COMPUTATIONAL WEAVING GRAMMAR OF TRADITIONAL WOVEN PATTERN

FAJAR I. HARNOMO AND ASWIN INDRAPRASTHA
School of Architecture, Planning, and Policy Development,
Institut Teknologi Bandung, Indonesia
fajarharnomo@gmail.com | aswin@itb.ac.id

Abstract. Weaving technique is one of the indigenous craftsmanship practices that are common in most of ethnic groups in Indonesia. Generally, it uses thin strips of organic material such as bamboo or rattan to make plane of surface that further can be developed into daily utensils or as a traditional architectural building components such as partition wall and floor. The research of weaving grammar as a system and process had been introduced and explored using Shape Grammar theory and principles. Having the potential implementation and to preserve the traditional weaving method, the grammar can be explored as a method of exploration in architectural design by extending the computation method based on the visual embedding of its pattern languages. The aim of the study is to discover the geometrical configuration underlied traditional weaving grammar by reconfiguring and elaborating procedures and further develop generative method using computational approach. We focused on the exploration of single and dual patterns of biaxial types of West Java woven pattern by using shape grammar principles. The result shows computational method is constructed by several rules which are defined as generative procedure. The result advised that traditional woven pattern has similarity according to its ruled-based system of generative algorithm.
Keywords: Weaving Grammar, Traditional Woven Pattern, Shape Grammar, Generative Methods.

1. Introduction

Woven is one of the culture products that has wide range of implementation from decorative arts, toys, daily utensils and building components. The basic form of traditional weaving can be found anywhere among different ethnic groups in Indonesia with relatively similar technique being used (Griffen, 2000). Basically, it uses thin strips of elastic and natural material such as

Bamboo *(Bambusa),* Rattan *(Calameae)*, Coconut leaf *(Cocos nucifera)* and also Pandan leaf *(Pandanus amaryllifolius)*. It can be developed into daily utensils or as a traditional architectural building component. (Frick, 1997, 2004; Dunkelberg, 1985).

As a product, woven is defined as a rule-based interlacing of parallel or perpendicular between two or more stripes or bands (Garha, 2001). The interweaving structure is divided into three systems of axis, biaxial structure, tri-axial structure and multi-directional structure (Anandhita, 2014; Tocharman, 2009). According to that context, the woven is a system that has input of materials, rule-based processes and also output (product). The research of weaving grammar as a system and process had been introduced and explored using Shape Grammar theory and principles.

The aim of the study is to discover the geometrical method of traditional weaving grammar by reconfiguring and elaborating procedures and further develop generative method using computational approach. We focused on the exploration of single and dual patterns of biaxial types of West Java weaving ornament by using Shape Grammar principles (Stiny, 1980, 2006, 2010) that are applied to the basic rules of traditional weaving method. Our goal is to codify traditional weaving pattern into computational method that can preserve local and indigenous knowledge.

2. Weaving Grammar

The basic technique of traditional weaving refers to a general instruction of warping and wefting in various modifications. The interlacing is the base structure of any weaving method. In the two-directional woven structure, it has two elements: (1) One that positioned perpendicular to the hand of weaver called warp *(Lungsin)* and (2) One that positioned parallel to the hand of the weaver known as weft *(Pakan).* Arifien (2011) had specified that a woven basic configuration is the baseline for its pattern (product) and methodology (process and procedure). The woven pattern can be analyzed by generating the pattern into a simple and two-dimensional configuration (Garha, 1990, 2001; Arifien, 2011) as shown below in Figure *1*.

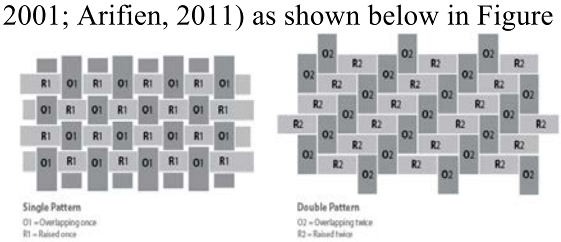


Figure 1. Two Dimensional of Traditional Weaving Configuration.

Another example by Muslimin (2014) explored a weaving grammar as a basic rule for weaving process based on the interlace structure. A weaving grammar essentially implements parametric shape grammar to define rules of pattern. It encapsulates weaving technique and structure of pattern configuration through computational process (Andino, *et al*., 2013; Jowers, *et al*., 2005).

3. Computational Weaving Method

3.1. UNDERSTANDING WEAVING PATTERN

Using a particular bamboo-based woven pattern called "*Sasag*", the pattern was analyzed and interpreted to be determined into three distinct segment categories by looking into its interweaving structure: (1) One-Way/One-Axis, (2) One-Way/Two-Axes, (3) and Two-Way/Two-Axes. Each segment unit has its own characteristic that determines the interweaving rules to produce generative patterns.

The *Sasag* woven pattern used two stripes perpendicular each other. The procedure starts with understanding rule of the woven where each strip has one state at a time. The state of this pattern is either up (means that a segment is being on top of another segment) or down (means that a segment is being under another segment). Figure 2 described weaving pattern of two groups of stripes in perpendicular direction.

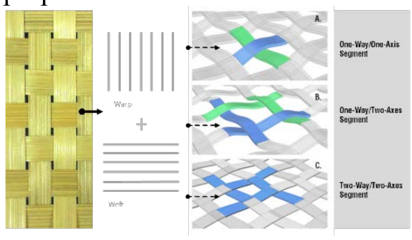


Figure 2. The Conversion of Woven Pattern and Segmentation Categories by Interweaving Structure.

As shown above, each segmentation unit determined procedures in which stripes interweaved and translated each other. Each segmentation units are applied by using five principles of Shape Grammar's theory: rotation, translation, scale, reflection and Boolean operation (Knight, 2000). Rules of each segmentation category are defined by looking at the previous research method. We defined rules into four basic main rules: (1) Labeling Rule as point definition, (2) Rotation Rule that concerns in interlacing the basic line segment, (3) Repetition Rule is the main aspect that generates pattern configuration and (4) Surface Rule can be interpreted as a profiling phase of every woven stripes. For other case to generate different pattern, this main rules can be manipulated or modified by adding or swapping from one and another.

3.2. RULES OF UNIT SEGMENT

The distinctive characteristic of each category of segmentation produces different woven unit pattern while retain the integrity of the pattern. In general, it consists of five rules that are elaborated from previous basic rule.

3.2.1. One-Way/One-Axis

The unit of basic segmentation category involving one-line segment (initial line) with length *(l)* that further generated a basic interweaving pattern by two basic rules, Labeling and Rotation rule. Labeling rule determines start and end point of the segment and the rotation point by taking parameter of ½ *l*, where *l* is the length of the line segment. While Rotation rule determines rotation angle (90^o CCW) from rotation point and producing a boundary line connecting four endpoints. The Repetition rule that is applied using two approaches: (1) Repetition approach that is based on the previous definition, and (2) array approach that is based on the translation. It takes advantage of boundary line connecting each individual unit by repetition order along planar axis of X and Y.

3.2.2. One-Way/Two Axes

This unit has same definition as previous and determination of rotation point uses half length of the initial length with parametric translation vector slightly off the line segment. This parameter takes range between ¼ and ½ of total initial line length. In this part, Rotation rule produces four line segments resulted from two rotation rules. The first rotation of initial line in 180^o CCW from rotation point produced a parallel line. The second rotation takes those parallel lines with 90^o CCW to produce its final formation. Basically, the Repetition rule is generated from rectangular unit boundary, whilst it has different procedure by mirrored in two axes direction X and Y repeatedly.

3.2.3. Two-Way/Two Axes

As same as previous line segment category, this segmentation system is generated by four lines that rotated at a rotation point. The rotation point is determined parametrically using a distance of ¼ *l* off the length of line segment as shown below. Following this rule, the initial line and its rotation point are rotated in three sequential CCW angles: 90^o, 180^o, and 270^o.

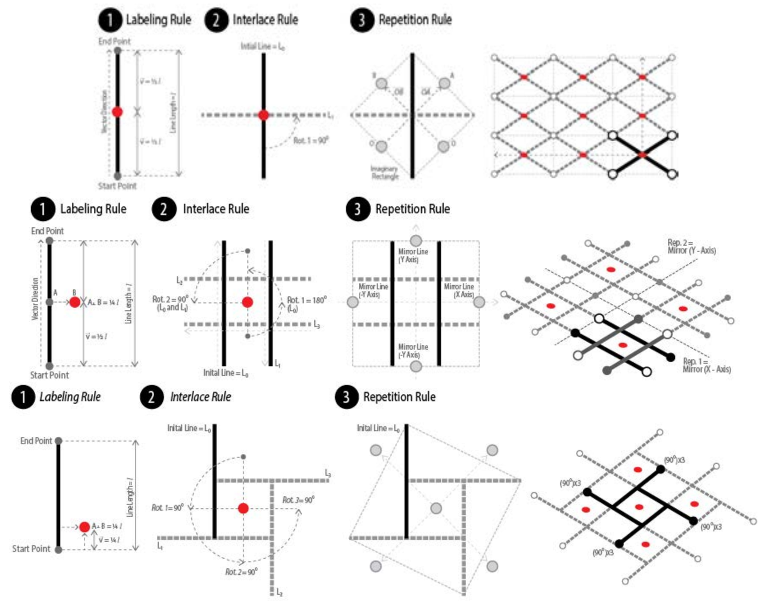


Figure 3. Woven Stripes Profile, Profiling Rule Diagram and Pseudo Code.

3.3 PROFILING RULE

The profiling rule controls parameters of stripe profile which are: width and thickness of those three segment units. This rule decodes material profile of the woven pattern that generally make-up the solid-void composition of the woven pattern. On fabrication point of view, these parameters constitute material properties with bending capacity and also flatness tolerance. Figure 4 shows the actual woven that its characteristic is depended on the width and thickness of its material stripes and interpretation of 'Profiling Rule' to produce parameters for width and thickness of the stripes.

The knot rule divides a line segment into five control points: start point (as control point #1, control point #2, knot point (control point #3), control point #4, and end point (as control point #5). These control points determine the curvature and height of the knot point that transform line segment into control point curve. The height of the knot point is aligned with the normal vector of line segment that in consequence has two states: Up (+Z of normal vector) or Down (-Z of the normal vector).

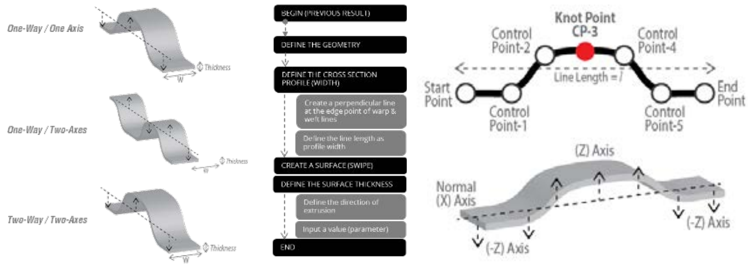
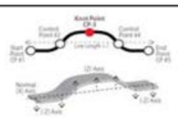
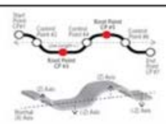
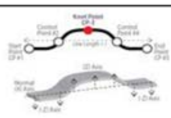


Figure 4. (Left)Woven Stripes Profile; (Right) Profiling Rule Diagram and Pseudo Code.

3.4 ANALYSIS OF INTERWEAVING RULES

We experimented weaving grammar by developing rules of three segment units of a woven pattern. The analysis of its interweaving rules displayed in TABLE 1 below with purpose to know the degree of flexibility and robustness of the rules to be applied to the surfaces.

TABLE 1. Interweaving Structures

Segmentation Categories		Interweaving Structure System		
		One-Way/One-Axis	One-Way/Two-Axes	Two-Way/Two-Axes
Computational Weaving Method	Labeling Rule	1 Line with l length; 2 line segments	1 Line with l length; 2 line segments	1 Line with l length; 4 line segments
	Interlace Rule	1 x 90° (on mid point of initial line)	2 x 90° (rotation point from vector cross product)	3 x 90° (rotation point from vector cross product) with collision rule
	Repetition Rule	Translation and rotation of line segment in certain direction / Rectangular Array in X and Y axis of unit module	Mirror / reflection unit module in X and Y axis	Translation and rotation of line segment in certain direction / Rectangular Array in X and Y axis of unit module
	Knot Rule	1 knot point and 4 control points	2 knot point and 5 control points	1 knot point and 4 control points
	Profiling Rule			
Shape Grammar Principles	Rotation	Yes	Yes	Yes
	Translation	Yes	No	Yes
	Scale	No	No	No
	Reflection	No	Yes	No
	Operation	Union	Union	Union & Intersection (Reciprocal)

The One-Way/One-Axis unit has advantage regarding its visual pattern and its rules as implementation of the Shape Grammar theory (Stiny, 2010): (1) The One-Way/One-Axis unit has the simplest configuration unit with basic structures remain as with traditional weaving technique, (2) The repetition rule is robust and flexible to be applied to planar and non-planar surfaces with possibility for additional and recursive rules. The Labeling Rule is the base rule that has significant impact to the subsequent rules and determine the definition of the woven pattern.

4. Discussion on Experiments

Experiment of the computational weaving method has been conducted on two types of biaxial woven pattern which are single and double pattern. Both patterns have been digitally interpreted and analyzed as previously explained. *Figure 5* showed the difference of single and double pattern of biaxial woven pattern.

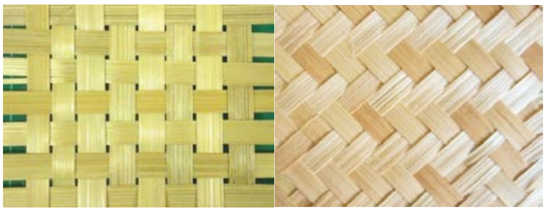


Figure 5. Single and double pattern of biaxial woven patterns.

In the single woven pattern, interlace rule is located at the center of line segment which was divided into two equal lengths and cause a symmetrical interlace as seen in Figure 5. By using the same logic in the interlace procedure, first, the line segment should be divided in eight segments. Considering control points and knot points of its woven pattern. By adjusting input parameter of curve evaluation in Grasshopper, the rotation point can be determined parametrically according to the length (*l*) of the segment (Figure 6).

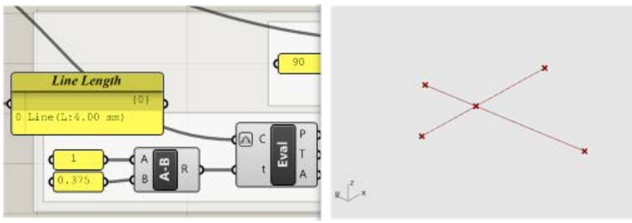


Figure 6. (left) Input value for rotation point.(Right) Result of rotated segment by point of rotation.

On the double pattern (or *Kepang*), the segments are determined by two segments that interlaced over a knot point. As such, numbers of control points on segment are higher than a single pattern.

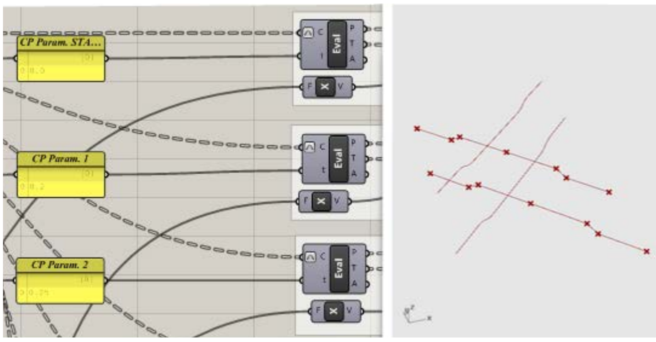


Figure 7. Determination of control points for interlaced segments.

Figure 7 depicted procedures and rules for double pattern biaxial woven, or *Kepang*. In this type, rule for labeling is crucial to determine points of interlacing segments. The result of this rule is two interlaced segments as a base unit for computational biaxial woven pattern (Figure 7, right).

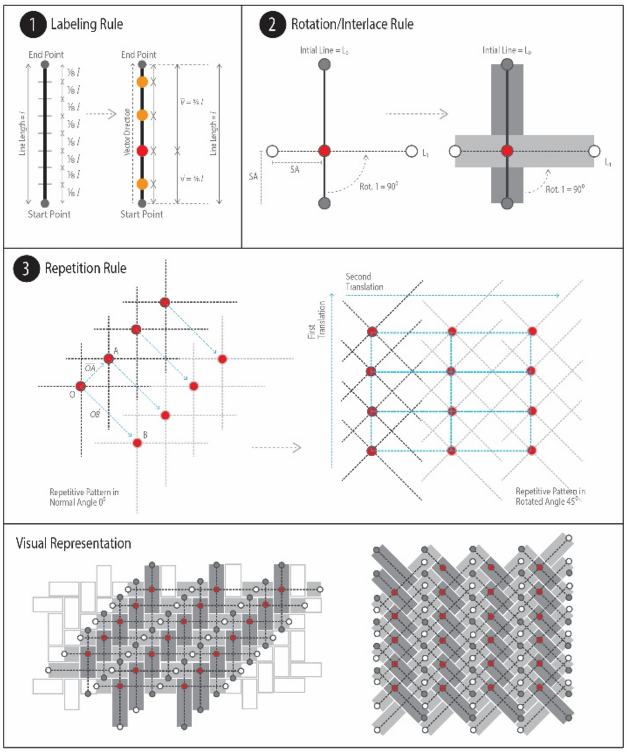
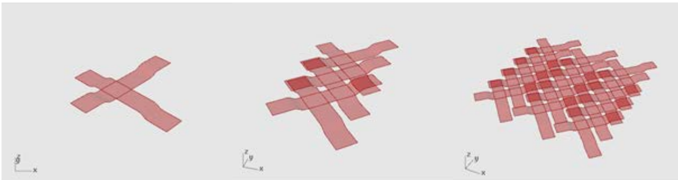


Figure 8. Pattern elaboration of Biaxial Weaving types.

Figure 8 showed three types of rules: Labeling Rule, Rotation/ Interlace Rule, and Repetition Rule along with its visual representation of *Kepang* woven.



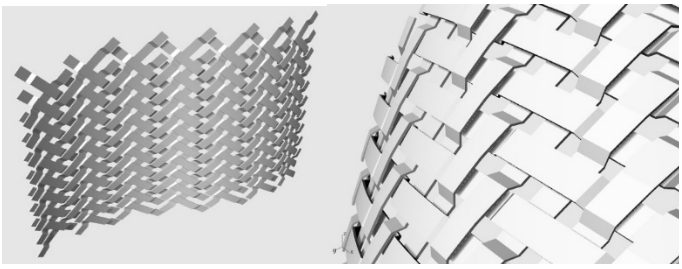


Figure 9. Hasil dari implementasi pola anyaman kepang pada suatu surface.

In Figure 9, *Kepang* woven pattern was implemented into non-planar surfaces as 3-dimensional object by means of Profiling Rule. It is shown that the difference weaving grammar between single (One-Way/One-Axis, single pattern) and double (One-Way/One-Axis, double pattern) lied on the number of its control points. The case showed that a woven basic configuration is defined by the number of control points of its base segment unit.

Furthermore, control points of the segment unit used to regulate amount of the "weaving" or, the normal vector distance of the stripes from the planar surface. Figure 9 also showed detail of the patterns implemented on a curved surface. Control points parameter of Knot Rule determine the weaving factor of the pattern.

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