Parameterization of Border Design Patterns with Interlacing Effect and Integrating CAD/CAM Technologies

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Abstract- This work focuses on integrated design computation and proposes methodologies and tools to build border designs integrating CAD-CAM technologies. Border patterns are recognized as intervallic and repetitive arrangement of a type of motifs. Further, motif is observed as polar array of a primitive which is a tiny geometric object required for the representation of motif. The designs of different border patterns are generated automatically with the help of developed algorithms and their fabrication methodologies, thus, helping the designer to reach his objective.

Keywords – Primitive, Interlacing, Border, Pattern

I. INTRODUCTION

In the area of decorative design, the artists are always in the thinking of new concept of grace the design. For this they prefer to in shape the design in the borders. The borders are available in the different form (figure 1). But the border with the interlacing effect of mostly preferred. Interlacing is pattern used by nature, birds, and animals and even by human beings in their day to day life. We have seen interlacing of earth layers and rocks down under the earth, birds use interlacing for building their nests, animals use this for their shelters. Human beings are using interlacing designs since the day they have learnt to weave cloths using grass, threads and so on. According to the theme of the patterns, interlace pattern are used for area filling and mostly for border application for give aesthetics to the designs. The designers are using manually marking method producing design using pen/pencil and paper.

Here, this work is dedicated toward creation of such patterns on the computer’s screen with the help of an algorithm in a programmable form by generating the motif of the design (which is further drawn with the help of a base element, known as primitive). This programmable environment completes the objective of the automation in the design art. One can draw their choice design motif according to availability of space and size for a particular design. Geometrically, it is created from different 2D entities defined with a set of points. In order to get variation in size of these motifs, the coordinates of these points have been devised in terms of modeling parameters. The following section is about the control the shapes and sizes of motifs via the coordinates in terms of parameters related to motifs.
II. LITERATURE

Many attempts have been made to produce computer-generated decorative patterns by using the field of computer graphics, which offers many algorithmic possibilities for creating two-dimensional decorative patterns. Chee Kai Chua [1] described a method of generating parametric patterns aligned along a circular arc with a set of parameters that interact to produce interestingly different patterns.

![Figure 1. Different types of border Designs](image)

This work provided a solution that can be implemented as a supplement to a basic CAD/CAM system to benefit application users in cartography, architectural design, watch and clock face design, and ceramic design. Kaplan [2] presented a process for creating computer-generated Islamic star patterns as per the user choice. User specifically selects motif for each regular polygon in the template tiling and then computer fill the remaining tiles using an “inference algorithm” to create a design consistent with the user's choices. Yanxi Liu [3] presented a frieze group, which is a class of infinite discrete symmetry groups for patterns on a strip. Shrivastva [4] made an attempt to develop parametric traditional Rangoli and Phulkari patterns. George Bain [5] presented with an instance of Celtic knotwork. Wong [6] described and explored the ways in which floral patterns can be created algorithmically. Kedar [7] proposed a design software for generating 2D floral border patterns. Anderson [8] presented an application, designed a user driven system that allows for the creation of beautiful, organic ornamental 2D patterns, which follows a user-defined curve.

III. HIERARCHICAL REPRESENTATION OF PATTERNS

From geometry of the patterns, the border patterns for have as periodic and repeated arrangement of a type of motifs and this motif is observed as an array of a small entity called primitive (Figure 2). In this work, patterns for border are generated with the account of three hierarchical levels which are labeled as: Primitive, Motifs, and Pattern.

At the first level, the primitives are designed. A primitive is viewed as a group of line segments that are joined with each other at their end points. At the second level, motifs are designed with a theme of having a primitive surrounded by other one. The aesthetic sense of a motif has been derived from its geometrical symmetry. Lastly, patterns are generated with regular arrays of motifs. These patterns are regarded as a planar map.
IV. PARAMETRIC MODELLING THE MOTIFS

This section presents an approach for parametric modeling of some of border pattern’s motifs:

A. MOTIF-I

This interlaced motif is drawn by using three primitive showing in colours alphabet shapes. These primitives have shape I, J and L. The primitive having I shape is made with the help of four lines (PQ, QR, RS and SP). These lines are obtained by joining the four points P, Q, R, and S via means of a straight line. The primitive having L shape is made with the help of six lines (IJ, JK, KL, LM, MN and NI). These lines are obtained by joining the four points I, J, K, L, M and N via means of a straight line. The primitive having J shape is made with the help of eight lines (AB, BC, CD, DE, EF, FG, GH and HA). These lines are obtained by joining the four points A, B, C, D, E, F, G and H via means of a straight line. By joining these three primitives with a special theme, the base element of the motif is obtained. This base element is rotated about a centre to complete the 360\(^{\circ}\) angle in object to achieve four number of the element. The coordinates of primitives have been devised in terms of the following intuitive modeling parameters (Figure 3):

- Number of petals (n=4) in the motif
- Size of the motif defined by its side ‘a’

![Figure 3: Geometry of Primitive of motif](image)

Table 1: Coordinates of the points in the primitive of motif –I
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B. MOTIF-II

From the geometry of the Motif, it is pragmatic that the shape of the motif is obtained from two interlaced triangles. This motif is drawn by using the primitive showing red and further this primitive is the combination of five lines (AB, BC, CD, DE and EA). Table 6 shows coordinates of these points in terms of modeling parameters. As shown in figure, the motif is drawn by polar array of the primitive six times within $360^\circ$. In CAD modeling, this motif is viewed as an array of primitive (shown with red color in Figure 4) which is made from 2D entities i.e. line. It is in the form a planar map having a set of points whose coordinates have been devised in terms of the following intuitive modeling parameters (Figure 4):

- Number of primitives (n=6) in the motif
- Size of the motif defined by its side ‘a’

![Figure 4. Geometry of Primitive of motif II](image)

<table>
<thead>
<tr>
<th>Points</th>
<th>Position of the Points</th>
<th>Points</th>
<th>Position of Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$\frac{a}{3}$, $\frac{a}{6}$</td>
<td>J</td>
<td>0, $\frac{a}{2}$</td>
</tr>
<tr>
<td>B</td>
<td>$\frac{a}{6}$, 0</td>
<td>K</td>
<td>$\frac{7a}{24}$, $\frac{19a}{24}$</td>
</tr>
<tr>
<td>C</td>
<td>0, $\frac{a}{6}$</td>
<td>L</td>
<td>$\frac{a}{3}$, $\frac{3a}{4}$</td>
</tr>
<tr>
<td>D</td>
<td>$\frac{a}{3}$, $\frac{a}{7}$</td>
<td>M</td>
<td>$\frac{a}{12}$, $\frac{a}{7}$</td>
</tr>
<tr>
<td>E</td>
<td>$\frac{3a}{8}$, $\frac{11a}{24}$</td>
<td>N</td>
<td>$\frac{5a}{24}$, $\frac{9a}{24}$</td>
</tr>
<tr>
<td>F</td>
<td>$\frac{a}{6}$, $\frac{a}{6}$</td>
<td>O</td>
<td>$\frac{a}{8}$, $\frac{5a}{24}$</td>
</tr>
<tr>
<td>G</td>
<td>$\frac{a}{6}$, $\frac{a}{12}$</td>
<td>P</td>
<td>$\frac{11a}{24}$, $\frac{3a}{8}$</td>
</tr>
<tr>
<td>H</td>
<td>$\frac{7a}{24}$, $\frac{5a}{24}$</td>
<td>Q</td>
<td>$\frac{a}{2}$, $\frac{5a}{12}$</td>
</tr>
<tr>
<td>I</td>
<td>$\frac{a}{6}$, $\frac{a}{3}$</td>
<td>R</td>
<td>$\frac{a}{4}$, $\frac{2a}{3}$</td>
</tr>
</tbody>
</table>

Table 2: Coordinates of the points in the primitive of motif II

<table>
<thead>
<tr>
<th>Points</th>
<th>Position of the Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>$\frac{2a}{\pi} \sin \frac{\pi}{7}$, $\frac{a}{7}$</td>
</tr>
<tr>
<td>B</td>
<td>$\frac{a}{2} \sin \frac{\pi}{3}$, $\frac{3a}{2} \cos \frac{\pi}{3}$</td>
</tr>
<tr>
<td>C</td>
<td>$\frac{a}{2} \sin \frac{\pi}{3}$, $\frac{2a}{2} \cos \frac{\pi}{3}$</td>
</tr>
<tr>
<td>D</td>
<td>$\frac{a}{2} \sin \frac{\pi}{3}$, $\frac{2a}{2} \cos \frac{\pi}{3}$</td>
</tr>
</tbody>
</table>

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This motif is drawn by using the primitive showing red, which is drawn by nine lines (AB, BC, CD, DE, EF, FG, GL, HK and IJ). These lines are drawn by joining the points A, B, C, D, E, F, G, H, I, J, K and L via a straight line as shown in figure 5. This motif is viewed as an array of primitive which is a base geometric object made from 2D entities i.e. line. It is in the form a planar map having a set of points whose coordinates have been devised in terms of the following intuitive modeling:

- Number of petals (n=2) in the motif
- Size of the motif defined by its side ‘a’

<table>
<thead>
<tr>
<th>Points</th>
<th>Position of the Points</th>
<th>Points</th>
<th>Position of the Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0, 0</td>
<td>G</td>
<td>a</td>
</tr>
<tr>
<td>B</td>
<td>7a/12, 5a/6</td>
<td>H</td>
<td>0, a</td>
</tr>
<tr>
<td>C</td>
<td>13a/12, 5a/6</td>
<td>I</td>
<td>0, 17a/24</td>
</tr>
<tr>
<td>D</td>
<td>7a/24, a/2</td>
<td>J</td>
<td>0.1464 a, 0.5 a</td>
</tr>
<tr>
<td>E</td>
<td>1.251 a, 0.615 a</td>
<td>K</td>
<td>0.249 a, 0.647 a</td>
</tr>
<tr>
<td>F</td>
<td>a, a</td>
<td>L</td>
<td>0, 7a/24</td>
</tr>
</tbody>
</table>

**D. MOTIF-IV**

The motif - IV is drawn by using the primitive showing red color which is the base element of this motif. This primitive is obtained by ten points (A, B, C, D, E, F, G, H, I and J). These points are joined via a straight line. The seven lines used to make the motif are AJ, BC, ID, DE, EF, FG and GH. During CAD modeling, this motif is viewed as an array of primitive. It is in the form a planar map having a set of points whose coordinates have been devised in terms of the following intuitive modeling parameters:

- Number of petals (n=2) in the motif
- Size of the motif defined by its side ‘a’
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V. PATTERN GENERATION

The border patterns are lies in its logical interrelation of motifs. Patterns are composed of motifs which are multiplied and ordered in regular sequences by using transformations between them. The role of transformations is to define positions of the motifs with respect to pattern in a 2D plane. Motifs are placed in a pattern with a special theme e.g. aligning motifs along a specified path or in a rectangular array. Different styles of fashionable patterns have been produced (Figure 8).

VI. VALIDATION

This work is implemented under the ActiveX and Visual Basic Application (VBA) programming environment using AutoCAD. The combination of the powerful ActiveX Automation object model in AutoCAD and VBA presents a compiling framework for customizing the AutoCAD software program. The design algorithm begins with mathematical description of the geometrical patterns. Then, CAD programming interfaces are used to turn the mathematical descriptions of patterns into computer program. The CAD data of these patterns can be transferred to a variety of computer-controlled machines. For validation, A CNC machine with laser cutting tool is used to manufacture the border patterns on plastic sheet as a lattice screen (see figure 7).

VII. CONCLUSION

This work presents a methodology for creating the border patterns for different applications of designer through fusion of computer aided geometric modeling. The presented work is a convergence of design and digital concept of technology. The presented CAD model complements traditional techniques in designing by understanding and adapting industrial/manufacturing processes as applicable, thus providing the designer and craftsmen with new CAD tool for manufacturing in computer controlled environment using CNC machines or laser machining.
Figure 7. Border pattern generated (left) and actual pattern piece manufactured by CNC laser Cutting Machine

Figure 8. The Border Patterns Generated By This Proposed CAD Paradigm

REFERENCES

Parameterization of Border Design Patterns with Interlacing Effect and Integrating CAD/CAM Technologies