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Asymmetric Symmetry: An Analytical Framework of Hidden Mathematics in Isfahan's Valuable Qajar Houses; A Video-ecology Approach*

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ABSTRACT

Geometry is one of the physical features of architecture, and the regular pattern of symmetry has a special place in geometric strategies. Symmetry is senseless without such concepts as equilibrium, balance, rhythm and proportions. This study aimed to investigate the principle of symmetry in the process of perceiving Qajar-era houses in Isfahan City, Iran. These houses, although featuring a kind of visual symmetry in the first glance, are considered an asymmetrical set within their own landscapes. This study analyzed symmetry as an evolutionary value in the architectural geometry of Iranian houses, using the descriptive-analytical method and the video-ecology technique, and evaluated the reasons why this value has been violated from axial and formal perspectives. Findings indicated that symmetry is one of the oldest spatial and formal-regulating dimensions in the public spaces of Iranian-Islamic architecture, which manages to link plurality with unity in the center of the space; however, diversity in various residential spaces and dimensions, as well as land forms, have made it impossible for general symmetry to be embedded within space designs, with the designer observing symmetry in façade components. Meanwhile, the focus on the center of the space, along with the establishment of a central courtyard, and the logical location of spaces in the plan and also the use of modules and similar elements for adapting to visual systems have led to the formation of an eye-catching, coherent and seemingly symmetrical image in the mind of the observer. Findings also indicated that although the ground form in the architecture of Iranian houses may make the formation of symmetrical architecture complex and difficult, the building designer creates an in-between geometric space (a central courtyard) and uses the quality of readability by means of locating and spatial proportions to establish a new relation of a stable balance within its latent layers; this impressions involves the user in an active action with the internal concepts of the work and turns him into a part of the perceptual process.

Keywords: Asymmetrical Symmetry, Regulating Pattern, Stable Balance, Qajar Houses, Video-Ecology.

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1. INTRODUCTION

Architecture refers to a work of art that is associated with the accurate and engineered manners of geometric drawing. Each and every architect needs to have the knowledge of mathematical and drawing principles, as the engineering knowledge of architecture is formed by geometric insight. This knowledge is what distinguishes architects from each other. In the past Iranian architecture, geometry enjoyed a special place as it was used as hidden networks in all levels of design (plans, façades, sections, perspectives, spatial relations, decoration and details). In this regard, most research has explained geometric shapes and forms in sample works of architecture (Kohi Fard; Taefi Nasrabadi, and Dehghan Toran Pushti 2013).

Meanwhile, symmetry has been one of the oldest spatial and formal-regulating elements that employs geometry in architecture; this concept is also closely associated with such components as equilibrium, balance, proportions and proximity, without which it is void of any meaning. Symmetry is also associated with repetitions in terms of balance and with scales in terms of rhythm and proportions (Von Meiss 2005). In an architectural space, symmetry uses repetitive patterns to help the beholder to touch the aesthetics used in the creation of the work of art better, more accurately and faster, while enabling him to predict spatial readability. By employing a similar approach to space, traditional architects use symmetry in the building to represent space authority and strength and reveal its effects on the user. This geometric practice is quite outstanding in public buildings such as mosques, churches, caravanserais, and seminary schools, due to their repetitive spaces in relation to central spaces and middle axes. However, in residential buildings, diverse ground forms, spaces and dimensions have produced limitations with the representation of symmetrical regularity, which is replaced with visual balance. Included in visual balance and equilibrium methods are Gestalt rules. However, there is a novel perspective called video-ecology that studies the human's visual systems and the way he receives images from the eyes. This method also analyzes the harmonious and inharmonious features of visual phenomena based on visual standards.

The present study used the video-ecological method to analyze symmetry in Isfahan's Qajar-era houses as the last generation of Iranian architectural buildings with traditional values, which link local and modern architecture together. The study also responds to the following questions:

a) What are the perceptual components of video-ecology?

b) What are the patterns of symmetry and equilibrium in Qajar-era houses?

2. RESEARCH LITERATURE

Architecture has a long-established relationship with mathematics and symmetry (Mehaffy 2020, 1). Vitruvius associated architecture with regularity, harmony, proportions, hierarchy, worthiness and economics. He defined regularity to be measuring and creating proportions in various scattered components, arguing that regularity is the selection of modules from among the components of a work that initiate from these separate parts to make up the work as a whole. For Vitruvius, harmony is beauty and balance between elements, which is fulfilled once the components of a work enjoy good dimensions in all directions. Proportions refer to the good congruity between the various components of a work and the relationship between various parts and the general plan. Hierarchy is the inclusion of the elements in appropriate places in a work, which is in harmony with the identity of relevant forms. Last but not last, worthiness is defined as the perfection, wisdom and expressiveness in a style (Fayaz 2009, 21).

Symmetry is meanwhile a technique to develop regularity and harmony in creating works of art and architecture; this technique was used in ancient times when many public and religious buildings applied it to express their governance and religious authority (Saremi and Radmard 1997, 50). Symmetry is a geometric system that creates an in-between centrality to regulate other spaces around itself and thus display the ultimate level of proportions and equilibrium. This centrality is the origin of each reality and force of life (Eliade 1958, 353); however, it is not simply located in the middle of the shape; rather, it is the most important point in the shape featuring the form of its structure (Arenheim 1982).

Symmetry is defined as the quality of having parts on either side or half that match each other, esp. in an attractive way, or are the same size or shape. It refers to the proximity and closeness of two things and other thigs with each other; it denotes the bond of two things together, as in the similarity of two animals' horns or human's eyebrows. Or, it is defined as the association of two phenomena with close meanings (Afram al-Bostani 1991, 63). Lexically, the term symmetry includes similar equivalences like similarity, repetition, harmony (Pirnia 2013).

According to English glossaries, the term symmetry is derived from the Greek word "syn" denoting together and the word "metron" denoting measurement, which altogether means harmony between the various components of an object and the way several sections are combined together (Leopold 2006, 4). As a concept, symmetry includes the observance of sizes and proportions in the horizontal and vertical dimensions of a building, which refer to the relationship between mathematics and architecture (Hales 2022). Symmetry has also been defined as the concurrence of two things, the closeness and proximity of two subjects and viewpoints, the occurrence of two things not expected of. The concept of the word symmetry is equivalent to the words of parallel, contrast, mirror and equality (Bemanian and Noorian 2013, 11-19).

Symmetry is a state of a physical system that remains unchanged following a transformation; it is like a 90° rotation of the corners of a square or the rotation of the points of a circle around the center of that circle, with the former called discrete symmetry and the latter continuous symmetry (Bolouri 2020). Symmetry includes the matching of each and every component of a building or a complex on either side of the axial symmetrical line of that building or complex (Saremi and Radmard 1997). Symmetry is the joint feature of objects, phenomena and hypotheses, which have no apparent relationship together (Newman 2003, 67). As an aesthetic criterion, which entails clarity and readability, symmetry plays a major role in understanding phenomena. Human's perception, in many cases, is unconscious and influenced by the symmetrical texture of the world of being; hence, the brain structure and functioning is assumed to be harmonious and concordant with the universal functioning.

Symmetry is seen in various areas in nature, including in plants, animals, small and large structures, such as galaxies, stars, planets, crystals, molecules, atoms, etc. Each of these structures follows their own special order and symmetry. For example, human organs (members, tissues, cells, and molecules) are each symmetrical. Given the presence of symmetry in universal elements and natural structures, it is critical to investigate architecture from the perspective of symmetry. This subject is not just confined to the contemporary era, because our ancestors had thought of the significance of symmetry thousands of years ago and employed it to create outstanding works. Understanding the significance of the concept of symmetry and its extended use in the theoretical investigation of basic sciences, especially physics, has facilitated the fast-development of these sciences and resulted in the production of many technical and industrial accomplishments over the past century (Bolouri 2020).

No doubt, symmetry is the most perfect type of equilibrium, which is focused attention both in terms of the aesthetic and stationary aspects of works of art and design (Azhdari 2017). Symmetry and symmetrical features can be seen in many old works of art. Few man-made containers can be found to bear no symmetrical shapes or forms. The design of military tools and appliances in common or noble houses or palaces have always tended toward symmetrical patterns. In illustrative designs, framing and the regularity of pages have been based on symmetrical patterns. In architecture, too, surviving patterns involve symmetrical ones. Pyramids, ziggurats, temples, mandalas, palaces churches, mosques and many houses are symmetrical. For this, observing symmetry was thought as a traditional phenomenon, and its disruption was seen as a solution to break down old stereotypes and arrive into the modern world; a practice adopted by the architects of several hundred years ago (Collins 1965, 7). It is thus suggested that despite the significance of the concept of symmetry in basic sciences and mathematics, symmetry has seen its role declining in the creation of works of art, due to the predictability of natural phenomena (Bolouri 2020) in modern times and the neglect of classic architectural principles. For this, symmetry has been replaced by equilibrium and harmony, which are assigned greater values. Under these circumstances, the critical factor is compatibility as configuration seems to be pleasant once the user is able to understand the comparative roots of the configuration and proportions created therein. This perceptual feeling also holds true of spatial relations and configurations (Salingaros 2016). In other words, new structures of micro scales can be obtained by linking each scale to other scales and creating a hierarchy of proportions (Salingaros 2006, 166). Thus, not only an effective relationship between geometry and architectural design is created but also the cultural background is protected (Leopold 2006, 8).

Many Muslim scholars believe that regularity, symmetry and proportions in the structures of Islamic architecture are equivalent to the concept of centralism in the Islamic architectural fabric (Taghvaei 2007, 50), suggesting it is indicative of the unity and oneness of God in the entire universe. In Iranian architecture, symmetry denotes the identical arrangement of two parts relative to an axis, a center or a middle element. In this state, symmetry can be interpreted as a formal equation where there are identical images on either side of the equation. In its simplest sense, there are two identical parts like two sides of a scale that establish the balance of the two sides of the equation as regards the middle element. This formal equation is sensible once the middle element differs from identical components on either side of the equation. Symmetry does exist on outer surfaces and inner spaces of most Iranian architectural spaces. Symmetry is represented in symmetrical square and rectangular-shaped plans and facades, the avoidance of unfamiliar breaks, the creation of rhythm and balanced geometry in buildings, etc. Other than ritual and visual concepts, the easiness of designing building structures is also another reason for using symmetry.

A symmetrical space is a full-strength stationary space that lacks the sense of motion and transformation, while representing itself completely without any defectives. Using the inherent features of symmetry, the architect strives to enliven the space and represent a reflection of metaphysical, splendid and spectacular spaces. The employment of symmetry in Iranian-Islamic architecture helps complement centralism and emphasize axes; in this state, symmetry rotates the eyes towards the center and in line with its axis. Meanwhile, since an axis matches with the center of symmetry on the axis or the main center of the

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building, symmetry highlights the significance of the axis and the center in the plan and thus evokes the sense of unity in space.
Examples of symmetry in Islamic-Iranian architecture include courtyards, porches on both sides of a building, rooms in the four corners of the central space of a pavilion or on both sides of a hall, symmetrical facades on two sides of a courtyard, domes, arcs, symmetrical archways, a pair of minarets above a portal with a porch, symmetrical divisions on a wall, symmetrical gardens on two sides of a courtyard, etc. (Lake 2012).
Mohammad Karim Pirnia argues that Iranian architecture has employed symmetry in structures that have evoked grandeur, authority and heaviness, while applying asymmetry in houses and pavilions that require disrupting uniformity and heaviness to create novelty (Pirnia 2013). Afshar Naderi considers symmetry to be a principle of radicalism in Islamic-Iranian architecture and believes that many patterns like Chahar-Ivani (four porches), Chahar Suffe (four seating places), vestibules, etc. are based on symmetry (Saremi and Radmard 1997, 54). Navaei and Haj-Ghasemi describe symmetry as a factor that makes the space humane, transcendental, tranquil and motionless, arguing that symmetry has been best employed in Islamic architecture to represent unity in plurality and plurality in unity, while featuring its unique qualities in the plan, façade and volumes (Karimian, Osanlou, and Hosseinnejad 2015, 3).
For this, symmetry and symmetry breaking are among the key concepts in designing and creating works of art, especially architecture, which can greatly contribute to the completion of a work or emphasize one part of the space. However, research has less focused on symmetry and parallel forms, as geometric strategies (Bemanian and Noorian 2013, 11-18).
The concept of symmetry as an organizing geometric system has been a key concept in the study by Deniz Sheibaniaghdam and Salma Arsalan Selcuk, who published their articles in the Journal of Nexus from 2008-2021. In this study, the authors aimed to identify the main and inspiring subjects for future research and investigate mathematics (ratios and proportions, geometry and symmetry) as cultural concepts and tools that govern architectural plans; they also debated models obtained from the relationship between architecture and mathematics, complexity and patterns, models, and digital representations (Sheibaniaghdam and Selcuk 2022).
Today, with the development of modern and digital technologies, large-scale instruction-based research is being carried out, along with the rewriting of patterns for form-producing machines. In this connection, understanding the logic of geometry and making changes to a symmetrical axis can help achieve a large spectrum of symmetrical groups, which contribute to diversifying identical patterns by making differences to patterns of similar patterns in the design process (Ligler 2022). These patterns can thus serve as references for comparing models and selecting components in various stages of design (Williams 2022).

2.1. Symmetry in Residential Architecture

Symmetry is one of the most outstanding space-recognizing factors, which is associated with the axis and the centrality. Symmetry comes with regularity and a pre-determined program (Omoumi 1997, 40). While an axial state can realize without symmetry, a symmetrical state cannot be formed without an axis or a center around it. A symmetrical state requires a balanced order of identical shapes in terms of form and space around a line (the axis) with a shared point (the center). It should be borne in mind that the space's center should be free from rigid and occupying elements in order to create an axial or central symmetry in the façade (Von Meiss 2005). In general, an architectural configuration makes use of symmetry for organizing forms and spaces by the following two ways:
a) Organizing the entire building in a parallel way
b) Establishing symmetry only in one part of the building and evoking it by creating orderly forms and spaces. In this state, regularity and parallel can be used for organizing major and outstanding spaces (Gooderzi 2016, 8).
Describing the structures of Iranian mosques, Pirnia considers the centrality of Qibla and the need to focus on its direction, writing "Mosque structures are always built based on symmetrical or paralleled forms to attract the attention to the center, which is regarded as the most important part of the complex, and to lead the Muslim entering the mosque to find and turn to the Qibla easily and straightforwardly" (Pirnia 2013, 277). He asserts "Symmetry pertained to large mansions such as palaces and temples, while the asymmetric and unparalleled forms and arrangement of houses and pavilions served to oppose uniformity. The land plotting of small buildings were major barriers to establishing symmetry across the plan. However, a sophisticated endeavor to establish symmetrical facades and parallel landscapes in the heart of those small houses could be noted, with relevant maps revealing those small asymmetrical houses as being parts of symmetrical spaces" (Saremi and Radmard 1997, 50).

3. METHODOLOGY

Gestalt rules are psychological methods concerned with structural analyses and design patterns; these rules, provided by a group of German psychologists in 1920, investigate the way man receives his visual information. The Gestalt theory provides a holistic view of the entire design rather than its individual components. Simply put, although each section of a configuration has its special meaning, an entire structure can help perfect the meaning of a complex (i.e., totality), because a total approach reveals a new meaning distinct from a variety of meanings from each section. Using the principle of symmetry, Gestalt theorists posit that the human's mind tends to conceive of objects as symmetrical and to develop a hypothetical relation in his mind to create a harmonious design when he receives two symmetrical elements without a relation (Taikendi and Ashuri 2020).

There is, however, a novel theory called video-ecology, first developed by Russian biologist Antonovich Filin in 1989. Video-ecology is a new scientific process and a body of knowledge about the interaction between man and the visual environment (Filin 1998, 295).

Video-ecology studies the human's visual system from a physiological and optical points of view and is concerned with how images are received by the eye, while exploring the harmonious and inharmonious features of visual phenomena based visual standards (Pourjafar and Alavi 2012, 6).

As the founder of this theory, Filin describes the environment with all its various aspects as a visual environment, perceived by humans through their visual senses. He divided the visual environment into two natural and artificial categories and explains that the natural visual environment fully corresponds to visual physiological standards, while the artificial environment is widely different from the natural environment, being most of the time in conflict with the rules of visual perception (Filin 1998, 45).

To understand which phenomena are harmonious with the visual system, there should be accurate knowledge of the functioning of the visual system to identify the quality of the reception and analysis of visual phenomena by understanding effective mechanisms and standards. Following the perception, processing and understanding of visual phenomena, the next step is to determine the physical and visual characteristics of visual phenomena to be harmonious with the functioning of the visual system in receiving relevant information. Also, the characteristics of visual phenomena should be determined to help the eye to receive the phenomena easily and without interruption. In general, video-ecology is basically concerned with enriching factors in images and vision-harmonizing factors. This will make the eye see the image more pleasantly. The literature done in this regard implicates five mechanisms in the visual system's reception and distinction of information, as follows:

a) Saccadic Movement Mechanisms: Here, this mechanism emphasizes the rapid movements of the eye in perceiving a visual scene. In other words, the images, which transmit visual information to the eye for focus and stabilization, are examined by the system. This information is obtained by creating diversity in elements and opposition in shapes that lack simple and networked geometry.

b) Off-On Mechanisms: Here, this mechanism emphasizes the difference of image contents as the criterion of recognition by visual neurons. This difference can be made in light, colors, edges, and diversity in details and elements (Pourjafar and Alavi 2012, 8-9).

c) Binocular Vision Mechanisms: This mechanism relates to the final recognition of an image totality. In other words, the six-centimeter distance of the two eyes makes each receive a different angle of the field of vision and transmit it to the eye (Coren and Ward 1994, 343). However, the brain, having the knowledge of this difference, combines them together and forms a united image. In this state, the creation of differences is more harmonious with the functioning of the visual system. The details of the images each eye transmits to the visual cortex is different. In other words, when large surfaces lack formal diversities, or all factors are similar and identical image, there won't be a necessary harmony with this mechanism.

d) Reflective Function Mechanisms: Since the eyes are more focused on natural surfaces than on artificial surfaces, this mechanism emphasizes the use of surfaces, natural textures and colors to provide more pleasant experiences for the eyes (Pourjafar and Alavi 2012, 10).

e) Spatial Frequency Mechanisms: This mechanism pertains to the functioning of the retinal cortex in receiving and analyzing data. Like the off-on mechanism, the spatial frequency mechanism considers information reception to be dependent on the proper understanding of object edges. Here, in this mechanism, the concept of spatial frequency and the encoding of a visual scene are key for perceiving the data of an image and representing it by the brain and the visual system (Carlson 1998, 254).

Video-ecology uses visual system features and the effects of the three factors of distance, amplitude and orientation to divide the perception resulting from environmental facades and bodies into three homogenous (uniform), aggressive and comforting facades. Out of this, comforting facades are more harmonious with visual mechanisms and deemed more suitable for the eyes, as described below:

- Uniform Facades: This category of facades enjoys uniform surfaces and involve sharp-ended angles, as well as rigid geometric shapes and artificially reflective materials used in their construction. However, they provide little visual information and are not thought of as desirable for the visual system, as the eye's focus on them is a little (Image 1) Networked facades are the best examples of this category.

- Aggressive Facades: They are facades with numerous similar elements, as the eye is unable to follow a sign there. These facades feature similar and identical information and are many. These facades are also characterized by the use of squared-shaped wavy patterns (rigid geometric shapes, vertical angles on surfaces, lines, and volume forms), light-reflecting materials, the lack of diversity in the elements constituting facades, and the use of fully artificial textures and materials. Modern facades mainly follow this pattern. As seen from Figures 2 and 3, these facades lack any breaking in the skyline and the point of inflexion.

Fig. 1. Uniform and Homogenouse Facafe

Le Grand Hotel in China (Filin 1998)

Fig. 2. Aggressive Facade (Comforting Facade)

Modern La Defense Building (Right) and Notre Dame Church in Paris (Left) (Filin 1998)

Fig. 3. Aggressive Facade (Comforting Facade)

Modern La Defense Building (Right) and Morozov's House (Left) in Moscow (Filin 1998)

- Comforting Facades: This category of facades involves sufficient visual information because of their specific details and edges and are harmonious with visual frequencies (Fig.s 2 and 3). Also, these facades are characterized by soft and curved lines, diverse constituting elements, points of inflexion on façade surfaces, the differences of shapes, light and color, which correspond to the visual mechanism and seem more pleasant for the viewer (Pourjafar and Alvani 2012).

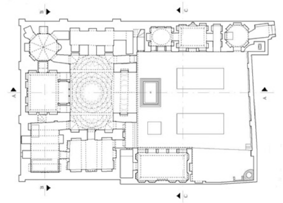
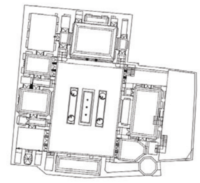
The notable point about the eye's structure is that it moves once in every 0.5 seconds and is physically unable to stop at a straight line, because it has no fixed points; as a result, each building should have adequate elements for stabilization, marking, and inducing the sense of comfort and pleasantness (Filin 1998). This requires providing the details of adequate visual information on the bodies and edges, using natural texture, colors and materials, creating opposition and differences in shapes, colors, and light; using soft and curved lines along with rectangular lines, and creating points of inflexion and concentration.

Below, there are eight houses of Qajar era (namely, Oftadeh, Jangjouyan, Salek, Sirfian, Toghrolian, Kadkhodaei, Vasigh-Ansari and Hemmat-Yar), selected from among the valuable houses of Isfahan. These buildings are physically in a good condition and have underwent little changes. (Table 1). First, using field surveys, roleve, photographing, the geometric patterns of symmetry and equilibrium on the main facades and relevant plans were analyzed, and then the components of the facades were examined and compared with the indictors of climatic ecology (homogenous façade, aggressive façade and comforting façade). In this connection, surface framing, symmetry in whole and in parts, proportions and modules used in façade divisions were focused. In the end, after data were collected from field surveys and software, extracted findings were described analytically.

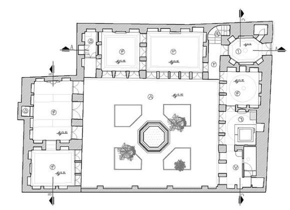
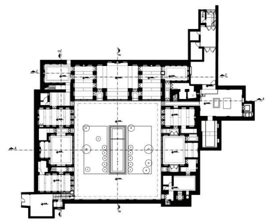
The reason why the houses of the Qajar era were selected was that the tendency to modern architecture in this era in Iran reached its highest levels, which was consequently followed by a departure from local and traditional architecture. On the other hand, in this period, architecture was evolved and for this, some scholars consider the housing architecture of this period to be the brightest architectural periods in Iran. In sum, the Qajar era can be regarded as a loop between local and modern architecture in this country. Here, in this period, the space experiences a new realm and offers a combination of two local and modern architectural styles. On the other hand, Isfahan has always been the cradle of architecture in Iran.

The study requires analyzing the unknown dimensions of Iranian architecture to better understand the essential forms of Qajar houses as the border between the world of traditions and the world of modernity in Iranian architecture and to use them in designing contemporary house architecture; the study also requires focusing on local houses as the main elements constituting historical neighborhoods for returning life to these historical sites and the significance of studies into historical houses because of their pace of destruction, and the necessity of recording them prior to destruction.

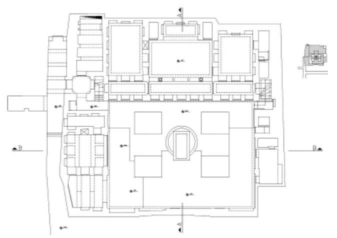
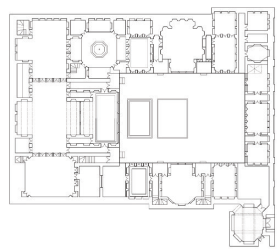
Table 1. Selected Houses and their Relevant Plans

House Names	Plans	House Names	Plans
Oftadeh		Toghr-olian	

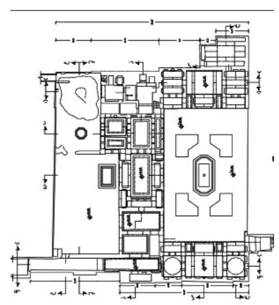
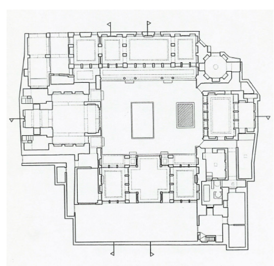
	Number of Main Frames in the Façade				Overall Symmetry on the Façade					Number of Main Frames in the Façade				Overall Symmetry on the Façade			
	Western	Eastern	Southern	Northern	Western	Eastern	Southern	Northern		Western	Eastern	Southern	Northern	Western	Eastern	Southern	Northern
	2	6	4	3	-	-	-	-		5	5	3	3	+	-	+	+

House Names	Plans	House Names	Plans
Jangjouyan		Kadk-hodaei	

	Number of Main Frames in the Façade				Overall Symmetry on the Façade					Number of Main Frames in the Façade				Overall Symmetry on the Façade			
	Western	Eastern	Southern	Northern	Western	Eastern	Southern	Northern		Western	Eastern	Southern	Northern	Western	Eastern	Southern	Northern
	2	3	5	4	-	-	-	-		7	6	7	5	+	+	+	+

House Names	Plans	House Names	Plans
Salek		Vasigh Ansari	

	Number of Main Frames in the Façade				Overall Symmetry on the Façade					Number of Main Frames in the Façade				Overall Symmetry on the Façade			
	Western	Eastern	Southern	Northern	Western	Eastern	Southern	Northern		Western	Eastern	Southern	Northern	Western	Eastern	Southern	Northern
	3	4	6	3	-	-	-	+		3	4	7	7	+	-	+	+

House Names	Plans	House Names	Plans
Sirfian		Hem-mat Yar	

	Number of Main Frames in the Façade				Overall Symmetry on the Façade					Number of Main Frames in the Façade				Overall Symmetry on the Façade			
	Western	Eastern	Southern	Northern	Western	Eastern	Southern	Northern		Western	Eastern	Southern	Northern	Western	Eastern	Southern	Northern
	7	-	5	5	-	-	+	+		3	3	5	3	+	+	+	+

4. FINDINGS

Based on the analyses of the spatial regularity and geometric patterns of the selected houses and comparisons of the four main facades with climatic ecological indicators, the following can be suggested. Symmetry in the plan is rarely seen in proportion designs and residential land separation, due to the diversity of land uses, the differences of dimensions and local patterns. However, space centrality relates to the middle space of the central courtyard, though with a greater difference, and the architect creates centrality to connect plurality with unity in the center of the space (Fig. 4). This subject is seen via the central organization of the spaces in all houses; for example, in the Jangjouyan House, the courtyard, compared to the cellar space, enjoys an integration ratio of 12.83 to 2.88 (Latifi and Diba 2020, 168).

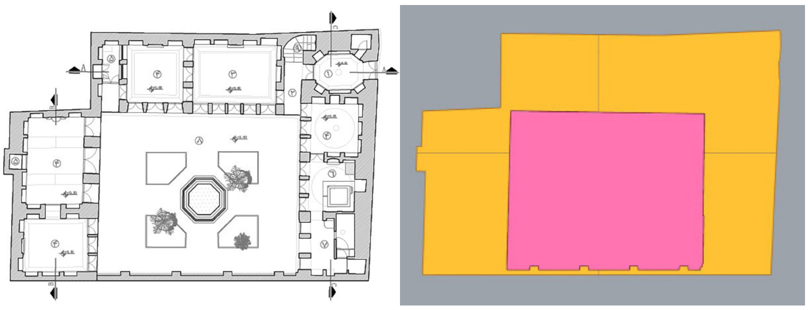


Fig. 4. Jangjouyan House's Plan (Geometry of Mass and Space in the Plan)

Although symmetry in the past architecture was indicative of the perfection value of the creation of works of arts and served as spatial regularity for architecture, the four facades of the local residences seldom followed general symmetry, as stated limitations highlighted symmetry in the components. For this, the concepts of equilibrium and harmony in residential spaces were examined (Fig. 5).

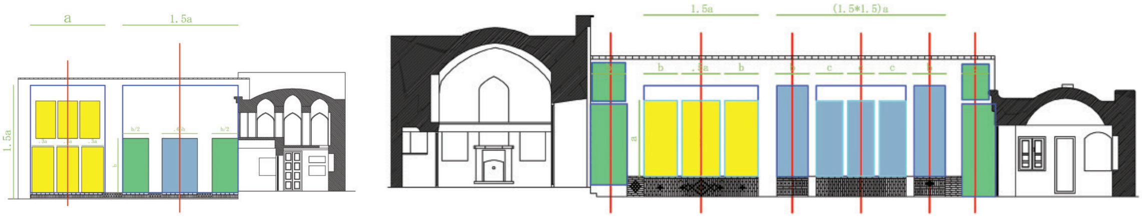


Fig. 5. Symmetry in Façade Components and using Similar Proportions in Jangjouyan House (from Right to Left: Northern Façade and Western Façade)

The designer has created a geometric space in the middle (the central courtyard) and used the quality of readability through the rational arrangement of the spaces and appropriate spatial communications to create a new relation between stable equilibrium within hidden layers, thus actively involving the user in a dynamic process of the mental concepts of the world and making him a part of this perceptual process (Fig. 6). Dividing the various fronts of the façade is a function of geometry and width-and-length dimensions, as there is no significant relation between the spans created on the various facades. For example, in the Jangjouyan House, the southern façade features 5 spans in the form of archways, and the northern, eastern and western facades feature 4, 3 and 2 spans each, respectably (Fig. 4). However, 75% of these facades are individually divided (Table 1).

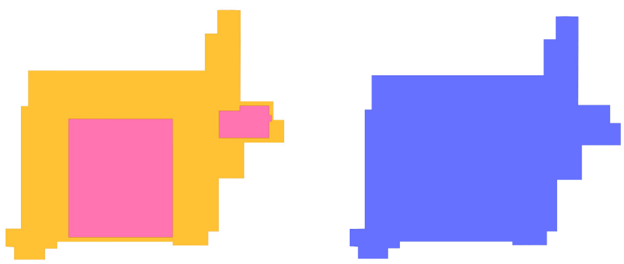


Fig. 6. Regular Geometry of the Courtyard Inside the Irregular Geometry of the Mass in the Kadkhodaei House

In the divisions of façade components, it is inevitable to see similar proportions in the space and the module, represented in the main Se-Dari (three-window) and Panj-Dari (five-window) spaces. For example, the western façade of the Jangjouyan House features two spans with Se-Dari spaces, while its northern façade features a Se-Dari and a Panj-Dari space (Fig. 5). Thus, using similar elements and modules can create coherent perception of the space, which forms a dynamic balance and pleasant, coherent, and an apparently symmetrical image in the mind of the viewer, despite the absence of full symmetry on the main facades. This symmetry was made out of the asymmetric plan and façade (Fig. 7). Meanwhile, despite the replacement of pure symmetry with equilibrium and harmony in most house facades, full symmetry can be added to courtyard bodies, also. For example, the Salek and Kadkhodaei Houses can be mentioned (Fig.s 8 and 9).

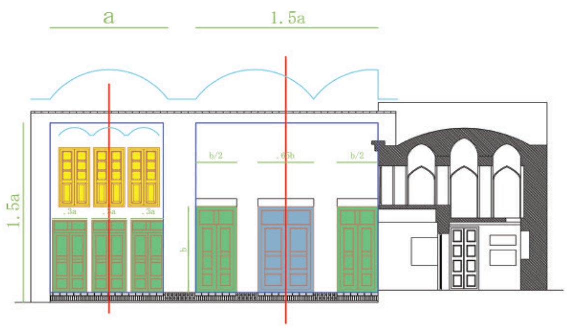


Fig. 7. Similar Elements and Module

The conformity of video-ecological indicators and facades under study can be interpreted as follows: The saccadic movement mechanism involves the use of light colors on the façade (Fig. 10), the employment of simple forms and the use of modules in different facades of sizes proportionate to human dimensions (Fig.s 8 and 9).

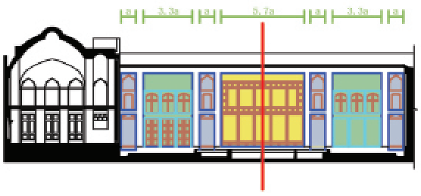


Fig. 8. Symmetry in Parts and in whole on the Eastern Façade of the Kadkhodaei House

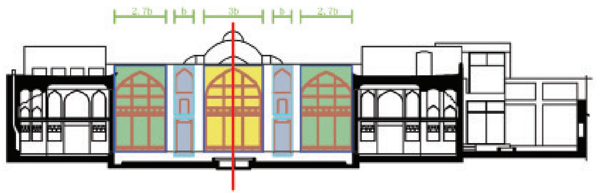


Fig. 9. Symmetry in Parts and in whole on the Northern Façade of the Kadkhodaei House

The off-on mechanism involves the framing and configuration of straight and curved lines (Fig.s 10 and 11), details on rooftop edges (Fig. 12), the differences of sizes, depth on the façade, the intensity of light and shading on various bodies (Fig.s 10 and 11), the different design of the four facades proportionate to each space and the difference in the size of the module (Fig. 5), focus on creating inflexion in space (Fig. 7), and focus on details in color, light and texture.

The binocular mechanism also involves the use of symmetry in the components of various facades, the creation of rhythm and repetition on the facades, diverse forms, materials, sizes, light, shade, and darkness, which appear to turn a kind of different perception into pleasant perception. Also, using natural materials (wood, stones, bricks, and plaster) reinforces the reflective function mechanism in perceiving facades. In the end, the spatial frequency mechanism can be noted in the details of façade component edges, including in farming, rooftop edges, window arches, etc. (Fig.s 10 and 11).

Fig. 10. Framing and Light Color

Fig. 11. Configuration of Straight and Curved Lines in the Window Arch of the House

Fig. 12. Creation of Depth and Intensity of Light and Shade in the House

5. CONCLUSION

Geometry is a body of knowledge used in designing works of art and architecture, and offers help into understanding world phenomena. One of the main reasons why geometry was used in the Islamic period was its ability in associating the religious nature of Islamic art. For scholars, it has been the only technique to express religious transcendence in art. Mathematics plays an essential role in Islamic architecture and Islamic decorative arts in a way that it is regarded as a holy science in Islamic worldview. In total, geometry has been a specific aspect of Iranian-Islamic art. One of the oldest features of spatial and formal regularity, which is created by employing geometry in architecture, is symmetry, which is senseless if used without relevant concepts as equilibrium, balance and proportions. Balance is blended with rhythm and proportions with scales.

As an outstanding feature of all natural rules, symmetry is a strategy recognized in the world as an engineering system in all works of art, especially local arts of various forms; symmetry is also known to leave considerable effects on the viewer's perception and experience of the space, as a spatial regularity or perfection. When it comes to element configurations, symmetry is not achieved without equilibrium; however, equilibrium is possible without symmetry.

In large spaces of public uses, including mosque, churches, schools, which require splendor and grandeur, it is evident to see symmetrical shapes in design. In residential spaces, however, less symmetry is seen due to asymmetric land and diverse forms of space and dimensions, as well as the need to avoid uniformity. For this, the designer employs a kind of dynamic structure in plan-organizing designs and volumes, which illustrates a major transformation in Iranian architecture and a confirmation of residential architectural values in the Qajar era that engage the user in perceiving the environment and meanings.

An example of architecture that is not intrinsically symmetrical but has its readability manifested symmetrically in the mind of the viewer, by directing the latter to the center of the space and creating a formal centrality using spatial regularity orientation and creating symmetrical units is an example of opposition between symmetry and asymmetry aimed at creating an attractive focal point that can serve as an equating agent. This role can be analyzed by locating the space and the way it relates to other spaces, so that an approach to modifying modern architecture and somehow modernizing local and original patterns of each culture and land can be achieved, which would thus help maintain their compatibility with the environment under local conditions.

For this, visual equilibrium measurements and video-ecology methods, corresponding to the natural mechanisms of the visual system, were used to analyze the studied facades. Findings indicated that in Islamic-Iranian architecture, there is a geometric system where if something lacks perfect symmetry-because there is no possibility of actions or reactions that would form a structure-the architect seeks to locate the space where it is expected to use similar elements and dimensions in various fronts and to observe symmetry in components to conform the building with exceptional site conditions. In this connection, the use of curved lines congruent with natural forms, proportionate details and natural textures on the façade, deemed more pleasant for the eye, make the space more desirable and somehow different.

In the end, analyzing the relationship between geometry and architectural design in historical works can greatly contribute to perceiving the geometric thinking governing the buildings and developing new domains in contemporary and future designs; this will certainly protect relevant cultural and identity backgrounds and add to the better quality of the space and the environment.

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CONFLICT OF INTEREST

The authors have no conflicts of interest to declare.

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