COMPUTING WITH TEXTILE BLOCKS: *Symmetry Studies on Frank Lloyd Wright's Textile Block Design Patterns*

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Abstract. This research focused on generating alternative designs from the textile blocks California Houses of Frank Lloyd Wright based on regular wallpaper symmetry patterns. A computational framework was developed that generates the designs of the original textile blocks in combination with all possible wallpaper symmetry patterns. This computational framework allowed for the creation of the catalog of possible regular patterns. The development of the framework allowed for a deeper understanding of the symmetrical relationships of the blocks and the wallpaper patterns created by Frank Lloyd Wright and a large collection of new ones.

Keywords: Symmetry Studies, Design Patterns, Blocks Computation, Frank Lloyd Wright, Textile Blocks.

Introduction

The Textile Block designs of Frank Lloyd Wright were originally done in the 1920's in southern California. As a catalyst for design, Wright chose to investigate the design possibilities of using modular blocks. Wright used these pre-cast concrete blocks to investigate cost-efficient means of construction, but more importantly as a new aesthetic for design based on patterns from Mayan architecture. Wright developed this aesthetic by combining original block designs for each one of his projects, with a construction technique based on weaving the blocks with steel rods. Wright only completed four built projects using this technique using different blocks for each project: the **Millard House** in 1923, the **Storer House** in 1923, the **Freeman House** in 1923, and most notably the **Ennis House** in 1924, and there is record of one additional unbuilt project, called Little Dipper, in which he produced two additional block designs. The efforts of this research are focused on building a complete catalog of possible designs of Frank Lloyd Wright using computationally generated patterns with the original block designs in combination with all possible wallpaper symmetry patterns.

1. The Symmetry of the Block Designs

One of the key elements to understanding the implications of this research is to understand the symmetries of the textile blocks. In total, the six block designs exhibit three distinct classes of symmetry. The Millard and Storer blocks have a D4 symmetry (Figure 1a and b). This means that the block has bilateral symmetry as well as being able to be rotated 4 times within a period of 360 degrees. Each of these operations will yield a design that is indistinguishable from the original design. The two blocks from the Little Dipper project have a C2 symmetry (Figure 1c and d). These blocks do not have bilateral symmetry, but can be rotated twice within 360 degrees. The last two blocks, the Freeman and Ennis, have a C1 symmetry (Figure 1e and f). These blocks are again without any bilateral symmetry, and can only be rotated once within a period of 360 degrees. Most would classify an object with C1 symmetry to be an asymmetric object.

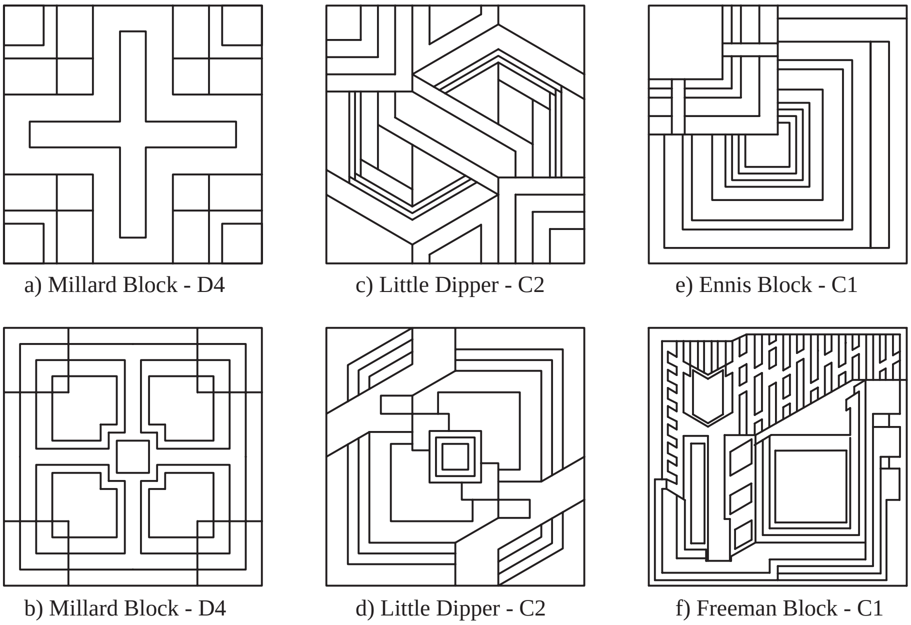

Figure 1. The six original Frank Lloyd Wright Blocks with their corresponding symmetry

After understanding the underlying symmetries of the whole block we determined to be important to generate the designs of the blocks via automated process. Due to the complexity of the blocks, the automated generations focused solely on the two dimensional representation of the blocks. This also allowed the two dimensional process to focus on the geometrical relationships of the elements that of the blocks. The first step in generating the blocks was to analyze the proportions of the blocks in relation to the overall width of the block. Through the proportional analysis we discovered that the portions of the block where primarily divided into halves, thirds, fifths and sevenths. With these proportions in mind, computer scripts were then written to generate the six original block designs based on a square shape as the input.

2. The Wallpaper Patterns

After the development of the automated generation of the blocks, the focus shifted towards generating patterns with the blocks. This investigation focused on **network patterns**, specifically **wallpaper patterns**. Network patterns are a network of designs in which the symmetry of a whole pattern is expressed as the relationship of the objects within that pattern to each other. These patterns were used in conjunction with the existing block designs to realize alternative design possibilities without having to modify the existing block designs. These new designs could have been able to be obtained by Wright because they would have utilized the forms that had already been created for the block. In our current research we have not found any indication that Wright used any of these patterns to enhance his designs.

One of the key elements of the pattern is the lattice around which the symmetries are made. This lattice begins with of a series of equidistant points created along two translational axes (Koptsik, 1974). Once the points are created they need to be connected with two or more axes in order to create the lattice. A series of points will have an infinite number of axes that could be created, but the structure of the axes will have implications in regards to the underlying symmetry of the lattice. For this investigation however, the structure and form of the original designs was not altered; therefore a square lattice was used to construct the patterns.

The wallpaper patterns are made up of four isometric operations; translation, rotation, reflection, and glide reflection. Of these four operations, glide reflection may be the one in need of further explanation. Glide reflection can be defined as an operation that consists of a reflection and a translation along that axis of reflection. Although seen as two separate operations, glide reflections are treated as one single operation. Through using these four operations there are a total of 17 possible wallpaper patterns that can be created. The finite number of patterns is due to the reciprocal nature of reflections and glide reflections as well as the lattice structure limiting rotations to the order of 2, 3, 4, or 6 (Schattschneider, 1978). Due to the limitation of using a square block as well as a square lattice, there are a total of 10 possible patterns that can be utilized for the textile block designs.

2.1. EXPLANATION OF APPLICABLE PATTERNS

The possible designs that can be created from the Textile Block designs expressed in crystallographic notation are as follows; P1, P2, PM, PG, PMM, PGG, PMG, P4, CM, and CMM. The first letter of the notation denotes whether the pattern "denotes a primitive or centred cell" (Schattschneider, 1978). The number denotes the number of rotations within 360 degrees. The second and third letter express the operation carried out along the primary and secondary axis, respectively, with M denoting reflection and G denoting glide reflection. Numbers are only specified when there are distinct rotations within the pattern. If a letter is omitted, there are no reflections or glide reflections along that axis.

A P1 pattern has a translation operation along each axis. Most would characterize a P1 pattern as a simple array.

A P2 pattern has a rotation of 180 degrees and a translation along the primary axis.

A PM pattern has a reflection along the primary axis and a translation along the secondary axis.

A PG pattern has a glide reflection along the primary axis and a translation along the secondary axis.

A PMM pattern has a reflection along each axis

A PGG pattern has a glide reflection along each axis.

A PMG pattern has a reflection along the primary axis and a glide reflection along the secondary axis.

A P4 pattern has rotations of 90 degrees

A CM pattern has a reflection and a glide reflection along the primary axis

A CMM pattern has both reflections and glide reflections on both the primary and secondary axis.

2.2 COMPUTATION ON THE WALLPAPER PATTERNS

Once the symmetries applicable to the Textile Blocks were determined, efforts shifted to writing scripts that would be able to regenerate the patterns with any given object. Translating the symmetry patterns into a set of operational instructions posed an issue that is fundamentally at the heart of the patterns; that the patterns (symmetries) are an expression of the resulting relationships and not necessarily the operations that created the pattern. As stated in the book Symmetry in Science and Art, "if we are speaking, not of operations, but of symmetry elements, we shall call the complete set of these elements the symmetry class...of the corresponding network pattern" (Koptsik, 1974). To add to this issue, as the complexity of the patterns progress, there becomes more and more interaction between the different objects resulting in emergent relationships that are represented in the full depiction of all the existing symmetries. The codification of the each pattern required a careful analysis and understanding of how the specific symmetry group would relate to the defined parameters. Only then could the patterns be translated into the operations needed to create the pattern.

There were two methods of creating the patterns that were developed, each one with its distinct advantages and disadvantages. The first method involved creating the smallest **repeating swatch** of the pattern and then creating a larger array with that swatch. The second method involved creating the final array, then going back and performing the necessary operation on each of the blocks in order to create the desired pattern.

The first method is very effective for creating large patterns. This is because the operations to create the pattern are carried out on the fewest number of objects possible and then those objects are repeated. Therefore, when the array is created there is no need to perform any additional operations. The downfall with this method is that it does not allow for any modification of the array. Although this is not necessarily an issue for the simple creation of patterns, but can be limiting for further investigations of smaller scale portions of the array.

The second method is very flexible in terms of the possibilities of the whole pattern. Since this method creates the pattern by doing the operations at the individual block level, the patterns have a potential degree of control that is not exhibited within the first method. Interestingly enough, this method requires that the pattern be expressed much differently then first method. This is because the resulting operation of each block had to yield a block that is in the exact same place as before the operation. Also, each operation started from the original block, where the first method may not have. This method, like the first, has problems, the main one being the processing power, or time, required for the script to execute. This is again due to each individual block requiring its own operation.

3. Catalogue

3.1 APPLYING WALLPAPER PATTERNS TO THE BLOCKS

Once both the blocks and wallpaper patterns could be achieved through computational, or automated, processes, the next step was to put the two elements together to see generate new designs. The development within this area was able to happen very rapidly due to the computational framework which had been already developed.

The first block that was tested was the Ennis block. (Figure 2) The P1 array creates the original design of Frank Lloyd Wright, which is a mere translation of the block. The only other pattern which is even slightly exhibited in the Ennis House is the PM pattern, which Wright used on selected corner conditions in a vertical orientation as opposed to the horizontal orientation of the generated wallpaper pattern. The rest of the newly created patterns were not exhibited within the Ennis House.

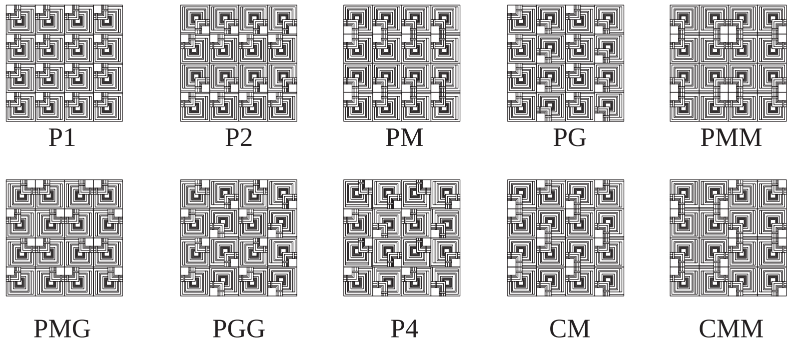

Figure 2. Wallpaper patterns for the Ennis Block.

3.2 SYMMETRICAL ISSUES OF THE BLOCKS IN CONJUNCTION WITH THE WALLPAPER PATTERNS

After the wallpaper patterns of the Ennis block were created, the next block that was tested was the Millard block. (Figure 3) As each pattern was created it was observed that each pattern showed no deviation from the original translation of the P1 pattern. This is due to the high D4 symmetry of the Millard block. Any of the operations that occur within the patterns will yield a block that is identical with the original, therefore none of the patterns in the wallpaper will show any change in the overall design. The same result was observed with the Storer block which also had D4 symmetry.

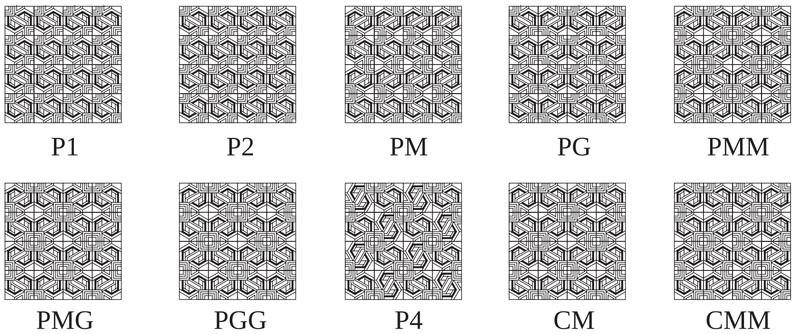

Figure 3 Wallpaper patterns for the Millard Block.

The last phase of the initial investigation was to use the blocks from the Little Dipper project to create the wallpaper patterns. (Figure 4) These blocks produced an even more interesting outcome as there were a number of unique patterns, but also a number of coincidental patterns. As can be noted from the earlier expressions of the wallpaper patterns, there are emergent rotations of 180 degrees that are evident within some of the more complex patterns. The Little Dipper blocks have a C2 symmetry, meaning that they will yield their identity after a rotation of 180. Thusly, a pattern such as P2, which is determinant on this 180 degree rotation, patterns such as PMM, PMG, PGG, and CM, which have emergent 180 degree rotations, have a tendency to coincide with other patterns.

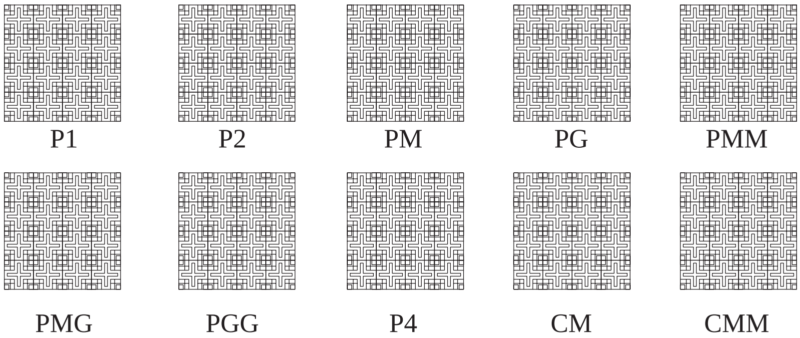

Figure 4 Resulting Wallpaper patterns for the Little Dipper Block.

3.3 BLOCK ORIENTATION AND THE IMPACTS ON THE WALLPAPER PATTERNS

It must be noted that the original orientation of the wallpaper does have an affect on the outcome of the pattern. This of course relates back to the symmetry of the block, with the rotation of the Millard and Storer blocks having no change and the Little Dipper designs having only one rotation of 90 degrees that can yield a different design. The Ennis and Freeman, with their C1 symmetries, have four rotations that can yield different designs. The designs resulting from these rotations are highly related to each other, but will produce discernibly different results.

There are two different classes of patterns when talking about rotated designs; one set that will yield unique patterns with every rotation of 90 degrees which consists of P1, PM, PG, CM, and CMM patterns (Figure 5), and another set that will only yield a unique pattern with the first 90 degree rotation which consists of P2, PMM, PGG, PMG, and P4 patterns. For the second set of patterns, there are unique results when the pattern is run from a specific starting location or element, but the patterns are intended to be infinite. Due to this notion of infinite patterns, the resulting pattern must be observed in a relative way. This is what allows the designation of the patterns to only have one unique rotation because rotations beyond that will result in patterns that are the same, but only with a slight shift in the phase of the pattern.

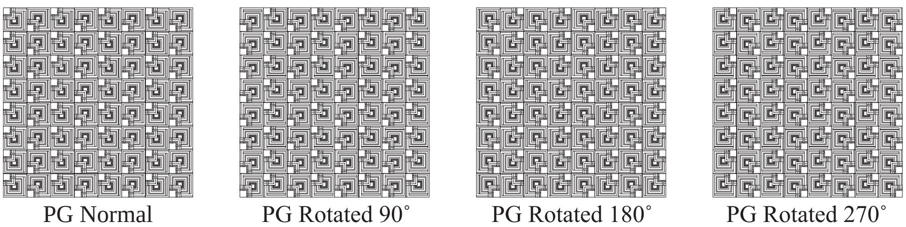

Figure 5. Ennis Block shown in different rotations within a PG pattern.

4. Conclusions

This research focused on generating alternative designs from the textile blocks of Frank Lloyd Wright. In order to generate those designs a computational framework was developed that not only generated the designs of the blocks, but also generated the wallpaper patterns from the blocks. This computational framework allowed for explorations into the possibilities of what the patterns could create in a very effortless way. The initial development of the framework allowed for a deeper understanding of the symmetrical relationships of the patterns, and the later use of the framework allowed the patterns to progress in a manner which would have been significantly challenging to do without the automation of the patterns.

There are a number of possible avenues of further exploration could involve varying the initial lattice, creating patterns with gaps in the resulting pattern and what becomes of those gaps, as well as creating random or increasingly random variations of the blocks within the pattern. Also, the geometry of the highly symmetrical blocks could be varied as to change the symmetry of those blocks, and therefore allowing the wallpaper patterns to be used with the altered designs.

The true implication of this research, however, is the capability for it to affect designs beyond the ones of Frank Lloyd Wright. Wright's designs were developed more than 80 years ago, and yield a significant number of distinct results. Designs could be created with the idea of using wallpaper patterns in mind as to interact with the resulting pattern. With the computational framework in place, a designer need not focus on the resources needed to create the pattern, but only on the design itself, its interaction with the patterns, and the implications of using the patterns.

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