INTRODUCTION
This research proposes a computational design framework to visually reason how these designers, inspired by weaving and developed similar designs, as well as propose a way to improve their visual affordance to synthesize more design variations.

THEORETICAL COMPARISON
In investigating these questions, this research uses Gestalt Laws (Wertheimer, Koffka, and Kohler, 1920s), a series of laws that describe how humans organize visual elements subconsciously into groups or unified wholes in order to recognize objects, and Shape Grammar (Stiny and Gips, 1971), a computational design method for analyzing and synthesizing designs by embedding and calculating shapes with a set of visual rules.

Although some of their shape operations are similar each other, their goals are fundamentally different: Gestalt Laws attempt to resolve ambiguity among shapes [1] while Shape Grammar embraces it. For instance, when two Gestalt Laws conflict with each other in the interpretation of a shape [ ][ ][ ][ ] (e.g. three squares by closure laws, or two columns and two half-columns by proximity laws), Gestalt Laws will choose only one interpretation at a given time (Katz, 1950). In Shape Grammar, both interpretations are valid since they can be flipped back and forth (Stiny, 2006).

To gain paradoxical benefits from the two theories, the study frame Shape Grammar with Gestalt Principles, as well as look at Gestalt Law with Shape Grammar perspective.

Shape grammar in the law of Prägnanz
While Part and Whole are ambiguously linked in Shape Grammar, the Law of Prägnanz attempts to solve this ambiguous relationship by reconstructing the whole from the part. Figure 1 shows how shape grammar constrained in Gestalt Laws.

- **Shape Atomization**: In the algebra of shape, Gestalt Law recursively unify smaller shapes as “Parts” into new atomic shapes that have the simplest and most stable forms (according to Koffka), called “Wholes”. This atomic shape...
tends to unify from a discrete point, into a discrete line, then a discrete plane and eventually into a discrete volume (fig 1a).

- **Shape Figuration:** In the algebra of \( U_{12}, U_{13} \) and \( U_{23} \), shape boundaries (e.g. planes with lines and volumes with both planes and lines) are not tightly bound to their content, since the boundaries of shapes are also shapes (Stiny, 2006). According to Gestalt’s Law, the boundary binds together with its figure in order to unify the closed contour figures and separate them from their surroundings (fig 1b).

- **Shape Constancy:** In Shape Grammar, transformation works for both embedding, to match the initial shape in different ways, and design, to transform the embedded shape into a new shape. Gestalt Law, on the other hand, uses transformation to return the two-dimensional retinal image (proximal stimulus) back to its original shape in the real world (distant stimulus). For example, fix a triangle that distortedly projected on our retinas (fig 1c).

- **Line Reduction:** Gestalt’s grouping mechanism tends to unitize a set of lines into one maximal line. This includes merging a set of overlapping lines, segmented lines or a missing line back into one maximal line. Accordingly, in larger sub-divided shapes, Gestalt Laws will unify them into one shape with the reduction rules (fig 1d).

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1a. Shape Atomization  
1b. Figurization | \( x \to b'(x) \)  
1c. Constancy | \( x \to t'(x) \)  
1d. Minimal to Maximal Lines | \( x \to \text{prt}'(x) \)  
Simplification | \( x \to \text{div}'(x) \)
The law of Prägnanz in shape grammar: whole-part ambiguity

Shapes formed by Gestalt Law’s reconstruction of “good” and “stable” shapes (i.e. regular, singular, and unified) may become unstable in Shape Grammar’s ambiguity while also preserving the basic property of the Laws. Figure 2 shows an example of how Shape Grammar sees different types of symmetrical shapes, continuous shapes, closures, etc.

- **Symmetry**: Gestalt Law would perceive an area between two symmetrical shapes as a figure. Shape Grammar on the other hand would see different symmetrical figures generated by different axes of symmetry’s location other than the horizontal and vertical axes (e.g. rotational, dihedral, rotor-reflection and other symmetries) (fig 2a).

- **Continuity**: Gestalt Laws tend to maintain the smooth continuity of a certain curve or linear composition rather than break them apart. However, in Shape Grammar, as long as the curve shares the same boundary with another curve, they can be linked together as one continuous shape. In addition, other types of continuous shapes might exist in different dimensions by reversing the boundary rule \( x \rightarrow b^{-1}(x) \) (fig 2b).

- **Similarity**: Gestalt’s Law of Similarity would group several shapes that look similar. Yet, unless the meaning is explicitly defined, the term “similar” remains ambiguous in Shape Grammar and can therefore lead to different kinds of shape groups. For instance, it can group shapes according to similar rhythm/composition rather than similar color (fig 2c).

- **Closure**: Gestalt’s Laws attempt to link disconnected lines to close contour figures. In Shape Grammar, other types of close figures may be generated from the boundaries of the disconnected lines (fig 2d).

While these four Laws of Pragnanz have a certain degree of ambiguity that can be exploited non-deterministically in Shape Grammar, the other two, the Law of Proximity and the Law of Common Fate, are more absolute and deterministic. The Law of Proximity measures the distance among shapes and group those that are close together (fig 2e). The Law of Common Fate delineates shapes that appeared to have the same directionality (fig 2f). Thus, it is difficult to explore the ambiguous aspect from these quantitative parameters and conditions. Nevertheless, these six laws can work collaboratively with each other (See Desolneux, Moisan and Morel, 2006 about Partial Gestalt and Global Gestalt).

**EXPERIMENT: VISUAL-WEAVING ROUTINES**

Weaving requires a complex physical and visual coordination of the weaver’s perceptual apparatus, as well as sufficient knowledge of material properties and haptic experience (Muslimin, 2010). However, visual perception can continue to play important roles outside of physical weaving activities. For instance, in studying a woven-basket design, the weaver may mentally reconstruct the weaving process by looking at the center-bottom of the basket, since they commonly start weaving from that point (Miebach, 2011). Additionally, the weaver might have an interest in discerning the hidden geometry by changing his or her focal point when fixating on the interwoven surface (Gerdes, 1986).

To understand how the designer is visually inspired by another’s weaving design; we limit our focus solely on the visual event during weaving activities, in the absence of physical feedback such as the properties of the material, hand coordination and haptic experience. The materials are the shapes, and the tool for weaving the shape is the visual perception driven by Gestalt Laws and Shape Grammar. Using a two-dimensional plaiting pattern, the experiment is conducted in three phases. First, the weaving pattern is reconstructed using the Law of Prägnanz. Second, Shape Grammar calculates the pattern without applying meaning to the shape. Third, both Gestalt Laws and Shape Grammar are switched back and forth to generate new weaving shapes.
**Gestalt laws on recognizing weaving geometrical properties**

In this example, Gestalt Law chronologically recognizes the symmetrical figure among the lines, and then continuous law applied together with closure law to connects the lines and adds shade to the contoured figure (fig 3a, 3b and 3c). Then, the Gestalt’s constancy is then applied to indicate the interweaving mechanism (fig 3d). The resulting over and under perception is defined as an overlapping schema on a local scale (x < t(x) or x is under t(x)), which can be further expressed as a reciprocal schema on the global scale (i.e. A > B > C > … > A) (after Knight, 2010).
However, as these shapes are not bounded by any particular meaning, they remain abstract and do not yet embody weaving properties.

**Gestalt grammar: forget → remember; remember → forget**

This experiment recursively uses Shape Grammar to forget any meaning of weaving on calculating the shape and Gestalt Laws to recall weaving properties of particular shapes.

Figure 5d shows the use of Shape Grammar in applying reduction rules from figure 1d to obtain four maximal lines, and then use the overlapping rule from figure 3d and 3e to recall the reciprocal schema from the Gestalt Laws experiment. We can also assign different initial shapes with the same schema. For example, the overlapping schema can be repeated again on the pinwheel shape in the figure 5b. Figures 5c and 5d use the same process. Moreover, this modular component can later be made continuous by recalling the hidden line on the interlaced area from the Gestalt schema (fig 5e).

This recursive Gestalt grammar can go even further with Shape Grammar parametric schema. Rules in figure 5a, for instance, can be derived parametr-
cally by modulating its rotation angle and the location of the rotation axis (Muslimin, 2010). The resulting shapes in figure 6 shows the recurring of some woven construction in architecture (also known as Reciprocal Frame, Popovic 2008) from the 900s to the present derived from the same parametric grammar from figure 5a.

**Results**

The experiment confirmed the pivotal issue from both theories, which is the deterministic aspect of Gestalt theories to construct the whole from the part, and the non-deterministic aspect of Shape Grammar that may exclude the Whole-Part hierarchical system. The first experiment shows a strong cognitive property of three-dimensional weaving that remains in its two-dimensional appearance, which may explain some similarity of weaving patterns in architectural construction as seen in figure 6. The second experiment with Shape Grammar generated more emergent shapes. However, with the absence of meaning (e.g., the overlapping and the reciprocal attribute), they do not embodying weaving properties. With the combined method of using both Shape Grammar and Gestalt principles recursively in the third experiment, a number of

Figure 5
Switching Shape Grammar and Gestalt Laws on and off to generate various weaving properties.

Figure 6
Pattern derivation(sources for the top image of each pattern: [2] and Popovic, 2008).
new emergent shapes that still maintain the physical property of weaving can be retrieved.

**DISCUSSION**

This paper has demonstrated the role of Shape Grammar in leveraging the capacity of Gestalt principles to recognize object in different way. This, in turn, highlights the non-deterministic value of the Shape Grammar method in the design process. As exhibited in figure 6, Gestalt principles and Shape Grammar can visually reasoning some architectural weaving designs with one interpretative rule.

As mentioned above, this experiment focuses exclusively on the visual aspect of weaving without constraints from the properties of the material and tactile experience, which are inseparable from visual perception in weaving. Further research to include these physical parameters would be a valuable addition to this study.

**REFERENCES**


[1] gth.krammerbuch.at/content/vol-32-issueheft-1 (Journal of the Society for Gestalt Theory and its Applications (GTA))
