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The Generating Process of Elementary Unit of Mosulian Ornaments Using Artificial Intelligence (AI)

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Abstract

The architecture of Mosul is rich in elements, and its history goes back thousands of years. Mosul ornamentation is one such element with a heritage value. This study aims to determine the algorithm for forming the smallest unit in the design of heritage ornaments of Mosul and use it in artificial intelligence programs to create new forms that are related to heritage. The study also aims to determine the elements of Mosul ornamentation and their formal design characteristics preserve these elements. The adopted approach in this study is qualitative–experimental, which is implemented through the use of the method of observation and visual analysis. The design characteristics are determined and input into special software to generate new ornaments after selecting samples of heritage houses in the old city of Mosul based on various determinants, including originality, importance, and availability. Results show that the harmonic diversity of the elements and characteristics of Mosul ornaments reflects the unity, diversity, and skill of Mosul artists. Therefore, new and innovative ornaments can be preserved and generated by using the patterns of Mosul ornamentation through a program based on a special algorithm.

Discipline: Architecture Engineering, Artificial Intelligence.

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1 Introduction

Ornaments exert different effects on the recipient, thus achieving the purpose of their use. The purpose may be aesthetic, symbolic, or others. Researchers (Ezdeşir and Şah 2020) have reported that ornaments are affected by various factors, including social, religious, nature of the available materials, and climatic conditions. In addition to these factors, political factors also

influence ornaments; an example is an influence of Indian Buddhist art on certain regions in China and the reciprocal effects on Western countries (Guixiang 2016; Xu, Huang, and Dewancker 2020). The old city of Mosul is rich in ornamental elements that are influenced by various factors, and this is reflected in the ornamental composition, forming one of the aspects of expressing the identity of the city. Among the Mosul ornaments that reached the world's museums are metal ornaments; for example, the Jug of Shujaa' Bin Man'a Al-Mousuli, which is preserved in a British museum, bears various ornaments that include calligraphy, animals, and humans (Al-Nu'aimi 2020; Mohammed 2017). This ancient area is located on the western side of Tigris River in Mosul and extends to the archaeological wall on the other side in a semi-oval form (Al-Juma'a 2020). Mosul City has been subjected to events that led to great destruction and the loss or exposure to the great damage of many of the city's heritage monuments (UNESCO 2018). The use of different materials and implementation methods has also affected heritage ornaments, in addition to the lack of studies that deal with Mosul ornaments to determine their characteristics and preserve them through technological means to achieve the continuity of heritage in a manner that expresses the zeitgeist. Various methods have emerged recently, and through them, items that are identical to or derived from the original ones can be produced. These methods vary in complexity, requirements (inputs), and results (outputs), but in their entirety, they provide high possibilities to deal with and preserve heritage elements and create a wide space for creativity and innovation while ensuring the continuity of heritage architecture and the connection with the original, which enhance the identity of the place. Thus, the following research questions are posited. How can new models of Mosul ornaments that fit the zeitgeist and are linked to heritage be produced? What are the stages or the proper algorithm for forming new ornamental patterns that are associated with heritage ornaments? What are the elements and formal design characteristics of Mosul ornamentation?

2 Literature Review

Previous related studies are presented through analytical studies (documentary and description of Mosul ornaments) and studies of the structural aspect of ornamental elements and methods of producing new models.

For Mosul ornamentation, researchers (Al-Juma'a 2020; Al-Obaidi and Sharif 2019; Talee and Sharif 2021) have mentioned that Mosul ornaments include geometric ornaments whose elements consist of geometric shapes, such as straight and broken lines, rectangles, stars, and polygons; an example is an ornament on the southern side of the minaret hall of Al-Nuri Mosque (Rasheed and Hussein 2017), which has botanical ornaments, the most prominent of which are palm leaves and rosettes that include chamomile flowers. An example of botanical ornaments is the mihrab arch of Mujahidi Mosque, as shown in Figure (1-B), and written ornaments about either Quranic or poetic verses or wisdom passages and proverbs (Hashim 2008). Some of the script types used are Kufic, Thuluth, Syriac, and the line script of the Bible. An example of written ornamentation is the window of Imam Ibrahim Mosque presented in Figure (1-A). The researcher (Hashim 2008) added another type of ornamentation, namely, animal ornaments, such as the use of

abstract shapes of birds and fish. In addition to these types are metal ornaments, which have different shapes, such as S, heart and spiral (Taha and Abdulqader 2020). Al-Obaidi and Sharif (2019) indicated that Mosul architecture is rarely devoid of the use of ornamental elements, and in cases where there are no ornaments, alabaster frames are used (Engineering Construction Office 1982).

A B C

Figure 1: Models of Mosul ornaments.
(Source: Al-Juma'a 2020; Rasheed and Hussein 2017).

With regard to the method of formation, Mosul ornaments are of various styles, some of which are central, spatial, striped, or framed around the architectural elements (Khudair 2017; Rasheed and Hussein 2017) and single or double (Al-Abbo 2015). For metal ornaments, the formation method is either linear, matrix, central, or radial (Taha and Abdulqader 2020). The design characteristics of the ornaments include the design rules and principles that are used to form the ornament. The principles used in Mosul ornamentation are sequence and alternation (Al-Abbo 2015; Rasheed and Hussein 2017); the principle of repetition as in the mat ornamentation in the first range of the minaret body of Al-Nuri Mosque 25 (Al-Abbo 2015; Khudair 2017; Rasheed and Hussein 2017); the principles of dynamism and continuity (infinite extension or bifurcation) (Al-Abbo 2015; Khudair 2017; Rasheed and Hussein 2017); the principles of facing and symmetry (Al-Abbo 2015; Al-Juma'a 2020; Khudair 2017; Rasheed and Hussein 2017); and the principles of rhythm (Al-Abbo 2015; Al-Juma'a 2020), balance, unity, and diversity (Al-Abbo 2015; Khudair 2017). The principle of repetition is associated with other principles because it is considered one of the essential principles (Taha and Abdulqader 2020). The design characteristics also include the formal relationships that are associated with elements, through which new forms can be obtained to create different ornaments. One or more of these relationships may be used in the ornamental composition (Hussein 2018), and these relationships in Mosul ornaments are represented by overlap (Al-Abbo 2015; Al-Juma'a 2020; Khudair 2017; Rasheed and Hussein 2017), intersection (Al-Abbo 2015; Al-Juma'a 2020; Khudair 2017), convergence (Rasheed and Hussein 2017), contact (Al-Abbo 2015; Rasheed and Hussein 2017), and juxtaposition (Al-Abbo 2015). The structure of Mosul ornaments is generally governed by geometric shapes that may be in the shape of nets, such as triangular, square, or polygonal nets (Al-Abbo 2015), or in the shape of geometric borders (Rasheed & Hussein, 2017). The general structure of the metal ornaments used in balustrades,

windows, and other places is a rectangle, circle, parallelogram, and arch (Taha and Abdulqader 2020).

With regard to the stage of installation, researchers (Rahman and Kaushik 2019) have established the shape grammar method to analyze ornaments and understand the historical patterns through shape and rule components to extract the design language through which new or identical models can be produced (Cenani and Cagdas 2006). Among the programmatic methods used to generate ornaments are the use of AutoLisp (Al-Hafiz and Abdulqader 2010) or mathematical modeling (Zahri 2019), parametric modeling, Matlab language (Zhang et al. 2020), and artificial intelligence programs, such as rhino and grasshopper (Mutaz, Khalid, and Kamoona 2021). In the study of Yao and Peng (2020), new models of ornaments were produced using the shape grammar method after analyzing the heritage ornaments. Different models were obtained by determining the initial shape, deduction rules, and sequence of rules to be applied to the initial shape; changing the sequence of applying the rules; or changing the initial shape.

2.1 Summary of Previous Studies

The summarized results of previous studies are:

- The elements of Mosul ornamentation are either lines or geometric shapes (e.g., square, triangle, circle, polygon, and stars), botanical shapes (e.g., flowers, leaves, twigs, and fruits), and written letters or abstract shapes of animals. The forms of metal ornamentation are S, heart, or spiral.
- The design principles of Mosul ornamentation are symmetry, repetition, rhythm, balance, continuity, bifurcation, sequence, alternation, unity, and diversity.
- The method of forming Mosul ornaments is either central, stripe, frame, spatial, single, double, matrix, radial, or linear.
- The relationships among the elements of Mosul ornamentation are overlap, juxtaposition, contact, and intersection.
- The structure of the installation is either geometric borders(e.g., lines) or in the form of a rectangle, square, circle, arc, and others. It could also be in the form of a net of shapes, such as triangular, polygonal, and circular nets.

From the foregoing text, we conclude that Mosul ornaments may consist of geometric, botanical, or letter shapes, or the overlapping of these shapes together to form integrated ornamental patterns. These ornaments are governed by a set of rules and relationships within a general synthetic structure, and through these components, the same ornaments or new models of them can be produced and associated with the original by using the rules of shape.

3 Research Design

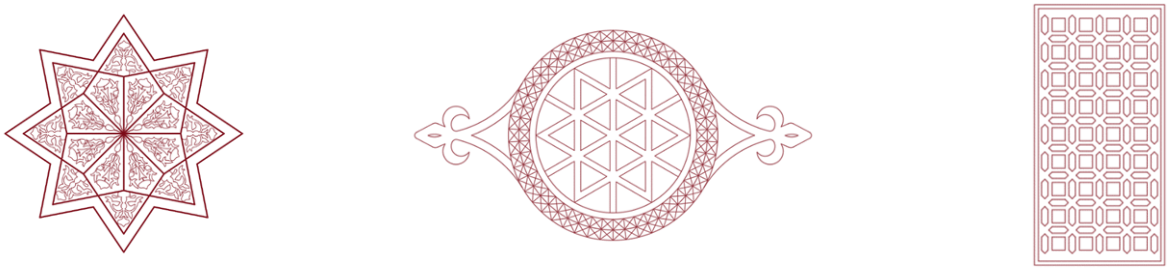
A special methodology was designed in this study to achieve the research objectives associated with the research problem. The research design relied on qualitative and experimental methodologies, as illustrated in Figure 2. It consisted of three parts: (1) designing the measurement

tools; (2) collecting information through observation, field survey, access to literature related to Mosul ornaments, and documentation; and (3) extensive observation of the information available on social media sites. Then, samples of Mosul ornaments were selected based on the following criteria: availability of heritage ornaments; availability of information, documentation, and data about the samples; and authenticity and importance of the ornaments. Then, the Mosul ornaments were analyzed by visual observation, and the structure of the shape was evaluated to extract the design rules, relationships among the elements, and formal characteristics of the ornament by using AutoCAD software. The analysis results were utilized to establish an algorithm for generating ornamentation and new models by using the special software designed for the research.

Figure 2: Methodology for generating new ornaments related to the original

3.1 Practical Study

The research samples were represented by ornaments selected from heritage houses in the old area of Mosul. They were selected depending on the availability of heritage ornaments and the availability of information and data about the sample documented by the Iraqi Heritage Department while ensuring the authenticity and importance of the ornaments. An ornament was selected from Ziada House, and two ornaments were from Al-Tutunchi House (Figure 3).



HA-1 HB-1 HB-2

Figure 3: Research samples: HA-1 from Ziada House, HB-1 and HB-2 from Al-Tutunchi House, and researchers' drawing.

4 Results Analysis and Discussion

4.1 Analysis of the Ornament (HB-1)

Figure 4 shows the ornament HB-1.

- Ornament Location: Al-Qataneen market area / Al-Tutunchi House / western Iwan – first floor.
- The material used: marble (Mosul Faresh)

Figure 4: Shape structure analysis of samples of ornaments from Al-Tutunchi House

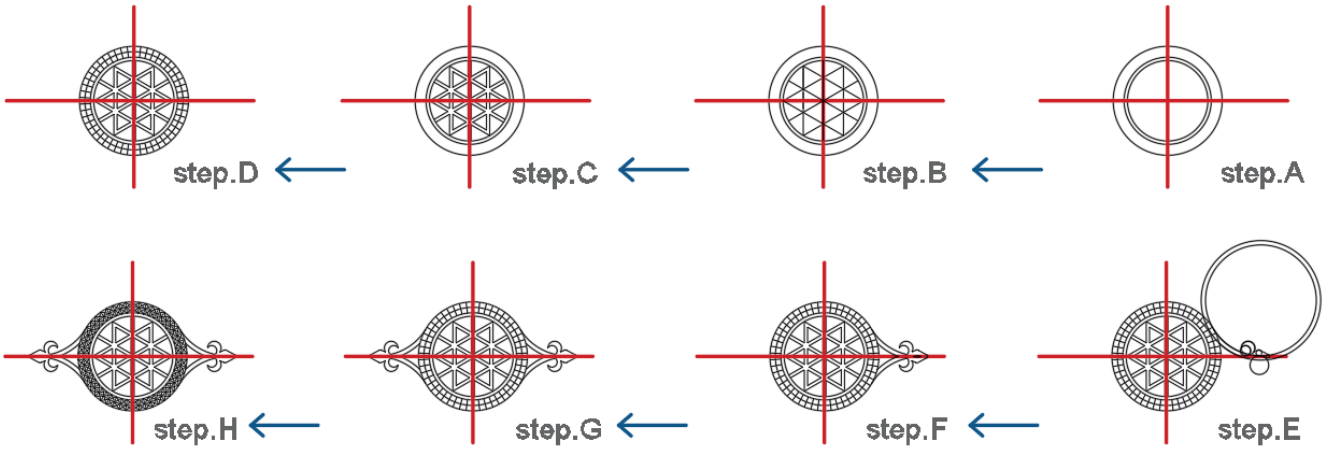


Figure 5: Formal analysis of sample HB-1 to determine the order of the ornament

By analyzing the steps of forming the ornament (Figure 5), the following points were derived:

- The ornament consists of four elements (circle, triangle, lines, and leaves) or five elements (circle, six-pointed star, hexagon in the middle, vertical and diagonal lines, and leaves).
- The style followed in forming the ornamentation is the central style. All of the elements are organized around the center point, but at the level of the whole formation, they are positional-double on both sides of the Iwan arch.
- The composition structure of the ornament at the total level is a rectangle, and at the parts level, it is a geometric shape-circle and organic shape-leaf.

4.1.1 Analyzing the Principles of Ornament Formation

Figure 6 shows the analysis of the principles of ornament formation. The design principles used in forming the ornament are

- Principle of repetition. The types of repetition are repetition on a circular path, repetition around the center, repetition with a change in direction, repetition with a change in scale, and repetition with the reflection around the center.
- Principle of symmetry. The types of symmetry are absolute symmetry (which means that the whole shape is symmetrical without any change in either shape or scale), half symmetry (which means that the shape completes the other), and symmetry with a reflection around the X and Y axes.

- The principle of balance and consistency in the proportions of shapes, unity, and diversity

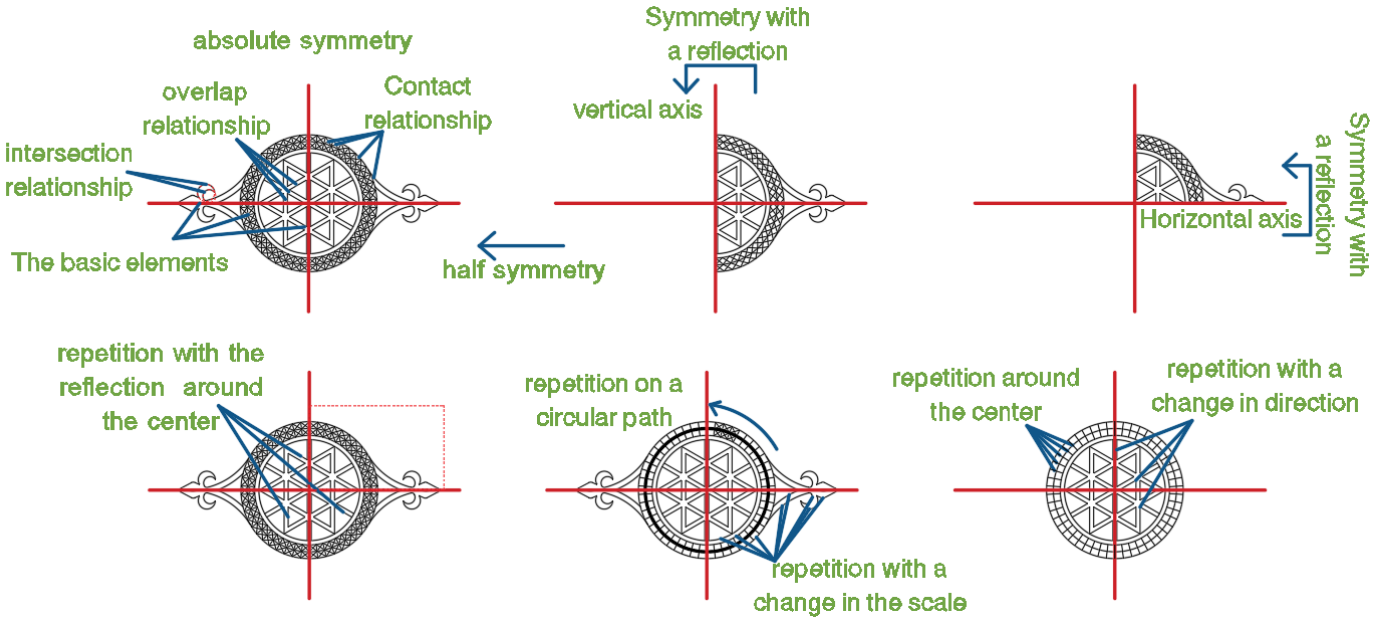


Figure 6: Design principle of sample HB-1 and steps of ornament formulation

The relationships among the elements of ornamentation are contact relationship among the ornamental elements surrounding the shape, intersection relationship among the circular shapes to form the leaf, and overlap relationship between the linear elements and triangle shape.

4.2 The Experimental Work

An algorithm was established to form different models of the small unit of ornamentation depending on the analytic results by determining the basic elements of the ornamentation and the number of shapes that form the small unit in the ornament. The process is shown in Figure 7. It may consist of two, three, or four shapes that overlap with each other to form the unit, as indicated in Figure 8.

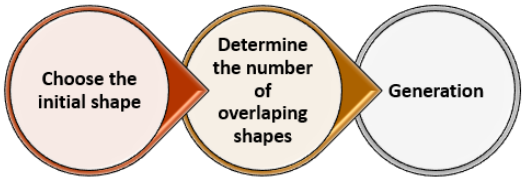


Figure 7: Process of generating ornaments using AI

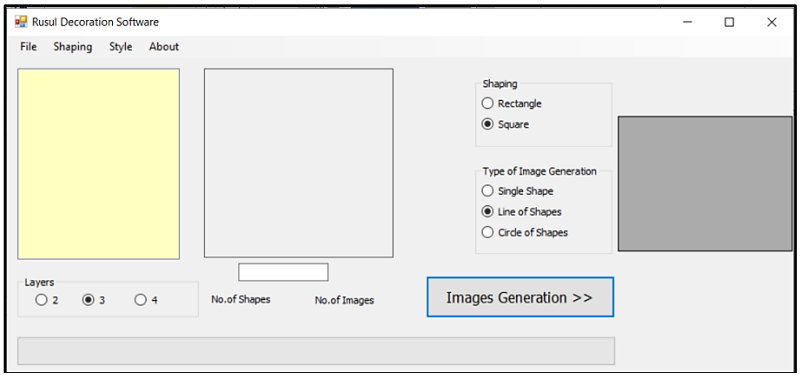


Figure 8: The main window of the developed software to generate new ornaments based on the heritage ornaments' rules

4.2.1 Results of Practical Application and Discussion

The symbols used in setting the algorithm are as follows:

R1-1: choose shapes

R1-2: choose layer 2

R1-3: choose layer 3

R1-4: choose layer 4

R1-5: Generation

The first case involves a change in the scale of the shapes extracted from the analysis and the stability of the angles. The rule (R1-1) is to select the essential shapes used to generate the new models of the elementary units of the ornaments, as illustrated in Figure 9.

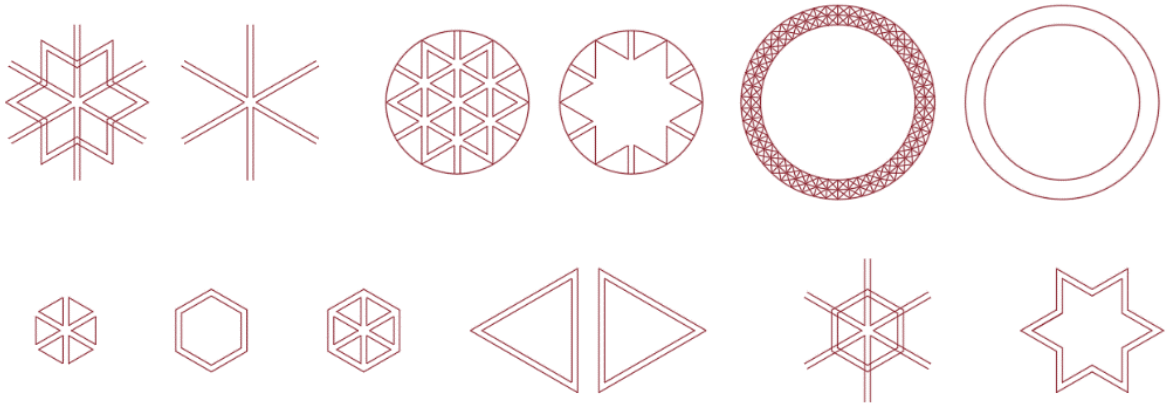


Figure 9: The essential shapes extracted from the analysis (data set)

The second step is to use the elementary units produced in the first step to generate new models connected to the original, as shown in Figure 10. As presented in Figure 11, the results of the process showed that the new models had similar design characteristics and geometrical principles as the original sample but with the increased complexity of the inner intersections and relations.

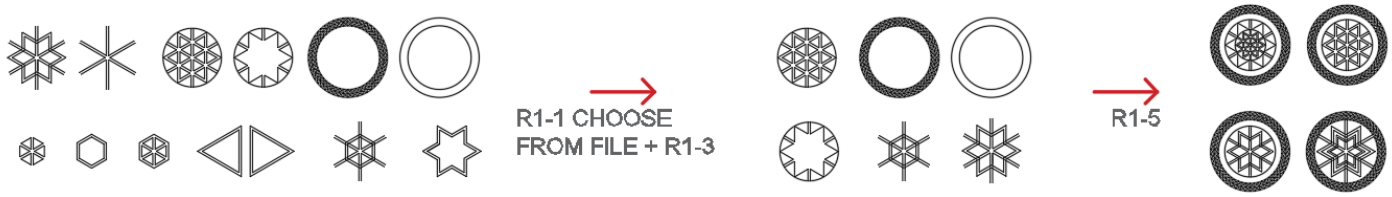


Figure 10: Three Algorithmic steps for generating ornaments

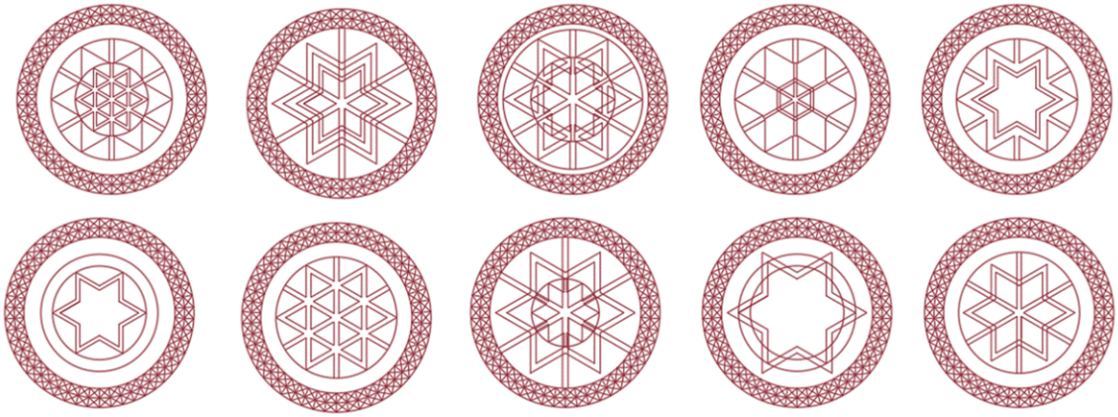


Figure 11: Set of new ornament models

The second case involves the stability of shape scales that were extracted from the analysis with the change in angles (Figure 13). As indicated in Figure 12, fixing the scale rule produced new models that matched the original sample with reduced complexity but were more connected than the first sample (multiple scales). The essential shapes of the two samples had a major similarity (Figures 10 and 12) in contrast with the new modes, as shown in Figures 11 and 13.

Figure 12: Algorithmic process of generating a new model from case 2.

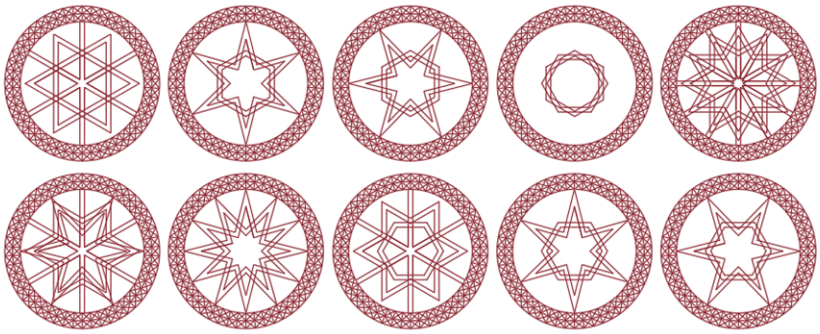


Figure 13: Set of new ornament models generated with fixing the scale rule.

The results of generating new models of Mosulian ornaments matched the original ornaments in overall shape, but in detail, they had more complexity in using the rules and principles of design. The first stage of the generation produced elementary units that can be used in the rebuilding or redesign of Mosulian buildings, in which ornament is considered an effective element to represent the identity of the style. However, the selection of essential shapes has a role in generating new models, where the designer is the main actor to nominate the related shape with the origin. Moreover, the rules R1-1, R1-2, and R1-3 are necessary for the process, so essential shapes (data set) must be prepared following the analysis study of the original ornaments. The rule R1-5 is a result of the process of the previous stage. The two cases of generating an ornament followed the same generation steps. However, the use of the multi-scale rule produced a complex elementary unit, which could create complexity in the final stage if the designer decides to use the elementary unit to create a pattern.

5 Conclusion

The study dealt with defining the components of Mosul ornamentation by reviewing previous studies and conducting visual and formal analyses of a sample of heritage ornaments to achieve the goal of the research in setting the steps or the algorithm for forming small units and generating new models. The study concluded that Mosul ornaments have various elements and properties, including geometric, botanical, epigraphic, and animal ornaments that overlap with each other, thereby forming integrated ornamental patterns that are linked by relationships of overlap, juxtaposition, intersection, and contact. They are based on design principles, the most

important of which are repetition and symmetry, and their structure is governed by either geometric or organic shapes. New and various models of ornamental units were generated using these components through a program based on a special algorithm by following the method of shape rules and using the basic elements of ornamentation as primary shapes and the overlap among the elements according to different possibilities depending on the results of the analysis.

The research recommends developing an algorithm by taking advantage of the analysis results, generating integrated and innovative ornamental models of Mosul, analyzing a group of Mosul ornaments, and establishing classifications that contribute to the development of the algorithm. The adopted approach could be beneficial in generating ornaments of different cultures.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

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