Process as the Link Between Design and Making

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INTRODUCTION

Design is not always associated with Making, however there is one key element which is central to both. That element is Process. Although the understanding of Process may be different between Design, where Process is a means or path of discovery, and Making, where Process is a means of instructions or steps, the idea of building upon a previous idea or component is central to both. When looking at the Design of Making it becomes necessary to have the Process of Design and the Process of Making inform each other, resulting in a dialog between the two. This dialog allows for both to proceed as a catalyst for each other; Design serving as inspiration for Making and Making serving as inspiration for Design.

This research is presenting a method of investigating computational roles within design through patterns, variations, and various inputs. We used the designs of Frank Lloyd Wright's Textile Block houses as a catalyst to test and experiment with these ideas. The use of the Textile Blocks gives the research a starting point and context to frame these investigations. The role of computation within the design is not meant to radically change the design, but rather to work within existing realms to discover alternatives that adhere to the existing design language.

Frank Lloyd Wright's Textile Block houses were built in California during the 1920's. There are a total of 6 block designs that resulted from this period in Wright's work; The Millard House, Storer House, Freeman House, Ennis House, and two blocks from an unbuilt project that is referred to as Little Dipper. Through these designs, variations have been created that have retained as much of the perceived design intent while allowing other factors to influence the block. Since these blocks had a method of construction with which they were designed, the fabrication of the new designs was rethought in light of the capabilities of digital fabrication techniques.

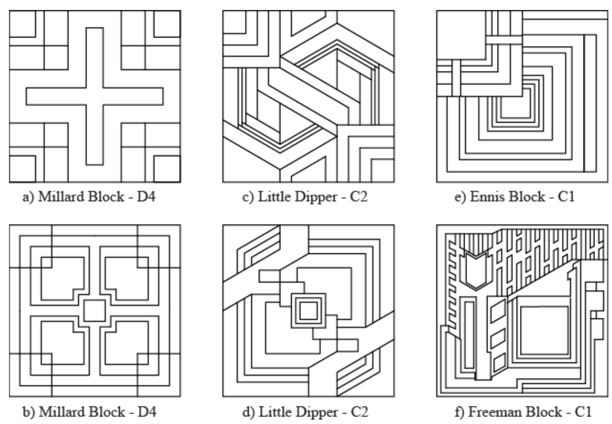

Figure 1: The original block designs of Frank Lloyd Wright

ON DESIGN THROUGH PATTERNS

Frank Lloyd Wright had originally intended for these block designs to be used within a mass-produced, modular building system. The designs of the blocks were his efforts to bring a notion of aesthetics into this modular system. Due to the intent of the block to be used at a macro scale of the building, the design consideration was not only of the block itself, but the resulting pattern that the block created when implemented at a larger scale. There is no indication that Wright examined the design potentials of larger scale patterns. The first path of the investigation was to investigate larger scale patterns with the textile blocks. This is an important starting point because the resulting designs are achievable without changing any of the existing designs or adjusting Wright's process of construction or fabrication.

The focus of these large scale patterns began with wallpaper patterns. Wallpaper 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 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 and rotations being limited to the order of 2, 3, 4, or 6 (Schattschneider, 1978). Due to the limitation of using a square block, there are a total of 10 possible patterns that can be utilized for the textile block designs.

VARIATION BY MAKING: CRACKING THE CODES OF WRIGHT'S BLOCKS

Codifying these wallpaper patterns proved to a considerable task for several reasons. Firstly, the wallpaper patterns have a great deal of complexity due to the interaction between different elements and the emergent relationships that result from full pattern. Secondly, the patterns are expressed as the resulting relationships, not necessarily the operations that are needed to create the pattern. Thus the codification required an understanding of the patterns in terms of the operations required to reproduce them. Only then could the code be written to create the patterns.

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. Thusly, 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, it 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. This method creates the pattern by making an array of objects, then carring our the required operations at the individual block level. This method allows the patterns have a potential degree of control that is not exhibited within the first method. Interestingly enough, this requires that the pattern be expressed much differently then previous technique 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 process to execute. This is again due to each individual block requiring its own operation.

IMPLEMENTING BLOCKS WITH THE WALLPAPER PATTERNS

Once the code for generating the patterns was written, the patterns could now be tested with the original block designs. Each of the ten patterns was created with the six block designs to create various design permutations. By creating the patterns with all six of the blocks, it was discovered that certain symmetries would create patterns that are indistinguishable from one another. The designs of the Millard and Storer houses yielded patterns that were identical to each other due to the bilateral and rotational symmetries within the block. The designs from the Little Dipper project generated some patterns which were unique and some which were coincidental. This is because of the blocks rotational symmetry. The Ennis and Freeman blocks have a very low symmetry, therefore all of the wallpaper patterns are unique (Figure 2)

The automated generation of the wallpaper patterns also allowed for the exploration of using multiple blocks as the initial element of the pattern. This allowed for nested patterns to be created using the same framework and very little additional effort. By using this technique, the number of potential patterns from a single design increase significantly.

Another development that was derived from this part of the investigation was the creation of random patterns. This emerged from the second process of automation and its application of an operation on each individual block. Rather than follow the order of operations of any of the specific patterns, the operation for each block was allowed to be determined randomly.

VARIATIONS: DESIGN AND MAKING

After investigating potential designs at larger scales, the next endeavor focused on the block at a smaller scale. This entailed automated generation of alternative block geometries. These geometries were derived from a single topology which retains aspects of the design language of the blocks.

The first step in varying the designs is to automate the process of building the original designs. Due to the complexity of the blocks in three dimensions this automation generated purely two dimensional designs. This also allowed the automation to focus on the primary relationships of the blocks. The generation of the blocks was recreated through a rigorous analysis of the proportions of the block. This analysis resulted in two important aspects for the generation. First off, the formations of the blocks were parameterized. This allowed the blocks to be easily recreated at a variety of scales and situations. Also, the process of adjusting the block could be achieved easily and retain as much of the original design intent as possible. Secondly, the method of forming a comparison between the blocks was developed. In many cases this was a correlation between the proportions of various elements, leading to an understanding of how these elements interact within each block and the design language as a whole.

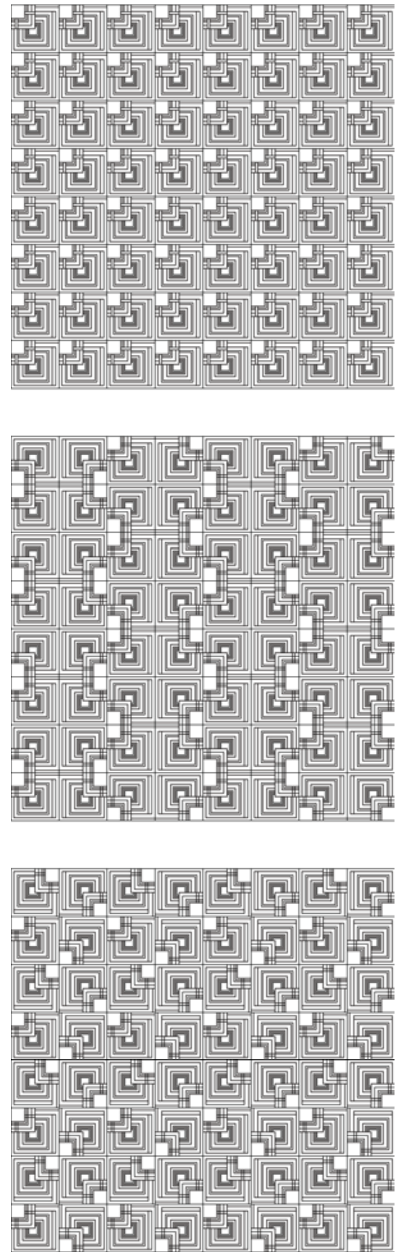

Figure 2: Original Frank Lloyd Wright design of the Ennis House textile block pattern along with two new designs using the wallpaper patterns

Once the automated processes for generated the block were developed, it then became possible to approach the problem of how to adjust the geometry of the block. It was decided to focus on one specific block as the starting point for this investigation. The Milllard block was chosen for the type of interactions that were exhibited within the block, the functional characteristics of the block within the house itself and also the implications of breaking the blocks high level of symmetry.

In order to actually vary the geometry, the topology and parameters of the block were evaluated. It was determined that the primary means of adjusting the geometry would be related to the central cross element in the block. There were three parameters that determined the structure of that block: the total width of the cross, the thickness of the cross, and, most importantly, the center point of the cross. The width and thickness of the cross were both parameters that were developed from the proportional analysis, so to vary the geometry, the control of those parameters was now a value that could be inputted by the user. The center point of the cross was very important because this is what allowed the block to break its high level of symmetry. Changing the center point of the cross also dictated a small, but necessary revision to the code to properly construct the cross. (Figure 3)

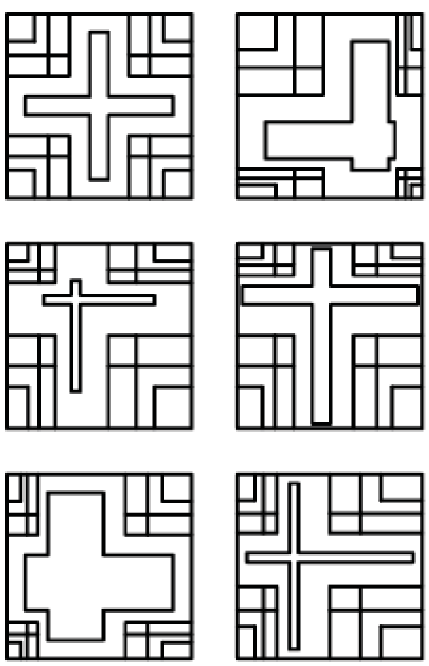

Figure 3: Original Frank Lloyd Wright design of the Millard House textile block and new designs from parametric variations.

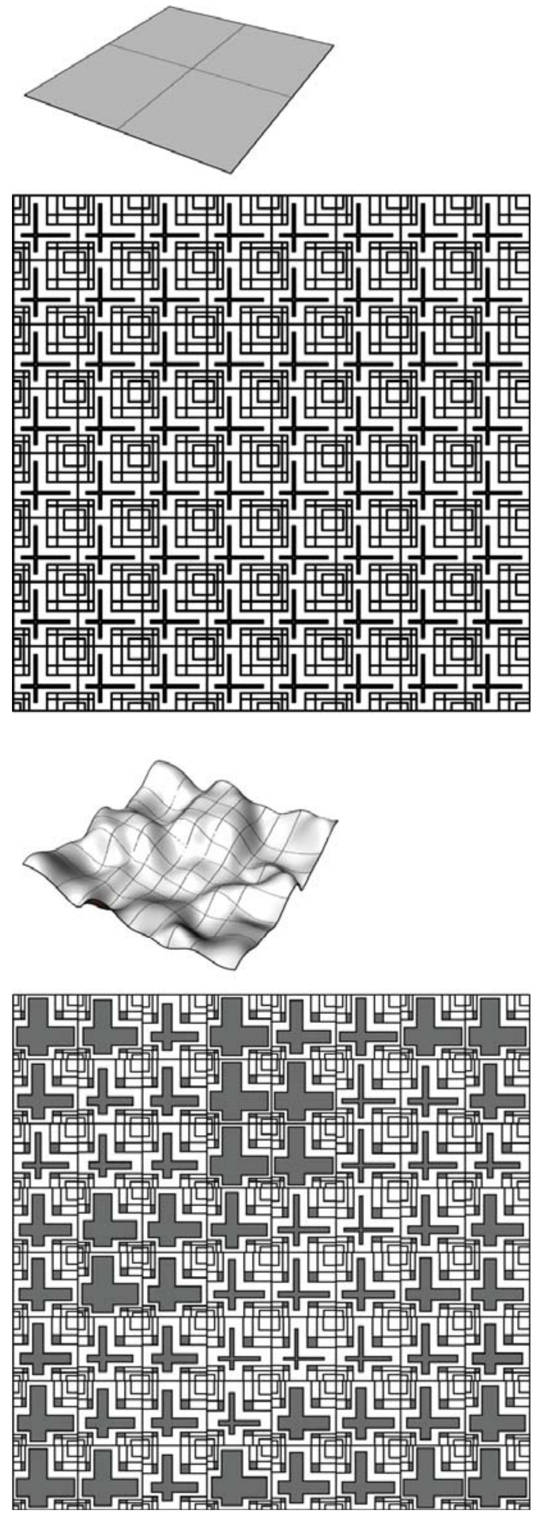

Figure 4: Pattern Variation through external controlled input. The relative height of the surface determines the degree of opening within the pattern

As a byproduct of changing the formation of the cross, the method of constructing the corners also was in need of significant change. Previously, the construction of the corners related to the proportions of the block as whole. This was fine when the block was merely being reconstructed, but now that the geometry of the block was changing, the construction of the corner element now needed to be expressed relative to the cross. Again, the original patterns of Frank Lloyd Wright were reanalyzed to find the relative proportions of the corner elements relating to the cross. The end result is a block that is widely variable and has a clear sense of control and proportion.

MICRO AND MACRO: MAKING COMPLEXITY

Now that the geometry was able to be easily manipulated through different parameters, a new means of experimentation became evident. Varying the block was extremely worthwhile, but on the scale of a single block with manual inputs there was little expansion that could take place. The next step that developed was to take the variations of the blocks to the macro level, adjusting each individual block within the whole pattern to add greater complexity.

In order to do this, a single means of expressing variation of the block was needed. Looking back at the block itself revealed a distinct opportunity for this unifying variation. One of the functions of the blocks, beyond aesthetics and structure, was to filter light into the houses. The amount of light relates to the amount of open area of the block. So rather then varying the results through individual manipulations of each of the parameters, those parameters were reevaluated, expressed, and varied in relation to the percentage of open area. This required that there be more additions to the code itself. Although the structure of generating the cross remained unchanged, there was an evaluation that was added to determine the amount of open area of the cross. Once the area of the cross is calculated this was then checked with the desired percentage of opening and methods for adjusting the width and thickness of the cross were created for increasing or decreasing the amount of open area.

DESIGN ADJUSTED THROUGH CONTROLLED VARIATION

With the structure of a single input for the variation in place different inputs can be utilized to dictate the percentage of open area. The first of these inputs was looking at simple gradients. These specified the area for each specific block was evaluated through the gradient function, which returned the required percentage of open area. This required percentage was then used to evaluate and manipulate the block. Although the gradient functions are relatively simple, this opens up the capability to use other mathematical functions to determine the percentage of open area. At this point only the code for horizontal or vertical gradients has been developed, but other shapes, such as diagonal or radial gradients may also be used.The next input that was looked at was generating the percentage of open area from the Z height of a given surface. (Figure 4) To accomplish this, the surface was evaluated at a series of points corresponding to the size of the pattern. Those points were then evaluated to determine the minimum and maximum values. Those values were then used to determine the amount of open area for a given block. This method could be used as a means to articulate ambiguous surfaces through the patterns and form of the block.

The last input that was investigated was using color information from images to determine the percentage of open area. In order to generate the open area percentage the image was sampled at a distance that would correlate to the size of the pattern. Then the value of that pixel was translated from a scale of 0 to 255 into a scale of 0 to 1. Those translated values would then determine the amount of open area. This was first done with grayscale images (Figure 5) to simplify the incoming information, but was also extended to support generating the open area from either the red, green, or blue channels of the image. The individual values of all the channels could also be blended together to determine the amount of open area.

These three experiments with alternative inputs opens up a great deal if potential mediums which could influence design. In each case, there was a substantial amount of translation that needed to occur between the input and the values needed for the patterns. This translation could be made for a variety of situations, thus allowing this process of manipulation to be applied under a range of different circumstances.

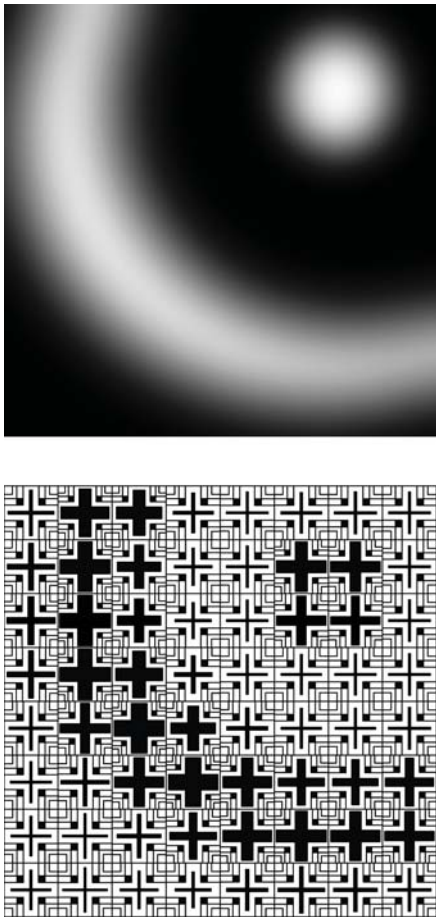

Figure 5: Pattern Variation through external control input. The value of the image determines the opening of the pattern at each point

PROTOTYPING DESIGNS

Although the majority of research focused on computational generation of design permutations, there was an understanding from the beginning of the investigation that these designs would also have to be built and fabricated. The original fabrication of the textile blocks was done with wood and metal molds. Wright's initial intent was for cost effective design, which dictated only one distinct mold for each design. Current capabilities of mass customization allows for the realization of numerous unique designs, something that would have been extremely hard to implement when the projects were originally constructed.

Although current methods of prototyping may not have necessarily been needed for the investigations of the wallpaper patterns, with the introduction of variational geometry it became a necessity. Since the research into the geometry of the block had chosen to look at the designs in only two dimensions, prototyping and fabrication methods also focused on two dimensional manipulation rather then three dimensional formations. This does not mean that understanding how these designs worked in three dimensions was disregarded, but rather the third dimension was understood through two dimensional translations.

The initial method of prototyping was through laser cutting. Small cubes and towers were made with several different wallpaper patterns. The cutting time between all of the different patterns varied by about 10 percent, so the introduction of the patterns did not have any adverse affect on production times. Also, models were made applying the wallpaper patterns to designs generated with developable surfaces. This allowed the designs to be integrated with more expressive forms, which was something that was not possible with using the designs as blocks. (Figure 6) It was observed that the open areas of the blocks actually released some of the surface tension within the models, which allowed for the sheets to be more easily applied to the forms. Larger scale mock-ups were also created by using a three-axis CNC mill. Although this machine would allow for us to fabricate three-dimensional elements, it was utilized as a two-dimensional cutting tool.

CONCLUSIONS

Through this investigation, the role of computation with existing designs has been explored in a manner which expands on those designs. This has been achieved through creating numerous patterns from a single design, user manipulation of the design, and automated generation of design variations via several inputs. The use of the Textile Blocks as the design element provided context, but the capabilities of the process can be applied through any number of designs.

Figure 6: Rapid Prototypes of the patterns applied to non-regular shapes

The creation of the wallpaper patterns allowed for the realization of a significant number of design possibilities. This is all without the need to modify the block in any way. Ultimately, the extent and complexity of a pattern can be the scope and scale of the resulting pattern. Multiple levels of nested designs could be used as well as implementing various levels of random manipulation.

Creating geometric variations allowed for the original designs to take on new forms and expressions, yet maintained their relationship to its predecessor. The ability for the user to control the variation was important, starting with manual adjustment and expanding to various inputs. The inputs expressed a number of compelling avenues of exploration as well as allowing alternative mediums to be used to express design.

There are a number of aspects of this research which can be further investigated. Within the realm of the Textile blocks, other designs besides the Millard block can be prepared for variation. Also, other parameters could be used for the dictation of the form of the block. Also, the two dimensional designs can be expanded to incorporate the three dimensional aspects of the designs.

From the stand point of the processes of generation, their development has the potential to be influenced by being applied to other designs. This would allow for an understanding of common elements of the design process, as well as where these elements needed to be adapted to the specific context of the individual project.

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