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AN EXPERT SYSTEM FOR THE DESIGN AND CLASSIFICATION OF ISLAMIC GEOMETRIC PATTERNS USING COMPUTER GRAPHICS

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ABSTRACT

Islamic geometric patterns (IGP) have often presented an enduring historic reverence to those who have strived to present a sensible classification of these structures. They are complex, beautiful structures, which combine elements of art, with elements of mathematics, especially relating to geometric patterns. This article proposes an innovative approach to classify and design IGP using computer aided technologies.

The researcher surveyed many existing methodologies regarding the classification of IGP like 7-frieze patterns, 17-wallpaper patterns theories and design approaches based on principles of classical gridding systems. The proposed methodology suggests a system which can design classification of a pattern (collection of unit patterns) and classification of a design (a collection of grids and geometric attributes). The Classification of a pattern consists of repeating the unit base pattern by isometric transformations (translation, mirroring, rotation and glide reflections) to generate a pattern that can be classified as 7-frieze patterns or the 17-wallpaper patterns. Classification of a design involves the normalization of the grids and geometries. In this paper, the researcher also presented an argument that those pattern theories are purely base models. The researcher has been successful in developing a new method of classification rightly validated by geometric and scientific analysis. The researcher succeeded in developing software that draws the grids of any IGP star/rosette design and displays its classification instantly.

So, the approach can be considered as a measurable method of classification for any given Islamic geometric design. The software is enabled to detect and classify the IGP star/rosette sub-motif grid from its gridding system of classification which will allow the user to explore and design the sub-motif pattern, motif pattern, unit pattern and finally the pattern in x-y direction.

Keywords:*IGP, Pattern Theories, Star/Rosette Classification and Design*

1. INTRODUCTION

A Geometric pattern is a kind of design or pattern formed of geometric shapes and typically repeating based on a set of rules. Geometric patterns are commonly associated with Islamic art, in which they have an iconic quality [1],[2]. The unique styles or patterns are the contributions made by Islamic mathematicians, astronomers, and other scientists, whose ideas and technical advances are indirectly reflected in the artistic approach. The circle became the foundation for Islamic patterns, in part because of the refinements made to the compass by Arabic astronomers and cartographers [3]. The basic geometric shapes like circles, squares, and straight lines are the basis of the geometric patterns. These basic elements are combined, duplicated, interlaced, or arranged in complex combinations to form different designs, or patterns.

Islamic artists adopted key elements of the classical artistic traditions, combined them with complicated and elaborate new patterns, to invent a new form of decoration that stressed the importance of unity and order in the resulting designs [4],[5].

The works of many mathematicians like Euclid and Pythagoras were among the earliest to be translated into Arabic. This is an excellent example of the thirst for knowledge among Arabic intellectuals, who studied geometry.

Motivated by the religious passion for abstraction and the related doctrine of unity, Al-tawhid, the Islamic intellectuals identified the significance of geometry as the unifying intercessor between the material life and the spiritual world. The remarkable intellectual contributions of Islamic mathematicians, astronomers, and scientists were essential for the creation of this unique style [6]. Researchers have often presented a long-standing historic astonishment for group geometric patterns like 7-frieze patterns [7],[8],[9] or 17-wallpaper patterns [10],[11]. This historic interest led us to a comprehensive analysis of the methodologies of existing classificationsystems as well as the work of other researchers [12],[13] get a detailed understanding of the academic works in this area.

The proposed article presents an argument that existing symmetrical classification methods like the 7-frieze patterns and the 17-wallpaper patterns are very base models for pattern classification and insufficient for the classification of Islamic geometric unit designs, in a wide sense [14]. The paper proposes a computer aided classification study and design based on the geometric features and the grids used for generating the IGP star/rosette.

2. LITERATURE REVIEW ON EXISTING PATTERN CLASSIFICATION AND DESIGN

2.1 Pattern Classification Systems

One of the popular types of pattern classification is based on the 7-frieze patterns [15]. A frieze pattern is defined as the mathematical concept to classify 2D designs which are repetitive in one direction, based on the pattern symmetry. Thus, A frieze pattern is a pattern that has symmetry in horizontal direction. A sample of frieze patter is shown in Figure 1, these are commonly seen patterns in architecture and decorative art. There are seven different frieze pattern groups based on the type of symmetry of the patterns.

The symmetry can be according to a translation, $(x,y) \rightarrow (n+x,y)$, optionally followed by a reflection in either the horizontal axis, $(x,y) \rightarrow (x,-y)$, or the vertical axis, $(x,y) \rightarrow (-x,y)$, provided that this axis is chosen through or midway between two dots, or a rotation by 180°, $(x,y) \rightarrow (-x,-y)$. The different possible symmetry scenarios are shown in Figures 2.1-2.7.

Figure 1: A Sample Frieze Pattern

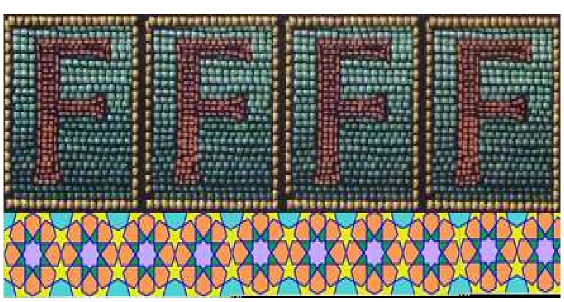

Figure 2.1: Frieze Translation

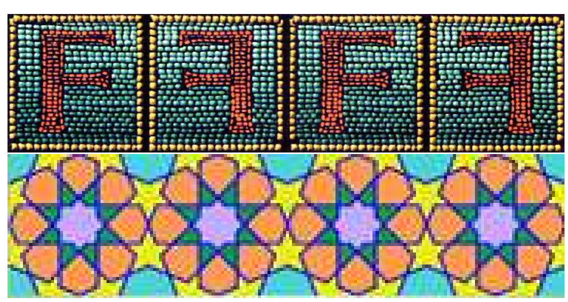

Figure 2.2: Frieze Vertical Reflection

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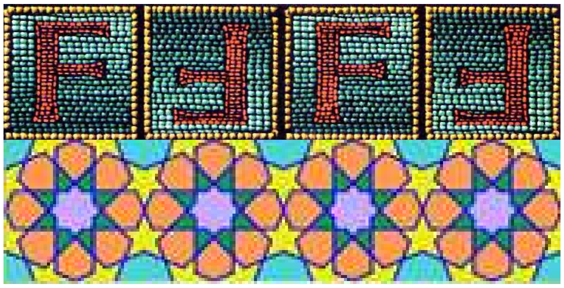

Figure 2.3: Frieze Corner Rotation

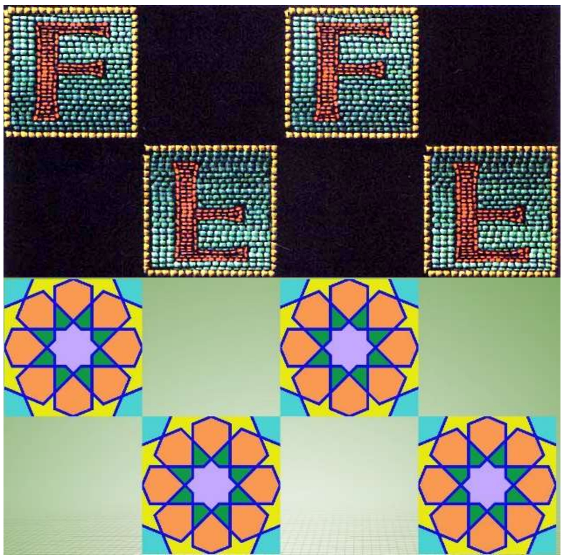

Figure 2.4: Frieze Glide Reflection

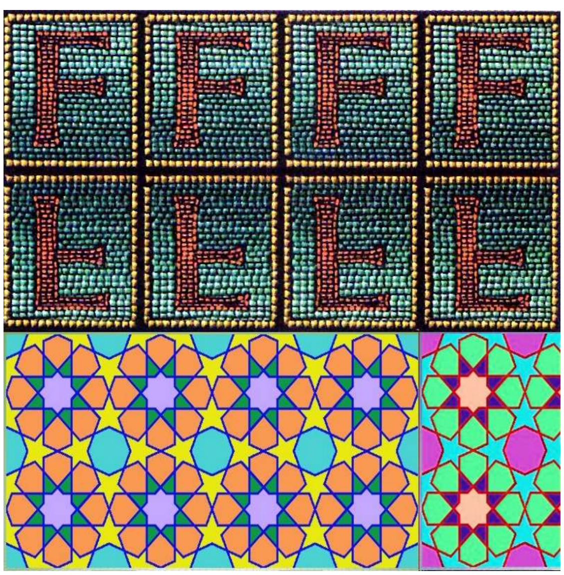

Figure 2.5: Frieze Horizontal Reflection

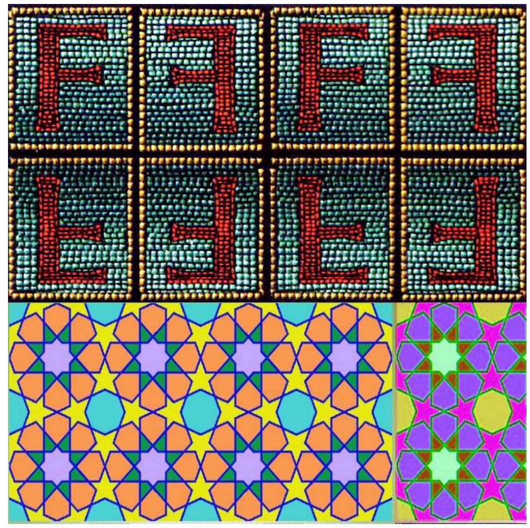

Figure 2.6: Frieze Rotation and Glide Reflection

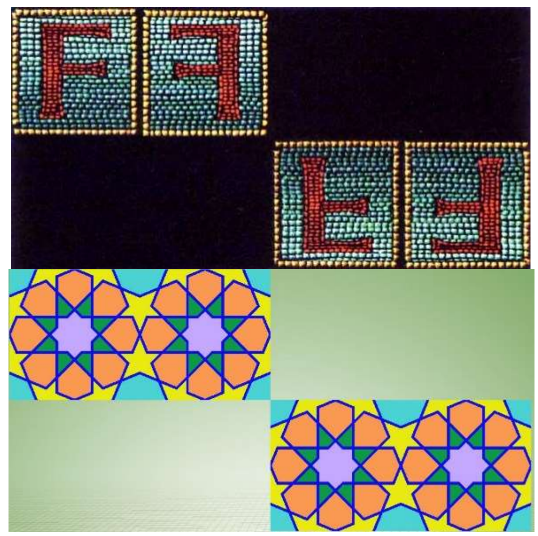

Figure 2.7: frieze Horizontal Reflection and Corner Rotation

The other conventional type of pattern classification is based on the 17-wallpaper pattern groups [16].It is a mathematical model-based classification of a 2D repetitive pattern, based on the symmetries in the pattern.

Arthur Cayley (1821-1895) and James Sylvester (1814-1897) were the earliest mathematicians to write about these groups. They gave the idea that the sets of transformations can be used to classify geometric patterns. In 1872, Felix Klein classified geometries by using these definitions. George Pólya in 1924 was the first one to prove that there were only 17 possible patternsare shown in Figures 3.1-3.17.Each wallpaper tiling is labelled with the standard names used by the International Union of Crystallography (IUC).

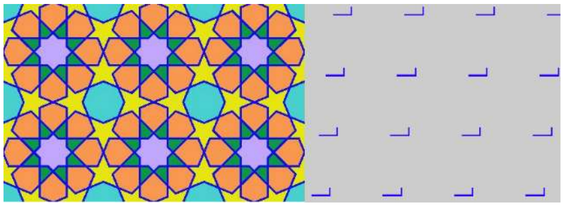

Figure 3.1: Wallpaper p1

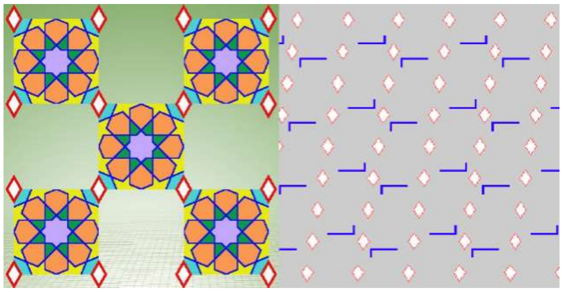

Figure 3.2: Wallpaper p2

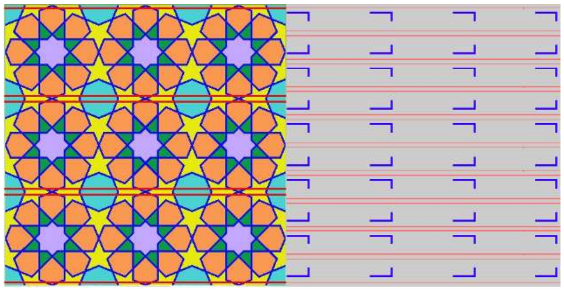

Figure 3.3: Wallpaper pm

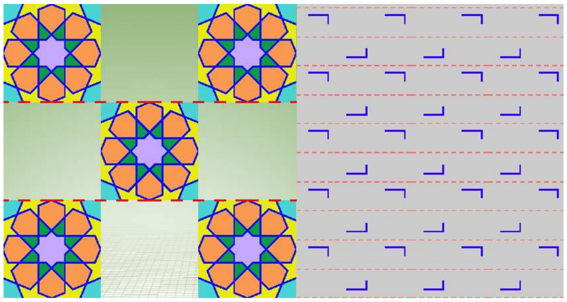

Figure 3.4: Wallpaper pg

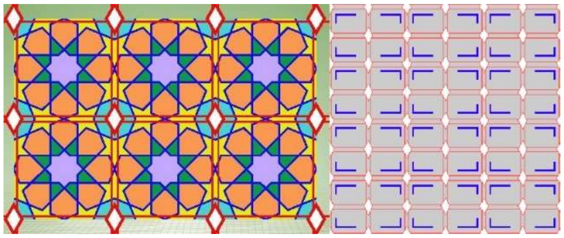

Figure 3.5: Wallpaper pmm

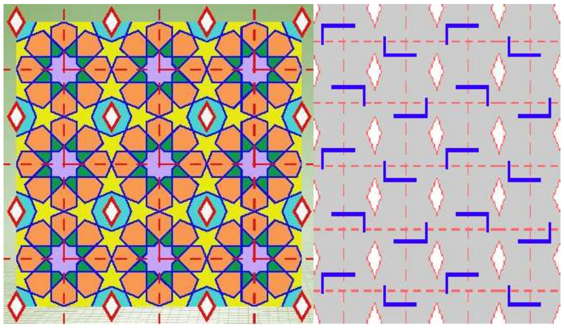

Figure 3.6: Wallpaper pgg

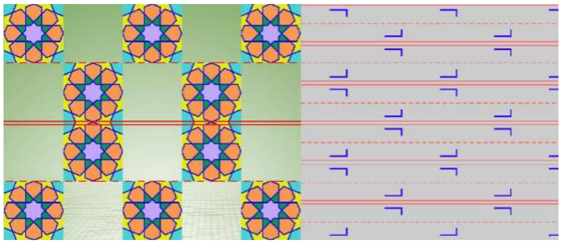

Figure 3.7: Wallpaper cm

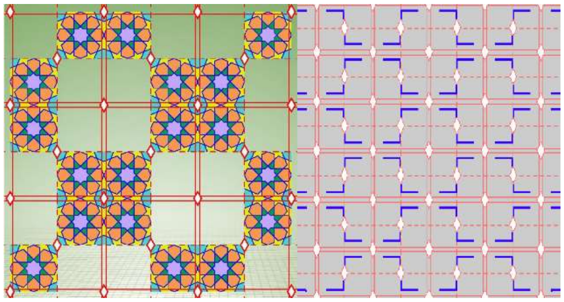

Figure 3.8: Wallpaper cmm

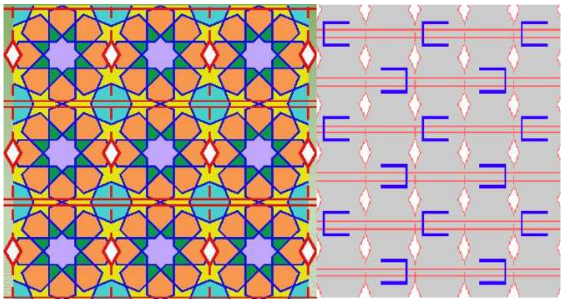

Figure 3.9: Wallpaper pmg

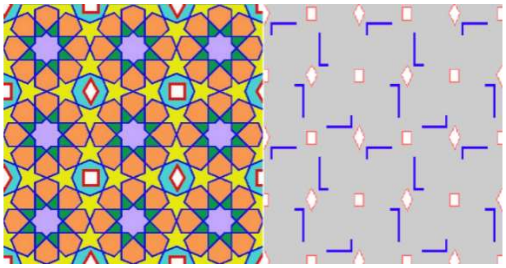

Figure 3.10: Wallpaper p4

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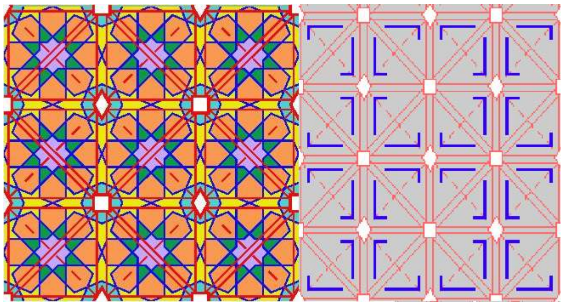

Figure 3.11: Wallpaper p4m

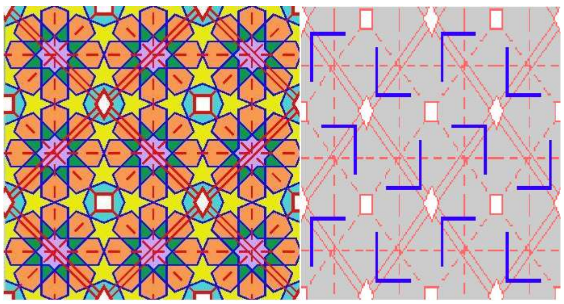

Figure 3.12: Wallpaper p4g

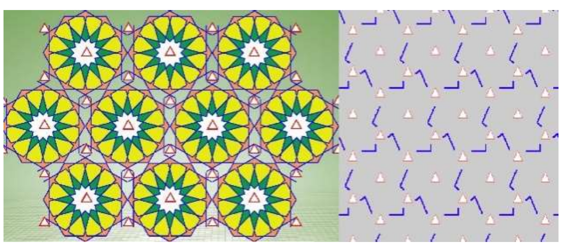

Figure 3.13: Wallpaper p3

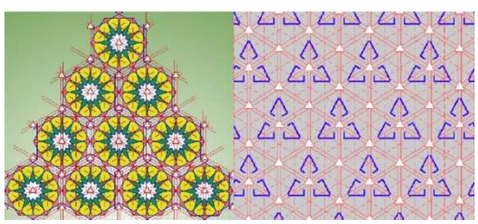

Figure 3.14: Wallpaper p3m

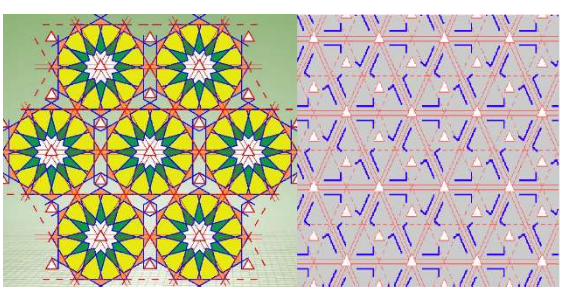

Figure 3.15: Wallpaper p3lm

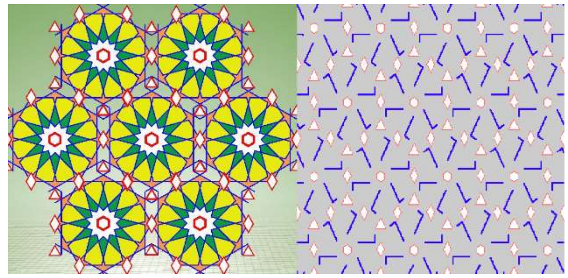

Figure 3.16: Wallpaper p6

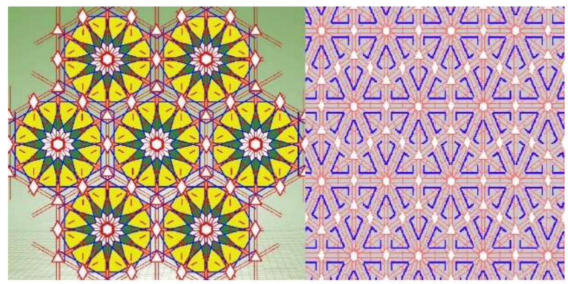

Figure 3.17: Wallpaper p6m

The wallpaper pattern theories present arrangement of patterns as the benchmarks, which enable us to decide the type of pattern used to organize the design rather than classifying the unit pattern. In Figures 2.1-2.7 and 3.1-3.17, the failure cases that the 7-frieze pattern and the 17-wallpaper patterns theories misdirecting the classification of IGP are demonstrated.

2.2 Pattern Designing Schemes

Several design methodologies were proposed by researchers [17],[18],[19] to create IGP. The former concepts of design practices comprise of square grid, intersecting parallel lines, dots, and overlapping grid, dual, connecting midpoints of sides, compatible shapes, dissecting shapes, star polygons, ruler/compass and numerical designs.

3. PROPOSED METHOD FOR COMPUTER AIDED AUTOMATIC PATTERN CLASSIFICATION AND DESIGNING

In this paper we modify the normalisation methodology we settled earlier [20] which was based on the concept of sub-motif grid and design of the unit pattern. The software that we developed for the classification of IGP also provides a platform for drawing the sub-motif grid of the pattern. Once the design in the sub-motif completed, by using rotation and reflection the software generates the unique pattern design of IGP.

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The main objectives of this work are to propose anew classification methodology and to develop a designing tool for developing IGP using computer software based on the grid system used to generate a unique pattern. Conventional classification and naming system [19] for IGP designs are on basis of their visual appearance and shapes such as pentagonal, hexagonal, heptagonal, octagonal etc. However, this classification is too general and often misleading. Hence, instead of looking at IGP designs in terms of star/rosettes naming, it is proposed to classify them based on their gridding attributes and geometrical features. According to grid-based classification [17], a deconstruction and normalization is applied to the unit patterns of star/rosette. Normalisation, which is a process of reducing to a norm or standard, canbe done bydetecting individual geometries and grids that make up the unit designs of Islamic geometric art. Figures 4.1-4.4 and Figure 5 are demonstrating the process of division of the circle, drawing the geometry and the gridding scheme. The classification is named after the gridding gets finished.

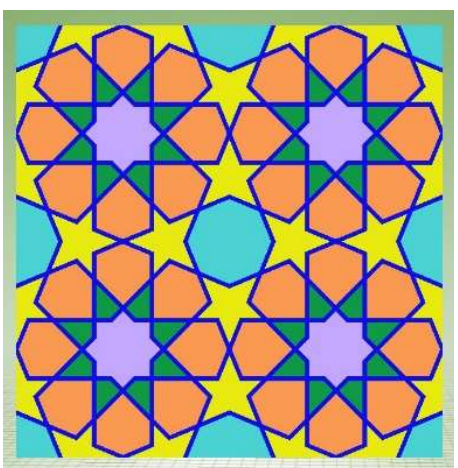

Figure 4.1: Identifying The Pattern

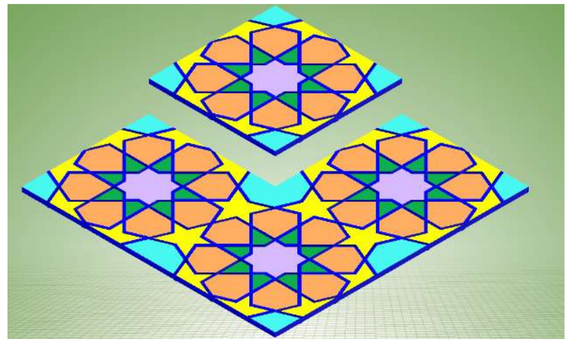

Figure 4-2: Identifying The Unit Pattern

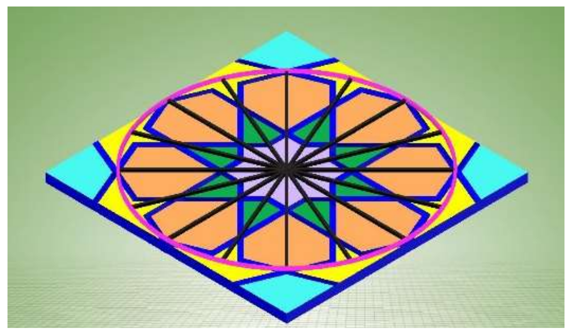

Figure 4-3: Identifying The Unit Pattern Division

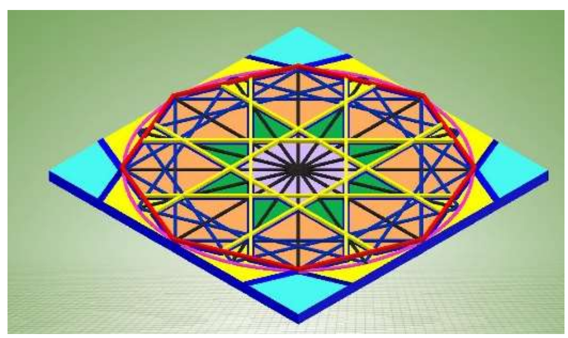

Figure 4-4: Identifying The Unit Pattern Grid System

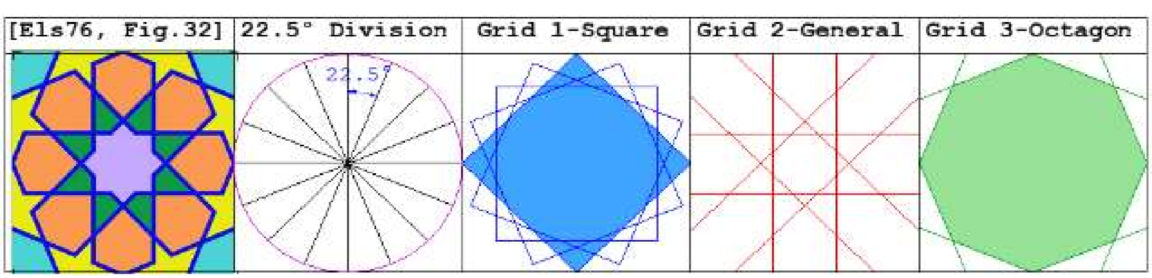

Figure 5: (22.5°3Q) ClassTriple Grid Quadrilateral

The proposed computer aided system for classification and reconstruction of the gridding system includes the following stages:

(i) The Circle Division Selection Stage
(ii) The Geometry Grid Selection Stage
(iii) The Frame Selection Stage
(iv) The General Grid Selection Stage
(v) The Classification Stage
(vi) The Grid Extension Stage
(vii) The Sub-Motive Selection Stage
(viii) The Design Stage
(ix) The Pattern Stage

3.1 The Circle Division Selection Stage

By using classification menu of the software GUI, the circle division stage can be initiated by opting the radius of the circle (R) which directs the placement of grids within the parameters of the size as shown in figure 6. In the same menu thecircle can be divided into (x) number of cones (arcs) based on the star/rosette design [21],[22]. As in the example figure, the circle has been divided by 16 points to obtain the angle of design as 22.5°. Automatically the classification software window displays the value of the angle on the screen as in Figure 6. This angle value is the 1st part of our proposed naming convention for classification. In the same menu user can also select the unit of measurement, pen size and pen color.

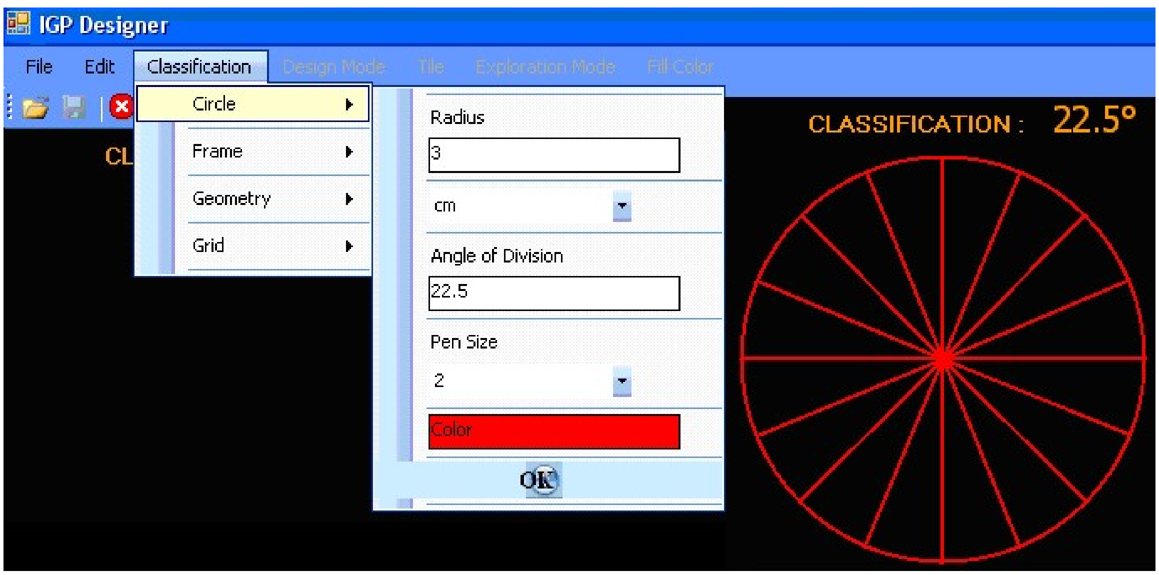

Figure 6: The Circle Division Selection Stage

3.2 The Geometry Grid Selection Stage

In the classification menu the user can chose the n-number and geometric style (triangular, quadrilateral, pentagonal or heptagonal) to design the gridding system of suitable star/rosette. In the example, we are selecting 4 squares from the quadrilateral menu inscribed in the circle drawn at equidistant points as shown in Figure 7. In addition to this, we are selecting an octagon as in Figure 8. At the same time the classification software window displays the type of geometry selected as in Figure 8. The display of the geometry on the screen is the second part of our naming classification system. In the same menu user can also select the pen size and the pen colour. In the naming convention of classification used in this system, the logic has been adopted to normalise the types of geometries used into their norms. In the above said example, the design choses four squares and one octagon. When Octagon is normalised it creates two squares. Therefore, the software classifies the naming convention as quadrilateral. Likewise, when triangles or their multiples of geometry are used, the proposed system will normalise the geometry into triangular classification.

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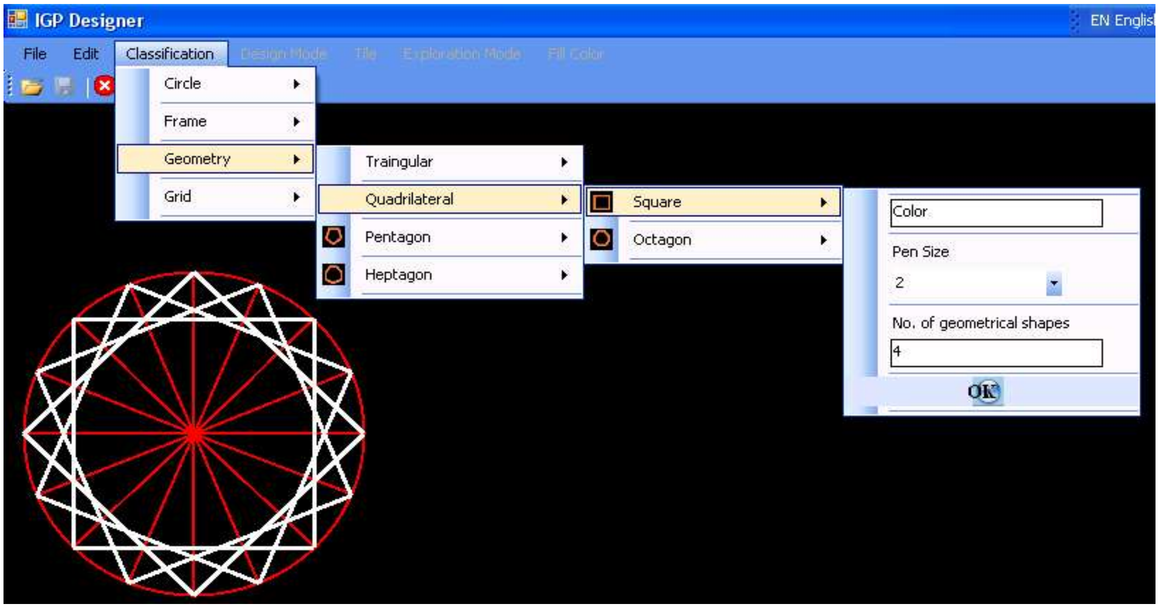

Figure 7: The Geometry Grid Selection Stage

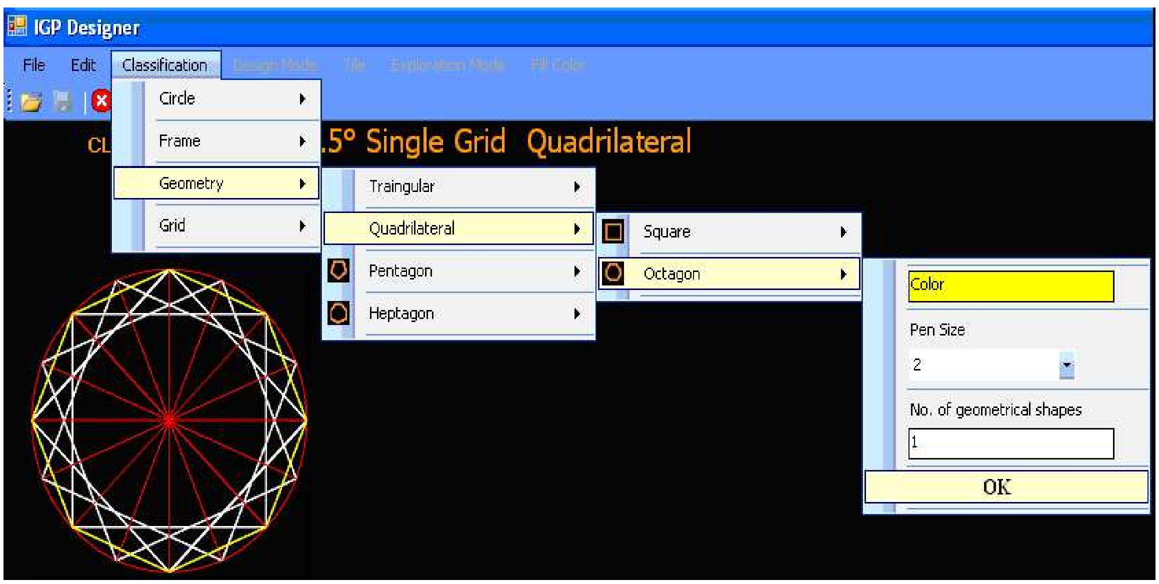

Figure 8: Octagon Geometry Selection

3.3 The Frame Selection Stage

In the classification menu, user can circumscribe the circle with a frame (external boundary) as in Figure 9. External boundaries such as a square or a rectangle are regarded as crucial in some designs. The external boundaries are associated with extended lines of grids and geometric units. The external boundaries are phantom to the star/rosette design and its presence cannot be always confirmed until and unless the existence of external mesh can be traced.

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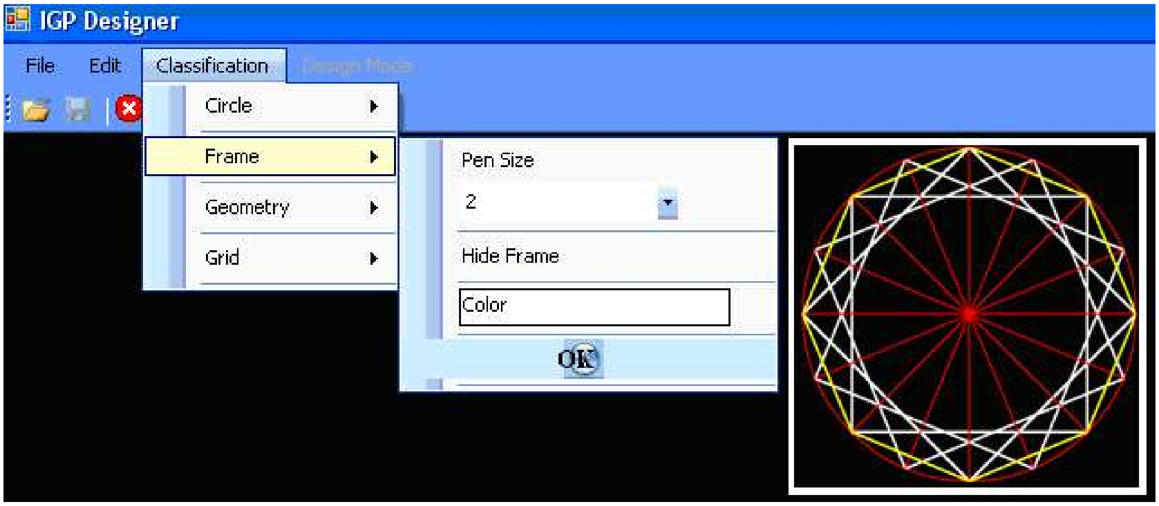

Figure 9: Drawing A Square Circumscribing TheCircle

3.4 The General Grid Selection

In the classification menu user have the provision to build array of grids as in Figure 10. After finishing each grid must click *Finish* button for the software to store a count and details of total grids. When the griding stage is finalized, by clicking the *Classify* button the software will classify the grid design accordingly. The number of grids on the screen appeared is taken for the 3rd part of ournaming classification system. In the same menu user can chose the pen size and the pen color. In addition to the grids, in certain unit-pattern thegrid lines areneeded to be extended to accommodate the design.

3.5 The Grid Extension Stage

The extension module has been included in the software where the required grid lines extended to border the notational boundary (the frame). The extended lines of grids and geometric features would generate intersection points to accomplish the seamless mesh in the external zone within the notational boundary as shown in Figure 10.

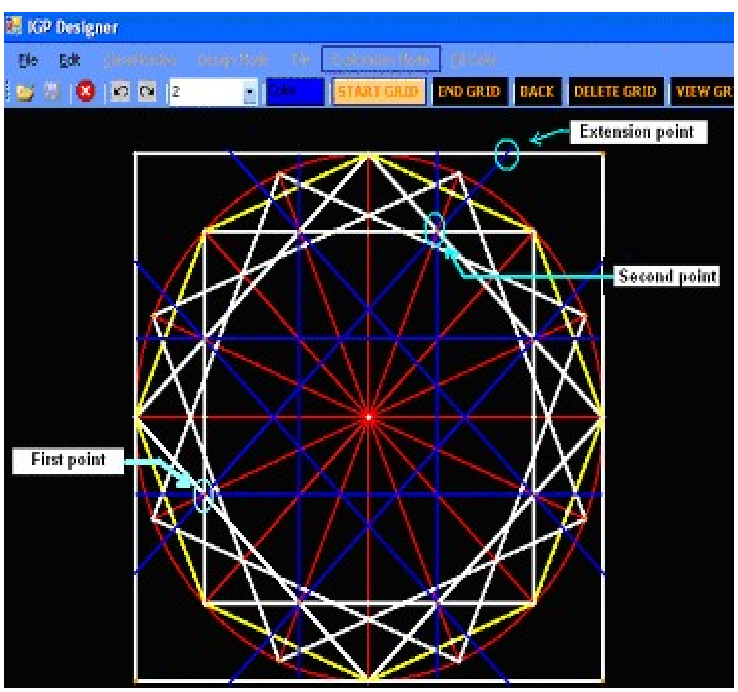

Figure 10: Extending The Grid Lines

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3.6 The Classification Stage

This is the final stage of classification where the structural system of the star/rosette is ready for designing purpose. The classification process is then completed and is shown on the screen as in Figure 11as 22.5° Triple Grid Quadrilateral (22.5° 3Q). Here (22.5°) represents the angle of sub-motif. '3' denotes the number of grids used for the design development and (Q) denotes the geometrical type, here it is Quadrilateral.

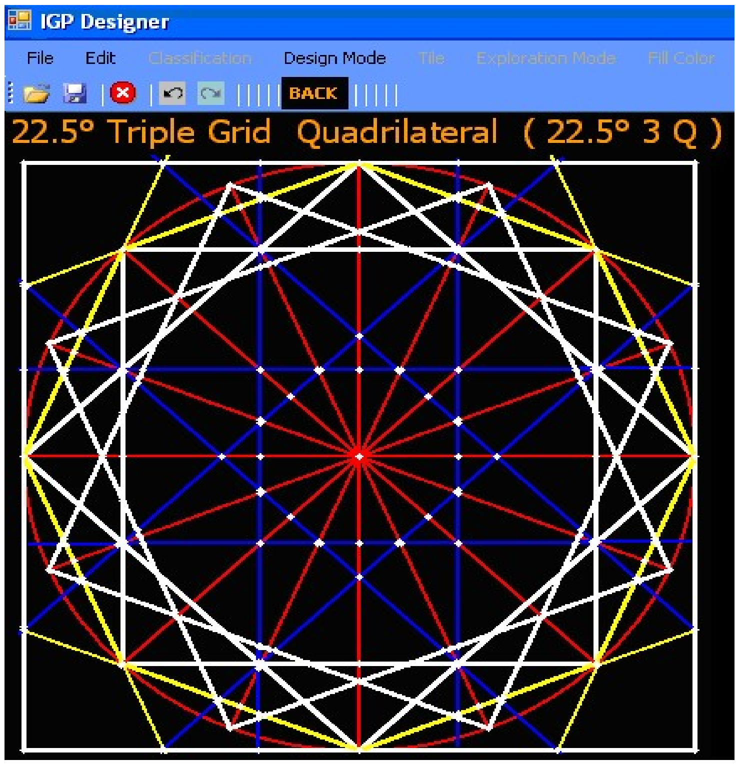

Figure 11: The Final Classification

3.7 The Sub-Motif Selection Stage, the Design Stage & the Pattern Stage

The sub-motif selection stage triggers the designing process and eventually the pattern development. The main objective of this phase is to select the sub-motif. This is carried out automatically by the software by recognizing the angle of division of the circle as the angle of the design and cuts the design grid view into the *Sub-Motif.* The angle can be altered to *Motif* or even *Full-Patter* as per the user's requirement. In the sub-motif designstage, the user can either Repeat & Rotate or *Mirroring & Rotate* and other parameters as in Figure 12. Finally, the user will get the *Full Pattern* in x-y direction as in Figure 13.

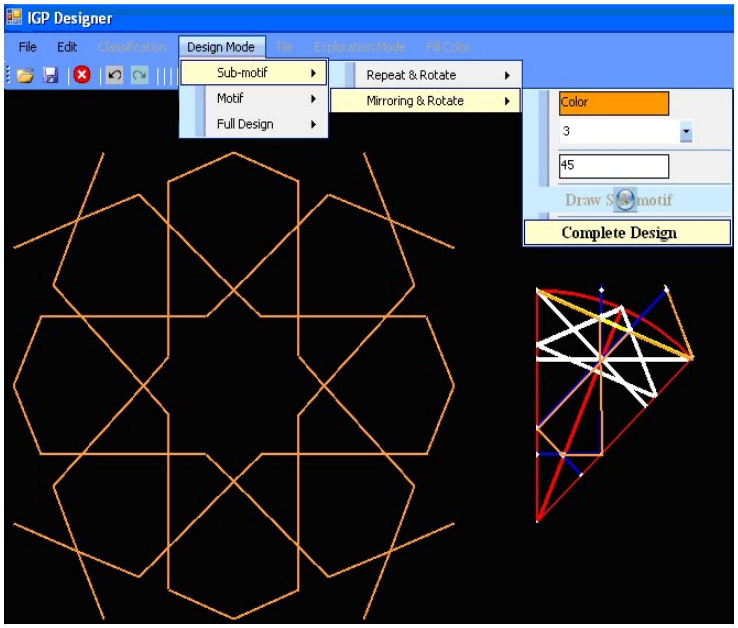

Figure 12: Unit Design Generation FromThe Motif

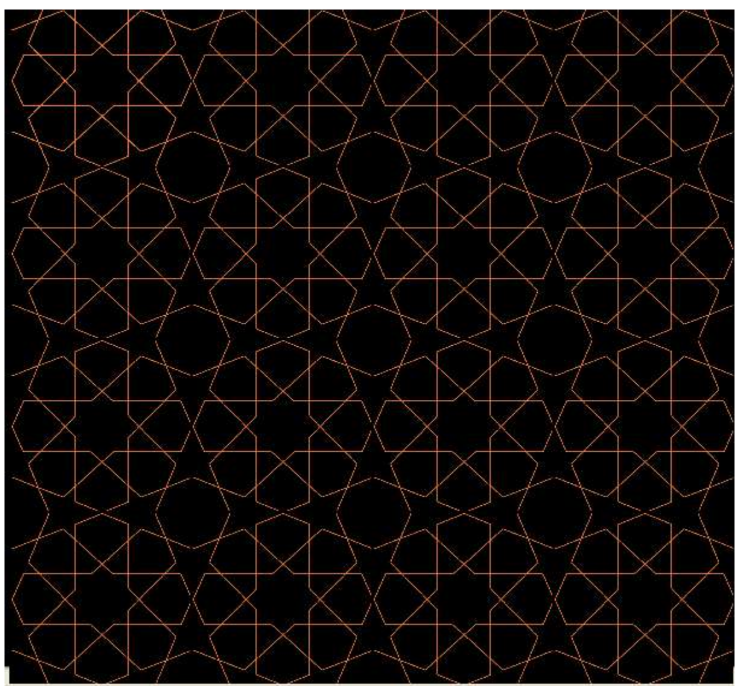

Figure 13: The FinalPatternDesign

4. CONCLUSION

Islamic geometric patterns have long been classified based on many pattern theories. However, the available pattern theories are not sufficient to classify the IGP based on its unit pattern but are classified on basis of their arrangements and not based on the designs. 17-wallpaper patterns theories and design approaches based on principles of conventional gridding systems often gives wrong classification results over IGP. This article stated the problem with a clear objective of classifying the IGP based on their gridding and geometric features which will helps to classify any star/rosette with much effectively. The classification gives the information such as angle of design, type of geometry and

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number of grids used in achieving the proper designing of IGP. On the design part we found that IGP have led to several significant design approaches that advocate the *Grids*, the *Design* and *Exploration* in different ways. The basic principles of all these design practices vary depend on the experiences and disposition of their proponents. We have also proposed and developed a new design strategy in addition to the effective classification using the grid methodology which can be used to design IGPs based on the sub-motif grid. The author developed a computer software program with a user-friendly GUI using C# in .NET platform. The software enables its users to create IGP from the scratch in stages and arrive at its classification with easy steps. The program will be an efficient tool in analyzing IGP for designers, architects,mathematicians and researchers working in related areas.

5. REFERENCES

[1]Loai M. Dabbour, Geometric proportions: The underlying structure of design process for Islamic geometric patterns, Frontiers of Architectural Research, Volume 1, Issue 4, 2012, Pages 380-391, ISSN 2095-2635

[2] Carol Bier., “Geometry in Islamic Art”, Encyclopaedia of the History of Science, Technology, and Medicine in Non-Western Cultures, pp 2048-2065, 2016

[3] Yahya Abdullahi, Mohamed Rashid Bin Embi, Evolution of Islamic geometric patterns, Frontiers of Architectural Research, Volume 2, Issue 2, 2013, Pages 243-251, ISSN 2095-2635

[4] El-Said Issam: Islamic Art and Architecture: The System of Geometric Design: Grant Publishing Limited, U.K. (1993): ISBN 1-873938-45-5

[5] AlpayÖzdural, Mathematics and Arts: Connections between Theory and Practice in the Medieval Islamic World, Historia Mathematica, Volume 27, Issue 2, 2000, Pages 171-201, ISSN 0315-0860

[6] Yvonne, Dold-Samplonius, The Volume of Domes in Arabic Mathematics, in Vestiga Mathematica: Studies in Medieval and Early Modern Mathematics in Honor of H. L. L. Busard, ed. Menso, Folkerts and Jan, P. Hogendijk, Amsterdam, Rodopi, 1993, pp. 93–106.

[7] Pepin Press, Arabian Geometric, published March 16th, 2011, ISBN 9057681560 (ISBN13: 9789057681561)

[8] Eric Broug, Islamic Geometric Design, Thames & Hudson USA 1st Edition, Oct 21, 2013, ISBN-13: 978-0500516959 ISBN-10: 0500516952

[9] M. Cuntz, Frieze patterns as root posets and affine triangulations, European Journal of Combinatorics, Volume 42, 2014, Pages 167-178, ISSN 0195-6698,

[10] Yanxi Liu, R. T. Collins and Y. Tsin, "A computational model for periodic pattern perception based on frieze and wallpaper groups," in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 26, no. 3, pp. 354-371, March 2004.

[11] Yanxi Liu and R. T. Collins, "Skewed symmetry groups," Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition. CVPR 2001, 2001, pp. I-872-I-879 vol.1.

[12] Zahra Sayed, Hassan Ugail, Ian Palmer, Jon Purdy, Carlton Reeve.: “Auto-Parameterized Shape Grammar for Constructing Islamic Geometric Motif-Based Structures”. Transactions on Computational Science XXVIII Volume 9590 of the series Lecture Notes in Computer Science, pp 146-162, 2016

[13] Peter Saltzman, “Quasi-Periodicity in Islamic Geometric Design”. Pp. 153–168 in Nexus VII: Architecture and Mathematics, Kim Williams, ed. Turin: Kim Williams Books, 2008

[14] Glassner Andrew: Andrew Glassner’s Notebook: Recreational Computer Graphics Morgan Kaufmann Publishers, San Francisco, CA. U.S.A. (1999)

[15] Lee X.: The 17 Wallpaper Groups: (1998) http://www.xahlee.org/Wallpaper_dir/c5_17WallpaperGroups.html

[16] Ahmad M. Aljamali, Ebad Banissi.: “Grid Method Classification of Islamic Geometric Patterns” Geometric Modeling: Techniques, Applications, Systems and Toolspp 233-254

[17] Rahim M.I.C., Ibrahim M., Daud M.Z., Anuar N.S.M.: “The Development of Islamic Geometric Pattern in Jewellery Product Design”. In: Contemporary Issues and Development in the Global Halal Industry. Springer, Singapore

[18] M. Ahadian and A. Bastanfard, "Classification of Islamic Geometric Pattern Images Using Zernike Moments," 2011 Eighth International Conference Computer Graphics, Imaging and Visualization, Singapore, 2011, pp. 19-24.

[19] Aljamali A. and Banissi E.: Normalisation and Exploration Design Method of Islamic

Geometric Patterns: London, U.K.: Published by the IEEE Computer Society, pages: 42-48 (2003): ISBN 0-7695-1985-7

[20] Abdelbar Nasria, Rachid Benslimanea, Aziza El Ouaazizib., "Geometric rosette patterns analysis and generation". Journal of Cultural Heritage, Volume 25, May–June 2017, Pages 65–74.

[21] Loai M. Dabbour, Geometric proportions: The underlying structure of design process for Islamic geometric patterns, Frontiers of Architectural Research, Volume 1, Issue 4, 2012, Pages 380-391, ISSN 2095-2635

[22] Jay Bonner, Islamic Geometric Patterns: Their Historical Development and Traditional Methods of Construction, Aug 19, 2017, 1st ed. 2017 Edition, ISBN-13: 978-1441902160, ISBN-10: 1441902163