Random Pattern Generation Method Using Shape Grammar and Application to Clock Dial

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Abstract

Computational design has the advantage of being able to quickly test the possibility that humans will take a long time or not reach it. However, dealing with many of them requires programming skills and is a tricky tool for many designers. So, Stouffs and Li (2020) are developing a computational design tool that requires no programming skills. The Shape grammar program is a tool that creates rules for visually replacing shapes and adapts them to the specified initial shape. This tool gives the user many design choices without any programming or other techniques. There are various ways to use it, but this time we will propose some versatile knowledge and specific application examples in a limited area. In this research, we make use of the characteristics of the program and propose a method of generating a random pattern using regular hexagonal Tessellation and a method of folding it. The dial and grille of the watch, a concrete example of uses of the pattern, are also introduced in this paper.

Keywords: *Shape grammar, Computational design, Pattern*

1. Introduction

In recent years, there have been proposed several techniques for designing in collaboration between computers and humans. Computers give us a myriad of options, given the conditions. As a result, it is valuable for humans to explore options that can take an enormous amount of time and discover unforeseen contingencies. On the other hand, dealing with many of them requires programming skills, making them awkward for many designers and the general public. Another disadvantage is that it is difficult to prototype on a shape basis through programming intuitively. The shape grammar developed by Stouffs and Li (2020) has been proposed as one of the computational design tools that are intuitive and easy to use without programming. Shape grammars are composed of initial shape and rules. This rule replaces shape A with shape B (If the original shape has shape A). You can choose from all the results that can be generated by the rule each time, or you can apply the rule repeatedly a certain number of times. You can also create multiple rules. Also, the shape here is considered to be the same even if it is inverted, rotated, scaled, or moved. An example is shown below.

Example 1

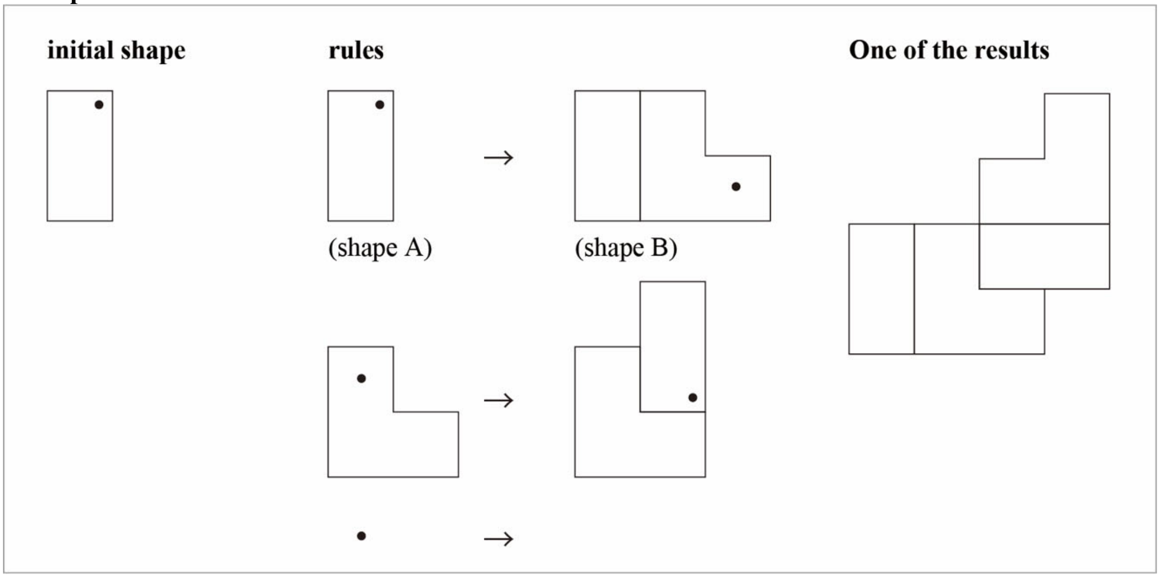

Figure 1-1 Shape grammar example1

In this way, if the shape, after applying the first rule includes the left side of the second rule, it is possible to apply the second rule next. It ends by applying the third rule. Fractals can be generated depending on usage.

Example 2

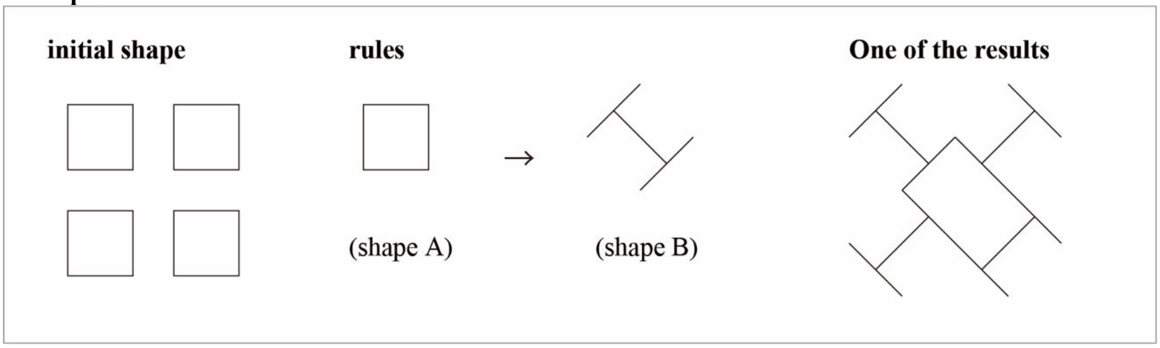

Figure 1-2 Shape grammar example2

It is also possible to include a lot of left sides of the rules in the basic form in advance and apply the rules sequentially to them. As you can see from Example 2, squares are congruent even if they are rotated 90 degrees, so there are two layout patterns for each basic square. If I dare to write it difficultly, the square is a congruent shape even if it is rotated 90 degrees or turned upside down, so there are eight views in all, but the result of replacing all the cases on the right side of the rule is Since there are only two types, we only have two placement patterns here. Even if this combination becomes more complicated, one of the functions of this shape grammar is to verify all cases obtained by the rule and show all the results except duplicates.

2. Objectives

In the shape glamor developed by Stouffs and Li (2020), it is possible to apply the rule to the basic shape that is tiled like Example 2. Also, with this tool, figures are considered to be the same when flipped, rotated, scaled, or moved, as described above. Therefore, when the right side of the rule is a rotationally symmetric or symmetrical line figure, the direction and the front and back of the figure are randomly selected each time the rule is applied. By utilizing this function, we believe that it is possible to create a "random" pattern that does not seem to be repetitive of the same shape at first glance. You can try a new pattern by just editing a rule shape a little, and of course, if you recalculate with the same rule, a new combination pattern will be created. In other words, it is possible to easily create several random and constant density patterns using only the initial shape of the Tessellation and one rule. The purpose of this study is to create and apply the random pattern using shape glamor, and to sublimate it into concrete works. I aim to be an example of the usefulness of shape glamor.

3. Materials and Methods

3.1 How to create a random pattern

This time, we try to generate a random pattern using a method similar to Example 2 (Figure1-2).

Shape grammar is composed of initial shapes and rules, and when applying it, directions are randomly assigned. Here, the initial shape plays a role of defining the overall size and outline, and the rule is one of the elements that define the pattern, and finally, the pattern is completed by being randomly arranged.

3.1.1 About initial shape

In order to spread a figure on a plane, it needs to be a Tessellation. It is also desirable that they are regular tiling in order to rotate and invert them to generate randomness. It is known that there are three regular plane filling shapes: regular triangles, squares, and regular hexagons, which is because a regular hexagon has the largest number of sides, and many variations can be created under the same constraints.

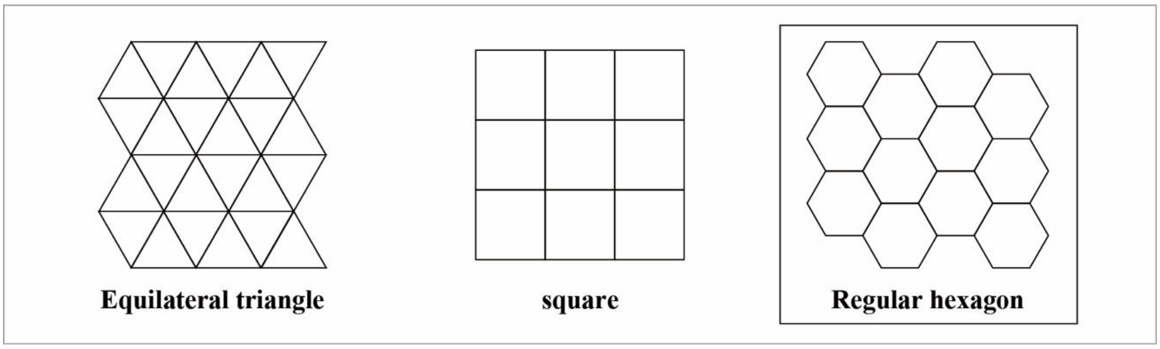

Figure 3-1 Regular tilings

In the mere Regular tiling as described above, adjacent figures share edges, so if the figures are replaced as they are, the adjacent regular hexagons will lose edges. To prevent this, scale down the hexagons and rearrange them. Initial shapes are created by this procedure. The number can be adjusted depending on the case. However, the figure below shows an example of the initial shape of the minimum unit that can confirm the connection in all directions. Patterns are created by replacing the shape that fits in the original plane-filling size hexagon with this small hexagon.

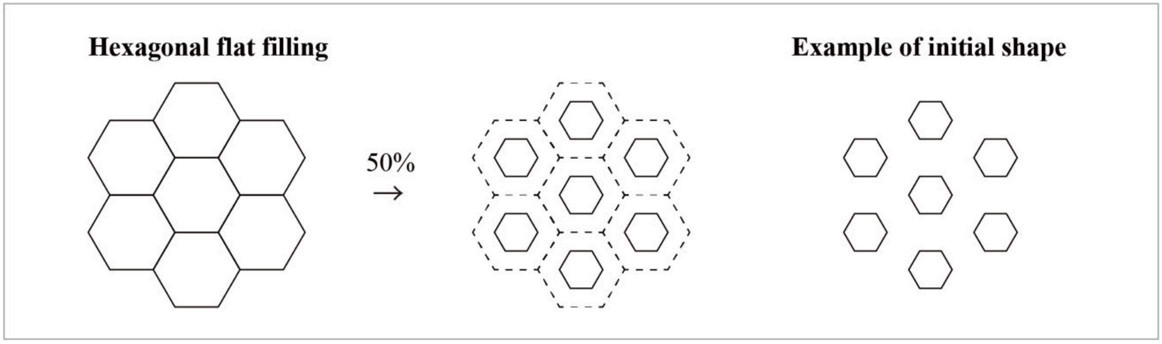

Figure 3-2 Initial shape generation procedure and an example of an initial shape

3.1.2 About the rule

Next, the requirements for rules for creating random patterns are summarized.

Consider one of the scaled-down regular hexagons described above as the left side of the rule and the right side as the size of the original plane-filled hexagon. In order to avoid finding that the same figure is repeated, the replacement figure requires 1) eliminate the outline of the original figure, 2) do not create a closed figure or intersection, and 3) create a connection with other tiles. Besides, to stabilize the structure because it can be shown as a surface or a line as a random pattern, it is necessary that 4) no excessive overcrowding is created, and 5) all lines are connected to both ends. Based on the above requirements, the following preparation conditions were determined.

- It passes through the midpoint of all sides of the regular hexagon of regular tiling (1), (3)
- It is rotationally symmetric (4)
- It is one-stroke, and the end is connected to the adjacent shapes (2), (5)

Also, the following condition is added based on the restrictions of this program and the fact that adjacent blocks do not intersect.

- Use straight lines (do not use curves)
- Within the range of regular hexagon of tiling

In other words, a set of straight lines drawn through the midpoint of all sides of the regular hexagon and within the range of the regular hexagon with rotational symmetry is set as the starboard of the rule.

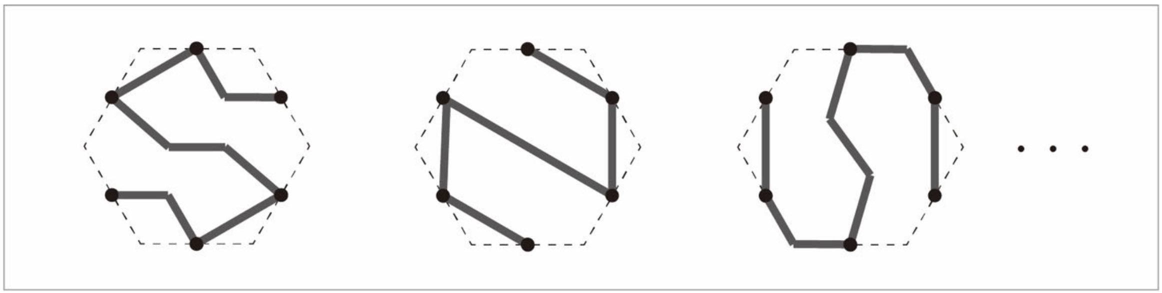

Figure 3-3 Right side example of a rule based on the above conditions

If the first rule in Fig. 3-3 is applied to one hexagon of the initial figure, the hexagon is rotationally symmetric and line-symmetric, so there are 12 possibilities. Since the left side of the rule is also 180 degrees symmetrical, one of 6 possibilities for one hexagon will be randomly selected each time.

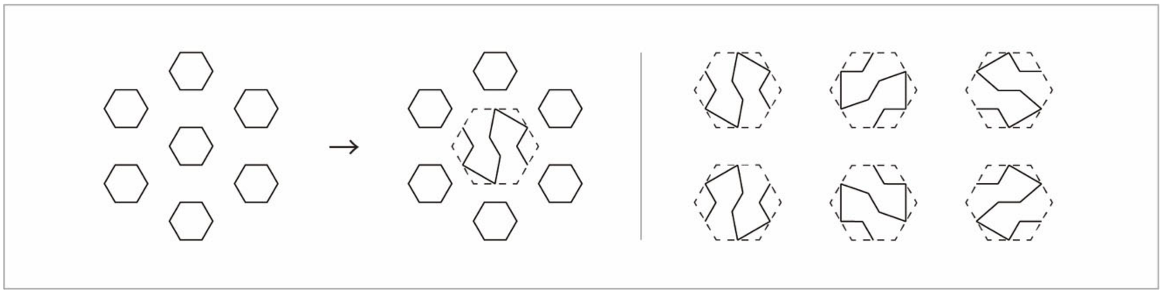

Figure3-4 An example of options that can be created once the rule is applied

3.2 Material

In the case of simple 2D data, this random pattern can be expressed both planarly and linearly. For a two-dimensional expression, a wooden board can be cut with a laser cutter and used as a puzzle, or it can be painted in different colors and printed as a paper design or a textile design. On the other hand, if the right side of the rule or the initial shape is 3D, it will be possible to output it with a 3D printer after adding thickness to create 3D data.

4. Results and Discussion

4.1 Planar pattern creation results

The prototyped rules and their application examples are shown below. Here, for the sake of explanation, seven hexagons are used as initial shapes.

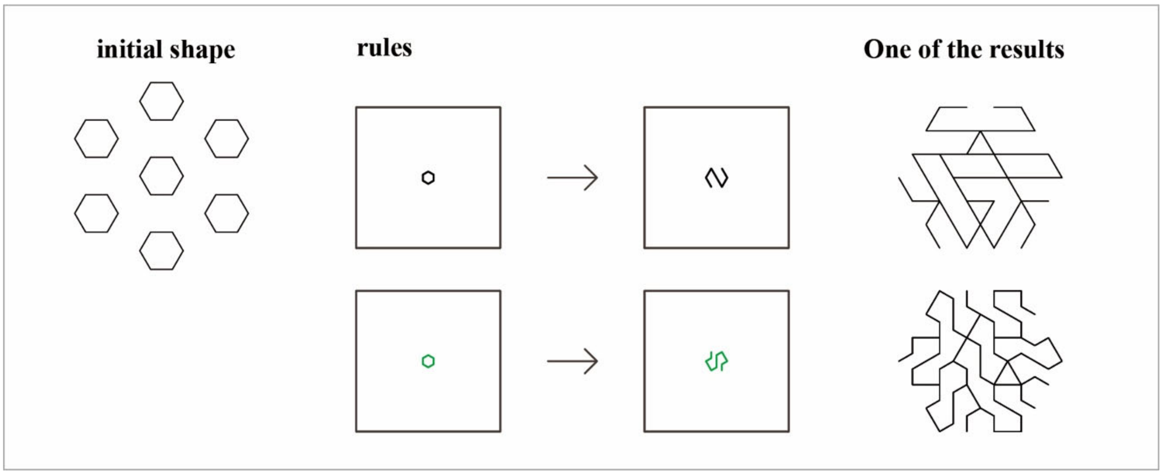

Figure 4.1 Prototype rules and examples of their application

As described above, it was confirmed that a pattern having a high degree of randomness was generated to some extent if the above-described creation conditions were satisfied.

4.2 3D development of random patterns

In developing this random pattern in 3D, I will also explain it by dividing it into basic forms and rules.

4.2.1 3D deployment of rules

Make each replacement form undulating. By moving the figure on the right side of the rule in the Z-axis (up and down) direction, it is possible to undulate each replacement figure. The number of points that can be moved is limited because it must pass through the midpoint of each side of the original plane-filled hexagon. As in the condition of section 3, move here also in point symmetry. By moving the right side of the first rule in Figure 3-3 in the Z-axis direction, the following undulating pattern was created.

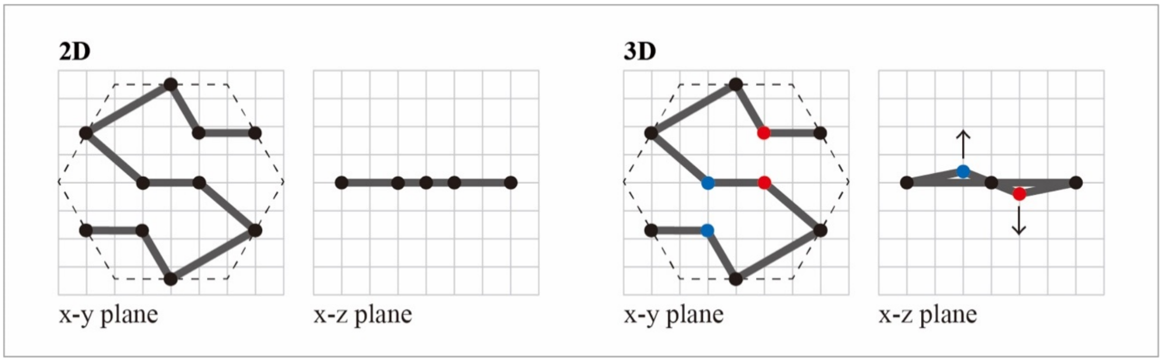

Figure 4-2 Example of 3D deployment of rules

4.2.2 3D development of the initial form

Consider whether the surface can be raised while maintaining the connection of each line after applying the rule. If all hexagons are replaced, adjacent figures will contact each other at the midpoint of each side of the plane-filled hexagon. Therefore, if you extract the midpoints, you can see that they are lined up in three directions, as shown below. In other words, if this filling plane is bent in this linear direction, the line connection will not be interrupted.

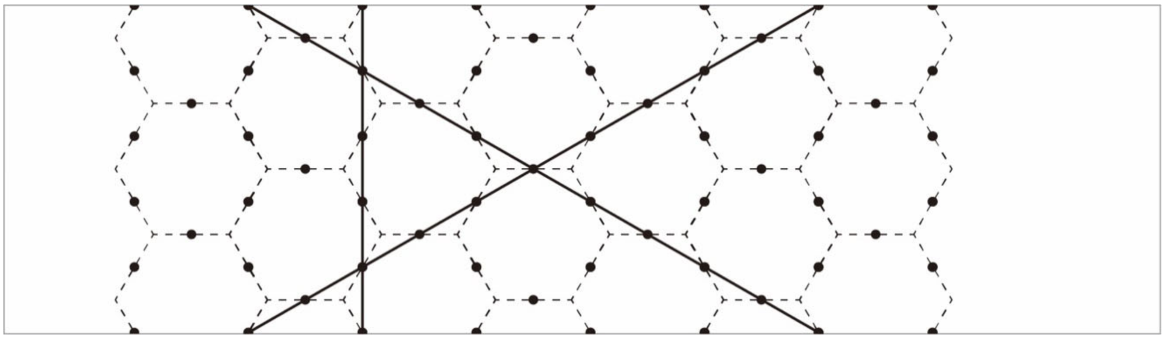

Figure 4-3 Bending direction of the initial shape for connecting random patterns without interruption

By bending along the straight line shown in Fig. 4-3, the initial shape could be created as follows, for example. The three-dimensional random patterns that can be generated by applying rules to these initial shapes are shown in the next section.

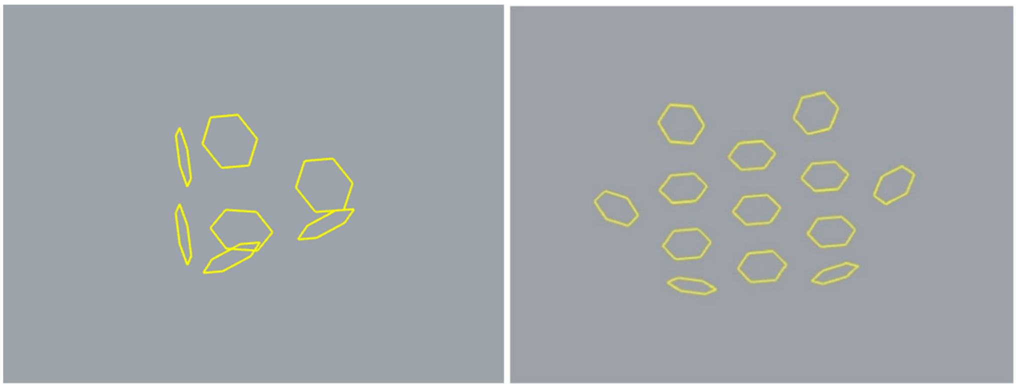

Figure 4-4 Two possible 3D initial shapes in which random patterns are connected without interruption

4.3 Concrete works

As a concrete example of the use of these random patterns, we will make a wall clock dial and grill. Both the dial and grill adopt the basic shape with protrusions in 6 directions on the right side of Fig. 4-4. The rules apply the 2D rule of Fig. 4.2 to the dial and the 3D rule to the grill. Twelve protrusions are created by placing the dial and the grill facing each other and displacing them by 30 degrees.

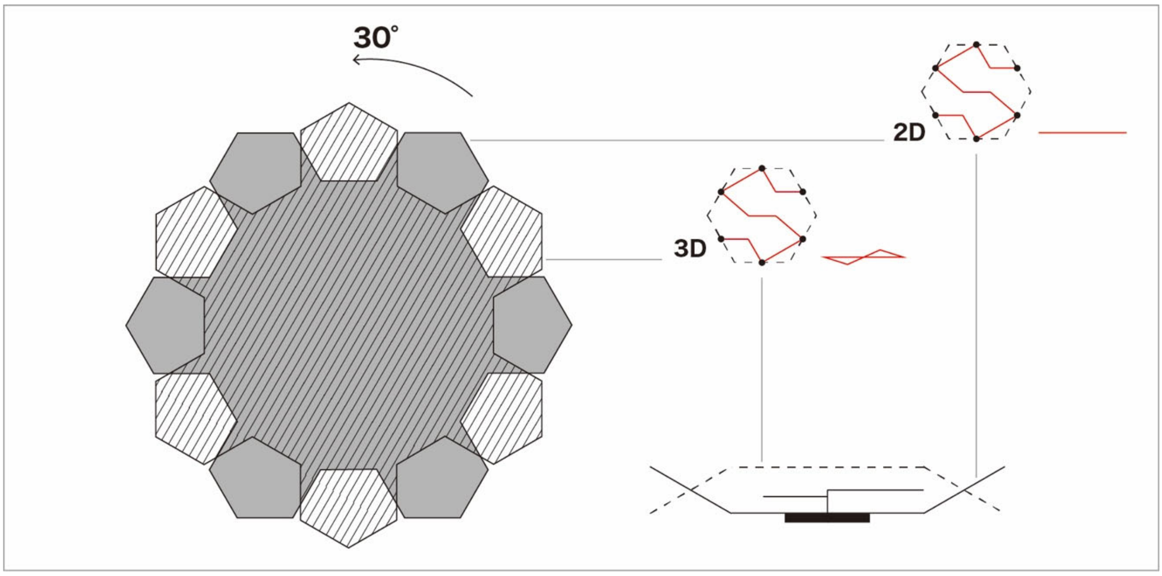

Figure 4-5 Diagram of clock face and grill

The figure below applies the rules for the dial. The circumference is surrounded to maintain the shape.

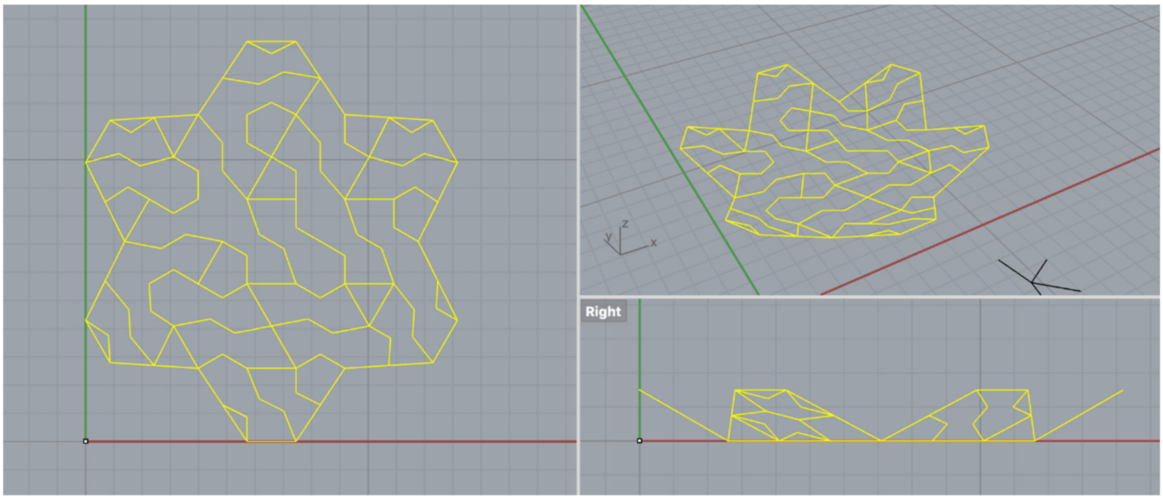

Figure 4-6 After applying the clock face rules (the line is added to the edge)

This time, I made it using only two rules, 2D and 3D, and one result each, but even with the same rule, each rotation and reflection direction is randomly determined so that a different pattern can be made each time. It is also possible to create rules other than those shown here by utilizing or applying the creation conditions in Section 3.1.2.

Each line of the pattern created here was given thickness, and a surface was attached to the dial to create solid data. By outputting it with a 3D printer, the following works were made.

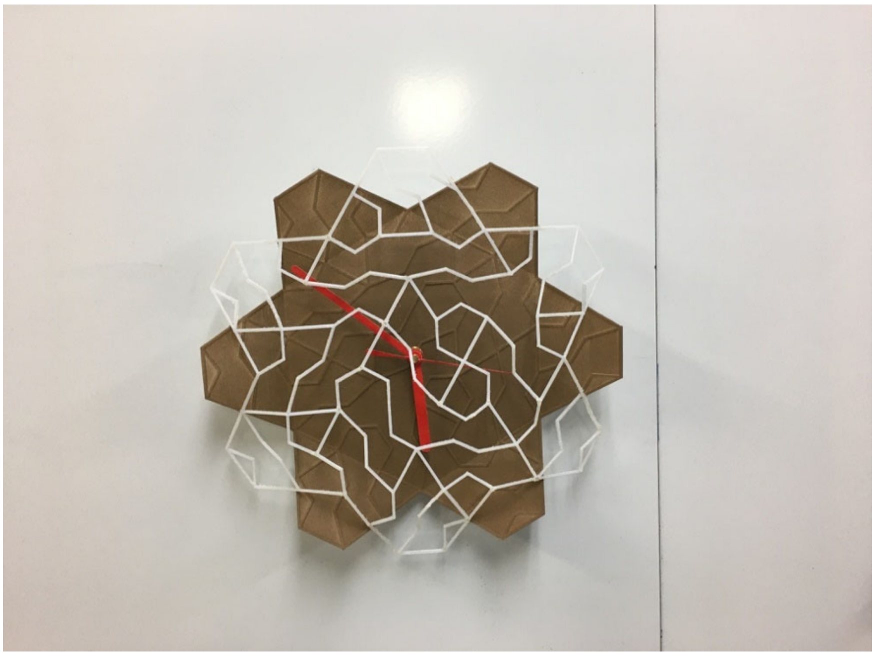

Figure 4-7 Picture of wall clock made

5. Conclusion

In this paper, I proposed a method of creating and applying random patterns based on planar filled regular hexagons. This paper showed that a shape grammar could be used to create a pattern with some density and complexity, and how to fold the pattern without breaking it. The clock face and guard are shown as specific examples of use, but the method of creating this pattern should apply to various fields with various scales and materials.

By using Stouffs and Li's shape grammar, you can create many random patterns simply by specifying the initial shape and rules. It is no exaggeration to say that I, who has no programming skills, can consider many such random patterns, which is one of the achievements.

6. Acknowledgements

I would like to thank Professor Li for giving me the opportunity to write this dissertation and for teaching me about shape grammar. I would also like to thank Reo Yasue for giving examples and advice in writing this paper.

7. References

Stouffs, R., & Li, A.I. (2020). Learning from users and their interaction with a dual-interface shape-grammar implementation. *Proceedings of the 25th international conference on computer-aided architectural design research in Asia CAADRIA 2020.*