The development of the principles of the Elements of Islamic architectural by using parametric algorithms

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Abstract

Islamic architecture represents a great civilization that passed through it, Architects constructed many buildings in different parts of the world. It is one of the most important Aspects of civilization that characterized Islamic history for decade, because it is rich in vocabulary, details and environmental treatments that move towards contemporary architecture.

But with the transformation of the architectural form of Islamic architecture by using parametric algorithms the principles of Islamic architecture had changed and new principles had appeared and some had neglected so we are going to obtain these principles to develop the Islamic architecture into parametric Islamic architecture.

Keywords: Islamic architecture, parametric architecture, Islamic parametric patterns, Islamic elements.

Introduction

In ancient times; Islamic architecture emerged in the Arabian Peninsula and spread east and west with the Islamic conquests covering a vast area of land. Within each country entered by the Muslims, many buildings are built, most of which adhered to the content of Islamic thought. Egypt received architectural and artistic groups from different successive civilizations for its rule in different Islamic eras from the Islamic conquest from 641 AD to 1878 AD. These monuments of all purposes are seen between mosques, schools, hospitals, khanqat, sabil, palaces, baths, wekalats, walls and citadel. Today Islamic architecture is one of the most important aspects of civilization, which has characterized Islamic history for decades, during which architects have created artifacts in different parts of the world [(1)].

2-Stages of development of Islamic architecture in Egypt

Many developments had happened to Islamic architecture through each era. In Umayyad era in Egypt: The Mosque of Amr ibn al-Aas had extended and renewed several times, four silos had built above the four corners, the first minarets, mihrab hollow, baths, markets, domes and mosques had built in Egypt. The Abbasid era affected by Sassanian architectural styles in using bricks and gypsum in covering the buildings. Then the Ibn Tulun Mosque was built. In State of Echidism: The internal revolutions increased in the country and were no longer in any significant way. The Fatimid had built the arches surrounding the courtyard, the higher ceilling Corridors and arches which is higher than the level of the Iwan. Jouhar had built an exterior wall with seven doors and Al-Azhar Mosque. In the Ayyubid State the schools were built. The development of the construction of fences, fortresses, castles and the most of its buildings were built from bricks while mosques, schools, and their houses were built from sculpted stone. In The Mamluk Period Magmoaat Qalawun and Sultan Hassan School were built.The most important Mamluk palaces large tombs were built by Prince Bashtak. In the Ottoman Period: The

church of Aya Sophia had turned into a mosque and added 4 minarets. The four iwans schools had disappeared. The markets and Wakalah also had increased in number [(2)].

3- Types of Islamic buildings

The main feature that were prominent in Islamic architecture is the Mosque. The other types are tekya and khanaqat, el wekala, gates and fences, houses and palaces. The Mosque was the main features prominent in Islamic architecture included a mihrab, minarets, domes and arches. Al Tekya is an open square courtyard surrounded by four shaded corridors, and behind each corridor there are rooms of residential Sufi. Khanaqa contains a courtyard surrounded by orthogonal iwans which are perpendicular to the square courtyard. In the corners of this box are the Sufi rooms. El Wekala: The ground floor contains a number of "stores" and opens on a shaded corridor that separates them from the middle courtyard. Gates and Fences: The city of Cairo was founded, with a defensive wall, the Fatimids built a second wall around Cairo, had a significant number of fortified gates. Citadel: One of the most important castles built by Salah al-Din. It consists of two main sections, the northern section, which is a rectangular military fort with towers, and the south-west section with accessories from palaces, mosques and stables. Houses and Palaces: It have been characterized in their composition and engineering, very harmonious with the climate conditions. Had an inner courtyard contain fountain, used internal windows bigger than external [(3)].

4- Characteristics of Islamic buildings

Islamic architecture was characterized by using elements and decorative patterns in a unique manner to produce magnificent structure. These elements such as: Gates, Entrances and Doors, Windows, Mashrabiyat, Qibla and Mihrab,Al Minbar, Columns, the arches, minarets, Domes, Roofs, Arays, Fountains, Moquarnas and Arabisque.

(4/1) Analysis of The Elements of the Islamic architectural form through eras

Islamic architecture took the appropriate for it as it is or developed in a manner that does not contradict the Islamic faith and has continued so far suitable for man and place and time because they have an architectural thought that is not associated with a specific time or certain elements[(4)].

Table 1: Evaluation of The Elements of the Islamic architectural form through eras

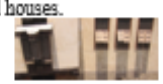
eras / elements	Umayyad era	The Abbasid era	The Fatimid era	The Ayyubid era	The Mamluk era	Ottoman era	Modern Islamic architecture	evaluation
gates		They were interested in building gates in palaces and castles.  Samarra mosque	Most of them were carved artistic elements. They characterized by decoration on the flanks and between the two towers of the gate there is a huge high door topped by an opening surrounded by a frieze that extends to surround the two towers of the door.  Cairo gates	Renovation of fences. Salah al-Din al-Ayyubi built the citadel and its entrance appeared similar to the Fatimid gates. It was two towers, and each of them is a semicircle, with a ledge connecting the gate and the two towers together.  Salah al-Din al-Ayyubi citadel	The external gates included rooms for soldiers. They were similar to Cairo gates, which are two circular towers the entrance in the middle. It is surmounted by a prominent frieze which was mounted on stone shoulders connecting the two towers to the main entrance.  Qaytbay Castle	Restoration and renovation of gates and fences.	Borrowing the gates shapes in residential towers or imaginary entrances between the buildings with the development of building materials and the construction method  AUC new Cairo	Repetition: Repeated / Unrepeated Symmetry: symmetry / unsymmetrical Stability: Stable / unstable
Entrances and Doors	  The entrance was prominent from the rest of the facade, and surrounded by two columns carrying a triple or rounded arch were topped with an inside window.	It is made from wood one floor height. They were from all sides and they used to give names to each door. They were very simple.  Ibn Tulun mosque	The entrance was prominent from the rest of the facade.Use carved stones instead of stucco patterns. Evolution in design arches. The use of muqarnas in decorating facades. The appearance of doors with wooden panels.  Aqmar mosque	These entrances have become taller topped with a muqarnas arches or arch formed from two small domes. The entrances of the buildings are in iwans, topped by a half of a muqarnas, grooved or smooth dome.  Madrasa_of_al Nasir Muhammad	Interest in the majestic entrances that are evident in the construction of the Sultan Hassan Mosque has increased. The entrance ends with a lobed arch at the top, in the center of it is half a dome carried by muqarnas  wekalt elGhory  Sultan Hassan Mosque	The entrance is a door opening with two wooden doors, topped by a semicircular arch decorated with interlocking floral motifs and muqarnas to carry a semicircular dome.  Tekya El Refaai	Revival and development of entrances with varing in dimensions and porportions.  Al Rahman Al Rahim mosque	Mass building: Traditional / unique Material: Traditional / modern Environmental treatment: Traditional / modern
Windows	The windows of the old mosque were decorated with stucco patterns, Still found in the southern wall.  Amr Ibn el Ass	The outside windows were small and inside they were pointed arches and covered with stucco and patterns.  Ibn Tulun mosque	The outside windows were few and small except for the ground floor windows in the mosques were taller than the others. They were decorated by moqarnas and arches.   Mosque of Salih Talai and Al Azhar	They were few and small except for the ground floor windows in the mosques were taller than the others. They topped by pointed arch centered a circle in the middle.  .Nagm_Al-Din_Ayyub Mosque	The deep double windows that come in and out of the façade.  Bashtak palace	The lower openings are rectangular covered in copper rods, topped by a solid, pointed arch covered by blue and green marble, stucco windows stained with glass.  El Fattah mosque	they differed between reviving the shape of the old windows or developing the same shape in a modern style.   AUC new Cairo El Fattah El Allem mosque	Construction system: Traditional / modern patterns: Islamic / geometric
Mashrabiyat		It was widespread and used in palaces and general buildings.	It was used in palaces and houses, but it is not found now because of their demolition.  Al Azhar Mosque	It was used in palaces and houses.	Mashrabiyat and Shanashili in the architecture of palaces and houses.	It was used in palaces and houses.  Gamal el Dein El Zahaby house	It development with the use of technology.  AUC new Cairo	Economic cost: expensive / Unexpensive

Table 2: Evaluation of The Elements of the Islamic architectural form through eras

Eras / Elements	Umayyad era	The Abbasid era	The Fatimid era	The Ayyubid era	The Mamluk era	Ottoman era	Modern Islamic architecture
Qibla and mihrab	The appearance of the mihrab and the apse for the first time in the Umayyad Mosque, especially because it was in the first church and was demolished and the mosque was built in its place.	It was covered in marble, and stucco decoration and Arabic calligraphy were used for decoration, with the formation of pillars to emphasize the qibla position. Ibn Tulun mosque 	It was decorated with Kufic calligraphy. It was covered in marble. It was topped by pointed arch. There were marble columns on the sides of el mihrab. Aqmar mosque Mosque of Salih Talai 	El Mihrab was cladded in marble and mosaics. Al Saleh Nagm_Al-Din_Ayyub Mosque 	The mihrab is covered with colored marble and decorated with Islamic patterns.  Sultan Hassan Mosque	The size of the mosques had increased. Therefore, the mihrab was confirmed by a curved circular double height arch ended by half dome, and it was covered in marble surrounded by an openings for lighting due to the high altitude that was covered with stained glass and mosaic from the inside.  Nuruosmaniye mosque	Few decorations around the mihrab with different height ratios.  Al Rahman Al Rahim mosque
Al Menbar		It was made from arabesque wood. Ibn Tulun mosque 	It was made from wood, Decorated by arabesque wood. Aqmar mosque 	The development of Islamic patterns in El Minibars.	Marble minbar with a copper hollow door. Sultan Hassan Mosque 	The development of Islamic patterns in El Minbar. Mohammed Ali mosque 	Riving the shape of el Minber. Al Rahman Al Rahim mosque 
Columns	The columns were removed from church Debris.	The appearance of half form columns fixed to the functional square column. Ibn Tulun mosque 	Old marble columns with casting bases and different crowns. Mosque of Salih Talai 	The muqarnas crowns were used on the columns for the first time in El Sham.	The columns are covered in marble and crowns are made of lush copper, or the column, base and crown are one unit from marble. Sultan Hassan mosque 	The use of simple marble columns without decorations they hold the arches in the open courtyard. Nuruosmaniye mosque 	Simplicity in the columns El Fattah El Allem mosque 
The arch	The round arch in the facade and in beams that carry the roof.  Amr Ibn el Ass	Arch shapes varied from semi-cylindrical, pointed, lobed, and horseshoe arch. Ibn Tulun mosque 	Use pointed arches to hold ceilings and lobed arches to shape the facades  Mosque of Salih Talai	The use of the pointed arch was common, as was the use of the triple-lobed arch to decorate it and the old bow over the windows in El Sham. In Egypt, however, the Fatimid arch, which ends with two straight lines, met at its top. Al Saleh Nagm_Al-Din_Ayyub Mosque 	Diversity in arches forms. Pointed arch , semicircular arch, arch decorated by moquarnas centered by half lobed dome and two semicircular arches and topped by a circle. Al-Ghuri complex 	New elements appeared, such as the Ottoman arch, which is a concave arc, exterior in its upper part, and the lower part of it is convex. , And use the semicircular arc in the openings. El Fattah mosque 	Evolution of arches with less decoration, different proportions and dimensions, Used to connect two buildings. AUC new Cairo 

Table 3: Evaluation of The Elements of the Islamic architectural form through eras

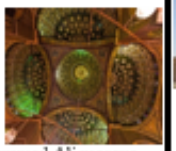
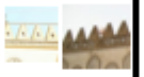
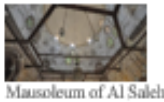
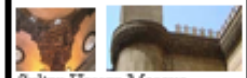
Eras / Elements	Umayyad era	The Abbasid era	The Fatimid era	The Ayyubid era	The Mamluk era	Ottoman era	Modern Islamic architecture
Minarets or lighthouses	it was a simple minaret consisting of one floor end with a conical top. Amr Ibn el Ass 	The appearance of minaret isolated from the mosque. The minaret is spiral. Samarra mosque 	The shape of the minaret evolved, and muqarnas was used in a more decorative way, with the widespread use of motifs. Al Azhar Mosque Aqmar mosque 	Square minarets continued in El Sham while the Fatimid minarets continued in Egypt. Rely on muqarnas to move from polygon or circle to square. Khanqua Bebars Kashenkar 	Diversity in minarets forms and decorated by stone, muqarnas or with faience. The appearance of double-headed minaret. Al-Ghuri Complex Sultan Hassan Mosque Qalawun complex 	It was dominated by the square or polygon shape, so it evolved into the slender cylindrical shape, which was higher, and was equipped with vertical grooves. El Fattah mosque 	Revival and development of the shape of the minaret. El Fattah El Allem mosque 
Domes	El Sakraa Dome: It is irregular in shape, with a diameter of 13-18 meters. El Sakra Dome 	Build domes and switch from square plan to the circle plan by using different sizes of octagonal plans. Ibn Tulun mosque 	The domes of that era were small and simple. Either from the inside or from the outside. The dome was transformed from square to circle by multi-row muqarnas. Aqmar mosque 	The use of domes has evolved in terms of height and fulcrums points. Most of the roofs were covered with domes, and these domes were pointed or domed with lobes. Al Saleh Nagm_Al-Din_Ayyub Mosque 	It came independently; or attached to the building, and the burial hall covers a dome with a circular or ribbed or octagon base in which several windows open, it looks very high decorated with lobules or vegetal or geometrical grids. Sultan Hassan Mosque, Qalawun, Al-Ghuri Complex 	Big dome interspersed with lighting windows was carried by 4 half domes or 4 big arches. The chapel is preceded by a courtyard covered with a small domes. Mohammed Ali mosque 	Revival and development of domes and changing the radius of the circle till it become flat. AUC new Cairo El Fattah El Allem mosque 
Roofs	Most of the mosques roofs were in the form of a wooden truss in hot countries or from palm-leaf and mud, and was carried on beams of palm trees. El Sakra Dome 	The ceiling is wooden beams, decorated with motifs and Qur'anic verses. Ibn Tulun mosque 	Its roofs, usually supported by crossbows, initially rest on columns with lush Corinthian capitals Aqmar mosque 	Roofing is highly dependent on domes. The vault was also used for roofing, and the cross vault was rarely used. Khanqua Bebars Kashenkar 	Roofs varied from flat roofs or a dome mounted on decorated wooden beams with muqarnas use to transform from square or octagonal ceiling to the circle. Qalawun complex 	A large dome in the middle centered on half-domes or large arches and small domes around it. Nuruosmaniye mosque 	Roofs varied between flat domes curved. El Fattah El Allem mosque 
Balconies and Arays		Using pointed arrays for the first time. Ibn Tulun mosque 	Diversity in designing el Arays Aqmar mosque Al Azhar Mosque 	It came in the shape of a step pyramid. Madrasa_of_alNasir_Muhammad 	New pointed arrays appeared. Sultan Hassan Mosque 		Lak of uses el Arrays. El Fattah El Allem mosque 
Fountains	A well known as the orchard used by the worshipers at the time of ablution.	It appeared in houses in an open courtyard. Ablution places developed into a building covered with a dome.	Fountains appeared in houses were centered in an open courtyard. Places of ablution came behind the places of prayer.	Fountains appeared in houses were centered in an open courtyard.	There is a large basin for ablution in the mosque courtyard, covered by a dome resting on eight marble columns. Fountains appeared in houses.	Fountains appeared in houses were centered in an open courtyard.	The use of technology led to the emergence of new forms in fountains AUC new Cairo 

Table 4: Evaluation of The Elements of the Islamic architectural form through eras

Era / Elements	Umayyad era	The Abbasid era	The Fatimid era	The Ayyubid era	The Mamluk era	Ottoman era	Modern Islamic architecture
Moqurnas and pendants	She appeared in the minaret to move from the octagonal shape to the conical shape and was taken from the Sassanid civilization.  Amr Ibn el Ass	They were small niches to move from the square shape to the octagon.  Ibn Tulun mosque	Development in the forms of muqarnas and its uses.  Aqmar mosque	Rely on muqarnas to move from polygon or circle to square.  Mausoleum of Al Saleh Nagm_Al-Din_Ayyub	Used below the domes or to form the facades or to move from arches to the half dome.  Sultan Hassan Mosque	It was limited to decorating the main doors and the arches.  Tekya El Refaai	Revival and development of moqurnas.  AUC new Cairo
Arabesque and Islamic patterns	Stucco patterns were used on the facades around doors.	Uses of mosaic, engraved wood, marble and mud cutter and faience and used plant patterns to decorate arches and columns.  Ibn Tulun mosque	There were wood, stucco, and stone and marble patterns, with geometric, floral, and arabesque patterns with Samarani and Byzantine origins. The patterns were more complex than previous Islamic patterns and were more adaptive to structural limitations. Star and hexagonal shapes appear with floral motifs. Egypt produced ivory fillings decorated with plant, animal and human elements.  Mosque of Salih Talai	The Islamic patterns in the buildings were limited in few places such as the decorative strips above the entrances doors and window frames, and new Islamic patterns elements appeared on the entrances to the buildings, which are the porticoes (symbols, slogans). Uses stone carved in large dimensions as a basic material in facades and columns and their capitals, sometimes in domes and vaults.	New patterns appeared in shapes of muqarnas and geometric patterns. The facades of the buildings are decorated in red, white marbled stone. Appearance of 16 pointed star in Sultan Hassan mosque. Use of gypsum geometric patterns and stained glass decorations in domes.  Sultan Hassan Mosque	Ablaq (motifs with geometric or floral motifs curved on stone and filled with stucco) is commonly used to decorate the façades, as painted wood, floral and geometric motifs or images of famous cities or landscapes in wall and ceiling cladding. Blue and green Kashani tiles with vegetal patterns were used as a main element in covering the interior walls and some parts of the facades above the doors and windows. Using stucco patterns below the dome or the top of the inner walls Using marbling or faience porcelain plates on the walls.	Development of Islamic geometric patterns.  El Fattah El Allem mosque
Calligraphy	It used to decorate Mihrab with Quran.	The oldest type of Kufic writing. Used to decorate Mihrab.  Ibn Tulun mosque	Flowering kufic calligraphy was the forefront of mihrab, arches frames, and windows.  Aqmar mosque Mosque of Salih Talai	Decorate the interior and exterior façades with bands of Thuluth calligraphy and the Square Kufic calligraphy.  Aleppo_Citadel	Calligraphy are used more broadly on top of columns, on top of arches and Mihrabs.  Qalawun complex	Quranic verses are written in frieze on the inner walls and below the main dome.  Nuruosmaniye mosque	The use of Quranic calligraphy in the decoration of walls, mihrab and doors.  El Fattah El Allem mosque

(4/1/1) Evaluation from the previous study (The principles of designing the Islamic elements):

From the previous analysis we can find that there are some features that sustained through eras for each element.

- **The Gates:** they are two high towers from the rest of the building and are linked together by a form object (frieze or shade ...) or functional (corridor or rooms).
- **Entrances and Doors:** The doors are decorated, surrounded by an arch that relief and higher from the rest of the building.
- **Windows:** Covered with blank wood and glass topped by an arch, or the window itself is an arch.
- **Mashrabiyat:** It covers windows and is made of hollow wood or arabesque, and is used for a functional purpose first, then formative second.
- **Qibla and mihrab:** It is a circular arch curved inside.
- **Minbar:** It consists of an ornate door and ascend the stairs to the top of the platform on which the Sheikh stand.
- **Columns:** Used to transfer loads from arches, whether internal or external.
- **Arches:** Used for formation purpose around doors and windows or functional to move loads from the ceiling to the columns and used in the inner corridors or covered outer corridors.
- **Minarets or lighthouses:** One of the most important architectural elements in the design of the mosque, they are either separate or connected to the mosque and graduate in size and thickness until they end with one point from the top.
- **Domes:** One of the most important architectural elements it is radius and height changes may be it stand on neck or not it found in the center of the building.
- **Roofs:** may be domes or flats with Islamic patterns from inside.
- **Arrays:** it is an element which can be dispensed.
- **Fountains:** it is an important geometric elements in houses or palaces.
- **Moqurnas:** It is a decorative element that distinguishes Islamic architecture and is found at the bottom of domes or in the minarets to transform from a square surface to a circular or octagonal, or vice versa, one unit is shaped of an arch curved inside so we can many forms from it by increasing or decreasing it is unit or putting it in different places.
- **Islamic patterns and Arabesque:** It is an important form component used to add aesthetic element to the building.
- **Calligraphy:** It is used to write Quranic verses on the walls, around doors, windows, and inside domes.

From the above we distinguished that in designing Islamic elements its shape must be symmetry around its axes, regularity, and repetition, straight lines, right angles, corners, and simple repetition of elements and patterns must be found.

The changes in construction methods compatible with the contemporary possibilities and the new building materials available in the same place with the cultural and social constants of the Islamic religion will produce new Modern architecture elements that expresses the contemporary of new building materials and methods and the authenticity of heritage values and the social values of Islamic society

Islamic architectural theory is a universal theory of all time and place, rather than a local theory that emanated in a particular place and time. It is a theory that works to deal with variables for every time and place.

So we will study the Islamic geometric patterns which the parametric algorithms redesigned them and re-represented in contemporary design to know the changes that happened to them and how it extracted new pattern from the old one.

(4/2) The Islamic geometric patterns

The Islamic geometric patterns derived from Islamic art. Many Islamic designs are built on squares and circles, typically repeated, overlapped and interlaced to form intricate and complex Patterns. In ancient times Muslims did not have books in which models of these motifs were described. Recently it explained as a system in which these geometric networks were divided into identical units that are repeated in regular order. This method has helped in the process of enlarging and minimizing the decorative schemes easily based on the relative relationship between the geometric shapes. The complexity and variety of patterns used evolved from simple stars and lozenges in the ninth century, through a variety of 6- to 13-point patterns by the 13th century and finally to include also 14- and 16-point stars in the sixteenth century. Artist and educator Roman Verostko argues that such constructions are in effect algorithms, making Islamic geometric patterns forerunners of modern algorithmic art [(5)].

(4/2/1) Analysis of Islamic Geometric Patterns (IGP)

According to many researches had divided the IGP into:

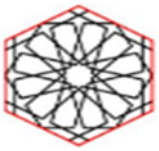


Fig.1: The basic unit (the Cell)

The Cell: The seed geometry or basic unit for the pattern which we will call the cell; and arrangement or tessellation which is the actual pattern generated by the repetition of the cell in one of the 17 plane symmetry groups.

The Fundamental Unit: In most cases, it is possible to examine the IGP cells and find symmetry within the geometry of the cell. It is also possible to dissect the cell into smaller units until the non-symmetrical part is found [(6)].

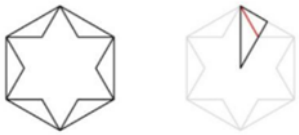


Fig.2: The Fundamental Unit

(4/2/2) The extraction of new from traditional

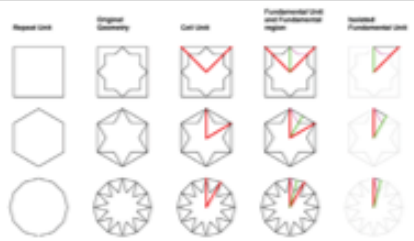
Many researches have analyzing the geometry of the IGP that made an analysis by isolating cells and populating them to reconstruct the corresponding pattern. Recently designers have used this knowledge to create modern versions of IGP designs from scratch [(6)].

Table 5: The extraction of new from traditional

The extraction of new from traditional

The fundamental unit

We determine the cell unit first. It can be created by dividing the polygon that contains the repeat unit into triangles. The first point of each triangle is located at the center of the polygon, and the other two points are located at the constructional points of one of the sides. The combined cell units that contains the fundamental unit are defined as the fundamental region



Fundamental unit parameterization

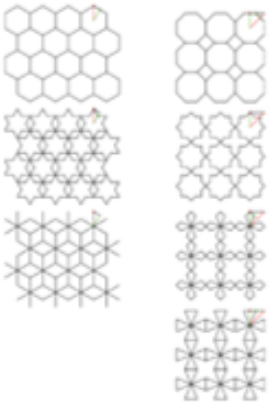
A point should be assigned at each segment intersection in the fundamental unit. An intersection can occur between one segment and another or between the intersection of a segment and the boundaries of the fundamental region. The next step is to build the parametric model. This step involves deconstructing each defined point from the previous step X and Y coordinates and then adding or subtracting a number from the coordinates to relocate a point with the new coordinates. The line segments should correspond to the changes that occur in the point, thus creating a new geometry.

Rules of spatial transformation

Points can be categorized into: (1) constrained points, or points that can travel toward and against the center of the polygon.
(2) Linked constrained points, which occur when two constrained points are symmetrical and located on the sides of the fundamental region. Anchored points, or points that cannot move at all cases. All the points located on the outer edge of the repeated polygon are considered anchored points, and the rest are either constrained or linked constrained.

The first approach

Qualitative Variant: the first method in which the manipulation of the geometry should result in a new geometry qualitatively different from the original geometry.

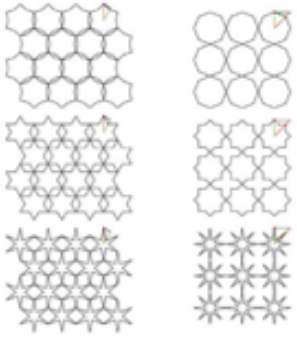


Rules for the first approach:
1st, one point should overlap. 2nd, Lines not allowed to overlap. 3rd, No additional intersections are allowed. Finally Points should not leave the fundamental region.

Results of the first method: the six point star, there is only one parameter to control because it contains only one constrained point. However, the eight point star has two points to control, and more geometries are possible.

The second approach

Qualitative Invariant. The manipulation of geometry should not result in a topological transformation, the new geometry should be always qualitatively same as the original geometry. The number of points, edges and faces in the resulted geometry should be always equal to that of the original geometry.

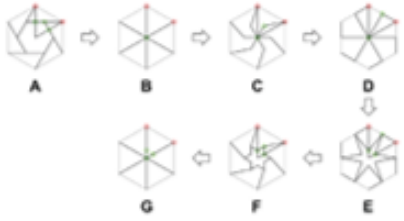


Rules for the second approach:
New geometries can be generated. 1st no point overlap is allowed. 2nd line overlapping is not allowed. 3rd, no additional intersections are allowed. Finally, points should not leave the fundamental region.

Results of the second method: the original geometry and the new geometry are qualitatively invariant. Reapplying the rules will always return the new geometry to the form of original Islamic geometry.

Metamorphosis Approach (the third approach)

All constrained and linked constrained points of the geometry should be relocated to the center of the polygon. Consider the geometry marked "A". If we relocate all the constrained points to the center of the geometry marked "B" all green circles are on the center. Then release one point at a time "C" until the point reaches the limits of the fundamental unit "D". then release the other point one step only "E" and move the first point back toward the center of the polygon "F", the point stops if it intersect line, overlap another point, or the point leave the fundamental region "G". This procedure will allow us to explore the design domain for both previous approaches. A point can travel a specific distance within a specific amount of time. The time and distance are variable.



Results of the Metamorphosis Approach: different geometries are existed with different status of one geometry in different points in time.

(4/2/3) During the research we have revealed that:

- The first step is to isolate the cell to delineate the fundamental unit. The fundamental unit is found by decomposing the cell to its constructional non repeating components. This operation will generate a fundamental unit for the pattern, which is defined as the minimum motif that cannot be reached with symmetry. Once the fundamental unit is attained we proceed to reconstruct its geometry with a parametric model. A geometrical construct with variable attributes (properties) that allows the exploration of design variations with ease. By defining certain rules that govern the parameters. The designer can to explore the patterns in a manual manner.
- Islamic geometric patterns have simple strict rules for creation and have infinite number of possible patterns.
- Can be metamorphosis into contemporary Islamic patterns that follow parametric architecture.
- Patterns can be used to emphasize cultural characteristics, and determining identity.

So we will study parametric architecture to identify them to develop an Islamic principles using parametric algorithms.

5- How could parametric design affect Islamic architecture?

Parametric design existed before our digital times. To design the church of Sagrada Família, Gaudí created an upside-down model, using strings weighed down by birdshot. A mirror placed below the model showed what the chapel would look like right side up [(7)].

(5/1) Parametric Design

It is one of the designs that was born with the digital system and its applied software to rethink the architectural design according to a numerical system. It allows the computer to deal with an algorithm system. It used mainly to design shapes, structures that respond to the general concept, to their environment, climatic issues and contextual features. Parametric design relies on control of 3D modeled components through modification of certain parameters of a building model. These modifications are driven by mathematical formulas, data values, numbers or specific computer algorithms rather than manual changes of the model properties [(8)].

(5/2) How the parametric model operates?

Parametric design form is shaped by values of parameters and equations are used to describe the relationships between the forms. We can distinguish between: CONCEPTUAL parametric design: It is the parameters of a particular design that are declared, not its shape. By assigning different values to the parameters different objects or configurations can be easily created. This design method requires knowledge of programming or scripting and it is inherent of the mathematical algorithms whereby interactive design is not possible. And CONSTRUCTIVE parametric design: Refers to data embedded within a predetermined 3D object. This parametric concept is realized in various CAD packages like Autodesk Revit… Instead of drawing lines, arcs, etc. designers can insert pre-drawn components, doors, windows, load elements, stairs or roofs etc. This results in 3D models instead of 2D drawings[(9)].

(5/3) Shapes of Parametric Design

(5/3/1) Voronoi diagrams

The Voronoi diagram is a system that divides the space into sub-spaces in an organic way. The diagram uses points to create cells that surround these points. Points can be placed as spontaneously or can be determined in the direction of a certain data and tessellation can be provided accordingly. The first use was seen in the disposition of the solar system and its environs. In 1854 Dr. John Snow used Voronoi diagrams effectively to detect the Broad Street Pump causing the cholera outbreak [10].

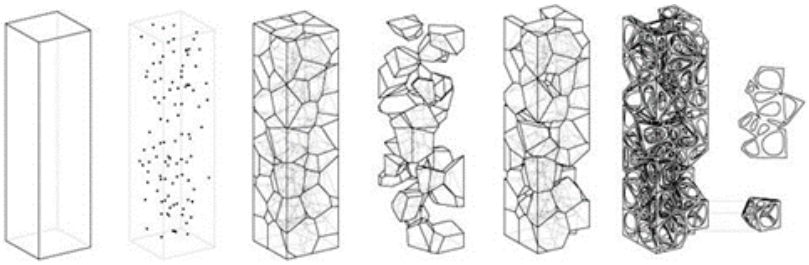


Fig.3: Steps of Voronoi diagrams in 3D

The Concept of Voronoi

Given a set of a finite number of distinct points in the 2D or in 3D :is to draw a line connecting adjacent point, to draw a perpendicular line to the one you just drew in the midpoint of it, to connect lines drawn in the second step into a network.

Voronoi Diagrams Elements

A simple voronoi diagram has the following elements: Voronoi vertex, Voronoi cell, Voronoi space, Voronoi foam [10].

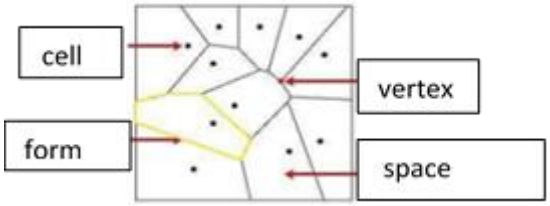


Fig.4: Voronoi Diagrams Elements

Voronoi application

Voronoi can be implemented in generative forms to save the time for Architects and Designers. There are many application: space filler, structural communication, urban planning, and sustainable tool in planning, landscape ecology, modulator, spatial customization, pattern generators, and proximity matrix developer and as navigator in GIS[10].

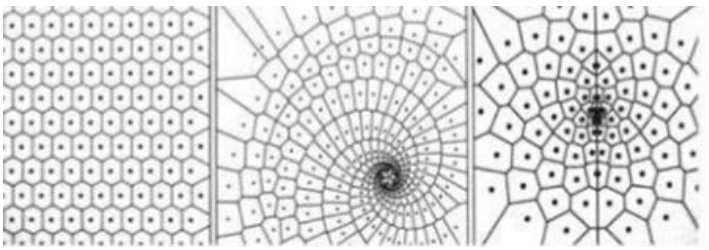


Fig.5: Dimensional study of voronoi One dimensional

Dimensional study of voronoi

Voronoi tiles have been created by a series of points. A cellular pattern that each of these cells includes the space surrounding the point. Place of the rest of the shapes created with these pattern fits into a close system. They form a collection of shapes that look like square, honeycombs, crystals or boulders.

One dimensional: These irregular tessellations on a plane occur spontaneously in nature at every scale

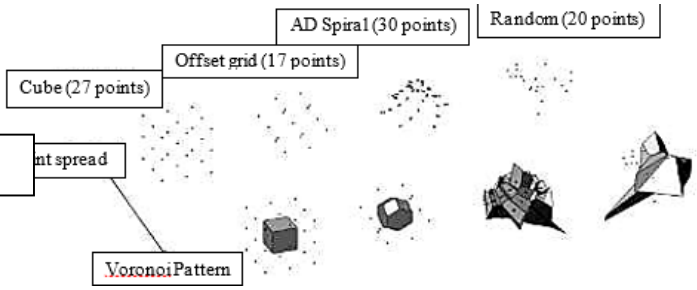
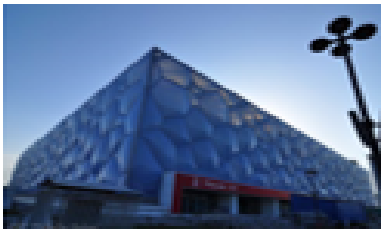
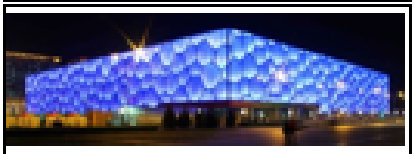
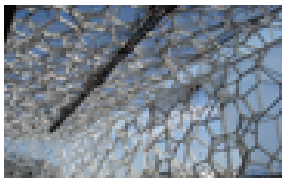
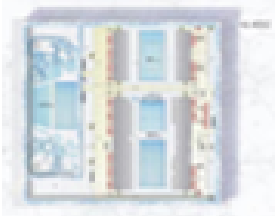


Fig.6: Two dimensional to three dimensional

Two dimensional to three dimensional: The minimal enclosure system of these bubbles and cells shows that tilings are a simple system, rather their thickness in three dimensions expands constructive towards infinity without any gaps [10].

Table 6: Voronoi example

Beijing National Aquatics Center, by: PTW Architects, CSCEC, CCDI, and Arup , Beijing, China. 2008			
	Picture	**Explanation**	**Evaluation**
Concept		It was designed by a Grasshopper program to design an aquatic center which symbolic a shape of a soap bubbles by using voronoi diagram to appear very random and organic.	Repetition Repeated / Unrepeated Symmetry symmetry / unsymmetrical Stability
Building material		Weaire–Phelan Bubble Structure is a 3-dimensional structure that represents an idealized foam of non-equal-sized bubbles which gives shape to the air filled bubbles made of ETFE, a transparent plastic material.	Stable / unstable Mass building Traditional / unique Material Traditional / modern
Environmental treatment		The ETFE cladding, supplied and installed by the firm Vector Foiltec, allows more light and heat penetration than traditional glass.	Environmental treatment Traditional / modern Construction system Traditional / modern
Construction system		The outer wall is based on the Weaire–Phelan structure. It was inspired by the shape of an array of soap bubbles and is highly repetitive and constructible whilst appearing very random and organic.	patterns Extracted from past / modern Economic cost expensive / Unexpansive
Metamorphosis		The use of a vorononi diagram to transform a cube building to a building that expresses a symbolic idea with the use of modern building materials, but it made it a unique sustainable building and expressed it in a contemporary way.	

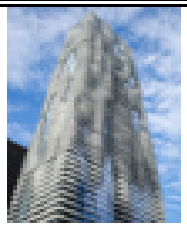
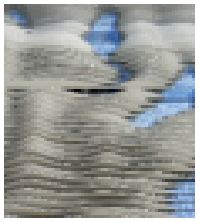
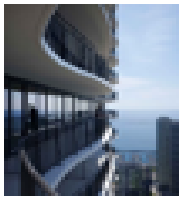
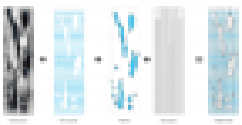
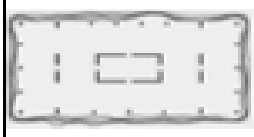
(5/3/2) Ripples

It's an interactive installation designed with the purpose of engaging passers-by through animating still sculptures. “ZEBRA”, a plug-in for Rhino developed by the Cypriot company “Seamlexity”, is implemented to facilitate the design and digital fabrication processes [(11)].

Fig.7: Parametric Bench – Interior Design by Oleg Soroko

Table 7: Ripple example

Aqua Tower, by: Studio Gang, Chicago, 2009

	Picture	Explanation	Evaluation
Concept		The building takes a form inspired by Lake Michigan and the Chicago River, which is manifested on its facade of rippling balconies on its surface.The ripples however are not random and were a carefully calculated each floor plate in Aqua is unique by using Grasshopper program expressed in Rippled shape.	Repetition: Repeated / Unrepeated; Symmetry: symmetry / unsymmetrical; Stability
Building material		Glass for opening and concrete for balcony.	Stable / unstable; Mass building: Traditional / unique; Material: Traditional / modern
Environmental treatment		The towers sculptural form allows for solar shading and views. All the façade covered by glass the balcony overhangs do however serve an environmental purpose. They not only shade apartments from the hot summer sun, but also protect the building from the force of wind.	Environmental treatment: Traditional / modern; Construction system: Traditional / modern
Construction system		Each floor plate in Aqua is unique, ultimately making the construction of the building quite complicated. The inconsistent floor plates also created variations in unit sizes. The main structure is the core box inside the tower.	patterns: Extracted from past / modern; Economic cost: expensive / Unexpansive
Metamorphosis		Using parametric design transfer a rectangular skyscraper to a symbolic shape, Each floor plate in Aqua is unique, The inconsistent floor plates also created variations in unit sizes by using the ripple shape. which creates visions in the interface in different places, making it cast shadows on the facade, which worked to reduce energy consumption.	

(5/3/3) Zome system

A structure emerging from the combination of a dome and zonohedron [11].

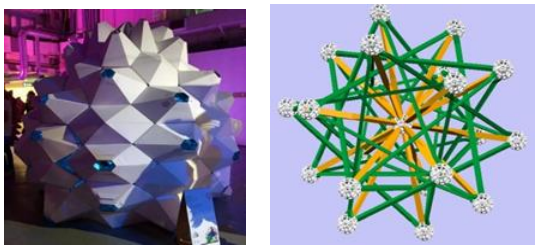
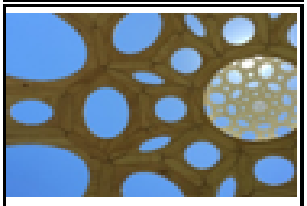
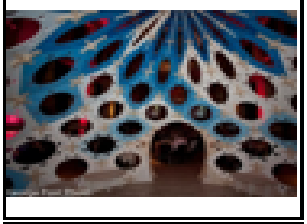
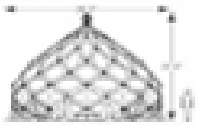


Fig.8: Zome system, geodesic domes

Table 8: Zome example

Daystar zome, Zonotopia City, San Francisco, 2013			
	Picture	**Explanation**	**Evaluation**
Concept		Exterior shade structure, archway entrance.	Repetition Repeated / Unrepeated Symmetry symmetry / unsymmetrical Stability
Building material		Wooden tiled floor and all the zome made from wood.	Stable / unstable Mass building Traditional / unique
Environmental treatment		Lighted by UV (LED) light inside it. Contain circle and oval holes in each panel to penetrate sun light and be a natural ventilation.	Material Traditional / modern Environmental treatment Traditional / modern
Construction system		It built from a single wood diamond sheet with a circular or oval hole inside it and connected together from the vertex by a cross wooden panels till they closed at the top of the zome.	Construction system Traditional / modern patterns Extracted from past / modern
Metamorphosis	 	Hexagonal floor meet at the top to form zome. The hexagonal shape transfer into the shape of a pointed dome using the zome style with its use to make external rest rooms or chalets that are easy to remove and install. Zoom was also used to develop the old dome shape and use it in a new way.	Economic cost expensive / Unexpansive

(5/3/4) Flex shell : Grid shells are efficient lightweight structures that are shaped to purely correspond to the forces of nature [(11)].

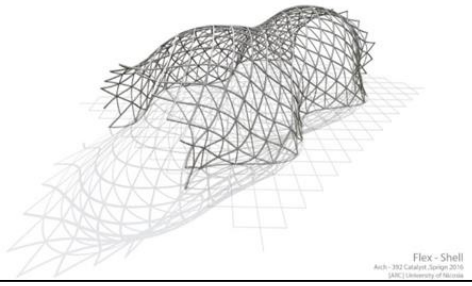


Fig.9: Flex shell

Table 9: Flex shell example

Butterfly Aviary, by 3deluxe, Al Noor Island, Sharjah, United Arab Emirates, 2016.			
	Picture	**Explanation**	**Evaluation**
Concept		The design combines a wealth of aesthetic stylistic elements in an interdisciplinary architectural language that spans space and cultures. Numerous installations and small structures, light and media objects, unusual plants and a musical soundscape it gives rise to a holistic, multisensory experience. The rainforest biotope covers 230m2 and boasts a spectacular landscape.	Repetition Repeated / Unrepeated Symmetry symmetry / unsymmetrical Stability
Building material		The mineral material is printed with patterns and ornaments repeated from the golden shading roof, and backlit in some places. Landscape made of thermoformed mineral material Krion merges horizontal and vertical.	Stable / unstable Mass building Traditional / unique
Environmental treatment		The all-over glazing merges floor and ceiling top penetrate sun light, a glance to the above reveals organically shaped skylights and the golden shading roof on and be a natural ventilation.	Material Traditional / modern Environmental treatment Traditional / modern
Construction system		The natural becomes artificial. They design the column which carry the golden ceiling in form of nature tree.The crystalline glass structure's ceiling is between 3.5 and 5.5 m high. It just a minimal barrier between inside and outside.	Construction system Traditional / modern patterns Extracted from past / modern
Metamorphosis		Parametric design turn a glass cube building into an organic building that integrated with the environment by using the flex shell shaded by its defining golden roof, it provide spectacular views into the shading structure and allow shadows of the golden leaves to enter the aviary.	Economic cost expensive / Unexpansive

(5/3/5) 3-dimesnional pattern: It creates as tessellated tile. The tile was modeled in Rhinoceros 3D [11].

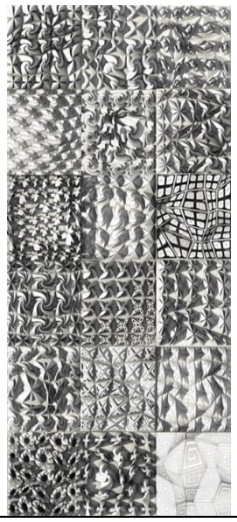
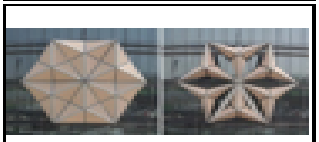
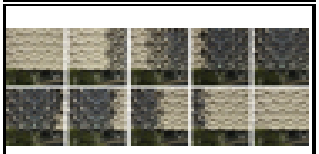
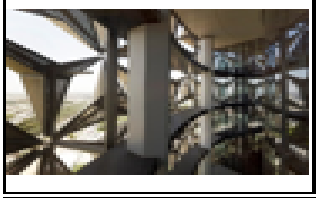
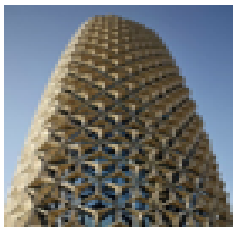


Fig.10: 3-dimesnional pattern

Table 10: 3-Dimensional example

Al Bahr, by Aedas, Abu Dhabi,2012.			
	Picture	**Explanation**	**Evaluation**
Concept		It was inspired by the masharabiya, a beautiful form of ornate sunscreen that shields windows in the Arab world from glaring sunlight and prying eyes. The screens, controlled by computers. open, close and even travel horizontally to block the sun.	Repetition Repeated / Unrepeated Symmetry symmetry / unsymmetrical Stability
Building material		Glass and steel.	Stable / unstable Mass building Traditional / unique
Environmental treatment		The solar-responsive dynamic screen decreases the towers' solar gain. The lightly tinted glass reduces the incoming daylight at all times and not only for temperature-critical situations. The system even includes about 2.000 umbrella-like modules per tower driven by photovoltaic panels.	Material Traditional / modern Environmental treatment Traditional / modern
Construction system		a double façade with a triangular pattern simulating a mashrabiya. The main construction system was in the core of the tower in the middle.	Construction system Traditional / modern patterns Extracted from past / modern
Metamorphosis		Transferring from a cylindrical glass tower to a parametric building when using the shape 3d tessellation in facade cladding as a technology to reduce energy consumption.	Economic cost expensive / Unexpansive

(5/4) The Evaluation of the shapes of parametric architecture (the principles of parametric architecture) are:

From the previous analysis study of the shapes of parametric design we obtained the principles of parametric architecture.

- Parametric design is a technique that can be used with any trends of the architecture.
- When it used with any trends, it changes the shape of the building to a contemporary one and also appropriate the environment.
- It is considered one of the most sustainable designs by using traditional environmental treatment by using the Islamic environmental treatment but in contemporary way and by using new technology and material .
- It gives more aesthetic shape to the building, making the building express the culture of the city in it or a symbolic idea.
- Using modern and old building materials in a different and modern style tends to a new modern design.
- Inspiration of Islamic tessellation and represented it in a contemporary tessellation.
- Conclusion based on Evaluation:
- Parametricism means no more axes, no more regularity, and no more symmetry nothing that smacks of the great architecture of the past. “Avoid repetition, avoid straight lines, avoid right angles, avoid corners, and avoid simple repetition of elements.

6- Conclusion

From this research we found that the Islamic principles had affected by the parametric principles and some changed and some disappeared like:

Islamic principles which upgraded:

- The parametric principles affected the Islamic principles in its Construction system and changed it so the construction system of the buildings are Contemporary modern.
- The building materials of the Islamic buildings changed from tradional one to Contemporary modern one which affected by parametric principles.
- The Presence of the Islamic elements but in symbolic parametric shape.
- The mass building of Islamic design affected by parametric principles and become unique it means not repeated and become modern one.
- Parametric principles respect sustainability and environmental treatment of Islamic principles so it re-represented it in Contemporary modern design.
- Parametric principles redesigned the Islamic patterns and changed them in a contemporary design which fits the modern design of the building.

Islamic principles which still the same:

- The mass buildings still symmetry and stable in some building which it looks like the old one from the first sight.
- The Islamic character of the buildings are compatible with the surrounding environment so parametric design affected by it and use it in design the buildings.

Islamic principles which neglected:

- The shape of the parametric buildings not follow the function of the them while Islamic design the shape must follow function so parametric design affected Islamic design so the shape of the parametric Islamic buildings not follow function.

Finally this means that:

- The Islamic parametric building must extracting from the past Islamic architecture.
- When parametric algorithms used with Islamic architecture changed in shape not in the principles of its element.
- Islamic architecture can be contemporary, progressive and inclusive but, above all, can act as a beacon of hope in opposition to nihilistic conflict that has gripped the Middle East region.

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