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Digitalization and Analysis of Traditional Cycle Patterns in the World, and Their Contemporary Applications

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1. Introduction

Many traditional designs consist of some geometrical properties of symmetry, periodicity/repetition, recursion or cycle with an endless stroke, especially in Tamil Kolam, Celtic knots, African Sona, Vanuatu Nitus, Arabesque or Asian knot etc. People like to feel infinity, recurrency and dynamism especially of trace animation in these cycle patterns, and are attracted by such a fact that the patterns are evolved from a simple line and arc to complex and beautiful structures with diversity on a few simple rules.

The traditional designs are useful not only for productions of daily necessities including textile or various ornaments in this modern life, but also for other contemporary applications.

2. Digitalization of the Cycle Patterns an N-line with Crossing (Twisting or Untwisting) Point

When dots are assigned in a regular matrix like Kolam, space-filling tiles could be arranged around the dots and to form tessellations with three regular polygons, e.g. a triangle, a square and a hexagon, even the surface polygons of a polyhedron. A curve in the tile is drawn with such ways as turning inside against an edge or going straight into the adjacent tile through one crossing point on the edge, represented with 0 and 1 respectively (Fig. 1) (NAGATA and YANAGISAWA, 2004a). "To pass smoothly" at the crossing (at the vertex) on the edge is a rule different from Eulerian cycle. Here we propose a line between two dots of the tiles, a shared edge of which has a crossing point on it, called Navigating line or N-line. One line of the crossing on a N-line goes (or turns to pass an edge) to the next crossing line and so on, and finally should return to a position of the beginning crossing. We can apply this N-line to an arbitrary (free) dot array (Fig. 2). Space filling tile is not necessary in this case.

For Celtic knot like patterns, a stroke passes around the dot in such 3 statuses as no crossing (0), one point crossing (1), or through two point crossings at the edge, turning

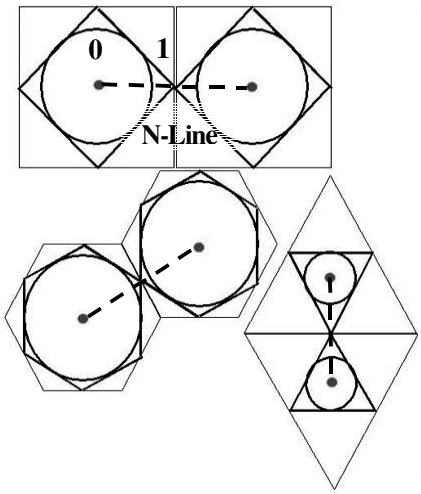

Fig. 1. A Stroke of arc or line in a tile goes with non crossing (0) or crossing (1) at an edge on N-line to a next crossing for the adjacent, finally one around all dots.

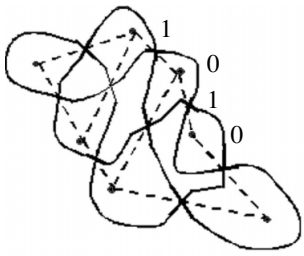

Fig. 2. A Single Cycle pattern on an arbitrary dot array with a curve around all dots ones.

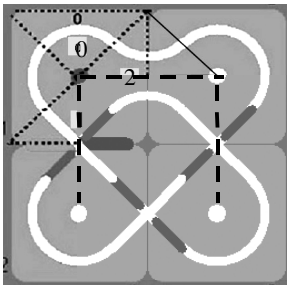

Fig. 3. Three Statuses of non-crossing (0) with inside turning, one point crossing (1) and two point crossings with outside turning (2).

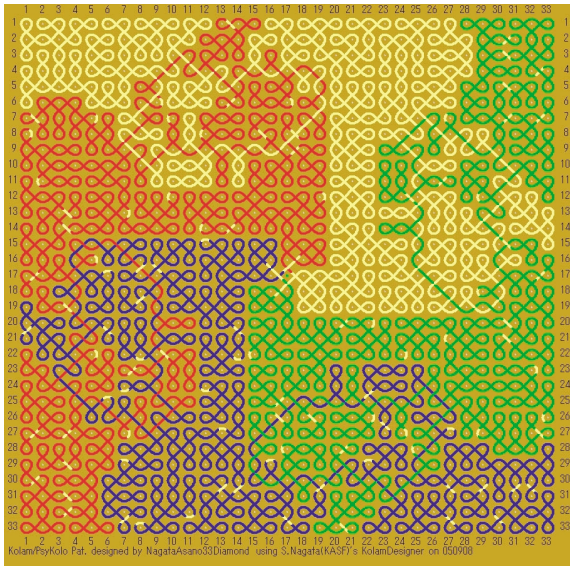

Fig. 4. Analyzing the stroke chain of Diamond Carpet Kolam results 4 same parts in the rotated symmetric structure shown with different colors.

Table 1. Numbers of generable patterns from a rectangle matrix array ($n \times m$) of the tiles with dot.

Dot	Multi stroke/cycle[a]	Single stroke[b]	Symmetric[d]
2 × 2	5	4	1
2 × 3	27	16	5
2 × 4	213	64	8
3 × 3	785	240 (35[c])	9 (32[e])
3 × 4	20479	3584	76
3 × 5	not counted	53504	236
4 × 4	not counted	196608	256
4 × 5	not counted	10747904	4576

All pattern number is 2 to the c-th – 1, $c = n*m*2 - n - m$, e.g. 4095 for 3 × 3.
[a]Including 4 iso-oriented and two mirror images.
[b]Including 4 iso-oriented and two mirrored.
[c]Excluding the isomorphic.
[d]Including the isomorphic.
[e]Excluding the isomorphic. These numbers drive mystery, scarcity and beauty.

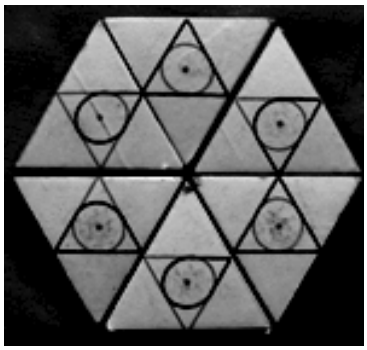

Fig. 5. PsyKolo Triangle Tiles of 3 primitive patterns available to design cycle patterns.

Fig. 6. PsyKolo 3-Status Triangle Tiles of only 3 primitive patterns engraved with 3-status cycle patterns for 20 primitive square tile patterns.

outside into an adjacent tile (2) (Fig. 3). Any pattern using these conditions can consists of some endless cycles. The direction of the stroke is alternately changed at the crossing point (1) to the clockwise or the counter clockwise around the dot. When a crossing at an edge is a two level crossing, the cycle becomes a knot (or a link) in Knot theory. The author found that only one type of two level crossing of each primitive tile is available to make any knot patterns (Fig. 3).

3. Stroke Chain-code and Analysis of the Cycle Patterns

N-line can show the construction of a pattern. On the other way, an elemental stroke chain consists of three codes of inside curve (0), crossing line (1) and counter outside curve (2) corresponding three statuses of no crossing, one point crossing, or two point crossings at an edge (Figs. 1–3). Using autocorrelation for this stroke chain, the structure of a pattern was analyzed, for example, the large 33×33 dot single stroke Kolam called Diamond

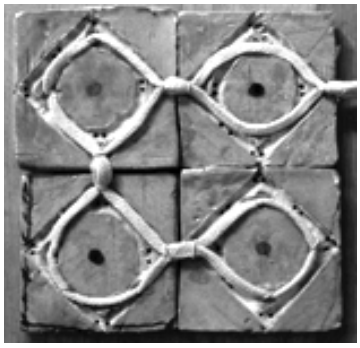

Fig. 7. PsyKolo Square ceramic Tiles with common a rhombus and a circle.

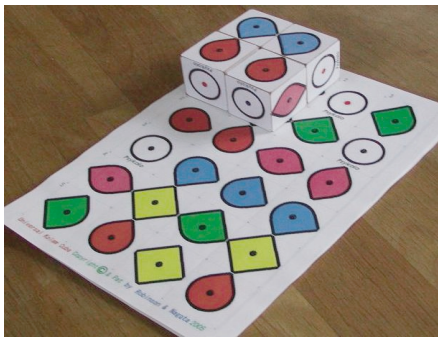

Fig. 8. PsyKolo Block with one of 6 primitive patterns on each side available to design cycle patterns.

Carpet has the chain of 4356 stroke elements, like 1, 1, 0, 1, 1, 0, 1, 1, 0, ···. starting at the point of (tile x, y, edge and direction), and the autocorrelation efficiency for the sequence with 1089 length is 1.0, which means 1089 strokes are repeated at 4 parts. On comparing with both of the halves of the chain, we can also find a rotated symmetrical structure like Swastika in it (Fig. 4).

About a number of cycles in a given pattern, we can say the followings; When N-line has only an opened tree-structure, each of them can be untwisted to reduce to one loop as a cycle (the trivial knot). When having a closed structure and crossing points of (1) of even number, the pattern is multi cycle (odd crossings for one loop). To joint between different cycles or to cut on the same cycle makes single cycle or multi cycle respectively. Such a pattern that consists of a matrix of $n \times m$ tiles and all edges are crossing of (1) consists of cycle of number of GCD (n, m). We have yet an open problem to get a general answer of a cycle (component) number in a given pattern with other conditions.

Numbers of possible patterns in a rectangle dot array with crossing (0, 1) are shown in Table 1.

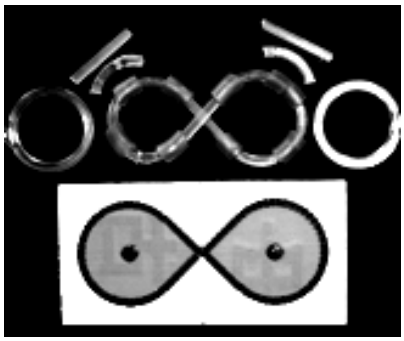

Fig. 9. PsyKolo R&R of only two parts of quarter Ring and Rod with jointing, for real 3-status knots.

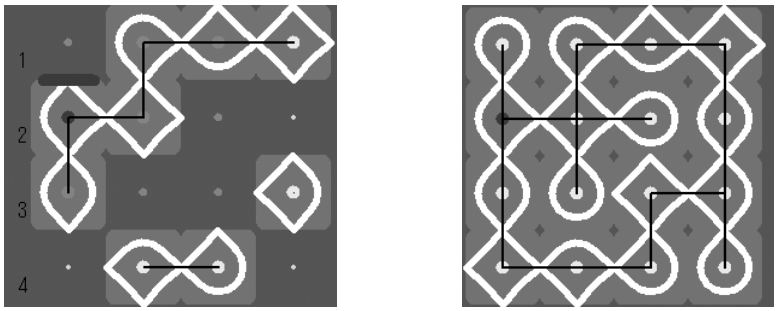

Fig. 10. (left) Kolam Number-place Puzzle of 4×4; Only once each of primitive patterns of 1–4 crossing points is usable in each of columns, rows and 2×2 cells and also Only once the stroke goes around each of all dots. An answer of a single cycle pattern (right) is got from an easy question (left).

4. Applications to Ornaments on wall, Floor or Threshold of House Using Cycle Pattern Tiles

When producing a pattern with tiles, It is advantageous for makers/users of the tiles to produce/use the primitive patterns of a minimum number of kinds for any patterns they want. On digitalization of the Cycle patterns, the author proposed such kinds of tiles (Figs. 5 and 7) (NAGATA and YANAGISAWA, 2004a) as PsyKolo tiles of Space Filling polygons of square (5 primitives for 2 statuses crossing), triangle (3) or hexagon (17), or the component tiles consisting of three patterns of a crossing line and a quarter of (octamerous) circle with right angle (90 deg) of a triangle (Fig. 6).

5. Applications to Education and Training the Brain

Rudolf Steiner (1861–1925) (KUTZLI, 1990) in Europe derived a "Form drawing" method for educating children from knot designs of Celtic culture. The author expected

Fig. 11. Ubiquitous play with Keitai/mobile phone. //www.seeda.jp/kolam

Cycle pattern would be useful for a user to understand and training his/her brain, and then developed some tools for education and training the human brain. At the first time, a creating and drawing computer graphic software was developed for a user including a person with low vision to play it.

Without haptic sensation, however, the identification of the patterns is not possible by the blind. The tool for them was developed as a universally designed cube (NAGATA and YANAGISAWA, 2004b; NAGATA, 2006; NAGATA and ROBINSON, 2006). A tangible cube block (Fig. 8) with 6 primitive patterns on each of 6 sides is more useful for children and the leaning disabilities, and also the tactile pattern made from colored Braille dot or Swell paper is universally accessible to the visually impaired This block is available to learn spatial pattern recognition while he/she is playing it. This block is useful for any persons to play it to promote their brain activities and also for recognitive—Psychological test, for example Kohs Block Design Test. Some conventional test/toy blocks have only 6 kinds or some limited pictures, or only a part of triangle or square pattern. On the other hand, this block allows a user to make the more complex patterns using the more blocks. An other tangible tool is proposed here, PsyKolo R&R (Fig. 9) consisting of only two parts; a quarter ring of radius size R (one edge/root (2)/2) and a rod of length $2 \times R$ with a jointing tube (or a pipe ring and a pipe rod with a jointing rod) for realizing real 3-status knots using a string.

A game using the Cycle patterns was designed (Fig. 10) and an ubiquitously playing system of creating the cycle images with 3 statuses was developed with a Keitai/mobile phone, which becomes popular in the world (Fig. 11).

These works presented here were realized on discussion or in collaboration with the members and friend members of KASF. I would like to thank them for their cooperation, especially Mr. Yanagisawa Kiwamu of Kobe Design University for basic digitalization of the cycle patterns, Mr. Matsunaga Takahiro for his discussions, and Mr. Suzuki Toshitaka for his assist to counting the pattern numbers. Mr. Thamburaj Robinson of MC College India for designing Braille patterns for a Psykolo block, Mr. Yasuo Ito of Keihin Kagaku Gogyo Co., Ltd. for producing non-repulsion magnets of the PsyKolo block, Ms. Kitayama Shizuko for the cooperation in experimenting with her students with learning disability, Ms Izuhara Ritsuko of KIT Institute for trying to make pilot tiles of the 3-status triangle primitive patterns with a numeric control machine called a 3D plotter, and Mr. Keiichi Isida of Web Atelier SeeDa for programming Psykolo Keitai/mobile version of the Kolam/Knot Designer.

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