A Design for Customer Preferences Model by Cluster Analysis of Geometric Features and Customer Preferences

Yuan-Jye Tseng, Ching-Yen Chen

***Abstract*—**In the design cycle, a main design task is to determine the external shape of the product. The external shape of a product is one of the key factors that can affect the customers' preferences linking to the motivation to buy the product, especially in the case of a consumer electronic product such as a mobile phone. The relationship between the external shape and the customer preferences needs to be studied to enhance the customer's purchase desire and action. In this research, a design for customer preferences model is developed for investigating the relationships between the external shape and the customer preferences of a product. In the first stage, the names of the geometric features are collected and evaluated from the data of the specified internet web pages using the developed text miner. The key geometric features can be determined if the number of occurrence on the web pages is relatively high. For each key geometric feature, the numerical values are explored using the text miner to collect the internet data from the web pages. In the second stage, a cluster analysis model is developed to evaluate the numerical values of the key geometric features to divide the external shapes into several groups. Several design suggestion cases can be proposed, for example, large model, mid-size model, and mini model, for designing a mobile phone. A customer preference index is developed by evaluating the numerical data of each of the key geometric features of the design suggestion cases. The design suggestion case with the top ranking of the customer preference index can be selected as the final design of the product. In this paper, an example product of a notebook computer is illustrated. It shows that the external shape of a product can be used to drive customer preferences. The presented design for customer preferences model is useful for determining a suitable external shape of the product to increase customer preferences.

***Keywords*—**Cluster analysis, customer preferences, design evaluation, design for customer preferences, product design.

I. Introduction

IN a product design cycle, with the given design objectives, there can be alternative design suggestions with detailed design specifications to define the product. If the external shape of a product is to be determined, a set of geometric features with the definitions of types and data values of geometric features can be used to represent the external shape. The external shape of a product can affect the customers' preferences resulting from the customers' functional assessment, operational experience, and emotional feeling. The customer's preferences can be connected with the customer's motivation and desire to perform purchase action. For example, the external shape of a mobile phone or a notebook computer can significantly affect the consumers' purchase behavior. To design a product, the external shape is mainly related with the functional objective, operational objective, and aesthetic objective in the main design objectives where each can provide certain portion of contribution to the customer's preferences. Therefore, it is aimed to enhance the customer's preferences by determining a suitable external shape in the product design.

In the previous researches, various product design objectives have been modeled. In [1], a design for supply chain model was presented to determine the shape and material of a product by integrated evaluation of the design cost and product value. From the point of view of closed-loop design, a design model by considering closed-loop design and closed-loop supply chain using a mathematical model was developed in [2]. A closed-loop design model was presented in [3]. The closed-loop design model is constructed by forward design and reverse design models, in which forward design is linked with forward supply chain and reverse is connected with reverse supply chain. A product development model by considering green logistics to evaluate design, manufacturing, and green supply chain has been presented in [4]. A model for designing a product with a goal of optimizing the assembly and disassembly operational sequences was presented in [5]. Based on the observation of previous research, various design models have been developed focusing on achieve different design objectives. In this research, the customer preferences index is evaluated and modeled as a design objective.

In the design tasks of a product design cycle, the external shape of a product can be determined with a set of geometric features; for example, the external case of a mobile phone can be determined with the geometric features of length, width, thickness, radius of corner, radius of edge, and so on. There is a relationship between the external shape and the customer preferences leading to the customer's purchase desire and action. Therefore, in a way to promote the customer's purchase desire and action, it is required to understand how the external shape of a product can affect the customer preferences.

In this research, a design for customer preferences model is developed by investigating the relationships between the geometric features of the external shape and the customer preferences, as shown Fig. 1. In the first stage, a text miner is developed and utilized to collected and evaluate the names of the geometric features of a specific product from the internet

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web pages. The number of times of a geometric feature that are shown and discussed indicates how the customers are focused and concerned about the geometric feature. The number of times also indicates how that customers pay attention to the geometric feature. A larger number of times that the geometric feature shown on the web pages means that it is an important one and can be designated as a key geometric feature. In the presented model, the number of times that the geometric features shown and discussed on the web pages can be used to determine the key geometric features.

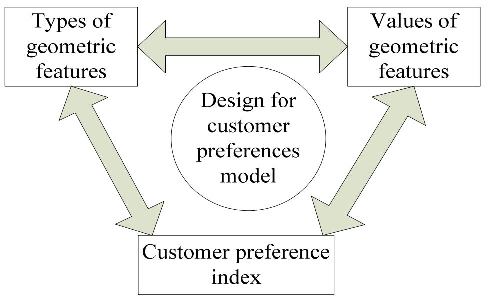

Fig. 1 The interactive relationships of customer preferences index in the design for customer preferences model

In the second stage, for each key geometric feature, the numerical values of each of the geometric features are investigated using the text miner to collect and evaluate the internet data from the web pages. The frequently shown and discussed numerical values of each of the geometric features are collected and analyzed. The numerical values of each of the geometric features can be divided into different levels according to the magnitude of the numerical values. A cluster analysis model is presented to form groups of external shapes according to the levels of the numerical values of the key geometric features. Using the screen of a mobile phone as an example, three levels of screen sizes can be classified as large-size screen, mid-size screen, and small-size screen with the corresponding numerical values of the length of the screen dimension. Using the cluster analysis model, several design alternative cases of a mobile phone can be suggested, for example, large phone model, mid-size phone model, and small phone model.

A mathematical formulation for calculating the customer preference index is developed by evaluating the numerical data of the key geometric features. The proposed design suggestion cases are compared according to the ordered ranking of the customer preference index. Based on the objective of design for preferences, the top priority is to select the design suggestion case with the highest customer preference index. The design suggestion case with the highest customer preferences index can be selected as the final design. The hierarchical relationships between the types of geometric features, values of geometric features, and customer preferences index is illustrated in Fig. 2.

In this paper, an example product of a notebook computer is demonstrated in the presentation. It shows that the design for customer preferences model is useful for integrated evaluating the relationship between the customer preference index and the geometric features of the external shape. In this research, the main contribution lies in the concept of a design for customer preferences model. If the design objective is to achieve a higher customer preference index, the presented model is useful for determining a suitable set of geometric features to represent the design of the product. The test results show that the presented models are useful and effective for providing references and suggestions in product design to attain a higher customer preferences index.

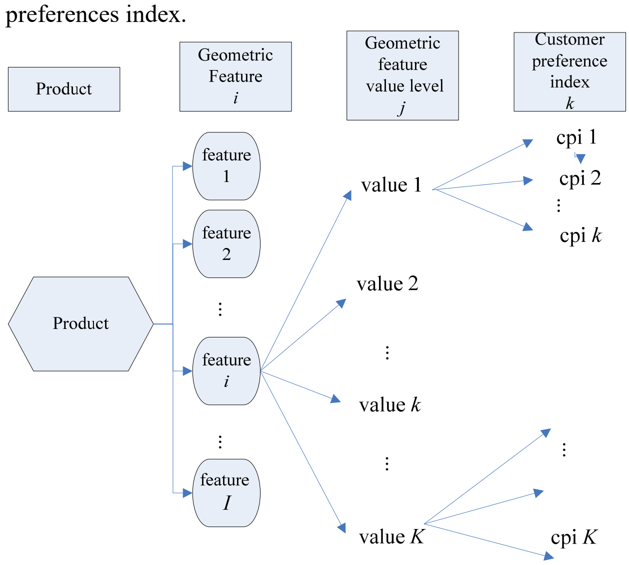

Fig. 2 The hierarchical relationships between the types of geometric features, values of geometric features, and customer preference index

The flowchart of the model is shown in Fig. 3. The paper is organized as follows. Section I presents an introduction and a literature review. In Section II, the design for customer preferences model is presented. In Section III, the implemented and application of the model is demonstrated and discussed. Finally, a conclusion is presented in Section IV.

II. Research Methods and Evaluation Models

In the research method, the types of the geometric features are collected from the internet data using a text miner. A geometric feature model is developed to represent the external shapes of the products. In the geometric feature model, the representation parameters include the geometric features and the connected customer preferences index. Using the developed cluster analysis model, several design suggestion cases can be modeled. The design suggestion cases are evaluated and ranked for decision-making to select the final design.

A. Geometric Feature Model

In the geometric feature model, the parameters are the design case, the type of geometric features, and the customer preferences index. The model is listed as follows.

$$F_i = \left(X_{i11}, X_{i12}, X_{i13}, \ldots, X_{ijk}, \ldots, X_{ijk_j}, \ldots, X_{iJK_J}\right) \quad i = 1, 2, \ldots, I \qquad (1)$$

F_i: design suggestion case, i: design suggestion case, i = 1, 2, …, I, j: geometric feature, j = 1, 2, … , J, k: customer preferences index, k = 1, 2, … , K, X_{ijk}: the decision variable of a design suggestion case, *if* X_{ijk} = 1, the geometric feature is selected, *if* X_{ijk} = 0, the geometric feature is not selected.

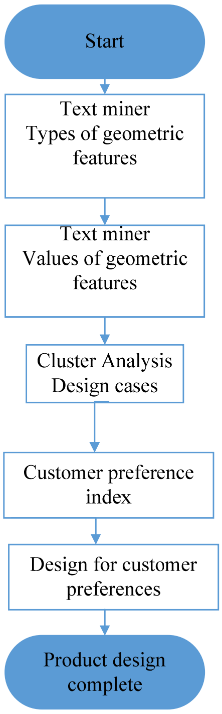

Fig. 3 The flowchart of the design for customer preferences model

B. Cluster Analysis Model

The numerical data of the key geometric features are evaluated using the developed cluster analysis model. The various design suggestion cases of the product can be divided into several groups. In this research, the hierarchical clustering method is applied for performing the cluster analysis. In the Ward's method, the objective is to minimize the sum of squares within the cluster. The distance between two points is used to represent the similarity of the two points. In the model, the Euclidean distance is represented as:

$$d_{ij} = \sum_{r=1}^{P} \left(x_{ir} - x_{jr}\right)^2 \tag{2}$$

d_{ij}: the Euclidean distance between i and j, x_{ir}: the r geometric feature in i product design case, x_{jr}: the r geometric feature in j product design case, n: the number of product design cases, P: the number of geometric features in product design cases.

The within-cluster sum of squares is represented as:

$$SS = \sum_{r=1}^{P} \sum_{t=1}^{M} \left(x_{rt} - \overline{x_r}\right)^2 \tag{3}$$

r: cluster r, t: the geometric feature in t product design case, P: the number of clusters, M: the number of product design cases in each cluster, x_{rt}: the geometric feature in t product design case in r cluster, x_r: the mean of numbers of the geometric features in r cluster.

As an example, the result of the cluster analysis model is illustrated in Fig. 4. In the figure, the hierarchical clustering result is illustrated. The number of clusters can be determined based on the analysis of the property of the product and the decision according to the evaluation judgment.

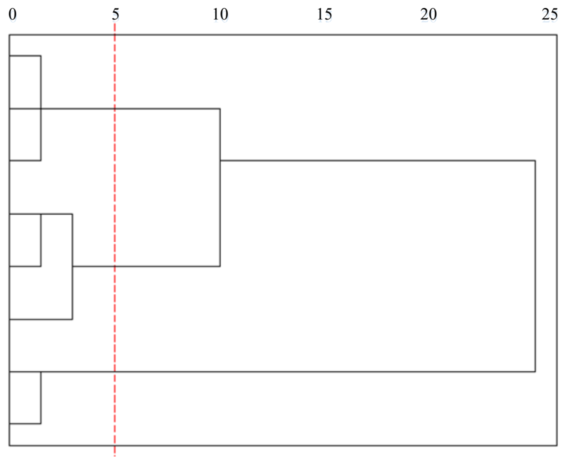

Fig. 4 The result of the cluster analysis model

C. Evaluation and Ranking of the Design Cases

The technique for order preference by similarity to ideal solution (TOPSIS) model is applied to evaluate the design cases. The model is described as follows:

1) Create the matrix of evaluation values of the criteria of the design cases.

$$P = \begin{bmatrix} P_1 \\ P_2 \\ \vdots \\ P_m \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{m1} & p_{m2} & \cdots & p_{mn} \end{bmatrix}$$

$$P = m \times n \tag{4}$$

P_m: design case m, P_{mn}: evaluation value of n criterion of design case m.

2) Calculate normalized evaluation value R. $R = \left(r_{ij}\right)_{m\times n}$: matrix of normalized evaluation values.

$$r_{ij} = p_{ij} \Big/ \sqrt{\textstyle\sum_{i=1}^{m} p_{ij}^2} \quad , \ i=1,2,\cdots,m \ , \ j=1,2,\cdots,n \tag{5}$$

r_{ij} :normalized evaluation value of criterion r in design case i,

3) Calculate weighted normalized evaluation values.

$$V_{ij} = \left(v_{ij}\right)_{m\times n} = \left(w_j r_{ij}\right)_{m\times n}, \tag{6}$$

V_{ij}: weighted normalized evaluation value of criterion *r* in design case *i*.

4) Determine ideal solution and negative ideal solution.

$$P^{+} := \{(max\ V_{ij} \mid j \in J), (min\ V_{ij} \mid j \in J')\},\ i=1, 2, \ldots, m,$$
$$= \{V_1^{+}, V_2^{+}, \ldots, V_n^{+}\}$$
$$P^{-} := \{(min\ V_{ij} \mid j \in J), (max\ V_{ij} \mid j \in J')\},\ i=1, 2, \ldots, m,$$
$$= \{V_1^{-}, V_2^{-}, \ldots, V_n^{-}\} \quad (7)$$

5) Calculate separation of positive and negative solutions.

$$S^{+} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{+}\right)^2} \quad (8)$$

$$S^{-} = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^{-}\right)^2} \quad (9)$$

6) Calculate similarity.

$$C_i^{+} = \frac{S_i^{-}}{S_i^{+} + S_i^{-}},\ 0 \le C_i^{+} \le 1 \quad (10)$$

The values of similarity C_i can be used to evaluate and rank the design suggestion cases. The values of C_i can be ranked in a descending or an ascending order. The design suggestion case with a larger C_i value can be determined as a preferred design case. The rule can be stated that a design suggestion case with the largest C_i value can be determined as the best design and selected as the final design.

III. Application to Evaluation of Design Cases Using the Models

The presented design for customer preferences model has been implemented and tested using example products. In this presentation, the shape of the external case of a notebook computer is used as an example for illustration. The example product is shown Fig. 5. The same example product has also been used as the example in [1]. Given the design suggestion cases, the experimental result shows that a design suggestion case with a desired high customer preferences index can be selected as the final design case.

IV. Conclusions

In this research, a design for customer preferences model for evaluating design cases is presented. The key geometric features for designing a product is analyzed and evaluated using the data from the text miner. The geometric feature model is developed to represent the relationships between the key geometric features and the associated customer preferences. A cluster analysis model is developed to construct the design suggestions cases. The design suggestion cases are evaluated and ranked based on the evaluation criterion of customer preferences. To achieve a higher customer preference index, the presented model can be utilized for determining a proper set of geometric features to design the product. The presented model can be used to select the most suitable design cases according to criteria of customer preferences. In this presentation, an example product is tested and illustrated. The test results show that the design for customer preferences model is effective for determining a design suggestion case to achieve a high customer preferences index. Future research can be directed to investigate more practical criteria related to external shapes and customer preferences.

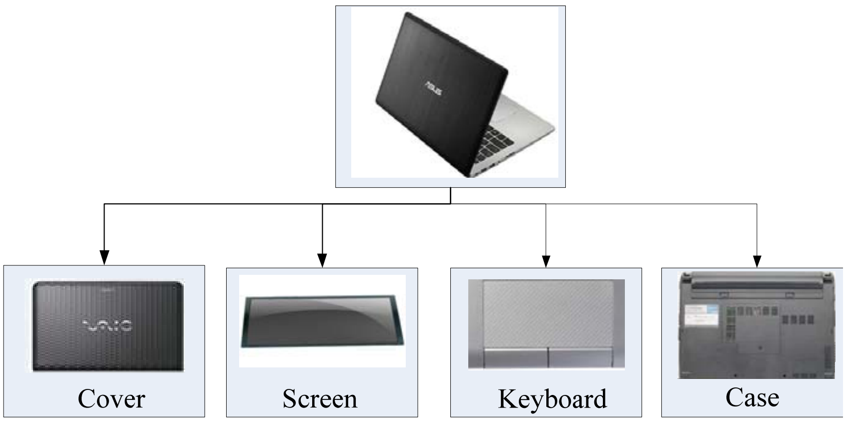

Fig. 5 A notebook computer is used as the example product for testing and illustration

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