‘QENDËR’ - A DYNAMIC GRAPHIC DESIGN WITH SYMMETRY GROUP GENERATORS IN JAVA

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Abstract: This paper presents the implementation and use of properties of symmetry groups in plane for graphic design with Java software. The project has both the pedagogical property of demonstrating the features of symmetry groups over the web, and it can be used as a useful generative tool for graphic designers and architects. The software enables the user to input drawing elements as generic objects, and combine them with several generative operations that are based on the symmetrical transformations of cyclic, dihedral, frieze, and wallpaper groups. The combination of transformations on simple drawing elements is a feature that allows the applet to be used for educational purposes. Adding several elements and changing the state of generators during the drawing procedure can lead to unexpectedly complex shapes that help enhance designer's imagination and practically can be used as generative tools for decoration designs. The paper essentially describes a graphic design-based software application and its possible uses.

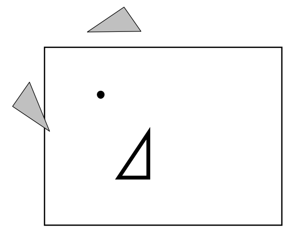
Keywords: computational design, symmetry groups, Java software.

Introduction

The properties of the cyclic, dihedral, frieze and wallpaper groups have been previously used in other packages that generate periodic patterns such as *Kali* (Amenta and Phillips 1996), *Symmetry Java* (Ligget), etc. They offer the user patterns to choose, or require drawing a motif on a subset of the drawing field and later replicate it. This Java applet is an attempt to merge the properties of the periodic groups with simple translations and displacements that may be applied simultaneously during the process of drawing. In spite of using a part of the drawing canvas for drawing the motif, the whole area is used for drawing and displaying at the same time. The dynamic floating of the center of the periodic group results in unpredictable outcomes that could enhance the designer's imagination.

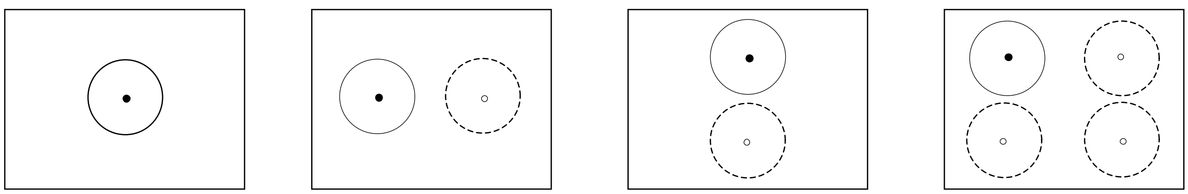
Applet Description and Generation Concept

The applet is called ‘Qendër’ which means ‘center’ in Albanian. The tool combines the operations of periodic rotation, reflection and translation so as modify a set of simple geometrical elements into figures with features of cyclic, dihedral, frieze, and wallpaper groups. These operations, that will be referred to as generators, have an unrestricted state for any set of elements, hence enable the user to enrich and modify the composition. The basic concept that the applet uses is the manipulation of all possible operations during the drawing process, either by adding more drawing elements, or by changing the state of the generators. Unlike other packages such as Tort-Deco, (Garbayo and Roanes 1998), where the motif is drawn in a subset of the screen, the whole area of the canvas acts a drawing and as a display field at the same time. This results, at the same time, in unpredictable situations due to the overlapping and the frame effect.



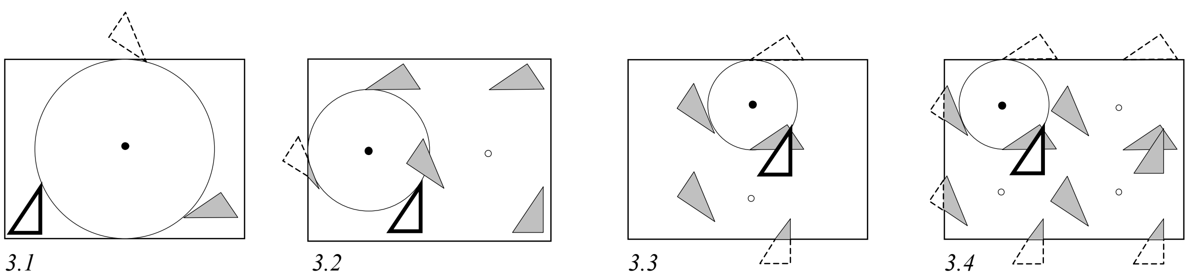
1.1 1.2 1.3 1.4

Figure 1. Positioning of the periodic center in relation to applied translation.
The input elements are shown in bold lines and the generated elements of the main set in gray.
(1) original state, (2)horizontal translation HT, (3) vertical translation VT, (4) Both HT and VT applied



2.1 2.2 2.3 2.4

Figure 2. Positioning of the translated subsets after each translation.
The original set is shown in continuous line circle and the generated subsets in dashed circles.
(1) original state, (2)horizontal translation HT, (3) vertical translation VT, (4) Both HT and VT applied



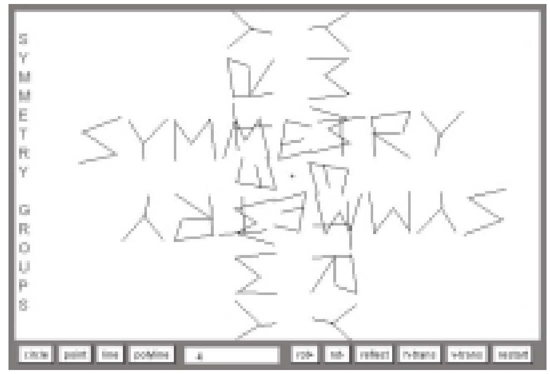
3.1 3.2 3.3 3.4

Figure 3. Elements drawn outside circles generate subsets that may not display in the canvas.
The input elements are shown in bold line, the generated ones in gray, and the ones outside in dots.
(1) original state, (2)horizontal translation HT, (3) vertical translation VT, (4) Both HT and VT applied

The applet is composed of a drawing canvas and a panel of buttons on its lower side. The canvas has a rectangular size of 400x600 pixels, and a little cross shows the current location of the center point of the original set. The left side buttons enable the user to choose one drawing element at a time such as circle, point, line, or polyline. The right side buttons modify the state of the generators. Buttons 'num+' and 'num-' modify the number of cyclic rotations; 'h-trans' and 'v-trans' apply or discard the horizontal 'HT' and vertical translation 'VT' respectively; 'reflect' applies or removes the reflection. The text area in the middle displays the current state of the number of rotations and the types of generators that are active.

The user chooses one of the drawing elements, and draws with the mouse. The rubber-band graphics technique has been used in order to facilitate the positioning of the drawing elements more easily. The floating center constitutes one of the key features of the applet. It can have one of the following positions according to the state of the translation generators. When no translation is applied, the center is positioned in the middle of the canvas, figure 1.1; for horizontal translation it shifts to the center-left, figure 1.2; for vertical translation it takes the top-center position, figure 1.3; and when both translations are applied it is positioned in the upper left corner of the canvas, figure 1.4. The reflection operation generates a reflected mirror of the periodic group towards an imaginary vertical line that passes through the periodic center. When the periodic center shifts position, the reflection line moves accordingly into the new position.

4.1



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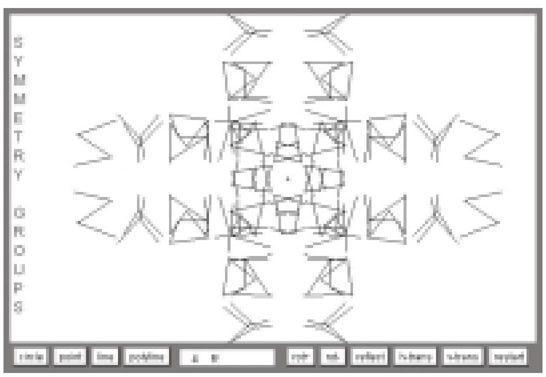

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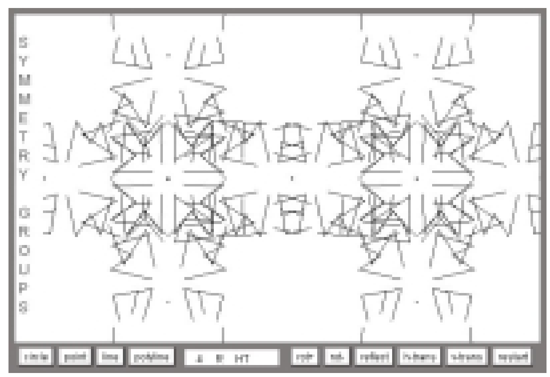

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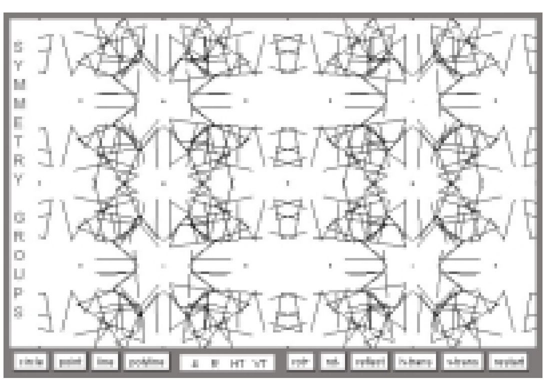

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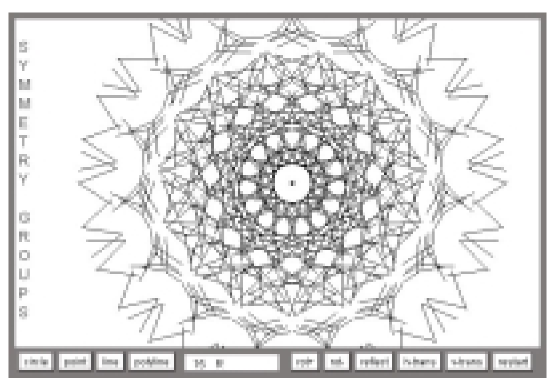
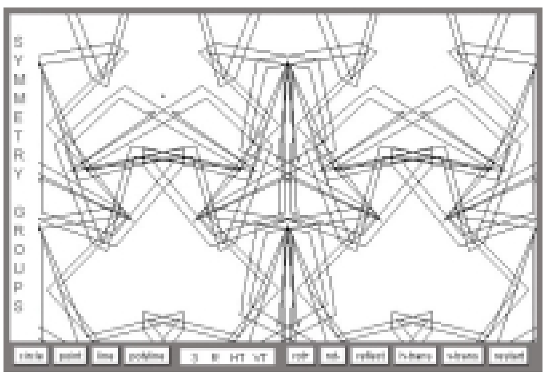
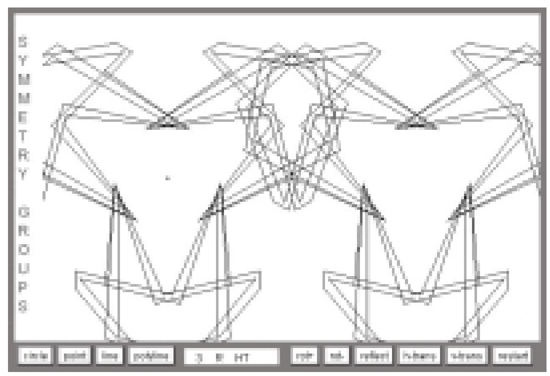


4.6

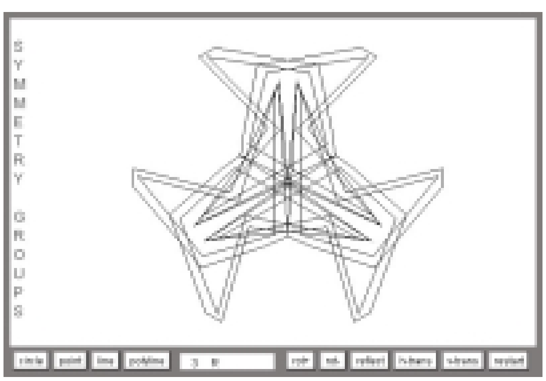
Figure 4. Results of several transformations on an original set of lines.
(1). no transformations, (2) cyclic rotation with period 4, (3) reflection added, (4) horizontal translation applied, (5) vertical translation applied, (6) VT and HT translations discarded, increase of period number to15

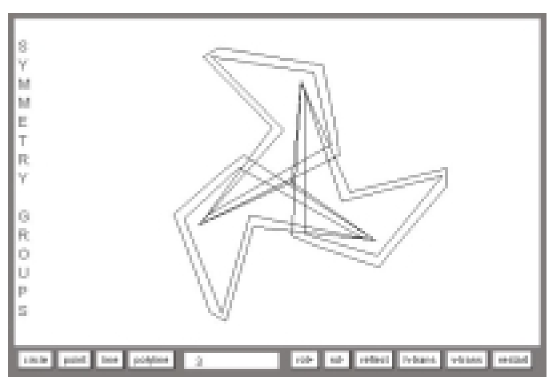
The system stores in the memory the input elements, and generates two sets of elements: First, it generates a set that has the properties of point groups around the center, from the elements drawn by mouse. Second, it generates subsets, which are copies of the original set and translate them vertically or horizontally with a given offset so as to create figures with features of frieze and wallpaper groups. While the center changes its position, the input elements that are drawn by mouse keep the same position in relation to the screen. The number of subsets is the minimal needed, i.e. one or three for the friezes and wallpaper groups respectively. Figure 2 illustrates the positioning of the translated sets in relation to the state of translations. The combined change of the position of the center and the translation of the generated set result in a symmetrical display of the whole frieze and wallpaper group in relation to the canvas border, thus minimizing the elements that are left outside the screen. For this reason the center shifts at quarter width or height, and the translation offset is equal to half width or half height. Due to the rectangular shape of the canvas, and the asymmetrical positioning of the center in some cases, a part of the generated elements are not displayed. Only elements that are drawn close to the periodic center generate subsets that are fully displayed on the screen, as shown with the circular areas in figure 3. Meanwhile, this is the same condition for avoiding the overlapping of translated subsets with each other.





5.1 *5.2*





5.3 *5.4*

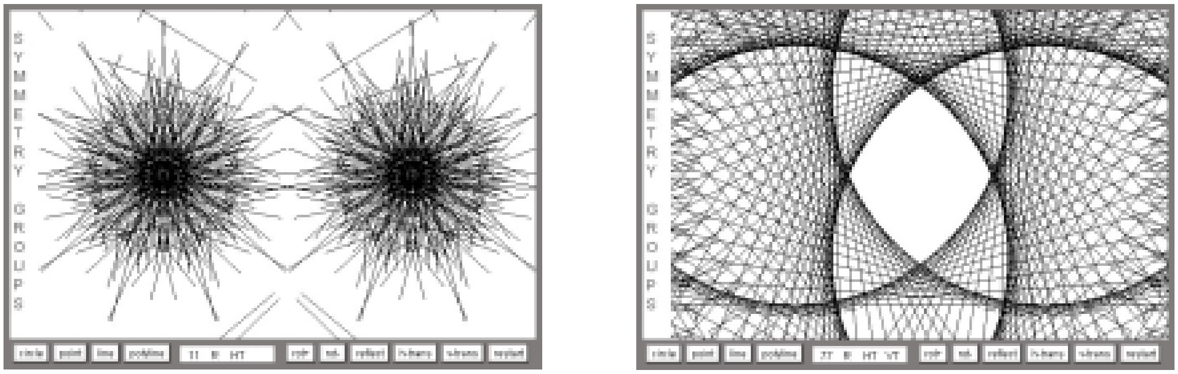
Figure 5.Generation of a set of polylines in a preset canvas and the reversing of operations (1) wallpaper groups, (2) frieze groups after discarding VT, (3) dihedral group after discarding HT, and (4) cyclic group after discarding reflection

One case of the use of the tool is when the user starts a drawing without any activated generator, and later changes the state of the generators step by step, as illustrated in figure 4. The drawing has started as a simple set of lines in a canvas with a periodic number one, which resembles an ordinary drawing field, figure 4.1. In later cases rotations have been increased, and reflection and translations are added to produce a figure with features of dihedral, frieze and wallpaper groups. When the horizontal translation is applied two operations occur simultaneously, from figure 4.3 to 4.4. First, the periodic center changes position from the canvas' center at half width and half height, into the left at quarter width and half height. The original elements, which were drawn by mouse, generate a point group to the new center. Due to the different distance to the new center, the point group set results modified. Second, a copy of this newly generated set is copied and positioned to the right with an offset of half canvas width, thus resulting in a symmetrical display of the whole figure in relation to the frame. In similar way, after applying the vertical translation, figure 4.5, the center is repositioned in the top left corner at quarter width and quarter height, and a new dihedral set is generated from that point. Three subset copies of the original one are translated with offsets resulting in a wallpaper-like figure. The overlapping of the subsets in this case gives the illusion of more than four sets being generated. Another case of the use of the applet is when the state of generators has been set up before starting the drawing on the canvas. This aspect brings the tool close to previously designed packages that use one kind of motif to choose for drawing. At the same time, the applet allows the reverse modification of operations to the state without generators, which allows demonstrating the set of elements that were input by mouse. Figure 5 illustrates a drawing that started in a canvas with all generators active. Discarding generations one by one enable us to see the original set of elements input by mouse, figure 5.4. The reversibility of operations represents a real advantage when the tool is used for educational purposes.

Structure, Randomness, and Frame Effect

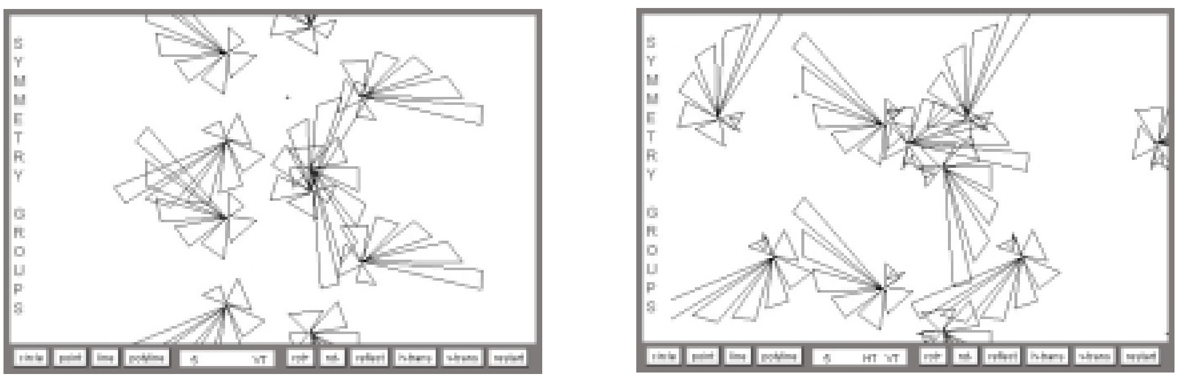
In the creative use, exploring the capabilities of the tool to generate different figures reveals some interesting features. While using a low number of rotations, and a small number of elements, the results of the drawing are rather predictable. By increasing the number of elements, the figures become more complex and start to display certain features. As resulted from a user analysis study carried out with five architecture students at Georgia Institute of Technology, the users tend to be influenced by the outcome of the transformations, and manipulate the drawing to further refine a motif that was generated randomly. For instance, it is common to add smaller or shorter elements to a pattern generated with few elements. At some point during the drawing, the user is not particularly aware of the difference between elements he is drawing to the generated ones, which are displayed simultaneously. The user is influenced by the results of the generation during the drawing process, he distinguishes a pattern which may seem plausible to him and proceeds by adjusting the rest of elements so as to better complete the picture. Meanwhile, particularly the early input of elements from the user has a random nature. Hence, the results are unpredictable, and the randomness of sketching influences the outcome. In the case of great number of cyclic rotations, the rules of the field overcome the randomness of the location of inputting elements, and the generated patterns resemble each other such as the drawing on figure 6.1. The structure of the canvas is determined from the current combination of transformation operations on one hand, and from the relation between positioning of the periodic center, the offset distance, and the dimensions of the canvas on the other.

The significance of relation between dimensions of the canvas and the drawn element becomes evident when relatively long elements are drawn far from the cyclic center such as in figure 6.2. Apart from the effect that the relation of the size of elements to the dimension of the frame has on the generated set, the offset of the original set center in relation to the screen may create an asymmetrical situation. In wallpaper and frieze cases when the elements are drawn in a distance from the periodic center, i.e. outside the circular area as described in figure 3, and the periodic numbers are small, the general pattern loses some of the symmetries due to the partial display resulting from the frame positioning. The frame effect adds randomness to the system by allowing a partial display of the generated set such as figure 8 and figure 9, thus creating further unpredictable outcomes.



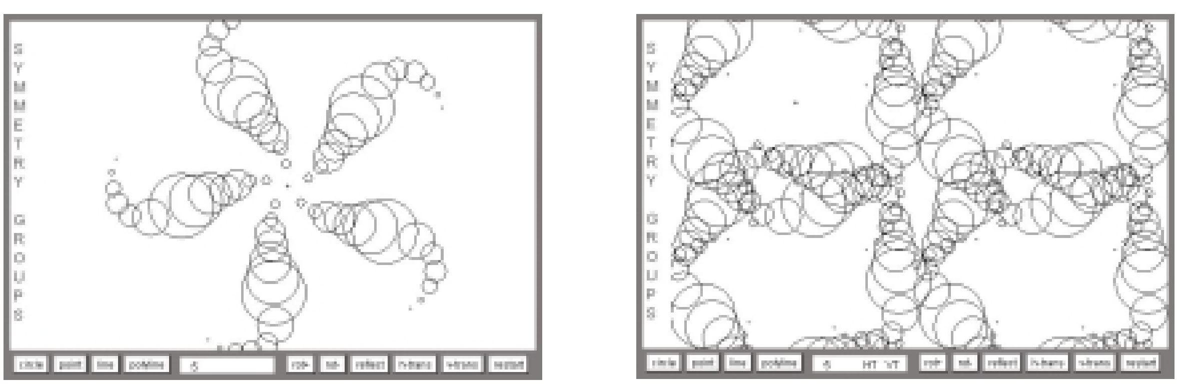
6.1 6.2

Figure 6. Structure of the field for large periodic number.
(1) Clustering around the periodic centers, (2) Drawing generated from a single line. The line length and its positioning in relation to the center are crucial for such



7.1 7.2

Figure 7. The shift from vertical frieze (1) into wallpaper group (2)
Results into an apparent loss of full symmetries due to the frame effect



8.1 8.2

Figure 8. The partial display after the shift from cyclic group into the wallpaper group.

Conclusions

'Qendër' was designed with the aim of creating an electronic environment accessible from the Internet, which can be addressed to two main population of users: those who teach and learn about the properties of periodic groups, and graphic designers who can use the tool for design purposes. The applet uses the whole canvas area for drawing and displaying which consequently results in partiality of display and lost of some symmetry, while suggesting interesting solutions due to the overlapping and frame effect. The tool functionality is based on the simultaneous modification of the set of drawing, as well as the generators, which often results in unexpected results. These two conditions create a situation best suited for graphic designers, as drawing few elements and applying different generations can lead to interesting plausible motives. Meanwhile, having in view the ability of the designer to recognize certain hidden patterns in a dense sketch, the generated figures may provide inspiration hints for designers. This is the beginning of an ongoing project that intends to develop the tool further towards a better functionality by means of improving some dependency of operations, and including other operations that can widen the users' choice. Future work may include adding the choice between leaving the drawn set stable in relation to the frame to moving it together with the periodic center. Zooming in and out, while associated with the emerging of other subset periodic centers may allow a better display of the wallpaper and frieze groups. The glide reflection and the pair reflection will allow the generation of all families of wallpaper groups.

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References

Amenta, N., Phillips, M., 1996, *Java Gallery Of Interactive On-Line Geometry*, http://www.geom.umn.edu/java/Kali/

Garbayo, M., Roanes, E., 1998, Tort-Deco: A Package for Drawing Periodic Geometric Designs, in *Mathematics and Design 98*, The University of the Basque Country.

Ligget, R., *Symmetry Java*, http://www.aud.ucla.edu/~robin/symmetry.html/

March, L., Steadman, P., 1971, *The Geometry of Environment*, RIBA Publications, London.

Note: The applet may be viewed at http://www.prism.gatech.edu/~7531b/ Qender /symmetry