RESEARCH REPORT

REVERSE INFEERENCE OF IMPRESSIONS FOR TRIANGLES
Estimation of Impression in Designing (3)

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Abstract: In order to study the impression regarding to the gestalt of designed commercial goods, the sensory evaluation experiments were carried out using triangles drawn and smeared with black ink on white paper, and reverse inference by which the optimal design solution could be determined was performed. After the three morphological elements, “sharpness”, “flatness” and “balance”, were extracted by the principal component analysis from the experimental data of sensory evaluation of the triangles, two kinds of equations indicating relationships between higher level impression and morphological elements, and those between morphological elements and basal angle were derived using the regression analysis. By combining them, the equations indicating relation between the higher level impression and the basal angle were obtained. By differentiating the formulas, the angle value which made the higher level impression maximum was obtained and inferred the optimum triangle. It was found that the most polished shape in the triangle was a figure with basal angle 66.8° and the most amiable was with angle 66.6°. Approximated optimal design solutions for the most amiable or polished triangles were also inferred.

Keywords: Reverse inference, Triangle, Morphological element, Impression for commercial goods, Sensory evaluation

1. INTRODUCTION

In the previous paper [1], we investigated the higher level impressions of triangles painted with black ink on white paper, and found that the impressions in the higher image levels such as ‘polished’ and ‘conspicuous’ not as ‘big’ and ‘sharp’ in the lower levels were commonly recognized even for simple triangles among many people. In this paper, we intend to apply the reverse inference method [2,3] to the triangles as model commercial goods and to determine the optimal design solution from the physical elements.

Mori and his coworkers [3-6] have tried the reverse inference for commercial goods such as automobiles, telephones and watches. However, it seems to be difficult to determine a design solution for the practical commercial goods because of their complexity of physical elements.

In our reverse inference experiments for triangles, the morphological elements of the triangle were extracted from the evaluation values so-called “image score” of impression in lower level, using the statistical method. Then the experimental equations as functions of image score, morphological element and basal angle were derived. Finally the optimal triangle as a design solution was successfully determined.

2. EXPERIMENTAL

2.1. Procedure

The procedure of the reverse inference in this study was as follows;
1) The image scores of various triangles were obtained using higher and lower level impression items as described in the previous paper [1].
2) The morphological elements of the triangles composing the psychological semantic space were extracted from the experimental data for the lower level evaluation items by the principal component analysis.
3) The experimental formulas expressing the relationships between the higher level impression values for evaluation items and the evaluated values for the morphological elements of the triangles were derived by the multiple regression analysis.
4) The another kind of formulas expressing the relationships between the evaluated value for each morphological element and the basal angle were derived by the regression analysis.
5) By combining above formulas, equations expressing relationships between the higher level impression and the basal angles were derived for each evaluation items.
6) The basal angle that maximized the higher level impression was calculated and determined the optimal
triangle as a design solution.

2.2. Preparation of visual samples

Five scalene triangles with same area and various basal angles were drawn and smeared with black ink one by one in the each center of white paper sheets as described in the previous paper [1]. The triangles used as visual samples are shown in Figure 1.

2.3. Selection of evaluation items;

(a) Lower level impression  To select the evaluation items for extraction of morphological elements, the lower level adjectives such as ‘sharp’ and ‘flat’ were collected and sorted as described in the previous paper [7]. Following 11 terms were selected;


Where, Japanese was described in parallel to clarify the nuance of each term. These 11 terms were used as sensory evaluation items at lower level.

(b) Higher level impression  Four adjectives were used as evaluation items for higher level impressions. Their image scores were strongly dependent on the basal angles in sensory evaluation in the previous paper [1] and their meanings were independent with one another. They were as follows;

1. conspicuous (目立つ), 2. amiable (親しみやすい), 3. polished (上品な), 4. attractive (魅力的な)

2.4. Sensory evaluation

Sensory evaluation were performed by the 7-point rating method using the evaluation items given in 2.3 (a) and (b). Evaluation experiments were carried out by 40 students of 20 - 22 years old on July, 1998.

2.5. Analysis of experimental data

The principal component analysis and the multiple regression analysis were carried out using the SPSS statistical software. In extraction of the principal components, the standard of the Eigen values was 1.0 or more.

3. RESULTS AND DISCUSSION

3.1. Morphological elements

Table 1 shows the result of principal component analysis. Three principal components were extracted from the data of 5 scalene triangles. The first principal component was named “sharpness”, the second was “flatness” and the third was “balance”. These principal components agreed with the morphological elements composing a triangle. In other words, the psychological estimation of triangle also agreed with three recognized morphological elements in the lower level during sensory evaluation.

Table 1: The extracted principal components

<table>
<thead>
<tr>
<th>Terms for expressing</th>
<th>Principal component 1</th>
<th>Principal component 2</th>
<th>Principal component 3</th>
</tr>
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<tbody>
<tr>
<td>shape</td>
<td>&quot;sharpness&quot;</td>
<td>&quot;flatness&quot;</td>
<td>&quot;balance&quot;</td>
</tr>
<tr>
<td>sharp</td>
<td>0.877</td>
<td>0.064</td>
<td>-0.176</td>
</tr>
<tr>
<td>protruded</td>
<td>0.839</td>
<td>0.029</td>
<td>-0.084</td>
</tr>
<tr>
<td>elongated</td>
<td>0.832</td>
<td>-0.061</td>
<td>0.098</td>
</tr>
<tr>
<td>slender</td>
<td>0.824</td>
<td>-0.139</td>
<td>0.080</td>
</tr>
<tr>
<td>narrow</td>
<td>0.728</td>
<td>0.065</td>
<td>-0.080</td>
</tr>
<tr>
<td>diverse</td>
<td>0.701</td>
<td>-0.038</td>
<td>0.031</td>
</tr>
<tr>
<td>flat</td>
<td>-0.056</td>
<td>0.805</td>
<td>-0.039</td>
</tr>
<tr>
<td>wide-based</td>
<td>-0.346</td>
<td>0.747</td>
<td>0.098</td>
</tr>
<tr>
<td>angular</td>
<td>0.441</td>
<td>0.614</td>
<td>-0.035</td>
</tr>
<tr>
<td>smooth</td>
<td>-0.053</td>
<td>0.010</td>
<td>0.985</td>
</tr>
<tr>
<td>balanced</td>
<td>-0.569</td>
<td>0.200</td>
<td>0.345</td>
</tr>
</tbody>
</table>

Contribution ratio(%) = 43.4 15.0 9.7
Total contribution ratio(%) = 43.4 58.5 68.2

3.2. Relationship between Yi and Pi

The experimental formulas (1) - (4) were obtained by the multiple regression analysis, where Yi shows evaluation value of higher level impressions and P1, P2, P3 are “sharpness”, “flatness” and “balance” respectively. R^2 is the coefficient of determination.

Y1 (conspicuous) = 0.834 P1 + 0.285 P2 + 0.291 P3  \( R^2 = 0.865 \)  (1)
Y2 (amiable) = -0.904 P1 - 0.141 P2 + 0.254 P3  \( R^2 = 0.904 \)  (2)
$Y_3$ (polished) = -0.512 P_1 - 0.482 P_2 + 0.863 P_3 \quad (3) \\
R^2 = 0.918

$Y_4$ (attractive) = 0.675 P_1 + 0.028 P_2 + 0.659 P_3 \quad (4) \\
R^2 = 0.885

The obtained formulas give the relationships between the each image score value for the higher level impression and the evaluation values of the three morphological elements at the lower sensory evaluation levels. The coefficient of $P_j$ shows the degree of contribution of each morphological element in these formulas. It becomes clear from Formula (1) that “sharpness” contributes strongly to ‘conspicuous’. On the other hand, negative coefficients of $P_1$ and $P_2$ and positive coefficient of $P_3$ in the equations (2) and (3) indicate that “balance” is important for ‘amiable’ and ‘polished’. For Equation (4), all coefficients are positive and those of $P_1$ and $P_3$ are relatively large, indicating that “sharpness” and “balance” contribute to “attractive”.

3.3. Relationships between $P_j$ and x

The principal component scores for the extracted three morphological elements were calculated and the mean value of the scores was calculated for the each basal angle $x$. The relationships between the above principal component scores and the basal angles $x$ were plotted as in Figure 2. On the basis of these plots, the formulas of the approximation curve that made the coefficient of determination $R^2$ maximum were derived using the linear or the quadratic function. The regression formulas obtained are shown in Equation (5) - (7) as follows;

$P_1$ (sharpness) = 0.0011$x^2$ - 0.1454$x$ + 3.6806 \\
$R^2 = 0.839$ \\
$P_2$ (flatness) = 0.0084$x$ - 0.3971 \\
$R^2 = 0.863$ \\
$P_3$ (balance) = -0.0002$x^2$ + 0.0327$x$ - 0.8845 \\
$R^2 = 0.865$

where, $x$ is the basal angle and $0 < x \leq 90^\circ$. The regression coefficients were described down to four places of decimals, as the coefficient of $x^2$ in Equation (7) was obtained at the fourth decimal place

3.4. Decision of design solution

The following formulas were derived by substituting three formulas of (5) - (7) to the formulas (1) - (4).

$Y_1$ (conspicuous) = 0.0009 $x^2$ - 0.1094 $x$ + 2.6991 \quad (8) \\
Y_2$ (amiable) = -0.0010 $x^2$ + 0.1385 $x$ - 3.4945 \quad (9) \\
Y_3$ (polished) = -0.0007 $x^2$ + 0.0986 $x$ - 2.4567 \quad (10) \\
Y_4$ (attractive) = 0.0006 $x^2$ - 0.0764 $x$ + 1.8904 \quad (11) \\

Then, the basal angles that give maximum of $Y_i$ for the formulas (8) - (11) were determined by differentiation. Tables 2 shows the basal angles $x$ obtained as described above. The basal angle $x$ for ‘amiable’ was determined to be 66.6° and for ‘polished’ to be 66.8°. Since the formulas (8) and (11) for ‘conspicuous’ and
Table 2: The optimal design solution for the each evaluation item

<table>
<thead>
<tr>
<th>Evaluation items</th>
<th>Basal angles x (degree)</th>
</tr>
</thead>
<tbody>
<tr>
<td>amiable</td>
<td>66.6</td>
</tr>
<tr>
<td>polished</td>
<td>66.8</td>
</tr>
<tr>
<td>conspicuous</td>
<td>$\pm 90^\circ (0 &lt; x \leq 90^\circ)$</td>
</tr>
<tr>
<td>attractive</td>
<td>$\pm 90^\circ (0 &lt; x \leq 90^\circ)$</td>
</tr>
</tbody>
</table>

'attractive' are the concave parabolas, the each solution diverges in the positive or negative direction. However, because of limitation used here, $0 < x \leq 90^\circ$, x for maximum $Y_i$ should be the smallest value in the range in which figures can be drown. Since triangles with $x > 90^\circ$ and those with $0 < x \leq 90^\circ$ are symmetric with respect to the vertical axis, the triangles with $x > 90^\circ$ are not taken into consideration. The figures are unable to draw when the solution diverged. Therefore, the triangle with $x=10^\circ$ is shown as a resolution with minimum basal angle for 'conspicuous' or 'attractive' triangle in Figure 3.

<table>
<thead>
<tr>
<th>'amiable'</th>
<th>'conspicuous'</th>
</tr>
</thead>
<tbody>
<tr>
<td>'polished'</td>
<td>'attractive'</td>
</tr>
</tbody>
</table>

Figure 3: The shape that maximized $Y_i$ of the each evaluation item in triangles

4. CONCLUSION

Experiments regarding to reverse inference for designing were carried out using triangles as model commercial goods. Five scalene triangles reported in the previous paper [1] were used as stimuli. The results obtained in this study are as follows;
1) By the principal component analysis, the three morphological elements, 'sharpness', 'flatness' and 'balance', were extracted by using image scores described in the previous paper.

2) Two kinds of experimental equations indicating the relationship between higher level impression $Y_i$ and morphological elements $P_j$, and that between morphological elements $P_j$ and basal angle $x$ were derived. By combining them, equations relating the impression $Y_i$ to the basal angle $x$ were obtained.
3) By differentiating the formulas, the basal angle with which $Y_i$ made maximum was obtained. It was found that the most polished shape in triangle was a figure with basal angle $66.8^\circ$ and the most amiable shape was a figure with basal angle $66.6^\circ$. We also approximated optimal design solutions for 'amiable' and 'polished'.

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