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Fundamental Study on Design System of Kolam Pattern

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Abstract. "Kolam" is a kind of string/knot pattern seen primarily in Tamilnadu state of South India, which has a very attractive system of pattern formation, that is to say, countless complicated Kolam patterns can be drawn following extremely simple elements and drawing rules. In this paper, the fundamental characteristic of Kolam patterns’ designing system is considered by converting these patterns into numbers and linear diagrams. Further discussions on the drawing methods to create new Kolams will also be given.

1. Introduction

The patterns called "*Kolam*" in Tamil are traditional auspicious motifs handed down from ancient times in South India. The high artistic quality of their graphical structure has attracted and aroused intellectual curiosity. Though there are various styles of Kolam, this paper is directed to the string/knot style called "*Kambi Kolam*" (see Fig.1) of abstract appearance, which seems to follow a system of pattern formation. Another remarkable feature is that some of them can be drawn by one-stroke.

This paper analyses experimentally the Kolam patterns from a morphological viewpoint, concretely in two: First, how many patterns can be drawn by one-stroke among the Kolam patterns under the same given set of conditions? Second, do Kolam patterns of one-stroke, which are seemingly quite complex and tangled, have any structural features or not? If they have, what are they? Those two subjects are discussed in this paper, by using a method of converting Kolam patterns into numbers and linear diagrams.

2. Definition: Elements and Rules for drawing Kolam Patterns

2.1. Elements Constituting Kolam Patterns [Fig.1]:

(1) *Array of points*, arranged on a square grid: the points are not necessarily arranged in a rhombic shape as the figure; square, triangle and other free shapes are allowed. In this paper, rhombic arrays are described as "1-5-1", and square as "3*3".

(2) *Drawing-line*, consisting of straight lines and arcs.

2.2. Rules for drawing Kolam Patterns

(1) Loop drawing-lines, and never trace a line through the same route.

(2) The drawing is completed when all points are enclosed by a drawing-line.

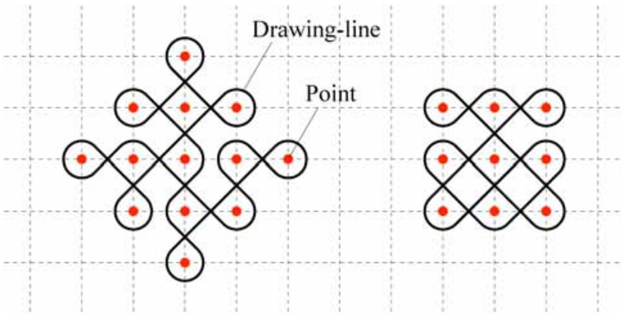


Fig. 1. Elements of Kolam pattern

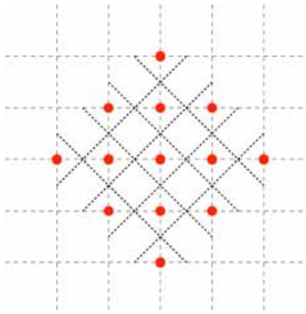


Fig. 2. Dual grid inclined at 45°

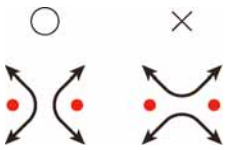


Fig. 3. Arcs are drawn surrounding the points

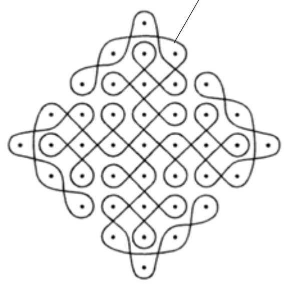


Fig. 5. An exception of the rules (from Manimaran:1999)

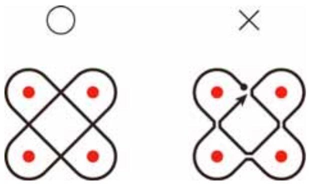


Fig. 4. Smooth drawing-lines

(3) Straight lines are drawn along the dual grid inclined at an angle of 45°[Fig.2].

(4) Arcs are drawn surrounding the points [Fig.3].

(5) Smooth drawing-lines. Lines should not bend in a right angle. For instance, a pattern like Fig.4-left should be drawn with 2 loops (2 strokes). It is forbidden to draw as Fig.4-right.

These elements and rules were extracted by organizing the general tendencies found on many sample patterns found on streets and textbooks of Kolam sold in South India. We can expect to find patterns which do not follow these rules [Fig.5]. It is not clear, at present, how much Indian Kolam painters are conscious of these drawing rules. Nonetheless, these elements are commonly used in Kambi Kolam. Besides, there is nearly no exception to the drawing rules (1) (4) (5), and there are few deviations from (2) (3). Therefore, it might be said that these are basic rules to draw Kolams. In particular, the regularity of the array of points is seen in most styles of Kolam, and it can be thought to be the first principle closely linked to the ideal basis of Kolam.

3. Conversion into Numbers and Exhaustive Computer Analysis

3.1. Way to Convert Patterns into Numbers

When certain array of points are given, an inclined grid paving the way of a drawing-line is uniquely defined. Comparing various Kolam patterns which can be drawn on the same array of points, with its inclined grid underneath, it is found that the shapes of circular arcs of a

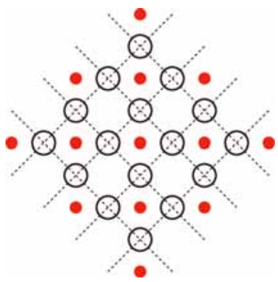


Fig. 6. Intersections of inclined grid
(1-5-1 array of points)

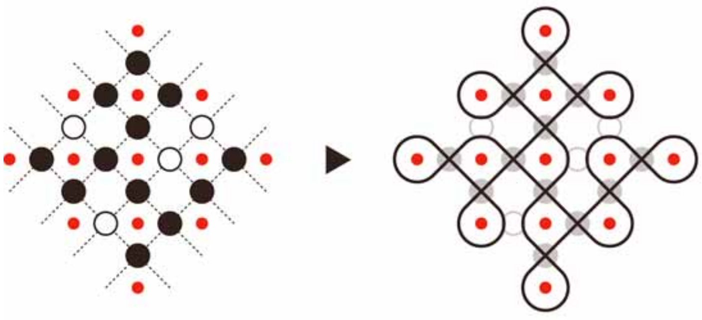


Fig. 7. Setting shapes at intersections [●: crossing, ○: uncrossing]

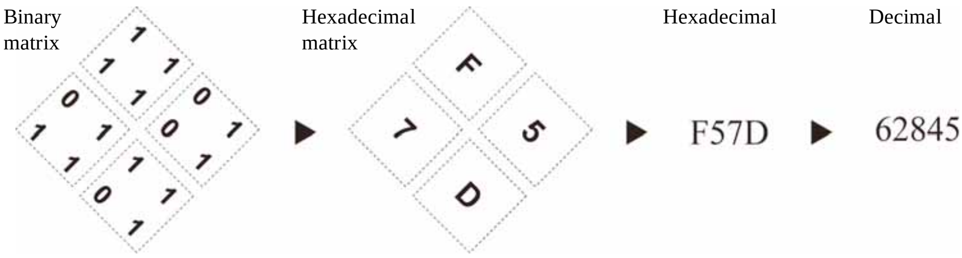
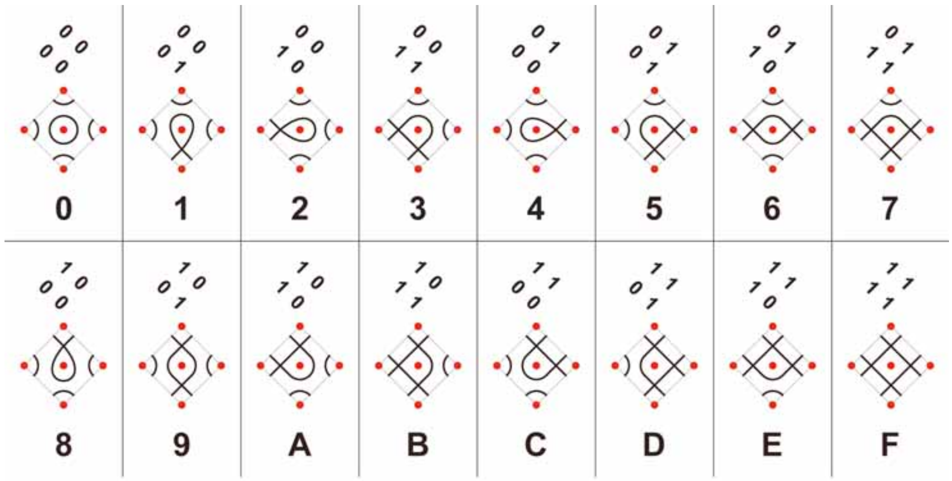


Fig. 8. Conversion into number

Table. 1. 16 Constituent units of Kolam Patterns, corresponding to hexadecimal numbers



drawing-line on the borders are common to the all patterns, and that the differences between them are only the shapes at the intersections of the inclined grid [Fig.6]. The types of shape at the intersections are two: "crossing (or a cross)" and "uncrossing (or two curves)". For example, setting the types at each intersection as Fig.7-left makes the pattern of Fig.7-right.

To sum up the matter, when certain array of points are given as a prior condition, the form of the pattern is determined only according to the accumulation of the choices of whether the drawing-line goes straight or curves at each intersection of the inclined grid. By setting "crossing=1" and "uncrossing=0", therefore, all the Kolam patterns can be represented as binary numbers. By additionally combining four contiguous intersections, they will be converted into hexadecimal and decimal numbers [fig.8]. The fact that Kolam patterns can be expressed with hexadecimal numbers means that they can consist of 16 types of units[1] [Table.1].

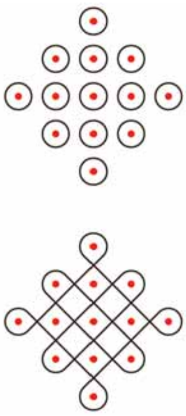


Fig. 9. Patterns of #0000 & #FFFF (in hexadecimal)

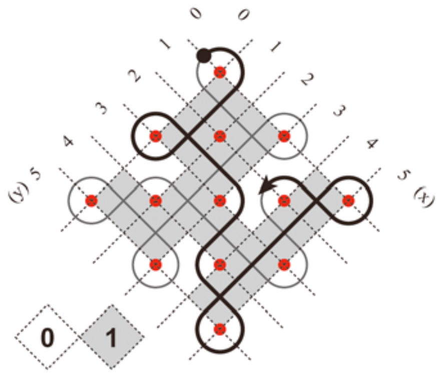


Fig. 10. Pattern generation and one-stroke judgment

Table. 2. Result of analysis on Kolam of 1-5-1 array of points

Total Number of Patterns	65,536	
of them, One-Stroke	240	(0.366 %)
of them, Unique	35	
of them, Symmetrical	9	
1-Axial	5	
180˚ Rotational	2	
90˚ Rotational	1	
2-Axial+180˚ Rotational	1	

3.2. Exhaustive Computer Analysis

One of the usefulness of numeric representation is that an exhaustive analysis on a computer becomes easy. Consequently, with computer programs, the author tried to count the number of *one-stroke patterns*, drawn with one stroke of drawing-line, among the whole Kolam patterns which can be drawn on 1-5-1 and 1-7-1 array of points.

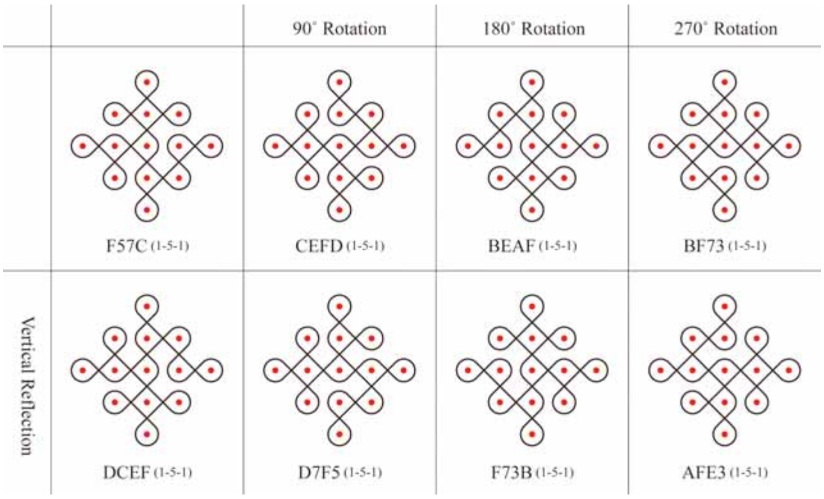
3.2.1. Method to Generate Patterns and Judge them as One-Stroke or not

In the case of 1-5-1 array of points, the total number of patterns is 2^{16} = 65,536, because there are 16 intersections in the inclined grid as Fig.6. The author therefore wrote a program in Perl language, which automatically generates a pattern corresponding to each number from 0 to 65,535 (from 0000 to FFFF in hexadecimal numbers) [Fig.9] and checks one by one. Conversion of numbers into patterns is carried on in a reverse process of patterns to numbers. Patterns are virtually drawn on a X-Y coordinate with 0 and 1, and checked as if tracing a drawing-line with your finger. Setting the initial location and direction, the finger moves as follows: go straight at crossing=1 square, and curve centering around the nearest point at uncrossing=0 square [Fig.10]. The judgment as one-stroke or not is done by checking that the finger has passed through all the inner squares twice when it returns to the starting location. Finally, the author also checked if each one-stroke patterns are symmetrical or not.

3.2.2. Results

The results of the analysis on Kolam patterns of 1-5-1 array of points are shown in Table 2. The number of one-stroke patterns is 240 (0.366%) among 65,536 patterns which can be drawn on this array of points. Among them, 35 are unique without isomorphic patterns, which have the same

Table. 3. Isomorphic patterns: these patterns are regarded as same shape



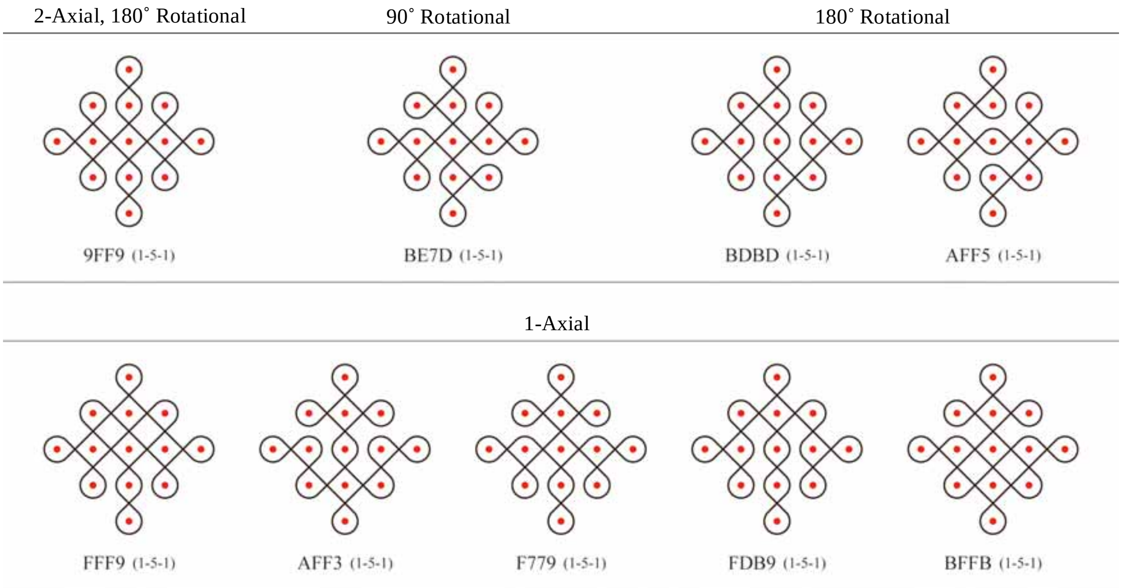


Fig. 11. The 9 symmetrical patterns drawn on 1-5-1 array of points

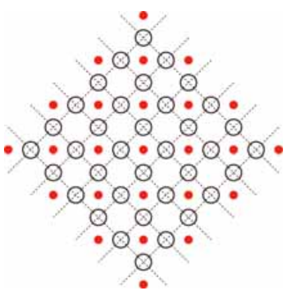
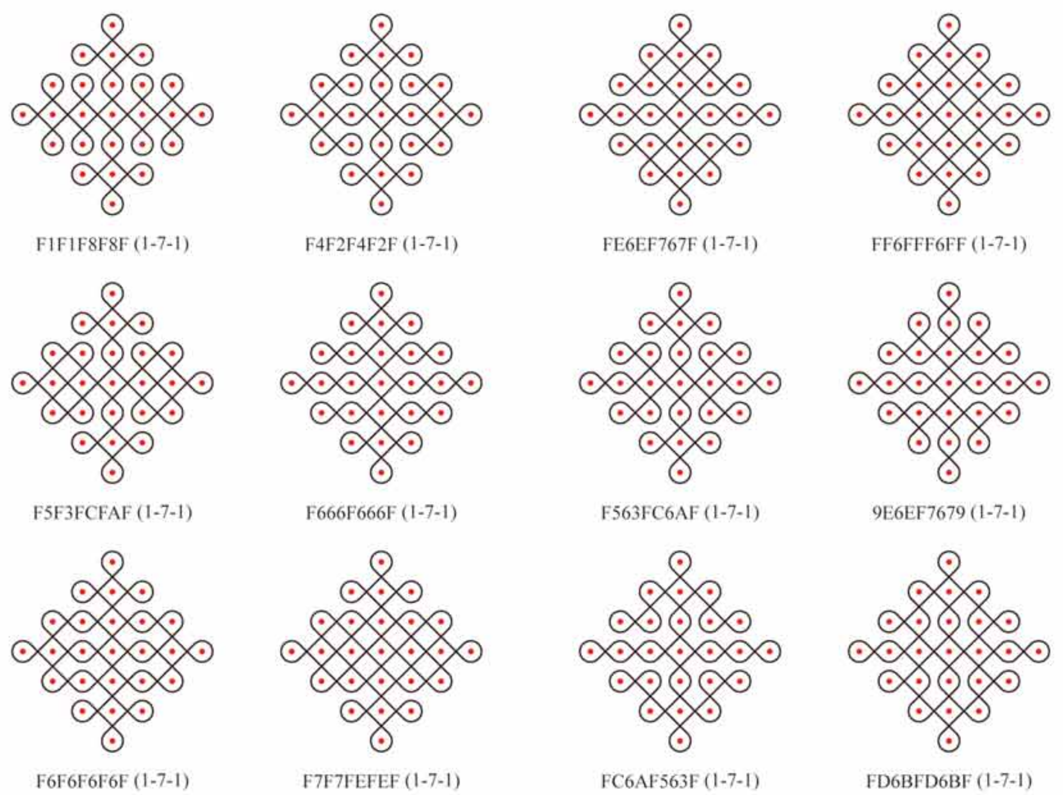


Fig. 12. . Intersections of inclined grid (1-7-1 array of points)

Table. 4. Result of analysis on Kolam of 1-7-1 array of points

Total Number of Patterns	68,719,476,736	
of them, One-Stroke	11,661,312	(0.017 %)
of them, Unique	1,458,430	
of them, Symmetrical	1,520	
1-Axial	884	
180° Rotational	612	
90° Rotational	12	
2-Axial+180° Rotational	12	

2-Axial, 180˚ Rotational



90˚ Rotational

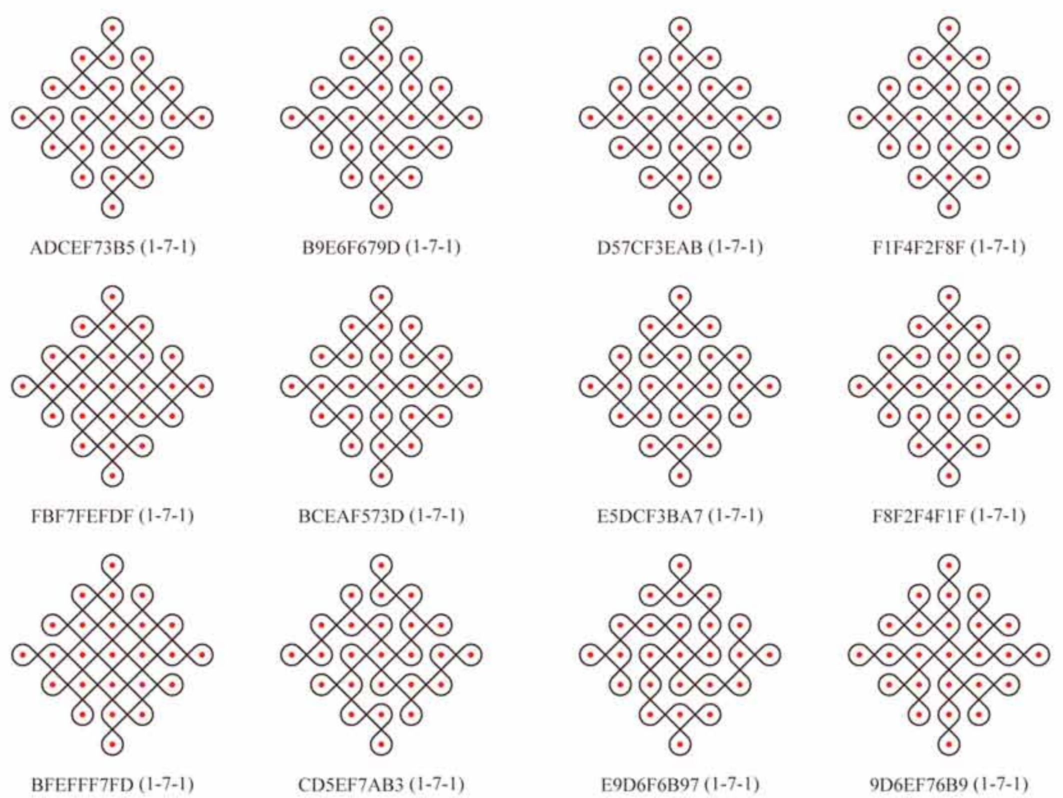


Fig. 13. The 24 highly symmetrical patterns drawn on 1-7-1 array of points

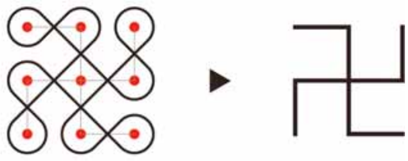


Fig. 14. Conversion into linear diagram

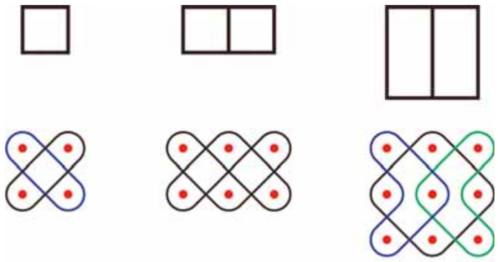


Fig. 16. Patterns with closed paths in linear diagram

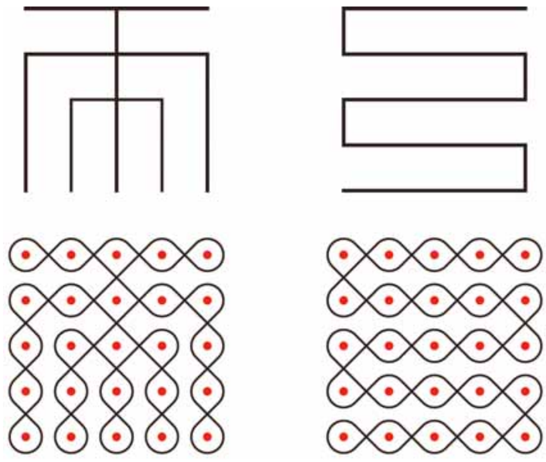


Fig. 15. Patterns with tree structure in linear diagram

shape if they are rotated or reflected [Table.3]. In addition, only 9 of them are symmetrical, which are regarded as beautiful patterns suitable for use as auspicious motifs [Fig.11].

The results on 1-7-1 array of points are shown in Table 4. This array of points has 36 intersections in the inclined grid [Fig.12], on which 2^{36} = 68,719,476,736 patterns can be drawn. The number of one-stroke patterns is 11,661,312 (0.017%). Among them, 1,458,430 are unique without isomorphic patterns, and only 1,520 are symmetrical. The 24 patterns of especially highly symmetrical form are shown in Fig.13.

4. Conversion into Linear Diagram and Analysis of "Diamond Carpet"

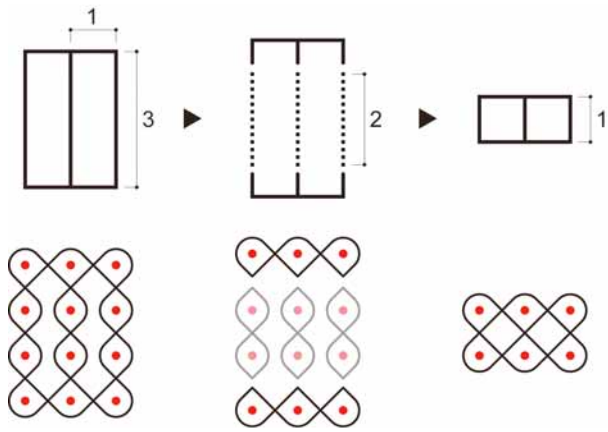
4.1. Conversion into Linear Diagram

In order to make it easy to grasp the structure of a complicated Kolam pattern, it is effective to convert string/knot style into a simpler *linear diagram*. The method of conversion is as simple as follows: if the drawing-lines around two adjacent points are connecting, make another straight line, named *N-line* or *Navigating-Line*, between the two points [fig.14].

A unit length of N-line in linear diagram represents a knot of single loop once twisted. Stretching the length of N-line therefore means twisting the loop further, and shortening means untwining knots. The operation bending or straightening N-lines does not change its knot structure. Repeating to untwine knots ends up in a single ring. Therefore, it is found that when the linear diagram of a certain Kolam pattern shows the shape of a line, the pattern is made of a single twisted loop, which can be drawn by one-stroke. The same can be said for the patterns with tree structure, with a combination of lines [fig.15].

In the case where a linear diagram has closed paths, although there are different cases depending on its size or shape and it is not formulated yet [Fig.16], the clear one thing is that the number of strokes to draw the pattern stays constant when the contacting sides of closed paths are shortened (or stretched) by 2 units length at a time [fig.17].

In either case, however, it can be said that if some one-stroke patterns are jointed linearly avoiding making closed paths, the joint pattern is drawn by one-stroke, too. Even conversely, it is



1 stroke still, 1 stroke

Fig. 17. Number of drawing strokes stays constant, when contacting sides of closed paths shortened (or stretched) by 2 units length at a time

also one-stroke when cutting down branches of a linear diagram of a one-stroke pattern. That is to say, by operating a linear diagram, it is possible to easily simplify a complicated pattern while keeping the property of one-stroke.

4.2. Analysis of "Diamond Carpet"

By this means, the author attempted to analyze the structure of a huge one-stroke pattern called "*Diamond Carpet*[2]", which is drawn on 33*33 array of points [fig.18]. The analyzing process is as follows:

(1) Converting the quite complicated Kolam pattern into linear diagram [Fig.19].

(2) Observing the diagram carefully, it is found that the whole pattern consists of several small units, that is, various patterns of swastika shape on 5*5 array of points, "E" or trident shape on 3*3. Removing lines jointing each units and frills on the borders, the 90˚ rotational symmetrical structure (same as a swastika) of this pattern becomes also clear [Fig.20].

(3) Next, the patterns are simplified by cutting down branches of N-Lines [Fig.21], straightening and shortening each N-lines keeping the attention of preserving the property of one-stroke [Fig.22].

(4) Finally, it can be reduced to a small pattern, which is regarded as the framework of Diamond Carpet [Fig.23-left]. Furthermore, this pattern is predicted to be simplified to the pattern consisting of 8 rectangles combined in swastika-shape on 5*5 array of points [Fig.23-right], though the procedures are not formulated yet. This pattern is extracted through the above process for the first time ever, as far as I know, it is one of the most beautiful patterns with an attractive and simple as well as a complex composition.

5. Summary and Future Issues

The points of this paper are summarized as below:

(1) First, the author reviewed the elements and drawing rules of Kolam patterns.

(2) The method to convert Kolam patterns into numbers was presented. Kolam patterns can be digitalized depending on the shapes at the intersections of the inclined grid which are determined by the array of points. It is also possible to convert numbers into patterns in a reverse process.

(3) By the computer analysis of the patterns on 1-5-1 and 1-7-1 array, it was revealed that the

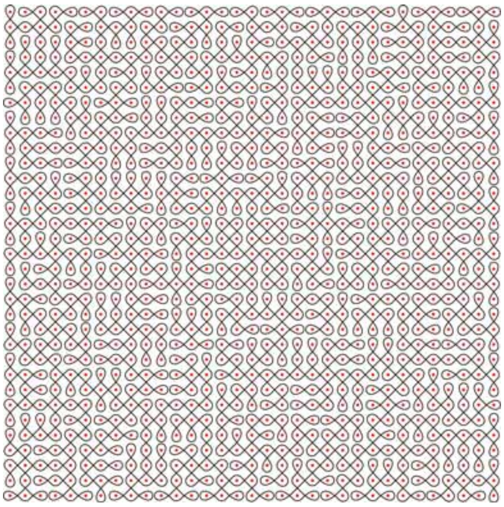


Fig. 18. Diamond Carpet (33*33)

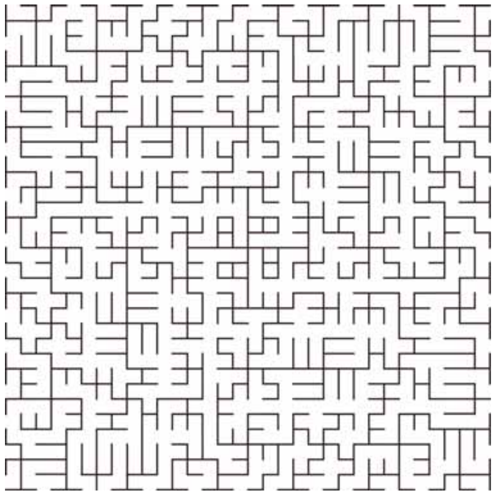


Fig. 19. Conversion into linear diagram

removing joints and border frills

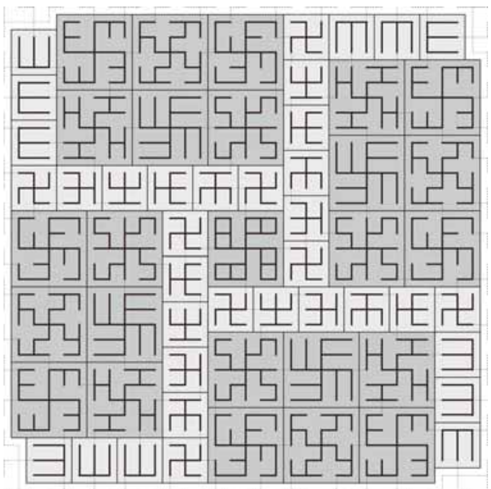


Fig. 20. Swastika units organized in rotational symmetry

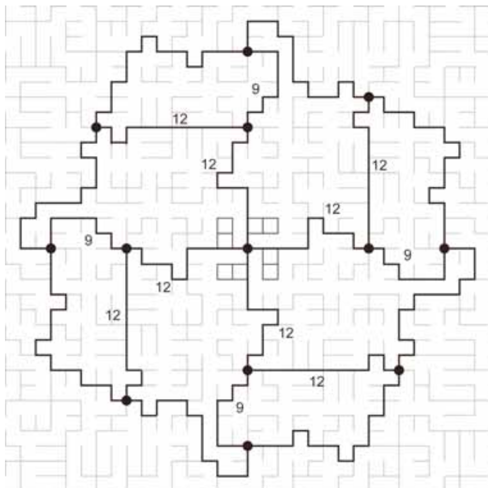


Fig. 21. Simplification by cutting branches
(numbers show length of sides)

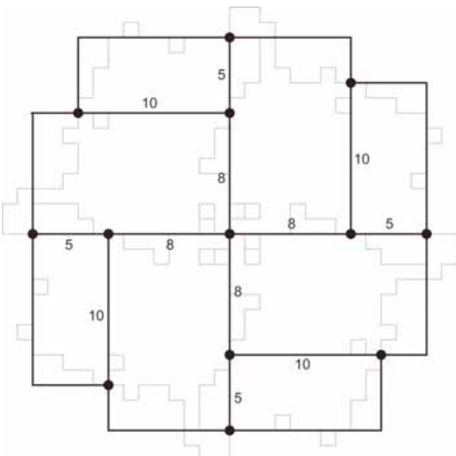


Fig. 22. Simplification by straightening sides

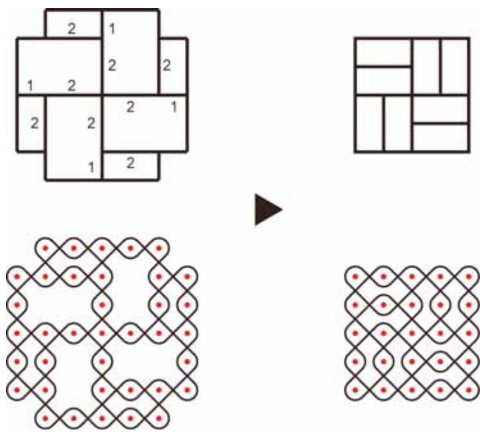


Fig. 23. Archetype of Diamond Carpet

number of one-stroke pattern is quite small and precious few patterns are symmetrical, which regard them as suitable as auspicious motifs.

(4) The method to convert Kolam pattern into linear diagram with N-lines was presented. Using this method, it becomes easy to understand the structure of a complicated Kolam pattern. The patterns with tree structure can be drawn in one-stroke. The patterns made by jointing one-stroke patterns are also one-stroke except when they have closed paths.

(5) Applying this method of linear diagram to the "Diamond Carpet", the author revealed that it consists of several smaller patterns organized in rotational symmetry, and extracted a simple pattern considered as its archetype.

As described above, Kolam patterns have such a clear and interesting design system, that is to say, countless various one-stroke patterns can be drawn following extremely simple elements and a few simple drawing rules. Large and complicated ones are also designed by joining small patterns based on a simple framework. These characteristic features of Kolam patterns have prospects to be applied to other areas, such as toy, puzzle game, tiling design, graphical language, architecture and city planning.

One of the future issues for more detail discussion is to establish a unified notation, with which Kolam patterns can systematically be described and classified. In this paper, the author proposes the notation with hexadecimal units and array of points, such as "FB97 (1-5-1)". However, room for discussion is left about the way to determine the units and to describe patterns on irregular arrays. It also remains as an issue to formulate the method to judge patterns as one-stroke or not, including the ones with closed paths.

Acknowledgment
The author is grateful to Mr. Asano Tetsuya for his inspiring me to consider this problem, and the analysis of Diamond Carpet was a collaborative work with him.

Note

1. Removing symmetrically same units, it is possible to put these 16 units into 6 and to assemble them into a dice-shape [Fig.24].

2. This pattern was recorded by Mr. Tetsuya ASANO, an illustrator and a member of KASF, at the Meenaksi Temple in Madurai, Tamilnadu.

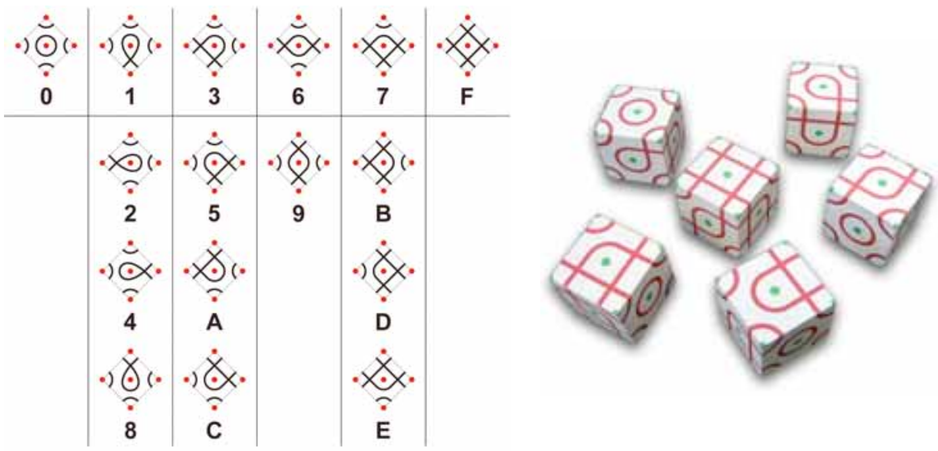
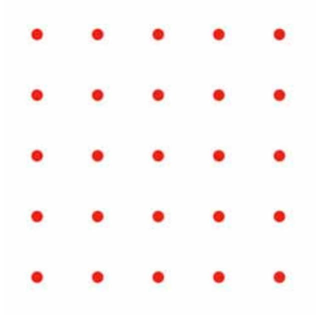


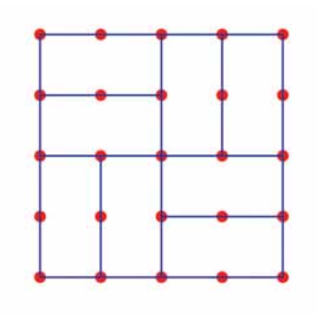
Fig. 24

Appendix. Kolam Drawing Method Using the N-Line

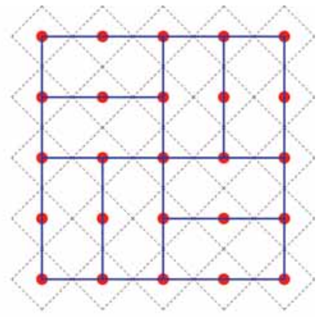
Although it is not clear which kind of thought process women in Tamilnadu follow when drawing Kolam patterns, by using N-Lines as a literally navigating guideline, you can correctly complete any complex patterns without difficulty [fig.25]. Furthermore, it is also easy to create new beautiful patterns by symmetrically arranging a variety of small patterns and joining them as well as the Diamond Carpet.



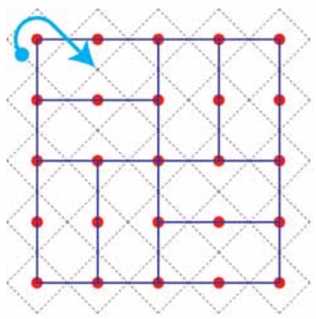
1.
Arrange an array points on square grid.



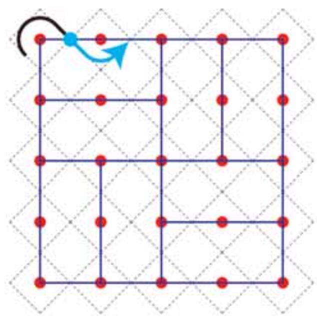
2.
Draw N-lines linking points.



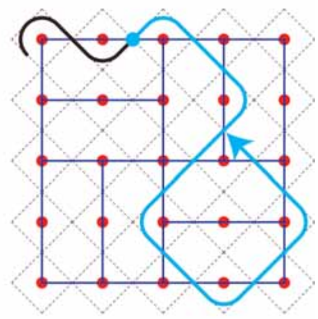
3.
Imagine a grid inclined at 45°.



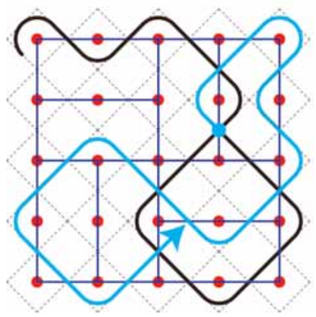
4.
Start to draw a line from anywhere, and go straight when N-line lies at the forward intersection of the inclined grid.



5.
Curve centering round the nearest point when there is not N-line at the forward intersection.



6.
Continue to draw in the same way.



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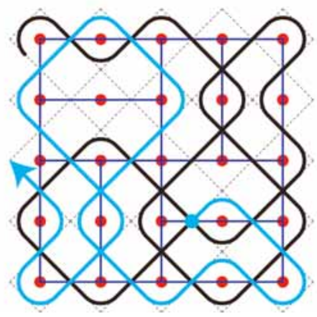

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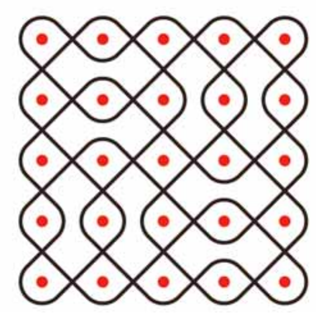

9.
Completion

Fig. 25. Kolam drawing method using the N-line

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