A Textile Block Grammar: An analytical Shape Grammar to Study the Block Designs of Frank Lloyd Wright's Californian Textile Block Houses

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Abstract

This paper presents an analytical shape grammar to study the designs of the ornamental blocks in Frank Lloyd Wright's Californian Textile Block Houses. The paper introduces the textile block system and expands on the design of the Millard house as a case study. The paper presents two formalistic applications of the shape grammar to generate the original block design: one as a sequential shape grammar and the other as a parallel shape grammar. Both examples are able to generate the same results; and they hint at the potential to expand the shape grammar to generate other design alternatives.

Keywords: Shape grammars; Parametric design; Design analysis.

Introduction

During the period between 1923 and 1924, American architect Frank Lloyd Wright designed and built four houses in southern California in a unique architectonic style that to this date is the subject of continuous studies. Using, what at the time was regarded as an innovative construction system, the houses where later described as the *textile block houses.* The name is due in part to the quilt-like visual quality portrayed by the block units, and the woven nature of layering precast concrete blocks between steel bars as reinforcement. Considered by Frank Lloyd Wright as the first *Usonian houses,* the house design along with the construction system was an attempt of the architect at creating a new architecture that departed from the prairie style. One that he will latter regard as more "organic" and suited for the time (Moor, 2002).

The construction system in itself was not an invention of Frank Lloyd Wright. However, the designs of geometrical patterns imprinted on the individual blocks gave a new dimension to the use of the concrete tiles as elements of the architectural language beyond the utilitarian role of providing enclosure. The design of the patterns still attracts admirers of all sorts. From scholars to practicing designers, to students and the general public. These houses are even sought out by Hollywood producers and directors as prime locations for movies and TV shows. The list includes movies such as Ridley Scott's dystopian science fiction hit Blade Runner, Black Rain and The Karate Kid part III just to name a few.

While the construction of the textile block houses are close to reach their hundredth anniversary, they can be regarded as contemporary and even futuristic. In light of the complex forms brought by the age of computing, the Textile Block Houses can rival some of the most intricate and complex designs of the present.

The Textile Block System

As a construction system, the *textile block* consisted in precast concrete units layered double wall with an in-between air chamber. Both walls were erected with square concrete blocks joined with mortar and reinforced with small steel bars between the joints. The blocks have a decorative relief on the exposed face and it is flat on the opposite side. Blocks where pre-cast with a concrete mixture made with aggregates extracted from the construction site. Frank Lloyd Wright (FLW) used wooden molds at first, but they were latter substituted with metal to prevent deformation due to the water absorption that wood molds experimented. While there are more buildings built around the same era that FLW experimented with the textile block system, the unique feature of his designs are the decorative block patterns. Each of the houses was built using concrete blocks with an original designed geometrical pattern.

It is interesting to note that the textile block wall system and the spatial qualities of the houses themselves have been the subject of extensive studies by various scholars. However, very little is known about the design of the individual block patterns giving the characteristic look of the textile block design language. Kenneth Frampton (1991) discusses some historical aspects of interest in regards to wall and surface ornamentation in architecture preceding FLW's textile block system. In particular Frampton (1995) refers to FLW interest in creating "ornament from the fabrication process" as key feature in the development of the textured block as a building unit; integrating function and ornament. March and Steadman (1974) briefly discuss the Millard House block as an example of the planar symmetry group, although no explanation of the design itself is offered. Yet despite these studies, there remains very little known about the actual design of the ornament of the textile block unit, and the patterns that the system creates.

Design & Computing with Textile Blocks

In an effort to look at the textile block system as a design and computational problem, our research has investigated this question at different levels. In a previously published paper we concluded that "*applying simple transformations to the original design, new and complex designs are created which extend the current vocabulary of blocks*." (Barrios & Lemley, 2007). The paper shows how the use of simple rules in a computational setting can create a large number of possible new designs, including all original FLW designs and new ones in the language.

The focus of that research was on the combinatorial aspect of the blocks as units in a large design setting. This was achieved using the rules of the wallpaper symmetry group and other transformations, including some randomized algorithms. Subsequent work has argued in favor of a contemporary application of the design principles of the textile block, both as a parametric enterprise involving digital fabrication (Barrios & Alomar, 2008), and crude attempts to sustainable applications. The goal of these studies is to use the textile block system as a catalyst for design studies, rather than a design analysis with a historical perspective. However, one question remains to be answered from these precedents and that is *the design individual block pattern as part of the computational system*. We attempt to answer this question by proposing a shape grammar that will allow the creation of the original block.

Design of the textile block: the Millard residence

The Millard Residence was built between 1923 and 1924. The design of the block is perhaps the simplest of the four, due perhaps to the fact that the molds used in this original house were made out of wood, and that this was the first to be built entirely in the woven block system. The motif of the block allowed the creation of half-blocks and quarter-blocks which made it easier to turn corners and adjust to changing dimensions. The Millard house blocks (FIGURE 1) are used as the case study for the analytical shape grammar to create the original FLW block designs. The attention is focused on the solid and perforated blocks, as well as the side and corner alternatives.

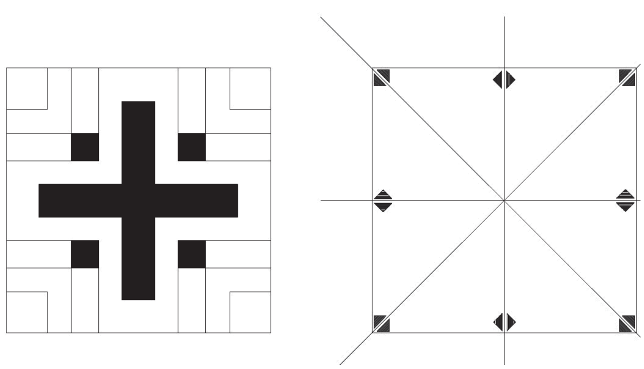

Figure 1: Original design of Millar House Blocks

Geometry of the Millard house block

The design of the block is denoted as having a symmetry of the group D4 (March & Steadman, 1974) while the design of the wallpaper for the Millard House can be part of several symmetry groups (Barrios & Lemley, 2007). This is due to the nature of the symmetry of the block design which creates ambiguity in some of the Euclidean transformations. In some cases it is difficult to discern if the position of a particular block is the result of a translation, a rotation or a reflection since all operations can yield the same visual result.

The Shape Grammar

The shape grammar introduced in this paper is an analytical shape grammar intended to dissect the original block into shape rules which are later used to create the original design of the block. For this study we will not attempt to use the shape grammar to generate new design solutions. Furthermore, refinement of the rules might be necessary to account for the three dimensionality of the block, and for the draft angles required to extract the block from the mold. The shape rules are presented concurrently with the design dissection and derivation. At this stage we don't make any distinction between all four alternatives of the blocks, as all of them can be produced using the same rules.

As a single unit the Millard house block has D4 symmetry. The block design is composed of four quadrants, each of them with a diagonal reflection line. We will use this feature to create a set of shape rules that can generate the single corner of the block, or all the corners simultaneously as a *parallel grammar*. The shape grammar is composed of two parts: Part one is the basic configuration with three basic rules, rules 1 through rule 3. Part 2 is the ornamental phase with three rules: rules 4, 5 and 6. The square shape of the outer boundary of the block will be used to represent the *initial shape* of the shape grammar.

Basic rules

In rule 1 a square is subdivided into four smaller identical squares preserving a cross shape in the center of the outer square (FIGURE 2). This rule needs to be applied recursively five times in order to construct the basic pattern. The same rule can be applied in parallel at all four corners. Rule 2 shows the subdivision of one square into four regions that must be symmetrical through the diagonal (FIGURE 2). This rule will need to be applied four times to the second squares from the center in all corners. This rule can also be applied in parallel to all second squares from the center at once. Rule 2 creates four regions that are symmetrical with respect to a diagonal axis. A restriction for this rule is that all created regions must be of different sizes keeping the smaller one towards the center of the block. Rule 3 shows how to turn the first four squares to a cross figure which floats in the center of the large square (FIGURE 2).This rule will only be applied once. These three rules create all the basic configuration of the Millard House block.

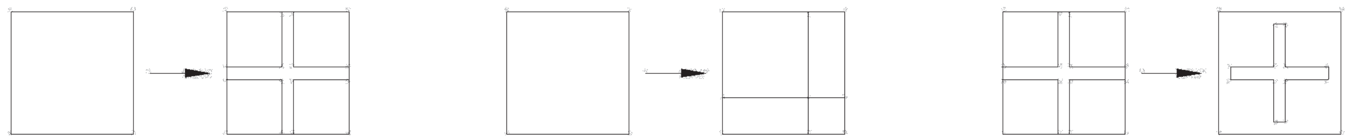

Figure 2: Shape rules 1, 2 and 3 used for creating the basic configuration of the Millard house block design.

Ornament rules

The second stage of the shape grammar is composed of three ornament rules. Rules 4 and 5 are used to create the half-block and quarter-block also used in the house design (FIGURE 3). Rule 6 changes a closed white shape into a filled shape. This rule is used to indicate the openings in the perforated block that allows light to pass through. This particular rule must be accompanied with labels showing the openings to be filled Labels are used to avoid creating openings in undesired places.

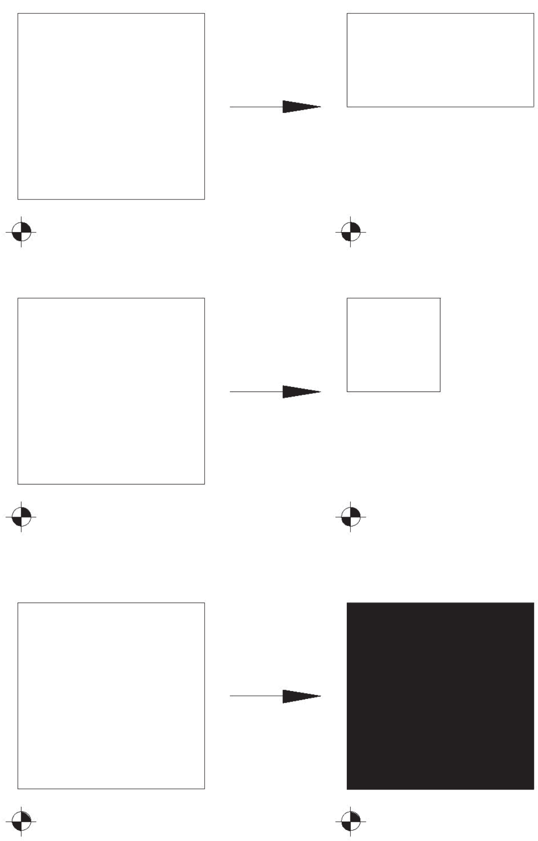

Figure 3: Ornament Rules

Design derivation

We will now turn to the design derivation of the Millar House block following the rules of the shape grammar. The first step is the initial shape and the application of rule 1. When applied recursively five times we obtain the basic shape (Figure 4). Once rule 1 has been applied five times, we move to rule 2. In order to obtain the Millard house solid block Rule 2 must be applied to the second squares from the center. Rule 2 can also be applied between the second and third step of applying rule 1. The shape rules are not imposing a restriction of where to apply rule 2, but the application of rule two in other place or at another time will not create any of the original block designs or any of the corresponding variations. When rule 1 has been applied five times and rule 2 applied once to the second squares from the center, we will move to rule three. Rule 3 will also be restricted to the first set of squares created by Rule 1. Once again, Rule 3 does not impose a restriction on when or where to use the rule, but applying Rule 3 out of sequence, or on a different set of squares other than the first set will not create an original block design. Once rules 1, 2 and 3 have been used the basic shape is complete (Figure 4).

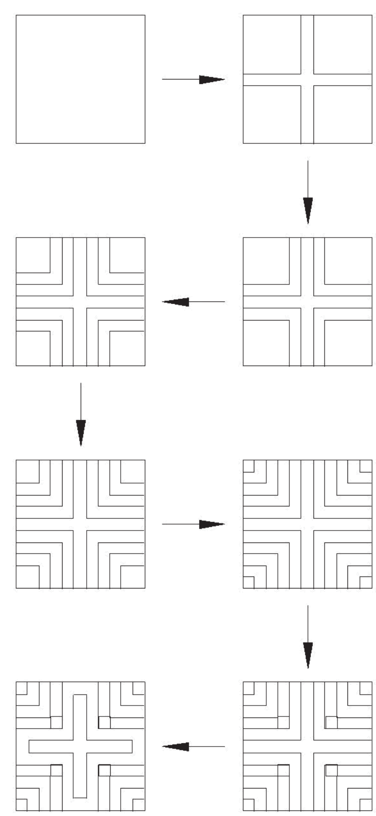

Figure 4: Design Derivation of the basic shape

Once the basic shape is complete we turn to the three ornament rules to create the other three variations of the blocks. In order to create the original Millar house block, the shape grammar restricts the application of the ornament rules to only once. Rule 4 is used to create the half block used for 90 degree turns. Rule 5 is used to create the quarter block, which is used in corners. Rule 6 is restricted for use only when a perforated block is to be created. Figure 5 shows all design alternatives from the ornament rules.

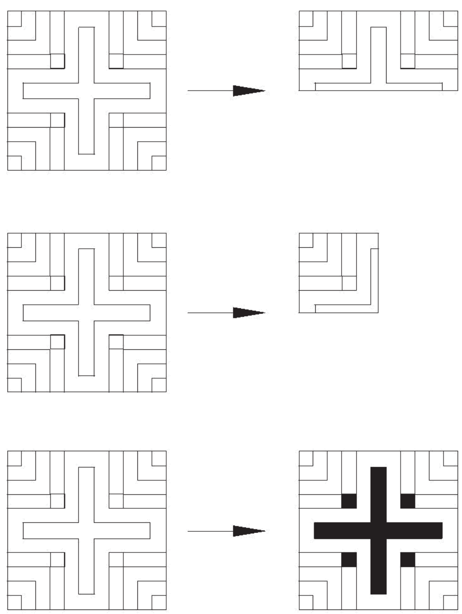

Figure 5: Design Derivation of the block variations using the ornament rules

Discussion

This simple grammar allows the creation of the main decorative blocks from the Millard House. The Millard house also has two additional designs: a smooth block with no decorative patterns; and a separate design for the house piers. The pier block has also a half block and a cap for design alternatives. Both variations can be generated using the ornament rules. Rule 1 can be used to generate the basic pier with a slight modification.

The current stage of the grammar gives the designer a high degree of freedom which serves the purpose of the design analysis. For the generation of the original block, the restrictions on the rules must be observed.

Additional Designs

The shame shape rules can be used to create the blocks of the Storer House which was built around the same time. For the Storer house the application of Rule 1 becomes more elaborative and will need additional restrictions. An additional ornament rule will be necessary to reverse some of the interior corners of the block design. This is a possible way to expand the grammar.

For the design of the remaining two houses, the Freeman house and the Ennis Residence, a separate shape grammar must be constructed. The block designs of these two houses is more elaborate and intricate. It would be very difficult to use the original shape rules as a starting point. Furthermore, these two designs have a symmetry different than D4 (Barrios & Lemley, 2007) for which a parallel application of the rules must also be discarded.

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