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Generation of Ceiling Rose Patterns by Shape Grammar Approaches in Safranbolu Traditional Houses

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Abstract: This study aims to examine the ornament parts of the traditional ceilings, one of the essential elements of the space with physical and psychological aspects, in terms of design methods and approaches. In this study, the ceilings of the houses have been discussed in the Safranbolu region, which was chosen as the study area. Star-formed ceiling rose ornament, which is one of the indispensable components of these elements and is widely used in these houses, has been evaluated by shape grammar implementations that are commonly both generative and analytic tools for assessing design languages. By determining generation rules, a design process has been defined. With these rules, by using samples of present ceiling ornaments, variations have been generated in the frame of different scenarios. The richness and innovative sustainability of Star-formed ceiling rose ornament are demonstrated by the proposal of an analytic and generative approach based on inferences from traditional implementations. This study makes contributions to the literature by offering an alternative process to imitations and iterations of traditional architectural components and by enriching the design language of the craft implementations

Keywords: Shape grammar, Ceiling ornaments, Ceiling rose, Crafting, Traditional Safranbolu Houses.

1.Introduction

Ceilings are one of the most critical environmental components which have existed by the thought of space belonging to Turkish houses tradition in Anatolia. A ceiling as a top cover in a room design has been defined as a complementary of a bottom cover which has been formed by the functions needed in daily life. While the bottom cover is a space in which daily functions are realized practically, the top cover is conversely an abstracted product of ancient tradition (Küçükerman, 1973) (Figure 1).

It is seen that ceilings vary in different houses and other rooms of the same house. Ceilings have been designed in different ways and with aesthetic concerns according to the degree of importance of the room (headroom, kiosk room) in house, master's skill, owner's wishes, and economic power. In the main room, which is the largest room of traditional Turkish houses where the guests are accepted, adornment design is more intense than in the other rooms. Generally, the care and elaborative craftsmanship for the headroom has not been naturally shown for small spaces

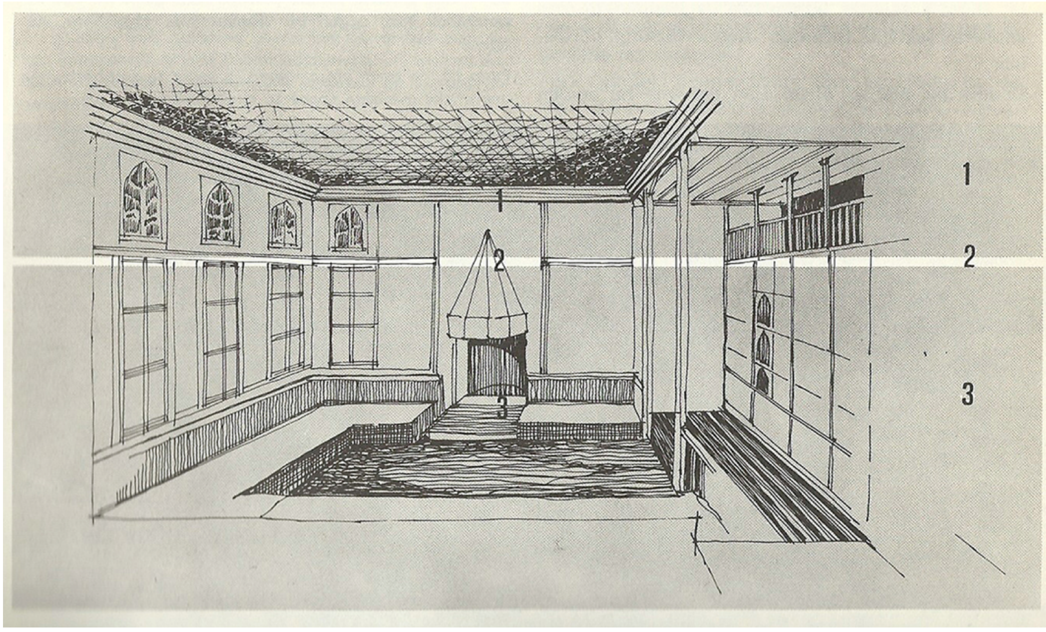

Figure 1: *The abstracted top environment (1); The limit of functional space (2); and functional space (3) (Küçükerman, 1973).*

, and the ceiling designs in these rooms have been made in a simpler way.

Turkish craftsmen have designed the ceilings, which are important in interior space, compatible style with the other components of the space like wall ornamentation, windows, and oven, and harmony with building characteristics. It has been tried to find a balance between the used and calculated motifs for each ceiling ornament. Besides the ornaments ordered by geometric repetitions, various birds, animal, flower motifs, and handcrafted carvings occur in the ceiling ornaments. While the edge-ornament elements are used at their edges, the ceilings are enriched by the ornament elements called a rose in its center (Erbüyür, 2003). In-ceiling

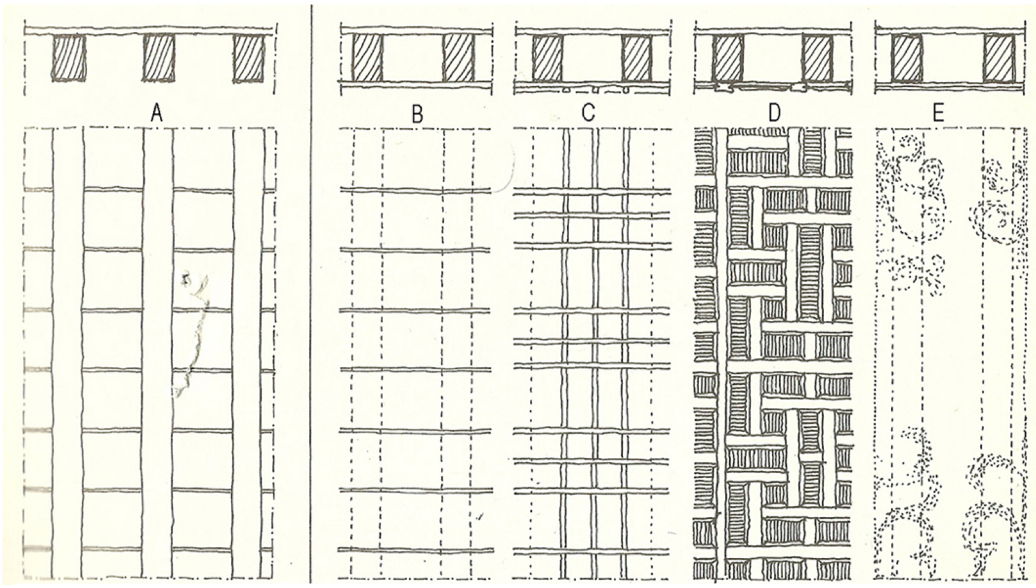

Figure 2: *Application methods in-ceiling coverings: A) uncovering, B) Flat covering, C) Slatted covering, D) Tongued covering, and E) Painted covering (Küçükerman, 1973)*

ornaments, while the woods are preferred as a primary material, the materials like gypsum, chine, fabric, madder are also evaluated (İşler and Aras, 2013). One of the fields where wooden ornament art has been used intensively, the ceiling, has increased the aesthetic value of the space through both material and construction techniques. With wood crafting, unique samples have been created in, especially ceilings. In terms of the application techniques, Küçükerman and Güner (1995) sorted formation of ceiling claddings from simple to complex as uncovering, flat covering, slatted covering, tongued covering, and painted covering (Figure 2). Among them, slatted and tongued ceiling implementations are remarkable. Various slats form the covering under the ceiling beams in slatted ceiling implementations. It presents amenities and has become common due to opportunities for obtaining different variations by various solutions of slats. In tongued ceiling implementations, the bottom face of ceiling beams is covered by small wooden parts that are combined with tongue-and-groove joints in different types.

In the literature, the sections related to ceilings take place in the studies in the title of the traditional Turkish house. However, in these studies, the general characteristics of the traditional Turkish house are mentioned regionally. Among the studies based on only ceilings, the ceiling application techniques and the ornament style are generally explained (Aras et al. 2005; İşler and Aras, 2013; Yüksel and Yaz, 2016; İnce Gayberi and Neslihan, 2021). Thereby, there is no study on the generation of variations of the ceiling ornaments. However, the mathematical background, complex patterns, and repetitions of Islamic patterns, which have an intensive influence on artistic elements after Turks' conversion into Islam, have attracted the attention of researchers. When the ceiling ornaments are also examined, it is possible to see the presence of similar characteristics. So, it is worth analyzing ornament samples applied on these surfaces and generating variations that lead to more unique models instead of imitations.

A sustainable future requires the continuity of any valuable socio-cultural heritage. A basic criterion of sustainability is the preservation of the traditional character (İsmailoğlu and Sipahi, 2021). Ensuring the sustainability of the handicrafts that existed in the past is one of them. Today, new technologies have replaced craftsmen (Hofverberg et al. 2017). With these new technologies, thanks to the applications made for centuries, geometric patterns that develop and take their source from a deep geometry knowledge and skill can be converted into a mathematical form and coded more easily and quickly. It also provides important opportunities for the development of new variations by examining existing geometric patterns. In particular, the use of contemporary techniques has an important place in understanding the geometric logics of the existing cultural heritage and transferring them to the future (Refalian et al., 2021). For this reason, the sustainability of crafts depends on their openness to innovation and similarly, it is a need to use technology for the continuity of ceiling decorations.

It is important to comprehend and develop the formal language which belongs to these patterns, whose intense similar repetitions and unconscious applications we encountered. Today, the commonly used digital design tools have contributed to analyzing and developing these patterns and increased craftsmens' vocabularies. In the scope of the study, in the frame of these opinions, the ceiling ornaments in Safranbolu where traditional patterns are intensive and the design language of rose ornaments, one of their main elements, by the approach of shape grammar are researched and their variations have been generated by the developed method. In this study, this process is introduced, and their results are discussed.

2.Corpus of the Ceiling patterns in Traditional Safranbolu Houses

Safranbolu, which is chosen as the study area, is a town in the Black Sea Region of Turkey and reflects the typical Ottoman City feature, so it has been included in UNESCO's World Heritage List since 1994. The old city has three regions which are Eski Çarşı, Bağlar, and Kıranköy. "Eski Çarşı" is a region where the houses were intensively used in winter. On the contrary, Bağlar is where summer residences were in the past. Kıranköy is near "Eski Çarşı" and a region where Greek minorities lived in time. There are about 1200 houses under the conservation in these regions. Therefore, there is a wide variety of samples in terms of ceiling ornament in these regions.

Ceiling craftmanship is paramount in Safranbolu and its surrounding area (Bayazıt, 2014a). The decoration has been taken care of and protected in headroom, sofas, some "iwans," and entrances of the low-ceilinged room. When creating patterns with slats, the ornaments with a ceiling rose in the center and quarter ceiling roses at the edges are typical (Bayazıt, 2014b). Bozkurt (2013) points out that vessel ceiling implementation is customary, the ceilings are usually square-shaped, and their central parts are ornamented by geometric patterns (circle or polygon shapes) in Safranbolu houses. Bozkurt expresses that their edges are arranged to support the significant effect, and techniques of carving or tongue-and-groove joints (called Kündekari in Turkish) are applied on these surfaces. Yıldırım and Hidayetoğlu (2006) pointed out that in Safranbolu, the ceilings of the houses, many of which belong to the 19th century, were usually ornamented by a technique named "çıtakari," which is one of the oldest known methods. The other methods were not much preferred.

In the past, in Safranbolu, until the population exchange process in 1923, Greek minorities and Turks lived together. Accordingly, there was a work-sharing between them. Turks mastered carpentry and woodwork when Greek minorities were interested in stonework (Günay, 1998). Naturally, there was an interaction between the two cultures. Therefore, there are naturally similar characteristics in the ceiling decorations in the housing types of both cultures.

Ornament organization of the ceilings consists of three sections. These are a ceiling rose, edges, and the middle part. In the houses in Safranbolu, it is possible to say that ceiling roses are two different forms which a star-shaped and polygon-relief. Moreover, the composition of edges and the middle part can be in various forms (rectangular, triangular, and hexagonal grids, etc.). However, this study focuses on ornaments of ceiling roses. As will be seen in the examples, among them, star-shaped ceiling roses are preferred.

3.Literature Review

Stiny and Mitchell (1978) explain the characterization of an architectural style with three functions which are to clarify common features in the corpus; to determine its criteria, and to present compositional mechanisms that are necessary to its new instances. In other words, it must satisfy the properties of being descriptive, analytic, and synthetic. In this context, the star-shaped ceiling roses, which are also common outside Safranbolu, have a specific design language with features repeated by specific elements and developable potentials.

Shape grammars are also a computational process used to analyze or design language development tools to solve existing design states (Knight, 1981; Çağdaş, 1996; Singh and Gu, 2012; Tepavcevic and Stojakovic, 2012). Shape grammars also contribute to the organization and computation of designs through rules based on physical factors for production (Sass, 2008). They comprise four components: shapes, a set of symbols, a set of shape rules, and an initial shape (Stiny, 1980). They are formal rewrite mechanisms in which shape rules (α ☾ β) change the existing state, a Euclidean transformation of a shape ($t(\alpha)$) in design (C), by the other state, a new shape in the same transformation ($t(\beta)$). Whereby a new design ($C' = C - t(\alpha) + t(\beta)$) exists (de Klerk and Beirao, 2016). In shape grammar implementations, the degrees of predictability of emergent shapes are changeable. In this viewpoint, Knight (2003) divides shape grammars into three groups: anticipated, possible, and unanticipated emergencies. She puts analysis studies into the group of anticipated emergences. However, she said this grouping would change relatively to designers' comprehensiveness. In the literature, some studies incorporate Islamic patterns with this method. Some of them are as follow:

Cenani and Çağdaş (2006) generated variations from the basic shapes like a rectangular, pentagon, and triangle, and they used color parameters in some samples. Also, they exhibited 3D models of these samples in their other studies (Cenani and Cagdas, 2007). Çolakoğlu et al. (2009) examined the ornament model at Jaffa Gate and, by defining the initial parametric shape, obtained new shapes from it. Similarly, Bökü (2009) described the point grid layouts of ornament patterns in the existing buildings. After finding their initial parametric elements, she generated their similarities and variations by transformation rules on the grids; also, she made trials with changes between initial shapes and rules. Using the shape grammar method parametrically, Çolakoglu et al. (2008) analyzed the module, including an eight-pointed star rosette with four rhombuses. Ulu and Şener (2009) generated samples covering a square surface by using tie and bowtie, which are parts of a decagon. Jowers et al. (2010) researched the effects of emergence upon Islamic patterns by using different methods. In their study, they tried three ways: compass and rule, set-based and motif-based constructions. Motif-based construction was organized with shape grammar rules. In this study, there are rules like creating a grid system on a right triangle, recognizing, and identifying new lines in different types on the grids for a pattern, and then obtaining a unique grid pattern on a large scale from the right triangle by Euclidean transformations. Sayed et al. (2016) diversified three-dimensional motifs by using "n"-edged regular polygons as initial shapes. Agirbas (2020) studied 3D star polygon patterns that exemplify ornaments of tombstones in the Seljukian cemeteries by using shape grammar theory. In another study, Ağirbaş et al. (2022) also examined the formation of muqarnas plans at the main doors of some Ottoman-era mosques with a shape grammar approach by associating them with the composition of unequal star forms.

In addition to these, Gips (1975) demonstrated the variations of the star form, frequently encountered in Islamic patterns, in the first applications of shape grammar through both shape and color rules. Furthermore, Hu et al. (2021) examined the examples of bronze drum in traditional batik patterns which have similar formal properties with a star shape by using shape grammars together with the artificial neural network approach.

Knight and Stiny (2015) stated that designing with shape grammars was related to moves of doing and seeing with essential spatial elements for making a shape. They focused on the idea of making instead of designing in a larger perspective. Accordingly, Making was defined as doing (drawing) and sensing (seeing) with stuff (line) to making things (shape). By this definition, shape grammars were adapted to making grammars. Making grammars make proposals for exploration of the spatial and temporal qualities and structural rules of making things (Knight, 2018). In making grammar, time is important and rules are separated into two parts which are sensing and doing rules. Craft practices comprise continuous and temporal actions and events. These are compatible with temporal and spatial segmentation logic in making grammar.

4.Materials and Method

In the study, firstly, the configurational features of ceiling roses which were chosen from the Safranbolu mansions were determined. Secondly, their close relationships with shape grammars and their practices were explained. Then, by evaluating the determined configurational features with a shape grammar approach, a generation model proposal has been developed. Finally, the generations of the model in which the initial shape is based on different existing ceiling roses have been made.

The data (technical drawings, photographs, etc.) about the houses in the study were obtained from literature research, communication with the architects and craftsmen following the restoration studies, talks with the authorities in Cultural Heritage Conservation Committee of Karabük, and mansion trips individually. Lists and locations of the examined houses are given in Figure 3.

4.1.Analysis of the ceiling rose patterns

A star form emerges with the combination of angular lines around an axis. In other words, a standard star form is obtained by way of multiplication of an angular line, rotation of its copies around an axis, and union of their open-ended points for completing 360°. Angular lines are in the forms of "V" or "Λ". Corner points of a star create circular borders. These borders define "trajectories" naturally. It is possible to reach a rectangular shape, a rhombus, or other polygons in a similar vein.

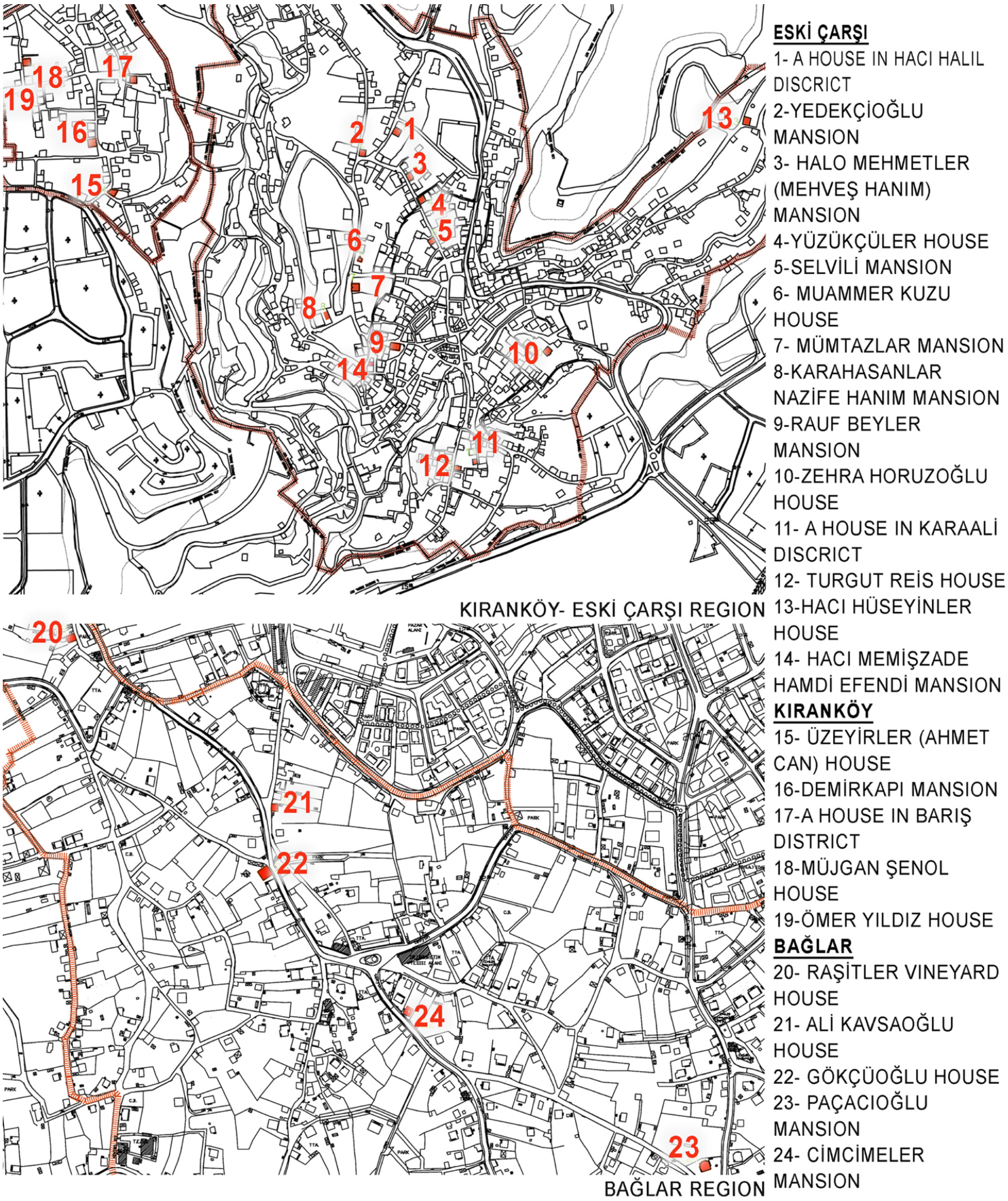

Figure 3: *List and locations of the chosen houses on the map of Safranbolu.*

At first glance of the examination of the existing samples, we can easily observe the existence of the series of hidden circular trajectories that lead to the creation of the star-shaped form of the ceiling roses. These circular trajectories are visible with wooden slats in some examples. They provide the formation of intertwined stars. They have an essential effect on the complexity and the variety of the ceiling

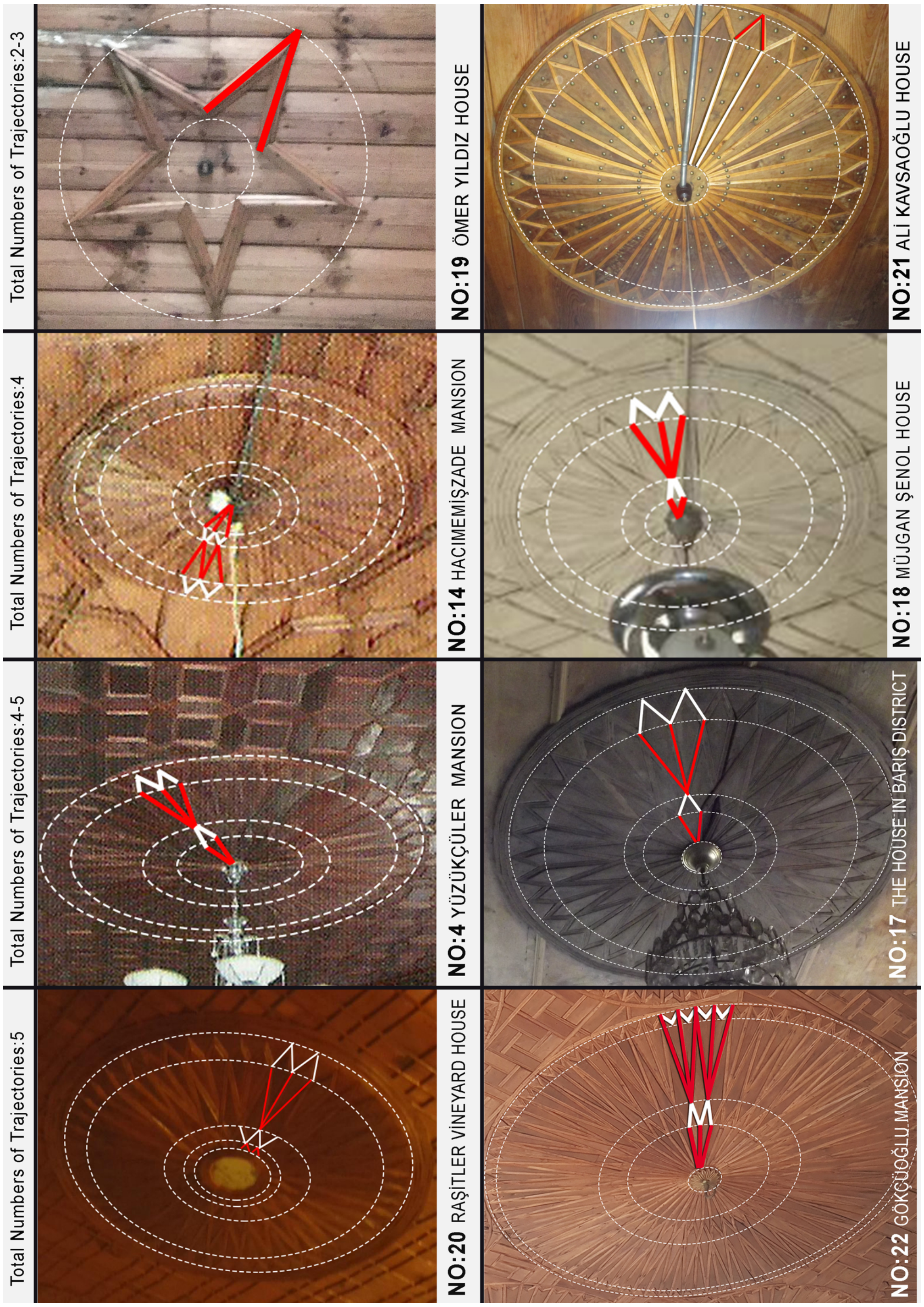

Figure 4A: *The patterns of the ceiling roses in the Safranbolu Houses.*

roses with the numerical and dimensional differences between their elements besides defining the starting and the finishing processes of placement of wooden parts between themselves. In Figure 4A, 4B, and 4C the ceiling roses in the houses are listed according to the numbers of trajectories. The numbers of the trajectories are listed as 2,3,4,5 and 6.

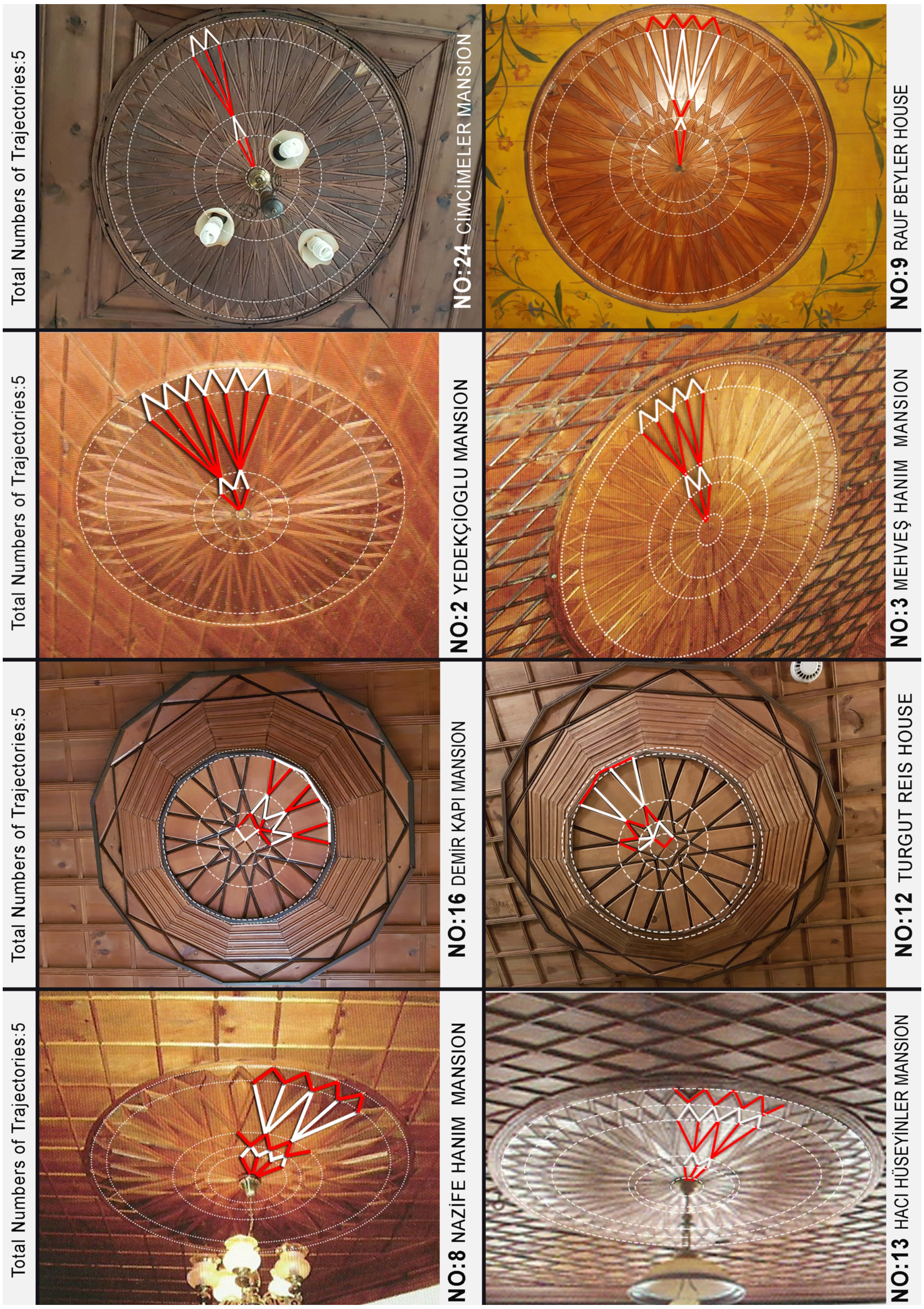

Figure 4B: *The patterns of the ceiling roses in the Safranbolu Houses.*

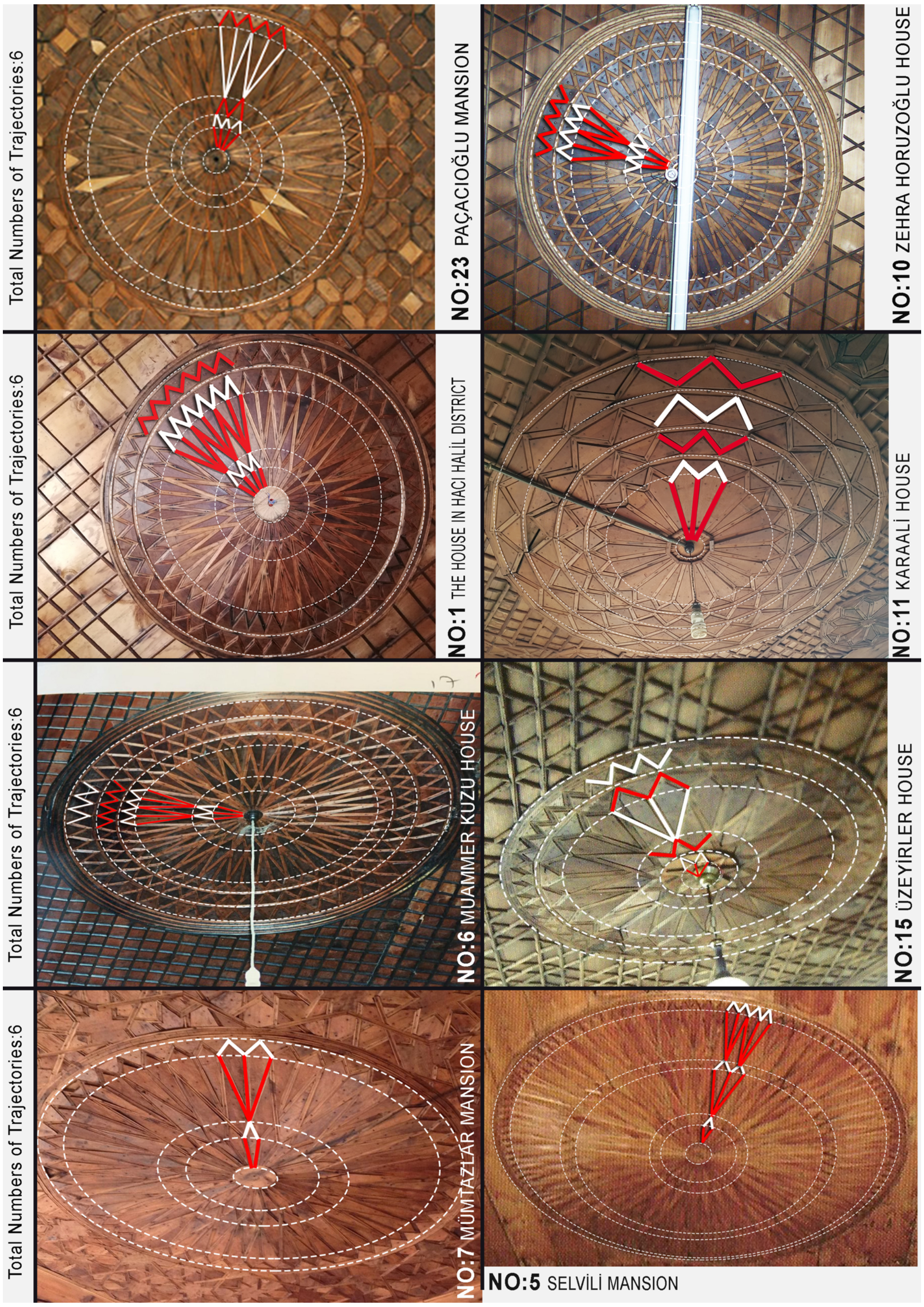

Figure 4C. *The patterns of the ceiling roses in the Safranbolu Houses.*

Additionally, there are also differences in the organization of wooden materials that usually fill in the blanks among these trajectories with "V" or "Λ" shaped elements. These differences can be observed both numerically and formally. In the innermost circular trajectories of some samples there are no "V" or "Λ" shaped elements (See the Houses 1, 2, 3, 5, 7, 8, 11, 13, 17, 19, 20, 21, 22, 23, 24 in Fig. 4A, 4B and 4C). Also, in many of these samples, "V" shaped elements between the center points and second trajectories are trimmed by the first trajectories. Generally, if "V" shaped elements are placed on one trajectory, "Λ" shaped elements are positioned on the next trajectory. During the process, this logic continues cyclically. However, in House 22, it is seen that the placement of "V" shaped elements continues successively on the last two trajectories. Furthermore, due to the expanding dimensions and angles of "V" shaped elements, these elements are segmented by new smaller "V" shaped elements on some trajectories. Except for House 19 and 21, this application exists and usually results in double "V" shaped elements. While it seems on two separate trajectories in only House 5, "V" shaped elements are segmented into triple smaller "V" shaped elements in House 2. "V" or "Λ" shaped elements among the trajectories are usually connected via their endpoints or corner points, however, this rule is broken on the last trajectory in House 1 where the "V" or "Λ" shaped elements are not in touch with the others on the previous trajectory. Similarly, the corner points of some elements on the trajectory in House 15 are not connected to the elements on the previous one. Finally, in house, star-shaped and relief models were used together. Although these samples resemble the others, there are some differences due to combinations and intersections between relief and star-shaped polygons

4.2.Shape rules

As seen in the analyses of the examples, these patterns have or may have different variables even though they are usually like each other and there are some certain shape rules. Besides being programmed and parametric, they can be developed by adding new rules. These rules can be explained sequentially as follow:

Firstly, there is a rule for creating circular trajectories before a generation process (R_0). By this rule, circular trajectories are nested in one center. This rule determines the dimensions and numbers of the trajectories. Also, the total number of trajectories defines the termination rule (R_t) for a generation. Another rule based on circular trajectories is their visible or hidden states (R_1) (Figure 5A). This rule can be applied together with placements of "V" or "Λ" shaped elements or independently from them.

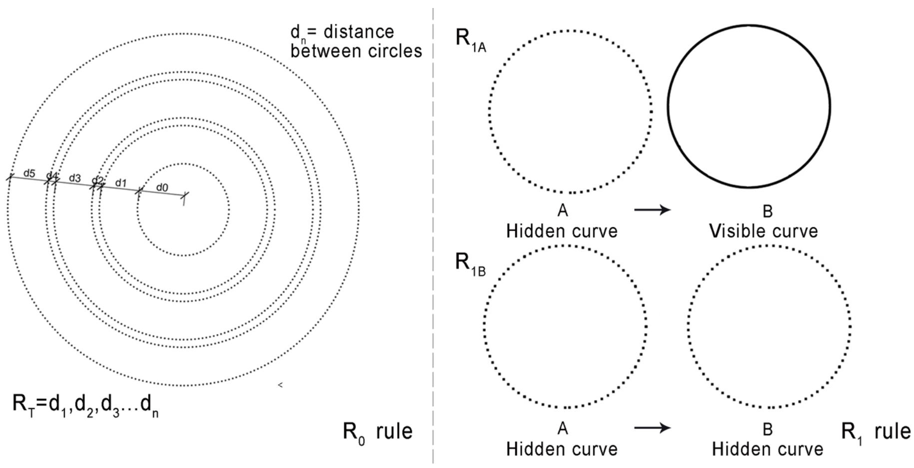

Figure 5A: *Shape Rules for trajectories/circles*

Then, there are some rules for settling parts of a star shape on a trajectory. One of these rules is whether these basic parts exist between the initial trajectory and the CenterPoint of a model (R_2) (Figure 5B). In this study "V" or "Λ" shapes are evaluated as basic parts of a star, so the other rules are generated from these elements. If the R_2 rule is inactive, the initial "V" shape emerges between the initial trajectory and the CenterPoint (R_{3A}). Otherwise, the initial "Λ" shape emerges between the first and second trajectories (R_{3B}). Meanwhile, the angle value is defined for the initial "V" or "Λ" shape. After the placement of the initial shapes, the creation of new "V" or "Λ" shapes starts on the same trajectory (R_4) (Fig. 5C). This rule repeats until "V" or "Λ" shapes fill the gaps in a trajectory.

Optionally, after completing the placement of the shapes on a trajectory and before generating new shapes on the subsequent trajectory, the states of "V" shapes are evaluated, and new smaller "V" shapes can result from these shapes. For this, "V" shapes are segmented by a user-defined value (R_5). Additionally, the positions of the corner points of "V" shapes on the trajectory curve can be changed by a distance value according to the direction of each shape (R_6). Thus new "V"

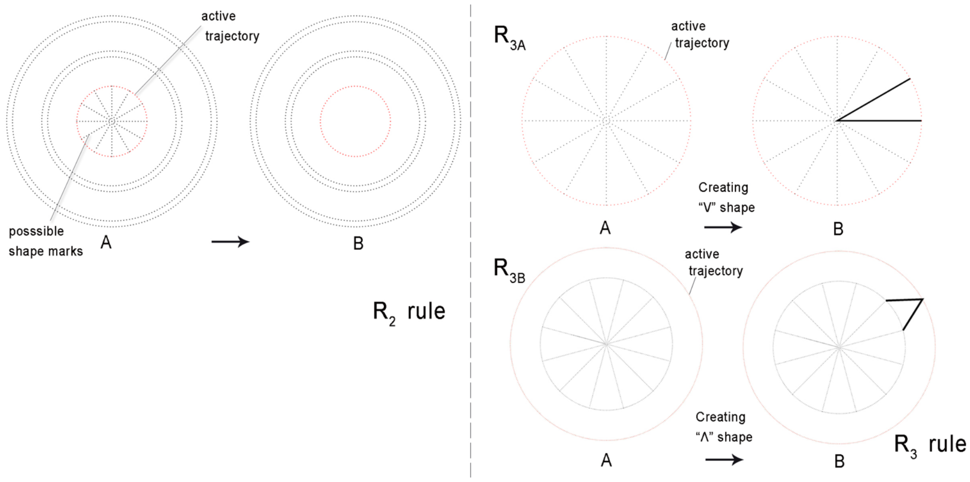

Figure 5B: *Creation of "V" or "Λ" shapes for starting.*

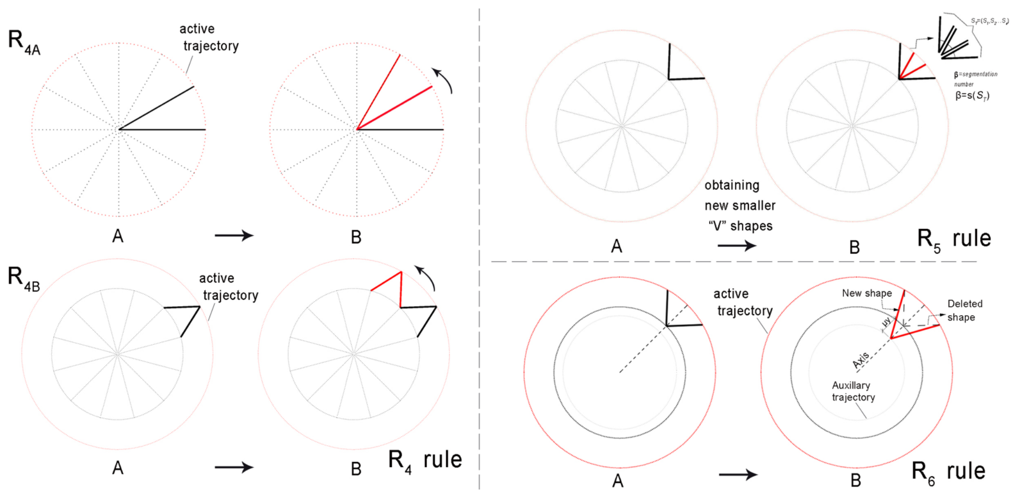

Figure 5C: *R_4, R_5, R_6 shape rules.*

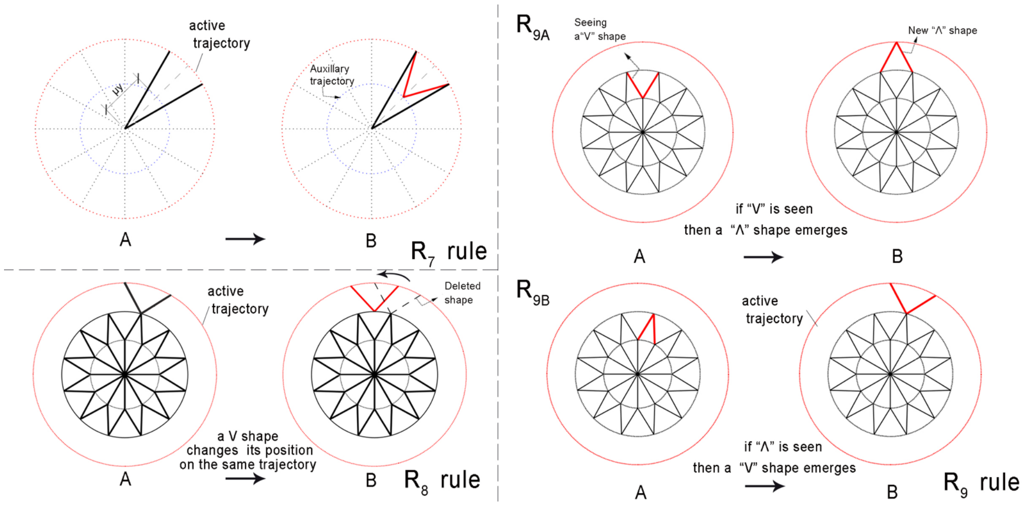

Figure 5D: *R_7, R_8, R_9 shape rules.*

shapes are obtained. Otherwise, new "V" shapes that are intricated with these V shapes can be created by the help of derivation of new auxiliary hidden curves from the active circular trajectory (R_7).

Furthermore, there is a displacement rule (R_8) in which these shapes can change their positions on the same trajectory (Figure 5D). When this rule is applied to one shape, it repeats for the other shapes on the same trajectory. This rule is not applied to the shapes on initial trajectories.

In the transition from one trajectory to another one, according to states of "V" and "Λ" shapes on a previous trajectory, new "V" or "Λ" shapes are decided on the next one. If a "V" shape is selected, then a "Λ" shape exists on the next trajectory (R_{9A}). On the contrary, a

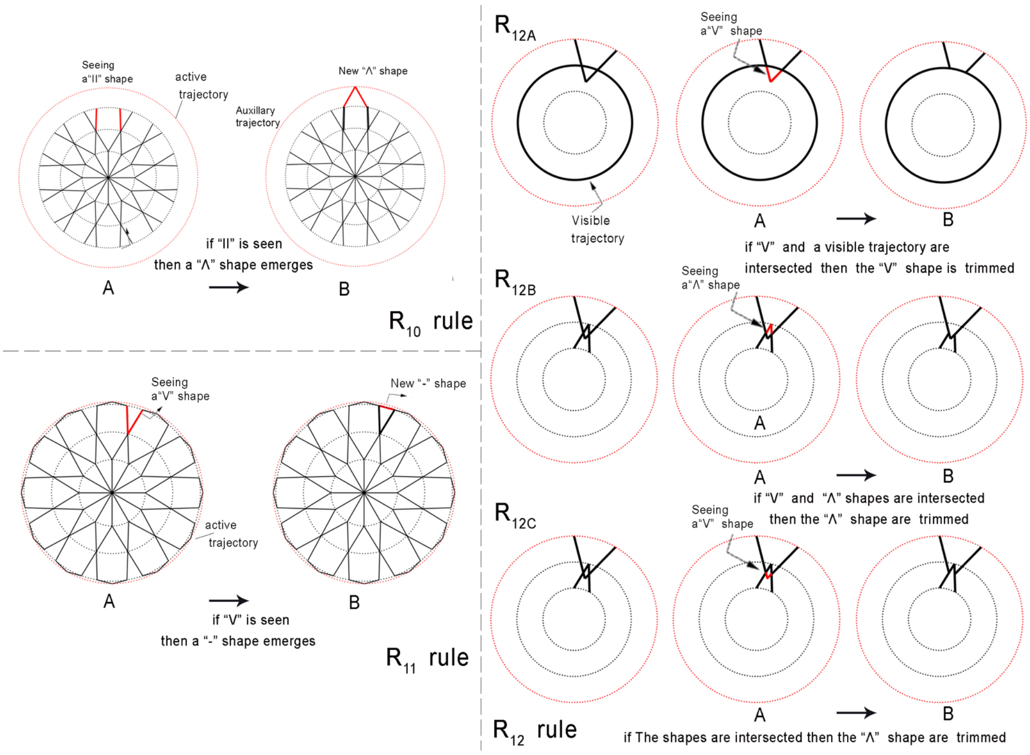

Figure 5E: *R_{10}, R_{11} and R_{12} shape rules.*

"V" shape emerges in the case of a "Λ" shape on the previous one (R_{9B}). Dimensions and angles of new "V" or "Λ" shapes naturally change according to the distance between active and following trajectories.

There are also rules concerned with the elements apart from the "V" or "Λ" shapes. The "V" or "Λ" shapes on the same trajectories are usually connected. Nevertheless, disconnections between these shapes may emerge on the same trajectory. If there is such a situation in the previous trajectory, "II" shaped elements are determined among disconnected shapes. Accordingly, a new "Λ" shape occurs on the active trajectory (R_{10}). Furthermore, one more rule can be used on the last trajectory to obtain a polygonal shape. This rule states that if there is a "V" shape on the previous trajectory, then "- "shape will emerge (R_{11}) (Figure 5E).

Finally, there are some intersection rules between "V" and "Λ" shapes and between "V" shapes and visible trajectories. Although some of them are not found in the existing samples, they have been added considering their possibilities. In these rules, if a visible circle intersects a "V" shape, a part of the shape inside the circle is erased (R_{12A}). Also, if "Λ" shapes intersect a "V" shape, then a part of the "V" shape inside the "Λ" shape is erased (R_{12B}) or a part of the "Λ" shape inside the "V" shape is erased (R_{12C}).

4.3.The generation process of the ceiling rose pattern

The algorithmic structure of the model, which applies the rules utilizing digital design tools can be explained as follows:

At the beginning of the process, the basic dimensions, and the numbers of the elements for hidden trajectories are defined. The dimensions are distances between intertwined circles (trajectories) which effect the variations. The sum of the distances which are entered for each circular trajectory determines the outer border of a star to be created. Also, the total number of dimension values represents the total number of trajectories and naturally incremental process steps. These distances (d_0, $d_1 \ldots d_4$, dn) are used as data inputs in the process. Thus, the creation of hidden trajectories (R_0) is completed.

There is a sequence of stages in the process. When stage 1 includes the applications between the CenterPoint and the first trajectory, stage 2 consists of the applications between the first and the second trajectories. Stage "n" defines the gap between (n-1)th and nth trajectories. In stage 1, as stated before, If the R2 rule is inactive, the initial "V" shape emerges (R_{3A}) according to the angle value that the user defines. Then, next to the initial "V" shape, new "V" shapes are generated successively on the same trajectory (R_4) until the 360° radial cycle is completed. In this stage, new smaller V shapes can be generated from the V shapes or some part of them rhythmically (R_5). For this rule, segmentation value is defined by the user. Additionally, new "V" shapes may occur by changing the positions of the corner points of the shapes (R6). Furthermore, as stated before, the creation of new "V" shapes that are intricated with the existing V shapes can be realized (R7). In this rule, offset value (μy) is defined for the corner points of the new "V" shapes.

In Stage II, each one of the created "V" shapes is evaluated and "Λ" shapes occur around the new trajectory (R_{9A}). "Λ" shapes define an external border for a star. Optionally "V" shapes are detected on the border. R5, R6, or R7 rules are applied with their parameters on these shapes. In Stage III, "Λ" shapes are evaluated and "V" shapes are created by R_{9B} rule. If the inner angles of the created "V" shapes are equivalent to that of "Λ" shapes, the gaps between "V" shapes may emerge depending on the distance between the trajectories. These gaps may be filled with new "V" shapes (R_4). After this stage and R_5, R_6 or R_7 rules implementations, R_8 rule activates. With the rule, all "V" shapes change their positions around the trajectory. During the process, these iterative steps continue until the end of the stage n.

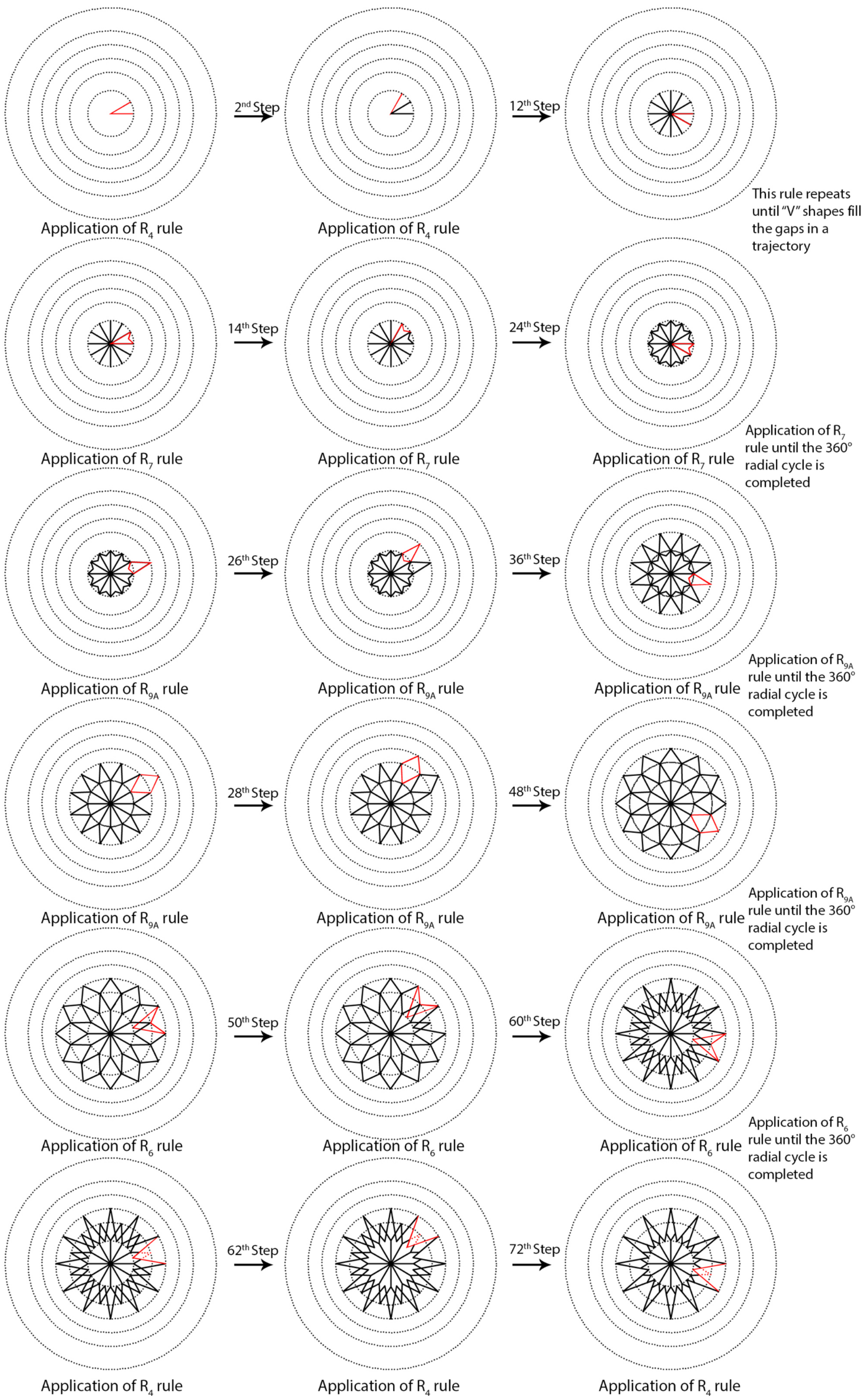

***Figure 6A:** The implementation process of the proposed model.*

In stage I, if the R_2 rule is inactive, the first trajectory is invisible (R_{1B}), but the next trajectory becomes visible (R_{1A}). If the R_5 rule is applied in a stage, the outer trajectory will

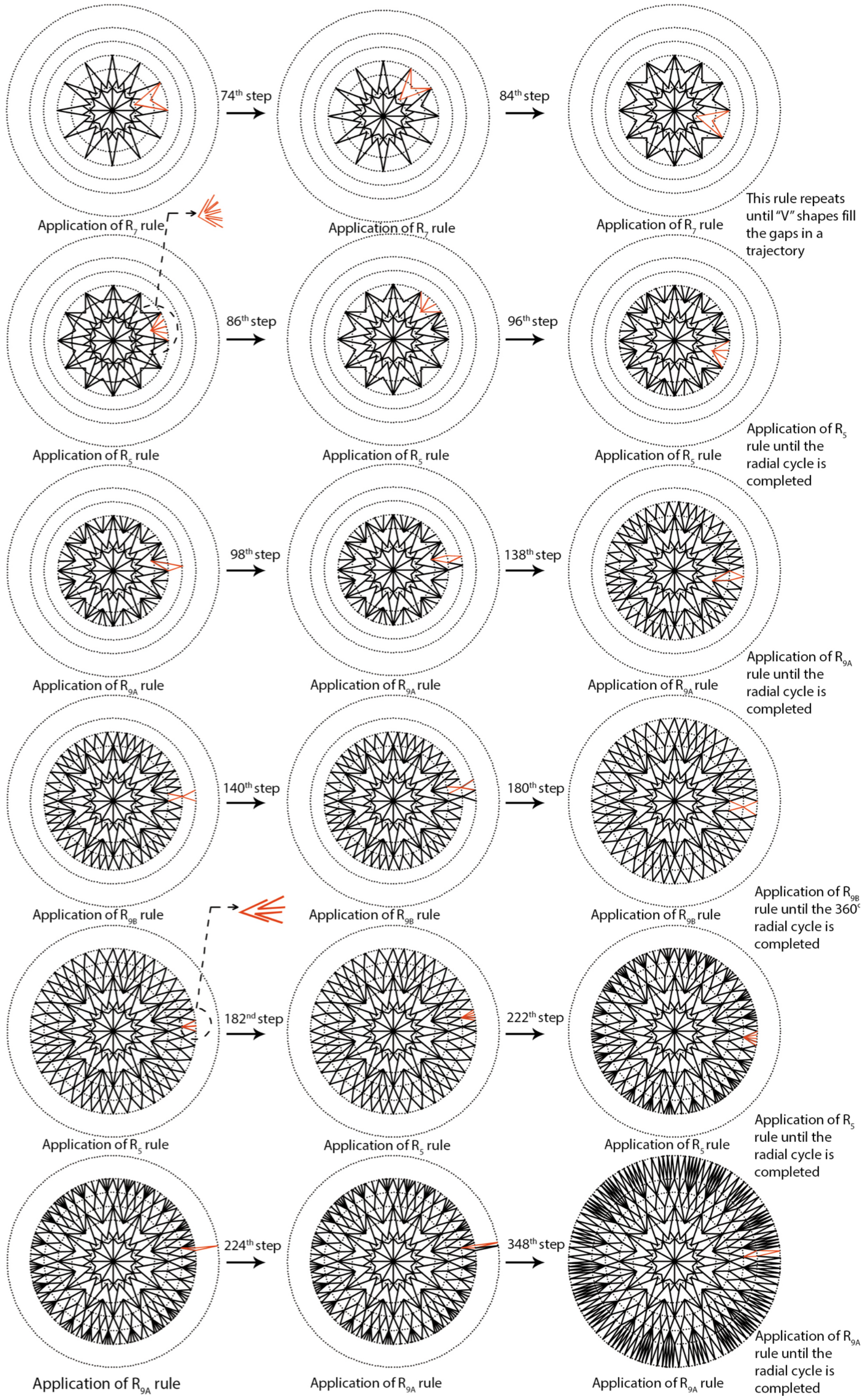

Figure 6B: *The implementation process of the proposed model (Continued).*

be invisible. On the contrary, the R8 rule is applied, and the active (inner) trajectory will be visible. During the process, while seeing "V", "Λ" and "II" shapes in the stages can be evaluated as "seeing" rules, drawing new ones according to the identified shapes exemplify "doing" rules.

In this study, there is an analysis approach on the ceiling roses, but it is considered that the developed model can present the alternatives which are difficult to predict because of combining the rules in the existing samples by different experiences and using multiple parameters. Therefore, it is possible to evaluate the results of this study in the group of possible emergences in Knight's classification (Knight, 2003).

4.4.The sample implementations generated by shape grammar

To facilitate measuring the possibilities of the potential offered in the decision-making process in the sample applications of the described procedure, trials of rules and parameters, from simple to complex, were made gradually. First, a simulation of the existing example with the defined grammar was made. Then its variational potentials were shown both by adding new ones from the

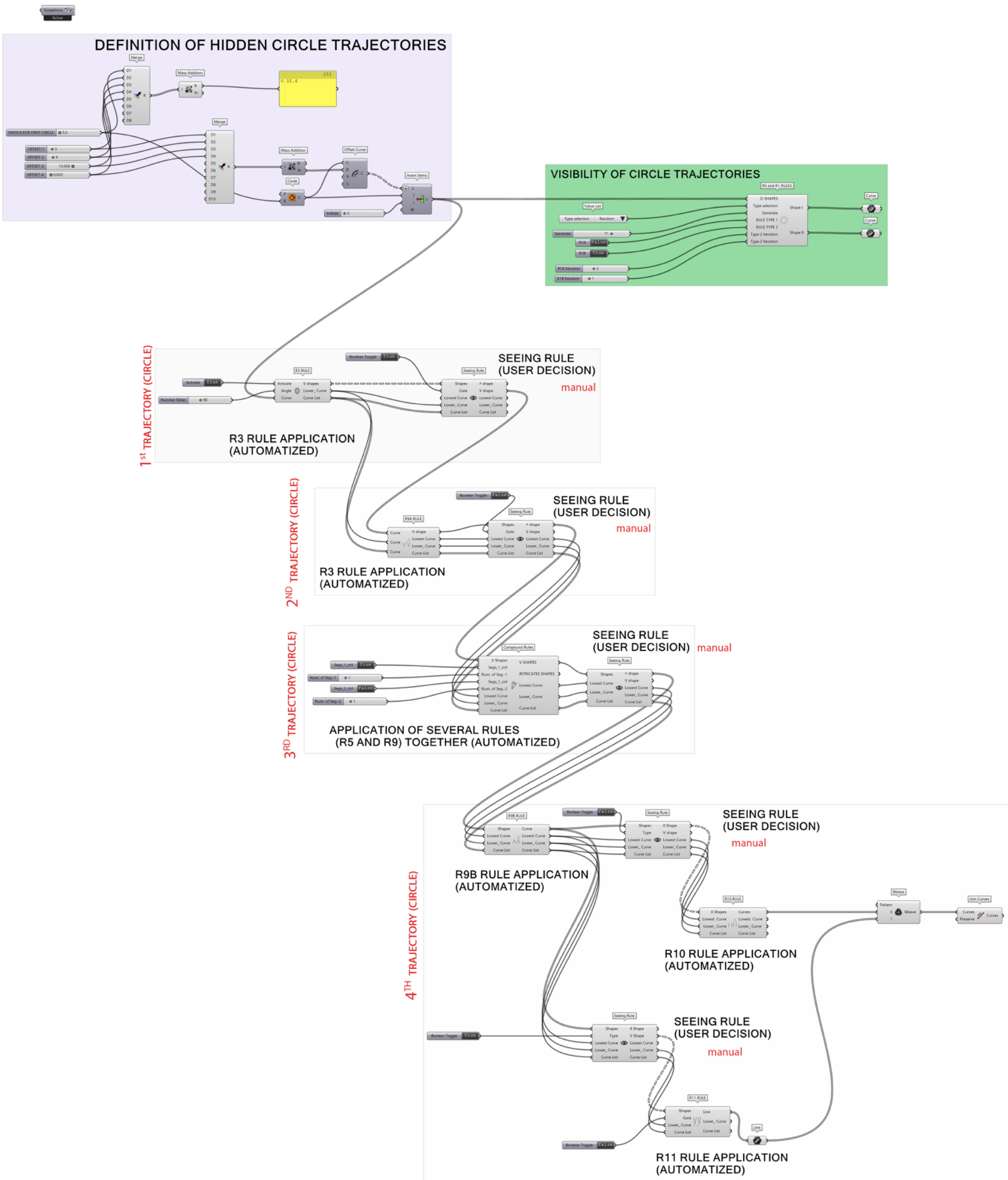

Figure 7: *The algorithm for the ceiling rose in House 16.*

prescribed rules by changing the dimensional parameters in the existing structure. In the chosen example, the ones which differentiate from the others in terms of their configurations were handled.

In the examples of the first implementation (Figure 8), from top to bottom, the angle value of the "V" starting shape has changed. Then the iteration numbers of the R_5 rule have increased in the second circular trajectory, and these numbers have differentiated rhythmically. Finally, distances between hidden courses are changed. From right to left, variations concerned with the visibility of the circles have taken place (the implementation of the R_1 rule).

There are four examples in the second implementation, whose processes are shown step by step in Figure 9. Unlike the previous one, these examples are not related to the

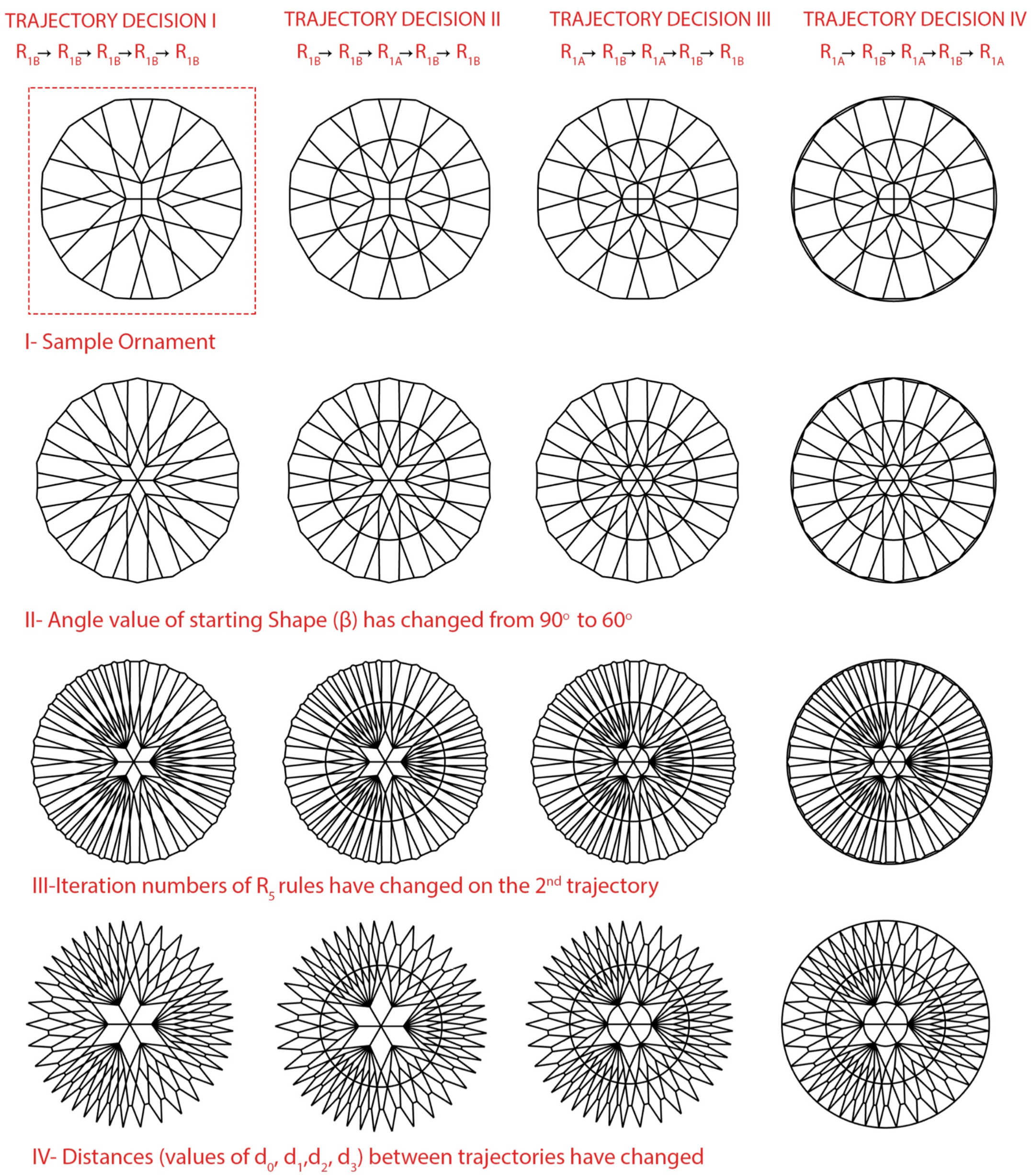

Figure 8: *The generated alternatives for the ceiling rose in House 16.*

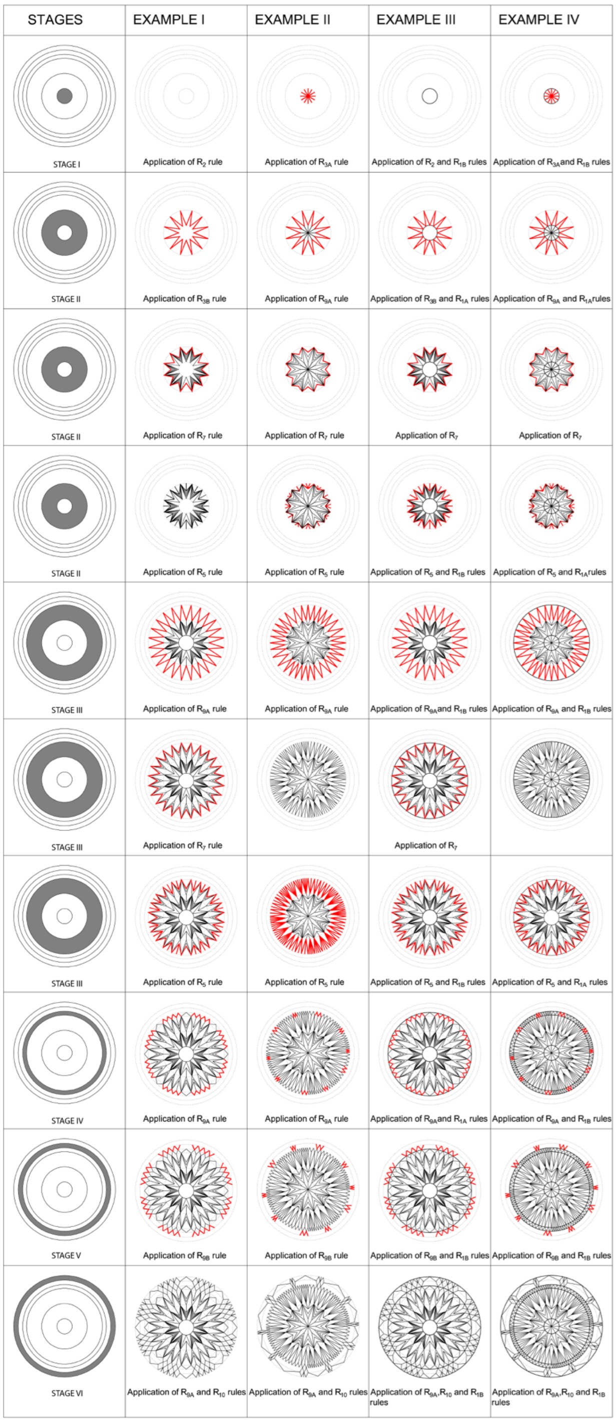

Figure 9: *The generated alternatives for a ceiling rose in the second implementation.*

existing ornaments. Conversely, the authors' own experiences have generated them. These examples are divided into two groups with visible trajectories (Example III and IV in Figure 8.) or no trajectory (Example I and II). In other words, the visibility of trajectories has been tested on two different star-shaped patterns. Although the similar rules are

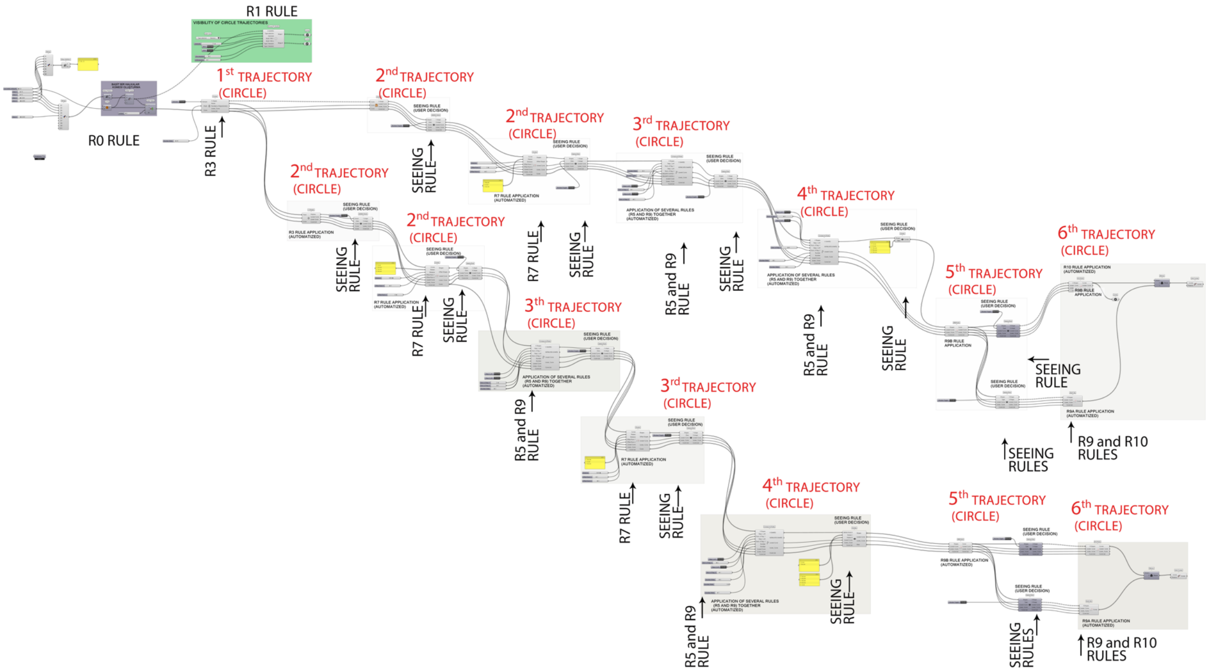

Figure 10: *The used algorithm for the examples in the second implementation.*

generally identical in the design of the star-shaped patterns, numbers, and types of the rules in the trajectories are partially differentiated. Another difference from the other implementation is that the steps/moves concerned with “Seeing the basic existing shapes” are reduced in the outer trajectories (See Stage IV in Figure 9).

5.Results

The application of the study refers to Schön's (1985) "Reflection in Action" approach. The steps like seeing "V", "Λ" or "II" shapes, then deciding the creation of new figures from these shapes and keeping on these states with the created ones in this semi-automatized proposed model are like principles of this approach. The visual programming tools used in the proposed model have also facilitated intelligibility and adaptability.

R_1 rule has supported variations of ceiling roses. However, the efficiency of using the R_1 rule decreased reversely as the formal density of star-shaped ceiling rose increased. However, the efficiency can be increased further by changing the thickness of the material to be chosen in the implementation and creating height differences among the visible circle trajectories.

The decreased angle of the initial rule (R_3) and the visually increased circle trajectories have resulted in ever-increasing formal density. The applications of R_5 have increased it much more. The visual efficiency evaluation of this density increase depends on the spatial conditions like the dimensions of the ceiling rose, space size, and functional states of spaces. For example, the examples with visual density may be beneficial for pure rooms surrounded by non-pretentious spatial elements. However, depending on individual evaluations, it is possible to say that this evaluation is somewhat relative.

Repeating the R5 rule and R7 in different numbers in the same orbit created a cyclic rhythmic visual density difference. Besides, the other rules that are not applied in these examples can also result.

While taking the symmetries of "V" or "Λ" shapes (R9 rules), the new ones may exceed the limits of the controlled circle trajectory. The trajectory could trim them. The trimmed ones may not be related to each other. However, together with seeing rules, these independent shapes extend the repertoire of pattern diversity. The implementations have also confirmed it.

Increasing the number of trajectories may cause extreme pattern density from inside to outside. However, as shown in the second implementation, this density can be decreased, and different and valuable patterns can be obtained by reducing the designer's ability to see "V", "II", and "Λ" shapes and to do new ones in each trajectory/stage. The scale of vision styles may differ.

6.Conclusions and Suggestions

In traditional houses in Safranbolu and Anatolian Cities, the ceiling ornaments include culture and richness like the other components of these buildings. The ornaments (of edges, middle area, and rose) of these surfaces where geometric forms were commonly used due to the material and cultural features are easily adaptable into digital media. In this study, the potential richness of the variations has been demonstrated in the framework of the ceiling rose by identifying general features/differences from existing examples and using shape grammar and a parametric approach.

When examining the mansions, some house ceiling ornaments were not found in their originals and were later added as copies or simple examples. It is understood that there is not enough consciousness on this subject. As stated before, it is more suitable for using newly added elements, which are innovative and unique but follow the traces of the past in these buildings. At least, evaluating alternatives is always helpful in every aspect (aesthetic, sustainability, innovations, etc.).

There are opportunities for ease of production and obtaining accurate products with digital fabrication. Today, specific standard patterns are produced relatively in this way. However, it is explicit that the richness of theoretical knowledge will also influence the practice. So, by taking advantage of these digital design tools, it will be beneficial to develop designer-practitioner interaction in design areas where traditional qualities are maintained, but innovative approaches are also needed. As a result, a mutually correct and gradual interaction between designers' interventions/evaluations and automated processes with an exploratory approach will increase originality in these motif designs. Consequently, the presence of different interventions and systems, albeit a little, has been shown in the research of the samples. So, it is possible to say that innovative examples can be explored based on generations from the existing models.

The variations/generations on one type of only the ceiling rose ornaments have been made in this study. However, the ceiling rose is a part of the ceiling ornaments, and the others also have a potential for parametric variation and characteristic features. The developed rules for ceiling roses can be used for these parts of the ceiling ornaments by adding new rules. So, it is strongly likely to create and acquire much more different and rich samples together.

The rules and the applications are two-dimensional because so are the ornaments of star-shaped ceiling roses in Safranbolu. Similarly, new rules can be added, or existing ones can be adapted for two-dimensional surface elements and three-dimensional solid models. New seeing rules can be developed. Rule repertoire can be increased for two-dimensional wireframe implementations.

Professional practice carried out with the master-apprentice relationship has been abandoned over time, and most of the technical knowledge previously learned through on-site experience has been reduced to theory. Considering the requirements of the age, although it does not seem possible to return to a master-apprentice-based architectural education approach, it may be possible to provide an environment where professional skills are experienced by using VR toolkits. As a result, VR applications with three-dimensional models in various educational applications attract the attention of users (Şahbaz, 2021). Similarly, the approach of this study, which was developed in two dimensions, can be transferred to the third dimension and generalized in educational studies in VR environments. Thus, the sustainability of this craft, which is recommended to be developed with innovative approaches, can be ensured.

Finally, Knight (2018) suggests making grammar an alternative way of recognizing and representing craft practice and performance. Temporal steps of making activities present new perspectives on what has been done at that moment. The proposed approach of this study has exemplified it effectively with its sensing/seeing and doing activities. Hence it promotes the application of Knight's proposal to other traditional craft practices for sustainability.

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