an alternative approach through the integration of creative architecture and the use of mathematics to analyze drawings .and symbols from Islamic civilization, and to create a design model that can be applied

6.1.1 THE DESIGN CONCEPT:

Utilizing elements from Islamic civilization old dome through abstraction of Islamic decorations and symbols, and analyzing them mathematically to find the proposed design. are shown in **Fig. 16**.

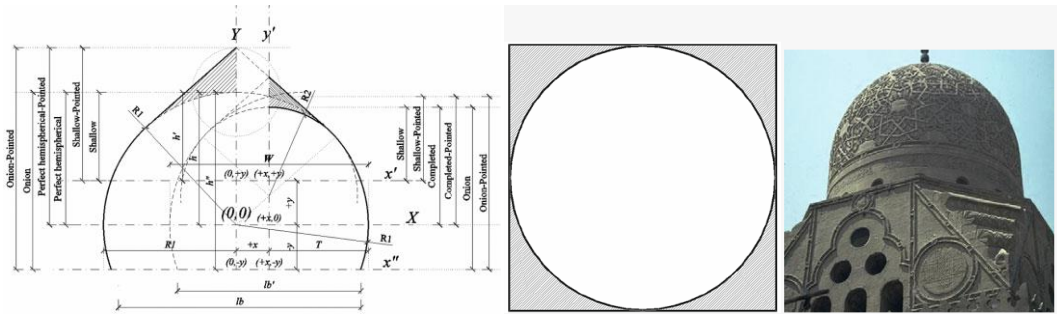


Fig. 16. Inference of Dome Ratios source: researcher

6.1.2 THE GEOMETRIC ANALYSIS TO DEDUCE THE ALTERNATIVE:

Designing a mosque in Al-Obour city using geometric analysis of domes in Islamic architecture and studying proportions are shown in **Fig. 17**.

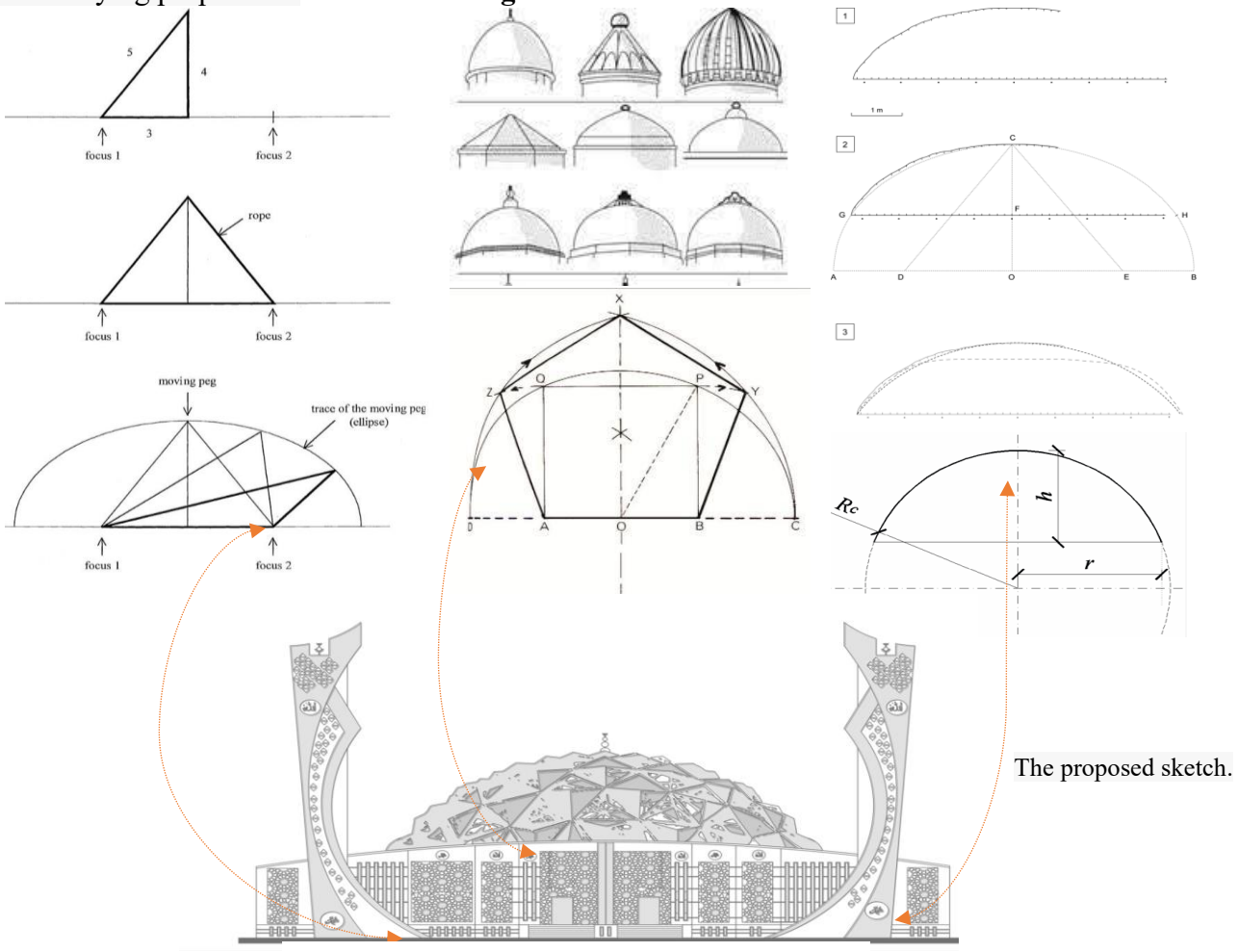


Fig. 17. The Alternative source: researcher

6.1.3 STUDYING THE CONCEPT LAYOUT :

Geometric shapes were employed to fulfill the function, and Islamic decorations were abstracted to reach the initial form are shown in **Fig. 18**.

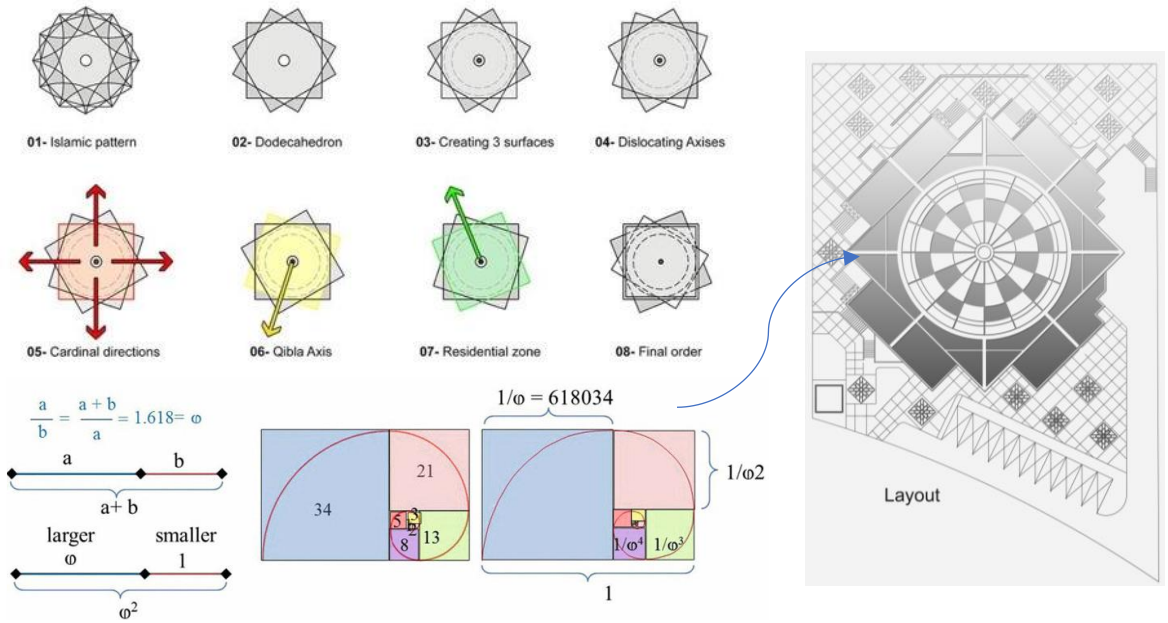


Fig. 18. Studying the concept layout source: researcher

6.1.4 STUDYING THE CONCEPT OF FACADES :

The hexagonal shape was used because it is present in many mosques and Islamic palaces. Additionally, it represents the six directions of prayer. Geometrically, it is one of the strongest regular shapes and provides the largest area with the least perimeter, which aids in the passage of natural light are shown in **Fig. 19**.

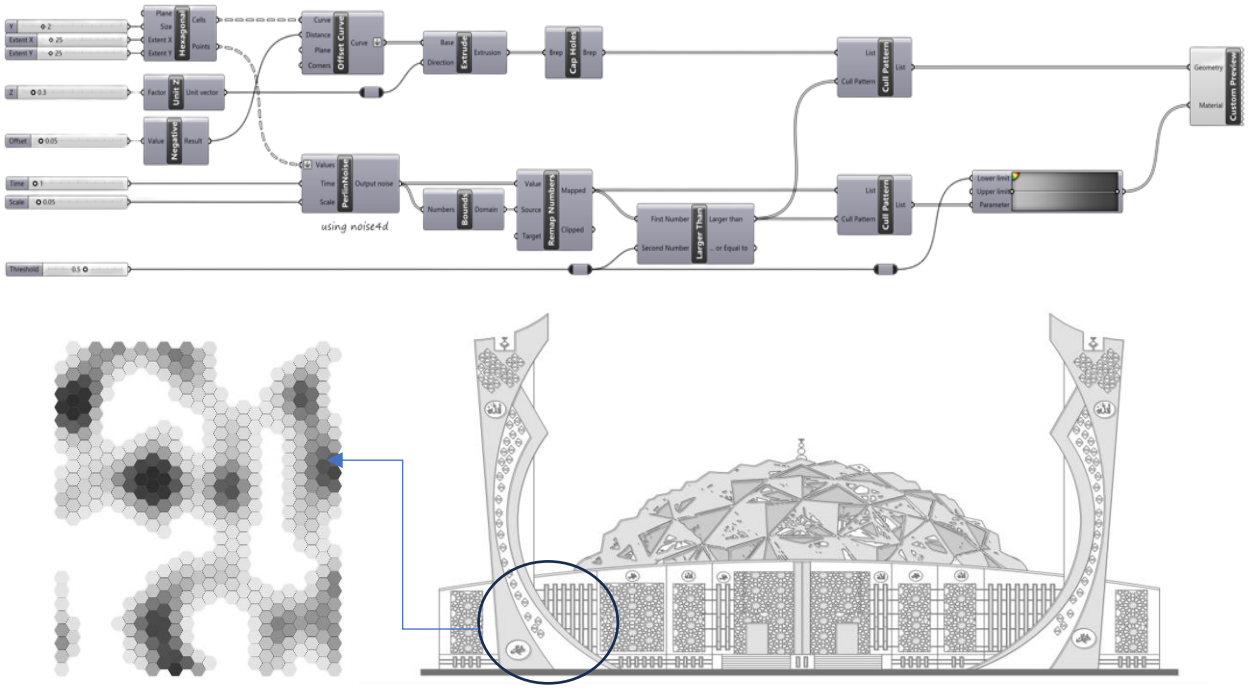


Fig. 19. Studying the concept of facades source: researcher

SUMMARY AND CONCLUSIONS:

The research concludes the necessity of utilizing an understanding of mathematics, geometric shapes, their laws, and their relationship to achieve the optimal form of a building. It emphasizes the integration of this knowledge with creative architecture, particularly parametric architecture and the use of algorithms, to create contemporary designs that preserve the cultural identity of the building.

The key findings of the research paper can be summarized as follows:

1- Mathematics provides the foundation for calculations and measurements in architectural design. By applying mathematical principles, architectural engineers can ensure the structural stability and efficient utilization of space in the proposed design.

2- Understanding mathematical ratios, such as the golden ratio, enables architectural engineers to create innovative and harmonious designs that simultaneously interact with cultural identity and allow them to express their ideas.

3- Parametric architecture allows for designs that effectively address and solve architectural problems, such as controlling lighting and natural ventilation through the use of specific patterns in building facades. This makes the designs energy-efficient and promotes sustainability.

4- The use of algorithms in architecture empowers architects to achieve a balance between the functional requirements of a building and its aesthetics. By analyzing building data and creating design models that consider the site and environmental considerations, architects can utilize specialized software in this field, including the use of parametric design tools.

5- Understanding the nature of a building and preserving its identity are crucial in design. This has been achieved practically through the design of a mosque that incorporates elements from Islamic architecture, analyzing and re-presenting them in an innovative manner.

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