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Analysis of the Spiral Pattern *Karakusa*

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Abstract. In this paper I discuss the properties of a pattern known as *"Karakusa"*. *Karakusa* is Japanese and means "foreign plant" or "winding plant". The pattern consists of various spirals, and these spirals take their shape from vines and other natural forms. I will examine and demonstrate how features of the pattern were abstracted from these natural forms. In addition, it will be argued that an algorithm employing a mathematical element could be involved in generating those features, and I will claim that we will be able to utilize this algorithm for generating new spiral forms. In this study I examine a *Karakusa* pattern familiar from its use on Japanese wrapping cloths. In this particular pattern only a geometric spiral is employed. It is a simple pattern constructed from many spirals, each of which extends freely in all directions. In this paper I examine such features in turn and describe my results.

Key Words: spiral form, pattern, algorithm

1. Introduction

At the 7th (Cracow) and 8th (Austin) ISGG conferences, I reported on form generation methods using rotation and twist, methods which resulted from my research on the mathematical properties of spiral form. The purpose of that research was to carry out a mathematical interpretation of natural forms and to pursue the possibility of generating various forms that the mathematics produce. The number of forms that we obtained was greater than predicted, and results were very satisfactory. The shapes were abstract, but the properties of the natural forms still remained. It was shown how natural forms, mathematical elements and abstraction were all related to each other.

This paper is also one of a series of research papers on this spiral form. My research in the past started from the natural form; in this study I start with the shape in its already abstracted form. Then I clarify the mathematical features of the shape and review work already done on the possibilities of the shape.

The term *"pattern"* is chosen for the shape in its abstracted form. This pattern exists in art from all parts of the world and appears in countless types and with countless features.

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From these patterns the spiral pattern of *"Karakusa"* was chosen. The spiral pattern of *Karakusa* is noteworthy for two reasons: one is that it is a form abstracted from nature; the other is that it has resulted in some excellent design work. In this paper it is the pattern of *Karakusa* that is familiar to the greatest number of people that is analyzed, and its objective molding element is revealed. The procedure for analyzing the pattern distinguishes part from whole, and both general and particular features are examined. Finally I look at how parts of the shape constitute the whole.

2. Pattern

When we say "pattern" we mean a two-dimensional shape abstracted from nature. We can find patterns all over the world, throughout history and amongst all peoples. They are passed down with subtle changes from generation to generation, and they are used in the decoration of household goods, furniture, clothes and buildings. It has been shown that these motifs originate in nature and patterns are produced by life itself.

Some countries have family crests that incorporate patterns. Family crests are reproduced on clothes and furniture as genealogical symbols. The design often consists of a plant or animal motif in a small circle (Fig. 1). Also, many family crests are symmetrical. This geometric symmetry is useful in that it emphasizes the "symbol-ness" of the family crest. Family crests are one comprehensible example of an abstracted shape using geometry, and various other patterns are similar to family crests in the way that they abstract their form. The main elements involved in this abstraction and formation of patterns are regularity and geometry.

Figure 1: Family crests of Japan

3. *Karakusa*

The *"kara"* of *Karakusa* means "China", while *"kusa"* means "plant". The *Karakusa* pattern came to Japan from China, although it is said to originate in ancient Egypt. Elements which seem to have influenced the form of the *Karakusa* pattern are palmettes, lotuses, plants such as the acanthus, and marine organisms from the Mediterranean. It took a long time for the pattern to be transmitted from Europe to the Orient, and by the accretion of slight changes from each country and culture the original curve pattern has been modified. In particular, Byzantine Christian culture and Buddhist art of the Gandhara added their own touches to the pattern, and coming along the Silk Road these influences fused with the Buddhist culture of China, before finally reaching Japan in the ASUKA period (7th Century AD). The splendid workmanship of many artifacts utilizing the *Karakusa* pattern and brought into Japan with Buddhism can still be seen today (Fig. 2). After this, the design peculiar to Japan became fixed and reached its final form as a decorative pattern.

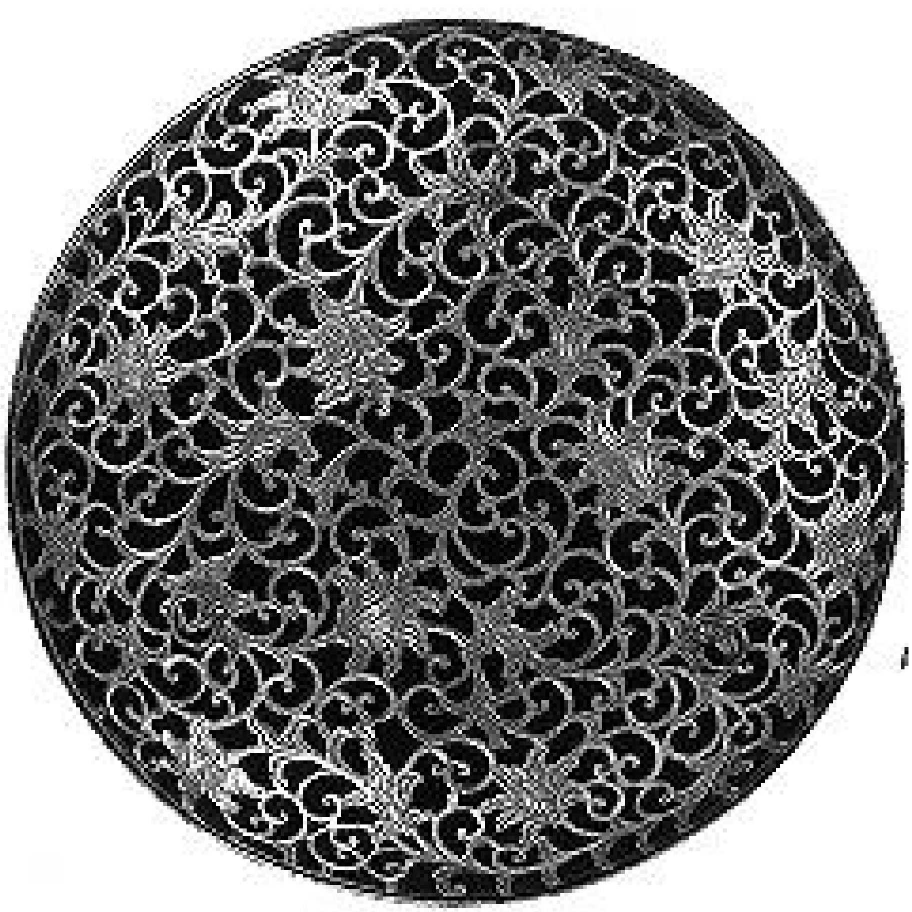

Figure 2: The flower basket at Shinshou-ji temple

Although *Karakusa* includes the element "plant" in its original meaning, there was no one particular plant used as a model. "Plant" merely referred to a flowery shape or a shape like grass. The shape includes a vortex-like curve similar to that of a vine, and this feature, combined with a specific flowering herb, all *Karakusa* patterns have in common. Types include the "Japanese Apricot *Karakusa*", the "Peony *Karakusa*", the "Lotus *Karakusa*", the "Clematis *Karakusa*", etc. (Fig. 3). Because of its stout growth the vine was considered a symbol of prosperity, and so also was the spiral pattern seemingly abstracted from the vine.

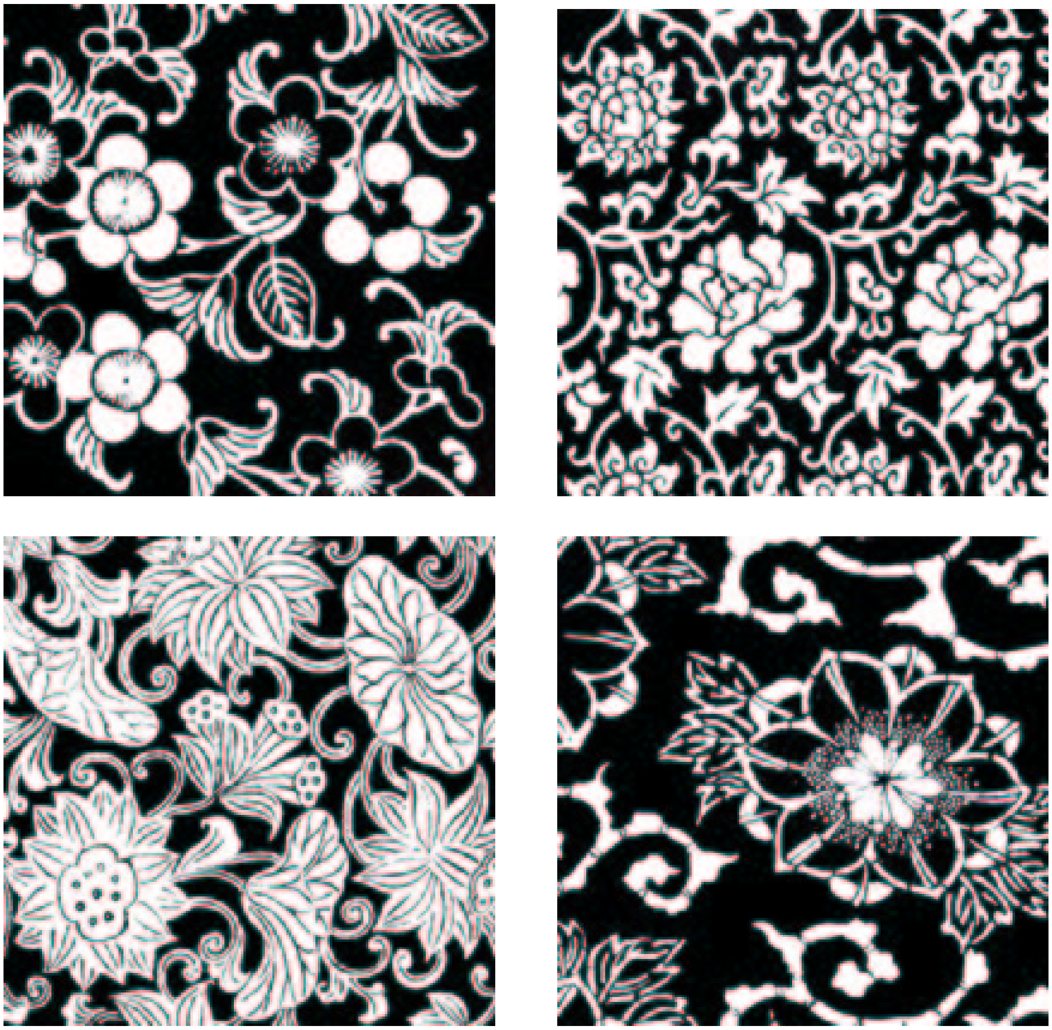

Figure 3: Various *Karakusa* patterns

4. The Spiral in *Karakusa*

The pattern used in this study is that used on Japanese wrapping cloths (Fig. 4). The shape of this cloth is square, and it is possible to wrap items of various shapes in it. In addition, when it is not being used it can be made smaller by folding it. In this way, Japanese wrapping cloths can be used for storing and for carrying things. The materials used are silk or cotton, and various patterns are printed on the cloths. Specifically, the *Karakusa* cloth was a large cotton cloth, and it was used to wrap large or heavy goods. However, in recent times its use has decreased. There are two colors printed on the cloth, green and white, and the pattern is white. Sometimes, thieves in comics use this type of cloth to wrap their stolen articles in. In the pattern of the *Karakusa* cloth, only geometric spirals are used. It is a simple pattern consisting of many spirals drawn in a plane, but there are small leaves here and there, and it looks to anyone seeing it like a pattern derived from a plant.

4.1. General features

Firstly, I would like to clarify the nature of the pattern as a whole. When the cloth is spread out we can see many spirals drawn on the cloth. Moreover, these have been equally spaced. In

Figure 4: *Karakusa* pattern of a Japanese wrapping cloth

addition, most spirals of the pattern have been connected to each other, forming a labyrinthine appearance. It is difficult to immediately identify a starting or end point to the pattern.

This Japanese wrapping cloth is a dyed textile. Although there are various methods for dyeing the cloth "printing" is used in this case. This method is particularly effective when equal patterns are repeated, and this is true in the current instance. By isolating this equal pattern it is possible to identify the basic unit of the pattern. Fig. 5 shows points at which the equal pattern appears. In this case there was an equal pattern at three places, and from this it is possible to identify the shape of "one unit". If we try and trace the pattern from one unit to the next, we can find a wide combination pattern at two places, as shown in Figure 6. There is one in the left upper part of the figure, and another in the right lower part. However, the left upper part includes two equal patterns. This fact is mentioned to show that the joint of unit and unit has not been proved.

A quick glance at the features of the combination pattern does not prove the joint of the unit, and a considerably wide range is occupied. From this fact, we can show that this pattern has the property of a spiral plane filling pattern.

4.1.1. Plane filling

In a plane filling pattern straight lines and curves equally fill up the plane. Famous examples of plane filling curves are the Dragon curve (Fig. 7), the Hilbert curve (Fig. 8) and the Peano curve. The basic figure of these curves is very simple. By repeated reduction and mapping, the simple figure makes the filling pattern. This is a promising method for producing a *Karakusa* pattern, as the *Karakusa* consists of a plane filled by a spiral.

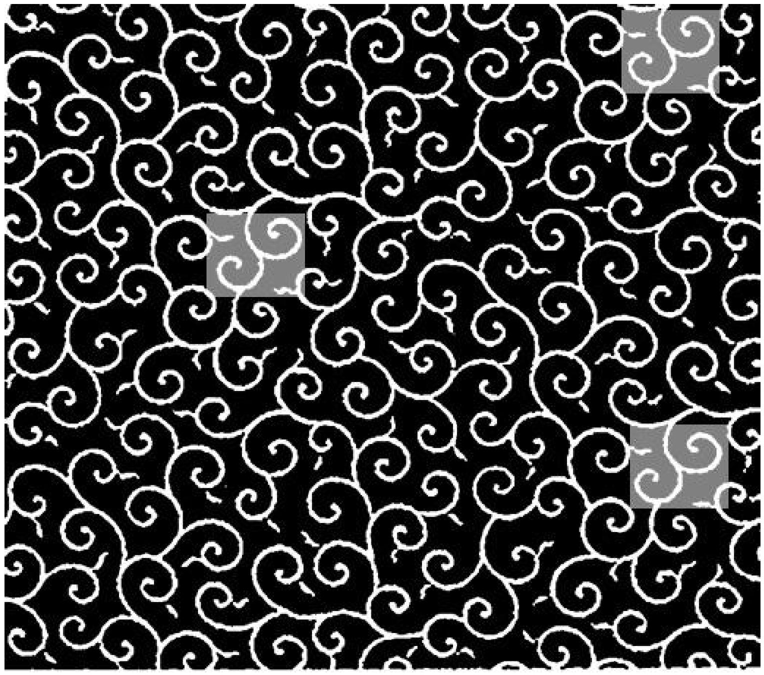

Figure 5: We can find equal patterns at three places

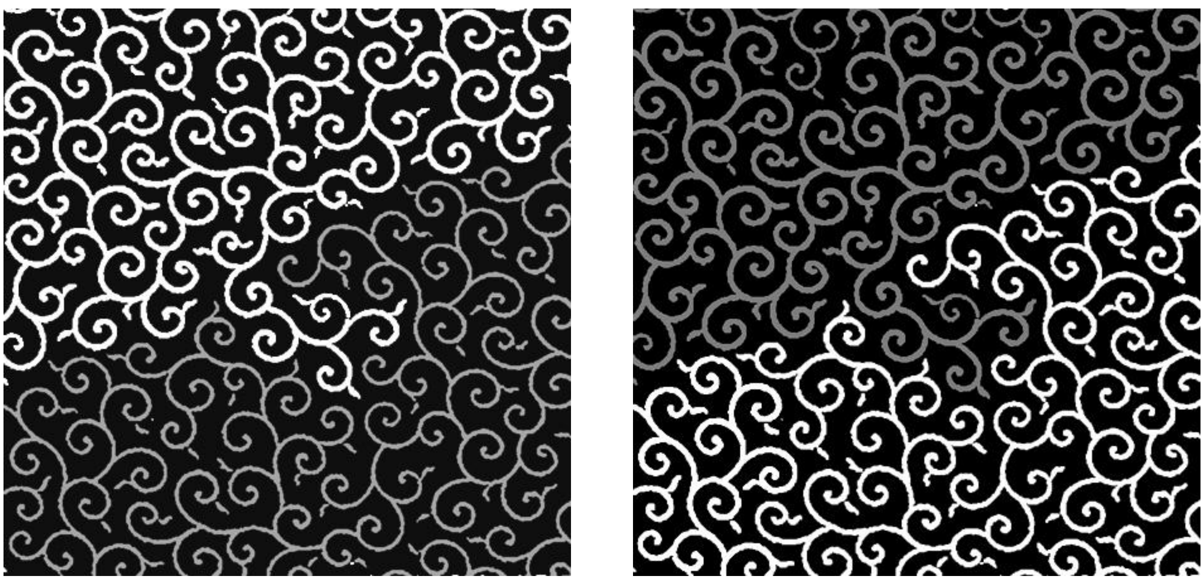

Figure 6: Wide combination pattern. There is one in the left upper part, another is in the right lower part

4.2. Partial features

Next, I describe my results in examining how each individual spiral is coupled to another. The spirals extend in all directions, and counterclockwise spirals coexist with dextrose spirals. However, they do not cross or come into contact with each other. They give the appearance of growth, even though crossing and contact are avoided. I will isolate parts of the pattern and draw attention to particular features:

1) A counterclockwise spiral forms a pair with a right-handed spiral. In forming a partnership the spirals are wound to each other reversibly (Fig. 9).

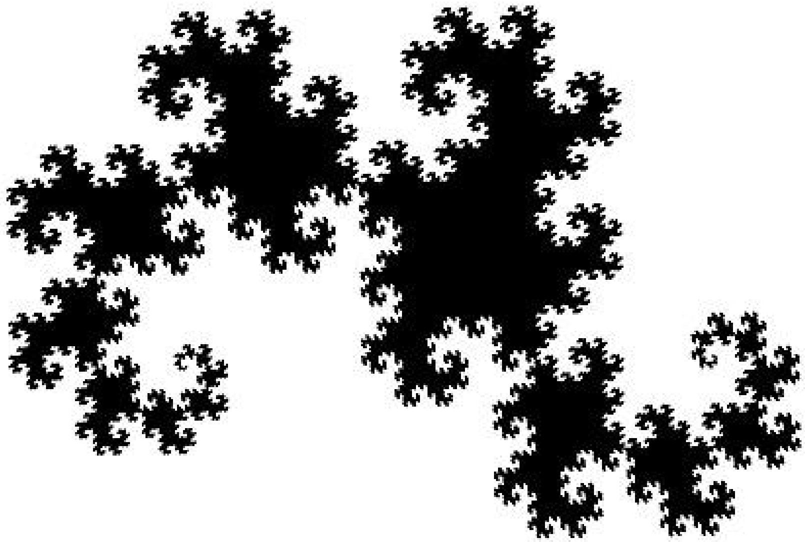

Figure 7: Dragon curve

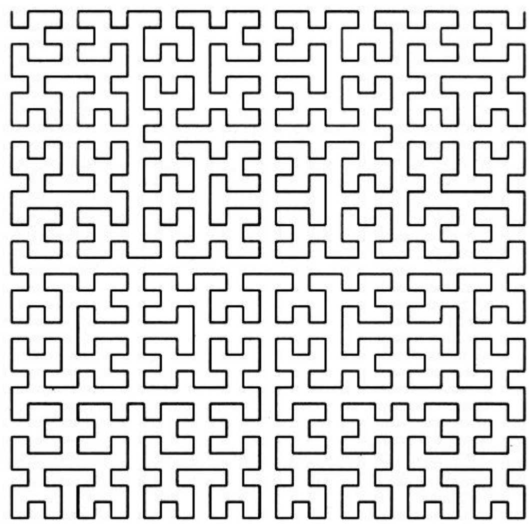

Figure 8: Hilbert curve

2) Double branching. When branching occurs the spiral branches in two; triple (or over) branching is not observed.
3) A new vine emerges from the middle point of its parent vine before generation. The new vine grows from the same position as that from which the previous vine began to wind (Fig. 10).
4) The new vine spirals in the opposite direction from that of the vine before.
5) The number of winds is small. Each spiral consists of between 1 roll (360 degrees) and 1 and a half rolls; there are none consisting of 2 or 3 rolls.
6) The size of the spiral is constant. The diameter of each spiral is almost identical (Fig. 11).
7) It is Archimedian spiral. Each spiral has a shape which approximates Archimedian spiral in which the radius gradually increases from the center out.

8) There are some cases in which it branches, and others where it does not.

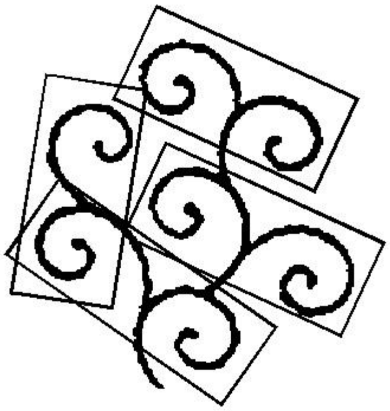

Figure 9: It has branched in two

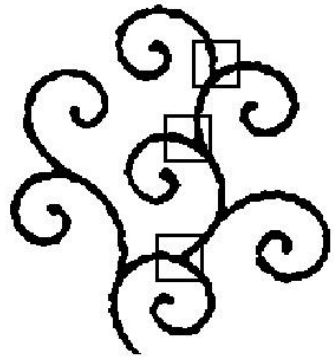

Figure 10: A new vine emerges from the middle point of the parent vine before generation

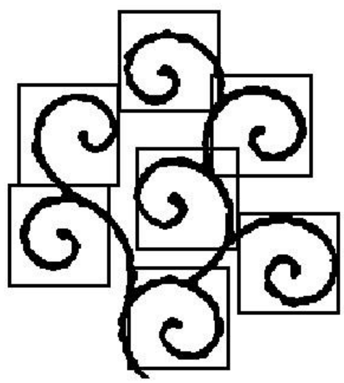

Figure 11: The size of the spiral is constant

4.2.1. Growing pattern

As this pattern is formed the fact that it is growing is obvious. This is clear because the pattern has branched, and a new vine has emerged from its parent vine before generation. But it is impossible to create this *Karakusa* pattern just by one-by-one placement of the spirals. The Growth Model of Kawaguchi3 is a famous piece of research on the growth of form. A random number is used to generate branching and growth rate. A random number is not required in this *Karakusa* pattern because branching number and growth rate are fixed. However, algorithms of growth and the approach known as "artificial life" are both relevant here. "Artificial life" seeks to model life activity in a computer. It seems that this approach may be applied to the generation of patterns in which spirals do not cross.

5. Conclusion

The *Karakusa* pattern was analyzed as a characteristic example of a spiral pattern. This pattern, as it appears on a Japanese wrapping cloth, looks simple, but on closer inspection it reveals itself as a considerably more intricate pattern. Features of this pattern are summarized below. Firstly, it is a filling pattern in which the plane is equally filled up. Secondly, many other patterns are formed by simple repetition. However, this simple repetition is not immediately apparent, and it is a pattern of a type which increases in complexity as it grows. In this paper, my results in examining features of the *Karakusa* pattern were described. In the future, some mathematical elements may be clarified from an examination of these features, and an algorithm produced.

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