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Research Article

Developing the framework of harmonised shape grammar to regenerate traditional textile patterns from northern Thailand

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Abstract

This article focuses on pattern designs of "sin tin chok", a type of traditional skirt from northern Thailand. Its lower section ("tin chok") is a woven fabric comprising frieze patterns. Harmonised Shape Grammar (HSG) can assist in the design process to achieve harmonized and meaningful designs. We developed the generic framework of HSG to suit a specific context, so that the pattern sets in "tin chok" can be regenerated. We applied this framework to six pattern sets decoded from vintage skirts. This framework consists of five levels of analysis (identifying shape elements, identifying fundamental units, identifying/ understanding a set of rules, generating frieze patterns, arranging frieze patterns on the design structure). We find that their shape elements can be classified into trilateral shapes and quadrilateral shapes. There are 24 fundamental units confined to rectangular spaces. "Tin chok" is designed to have four parts: a main part, two supplementary parts and a hem. By applying the rules of seven frieze groups, a fundamental unit for each part can be generated to seven design derivations. There are 28 possibilities for design derivations per set. However, only 12 possibilities for design derivations appear. Among these, only three out of seven frieze groups are employed.

Keywords: Design structure, Frieze group, Harmonised shape grammar, Symmetry analysis, Textile pattern

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Introduction

This article presents multidisciplinary research that involves the design of "sin tin chok", a type of traditional skirt from northern Thailand, its pattern designs, symmetry analysis and shape grammar. It is initiated by three of us who have a common interest in pattern designs. Chudasri is a design researcher, who has been researching indigenous woven textiles in Thailand. Recently, she applied visual and symmetry analysis in design research that examines the pattern designs of "chok" fabrics in relation to weaving methods and cultural adherence, continuity and change. Sukantamala is involved in symmetry analysis because he is a mathematician, specializing in ethno-mathematics, traditional art and culture, especially handwoven textiles. He is also looking into applied mathematics in other knowledge domains. Kunkhet joined us because he wanted to develop a generic framework for Harmonized Shape Grammar (HSG) that is applicable to real case studies. Having seen traditional textile patterns and a flow chart for classifying frieze patterns based on their symmetries (Figure 7), he commented that symmetry analysis is applicable to a set of shape rules in the generic framework of HSG. Symmetry analysis is critical knowledge that brings us together. In this article, we intend to develop the generic framework of HSG further to suit the specific context in which traditional textile patterns will be regenerated.

1. Pattern, design, symmetry and cultural significance

The word *"pattern"* means a repeated decorative design (Washburn & Crowe, 1988, p.ix; Oxford University Press, 2019). For example, a design composed of a set of lines, shapes and colours (Macmillan, 2009-2022) that are repeated and arranged in an orderly sequence (Christie, 1929, as cited in Washburn and Crowe, 1988, p.8). A pattern comprises "the repetition of a motif, or motifs, at regular intervals. Motifs may be either symmetrical or asymmetrical. A symmetrical motif is a figure which is comprised of two or more parts of identical size, shape and content; each identical part is known as a fundamental unit" (Hann & Thomson, 1992, p.1). Traditional patterns can reflect some aspects of past culture and/or some aspects of present culture (Hann, 1992, p.581). *Traditional patterns* are those considered by indigenous informants to have been produced for several generations by using similar techniques, and those patterns have not undergone significant change even when they are produced in recent times (Hann, 1992, p.581). The *design structure* of traditional patterns from any given cultural group shows their unique preferences for a cultural system in many aspects, for example, cultural and historical principles, geometric principles in practice (Washburn and Crowe, 1988, p.ix; Hann & Thomson, 1992, pp.2, 55). Within a given cultural group, there will be a preferred symmetry or symmetries used to decorate objects (Brainerd, as cited in Hann and Thomson, 1992, p.8). Their group will consistently use specific symmetries in their design systems (Washburn & Crowe cited in Hann and Thomson, 1992, p.55), for example the design of "sin tin chok" from Long district, Phrae province in northern Thailand (Figure 1). Handwoven textiles and cloth-making are an intangible cultural heritage of the local people. "Sin tin chok" is designed to comprise three parts: a waistband, a body section, and a lower section. Its lower section ("tin chok") is a woven fabric comprising frieze patterns (Figure 1: right). "Tin chok" was originally designed to have four parts: one main part, two supplementary parts (above and below the main part) and a hem (Figure 1: right). Hence, we use the phrase "pattern set" to mean a set of four frieze patterns placed in "tin chok" according to this design structure. The use of geometrical symmetries on decorative objects represents the union of two disciplines–mathematics and design (Washburn and Crowe, 1988, p.ix). Symmetry classification is an analytical tool, which anthropologists, archaeologists and design historians use to examine traditional patterns, and indicate cultural adherence, continuity and change (Hann & Thomson, 1992, p.55; Hann, 1992, pp.581, 589).

Figure 1 "Sin tin chok" from Komol Phaboraan Museum, Long district, Phrae province
source: Chudasri, 2018

2. The need to revitalize traditional handwoven textiles in Thailand

There are three general observations about traditional makers; they are involved in a life-long process of making artefacts, embrace culturally significant meaning in making, and create artefacts from memory (Gilsdorf, 2012). For example, weavers usually use weaving techniques that they are familiar with making textile artefacts that have a cultural meaning for them. They develop textile patterns from what they see in their local environments, such as "stylized birds, plants and flowers and abstract patterns of squares, diamonds, hooks, hexagons, and zigzags" (Conway, 1992, p.141). They memorise many thread-counts – in both the weft and the warp as well as symmetric properties, but they do not usually write patterning down (Conway, 1992, p.9). Instead, they pass on textile knowledge to the next generations by giving them textile artefacts such as clothes; those ones with complex patterns are usually kept for a reference (Conway, 1992, p.9). In Thailand, there is a variety of traditional handwoven textiles and these represent an intangible cultural heritage (ICH) of Thailand (Intangible Cultural Heritage, 2019; Ministry of Culture, 2009). In the last two decades, the number of weaving communities in Thailand has been declining and few young people are being trained in weaving. Traditional weaving is likely to be lost in the near future unless sufficient action is taken to elicit and record this knowledge and enable knowledge transfer between weaving masters and younger generations (Chudasri et al., 2020). Designers are encouraged to get involved in design for cultural revitalization (Walker & Evans, et al., 2018). It is also critical to enable our understanding of the designs in traditional handwoven textiles and cloth-making, including their design structure and patterns – and correlate them with cultural significance.

3. Harmonised shape grammar

In 2015, Kunkhet introduced "harmonised shape grammar" (HSG), a generic framework that can assist in the process of design development. It can be applied to a specific context of design practice to generate a set of harmonized and meaningful designs. The generic framework of HSG was developed based on an existing concept of "shape grammar" initiated by Stiny and Gips in 1972. They adopted the concept of grammar from natural languages[1], but they conceived of grammar in terms of how shapes can be constructed and designed. This is known as the concept of shape grammar; it is a set of rules that are recursively applied to initial shapes/ forms that can be transformed into new shapes/ forms (Knight, 2000). For example, a square and a triangle, as initial shapes, can be used to create new shapes such as the shape of a house. Stiny and

[1] Natural languages are the languages, including written and spoken languages that humans learn and use in everyday life to communicate with each other (Harris, 1985).

Gips's initial method of shape grammar comprises two level of analysis: a shape level and a grammar level. Shape grammar can randomly generate massive derivations of shapes; however, design results may or may not be harmonised or meaningful or presented in diverse directions. The generic framework of HSG extends Stiny and Gips's existing method by adding two important levels of communication: semantics and pragmatics into design consideration. In terms of visual language, semantics and pragmatics can be considered as context and harmony, respectively. Context provides a design direction and produces only meaningful designs, whereby several units of design are syndicated in harmony as one whole design. The addition levels of design consideration in the generic framework of HSG can increase the quality of design, bringing about design results that are meaningful and harmonious with less time spent on generating a random set of massive derivations of shapes (Kunkhet, 2015).

The concept of "natural language processing" (NLP) was also incorporated into the creation of this generic framework of HSG. NLP is a subfield of linguistics, computer science and artificial intelligence that is concerned with how humans communicate through natural languages, how to program computers to mimic/generate and analyse the amounts of natural language data, and how humans interact with computer programs (Liddy, 2001). In computer science, NPL becomes a theory of computational techniques used to analyse text and speech communicated by humans (Harris, 1985). The NLP divides languages into six levels of linguistic analysis: prosody, morphology, lexicon, syntax, semantics and pragmatics (Liddy, 2001). According to Allen (1995, pp.10-11), prosody concerns the rhythm and intonation of a language, whereas morphology focuses on morphemes, the smallest unit of meaning in a language, which can be a whole word (e.g. the) or part of a word (e.g. "in" in inability). Lexicon concerns the meaning of all the words and phrases in a language and their functions (e.g. noun or verb) in parts of speech. Syntax is the rules about how words are arranged and connected to make phrases and sentences. This is known as a grammar structure, which can be used to analyse a structural dependency relationship between words. Semantics concerns the meaning of words and phrases and how they interact in sentences. Pragmatics determines the overall context of how language is used in particular situations to express a meaning or attitude that may not be obvious from the words themselves. A word can have different meanings, for example, "a bar" can mean a long narrow rod, or a place serving alcohol. To interpret what that word really mean depends on the overall context, including the sentence in which it appears and other sentences around it. Kunkhet's generic framework of HSG correlates with the five levels of the NLP: morphology, lexicon, syntax, semantics and pragmatics. (Prosody is omitted because it is about language intonation – the way in which the human voice rises or falls when someone speaks – patterns of sound and beats). In the context of HSG, morphology is a level of analysis that concerns shape elements (points, lines, planes), shape algebra[2] and their relationships. Lexicon analyses shape vocabulary, how shape elements mathematically form a shape. Syntax is a set of rules that explain the ways in which shapes can be operated to create new shapes/ forms, and these relate to the spatial relations and operations of shapes. Semantics analyses a design context and its meaning. Pragmatics analyses a harmonious design, including its attributes, characteristics and behaviour.

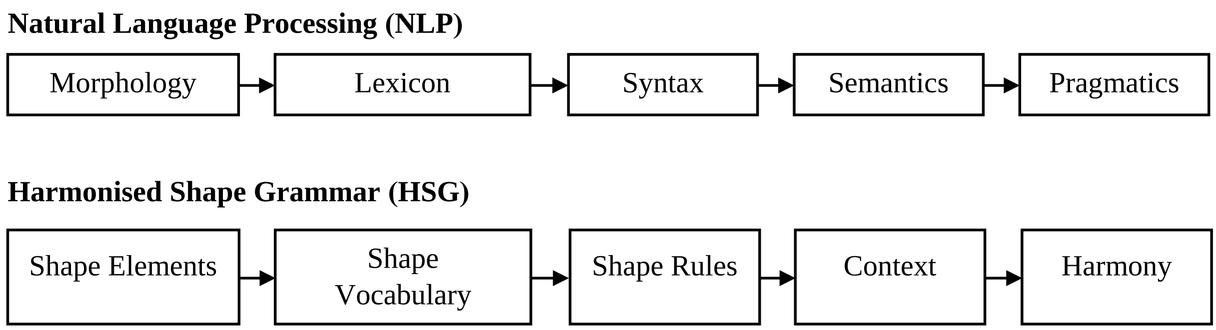

Figure 2 Correlation between the NLP and the HSG.
source: Kunkhet, 2015

[2] *Algebra* is "a type of mathematics that uses letters and symbols in place of numbers" (Macmillan, 2009-2022), for example $3X - 10 = 11$. *Shape algebra* is an algebraic formula to determine the perimeter, area, surface and volume of any geometric shape.

Research methodology

We aim to develop the generic framework of HSG further to suit the specific context in which traditional textile patterns will be regenerated. We relate this pilot study to another recent research that examined a set of 17 vintage "sin tin chok" that are exhibited in Komol Phaboraan Museum in Long district. We began this pilot study with six pattern sets (Figure 3) based on findings from our recent research. The pattern sets in these 17 skirts can be sorted into six groups indicated by their same symmetry classes in the design structure. Therefore, we selected one pattern set from each group to represent a different symmetry class for experimentation.

Figure 3 Six pattern sets.
source: computer-generated images from Chudasri, 2022

Based on the generic framework of HSG introduced by Kunkhet in 2015 (Figure 2), we develop it further for this specific design context of traditional textile patterns. Figure 4 shows the relation between the generic framework and the specific framework where these six pattern sets are objects of study. This specific framework of HSG consists of five levels of analysis, including identifying shape elements, identifying fundamental units, identifying/ understanding a set of rules for symmetry operations, generating frieze patterns, arranging frieze patterns in the design structure (Level 1– Level 5). All of these five levels are applied to the six pattern sets to demonstrate how traditional textile patterns can be regenerated.

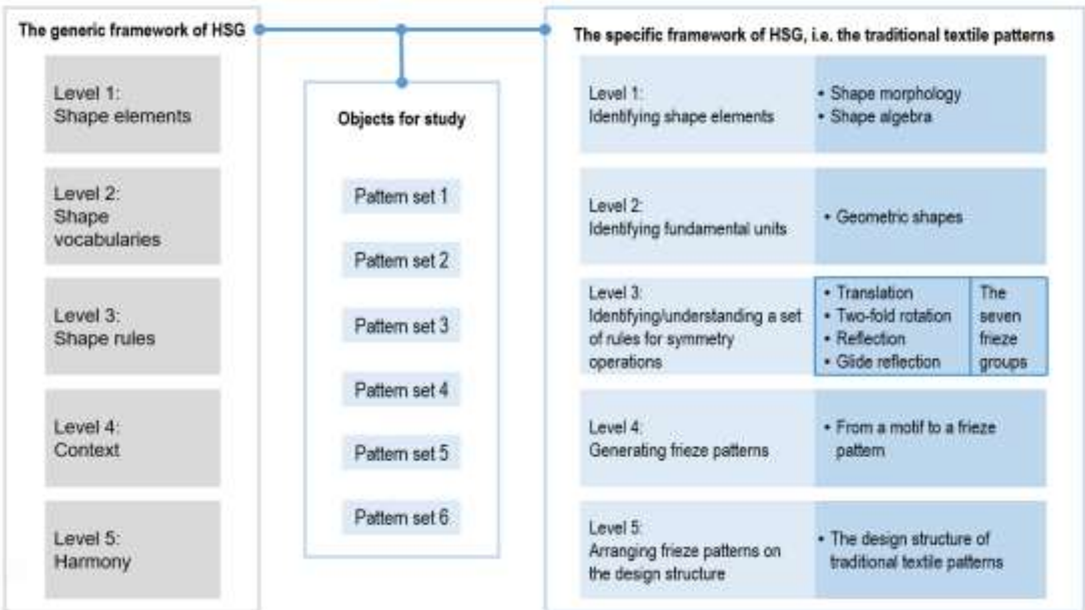

Figure 4 The relation between the generic framework and the specific framework of HSG.

1. Level 1: Identifying shape elements

In Level 1, elements of shapes are identified to inform identical parts. A shape represents a geometrical relationship amongst four basic elements: point(s), line(s), plane(s) and solid geometry. It must be defined with a non-zero dimension. A point is the smallest shape element. However, it contains a zero dimension so, by itself, a point is not a shape. A line can be defined with two points, one at the beginning and another at the end. A plane consists of line segments that are connected to create a solid. Two separate shapes may share one or more but not all of their basic elements. For example, two rectangles sitting next to each other that share two points and one line are considered to be two separate shapes. In computer-aided design, the four basic elements can be referred to as vertices (points), edges (lines), faces (planes) and objects (solid geometry). In this research, we use U_{ij} shape algebra as a formulation to analyse the basic elements of shapes, and we refer to the terminology used by Stiny (2006) to describe the properties of shapes (Table 1).

Table 1 Terminology of the U_{ij} shape algebra that describes the properties of shapes (Stiny, 2006)

Algebra U_{ij}	**U_{i0}**	**U_{i1}**	**U_{i2}**	**U_{i3}**	**Basic Elements**	**Boundary Shapes**	**Number of Parts**
U_{0j}	U_{00}	U_{01}	U_{02}	U_{03}	Points	None	Finite
U_{1j}		U_{11}	U_{12}	U_{13}	Lines	U_{0j}	Indefinite
U_{2j}			U_{22}	U_{23}	Planes	U_{1j}	Indefinite
U_{3j}				U_{33}	Solids	U_{2j}	Indefinite

Shapes can be analysed using U_{ij} shape algebra. The value of index “i” is indicated by the number of coordinate axes of the shape itself, whereas the value of index “j” is indicated by the number of allowable dimensions. For example, a point-based shape is described as U_{0j}, a line-based shape as U_{1j}, a plane-based shape as U_{2j} and a solid-based shape as U_{3j}. The value of index “i” can be between zero and three, whereas the value of index “j” must be greater than the value of index “i” for the same shape. For example, a point has a zero coordinate axis. The values of index “i” and “j” are both zero which is represented as U_{00}. When there are two or more points, more numbers of allowable dimensions are required. For example, two points placed on the Y axis are described as U_{01} (one allowable dimension of a zero coordinate axis). Three points placed along the X and Y axes are described as U_{02} (two allowable dimensions of a zero coordinate axis). The same rules apply to all shape elements. We exemplify a set of shape elements with a description of shape algebra, as shown in Figure 5. These elements can be called a sub-vocabulary, which can be used to form a variety of fundamental units for generating patterns. This is explained further in the next section.

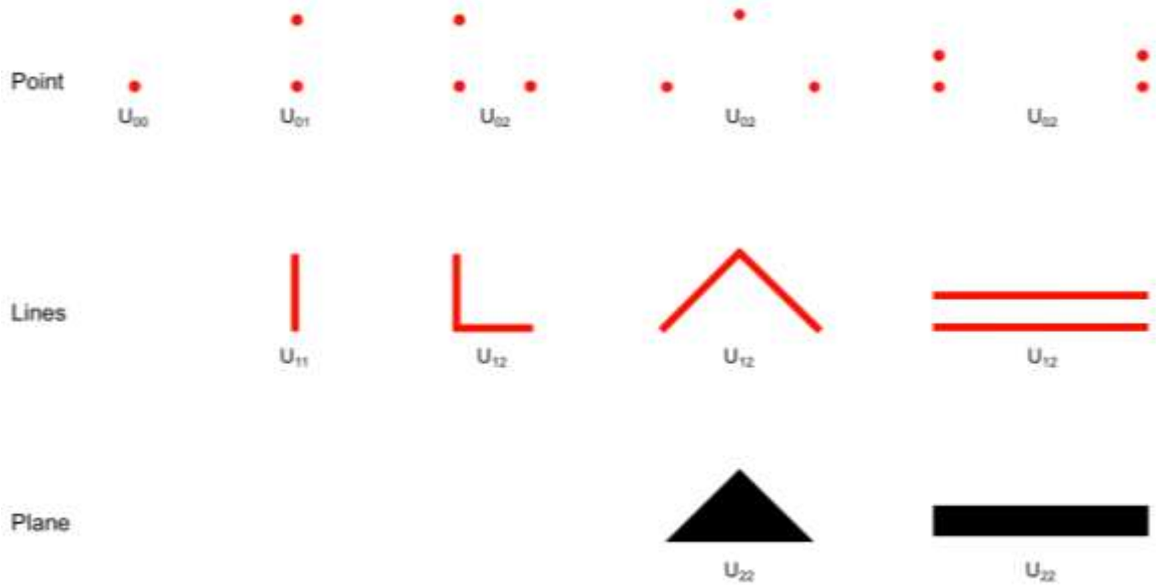

Figure 5 Example of shape elements described based on the U_{ij} shape algebra.

2. Level 2: Identifying fundamental units

In Level 2, we identify the fundamental units in patterns. A fundamental unit is the smallest unit that can be repeated in a pattern. A fundamental unit is itself asymmetric, but it can be symmetrical with an adjacent unit that is placed on a reflection axis (Hann, 2013, p.25). There are two ways to operate shape elements to form a fundamental unit. One way is to create as many sub-vocabularies as possible and store them in a database of sub-vocabularies (e.g. triangles, rectangles) (Figure 6A). Another way is to create a set of sub-vocabularies and apply modification rules to it in order to develop sub-vocabulary derivations (Figure 6B). Fundamental units in these six pattern sets are confined to rectangular spaces. Either way, whatever sets of sub-vocabularies are created, they are placed in a rectangular space to form a fundamental unit. For example, a set of shape elements created in Level 1 can be used to form a fundamental unit as shown in Figure 6C. The process of placing shape elements can be revised again and again until they meet the design requirement. A fundamental unit itself can be called a “shape vocabulary” and it is asymmetric at this level.

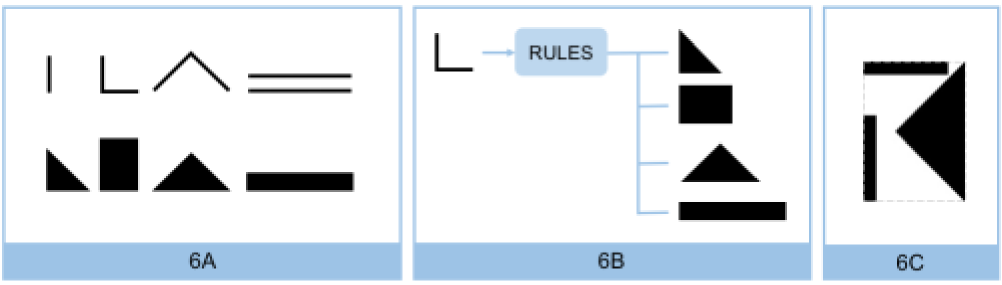

Figure 6 Forming a fundamental unit from shape elements

3. Level 3: Identifying the rules for symmetry operations

In mathematics, a frieze or frieze pattern is a two-dimensional design that repeats in one direction. This principle is applicable to “chok” fabrics because their patterns are two-dimensional designs and they are woven incrementally in one direction that increases the fabric’s length. Therefore, in Level 3, the seven frieze groups are employed as a set of rules to form fundamental units and regenerate textile patterns. The balance or symmetry of something can be described mathematically by using the idea of rigid motions. Rigid motions are also known as symmetry operations (Hann, 2013, p.24), rigid transformations (Study.com, 2021) or isometry. A rigid motion occurs when an original motif is moved in plane or in space, resulting in a new image that is transformed based on the original motif. They are congruent in size, shape and content (Shubnikov & Koptsik, 1974, p.159). There are four types of rigid motions: a reflection, a twofold rotation, a translation, and a glide reflection (Figure 7: left), which can generate any pattern (Shubnikov & Koptsik, 1974, p.159; Hann, 2013, p.24). When a rigid motion is applied for designing an image that is repeated or translated in one direction, a total of seven frieze groups can be produced according to its symmetry. Figure 7 (right) shows a flow chart for classifying the seven frieze groups (Washburn and Crowe, 1988, pp.44, 58-59, 83; Hann, 2013, pp.24-27). In this article, we employed the methodology and crystallographic symbols of Washburn and Crowe (1988) to classify the seven frieze groups.

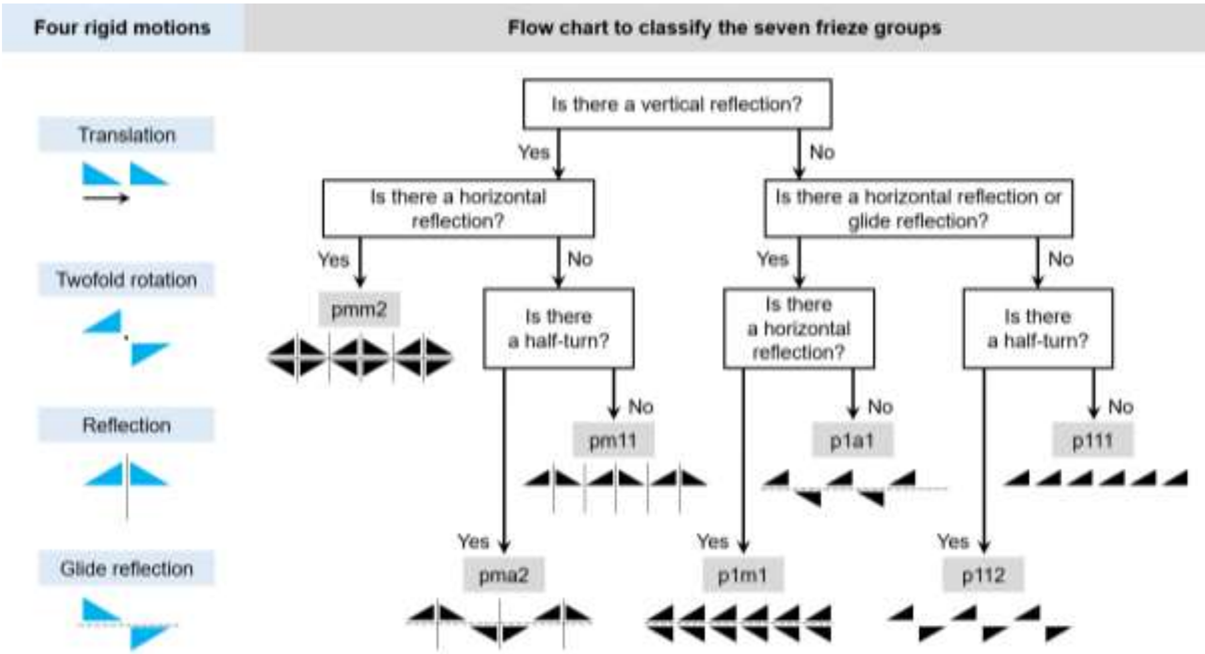

Figure 7 Four rigid motions, and a flow chart to classify the seven frieze groups.
(reproduced based on Washburn and Crowe, 1988)

4. Level 4: Generating frieze patterns

In Level 4, the rules of the seven frieze groups (from Level 3) are applied to fundamental units (from Level 2). Figure 8 exemplifies a fundamental unit that conforms to the rules of the seven frieze groups, hence a set of motif designs. A symmetrical motif is a figure which is comprised of two or more parts of identical size, shape and content (Hann & Thomson, 1992, pp.1-2). The repetition of a motif at a regular interval creates a frieze pattern.

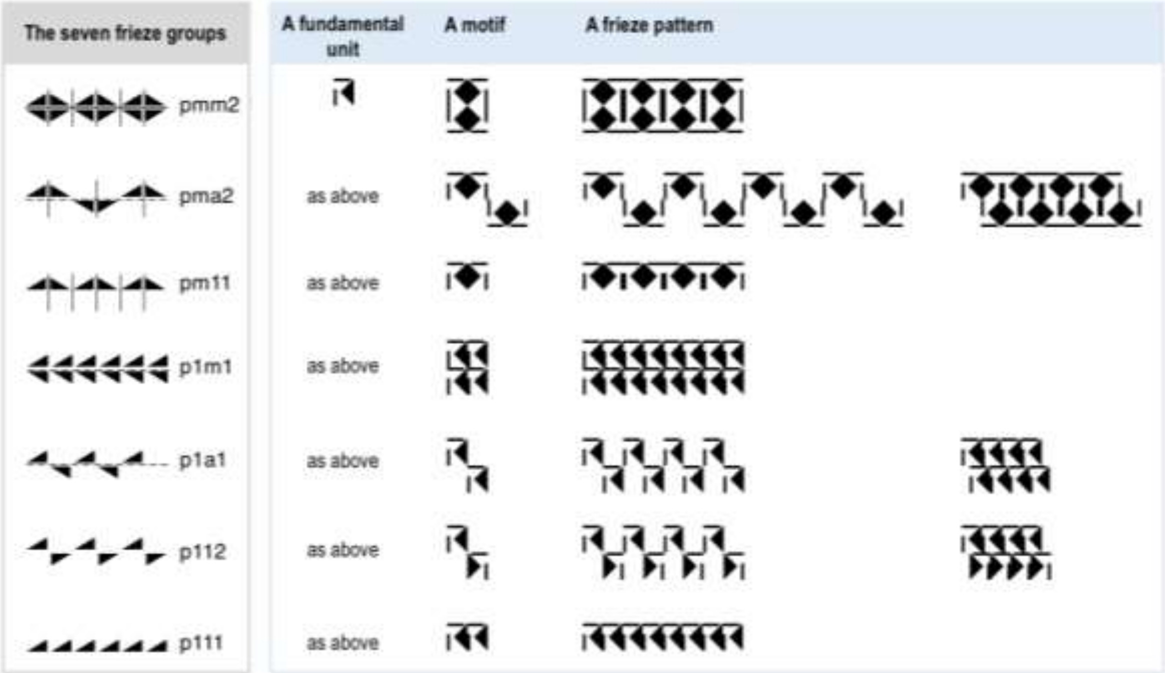

Figure 8 Example of a fundamental unit that conforms to the rules of the seven frieze groups.

5. Level 5: Arranging frieze patterns on the design structure

In Level 5, frieze patterns resulting from Level 4 are arranged in the design structure of "tin chok". It comprises four parts: one main part, two supplementary parts (above and below the main part) and a hem. Each part has a certain position in a space and informs the hierarchical structure of the design. Figure 9 exemplifies four fundamental units that are generated to form motifs followed by frieze patterns.

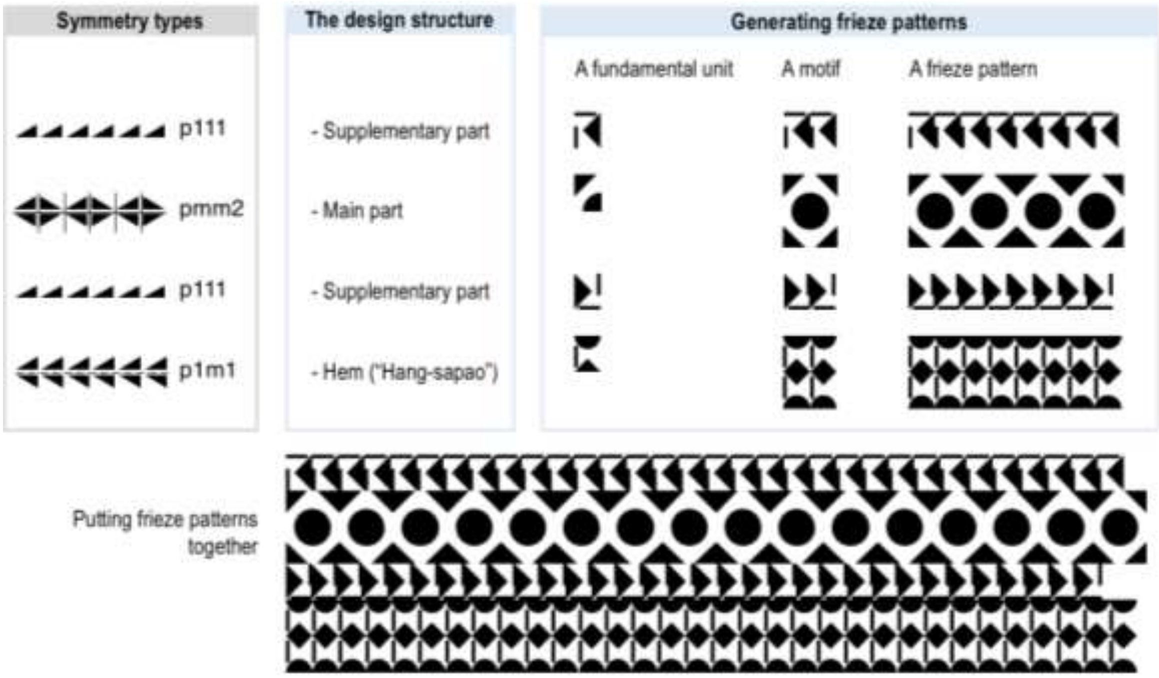

Figure 9 Design structure exemplified with fundamental units and symmetry classification.

Results from the pattern regeneration

The results of pattern regeneration are presented in relation to the five levels of analysis in the specific framework of HSG, as follows.

1. Identified shape elements

U_{ij} shape algebra was used to analyse shape elements in the six pattern sets. These patterns are two-dimensional designs, therefore, U_{11}, U_{12}, and U_{22} are used to trace the shape elements in each set (Figure 10: I-01 to I-05, I-14). Considering the six pattern sets together, their shape elements can be classified into two main types: trilateral shapes and quadrilateral shapes. Trilateral shapes include equilateral triangle, isosceles triangle, and right triangle. Quadrilateral shapes include square, rectangle, rhombus, parallelogram, and isosceles trapezoid.

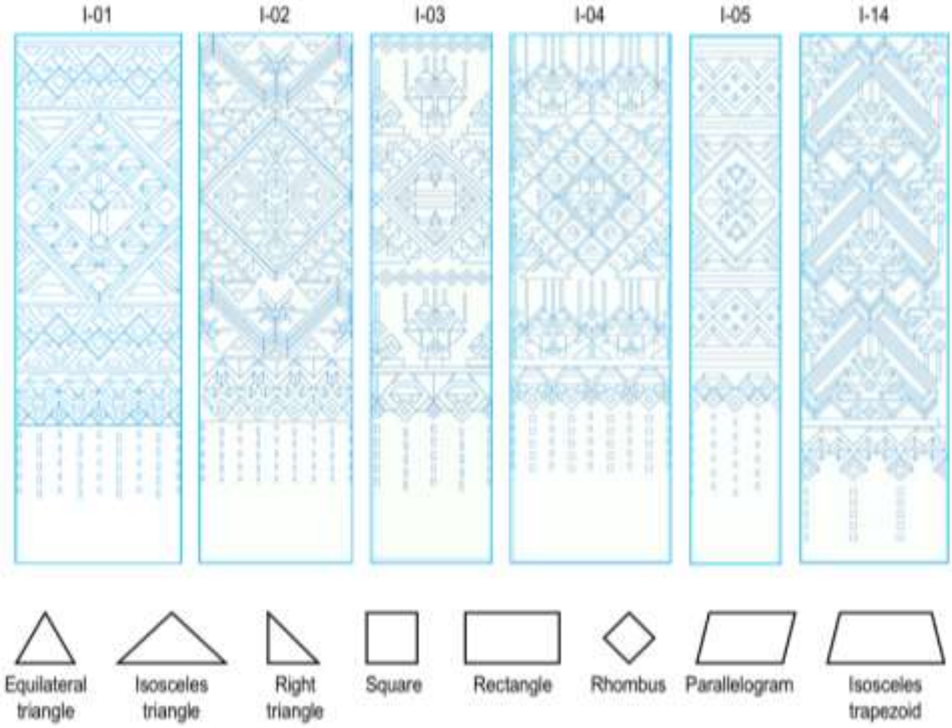

Figure 10 Shape elements extracted from the six pattern sets.

2. The identified fundamental units

Each of these six sets comprises four frieze patterns, so there are 24 fundamental units in total (Figure 11). These fundamental units are confined to rectangular spaces and comprise the shape elements. The identification of fundamental units is useful for creating a database of shape vocabularies in preparation for pattern developments.

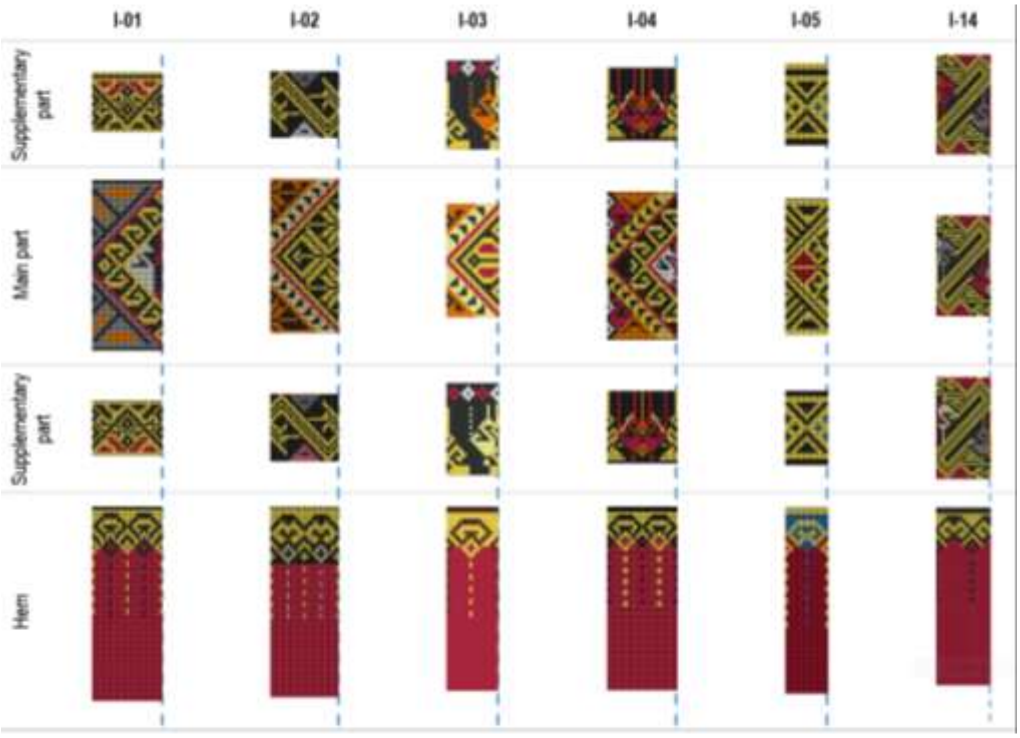

Figure 11 Fundamental units extracted from the six pattern sets

3. The number of possible frieze patterns compared to real fabrics

A fundamental unit can be generated to seven design derivations based on the rules of seven frieze groups (pmm2, pma2, pm11, p1m1, p1a1, p112, and p111). As indicated before, a "tin chok" is usually designed to have four parts: one main part, two supplementary parts (above and below the main part) and a hem. By applying those seven frieze groups, there are 28 possibilities for design derivations per set. However, having conducted symmetry analysis, we find that only 12 possibilities of design derivations appear. Among these 12, we find that only three out of seven frieze groups (pmm2, pma2, pm11) are employed, as shown in Table 2.

Table 2 Symmetry classification identified from the six pattern sets.

Symmetry operations	Pattern set					
	I-01	I-02	I-03	I-04	I-05	I-14
pmm2		Yes	Yes		Yes	
pma2	Yes	Yes				Yes
pm11	Yes	Yes	Yes	Yes	Yes	Yes
p1m1						
p1a1						
p112						
p111						

4. Regenerating the frieze patterns

Fundamental units are moved on in one direction, but with the particular symmetry operations (identity above), hence the motifs. These symmetrical motifs are repeated at regular intervals, hence the frieze patterns. Figure 12 depicts the frieze patterns in each pattern set, along with their symmetry classification.

Figure 12 Frieze patterns identified with symmetry classification.

5. Pattern arrangement on the design structure

To regenerate six sets of traditional textile patterns, frieze patterns (Figure 12) are arranged in the design structure, comprising one main part, two supplementary parts (above and below the main part) and a hem. They do not cross over the others, as shown in Figure 13.

Figure 13 Pattern arrangement on the design structure.

Conclusion

This pilot study was initiated by us, who specialise in different knowledge domains (design, mathematics, and shape grammar). This is a multidisciplinary research that focuses on the pattern designs of "sin tin chok", a type of traditional skirt from northern Thailand. The terms: pattern, design and symmetry are described in relation to cultural significance. "Sin tin chok" is an intangible cultural heritage of local people in northern Thailand; however, there is a need to revitalize traditional handwoven textiles. Designers are encouraged to become involved in design for cultural revitalization (Walker, Evans, et al., 2018). Next, we described the generic framework of Harmonised Shape Grammar (HSG) that can assist in the process of design developments. It can be applied to a specific context of design practice to generate a set of harmonized and meaningful designs. Conducting multidisciplinary research is a way to exchange knowledge and understand the designs of the traditional textile patterns. As a result, we developed the generic framework of HSG to suit the specific context in which traditional textile patterns can be regenerated. This framework is used as a guideline for experimentation with the six pattern sets decoded from a vintage collection of "sin tin chok" exhibited in Komol Phaboraan Museum, in Long district, Phrae province in northern Thailand.

This specific framework of HSG consists of five levels of analysis: identifying shape elements, identifying fundamental units, identifying/ understanding a set of rules for symmetry operations, generating frieze patterns, arranging frieze patterns in the design structure. Having regenerated the pattern sets, we find that their shape elements can be classified into two main types: trilateral shapes and quadrilateral shapes. Trilateral shapes include equilateral triangle, isosceles triangle, and right triangle. Quadrilateral shapes include square, rectangle, rhombus, parallelogram, and isosceles trapezoid. Next, there are 24 fundamental units identified from the six pattern sets. These fundamental units are confined to rectangular spaces and they comprise shape elements. The identification of fundamental units is useful for creating a database of shape vocabularies in preparation for pattern developments. A "tin chok" is usually designed to have four parts: one main part, two supplementary parts (above and below the main part) and a hem. A fundamental unit for each part can be generated to seven design derivations based on the rules of seven frieze groups. By applying these seven frieze groups, there are 28 possibilities for design derivations per set. However, we find that only 12 possibilities of design derivations appear. Among these 12 possibilities, we find that only three out of seven frieze groups (pmm2, pma2, pm11) are employed. From this experimentation, we see a potential for conducting further multidisciplinary research to develop digital applications that can store information about shape elements and fundamental units of traditional textile patterns in databases, and redesign textile patterns. In the future, we will apply this research with a larger number of samples that include different types of textiles. Ultimately, we hope that in the near future our research effort, including digital applications, can be useful to weaving masters and their younger generations, especially in such a way that they can co-work on the designs of textile patterns as a practice in weaving-knowledge transfer.

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