THE SYMMETRY EXERCISE: USING AN OLD TOOL IN A NEW WAY

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Abstract

The present paper describes an exercise for architecture students that has two objectives: (1) to present the different types of symmetry and introduce the importance of symmetric design in graphic and architectural composition; and (2) to describe an example of how common CAD tools can be customized and turned into specific symmetric design tools. The final aim is to show how computer drafting can be more efficient than hand drafting in certain cases, especially when the computer's real-time shape computation abilities can be used to the designer's help.

1. Introduction

The present paper describes an exercise that has been proposed to architecture students in different schools, with the aim of discussing symmetry in design and at the same time making them see computer-aided design – CAD – in a new way. Other similar exercises, some of them using VBA programming, have been published in a recent book by the author [1]. In some of them repetition of shapes with changes in scale are also introduced.

Symmetry is one of the most commonly used computational concept and design-generation method in architecture. Vitruvius defined symmetry as "the proportioned correspondence of the elements of the work itself, a response, in any given part, of the separate parts to the appearance of the entire figure as a whole" [2, p.25]. In algebra and geometry, symmetric operations are those that introduce no change when applied to a number or shape. Similarly, in design, patterns can be generated by the recursive application of symmetrical operations.

The reason why symmetric compositions have been so common throughout time and the different cultures is a commonly raised question. Explanations have been suggested, for example, by psychology. According to Jungian psychology, concentric designs – also called mandalic structures – are often related to the search for an interior order [3]. Such questions are, however, beyond the scope of this work.

Symmetric designs are based on different combinations of motifs or basic units, through *isometries*, i.e., distortion-free transformations (translation, rotation, reflection and their combinations, such as glide-reflection, and roto-translation). There are twenty-six symmetry groups in the plane [4], classed according to their translational structure: (1) no translations (the two finite point groups); (2) one direction of translation only (the seven infinite frieze groups); and (3) more than one direction of translation (the seventeen infinite wallpaper groups).

The point class comprises the cyclic and dihedral groups, the former obtained by rotations and the later by a reflection about a radial axis, followed by rotations. Bilateral symmetry, which comprises only one reflection, is a special case of dihedral symmetry, and is included in this class, since it does not involve translations. The frieze class comprises seven groups based on straight translation along a line combined with rotation (half-turns) and reflection along a horizontal or vertical axis. The 19 wallpaper class groups use different combinations of rotation, reflection and translation along two axes (not necessarily perpendicular to each other).[1]

While bilateral symmetry has been the most common type used by architects, other types of symmetry have had a major importance in the decorative arts, from Moorish ornaments to the Arts and Crafts movement. Modern architecture rejected simple bilateral symmetry, reintroducing it in more complex ways. According to March and Steadman [5] "Le Corbusier and FLW were those who most understood symmetry as an abstract idea, Viollet-le-Duc's principle (...) [they] even bring new life to symmetry in many of their projects."(p.40) "Complex" examples of the use of symmetry in contemporary architecture can be found in geodesic structures and spatial trusses.

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[1] An excellent visual explanation of how each symmetry group is formed, including colorful animations, can be found in a website by C. Robles, from the *The Geometry Center* (University of Minnesota): http://www.geom.uiuc.edu/~crobles/symmetry/sym.html

2. CAD and symmetry

In most CAD systems, symmetry groups can be easily obtained through the use of operations such as rotating, mirroring and copying objects in rectangular or circular (sometimes called polar) arrays, both in 2d and 3d. Yet, such systems do not include built-in features that allow dynamically visualizing different symmetric arrangements. Computer programs can help in the design of symmetric compositions by, for example, showing in real-time how changes made to the motif affect the different symmetric patterns based on it. The computer thus becomes an exploratory medium for symmetric designs.

In the present experiment, AutoCAD was used to explore symmetric design with a dynamic environment prepared with the unorthodox use of viewports. With this technique, rotated and mirrored views of the same motif can be overlapped or laid out in regular patterns, producing bilateral, cyclic, dihedral, frieze and wallpaper compositions. In this configuration a motif can be drawn inside one of the views, while the other ones are dynamically updated. The effect is similar to a kaleidoscope, with the difference that it is possible to simultaneously see different symmetric compositions based on the same motif. Although the resulting compositions are virtual, i.e., their are the result of the superposition of different views of the very same motif in Paper Space (only one motif exists in Model Space), it is possible to develop a program that saves them as separate drawing files once the user has reached a satisfactory result.

Similar symmetry exercises have been proposed before, either with special applications or with the use of computer graphics programming, such as in Mitchell et al. (1987). The present exercise can be developed by students with no programming experience using AutoCAD. In order to mirror and rotate the views in Paper Space viewports, commands such as VPOINT and DVIEW are used in an unorthodox way. Different arrangements of these viewports are used to create dynamic environments for developing frieze, wallpaper and cyclic designs, as explained in the next section.

3. Exercise description

This section describes the AutoCAD command sequences used to create dynamic design environments for different types of symmetry.

3.1. Bilateral symmetry

In Model Space, draw any non-symmetric shape (such as the letter "R"). In Paper Space, create two viewports. Double-click on the right side viewport and type:

```
VPOINT
Enter
0,0,-1
Enter
```

Double-click one of the viewports to continue developing the motif design, while observing the dynamically updated reflection on the other viewport (Figure 1).

3.2. Point symmetry

In Model Space, draw any non-symmetric shape (such as the letter "R"). In Paper Space, create three viewports. Double-click on the middle viewport and type:

```
DVIEW
Enter
All
Enter
Enter
TWIST
Enter
120
Enter
Enter
```

Double-click on the right side viewport and type:

```
DVIEW
Enter
All
Enter
Enter
TWIST
Enter
240
Enter
Enter
```

Double-click Paper Space and move viewports 2 and 3 on top of viewport 1. Double-click the overlapping viewports to continue developing the design (Figure 2). To obtain other cyclic compositions, use more viewports and the corresponding rotations ("twists").

3.3. Dihedral symmetry

In Model Space, draw any non-symmetric shape (such as the letter "R"). In Paper Space, create six viewports. Repeat instructions in 3.2 for the three first ones. Double-click the fourth viewport and type:

```
VPOINT
Enter
0,0,-1
Enter
```

Double-click on the fifth viewport and type:

```
VPOINT
Enter
0,0,-1
Enter
DVIEW
Enter
All
Enter
Enter
TWIST
Enter
120
Enter
Enter
```

Double-click on the sixth viewport and type:

```
VPOINT
Enter
0,0,-1
Enter
DVIEW
Enter
All
Enter
Enter
TWIST
Enter
240
Enter
Enter
```

Double-click Paper Space and move viewports 2 through 6 on top of viewport 1. Double-click the overlapping viewports to continue developing the design (Figure 3). To obtain other dihedral compositions, use more viewports and the corresponding rotations ("twists").

3.4. Frieze symmetry

In Model Space, draw any non-symmetric shape (such as the letter "R"). In Paper Space, create a row of viewports. Double-click every other viewport and apply the rotation (with a 180 degrees turn) or the reflection techniques described above, or combinations of both. Double-click the first viewport to continue developing the motif design (Figure 4).

3.5. Wallpaper symmetry

In Model Space, draw any non-symmetric shape (such as the letter "R"). In Paper Space, create an array of viewports. Double-click every other viewport and apply the rotation (with a 180 degrees turn) or the reflection techniques described above, or combinations of both. Double-click the first viewport to continue developing the motif design (Figure 5).

4. Conclusion

Figure 6 shows examples of bilateral, cyclic, frieze and wallpaper designs developed by architecture students with the techniques described above. By developing their motifs while simultaneously observing the resulting overall composition, students were able to focus on the emergent symmetric pattern, rather than on the unit alone. The resulting pattern was usually unexpected if compared to the motif. Figure 7 shows a sequence in which a student finds a not-orthogonal wallpaper pattern, after experimenting with his AutoCAD environment.

The experiment was not only useful for the development of symmetric compositions, but above all to show students how computer tools do not necessarily need to be used in an orthodox way. Besides, it was possible to demonstrate how CAD software, such as AutoCAD, can help beyond simple drafting, as a real aide in the creative phases of the design process.

Figure 1. Bilateral symmetry.

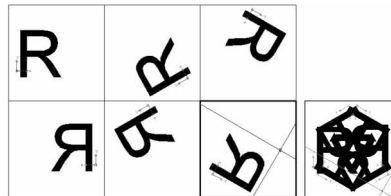Figure 2. Cyclic symmetry.

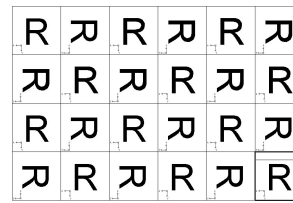Figure 3. Dihedral symmetry.

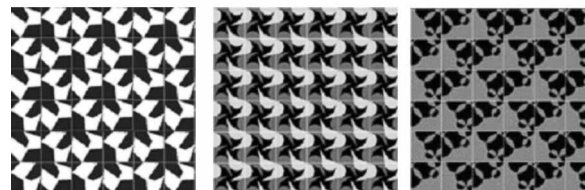Figure 4. Frieze symmetry

Figure 5. Wallpaper symmetry.
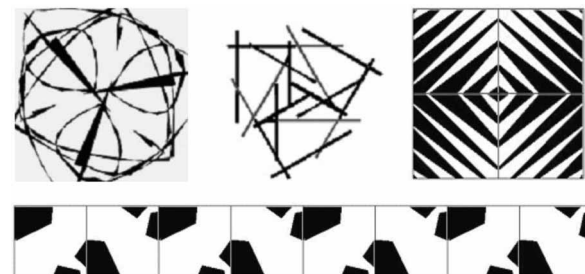

Figure 6. Compositions developed by students in each symmetric design environment.

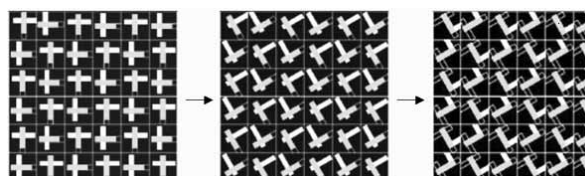Figure 7. Non-orthogonal wallpaper composition design process.

References

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3. Jung, C. G. (Ed.) <u>The man and his symbols</u>, Aldus Books, London, 1964.

4. Fejes-Toth, L. <u>Regular Figures</u>, Pergamon Press, Oxford, 1964.

5. March, L. and Steadman, P. <u>The geometry of environment: an introduction to spatial organization in design</u>,: The MIT Press, Cambridge, MA, 1974 (original work published 1971).