

LEARNING, PROTOTYPING AND ADAPTING

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INDUCED GROUP AND SYMMETRY GROUP THEORY: GENERATING NEW DESIGNS FROM KNOWN ONES

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Abstract. Symmetry Group theory has been extensively used to analyse pattern design not only in a design field but also in other fields, such as art history and anthropology. However, there is a rare study that focuses on how to utilize symmetry groups in generating new pattern designs from known ones. Induced group theory is an expansion from Symmetry Group theory that can be used to create constructive patterns. This paper shows how to incorporate both theories in generating new design patterns along with a designated design unit. This study will provide a new idea on how to incorporate theories of pattern analysis into a practice of generating new pattern designs.

Keywords: Pattern; symmetry group; induced group; generative design; design unit

1. Introduction

Combination of Induced Group and Symmetry Group theories gives a new perspective in creating a new design. This paper will be started with a definition of symmetry group and induced group theory, continued with creation of new design patterns from a designated design unit with symmetry group theory, and creation of new design patterns by utilizing both theories, symmetry and induced group.

Symmetry Group theory (Woods, 1935; Stevens, 1981; Washburn and Crowe, 1988) has both finite and infinite groups, with infinite ones found under seven one-dimensional classes and seventeen two-dimensional classes. A pattern that has a repetitive design unit means that the pattern has symmetry, and the design unit repeats in only four motions: rotation, reflection, translation, and glide reflection. The set of motions of the symmetry is systematically

defined under classes within Symmetry Group Theory. If a pattern shows no translation then it is classified under finite group; if a pattern demonstrates translation in one-direction, this means that the pattern goes under a one-dimensional group; while the pattern that displays translation in more than one direction goes under a two-dimensional group.

Symmetry Group theory has expanded by the introduction of “induce group” theory (Grunbaum and Shephard, 1987; Hann and Horne, 1996). Induce group involves one-point symmetry that is inserted into the symmetry group classes (Figure 1), and shows the detail explanation of induced group:

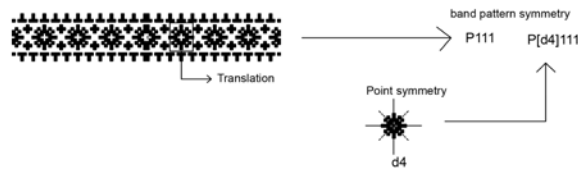


Figure 1. Symmetry pattern and Induced group

Figure 1 illustrates a pattern that is considered as one-dimensional symmetry, since it only admits translation in one direction, and is based on the symmetry group this pattern is a $p111$ class. However, each design unit in the pattern has its own symmetry which is a $d4$. Therefore Grunbaum (1987) and Hann (1996) introduced an induced group theory that inserted the unit design class into the symmetry group class, so the class name is $P(d4)111$ instead of $P111$. So far, both theories of Symmetry Group and Induced Group offer limited use in the pattern analysis. Therefore, this paper attempts to show how to utilize these theories to generate new design from the designated design unit.

2. Design unit

This paper uses one design unit as can be seen in Figure 2 below. The design unit is found by tracing the original pattern, which has been repeated in vertical and horizontal reflection. The design unit will then be used to generate a new design by using the Symmetry Group and Induced Group theory.

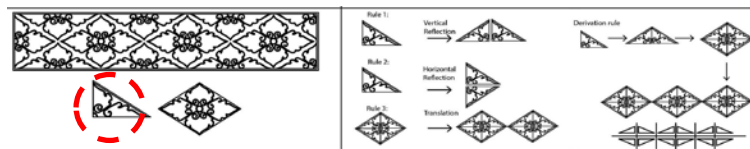


Figure 2. A design unit in the red dash circle (source: Pebryani and Kleiss, 2017)

3. Pattern generation

3.1. SYMMETRY GROUP THEORY

Symmetry's rigid motions consist of four types: rotation, reflection, translation, and glide reflection. For the seven one-dimensional groups, there are four generally accepted notations, $pxyz$. Each begins with p . If there is a vertical reflection, then x is m ; otherwise, x is 1. If there is a horizontal reflection, then y is m ; if there is a glide reflection but not a horizontal one, then y is a ; otherwise, y is 1. If there is a half-turn, z is 2; otherwise, z is 1 (Washburn and Crowe, 1988).

In this section we will apply the set of motions from the one-dimensional symmetry group theory into the designated design unit. This paper only focuses on one-dimensional symmetry group classes (Table 1). It shows the new seven pattern generation.

INITIAL UNIT DESIGN	
p111	
p1m1	
pm11	
p112	
pmm2	
pma2	
p1a1	

Table 1. New design from symmetry group theory

The new pattern shown in Table 1 is generated by using symmetry group theory. From these seven, one is the original design (pmm2) of the design unit. Therefore, this theory does not give a creative new design pattern. In the next session, induced group theory will involve the process of creating new design patterns. In the next session, induced group theory will involve in the process of creating new design patterns.

3.2. INDUCED GROUP THEORY

In this section, we created a new design unit distinctive from the previous one. Figure 3 shows three new design unit generations.

- **The first new design unit:** is created by rotating in 90-degrees, which considers a finite design as c_4 .
- **The second new design unit:** is created with reflection then continued with rotation which considers a finite group of a d_4 designation.
- **The third new design unit:** is created with rotation then continued with reflection, with no classes under this symmetry group supporting this particular set of motions.

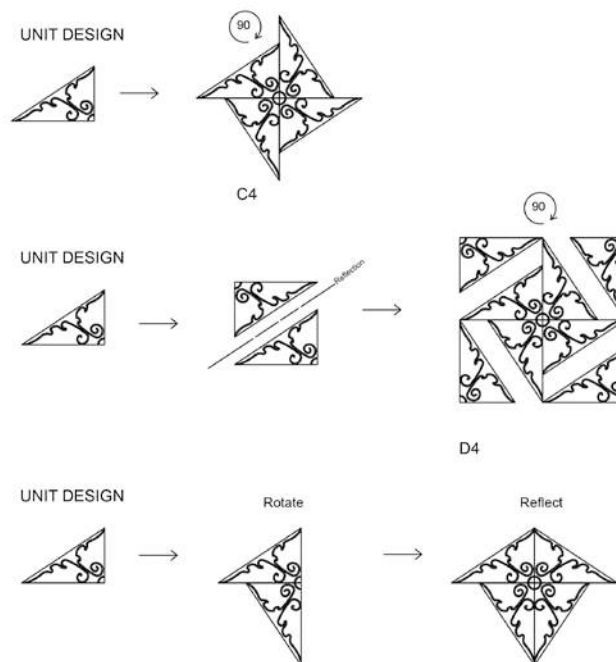


Figure 3. New design unit generation

Once the new design unit has been generated, then the process will be continued by incorporating the symmetry group's one-dimensional set of motions with the new design unit as can be seen in Table 2. This paper only uses the set of motions from the one-dimensional portion of symmetry group theory.









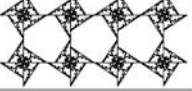













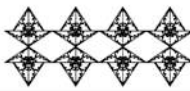








INITIAL UNIT DESIGN			
p111 			
p1m1 			
pm11 			
p112 			
pmm2 			
pma2 			
p1a1 			

Table 2. New patterns design from Symmetry Group and Induced Group Theory

Three design units generated twenty-one new one-dimensional patterns, and from these patterns there are five that can be expanded into a tiling pattern. Periodic tiling has a repeating pattern with no overlaps and has specific gaps. Images below show some of the designs.

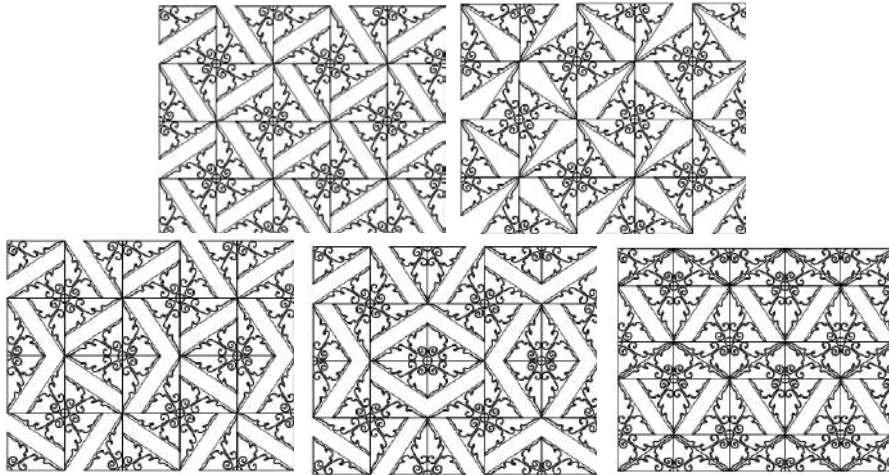


Figure 4. New tiling design

4. Conclusion

Understanding the structure of the pattern based on the symmetry analysis is important to deduce the design unit and the motions that are repeated within the design. Induced theory gives an understanding that in order to generate a new design from a known unit, we must rearrange or recombine the current design unit to create a new one — before involving the symmetry group's set of motions in generating a new design. In this study, the set of motions that have been determined within the symmetry group classes provide a template in creating new designs.

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