Construction of Perfume Bottle Visual Design Model Based on Multiple Affective Responses

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Abstract
Visualization of goods package has become an important factor in communicating goods characteristics to consumers and plays a critical role in influencing consumers’ purchase decision. This phenomenon is particularly apparent in the case of mature consumer goods such as perfume products, chocolate, daily commodity, and so on. To construct a design support model for assisting package designers to create a satisfying product package based on multiple affective responses, the perfume product is chosen for illustration purposes since the consumers’ purchase decision is governed not only by its perfume characteristic for use, but also by the affective response induced by its package. The remainder of this study is organized as follows: Section 2 reviews the background of AHP and fuzzy set theory. Section 3 presents the research implementation. Section 4 illustrates the construction of perfume bottle design model based on FAHP. Section 5 presents a brief conclusion.

Key words: Package design, Perfume bottle, Fuzzy AHP

1. Introduction
A conspicuous or high quality package design is one way a new product can stand out from familiar packages offered by the competition [1]. If the package design of a product communicates high quality, consumers frequently assume that the product is high quality, and vice versa. Furthermore, consumers are likely to generate affective response to a product by means of its package, i.e. a product feels, looks, while viewing product package [2]. The consideration of consumers’ affective response (CAR) to package design becomes an important factor. This phenomenon is particularly apparent in the case of mature consumer goods such as perfume, chocolate, cosmetic, daily commodity, and so on. Therefore, it is essential for package designers or companies to comprehend CAR to package design of a product and to develop a consumer perception-oriented design model for assisting package designers to create a satisfying product package.

Many package design studies have conducted systematic approaches to construct a design model and to obtain a better understanding regarding CAR to package design [3, 4, 6]. In general, the effectiveness of the systematic approach is crucially determined by the choice of analytical techniques. Techniques such as Analytic Hierarchy Process [5], Conjoint Analysis [3] and Quantitative Theory Type I [6] are commonly employed. Analytic Hierarchy Process (AHP) is particularly useful to demonstrate the weight of each design element by the unsophisticated calculation process. However, consumers’ expression is commonly vague and multiple. AHP does not take into account the uncertainty of one’s description to a number. To take the imprecision of human linguistic expressions into consideration, the fuzzy set theory [7] is introduced to strengthen the capability of AHP to construct the design model which satisfies the multiple CARs in this study.

An integrated approach which combines fuzzy set theory with AHP (designated hereafter as a FAHP) is proposed to develop the design support model for perfume bottle. The perfume product is chosen for illustration purposes since the consumers’ purchase decision is governed not only by its perfume characteristic for use, but also by the affective response induced by its package. The remainder of this study is organized as follows: Section 2 reviews the background of AHP and fuzzy set theory. Section 3 presents the research implementation. Section 4 illustrates the construction of perfume bottle design model based on FAHP. Section 5 presents a brief conclusion.

2. Background Review
2.1 Analytic Hierarchy Process (AHP) and Fuzzy set Theory
AHP is a systematic method. It is able to order individual professional comments into a hierarchy and then analyze this hierarchy to increase the efficiency of the evaluation. 9-point scale is frequently used to convert the participants’ verbal responses [5]. Although the 9-point scale has the advantages of simplicity and easiness for use, it does not take into account the uncertainty associated with the mapping of participants’ perception to a number. To take the imprecision of human qualitative evaluations into consideration, fuzzy set theory is introduced to solve the problems. The key idea of fuzzy set theory is that an element has a degree of membership in a fuzzy set. A fuzzy set is defined by a membership function. The most commonly used range for expressing the degree of membership is the unit interval [0, 1] [7]. In this study, the triangular fuzzy number is used to represent subjective pairwise comparisons of selection process in order to capture the vagueness. As shown in Figure 1, the triangular fuzzy number \( A = (l, m, u) \), \( l \) and \( u \) mean the lower and upper bounds of the fuzzy number \( A \), respectively, and \( m \) is the median value for \( A \). The membership function is defined as Eq. (1). The operational rules of addition and multiplication of \( \tilde{A}_1=(l_1, m_1, u_1) \) and \( \tilde{A}_2=(l_2, m_2, u_2) \) are displayed as following Eqs. (2)-(3).

\[
\tilde{A}_1 \oplus \tilde{A}_2 = (l_1, m_1, u_1) \oplus (l_2, m_2, u_2) = (l_1 + l_2, m_1 + m_2, u_1 + u_2)
\]

Addition of the fuzzy number \( \oplus \)

\[
\tilde{A}_1 \otimes \tilde{A}_2 = (l_1, m_1, u_1) \otimes (l_2, m_2, u_2) = (l_1 \times l_2, m_1 \times m_2, u_1 \times u_2)
\]

Multiplication of the fuzzy number \( \otimes \)
2.2 Fuzzy AHP

This study proposes an integrated scheme, combining fuzzy set theory with AHP (FAHP). The triangular fuzzy numbers parameterized by triplet numbers are used to represent the perfume bottle evaluation of multiple affective responses as well as to construct the pairwise comparison matrix. The procedure of FAHP is described as follows.

Step 1: Constructing the fuzzy judgment matrix and determining the weight vector: The fuzzy judgment matrix $A$ is the matrix of the combination of $m$ candidate alternative and $n$ evaluation criteria and the weight vector $W$ based on $n$ evaluation criteria is constructed as following Eqs. (4)–(5).

The elements of the fuzzy judgment matrix $A$ and weight vector $W$ are represented by five triangular fuzzy numbers, i.e. $\tilde{a}_{ij} \in \mathbb{F}$.

$$A = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \tilde{a}_{m2} & \cdots & \tilde{a}_{mn} \end{bmatrix}$$

$$W = \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \vdots \\ \tilde{w}_n \end{bmatrix}$$

Step 2: Constructing the weighted fuzzy judgment matrix and calculating the final fuzzy scores of candidate alternatives: The weighted fuzzy judgment matrix can be obtained by means of Eq. (7). Based on the result of Eq. (7) calculation using the operational rules of Eq. (2) and Eq. (3), the fuzzy sequencing vector $\tilde{S}$, show as $\tilde{S} = (\tilde{s}_1, \tilde{s}_2, \ldots, \tilde{s}_m)$, can be obtained. Then, the $\tilde{s}_j$ of fuzzy sequencing vector is the final fuzzy scores of the candidate alternatives.

$$\tilde{S} = A \otimes W^T = \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \tilde{a}_{21} & \tilde{a}_{22} & \cdots & \tilde{a}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{a}_{m1} & \tilde{a}_{m2} & \cdots & \tilde{a}_{mn} \end{bmatrix} \otimes \begin{bmatrix} \tilde{w}_1 \\ \tilde{w}_2 \\ \vdots \\ \tilde{w}_n \end{bmatrix} = \begin{bmatrix} \tilde{s}_1 \\ \tilde{s}_2 \\ \vdots \\ \tilde{s}_m \end{bmatrix}$$

Step 3: Defuzzifying the fuzzy scores and ranking the candidate alternatives: It is necessary to define a method for building a crisp ordering of $\tilde{S}$ to rank the candidate alternative since the final fuzzy scores of candidate alternatives are the type of fuzzy numbers. In this study, the fuzzy numbers are defuzzified and ranked by the fuzzy mean value. $\tilde{s}_j$ is a triangular fuzzy number $(l, m, u)$. Its mean $\bar{x}(\tilde{s}_j)$ is defined:

$$\bar{x}(\tilde{s}_j) = (l + m + u) / 3$$

Then, the fuzzy numbers $\tilde{s}_1$, $\tilde{s}_2$, ..., $\tilde{s}_m$ can be ranked according to the value of the fuzzy mean $\bar{x}(\tilde{s}_j)$ to determine the optimum candidate alternative.

### TABLE I

<table>
<thead>
<tr>
<th>Fuzzy number</th>
<th>Meaning</th>
<th>Membership function</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equally important (1, 1, 3)</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Moderately important (1, 3, 5)</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Strongly important (3, 5, 7)</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Very strongly important (5, 7, 9)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Extremely important (7, 9, 9)</td>
<td></td>
</tr>
</tbody>
</table>

### TABLE II

<table>
<thead>
<tr>
<th>Shape of bottle cap</th>
<th>Material of bottle cap</th>
<th>Surface of bottle cap</th>
<th>Width-to-height proportion of bottle cap shape</th>
<th>Shape of bottle body</th>
<th>Surface of bottle body</th>
<th>Proportion of cap shape height to body shape height</th>
</tr>
</thead>
<tbody>
<tr>
<td>(X1)</td>
<td>(X2)</td>
<td>(X3)</td>
<td>(X4)</td>
<td>(X5)</td>
<td>(X6)</td>
<td>(X7)</td>
</tr>
<tr>
<td>Square (X11)</td>
<td>Glass (X21)</td>
<td>Transparent effect (X31)</td>
<td>2: 1 (X41)</td>
<td>Square (X51)</td>
<td>Transparent effect (X61) effect (X62)</td>
<td>3: 1 (X81)</td>
</tr>
<tr>
<td>Sphere (X12)</td>
<td>Plastic (X22)</td>
<td>Semiopaque effect (X32)</td>
<td>1: 1 (X42)</td>
<td>Circle (X52)</td>
<td>Semiopaque effect (X63) effect (X64)</td>
<td>1: 2 (X82)</td>
</tr>
<tr>
<td>Trapezoid (X13)</td>
<td></td>
<td>Plating effect (X33)</td>
<td>1: 0.67 (X43)</td>
<td>Trapezoid (X53)</td>
<td>Facet effect (X65) effect (X66)</td>
<td>1: 1 (X83)</td>
</tr>
<tr>
<td>Inverse trapezoid (X14)</td>
<td></td>
<td></td>
<td>1: 0.5 (X44)</td>
<td>Inverse trapezoid (X54) effect (X55)</td>
<td></td>
<td></td>
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<tr>
<td>Hexagon (X55)</td>
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<td></td>
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</tbody>
</table>

### 3. Research Implementation

3.1 Definitions and Evaluation Samples for Perfume Bottle

To explore the CARs to perfume bottle visual design, approximate 130 perfume bottle pictures with similar view-angles are collected in this study. The discussion of focus group involving 5 package/graphic designers is conducted to classify the perfume bottle pictures based on the similarity of their appearance, and 46 perfume bottle pictures are retained in accordance with the similarities. Then, the morphological analysis is used to define the perfume bottle into design elements and features based on the experiences of 5 designers. Table 2 presents the 8 design elements and the corresponding features. Subsequently, the orthogonal design is conducted to array the conditions of evaluation samples in this study. The result of orthogonal design shown in Table 3 is then applied to create the 32 perfume bottle evaluation samples.
3.2 Selection of Representative Consumers’ Affective Response

In this study, 3 package/graphic designers and 3 white-collar individuals are invited to participate in a discussion aimed at identifying suitable image words with which to describe the possible CARs when presented with the perfume bottle samples. The image words are elicited from the participants using the following three-step procedure:

Step 1: The 46 perfume bottle samples are reviewed, and the image words used by the individual participants to describe their CARs projected by each perfume bottle are recorded.

Step 2: 25 suitable image words are selected, and the three CARs, i.e. “Y.&V.”, “F.&G.” and “M.&N.”, are 2.98, 2.25 and 3.52, respectively. According to the definition of first column of Table 4. For sample 1, the average values of the three CARs, i.e. “Y.&V.”, “F.&G.” and “M.&N.”, are 2.98, 2.25 and 3.52, respectively. According to the definition of first column of Table 4 and Eq.(4), the average values of the three CARs can be represented by a fuzzy number 5, 3 and 5, respectively. Accordingly, the fuzzy judgment matrix A can be shown below.

$$
A_{perfume\ bottle} = \begin{bmatrix}
3 & 3 & 3 \\
3 & 3 & 3 \\
5 & 1 & 3 \\
5 & 5 & 7 \\
\vdots & \vdots & \vdots \\
3 & 3 & 7 \\
3 & 3 & 3 \\
1 & 3 & 3
\end{bmatrix}
$$

3.3 Visual Evaluation of Perfume Bottle

84 subjects (age from 19 to 34 years old) are invited to evaluate the CARs induced by the perfume bottle. The three representative CARs are quantified using three 5-point scales. The 32 perfume bottle samples and the three 5-point scales are integrated into an interface constructed by using Visual Basic software, as shown in Figure 3. After each subject has evaluated all of the samples, the evaluative data are recorded for establishing the design model of perfume bottle.
With respect to the weight decision, a set of specific multiple CARs to perfume bottle are hypothetically designated by consumer groups or package designers in this study. For example, if a particular consumer group expects a new perfume bottle with “strongly Y.&V. (4)”, “slightly F.&G. (2)”, and “moderately M.&N. (3)”. According to the definition of second column of Table 4, and Eq.(5), the fuzzy weight vector for perfume bottle can be represented below.

\[ W_{\text{Perfume Bottle}} = \begin{pmatrix} \frac{1}{2} \\ \frac{3}{5} \\ \frac{7}{10} \end{pmatrix} \]

(10)

4.2 Constructing the Weighted Fuzzy Judgment Matrix and Calculating the Fuzzy Scores of Perfume Bottle

Subsequently, \( W \) for perfume bottle can be obtained from the transpose of the weight vector \( W \), and the weighted fuzzy judgment matrix can be constructed based on Eq. (7). Then, we can calculate the fuzzy scores of Perfume Bottle by using the fuzzy sequencing vector \( S_{\text{Perfume Bottle}} \) shown below.

\[ S_{\text{Perfume Bottle}} = \begin{pmatrix} \frac{7}{10} \\ \frac{3}{5} \\ \frac{1}{2} \\ \frac{2}{3} \end{pmatrix} \]

(11)

4.3 Defuzzifying the Fuzzy Scores and Ranking the Perfume Bottle Alternatives

Finally, the defuzzification process is calculated in this step of the current study. Based on Eq.(8): \( \tilde{x}(\tilde{y}) = \frac{l + m + u}{3} \), the mean values of the triangular fuzzy numbers \( l, m, u \) for each perfume bottle sample can be obtained by calculating the fuzzy number of fuzzy sequencing vector \( S_{\text{Perfume Bottle}} \). Consequently, the 32 perfume bottle samples can be ranked the highest to lowest based on their fuzzy mean values. As an illustration, Table 6 shows the top 5 ranking perfume bottle alternatives, and Figure 4 shows the optimum combination of the design elements and their corresponding features for Top 1 alternative with the “strongly Y.&V.”, “slightly F.&G.” and “moderately M.&N.” of multiple CARs. The modeling result can provide designers with the useful information when he/she developing a new perfume bottle design based on the considerations of multiple CARs in the conceptual design stage.

### References


