Classification of the Design Elements inside *Kamon*, the Japanese Family Crest, Using Image Processing

Marino Ikeda*, Nozomi Miike*, Atsushi Osa**, and Hidetoshi Miike**
**Faculty of Engineering, Yamaguchi University; 2-16-1, Tokiwadai, Ube-shi, Yamaguchi, 755-8611,Japan*
***Graduate School of Science and Engineering, Yamaguchi University*
E-mail: j005fh@yamaguchi-u.ac.jp

Abstract

Kamon, the Japanese family crest, has been used as a family symbol for a long time. Today, many companies and organizations have their visual identities, which functions and designs are very similar to that of *Kamon*. This paper examines *Kamon*'s design elements, and classifies them with a new method by using image processing and statistical analysis. By doing this, main features of *Kamon* designs is revealed, and *Kamon* is classified into typical ones and the others. In this paper, 2000 kinds of *Kamon* were used in the classification. We introduce evaluation indexes that seem to be features of *Kamon*. The indexes are "Height and width ratio", "Figures and ground ratio", "Center of gravity", "Symmetry to line", "Symmetry to point", and "1-dimensional spectrum". These evaluation indexes are calculated by using image processing, and used in the principal component analysis. According to the first principal component, we classified the samples into *Kamon* with periodicities of horizontal & vertical directions, *Kamon* with periodicity of diagonal directions, radial *Kamon* and decorative *Kamon*. According to the second principal component, we classified them into *Kamon* with an uneven out line, and decorative *Kamon*. Furthermore, because the almost *Kamon* have the similar scores of first and second principal component. It was possible to classify *Kamon* into typical *Kamon* and the others. Also, it seems that the image processing of "1-dimensional spectrum" is useful way to evaluation a periodicity in the structure of *Kamon*.

Key words: *Kamon, Image Processing, Principal Component Analysis, Fourier transform*

---

1. Introduction

Kamon has been used as a Japanese family symbol for more than 1000 years. It started to be used as a sign to distinguish belongings from others. On the battlefields in the *Sengoku* era, *Kamon* had roles to show-off the power of warriors as well as to identify their allies from enemies. In the *Edo* period, *Kamon* was stitched on clothes and painted on lacquer wares. This trend was helpful to identify who is from which families or in which social ranks (Nousaka, 2009). Although the use of *Kamon* is getting less today, it is still possible to see on the emperor's crest, corporate visual identities, and on the occasions like family ceremonies, such as weddings and funerals. Today, the beauty of *Kamon* design, which history ascends to the 12^{th} Century, still appeals to many artists and designers (Dower, 1971). Various companies and organizations nowadays have their own visual symbols, which actually have many common features to *Kamon*, such as their roles as identifications simple and abstract shapes (Fig. 1) (Mitsui, 1996).

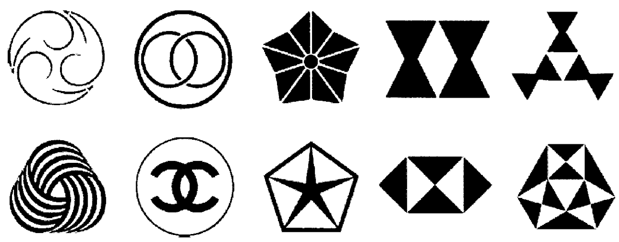

Fig. 1 Design resemblance between *Kamon* (avobe) and symbols of companies (below)

It is studied that *Kamon* has more than 20,000 designs they have been classified by some methods (Nousaka, 2009). One of the commonest methods is classification by family names and histories, and another is by motifs used in the designs, such as plants, letters, and appliances. In this paper, a new classification of *Kamon* is examined by using image processing of its design elements as well as applying statistical analyses. This will reveal similarities between *Kamon* and company symbols mathematically. Also, it is expected to understand basic design elements and principles of symbols, which can be useful for future creations of symbol designs.

[Table 1] Relations between "Elements of beauty" by Mitsui and "Evaluation indexes" in this study.

Elements of beauty	Evaluation indexes
Proportion	Height and width ratio
	Figures and ground ratio
Balance	Center of gravity
Symmetry	Symmetry to line
	Symmetry to point
Rhythm	1-dimensional spectrum

2. Methods

2-1. Introducing evaluation indexes on *Kamon*'s design features

In order to classify *Kamon* regarding its design, we introduce evaluation indexes on features of *Kamon*. According to Mitsui, "Principle of aesthetic forms" is an aesthetic standard, which observes images on shapes and forms objectively, apart from their contents, meanings or preconceptions (Mitsui, 2000). Mitsui enumerates five elements of beauty that compose "Principle of aesthetic forms", which are symmetry, proportion, balance, rhythm and composition. By referring to this, some elements that are usable for image analyses are chosen. Table 1 shows the relations between the elements of beauty by Mitsui and evaluation indexes we set for this analysis.

2-2. Evaluation indexes for image analysis

Images used for analysis are from a data CD called *Kamon Collection* (MATSUI SYSTEM), which contains 2000 choices of principal *Kamon*.

In this paper, *Kamon* is allocated in a minimal rectangle that comes in contact with its outline of *Kamon*, and we define this as Image f. W [pixels] is a width of Image f, and H [pixels] is a height of Image f. A position of the respective pixel point is described as (x,y), and this pixel's gray value is described as f_{xy}. Therefore, the range of x is $1 \leq x \leq W$, and the range of y is $1 \leq y \leq H$. Then, we binarize *Kamon* images (the original image are quantized by 8bit), which are represented from 0 (background) to 1 (figuret). The followings go into details of each evaluation index for image analyses.

・Height and width ratio = H / W

・Figure and ground ratio = $\sum_{x=1}^{W}\sum_{y=1}^{H} f_{xy} \Big/ WH$

・Center of gravity

$$g_x = \left(2\sum_{x=1}^{W}\sum_{y=1}^{H} x f_{xy} \Big/ \sum_{x=1}^{W}\sum_{y=1}^{H} f_{xy} W \right) - 1$$

$$g_y = \left(2\sum_{x=1}^{W}\sum_{y=1}^{H} y f_{xy} \Big/ \sum_{x=1}^{W}\sum_{y=1}^{H} f_{xy} H \right) - 1$$

g_x is a "center of gravity" to horizontal direction, and g_y is a "center of gravity" to vertical direction. The center of Image F is described as g_x =0 and g_y =0, and a range of g_x and g_y is $-1 \leq g_x \leq 1$ and $-1 \leq g_y \leq 1$.

・Symmetry to line

Line symmetry targets at left-right and top-down symmetries.

$$\text{left-right} = \sum_{x=1}^{\frac{W}{2}}\sum_{y=1}^{\frac{H}{2}} f_{xy} f_{\left(x+\frac{W}{2}\right)y} \Big/ \sum_{x=1}^{W}\sum_{y=1}^{H} f_{xy}$$

$$\text{top-down} = \sum_{x=1}^{\frac{W}{2}}\sum_{y=1}^{\frac{H}{2}} f_{xy} f_{x\left(y+\frac{H}{2}\right)} \Big/ \sum_{x=1}^{W}\sum_{y=1}^{H} f_{xy}$$

・Symmetry to point

Point symmetry is frequently seen in *Kamon*, which targets at nine angles: π, $2\pi/3$, $\pi/2$, $2\pi/5$, $\pi/3$, $\pi/4$, $\pi/5$, $\pi/6$, and $\pi/8$. We set Image R as rotated versions of Image F in each angle on the center of gravity. We place Image F's center of gravity on top of Image R's center of gravity, and the total amount of pixels, $f_{xy}=1 \wedge r_{xy}=1$, are divided by $\sum_{x=1}^{W}\sum_{y=1}^{H} f_{xy}$, which will be an index to show the amount of symmetry. However, the image that has a high "Figure and ground ratio" tends to have a high value of point symmetry. And the image that has a low "Figure and ground ratio" tends to have a low value of point symmetry. To solve this problem, we introduce the standardized data in nine angles, that have averaged value = 0, and standard deviation = 1.

・1-dimensional spectrum

First, we transform a 2-dimensions data into two 1-dimensions data (see Fig.2) by use of a projection to x and y axes: data d_x is based on horizontal axis that is expressed as $d_x = \sum_{y=1}^{H} f_{xy}$, and data d_y is based on vertical axis that is expressed as $d_y = \sum_{x=1}^{W} f_{xy}$.

Next, we get each power spectrum $D_x(k)$ and $D_y(k)$ out of d_x and d_y by the Fourier transform, respectively. The power spectrum with spatial frequency: k =1~10 [1/pixels] is added in this evaluation index, because there is only little power-differences between each frequency when k becomes higher. When a periodicity is strong, the power spectrum at k or ks tends to incline; meanwhile, when a periodicity is weak, power spectrum is the highest at k = 1, and it decreases gradually as k increase. Therefore, the following expressions: (1) and (2) are added to the evaluation index, which will be evaluation criteria of periodicity.

$$P_{max} \Big/ \frac{2}{N} \sum_{k=1}^{\frac{N}{2}} P_k \quad (1)$$

$$P_1 / P_2 \quad (2)$$

Where, P_k is power spectrum components of k, P_{max} is the maximum component of power spectrum and N represents the height of image: H or the width of image: W. A denominator of expression (1) is equivalent to the average of power spectrum that excludes a direct-current component; and we divide this into the maximum of power spectrum. .

2-3. Statistical analysis (Principal component analysis)

The followings, En(n=1,2,3, ··· ,39), are evaluation indexes used on a principal component analysis, which are defined in 2.2.

- E_1 : Height and width ratio
- E_2 : Figures and ground ratio
- E_3,E_4 : Center of gravity (vertical, horizontal)
- E_5,E_6 : Symmetry to line (left-right, top-down)
- E_7 —E_{15} : Symmetry to point (nine angles)
- E_{16} —E_{35} : 1-dimensional spectrum components (vertical, horizontal) (power spectrum frequency: k =1~10)
- E_{36},E_{37} : Ratio of the maximum to the average of power spectrum
- E_{38},E_{39} : Ratio of frequency: k = 1 to frequency: k = 2 of power spectrum

We use above 39 variables as evaluation indexes for this analysis, and a method to get obtain the eigenvector from correlation matrix is used.

3. Results and discussion

As a result of the principal component analysis, the contribution ratio of the first principal component (PC1) was 10.2% and a contribution of the second one (PC2) was 10.0%.

Figure 3 shows a scatter diagram of weight coefficients in the PC1 and PC2. In the eigenvector of PC1, the weight coefficient of "the point symmetry of π/5, π/6, and π/8" are large and that of "the ratio of the maximum to the average of power spectrum" is small.

Figure 4 shows a scatter diagram of the principal component scores. It seems that point symmetry of π/5, π/6, and π/8 don't appear, though they have large weight coefficients of PC1. The result of "the ratio of the maximum to the average of power spectrum" appears well in the scatter diagram. In Fig.4, it is divided into *Kamon* with periodicity of horizontal & vertical directions, and *Kamon* with diagonal directions. Decorative *Kamon* without any periodicity and radial *Kamon* which is point

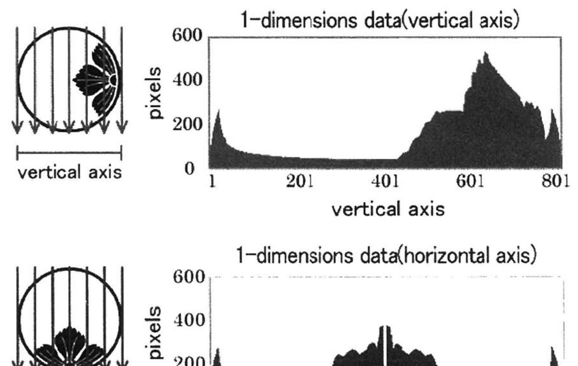

Fig.2 Conversion from one 2-dimension data to two 1-dimension data by use of a projection to x and y axes.

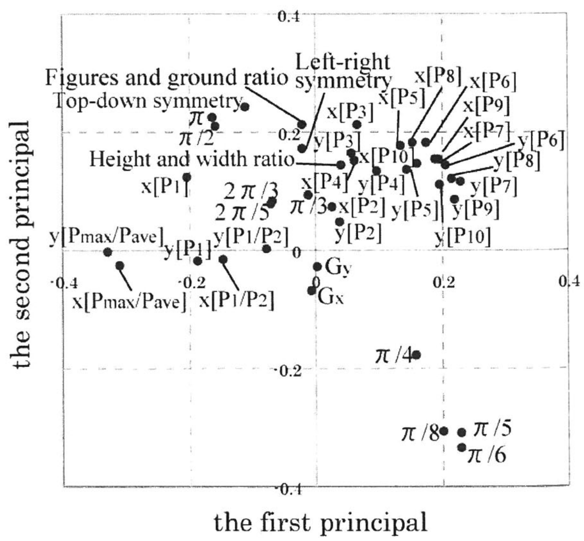

Fig.3 A Scatter diagram of characteristic vectors on the first and second principal axes.

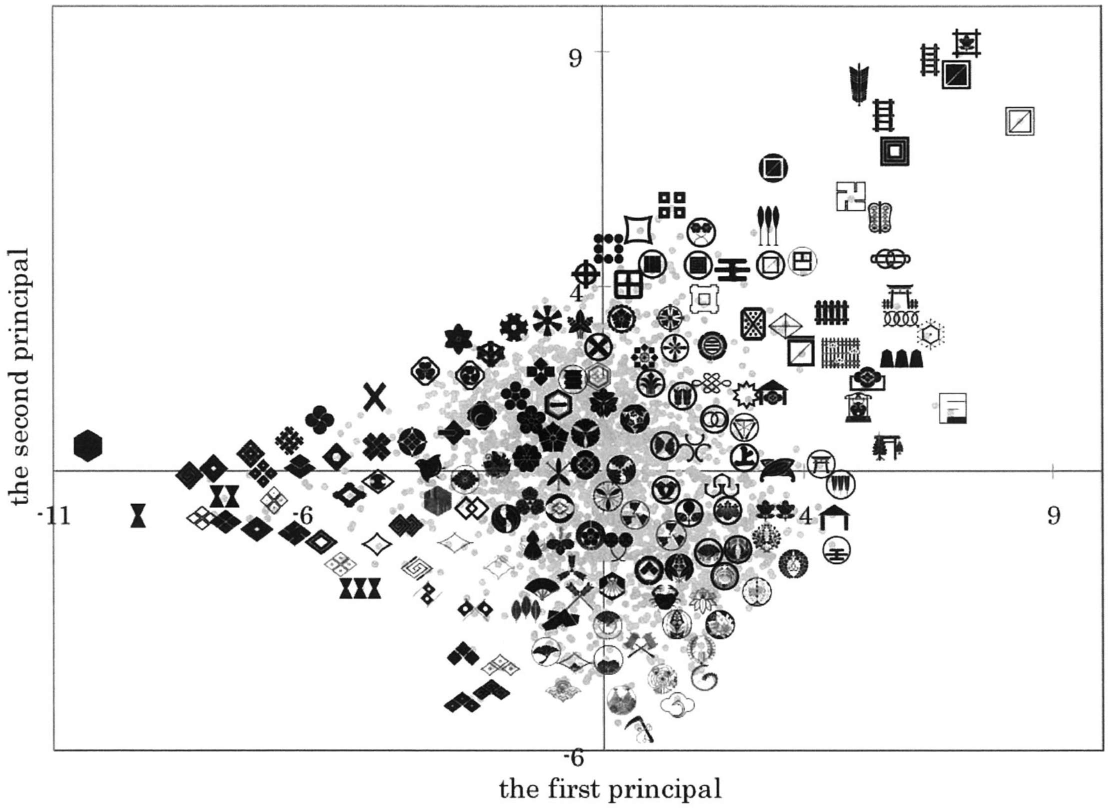

Fig.4 The result of statistical analysis using 39 evaluation indexes. Typical *Kamon* patterns are pictured on the scatter diagram of the principal component scores.

symmetry concentrate in the center.

In the eigenvector of PC2, weight coefficients of "figures and ground ratio" and "line symmetry of top-bottom" and "the point symmetry of π and $\pi/2$" are large. Additionally, "point symmetry of $\pi/5$, $\pi/6$, and $\pi/8$" are small. Therefore, we think that the positive direction of this axis shows *Kamon* with a uneven outline. The negative direction of this axis gathers decorative and a dim impression *Kamon*.

Though we expected that the images of *Kamon* were classified into some groups by the analysis, in this result, many *Kamon* concentrate on around the center of coordinates. *Kamon* locatied far from the center are not so much. It is possible to classify *Kamon* into typical *Kamon* and the others.

From these results, we think that the image processing was useful for extracting features of *Kamon*. Moreover, it was found that our new method for classification revealed the features of shapes and forms in *Kamon*.

4. Summary

In this study, we proposed a new classification method for *Kamon*. The new method includes an image processing and the principal component analysis. We defined evaluation indexes of *Kamon*, which were extracted from *Kamon* images by the image processing. As the result of analysis, we found that our method could classify features of *Kamon* designs. In the scattering diagram of the first and second principal component scores, it was possible to classify *Kamon* into typical *Kamon* and the others. We would now like to go on to investigate similarities between *Kamon* and company symbols mathematically.

5. References

Dower, J. W. (1971) The Elements of Japanese Design. John Weatherhill Inc.

Mitsui, H. (1996). Bi-no Kousei-gaku. *Chuko shinsho*, pp. 107-110 (in Japanese).

Mitsui, H. (2000). What is the beauty of shape. NHK books, pp. 57-60 (in Japanese).

Nousaka, T. (2009). A book for understanding all of "Kamon". Shin-jinbutsu Ourai-sya, pp. 18-29 (in Japanese).