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Research Article

An examination of ironworking examples in traditional Safranbolu house doors through the approach of shape grammar

Asst. Prof. Dr. Ege Kaya Köse[1*], Assoc. Prof. Dr. Ahmet Emre Dinçer[2]

[1]Ankara Yıldırım Beyazıt University, Faculty of Architecture and Fine Arts, Department of Industrial Design, Ankara, Turkey.
egeekaya@gmail.com

[2]Ankara Yıldırım Beyazıt University, Faculty of Architecture and Fine Arts, Department of Architecture, Ankara, Turkey.
aedincer@aybu.edu.tr

*Corresponding Author

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Abstract
Safranbolu is renowned for its traditional architecture and the local tradition of ironworking in Turkey. The importance attached to sustaining ironworking as well as traditional architectural heritage has led to the launch of a research initiative to study examples of ironworking and to encourage diversification of production. This study uses a mathematical analysis to investigate the latch mirrors on traditional Safranbolu house doors. The research methodology consists of several basic steps. These are the literature data that form the background of the research, their interpretation, and the steps used to implement the proposal. After collecting literature and visual data, the research continued with the two-dimensional digital drawings to reveal the form and components of the door latch mirrors. Then, the analysis of the shape of the keyframe in the plate, the most common ornamental area in latch mirrors, was carried out. Finally, new patterns were produced through the algorithmic process using Rhinoceros-Grasshopper plug-in. This study provides valuable information about the ornamentation techniques used in the traditional house doors of Safranbolu and significantly contributes to the maintenance of local craftsmanship. Importantly, it empowers craftsmen by offering practical benefits by providing sample models and suggestions for improving decorative ornamentation.

Keywords: Traditional Safranbolu house, Ironworking, Shape grammar, Door latch mirror

Extended Abstract

Introduction: Safranbolu, located in northwestern Turkey, is famous for its traditional architectural housing texture. These houses reflecting the Turkish architectural style are part of the cultural richness in the city (Aksoy & Kuş, 1999). Like the traditional Safranbolu houses, the doors, which are the building components of these houses, and the local blacksmith craft examples on the doors are also among the components of this culture (Alpman & Sezgin, 2009: 32). The metal elements on the doors were shaped by local craftsmen with their knowledge not only for functional purposes but also for ornamental purposes. This approach has enabled metal ornaments, which have a particularly essential position in blacksmith craft, to emerge (Tunçözgür, 1999: 103; Pamuk, 2010; Göktaş Kaya, 2010). Metal elements on doors include nails, rings, knockers, door handles, latches, bolts, bolt mirrors, locks, and lock mirrors. The craftsmen elaboratively customized the examples of ironwork here according to the profile of the homeowner, with individual and original motifs. Motif designs are inspired by ancient motifs, stylized animals, plants, and geometric shapes found in Anatolia (Barlas, 2004: 31-34). When the literature is examined, many studies investigate the history, ornamentation, sustainability, and producer experiences of ironwork. However, there is yet no published research examining the creation of implicit knowledge-based variations of ironwork ornamentation on Safranbolu's traditional house doors.

Purpose and scope: The goal of the present study is to analyze the design configurations of the door latch mirror, which is the most densely ornamented example of ironwork, and create diversity from the obtained knowledge through digital design tools, with the criteria of preserving it as a local craft, identifying its design approaches and productive potential,

and passing them on to future generations. Considering sustainability as a form of reproduction, it exhibits a different and unique approach. By using the potential and techniques of the shape grammar approach in the analysis, it explores the conditions for useful proposal methods for innovative designs to prevent the production of non-original imitations.

Method: The exterior doors of Safranbolu houses are adorned with metallic elements comprised of multiple recurrent geometric shapes. Specifically, metal plates featuring engravings of equilateral triangles arranged in various configurations constitute an integral facet of the overall decorative scheme (Sönmez, 1976: 18). The preeminent example of ironwork incorporating these embellishments is manifested in the form of door latch mirrors. The observation that the embellishments adorning each latch mirror are derived from the combination of equilateral triangles underscores the potential for geometric feature development through the analysis of recurring elements. For the purpose at hand, this study employs shape grammar to delineate designs and engender forms predicated upon a set of rules or principles. The shape grammar approach primarily employs the qualitative method, focusing on constructing and analyzing space and object configurations based on predetermined rules or grammar. Within this approach, emphasis is placed on spatial relationships, patterns, and design principles. While quantitative data may occasionally support rules governing specific dimensions or proportions, the qualitative aspect remains paramount. Design similarities are scrutinized by identifying recurring motifs or patterns across multiple products. Through these similarities, overarching rules defining the grammar, such as pattern-design principles, are discerned- these may include repeating motifs or similar geometric shapes. These rules delineate how shapes can be manipulated and combined to generate new designs. By utilizing visual scripts in Rhino Grasshopper, which encodes the rules of shape grammar, designers can produce new designs by adjusting the parameters of the shape grammar. This study uses a mathematical analysis (Rule Formalization, Pattern Recognition, Algorithmic Generation, Parametric Variation) to investigate the latch mirrors on traditional Safranbolu house doors. The research methodology consists of several basic steps. These are the literature data that form the background of the research, their interpretation, and the steps used to implement the proposal. After collecting literature data and visual data (15 images of door latch mirrors), the research continued with the two-dimensional drawing of the latch mirrors using the AutoCAD program to reveal the form and components of the door latch mirrors. After this step, the plate that forms the keyframe, the most common area of ornamentation on the latch mirrors, was determined to be used in the application step. The mathematical analysis of the two-dimensional drawing of the current examples and shape in the frame of the key was carried out. In other words, design languages were determined. As a result of this analysis, new patterns were produced using Grasshopper, which works as a Rhino modelling program plug-in. As a result of the application, 20 new patterns were created.

Findings and conclusion: This study presented a mathematical representation of tacit knowledge in a craftsman's design approach. The algorithmic structure designed by parametric design tools has triggered new variations in an interactive way based on the tacit knowledge in the designers' subconscious. Thus, it has defined an alternative way to the similar repetitions in the examples by the contributions of the instant seeing-doing approach. By the sample implementations of the proposal approach, the study has demonstrated that the deep potential in ornament variations can be increased with shape and size differences of the basic elements formed by drilling and forging, and by spatial diversities of how to put them together. By the sample implementations of the proposal approach, the study has demonstrated that the potential in ornament variations can be increased with shape and size differences of the basic elements formed by drilling and forging, and also by spatial diversities of how to put them together.

Keywords: Traditional Safranbolu house, Ironworking, Shape grammar, Door latch mirror

INTRODUCTION

Safranbolu, situated in the northwest part of Turkey is renowned for its houses that showcase the architectural style of the Ottoman era. The most crucial factor that makes Safranbolu stand out not only in Turkey but also in the world is that Safranbolu houses reflect traditional Turkish architecture. The presence of Safranbolu houses serves as a testament to the enduring vitality of culture, even in contemporary times (Aksoy & Kuş, 1999).

The houses in Safranbolu attract attention with their architectural examples from the past to the present. One distinctive feature of these houses is the doors, which hold significance beyond their purpose of providing an entrance to the outside world. The doors are deeply intertwined with the beliefs, traditions, and cultural identities of the people residing in these houses. As noted by Sönmez (1976: 18) they have become representations of the individuals' personalities, virtues, and dignity, within their households. The importance of doors in traditional Safranbolu houses can be attributed to the influence of the blacksmithing profession, which has long been an integral part of the city's cultural heritage. This profession added a unique spirit to

the city's architecture, as is evident in the ornate ironwork found especially on the doors of traditional Safranbolu houses (Alpman & Sezgin, 2009: 32).

In the traditional houses of Safranbolu, street doors are usually double leafed, which are adorned with intricate carvings and serve as a characteristic feature of the architectural style. Metal decorations also start on the street doors. The metal ornaments on the doors consist of many elements such as rings, knockers, door handles, latches (and mirrors), locks (and mirrors), and nails. These elements are produced in the Safranbolu blacksmiths' bazaar (see Figure 1). The craftsman in the blacksmiths' bazaar shape the metal parts on the doors not only for functional purposes but also to decorate the doors. Metal ornaments reflecting Safranbolu's cultural heritage emerged as a result of this approach (Tunçözgür, 1999: 103; Pamuk, 2010: 50; Göktaş Kaya, 2010: 342).

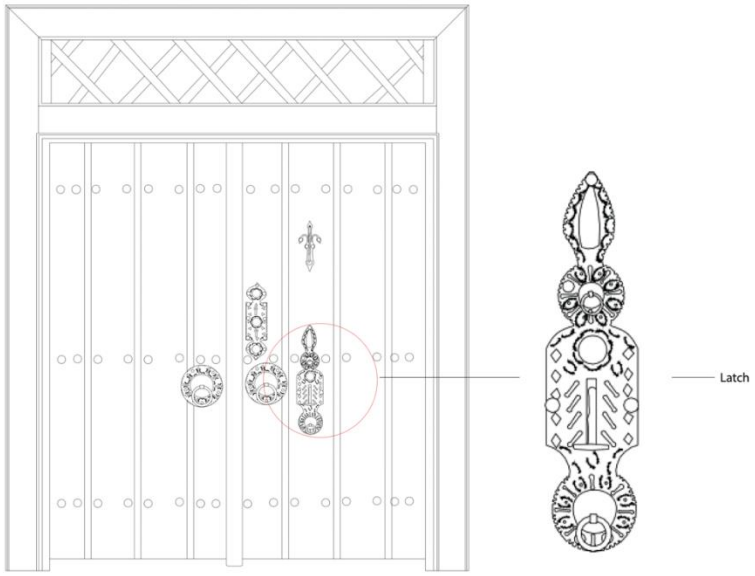


Figure 1. Positioning of latch on the traditional Safranbolu door

The local craft of ironwork is an important part of the metal pieces that decorate the doors of traditional Safranbolu houses. The city is characterized by both housing and the local craft of blacksmithing, which has been an important part of Safranbolu's cultural heritage for centuries. Blacksmithing and blacksmith craftsmanship developed Safranbolu to such an extent that a tradition emerged in which ornamentation was of equal importance to function. In addition, examples of metal ornamentation have led to the creation of different designs as unique examples of production (Barlas, 2004: 29; Günay, 1998: 322).

The literature on ironworking in Safranbolu is quite extensive. For example, Göktaş Kaya (2010: 341) and Pamuk (2010: 50) examined metal decorations in Safranbolu houses. Dağı and Çelik (2020: 26) focused on the history of ironwork in Safranbolu. Beyond the examination of existing examples, Kaya Köse and Gözlükaya (2022: 2), within the scope of a project, sought to answer the question of how the examples of ironwork on Safranbolu traditional residential doors can be transferred to future generations through design. Canbulat (2022: 380), and Deniz and Çelik (2020: 123) contributed to the literature with their studies examining the knowledge of ironwork craftsmen. When all these academic studies were examined, no study was found to examine the creation of variations of ironwork ornaments on Safranbolu's traditional house doors.

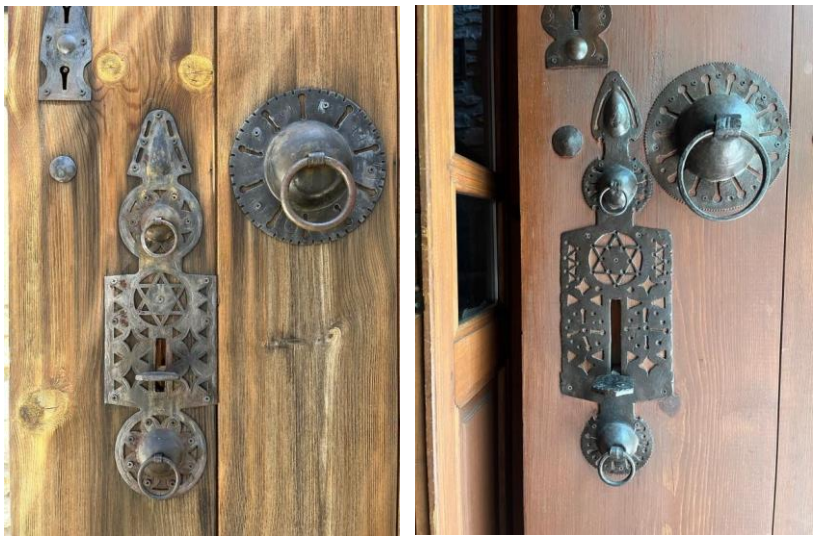
When the doors in Safranbolu traditional houses are examined, it is possible to say that the letters in the Central Asian alphabet are used or that various motifs belong to the ancient period. In addition, it is important and valuable to investigate the ornamentation approaches in ironwork examples (Barlas, 2004: 30), whose ornaments were developed over time under the Islamic understanding. Among the examples of door ironwork, the most prominent products with ornaments are the door latch mirrors. For this reason, examining the motifs on the door latch mirrors and creating original models can help transfer the ironwork craft tradition to future generations with innovative applications.

The studies in the literature on Safranbolu iron craft have mainly aimed to preserve ironworking as a local craft. However, this study takes a valuable approach to the craft as a form of reproduction, as it also incorporates sustainability. In particular, the study focuses on analyzing the geometric structure of ironwork examples and creating diversity in reproduction. The goal of re-creation involves systematizing tacit knowledge to generate new patterns. As a result, the study aims to fill the gap in the literature by analyzing examples of ironwork found on traditional Safranbolu residential doors using a shape grammar approach. To accomplish this, the research utilizes digital design tools that are widely available today, offering a new perspective that adds value to the existing literature.

Background: Metal Decorations on Traditional Safranbolu House Doors

Throughout history, doors have reflected humankind's beliefs, traditions, tastes, and characters. They are indispensable parts of architecture and have evolved, differentiating from period to period. These structures are used in various settings, from palaces and houses to baths and castles. With the locks, knockers, and keys on them, doors have taken their place in today's cultural history as striking examples of culture (Saraçoglu & Karakaş, 2008: 138). In traditional Safranbolu houses, stone walls separate the gardens from the street, and large double-winged doors lead into the garden or sometimes directly into the house. Even at the door, the splendor is visible, with large locks on each door, rings next to the locks, a knocker (known locally as "şakşak"), and a latch device for knocking on the door (Aksoy & Kuş, 1999). Examples of ironwork on doors differ in form, production technique, and ornamentation based on the function of the space in which they are used.

The examples of door embellishments found on traditional Safranbolu houses are unique in their various forms, each produced according to the homeowner's occupation. The blacksmiths of Safranbolu recreated ancient motifs -also found in Anatolia- to the homeowners' tastes. These motifs were stylized animals, plants, creatures of legend, and pieces of nature (Barlas, 2004: 31-34). Although door knockers, rings, and key rings may symbolize different meanings, the particular skill demonstrated by the blacksmith is considered the essential indicator of the craftmanship (Dağı & Çelik, 2020: 31).



a b

Figure 2. Door latch mirrors examples on the traditional Safranbolu house doors (a) Akbulut House (b) Imren House

Traditional Safranbolu house doors have a simple appearance consisting of flat and vertical plates. To open the door, it is necessary to lift the latch handle, which has caused the latch mirror to take an elongated shape depending on its function (Günay, 1998: 153). For this reason, latch mirrors tend to be decorated more elaborately than other metal elements on doors.

Figure 3. Samples of door latch

The exterior doors of Safranbolu houses are embellished with metal elements that consist of several repeated geometric shapes. These decorative features are visible on the doors of all the houses in the district that adhere to traditional practices. In particular, metal plates are engraved with equilateral triangles in various configurations, forming an integral component of the overall decorative scheme (Sönmez, 1976: 18). The shape of the latch mirror on Safranbolu doors is determined by the width and length of the latch handle required to open the door. As a reflection of the owner's financial status, the size of the latch mirror can either increase or decrease accordingly. Additionally, the ornamentation on the latch mirror is produced uniquely based on the craftsman's level of expertise. Triangular ornaments are commonly used to decorate the latch mirrors on the doors of traditional Safranbolu houses. These ornaments are placed around the area defining the door-opening function. The use of repeating geometric shapes on the latch mirrors has led to the idea that this similarity can be established in traditional Safranbolu residential doors. In this regard, door latch mirrors featuring triangular decorations were selected as the sample for the field study.

Shape Grammar Approach

Shape grammar is a methodology proposed by Stiny and Gips (1972: 6) to analyze painting and decorative art to describe designs and generate forms based on a set of rules or principles. It is one of the first algorithmic systems for understanding and reconstructing form through computation with shapes.

> A shape grammar has four components: (1) S is a finite set of shapes; (2) L is a finite set of symbols; (3) R is a finite set of shape rules of form a -+ 0, where a is a labelled shape in + (S, L), and 0 is a labelled shape in (S, L)*; and + (4) / is a labelled shape in (S, L) called the initial shape. In shape grammar, the shapes in the set S and the symbols in the set L provide the building blocks for the definition of shape rules in the set R and the initial shape /. Labelled shapes generated using the shape grammar are also built up in terms of these primitive elements. (Stiny, 1980: 347)

A shape grammar is a set of guidelines for the construction of shapes that are gradually applied to create a design set or language. As stated by Knight (1999: 213), these grammars are both generative and descriptive. Numerous design objectives, such as analyzing, synthesizing, and innovation, have been addressed by shape grammar (Knight, 1999: 213; Stiny, 2006: 1-9; Cenani & Çağdaş, 2006: 291). They make it possible to describe and analyze already-existing designs, generate alternate designs using rules, and to develop brand-new designs. Numerous design disciplines, including urban design, architecture, landscape design, crafts, painting, product design, and mechanical design, have extensively used these problems (Knight & Stiny, 2015: 10).

The primary objective of this study is to conduct an in-depth examination of the latch mirror, a remarkable example of ironwork on the door and an integral architectural element of the traditional Turkish house in the Safranbolu region. The study will utilize a range of analytical methods to explore the stylistic and functional characteristics of the latch mirror and to investigate its historical and cultural significance within the broader

context of the Ottoman architecture and decorative arts. Geometric patterns, also seen in the decoration of the latch mirror, are the essential ornamental design components of Islamic art which is derived from Greek mathematics based on pure geometry. According to Pythagoras, everything in the universe can be described by mathematics. Every number has a particular meaning. For example, the cube and square represent the world, the pyramid and triangle represent fire, and the dodecahedron represents the universe. In Islamic art, two-dimensional geometric patterns are compositions of closed polygons (Cenani & Çağdaş, 2006: 292). Examples in the literature of the form grammar method for Islamic geometric patterns include:

- The patterns derived from the geometric decomposition of the patterns of the eight-pointed star motif in Islamic art (Kaplan, 2000: 107),
- The symmetry of geometric patterns in Islamic art using rule sets for the production of two- and three-dimensional forms, and the potential of the mathematics of geometry (Cenani & Çağdaş, 2007: 1),
- The production of a geometric ornament selected from a sample ornament design by coding it with a computer programming language (Cenani & Çağdaş, 2006: 290),
- Discussing the algorithmic construction method of Islamic ornaments that can be used as a decorative element in architectural design (Nadyrshine et al., 2021: 1),
- Creating a three-dimensional parametric pattern generator of the star polygon pattern on tombstones (Ağırbaş, 2020: 113),
- Producing variations of the star-shaped ceiling rose ornament in the Safranbolu house within the framework of different scenarios (Dinçer & Kartal, 2022: 39).

The common point in the geometric surface decorations used on all these different materials is the reproduction of the analyzed ornaments by specific rules. Geometric surface decorations are frequently utilized across various materials, including ceramics, textiles, and architectural elements. However, they are characterized by a common thread: replicating analyzed ornaments according to specific rules. This process involves the application of mathematical principles and symmetrical designs, which can vary depending on the cultural and contextual influences shaping each art form.

In Islamic art, geometric and floral patterns are created with basic geometry rules such as isometric transformations and Boolean operations. Translation, rotation, reflection, and repetition are isometric transformations (also called Euclidean transformations). Boolean operations include addition, intersection, and subtraction (Cenani & Çağdaş, 2007: 3). Repetition is also the most influential and essential theme for geometric patterns. There may be one or two basic shapes in an Islamic ornament, but the interlocking designs of these basic shapes ultimately create different and complex patterns. Ornamental designs are often created by repeating square and triangle shapes (Cenani & Çağdaş, 2006: 292). In many houses, mosques, and inns within the historical texture and architecture of Safranbolu, it is possible to see the art of blacksmithing on the streets of Safranbolu, where blacksmith masters can show their skills (Dağı & Çelik, 2020: 31). Using equilateral triangles to form the decorative patterns on latch mirrors highlights the potential for geometric exploration by analyzing repeated elements. This analysis process, often utilizing shape grammar, can inform future design iterations by identifying areas for improvement and suggesting new directions for design. Through the ongoing examination and refinement of existing examples, the art of blacksmithing and other traditional crafts can be preserved and enriched for future generations.

METHODOLOGY

The shape grammar approach primarily employs the qualitative method, focusing on constructing and analyzing space and object configurations based on predetermined rules or grammar. Within this approach, emphasis is placed on spatial relationships, patterns, and design principles. While quantitative data may occasionally support rules governing specific dimensions or proportions, the qualitative aspect remains paramount. Design similarities are scrutinized by identifying recurring motifs or patterns across multiple products. Through these similarities, overarching rules defining the grammar, such as pattern-design principles, are discerned- these may include repeating motifs or similar geometric shapes. These rules delineate how shapes can be manipulated and combined to generate new designs. By utilizing visual scripts in Rhino

Grasshopper, which encodes the rules of shape grammar, designers can produce new designs by adjusting the parameters of the shape grammar.

This study uses a mathematical analysis (Rule Formalization, Pattern Recognition, Algorithmic Generation, Parametric Variation) to investigate the latch mirrors on traditional Safranbolu house doors. The research methodology consists of several basic steps. These are the literature data that form the background of the research, their interpretation, and the steps used to implement the proposal, as visually depicted in Figure 4. After collecting literature data and visual data (15 images of door latch mirrors), the research continued with the two-dimensional drawing of the latch mirrors using the AutoCAD program to reveal the form and components of the door latch mirrors. After this step, the plate that forms the keyframe, the most common area of ornamentation on the latch mirrors, was determined to be used in the application step. The mathematical analysis of the two-dimensional drawing of the current examples and shape in the frame of the key was carried out. In other words, design languages were determined. As a result of this analysis, new patterns were produced using Grasshopper, which works as a Rhino modelling program plug-in. As a result of the application, 20 new patterns were created. The application steps are explained in detail under the title A Case Study.

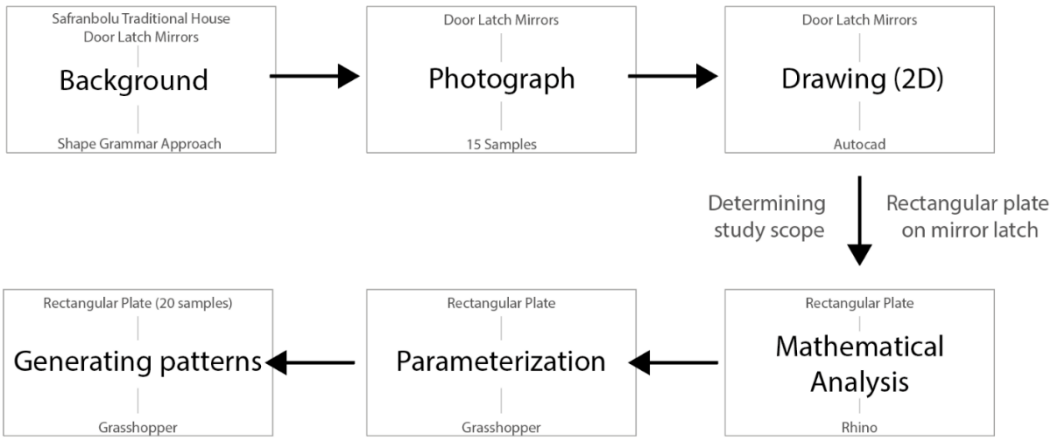


Figure 4. Methodology of the study

A CASE STUDY

Shape Grammar rules and implementations on Latch Mirrors

The decorations on the door latch mirrors of Safranbolu's traditional houses are directly linked to the social status of the householder, with each latch featuring a unique design. Maintaining diversity and originality in these latch mirrors, which continue to be produced as unique pieces today, is essential. The analysis of these door latch mirrors is crucial for the development of new products. Therefore, it is necessary to examine the existing door latch mirrors first.

When the door latches in Safranbolu traditional residential doors are examined, the shaping of the door latches consists of two stages. These are: (1) the shaping given to the main form of the metal plate, and (2) the decorations made on this plate with fullness-emptiness and marks on the plate. A combination of certain geometric forms characterizes the basic form of the door latch plate.

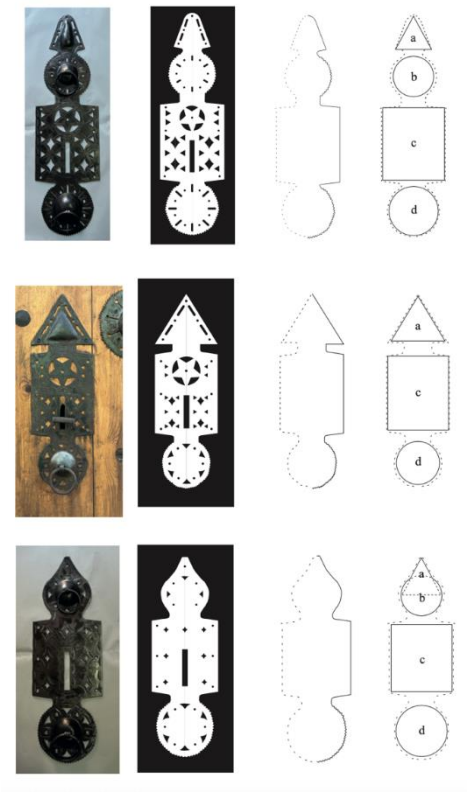


Figure 5. Door latch form and components

After determining the main layout of the plate, it is possible to evaluate the works of creating various patterns on the plate by drilling/opening gaps or forging/marking by dividing them into groups within themselves. The boundaries of this grouping are determined by the subcomponents of the main form (triangle, circle, rectangle, etc.). The variety of patterns is observed in the rectangular shape, which is the main component of the plate. However, variations in other components are limited for dimensional reasons. The center section of these components is forged into a concave shape and the edges are patterned. Therefore, the patterns are linear or radial. The limiting element is the key blank in the rectangular shape (latch mirror). Because past key sizes were relatively large and standardized, this key blank on the latch mirror is distinct, fixed, and features a striped rectangular pattern on the plate surface. Its position is in the center, near the underside or the top of the plate throughout the central axis. In the present examples, although there are exceptions, the key blank naturally defines boundaries that are not visible, especially for producing blank patterns. These limits include a certain combination (Figure 6). Certain geometrical elements are brought together in a linear, radial, grid, or mixed pattern for the pattern on these borders. Although these boundaries are different, the craftsman's general sensitivity to symmetrical balance in the holistic order leads to repetitive solutions in the compositions.

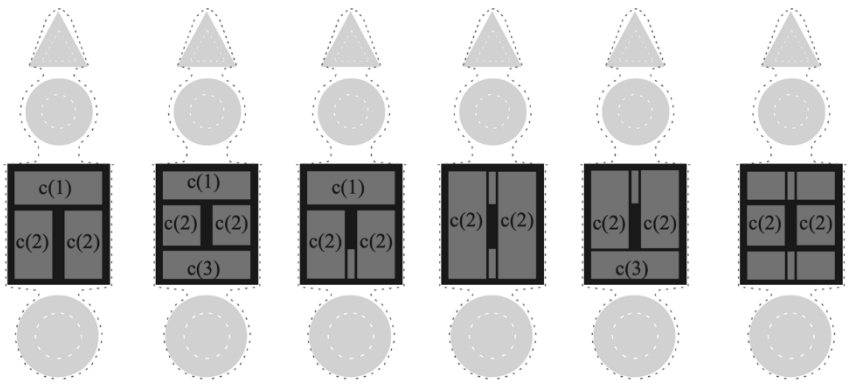


Figure 6. Details of the combination of plates

Basic elements such as circles, thin and long rectangles (with or without chamfered short sides), triangles (with straight edges or arc-shaped edges), and quadrilaterals (with straight edges or arc-shaped edges) are used for blank creation (Figure 6). Among these, the triangular elements used to form the star symbol are mainly preferred. Circular and quadrilateral elements are usually found together in the compositions. The large square or nearly square shape is found only in one or two examples. Thin and long rectangle elements are also mostly applied in other components of the plate (triangle and circle).

Finally, the latch mirror design is completed by repeating patterns around the plate layout in a zigzag or "set symbol" pattern. These patterns may not be present in each of the components of the main layout, may be of a different type, or may be repeated a different number of times (see examples of latches in Figure 3).

FINDINGS: PROPOSAL MODEL

This chapter comprises of a set of parametric and interactive applications to assist designers in decision-making and alternative generation has been made by the Rhinoceros-Grasshopper plugin. These practices encompass five stages: determination of the main layout of the plate, creating rectangular plate ornaments, designing knocker section ornaments, fashioning upper head ornaments, and incorporating additional ornaments. This study primarily concentrates on the use of ornamentation in rectangular plates.

Rectangular plate ornament

The door latch mirror is defined as a "Rectangular plate" because of the shape of the plate where the key blank is situated. As mentioned in the analysis section, the position of the key blank is substantial for determining shapes on the latch mirror. The key blank can be positioned vertically in the center of the rectangular plate. While the key blank dimensions can be parametrically adjusted, it's worth noting that the key dimensions are typically standard, so there is usually no need to change them. Once the key blank layout is decided upon, the designer manipulates five different sets of design production areas for creating blank compositions. In other words, the rectangular plate is divided into sub-surfaces and these sets are solved independently. At this stage, it is up to the designer to ensure a cohesive composition on the plate or to establish the relationships between them.

The designer selects one of these sets and creates compositions for them. The harmony among the compositions in the set is achieved by applying the rule of symmetry, as the craftsman practices. The designer had the flexibility to adjust layout dimensions or create sub-layouts based on the design, incorporating vertical or horizontal orientation partitions and making parametric dimensional changes. Meanwhile, there are trade-offs involved in making dimensional interventions to the layouts. This means that the other layouts increase simultaneously when one layout's size decreases.

As mentioned in the previous sections, in the case of the latch mirror, the craftsman creates patterns by drilling or forging in the shape of specific elements, usually in a radial or grid pattern. Therefore, within the specified layouts in the model, the designer can create examples of grid and radial patterns that can be applied independently or in combination. When applied together, eliminations are made in the grid patterns that remain in the area of the radial ones. The geometric elements determined in the analysis are used in these ornament designs. Although these elements are essential geometric elements (circle, triangle, quadrilateral, etc.), they are customized by adding various transformation elements and making them available in a single module.

In the radial arrangement, geometric elements are placed around certain orbits according to the number determined by the designer. The designer also determines the number of orbits, which can be increased or decreased depending on the size of the layout boundaries. In the model, radial pattern elements extending outside the layout are deleted. The distances between orbits are variable. These distances determine the limit of the dimensions of the geometric elements. The designer can change the dimensions and shapes of the elements between these boundaries. The craftsmen's behaviors reveal that they chose this arrangement to achieve the star form in the arrangements. However, they produce variations by using different elements (such as circles and rods) in this order. It is, therefore, possible to create patterns with this model by using elements other than the triangular elements describing the star form.

Grid arrangements are often observed in the analyses conducted in areas on the sides of the key blank or beside the radial arrangement at the top of this plate. Three or four geometric shapes can be placed next to each other horizontally and repeated several times vertically. Accordingly, the designer defines the number of rows and columns in the model. The border determines the spacing of the grid layout by scaling according to the layout dimensions. The arrangement creates patterns by grouping the input data generated by Boolean operations and deciding which type of geometric elements to arrange next to each other. The choice of geometric elements and their combination in the arrangement is at the designer's discretion. Therefore, it is possible to choose different types of elements not used by the craftsman.

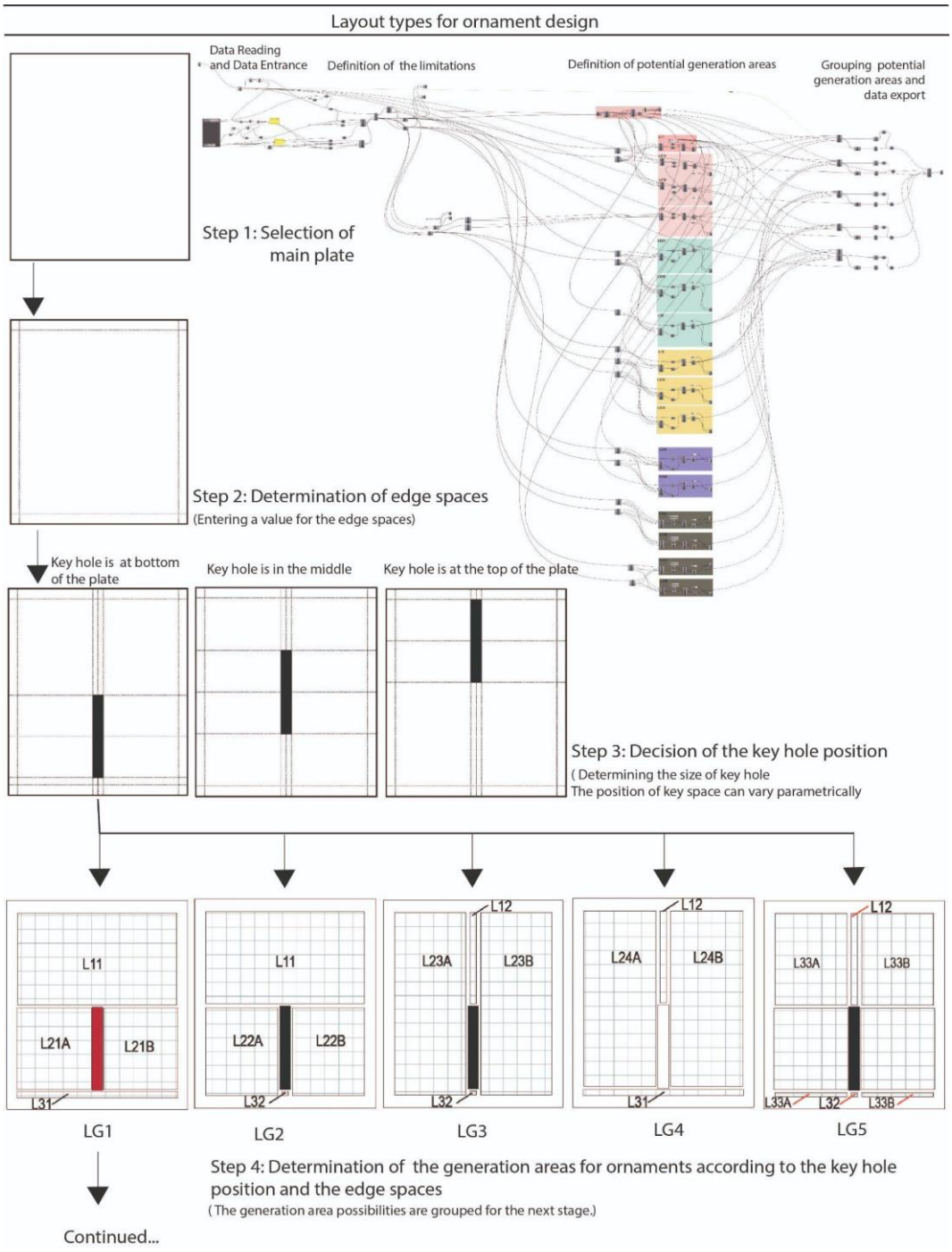


Figure 7. Ornament design process for the rectangular plate (latch mirror)

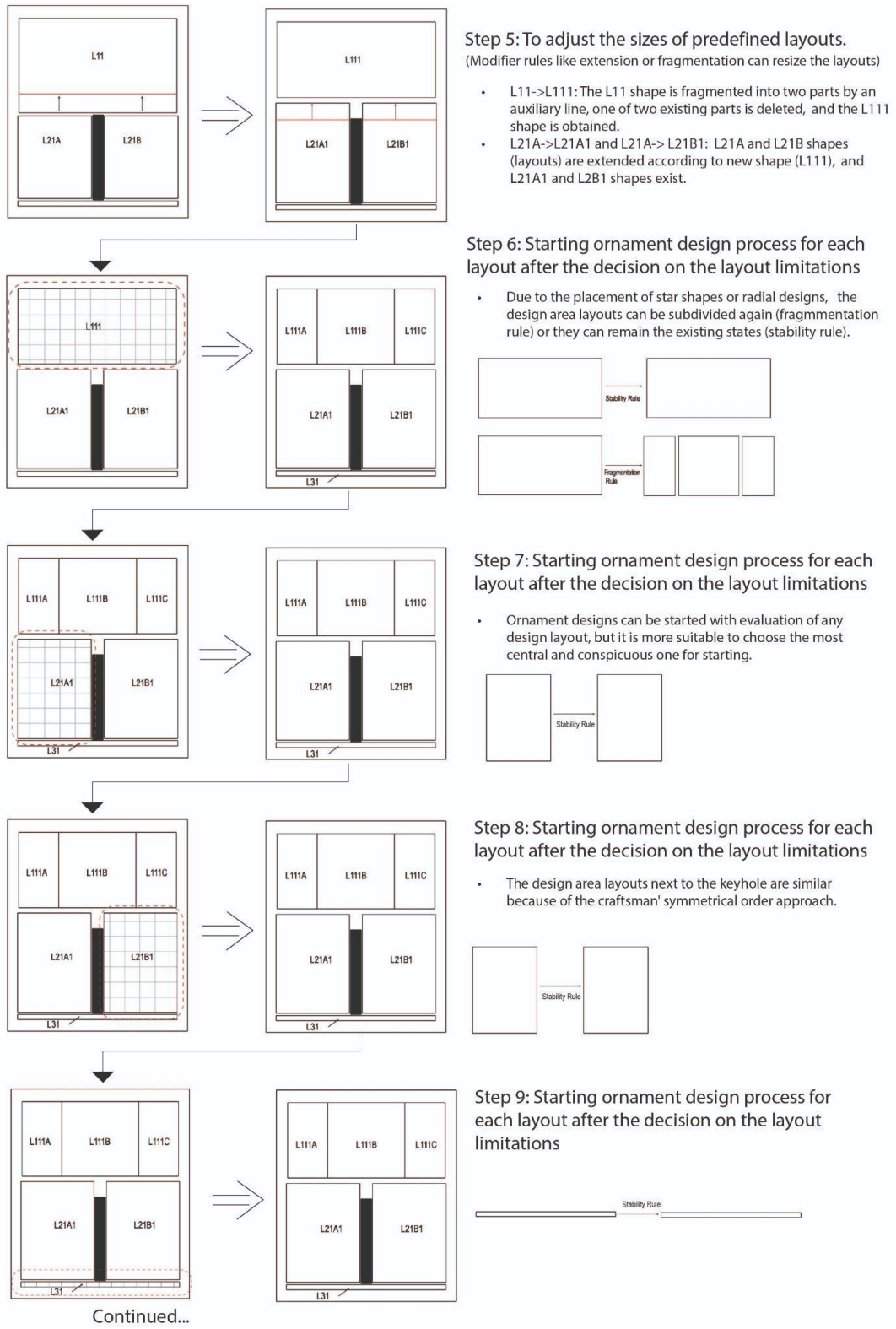
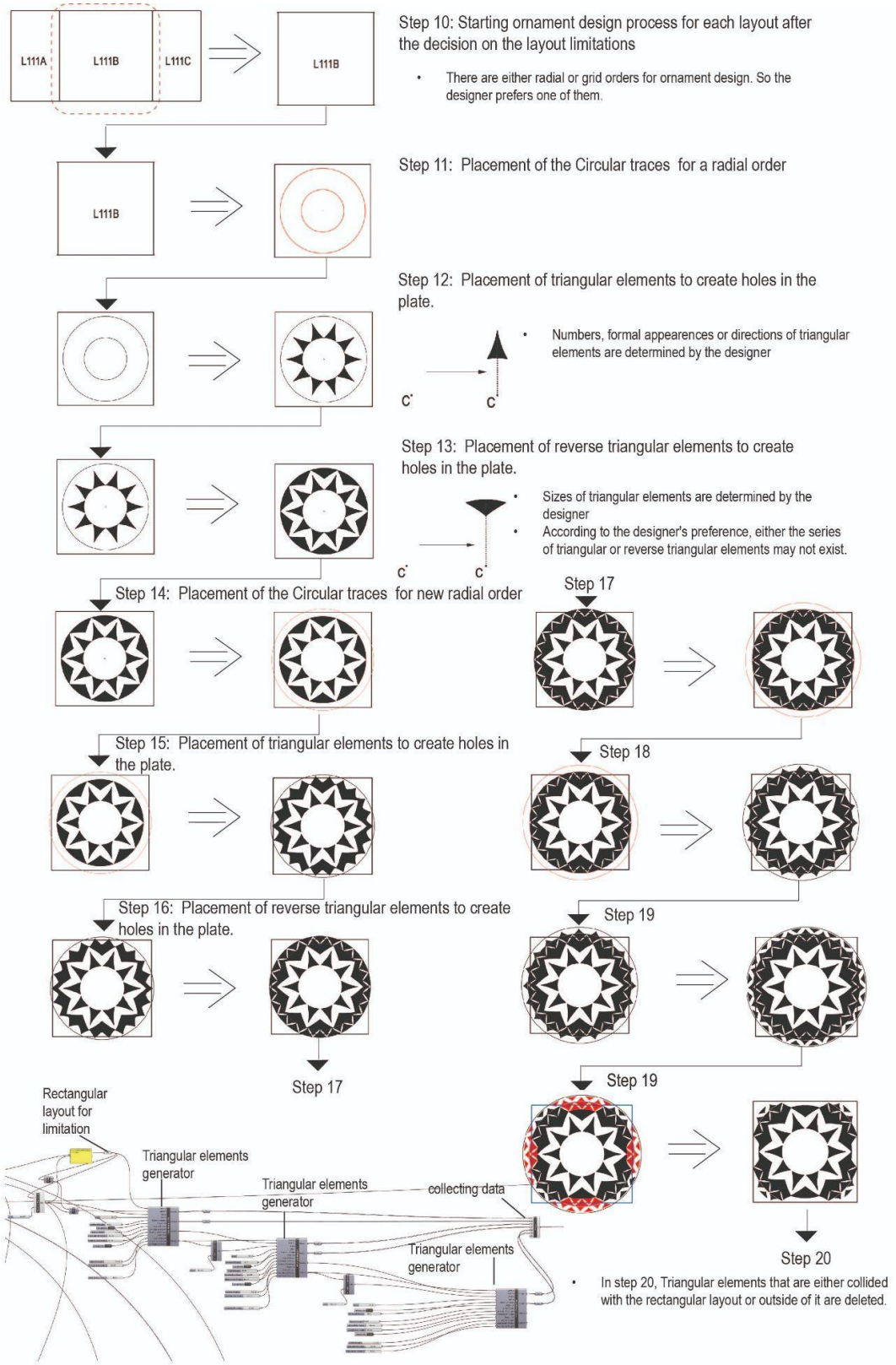


Figure 7 (continued). The ornament design process for the rectangular plate



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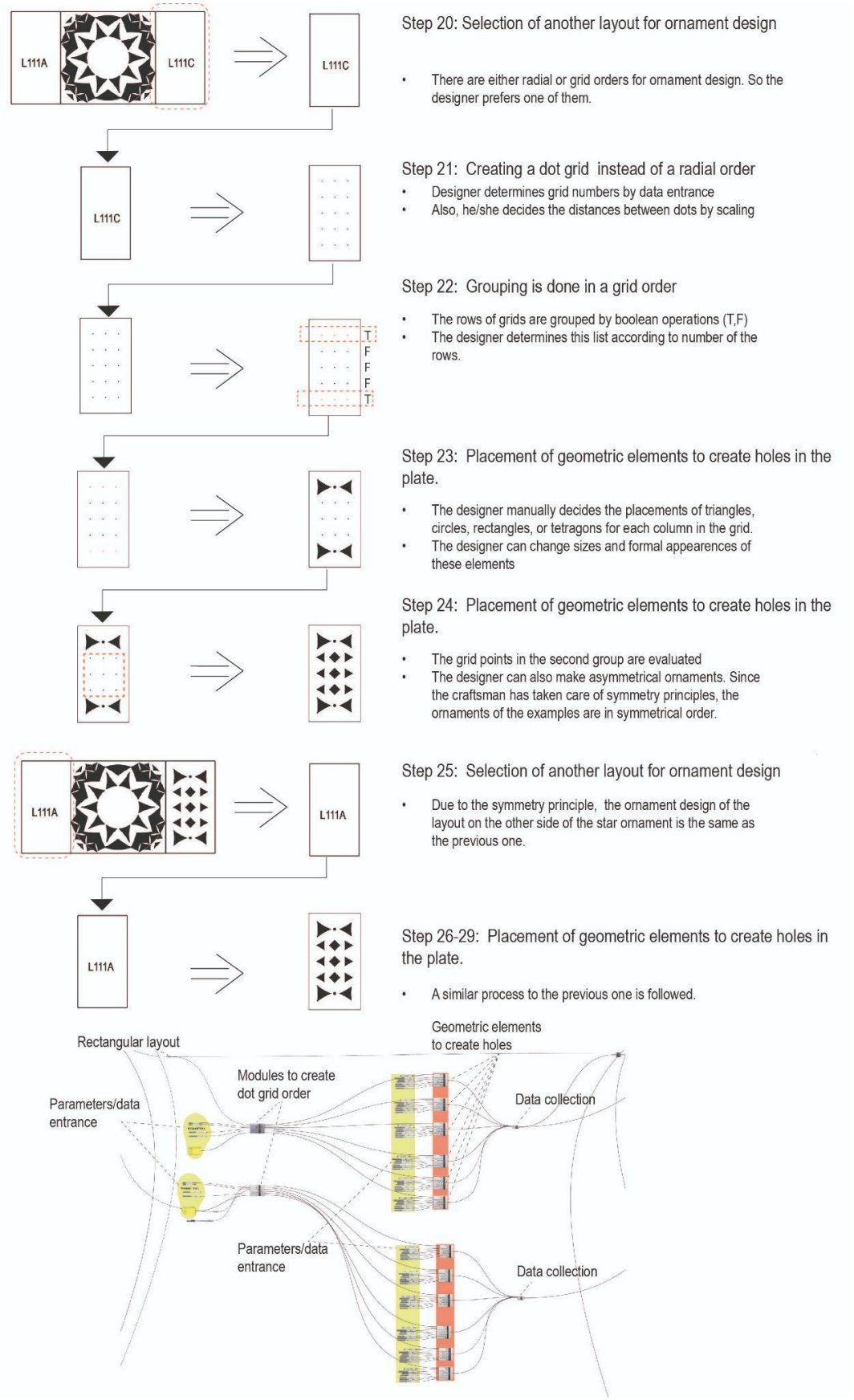

Figure 7 (continued). The ornament design process for the rectangular plate

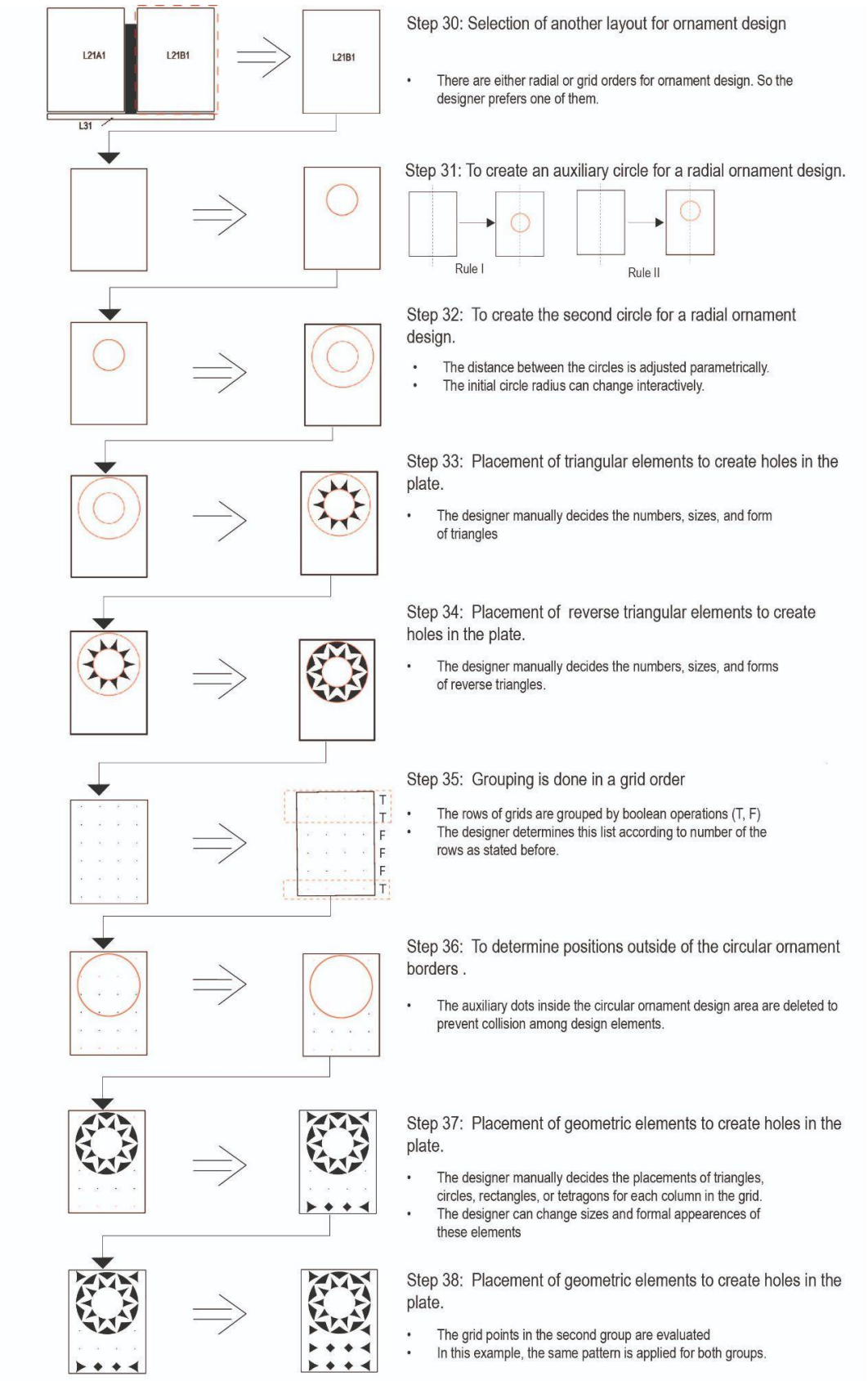

Figure 7 (continued). The ornament design process for the rectangular plate

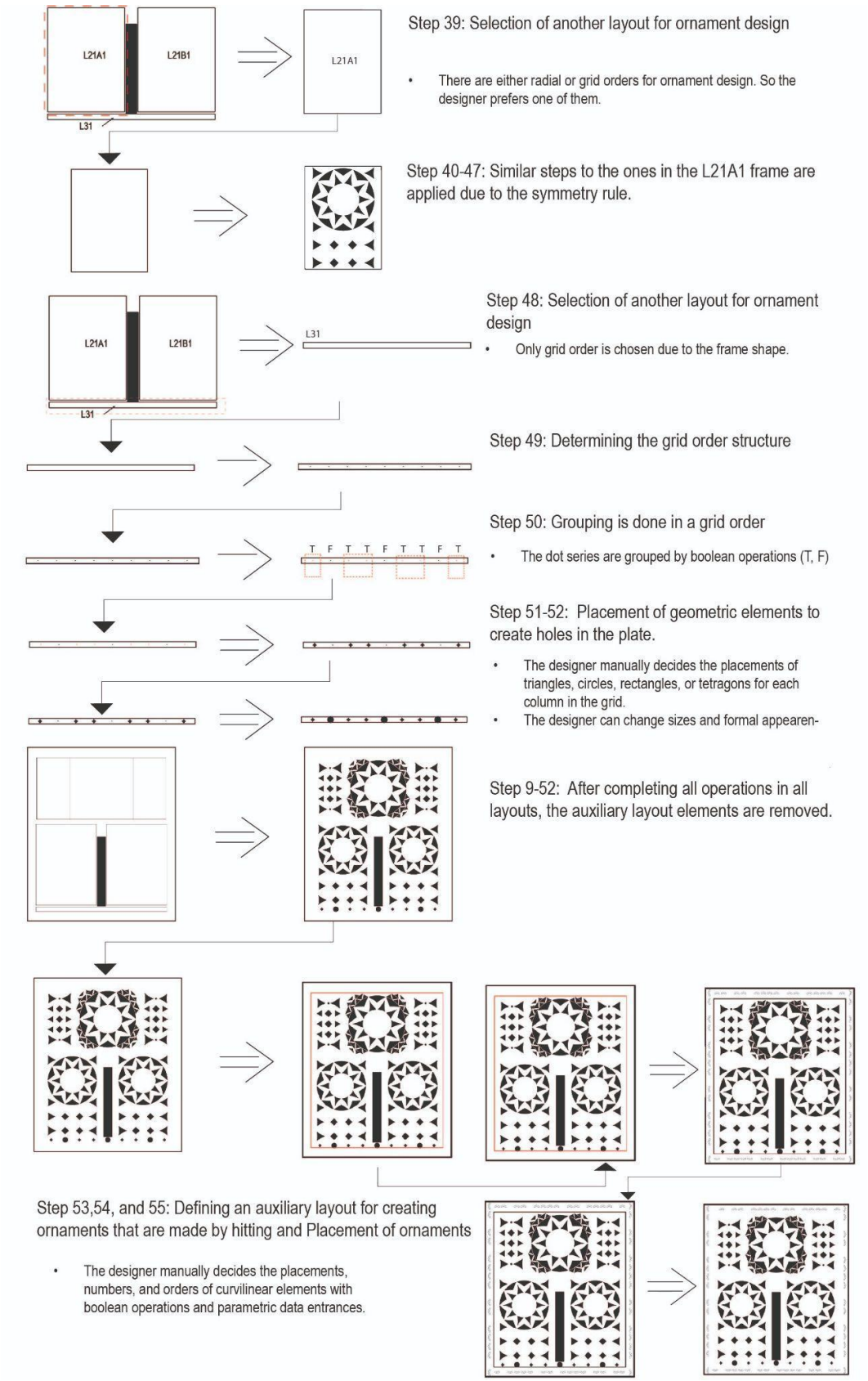

Figure 7 (continued). The ornament design process for the rectangular plate

The geometric elements in the patterns are shape elements and vocabularies. Centers of these elements, the points used for their placements in the grid order, and Boolean sets (true and false) affecting their creations are shaped rule sets. After choosing one of the elements as an initial shape, the other elements are placed on the grid or radial order according to the rule set, and thus a new shape set is obtained. This set becomes one of the new rules as subtraction elements to be used for raw iron plate, which is the initial shape. At the end of the process, after completing and applying the layout solutions as rules, an ornamented latch mirror emerges.

After or during the design process of the geometric elements for the drilling process in the layout sets, the design of the compositions for the grinding process is started. In the model, around the rectangular main plate, around the key blank or around individual geometric elements, the grinding process is sampled with triangular or quadrilateral-shaped traces in an arc form. The harmony between elements is made through scaling. This process can create grouped arrangements in the model with subtraction applications according to the pattern order defined by the designer through “boolean” operations.

Sample Implementations

Alternative patterns were generated on the latch mirror to expand the ornament repertoire. Some of them resembled the designs of the craftsmen in Safranbolu, while others differentiated. In Figure 7, these patterns were categorized based on the layout. We demonstrated the potential for variation in the interactive model by modifying specific design criteria. These changes were implemented step by step. The processes performed on them can be explained as follows.

In the LG1 layout example, a star symbol created by iterated radial order was positioned. Triangular elements in grid order were set out on the layouts near this element. On both sides of the key blank, basic design elements in the grid are placed in symmetrical order, and different patterns are defined in each row. The external layouts are designed with traces in an arch form and blanks in a circular shape. In the second example concerned with the LG1 layout, circular elements were designed behind the star ornament in the center. In the third example, the new elements were added to the star ornament, and the sizes of elements of the star ornament were changed. In the last example, a design like a star ornament was arranged on both sides of the key blank. Here, the elements in the existing grid order that collided with the new star ornaments were deleted as stated before.

In the second layout design (LG2), the sizes of layout were changed, as shown in the model explanation. Unlike the LG1 layout example, stick elements were preferred in both radial and grid ornaments. Around some basic elements, more knocking examples were applied. The key blank radial orders were designed on both sides in this layout example. In addition, the patterns next to the star ornament are different from the others. The design approaches of LG2-Ex2, LG2-Ex3, and LG2-Ex4 are very similar, but there are differences in the numbers and sizes of the used elements in each of them. In this LG2 layout example, different alternatives were generated on the exterior layouts.

In the third alternative (LG3), all layouts consist solely of grid layout examples. The grid layout has definitions for various types and sizes of elements in specific rows.

In the fourth alternative (LG4), all layout examples feature a combination of grid and radial arrangement patterns. These examples not only showcased the integration of different patterns but also demonstrated variations in the placement of radial arrangement examples at the top, middle, or bottom. Although the approach remained consistent in the grid arrangement, some elements in the arrangement have been modified, their dimensions varied or transformed into curvilinear forms. This type also included an example of forging within some internal layouts.

In the last type of layout (LG5), entirely new layouts were created. These layouts offer solutions that are in harmony with the overall design. In the examples, the numbers and sizes of the elements that defined the star shape changed gradually. Also, different compositions of quadrilateral elements were tried.

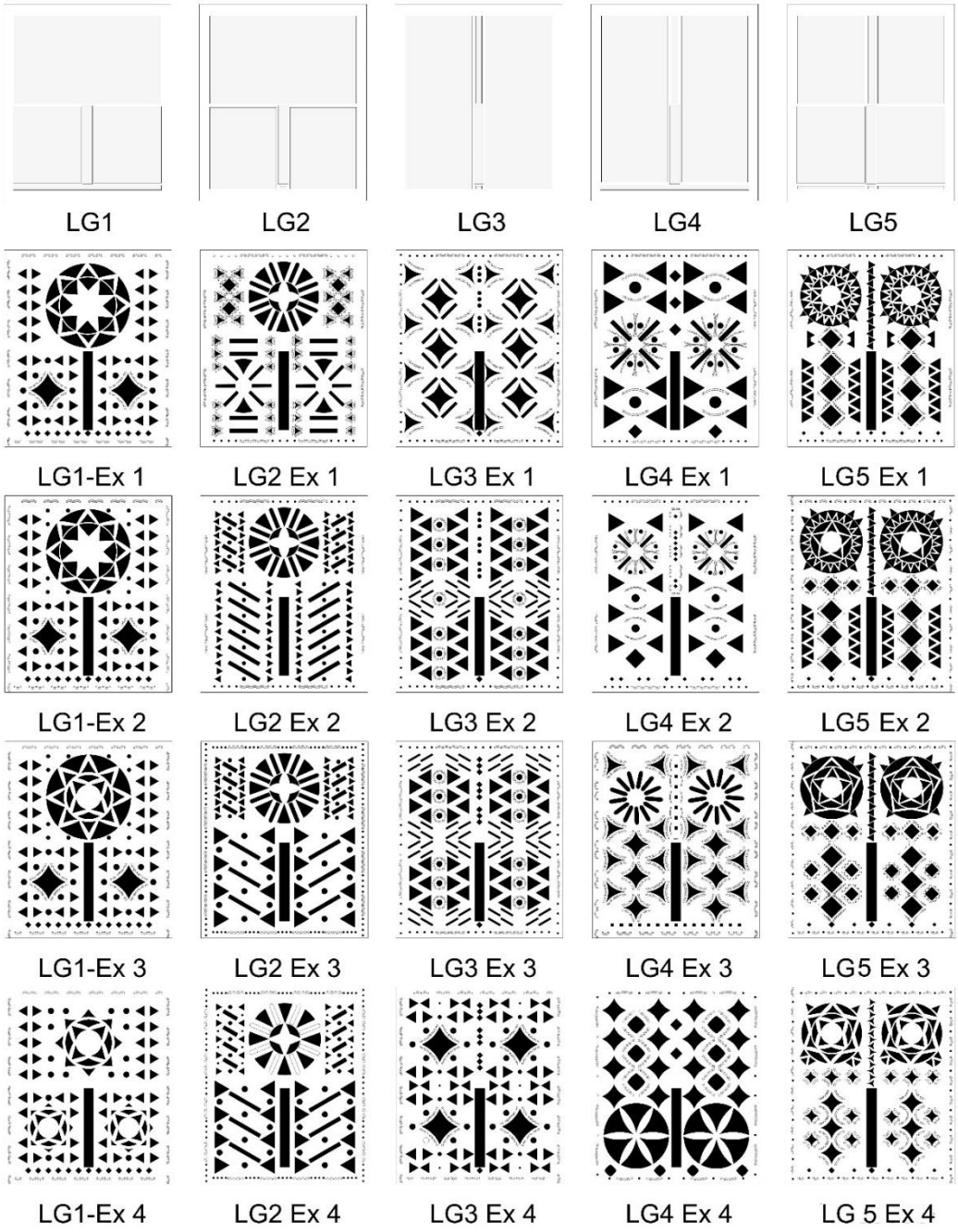

Figure 8. Alternative pattern practices

CONCLUSION

The knowledge acquired by craftsmen through the master-apprentice relationship has persisted to the present day with little or no alteration. However, as craftsmen adhere to traditional methods, they may require assistance developing new techniques, which could eventually challenge their ability to sustain craft production in Safranbolu. Thus, for the development of new products, the study begins by conducting a morphological analysis of latch mirror patterns on a doorknocker, an example of traditional craftsmanship, using the shape grammar approach. This analysis aims to ascertain the feasibility of new product development. Drawing from the designer's subconscious knowledge, this analysis employs a language structured by parametric design tools, enabling the generating of new variations. Ultimately, the study provides a

mathematical representation of tacit knowledge in a craftsman's design comprehension and seeks to support craftsmen in harnessing modern production methods to foster their products. As a result, the latch mirror patterns appear to be similar to each other with limited compositional elements; however, analysis experience has shown that there is a potential diversity with minor variations in the existing examples.

The implementation phase, the second step of the study, has demonstrated that the dimensional or formal differences in the arrangements made by puncturing, voiding, or knocking and the spatial differences in how the elements get together can increase the corpus of variations. The rules among the elements are flexible, and open to development according to design conditions. In other words, the probability, and rules of putting the basic elements together in this study can be increased by "seeing" and "doing" approaches. The craftsman can enrich the design configuration by adding new rules and making interventions for the next step after evaluating the design produced in the previous phase. There is no constraint between them. The ornaments in the craftsmen's implementations have a determined grid or radial order. There is very little randomness. In the repetitions, grid and radial orders have been restrictive criteria. In the model, the generation areas were defined for ornament. As mentioned before, the latch surfaces can be parametrically segmented into larger or smaller areas for generation. These segmentations define newly grouped basic design elements on the upper scale. Expanding alternative ways contributes to holistic design variations. These elements, whose basic limits are determined, provide ease of creating a whole for designers. Thus, besides allowing flexibility, the model leads designers to think systematically about the steps in a craftsman's production process.

When the latch mirror ornaments are considered together with the main shape of the doorknocker and its other components, the scope of this corpus will expand further. It is possible to say that these alternative proposals can, at the same time, become data that can be evaluated in today's popular machine-learning processes and AI implementation.

Authors' Contributions

The authors contributed equally to the study.

Competing Interests

There is no potential conflict of interest.

Ethics Committee Declaration

It is not a study that requires ethics committee approval.

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Figure References

Figure 1: Göktaş-Kaya, L. (2010). Geleneksel kapı halka ve tokmakları: Safranbolu. *ZKÜ Sosyal Bilimler Dergisi, 6*(12), 341-369.

Figure 2, 3: Author's personal archive, 2023.

Authors' Biography

Ege Kaya Köse holds a Bachelor of Industrial Design degree from Anadolu University (2011), a master's degree in interior architecture from Marmara University (2016), and a Ph.D. degree in Industrial Design from Gazi University (2021). She is currently working as an assistant professor at Ankara Yıldırım Beyazıt University, Department of Industrial Design. Her research interests are participatory design, collaborative design, and cultural studies in industrial design.

Ahmet Emre Dinçer graduated from ITU, Department of Architecture, in 2005. He received Master's and PhD degrees from the ITU Graduate School of Science, Engineering, and Technology in 2008 and 2014. He received the titles of assistant professor in 2014 and assistant professor in 2023. While in the private sector between 2005 and 2009 years, he worked as a research assistant and asst. professor at Karabük University between 2009 and 2023. He has been working at AYBU since February 2023. His main research areas are architectural design computing, architectural design, and building design.