DEVELOPMENT OF MASK DESIGN KNOWLEDGE BASE BASED ON SENSORY EVALUATION AND FUZZY LOGIC

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Abstract:

This article focuses on the development of the mask design knowledge base, which is expected to be applied in a personalized mask design system. To realize the proposed knowledge base, a perceptual descriptive space of the mask is first developed for the description of both functional and aesthetic perceptions of a mask. The mask ontology is also developed to form the mask element matrix. Mask design knowledge is expressed as the relationship between the perceptual descriptive space and the mask ontology, which is extracted by a group of experienced designers through a sensory evaluation procedure. This relationship is then simulated by fuzzy logic tools. The proposed knowledge base has been validated that it is reliable. The personalized mask design system can be further developed with the propose mask design knowledge base.

Keywords:

Mask, knowledgebase, fuzzy logic

1. Introduction

Recently, masks have attracted more and more public attention due to the functional and aesthetic demands of consumers. From the functional aspect, masks can effectively filter the air to prevent toxic gases and dust from entering the lungs, especially during epidemics and smoggy days. From the aesthetic aspect, young people usually wear different masks to highlight their unique personality and fashion taste [1]. For these reasons, masks are becoming increasingly popular.

Although the demand for masks is increasing, the current mask design cannot meet the functional and aesthetic demands of consumers. There is a huge gap between the increasing demand and the mask products available in the market. This is because the traditional mask design is mainly based on the designers' subjective understanding of fashion as well as their professional design knowledge [2]. Therefore, the personalized design for consumers has not been fully respected in the production of masks.

To solve the problems existing in traditional design methods, many researchers have tried to find solutions to the personalized design by adapting a knowledge-based design process. For example, Yan Hong developed a color recommendation system with the development of color design knowledge base [3]. Junjie Zhang developed an interactive jeans design system which is realized by a jeans design knowledge base [4]. Linzi Pu applied a similar idea to achieve a personalized design process for the development of children's raincoats [5]. In conclusion, a knowledge-based design process can efficiently solve traditional design problems and has been widely used in personalized design.

Based on existing research, the main task in knowledge-based personalized design is the development of the related knowledge base. In this context, we propose to develop a general design knowledge base for masks, which can be further applied to develop a personalized mask design process and related system. The proposed design knowledge base is based on a sensory evaluation and fuzzy logic integrated method [6]. First, sensory evaluation is used to extract the relationship between demands (functional and aesthetic demands) and design elements of the mask. Then, fuzzy logic is used to model this relationship. Finally, the mask knowledge base for masks can be developed.

The rest of the article is structured as follows: Section 2 introduces the methodology of this article; Section 3 explains the overall experiment design and related concepts used in the experiment design; Section 4 discusses the results; Section 5 describes the validation of the proposed knowledge base; finally, a conclusion is provided in Section 6.

2. Methodology

2.1. General research approach

This article focuses on the development of a design knowledge base for the mask types. Based on the literature, design knowledge is tacit and subjective [7], and normally, it can be expressed as the relationship between mask perception words (modern, chic, elegant, etc.) and design elements (stand collar, X shape, O style, etc.). In this context, the research methodology of this work is a sensory evaluation and fuzzy logic integrated method. Sensory evaluation is used to extract the conceptual relationship between mask perception words and design elements. This relationship is subjective and qualitative; thus, fuzzy logic is used to quantify the involved conceptual relationship.

2.2. Related concept

2.2.1. Quantification of human perception using sensory evaluation

The sensory evaluation has been widely used in the food industry and the automobile manufacturing industry [8]. Compared with physical measurement, the sensory evaluation method is more suitable for processing with human non-quantitative sensory perception, and it can be used as a bridge between human sensory perception and specific data; thus, the complex and subtle sensory perception of humans can be quantified [9]. In this research, to develop a mask design knowledge, the relationship between mask perception words and mask design elements should be simulated. Sensory evaluation is suitable to extract this kind of relationship. The designer's professional design knowledge can also be extracted in this process.

2.2.2. Using fuzzy logic to process data

The relationship between mask perception words and mask design elements, which is extracted based on sensory evaluation, is quantified. To process this kind of data, fuzzy logic is employed. Fuzzy logic can quantify qualitative data [10]. Using fuzzy logic, all relevant linguistic data can be quantified for further processing of the data obtained in the sensory evaluation process, so that these mask perception words are quantified as fuzzy numbers [11].

3. Experiment

As shown in Figure 1, there are three experiments in this research. *Experiment I* is designed to develop the perceptual descriptive space of mask design. Through *Experiment II*, an ontology of masks will be obtained. Then, based on *Experiments I and II*, the relationship between the proposed perceptual descriptive space and mask ontology will be extracted through a sensory evaluation procedure in *Experiment III*. In *Experiments I*, *II*, and *III*, 20 professional fashion designers are involved.

3.1. *Experiment I*: Development of the perceptual descriptive space of masks

The proposed perceptual descriptive space is developed to measure the aggregated perceptual data of designers about their perception of mask design elements. The proposed perceptual descriptive space has two subspaces: (1) aesthetic descriptive space and (2) functional descriptive space. The perceptual descriptive space of mask design will be able to describe people's various demands for masks. To realize the proposed system, the following procedure has been carried out: (1) generation of human perception criteria and (2) selection and evaluation of human perception criteria.

First, a training session was performed. The purpose of this experiment about souring mask demands was announced to the evaluation team (20 professional designers). After that, a brainstorming process was performed. During the brainstorming process, each of the panelists was free to access open resources (books, internet, literature, etc.) to get information about demands for mask design. After the brainstorming process, each trained member of the panel generated an extensive list of consumer demands criteria, which are in the form of words/phrases. Then, the generated words/phrases were collected and screened for all the members of the panel. A "round table" discussion among all the participants was carried out to vote for all the words/phrases. There were five main principles in the election: (1) Select positive mask perception words which
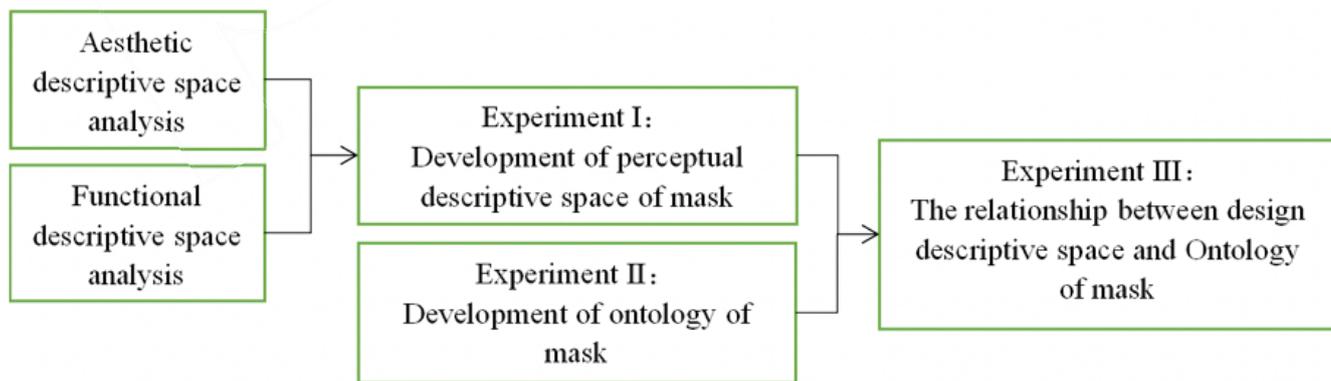

Figure 1. The flow of the experiments and the relationship between the experiments.

meet aesthetic standards (Paired adjectives generally express opposite perceptual evaluation, but it does not mean that one is commendatory and the other is derogatory); (2) The mask perception words are limited to the description of the masks rather than the description of the wearer; (3) Exclude the mask perception words of the overall preference for clothing; (4) Avoid repeating words/phrases; and (5) The selected words should cover all possible design schemes as far as possible. At the end of each step, we announced the results of that step to all the team members. Only the results agreed by all team members could be used in the next step.

3.2. *Experiment II*: Development of ontology of masks

Experiment II was designed to study the mask ontology, namely, the composition of mask-related design elements, which can be applied to establish the mask element matrix. There were three steps in *Experiment II*: (1) generation of mask elements; (2) selection and evaluation of the elements of masks; and (3) analysis of the different states of each element of masks.

We require each member of the evaluation team to consult relevant information and clarify the specific content of the aesthetic and functional categories of masks and their impacting mechanism. Then, combining with their own design experience, the members list the elements of masks and the different states of each element. Subsequently, as in *Experiment I*, we publish the results of each member and ask all participants to have a "round table" discussion and screen all words/phrases.

There are two principles in screening: (1) The essential elements of masks should be selected to be complete and not repeated; and (2) When determining the different states of the elements of masks, attention should be paid to exclude the over-professional and over-functional states. At the end of each step, we announce the results of that step to all the team members. Only the results agreed upon by all team members can be used in the next step.

3.3 *Experiment III*: The relationship between demands and form elements

Experiment III aims to establish the relationship between each of the mask design elements of the mask element matrix and every dimension of the perceptual descriptive space. First,

we ask each member of the evaluation team to evaluate each dimension of mask design perceptual descriptive space subjectively for each element in the mask element matrix. According to their sensory experience of these elements, each member gives the most appropriate score for a certain state of the element in scores 1–7. When scoring aesthetic evaluation criteria, 1 and 7 represent the highest scores of a pair of mask perception words, respectively. For example, for "Simple-complicated," 1 represents extremely simple and 7 represents extremely complicated. When scoring the evaluation criteria of image functions, 1 and 7 indicate that they have the least function and the most function, respectively.

4. Results and Discussion

4.1. The established mask design perceptual descriptive space

As shown in Table 1, there are four dimensions (pair of mask perception words) of the aesthetic descriptive space, which can describe consumer expectations of mask aesthetic demands. They are *Simple-Complicated*, *Daily-Professional*, *Practical-Aesthetic*, and *Mature-Lovely*. Detailed explanation for each pair of mask aesthetic perception words from the dictionary is given in Table 1.

As shown in Table 2, there are seven dimensions of the functional descriptive space, which can describe consumer expectations of mask functional demands. They are *dust prevention*, *anti-haze*, *warmth retention*, *prevent bask*, *breath ability*, *smog prevention*, *prevent lens from fogging*, and *assistance campaign*. Detailed explanation for each pair of mask functional perception words from the dictionary is given in Table 2.

4.2. The established ontology of masks

As shown in Tables 3–5, there are 15 elements of the desired mask ontology. Among them, there are 12 elements about mask body, 3 elements about mask type, and the other 3 about wearing method. Based on this ontology, a mask element matrix can be defined. We named it as a mask element matrix.

Table 1. The aesthetic sensory evaluation criteria and their explanation

Aesthetic evaluation criteria	Explanation
Simple-Complicated	Simple: not ornate or luxurious
	Complicated: consisting of many interconnecting parts or elements
Daily-Professional	Daily: happening, done, or produced every day
	Professional: connected with a job that needs special training or skill
Practical-Aesthetic	Practical: connected with real situations
	Aesthetic: made in an artistic way and beautiful to look at
Mature-Lovely	Mature: complete in natural growth or development
	Lovely: charmingly or exquisitely beautiful

Table 2. The perceptual function evaluation criteria and their explanation

| Perceptual function evaluation criteria	Explanation
Dust prevention	Prevent dust inhalation into the nasal cavity
Smog prevention	Prevent smog inhalation into the nasal cavity
Warmth retention	Keep out the cold and keep warm
Prevent bask	Prevent skin damage from the Sun
Breath ability	The ability of the body to breathe smoothly in some structure
Prevent lens from fogging	The frustration of fogged-up lenses
Assistance campaign	Make breathing and facial sensation more comfortable during exercise
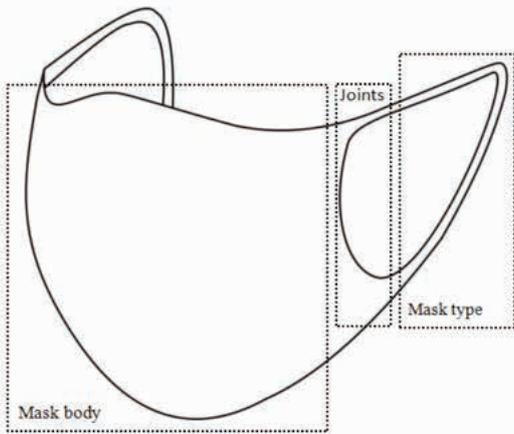
Figure 2. An example of a mask prototype.

Using the mask element matrix, a mask prototype can be defined. Figure 2 presents an example of a mask prototype using the obtained mask element matrix.

4.3. The established knowledge base of masks

The conceptual relationship between aesthetic descriptive space and functional descriptive space, as shown in Figure 3, is based on the result of *Experiments I*, *II*, and *III*.

Because of the involved data is full of uncertainty and imprecision, we used the fuzzy tools to analyze and model the data. In this research, triangular fuzzy numbers (TFNs), as a classic fuzzy tool is employed. The involved evaluation criteria and their corresponding fuzzy numbers are shown in Table 6.
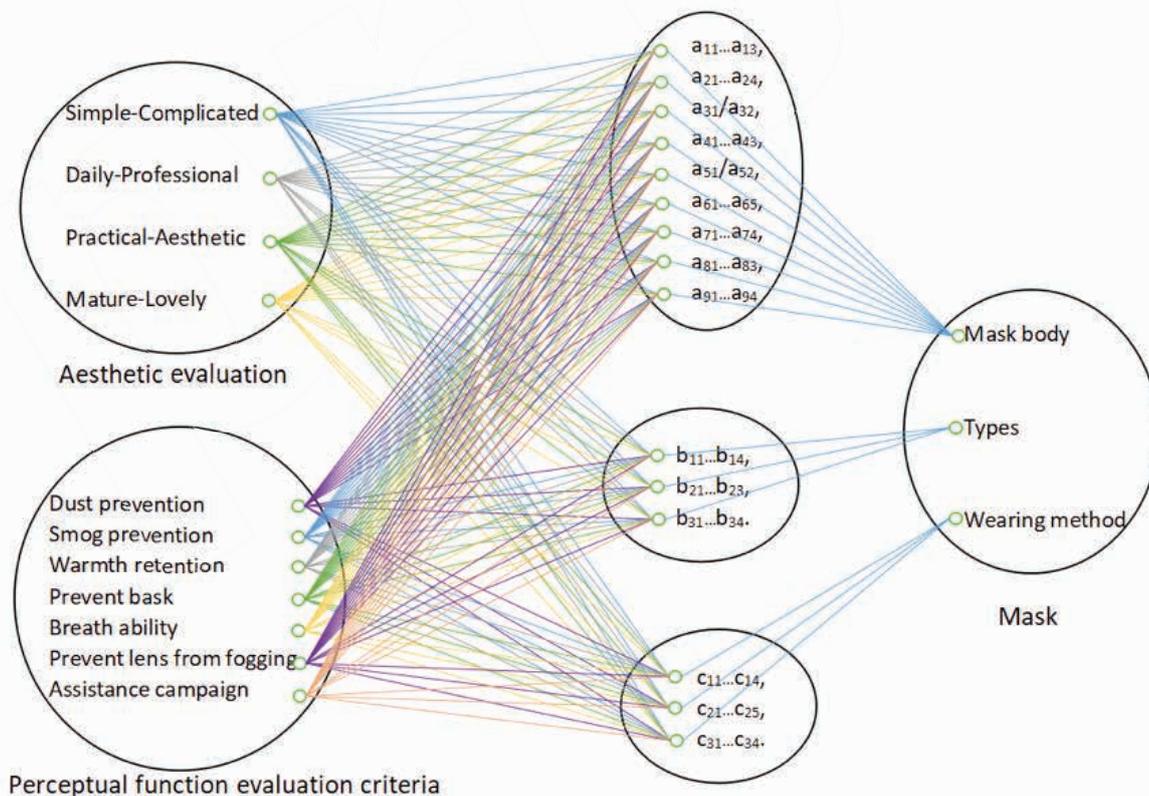

Figure 3. The corresponding relationship between different states of each element and demands' evaluation criteria.

Table 3. Elements of the mask body and the various states of the elements

	1	2	3	4	5
Stitches on the surface of the masks	a_{11} no stitches	a_{12} stitches in the center front	a_{13} stitches in the upper half of the center front		
Binding tape	a_{21} no binding tape	a_{22} surrounded by binding tapes	a_{23} binding tapes around the top and bottom	a_{24} binding tapes around the left and right	
Folds on the left and right	a_{31} no fold	a_{32} has folded on the left and right			
Front opening	a_{41} no front opening	a_{42} overlay front opening	a_{43} front opening that reveals the nose		
Plastic strip on the nose bridge	a_{51} no plastic strip on the nose bridge	a_{52} has a plastic strip on the nose bridge			
Chin cover	a_{61} no chin cover	a_{62} the chin covered by dart	a_{62} the chin covered by elastic drawstring	a_{64} the chin covered by stitching on the bottom edge	a_{65} the chin covered by stitching around the face
Neck cover	a_{71} no neck cover	a_{72} the neck covered for preventing bask by stitching on the bottom edge	a_{72} covers the neck and face together for preventing bask	a_{74} the neck covered for keeping warm by covering the entirety	
Ear cover	a_{81} no ear cover	a_{82} covers the ears and face together	a_{83} covers the ear separately		
Special parts cover	a_{91} no special parts cover	a_{92} nose bridge cover	a_{93} canthi cover	a_{94} covers the nose bridge and canthi together	

Table 4. The characteristics and number of the tape

	1	2	3	4
Form shape	b_{11} narrow and flat	b_{12} slender and round	b_{13} wide and flat	b_{14} thick and round
Length deformable	b_{21} nonadjustable but elastic	b_{22} adjustable and elastic	b_{23} adjustable but inelastic	
The connection method	b_{31} continuous cut	b_{32} suture	b_{33} bonding	b_{34} tie-up

Table 5. Wearing method and number

	1	2	3	4	5
Wearing parts	c_{11} ear hanging	c_{12} head-mounted	c_{13} neck-mounted with ear hanging	c_{14} neck-mounted with head-mounted	
The way of head-mounted	c_{21} not head-mounted	c_{22} tie-up	c_{23} elastic band	c_{24} pothook	c_{25} Velcro
The way of neck-mounted	c_{31} not neck-mounted	c_{32} Velcro	c_{33} zipper	c_{34} button	

The evaluation results are represented by TFN A_{ij}. We assume that $N(F_c)$ (c = 1, 2, 3, ..., 7) is the number of participating experts of each evaluation result $\left(\sum_{i=1}^{7} N(F_c) = m\right)$,

and the final evaluation results can be represented as:

$$A_{ij} = \left(\frac{\sum_{c=1}^{7} \text{TFN}(F_{c1}) \times N(F_c)}{\sum_{c=1}^{7} N(F_c)}, \frac{\sum_{c=1}^{7} \text{TFN}(F_{c2}) \times N(F_c)}{\sum_{c=1}^{7} N(F_c)}, \frac{\sum_{c=1}^{7} \text{TFN}(F_{c3}) \times N(F_c)}{\sum_{c=1}^{7} N(F_c)}\right) \quad (1)$$

where i denotes the form element, i = 1, 2, ..., b; j denotes the corresponding perceptual image, j = 1, 2, ..., l. For example, the states of "No front opening" which is one of the elements of masks suppose that 20 experts are invited. Among them, 15 of them think that the feeling is "Extremely Simple," 4 of them think that it is "Very simple," 1 of them thinks that it is "Extremely complicated," and the perceptual image of "No front opening" in the dimension of "Simple-Complicated" can be expressed by TFN:

$$((14 \times 0 + 2 \times 0 + 3 \times + 1 \times 2)/20, (14 \times 0 + 2 \times 1 + 3 \times + 1 \times 3)/20, (14 \times 1 + 2 \times 2 + 3 \times 3 + 1 \times 4)/20) = (0.25, 0.55, 1.55)$$

Its perceptual image is between "extremely simple" and "very simple." Using this method, the different states of each element of the masks were scored under different criteria.

5. Validation

We also experimented the validation of the proposed knowledge base. Another group of 20 designers is invited and involved in the validation experiment. The purpose of the validation experiment is to verify the rationality of the knowledge base by comparing the similarity of the results of two different times. The three experiments are carried out again. Fuzzy similarity measurement tools are employed in the calculation of the results between two times.

If there are two TFNs $\tilde{n} = (n_1, n_2, \text{ and } n_3)$ and $\tilde{m} = (m_1, m_2, \text{ and } m_3)$, the distance between $\tilde{n}$ and $\tilde{m}$ is denoted as follows:

$$d(\tilde{n}, \tilde{m}) \sqrt{\frac{1}{3}\left[(n_1 - m_1)^2 + (n_2 - m_2)^2 + (n_3 - m_3)^2\right]} \quad (2)$$

For making significant comparisons, we formalize the distance or dissimilarity between $\tilde{n}$ and $\tilde{m}$ so that it is uniformly

$$d(\tilde{n}, \tilde{m}) = \frac{\sqrt{\frac{1}{3}\left[(n_1 - m_1)^2 + (n_2 - m_2)^2 + (n_3 - m_3)^2\right]}}{10} \quad (3)$$

Therefore, the similarity between $\tilde{n}$ and $\tilde{m}$ could be described as follows:

$$s(\tilde{n}, \tilde{m}) = 1 - d(\tilde{n}, \tilde{m}) = 1 - \frac{\sqrt{\frac{1}{3}\left[(n_1 - m_1)^2 + (n_2 - m_2)^2 + (n_3 - m_3)^2\right]}}{10} \quad (4)$$

For example, as explained in Section 3, the perceptual image of "No front opening" in the dimension of "Simple-Complicated" defined in Group 1 is (0.25, 0.55, and 1.55), and the result offered by Group 2 is (0.24, 0.56, and 1.58), in this condition, the similarity degree is defined as:

$$s(\tilde{n}, \tilde{m}) = 1 - d(\tilde{n}, \tilde{m}) = 1 - \frac{\sqrt{\frac{1}{3}\left[(0.25 - 0.24)^2 + (0.56 - 0.55)^2 + (1.58 - 1.55)^2\right]}}{10} 100\% = 99.8\%$$

Using this method, all the similarities between two times of results are defined, and the average similarity of the results of the two different times is 96.7%. The similarity results show that the knowledge base developed in this research is reliable.

6. Conclusion

In this article, a mask design knowledge base is developed based on a sensory evaluation and fuzzy logic integrated method. A perceptual descriptive space of mask is developed for the description of both functional and aesthetic perceptions of the mask. The mask ontology is also developed to form the mask element matrix. The relationship between the perceptual descriptive space and the mask ontology is extracted by a group of experienced designers through a sensory evaluation procedure. In this process, professional mask design knowledge is extracted. This relationship is then simulated by fuzzy logic tools. The proposed knowledge base has been validated, which can be further applied to an automatic mask design system.

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