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Arraying Alternative Housing Archetypes: An Online Resource

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Abstract

This article provides an ongoing research on the interactive housing design online model for exploring possible housing layouts. Earlier research on the spatial composition of the Schindler Shelter is reiterated and then, an online resource model with a java applet is developed to illustrate possible housing layouts.

1. Introduction

In a previous paper (Park, forthcoming), symmetry applications in housing design were discussed and applied it to one of Rudolph M. Schindler's unbuilt housing designs, the Schindler Shelter project of 1933-42. The study introduced a formal methodology with an emphasis on the point group symmetry and subsymmetry in the analysis and synthesis of architectural designs.

In the study, mathematical techniques, including spatial transformations, a lattice of subsymmetries, and a multiplication table, were reviewed as formative principles of spatial compositions. Symmetry principles were also reviewed in the development of housing design and the results of multiplying the designs in some larger assembly were demonstrated. This technique presented systematical experimentation with symmetric transformations to generate design variations. The symmetry principle was also employed to test the compositional possibilities of arranging a shelter on a city block to maximize streetscape variety.

In this article, the research is developed further by enumerating possible layouts. First, unique compositional characteristics of the housing designs are revisited. Second, simple symmetry operations as well as a method of arraying alternative housing layouts are discussed. Then, the emphasis is shifted to an ongoing network-based housing model with a Java applet.

2. Housing Example

Rudolph M. Schindler's unbuilt housing design, the Schindler Shelter, is used as the focus for discussion. Developed from 1933 to 1942, the project was a reaction to the low-cost housing projects for the Subsistence Homesteads (Park, forthcoming). The project was intended to provide urban dwellers with economic efficiency as well as comfortable suburban shelter. In designing this project, Schindler responded to issues of flexibility of the floor plan, expandability for the changing needs of a growing family, minimal maintenance, new construction methods, and new materials. He intended to provide a variety of optimal room layouts and multiple unit orientations with the integration of both systematic composition and construction techniques.

Although the development of the project spanned about ten years and a series of shelter plans underwent a variety of spatial transformations, they all shared common compositional principles. Two different types of housings are developed based on two different types of construction: the Shell Construction and the Panel Post Construction. We focus our study on plans with the Shell Construction. The floor plan of the unit prototype with the Shell Construction is based on a 5-foot by 5-foot unit grid. The architect clearly marked the unit grid on the drawing with numbers and alphabets as shown in Figure 1.

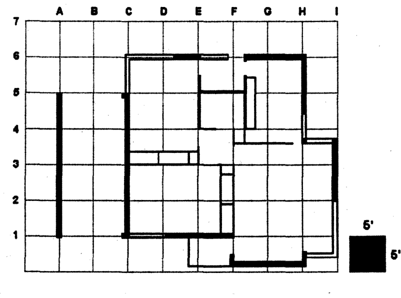


Figure 1: Four-room house plan marked the unit grid on the drawing with numbers, vertically and alphabets, horizontally

Besides the unit grid, pinwheel type symmetry governed the internal structure of functional zones in each scheme as well as its variations. The interior was subdivided by removable closet partitions which enhance spatial flexibility and create a pinwheel type of rotational symmetry. The use of symmetry principles was unique and prominent in Schindler's designs (Park, 1966, 2000, 2001). To add to the variety and flexibility of house designs, the garage as a separate unit, could be added to any side of the house.

Schindler provided variations of 3, 4, 4½, and 5-room house plans. The following figures are the standard prototypes of the 4-room house plan designed on the 5 by 5 grid unit.

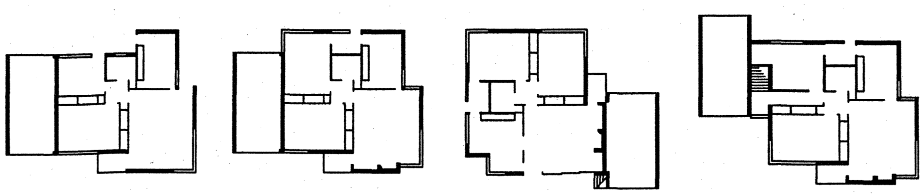


Figure 2: *Four different types of spatial configurations of the Schindler Shelter*

The designs achieve variations of symmetry while retaining their unifying design principle. As symmetry transformations take place and placement of garage locations vary, multiple exterior appearances are created. This ability to easily create multiple variations of housing designs using his symmetry and garage attachment method is the novelty of the Schindler Shelter. Six variations of a 4-room type scheme were identified in the investigation of archival drawings. To create the variations, the basic room type was rotated and reflected. Then a garage was added to a side of the unit. Although the variations looked different, a closer observation showed that they are almost identical based on the architect's compositional principle.

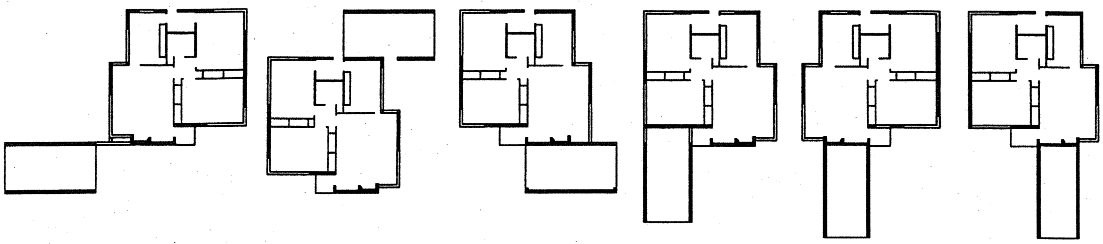


Figure 3: *Six other variations of the four-room type*

The creation of design variations provokes the question: how many possible new designs can be generated by the same design language of the architect. Schindler never thoroughly explored all possible layouts of the design. Thus, an exhaustive number of plans could be generated as probable designs. In generating combinations of possible layouts, symmetry principles are fruitful tools that can be continuously employed to produce numerous variations of housing designs. By manipulating the prototypical unit types, new designs can be generated and arrayed by simply rotating and reflecting the standard shelter plan and adding the garage in different positions.

3. Symmetry operations

At this point, the notion of symmetry operations should be discussed. Symmetry operations are concerned with spatial displacements which take a shape and move it in such a way that all the elements of the shape precisely overlay one another. Despite the displacement, the shape appears not to have been moved from its original position. Since the basic room type is square, we consider the symmetry of square. The motion of rotation through 90 degrees is called a symmetry operation of a square. Mathematicians call the collection of all the symmetry operations or motions that leave a particular geometric object fixed its symmetry group. The symmetry group of a square has eight spatial transformations, including four rotations (through 0°, 90°, 180°, 270°) and four mirror reflections (along the two orthogonal axes and the two diagonal axes).

In general, the symmetry group of a two-dimensional design can be either finite or infinite. Infinite groups are the symmetries of infinite patterns such as tilings or wallpaper patterns (March and Steadman, 1971). Infinite symmetry groups include the motion of translation which is a lateral shifting of the entire pattern by one unit. Point groups are finite symmetry groups and correspond to a finite design, such as a single square. Earlier papers (Park, 2000, 2001) proposed a theoretical model for analyzing and synthesizing architectural designs by using a mathematical technique.

In shape computations, symmetry operations naturally evolve to their spatial relationship. For example, in shape grammar (Knight, 1994), when two individual shapes are combined, the total number of shape rules is determined by symmetries of individual shapes. In their computations, symmetrical shapes have fewer potential rule applications than asymmetrical ones.

4. Arraying possible layouts

To keep the computation manageable, the housing unit is analyzed as a 5 by 5 unit module and the garage as 2 by 4 unit module. The total number of possible designs that can exist in the same language is also determined. The garage can be attached to the house in a number of ways; and the combinatorial possibilities of two shapes, the house and the garage, vary depending on how shape relations are setup.

Based on the analysis of housing designs, there are 8 distinctive spatial relations between two shapes under two conditions. Discreet cases are ignored.

1. Shape A (Garage: m x n) and B (Basic unit: a x b) are intersecting at the vertex,
2. The sides of shape A and B are touching according to their unit grids.

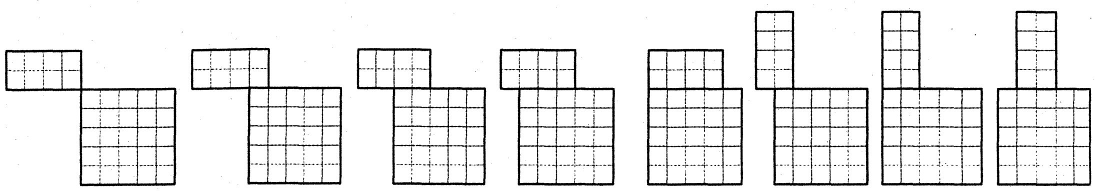
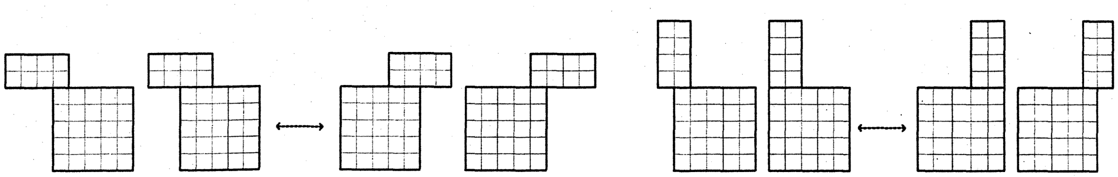


Figure 4: *Eight distinctive spatial relations between the house and the garage*

In shape grammar, when one of the above spatial relations is used, the computation of shape A and shape B generates 8 different designs. The number is determined by symmetries of individual shapes. Using all spatial relations, the total number of possible housing designs is determined. Since each spatial relation has 8 different designs, the total number can be 64.

There is another simple equation to count the total number of housing design layout combinations. First we define the unit module of each shape as m x n for a square and c x d for a rectangle. Then, we setup an equation as (m + n + c + d) x 4. Since the house is a 5 unit by 5 unit module and the garage is a 4 unit by 2 unit module, the total possible layouts of the housing design will be (5 + 5 + 4 + 2) x 4 = 64. This means that, based on the given shapes and rules, there are 64 possible designs.

There might be circumstances where it is inappropriate to place a garage on certain sides. If we get rid of each possible case by reducing the number of sides where the garage is attached. Then, a question arises how many possible designs can be produced where the garage can be attached to 3 sides of the building? There are 50 ways when removing the following 14 cases.

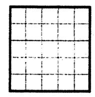
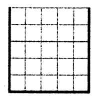
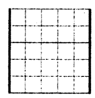
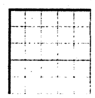
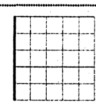


8 cases

6 cases

Figure 5: *Fourteen cases that the garage is attached on one side of the house*

The number of possible layouts of two sides depends on which side is taken out. When two parallel sides are taken, the number of possible layouts will be (10+8)x2=36. But when two diagonal sides are taken, the number of possible layouts will be 64/2=32. Finally, the number of possible layouts when the garage is attached to only one side of the building is 18 (10 +8). The following table summarizes the number of possible layouts in terms of the number of sides.

Number of available sides		Counting number of possible layouts
4 sides		64
3 sides		50
2 sides		36
		32
1 side		18

5. Online Interactive Model

Rather than enumerating all 64 possible designs here, a Java applet model to array the possible layouts online is developed. Java applet is a graphical component of user interface in a web browser. Basically, a java-enabled model can be built on Java's applet technology that allows users to explore new designs in the Web browser. It provides graphical user-oriented interface components for displaying and interacting, designing with an object-oriented model loaded in the applet. The following figure shows snap shots of our implementation of a Java based interface for dynamic retrieval of a set of housing design in plan.

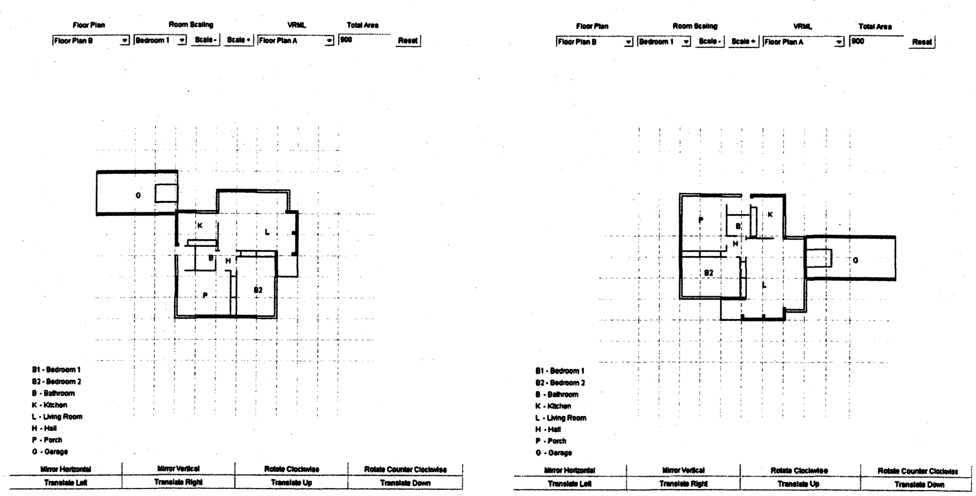


Figure 6: *Java models of the prototype floor plan that the house and the garage are intersecting at the vertex (left) or touching the sides (right)*

Initially the applet is composed of a simple unit plan on a window and a panel of buttons on the lower and upper side. And the basic grid line of the house is also shown on the window. The text area in the upper right corner displays the total square footage of the currently active unit. Users can select either the house unit or the garage to transform.

The upper part buttons allow users to adjust the following parameters:

1. Users can select a certain unit from given floor plan prototypes
2. Users can scale up and down each room of the unit house chosen.
3. To view 3D model, users can select VRML button.
4. To find out the total square footage of the house that users modify, they can select the "Total Area" button. The applet calculates the total square footage of the house that has been modified.
5. A button marked "Reset" accommodates to return to the default unit before users transform.

The lower buttons modify the position of the objects. "Rotate Clockwise" and "Rotate Counter Clockwise" transform the number of cyclic rotations, "Mirror Vertical" and "Mirror Horizontal" apply the horizontal and vertical reflections respectively. Translate "Up," "Down," "Right," and "Left" can shift the position of the garage. Translation button allows a selected object (either the house or the garage) to move according to the underlying grid system. The applet ensures that the transformation is always properly moved based on the given grid. Thus, each increment is based on the house unit module, which is 5-foot grid. The data for the buttons are setup according to this principle. The lower buttons allow users to transform the following parameters:

1. When the house unit is selected, the selected floor plan can be transformed by either rotations or reflections.
2. Users can change the position of the garage alongside the unit house by translations.

There are a few steps that users should follow to create the design properly. First, users should select the room type that they want. There are five options including prototype, 3, 4, 4½ and 5 room types. Then, in the applet canvas, two major components in the unit plan are illustrated: a house and a garage. When users drag the mouse and select an object, the object will be highlighted in a blue color. This means that the object is selected to be transformed and modified. The unit may be selected from standard plans, customized, or designed to fit users' needs.

Click on one of the objects in the window and select a transformation button to change the position of the object. Turning one of the two objects around the axis passing through the center and perpendicular to its plane, it is possible to recognize how a particular symmetry axis is acting. Users start to transform the object by choosing the definition of symmetric transformations using the "Reflect," "Mirror," and "Translation" toggle button. To manipulatively view the three-dimensional look of each design, the applet also provides a series of pre-built 3D VRML models stored on the server. Users can explore 3D models of each housing design by zooming, tilting, rotating, and panning the 3D model in the network environment.

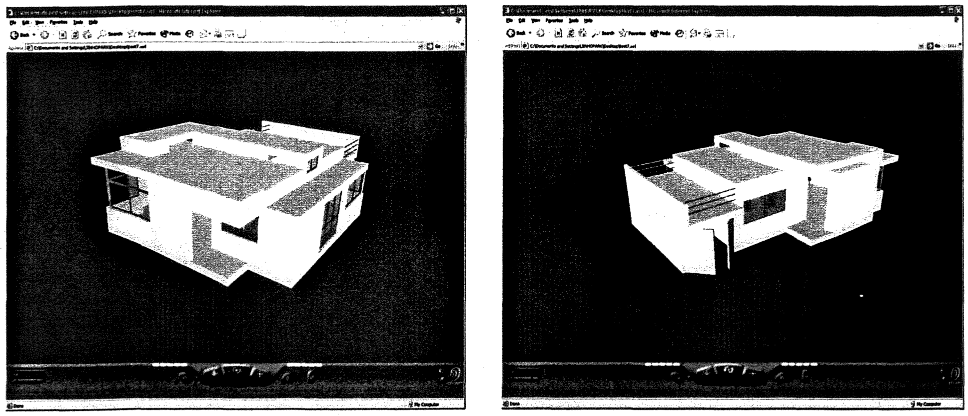


Figure 7: *Two VRML models of four room types of the Schindler Shelter*

In the model, we provide the capabilities of building 2D design models to encompass all possible user selections. After the transformations, users can toggle the scale button to alter the size of rooms in two dimensions. Scaling button works after users finish the basic transformation. With the Hall area set in the middle of each unit, each room extends its size in two directions. Again, each increment is based on the 5-foot unit grid. The transformations also generate numerous variations that could form a possible family of Schindler's designs. The following shows examples that rooms are expanded up with regard to its unit grid.

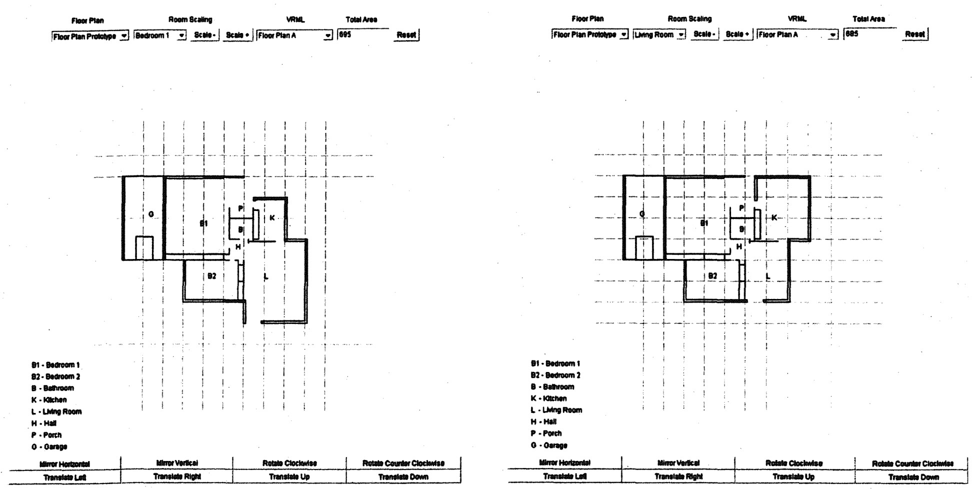


Figure 8: *Java models of the prototype floor plan that a bedroom and a living room (left), and a bedroom and a kitchen (right) are expanded.*

6. Summary

In summary, the model is constructed on the previous theoretical study of Schindler's symmetrical design operations. By reviewing all the records and searching for all possibilities of Schindler's design and computations, a computer model consisting of various layers that a user can interactively manipulate and use to design housing was able to be developed. In the Java applet model, all plans are coordinated in accordance with the grid system used by the architect. Its movement acts in accordance with the grid system. In the applet model, the unit house and the garage were treated separately and then grouped so that users can choose to reorient and move each object and explore all possible layouts.

The next step of this research is to develop a 3D real-time model that is designed and displayed on the user's screen using real-time rather than a pre-built Java 3D model stored on the server. When the users' designs and changes are completed in the 2D model, 3D Java models are automatically created on the user's screen. The data for making 3D housing prototypes have been carefully prepared in accordance with the basic unit typology and its variation capabilities. On the basis of the Java-based interface floor plans, a user can retrieve a variety of the 3D models depending on how the user manipulates the given data selection. In addition, the 2D and 3D models will be integrated with a multitude of spatial referenced data, including materials, colors, texture, etc. Further investigation will set up an information database that will provide all the detailed information and options for the network user.

Acknowledgement

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