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Quantification of Shape Design and Its Correlation with User's Preference

Nozomu MISHIMA[1]
Akita University

Abstract. Quantitative evaluation of shape is one of the remaining problems in product design. Since product shape is an important feature affects users' intention to purchase, knowing characteristics of preferred designs is helpful in designing attractive products.When a person watches some shape, a potential field named "induction field" is aroused in the brain, corresponding to the strength of the stimulation of the optic nerve. The induction field has a close relation between the strength of the impression. Value of the induction field in a certain point can be calculated based on the distance of the point from the contour line of the figure and the strength of the pixels expressed by 256 levels gray scale. Overall tendency of the induction field can be expressed by two values that are surface integral of the shape along the plane (PE), and difference of the maximum and minimum values of the strength of the induction field (DI). PE corresponds to the strength of the overall impression and DI shows the sharpness of the shape. The paper used smartphone as a case study and investigated the correlation between users' preference with PE and DI. The result showed negative correlations. The fact suggested that relatively calm and ambiguous shape is preferred in case of smartphone design. Through this study, it was concluded that the induction field is helpful in quantifying shape designs and determining preferred designs among several design plans. This is a significant step in reviewing product design processes by engineering approaches.

Keywords. Shape Design, Induction Field, User's Preference

Introduction

"Induction field [1, 2]" is a phycological concept that assumes a field like an electro-static field around a certain shape, in order to explain pattern recognition mechanism of human vision. Although letter fonts and shapes are different, human eyes can recognize same letter as the same. It is assumed that similar induction fields around the shapes enable that a human can recognize different shapes as the same letter. This assumption can explain the mechanism of human vision well. This paper also assumes that the induction field is the proper explanation of the human vision and applies the concept to people's recognition of product shape. There were many efforts [3, 4] to quantify the shapes of the products as some mathematical methods. However, since the users' preference of product shapes are very product-oriented, quantification of the shape cannot be the direct answer to design product shapes preferred by users.

In order to find a product shape preferred by users and clarify the theory behind the fact, another method is necessary. AHP (analytical hierarchy process) [5] is a well-known method often used in KANSEI engineering [6] to know the users' preference on

[1] Corresponding Author, Email: nmishima@gipc.akita-u.ac.jp.

a product performance, outlook and so on. By applying AHP to product design review, it is possible to know the importance of multi-criterion problem in which designers should determine the proper combination of several product features. The first half of the process is to determine product criterion that affect users' preference on the product and its' weights. The second half is to clarify the user's preference of alternative design plans. Through AHP, it is possible to know which design plan is preferred by users and what are the reasons for the preference.

Then, by calculating the correlations of user's preference and the 2 indicator values calculated from induction field, which product shape is preferred because of what kind of reasons. This information can be a significant step in designing an attractive product. The objective of this study is to propose a method to quantify the shape design of products and determine the shape preferred by the users using a smartphone as the case study example.

1. Background

1.1. Mechanism of human vision

"Induction field [2]" is a phycological concept that assumes a field like an electro-static field around a certain shape, in order to explain pattern recognition mechanism of human vision. Although letter fonts are different, or hand writings of human have different shape one by one, human eyes can recognize same letter as the same. It is assumed that similar induction fields around the shapes enable this. Although the shapes themselves are different, induction fields arouse by the shape are similar. In such cases, even though the letter fonts are different, human can recognize the same letters are the same. That is thought to be the background of human recognition.

1.2 Fundamental equation of induction field

In this study, Eq.(1) proposed in the precious study [7] is used for the mathematical model to express the induction field arouse by watching a certain shape.

$$S(x,y) = \iint_{\Delta s} \left\{ \exp\left(-\frac{(\xi-x)^2+(\eta-y)^2}{2*5^2}\right) - \frac{5^2}{14^2} * \exp\left(-\frac{(\xi-x)^2+(\eta-y)^2}{2*14^2}\right) \right\} L(\xi,\eta)\, d\xi d\eta \quad (1)$$

$S(x,y)$: strength of the indcution field
x,y: coordinate values on the XY plane of a certain point in the shape
ξ,η: coordinate values of a certain retinal photoreceptor cell
$L(\xi,\eta)$: value of the stimulas of the corresponding retinal photoreceptor cell

2. Quantification of product shape

2.1 Induction field of product shape

In calculating the induction field arouse from the product vision, the fundamental equation should be written to descrete expression, since the product shape is numerically processed. The product image is transformed to a 600 by 600 bitmap data expressed by

256 steps gray scale. The bitmap data is substituted to the fundamental equation shown in Eq. (1) and numerical integration was carried out. The calculation program was coded by C language. Figure 1. A to D are the 4 smartphone shapes analyzed in this sutdy and corresponding value distribution of S values.

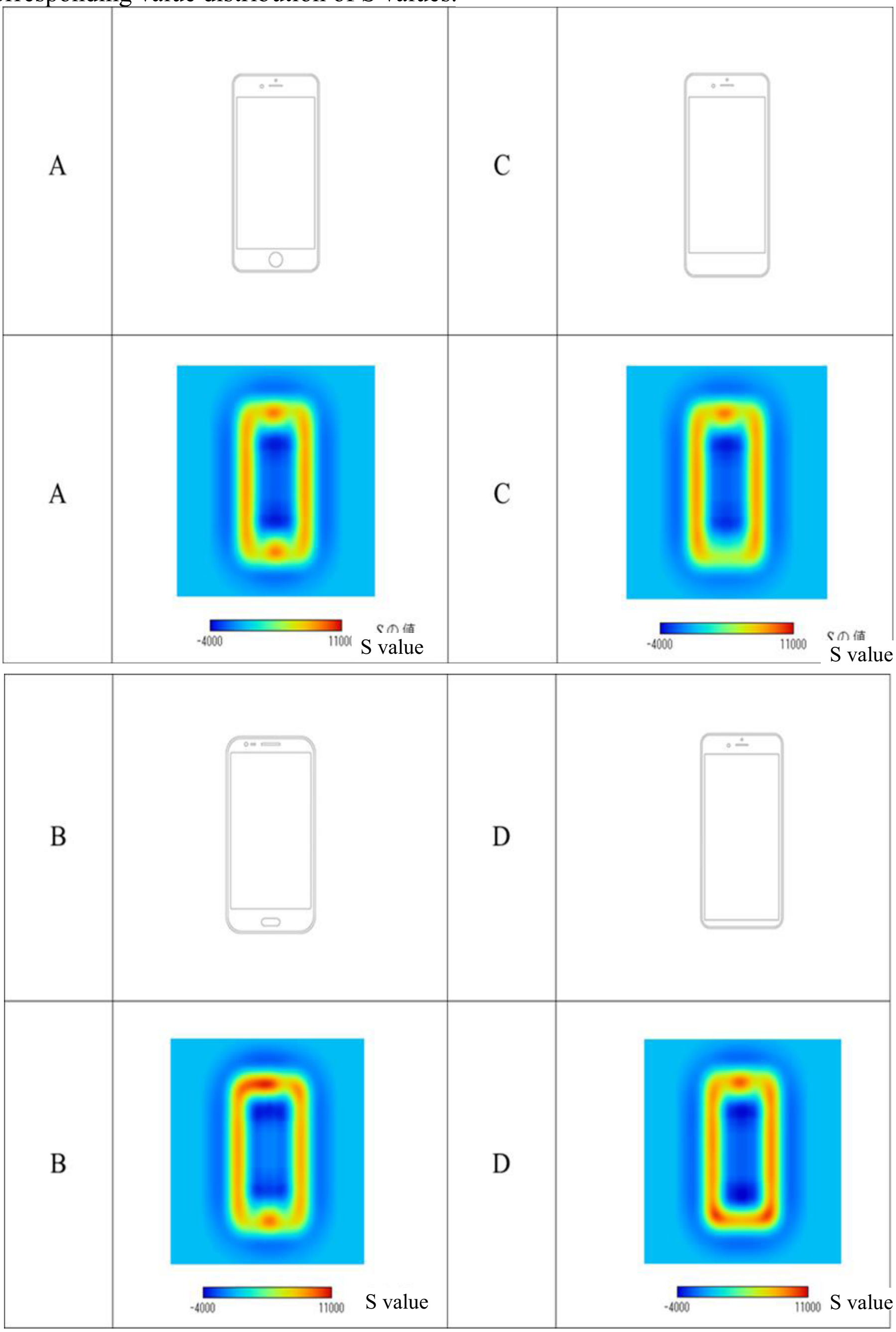

Figure. 1 Smartphone shapes analyzed in this study.

2.2 Potential value and DI value

In evaluating the induction field of the product, 2 new indices were introduced. Eq.(2) is expressing a value named "Potential Energy [8]" of the shape. As shown in the euation, this value can b calculated through surface integral of the function *S* which indicates the strength of the induction field. It is tought that this value is strogly related to "strength of impression." Figure 2 shows the *PE* values of the 4 smartphone shapes.

$$PE = \iint_0^{+\infty} |S| \cdot A(|S|) d(|S|) \quad (2)$$

PE: potential energy of the shape

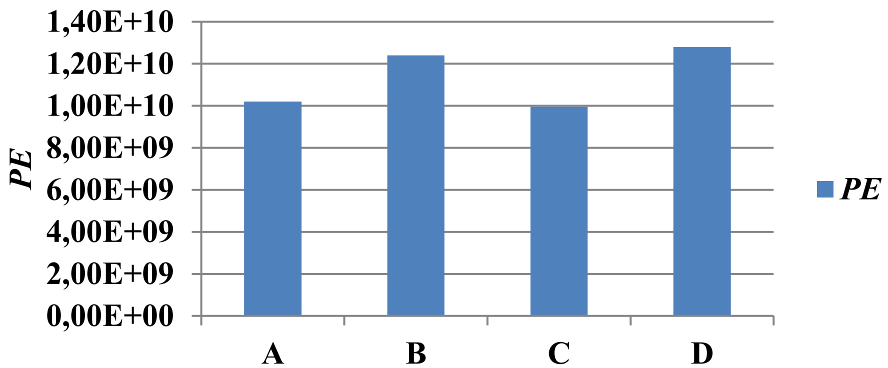

Figure 2. PE values of the 4 smartphone shapes.

In addition to *PE*, another index *DI* is defined as Eq. (3). This *DI* value is basicallt expressing the "sharpness" of the shape. Figure 3 is the DI values for the same smartphone shapes.

$$DI = S(x,y)_{\max} - S(x,y)_{\min} \quad (3)$$

DI: shape diffenciantion index

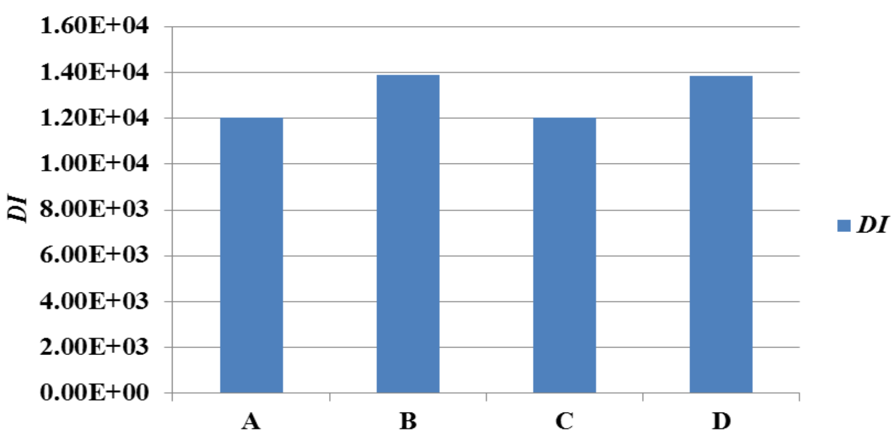

Figure 3. *DI* values of the 4 smartphone shapes.

3. User's preference of product shape

The next step of the study is to know the user's preference on product shape. AHP (analitical hierachy process) is a well-knowm method for muti-variance analysis, and often applied to quantify user's preference on a product which has multu-function, multi-criterion, and so on. By carrying out the steps of AHP, it is possible to know what kind of criteria can be listed in evaluating the product, how much weight does a user has on those criterion, and finally which design plan is preferred by the user for which reason. In applying AHP to this smartphone design, 3 criterion for shape design evaluation has been determined through brain storming, Those 3 were "familiarity," "ease of use" and "sophistication." In the first step of AHP, pair comparison of all the possible combinations of criterion are carried out. For example as Figure 4, if a respondent thinks Criteria A is much more important than Criteria B, corresponding place of the scale is marked. Then, relative score "5" is assigned to criteria A compared to criteria B.

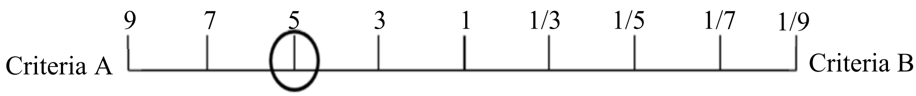

Figure 4. Pair comparison of criterion in AHP.

Throughout the pair comparison of all the possible combination of the criterion, a relational matrix of the criterion can be obtained. Eq. (4) shows an example of relational matrix. By multiplying the element of the matrix to horizontal direction, it is possible to calculate the value of $x_1^3/x_1x_2x_3$, $x_2^3/x_1x_2x_3$, and $x_3^3/x_1x_2x_3$, correspondingly. Then, it is possible to calculate the weight of the criterion, which is equivalent to the relative importance of the criterion under the respondent's decision.

$$A' = \begin{pmatrix} 1 & x_1/x_2 & x_1/x_3 \\ x_2/x_1 & 1 & x_2/x_3 \\ x_3/x_1 & x_3/x_2 & 1 \end{pmatrix} \tag{4}$$

Table 1 is showing the weight of the above-mentioned 3 criterion, by asking about 50 smartphone users. As shown in the table, the smartphone users think "ease of use" impression is important for smartphones.

Table 1. Relational matrix for the criterion.

Criteria	Weight
Familiarity	0.25634
Ease of use	0.54234
Sophistication	0.20132

The next step of AHP is to clarify the user's preference of alternative design plans by using the same procedure. The alternative plans are afore-mentioned 4 design plans shown in Figure 1. Table 2 shown next is indicating the weights of 4 smartphone design plans and the constitution of evaluation criterion.

Table 2. Weight of design plans and its' constitution of criterion.

Design plan	Failiarity	Ease of use	Sophistication	Overall weight
A	0.12411	0.24242	0.065962	0.43249
B	0.05382	0.13058	0.041518	0.22592
C	0.04403	0.09037	0.040858	0.17525
D	0.03437	0.07897	0.052985	0.16633

4. Correlations of induction field and user's preferrence

In the afore-mentioned sections, quantification of product shape has been carried out and user's preference of 4 design plans were determined. Then, the research question is whether there is a correlation between those two factors. The next two Figures 5 and 6 are the correlations of *PE* and *DI* with the weight evaluated by users. Correlation index was also calculated for both *PE* and *DI*. The values are shown in Table 3 and 4, correspondingly.

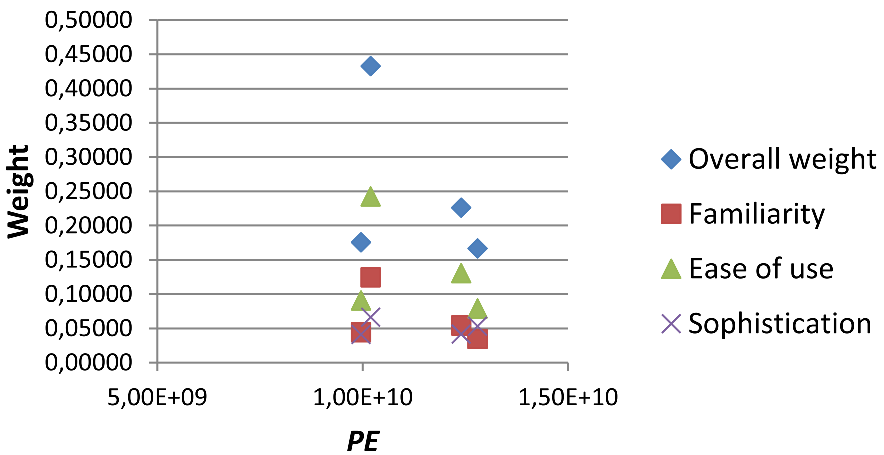

Figure 5. Correlation between *PE* values with users' weight.

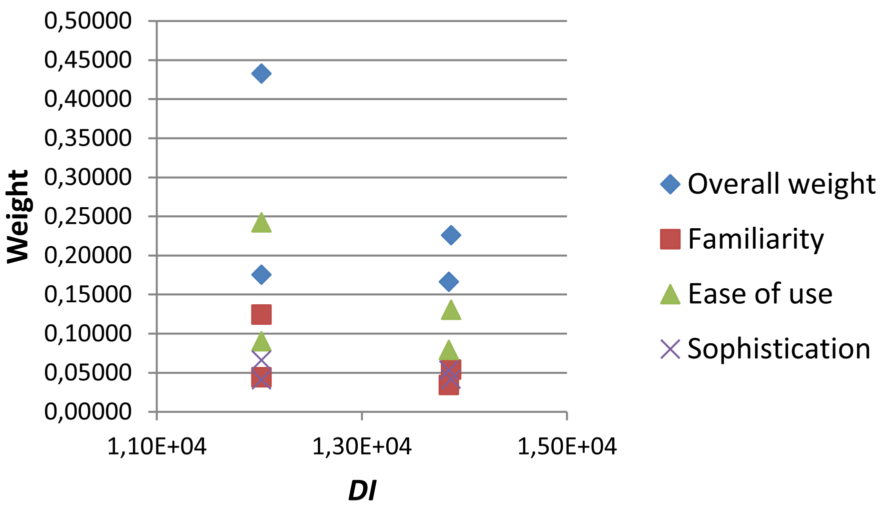

Figure 6. Correlation between DI and users' weight.

Table 3. Correlations of each weight and *PE*.

Correlation target	Overall weight	Familiarity	Ease of use	Sophistica-tion
Index value	-0.461	-0.529	-0.449	-0.196

Table 4. Correlations of each weight and *DI*.

Correlation target	Overall weight	Familiarity	Ease of use	Sophistica-tion
Index value	-0.498	-0.564	-0.475	-0.304

5. Discussions

As it is shown in Table 3 and 4, both for *PE* and *DI*, there are intermediate negative correlations with "overall weight," "familiarity" and "ease of use." This fact can be explained as following.

- For smartphone users "looks familiar" is the most important criteria.
- "Easy to use" is secondly important criteria.
- Design plan A is most preferred by users and B is the next.
- Overall weight, familiarity and ease of use have negative correlations with *PE*
- Overall weight, familiarity and ease of use have negative correlations with *DI*
- Plan A is the most preferred design plan, because the product shape looks familiar and easy to use

These facts suggested that as for smartphones, the keys to design attractive products are to design the shape looks familiar and easy to use. And the preferred product shapes have relatively weak impressions and low sharpness. It means that smartphone users prefer products with ambiguous and weak impression outlook.

Of course, there are still many problems to be solved. Below are the critical questions to these results.

- There can be some sort of "bias [9]" to the user's preference data. (Maybe the evaluation of design plans is affected by the practical products.)
- There were only almost two fundamentally different designs. (Plan A and C, B and D were very similar.)
- Number of respondents is not enough, and the result may not express the general users' preference.

6. Conclusions

The paper proposed a first step idea to design a product with a shape preferred by users. By quantifying the impressions of the product shapes using the concept called "induction field." By calculating the induction field of the product shape using a bitmap expression, it is possible to extract two additional indices from the product shape. The index *PE* expresses the "strength of the impression" and *DI* indicates the "sharpness" of the shape.

On the other hand, by applying AHP analysis to smartphone design plans, it was suggested that "looks familiar" is the most important product feature. Among the 4 design plans analyzed in the paper, design plan A was evidently preferred by the users, since it looked familiar and easy-to-use.

The paper also calculated the correlations between PE values and users' weight, and DI with it, as well. "Overall weight," "familiarity" and "ease to use" showed negative correlations with both *PE* and *DI*. This fact suggested that users tend to prefer product designs with low *PE* and *DI*. It can be interpreted that product shapes with "weak impression" and "low sharpness" are more attractive to users because it looks familiar and easy to use. The fact can be a significant step to a systematic approach in designing products with attractive outlook.

Since the study is the very primitive step in this kind of efforts, there are many problems to be solved. It is necessary to check whether there are some sorts of bias caused by user's knowledge, experience, external information, and so on. Plus, the number of different product shapes was too small. It is also necessary to provide much more different design plans to analyze effect of product shapes on user's preference more precisely.

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