Establishing product appearance specifications with the identification of user aesthetic needs in product conceptual design

Huicong Hu [1], Ying Liu [2] and Wen Feng Lu [3]

[1] Department of Design, Harbin Institute of Technology, Shenzhen, Guangdong, 518000, China

[2] Department of Mechanical Engineering, School of Engineering, Cardiff University, Cardiff, CF24 3AA, UK

[3] Department of Mechanical Engineering, National University of Singapore, Singapore 117290

This chapter presents the basic concepts of aesthetic needs and product specifications in conceptual design. The user aesthetics needs are considered one of the significant determinants in increasing user satisfaction. In this regard, the importance of establishing product appearance specifications to identify user aesthetic needs is discussed. A method is introduced to demonstrate the significance of considering aesthetic and emotional needs when establishing product appearance specifications in product conceptual design. To improve appearance specifications based on aesthetic experiences collected from users and designers, an approach using fuzzy logic is proposed and illustrated by a case study of digital camera design.

1 Essential of identifying the aesthetic need in product conceptual design

The focus of the conventional conceptual design is typically on functional design, which is targeted at generating appropriate structures so that required functions are provided [5, 56]. The user needs are generally structured into function or usability related statements, while design specifications are formalised into technical descriptions or values of functions. However, with the improvement of life quality, a major contributing factor contributing to a successful product is user satisfaction [9, 51, 57]. With the aim of meeting the competitive market requirements and enabling the purchase decision of a customer, the functional aspect is not enough. To increase user satisfaction, the product should be able to satisfy user needs to a higher level. In this case, the aesthetic aspect of user needs should be taken into consideration as well [1, 20, 40], especially for electronic consumer products, in which field the trend is getting more obvious.

As the transitional role, which translates the language of the users into technical descriptions of product requirements, product specifications are studied to understand user needs in conceptual design [7]. However, formalised into technical descriptions or values, product specifications are generally associated with usability or functional requirements in most related design studies [8-10]. Additionally, few studies look into the appearance of product specifications, which are characterised by the choices of surface materials and the dimensions of basic geometric. Also, regarding the establishment of product appearance specifications, few studies discussed emotional needs with aesthetic considerations regarding product appearance, and few studies have included the aesthetic aspect of design information.

In terms of quantifying user aesthetic needs, retrieving user responses to the visual appearance of design elements has been discussed as an effective approach to the establishment of product appearance specifications [2]. Under this approach, based on the perceived user reaction and product appearance specifications, the design team are enabled and facilitated to acquire user needs. In a study that investigates the sentimental response of the customer to a product, Kansei Engineering was developed by Nagamachi to translate user psychological feelings into product design elements [41]. By applying this approach, other related studies have been proposed as well [2, 9, 52]. Given the fact that there are successful applications of these methods in processing the emotional needs of users, the studies of Kansei Engineering face a constrain, which is the insufficient considerations of aesthetically attractive visual configurations. These configurations support the arrangement of design elements. Kansei words describe the user needs of product forms, which are usually adjectives, nouns, or verbs that describe specific emotions. As Kansei Engineering explains, it works by connecting Kansei words with design elements. According to existing product structures, it can effectively identify design elements that match Kansei words used by users. It could not, however, specify how the design elements should be arranged. Thus, the newly identified design elements can not align with the initial product structures in a visually pleasing manner [17].

To consider the aspects of both emotion and the arrangement of design elements, assessing the aesthetic experience of users could be an effective way. The aesthetic experience could reflect how a user perceives and responses to the aesthetic quality of a product regarding both the inherent attractiveness of the arrangement of design elements and the expression of implied emotions and meanings. Therefore, this paper is aimed at proposing a novel approach that supports the identification of user aesthetic needs and the establishment of product specifications in appearance (appearance specifications). It is aimed to improve appearance specifications by taking both the emotions and the arrangement of design elements into considerations.

First of all, based on the understanding of user aesthetic experience, the proposed approach investigates user aesthetic needs. The way people perceive and respond to a product's aesthetic quality can be indicated by the aesthetic experience, including the emotions and the arrangement of design elements. In this approach, appearance specifications are represented using a comprehensive model. A mapping task is then performed for establishing improved appearance specifications based on aesthetic experience. The mapping task consists of (1) the construction of a mapping model between initial appearance specifications and user aesthetic preferences of user aesthetic experience and (2) the implementation of the mapping model to obtain improved appearance specifications with enhanced user aesthetic preferences. A case study on digital camera designs was conducted to demonstrate the effectiveness of the proposed approach. The proposed method could help to establish appearance specifications-based user aesthetic needs.

2. Background and related works

2.1 Aesthetic information in conceptual design

The conceptual design is typically defined as the initial stages of the design process when design solutions are fuzzy [21]. The impact of conceptual design is substantial since a large number of ideas are generated during this process, which is considered to facilitate the achievement of a desirable design [28]. As the conceptual design process converts the design problem at an early stage into a transparent representation of design solutions, the uncertainty and unknown are reduced [35]. With the aim of reducing the uncertainty and the unknown, which lies in the design problem, decomposition of the problem and investigation of potential design solutions are typically conducted before generating a final concept [12]. In this case, the generation of creativity is usually considered to be motivated by the development of design solutions and problems at the same time [14].

The conceptual design process is usually divided into several phases, including user needs identification, specifications establishment of the product, concept generation, selection and evaluation [55]. First of all, with the aim of identifying user needs, the extraction and organisation of the statements from aimed users will be conducted in hierarchical order. Following the assignment of importance fuzzy, a set of carefully constructed user need statements are generated as the foundation and motivation for design specifications establishment. Subsequently, a rough description of the appearance and structures for the product is created within the product concepts. The information collected along the conceptual design process is essential to product development [42].

Conventionally, the functional and structural aspects are the primary focus in terms of the design information representation [43]. With the aim of delivering the expected effect, the represented information of functional aspects follows geometry restrictions. Meanwhile, the structural aspects focus on the design solutions which delivers the expected effect. For instance, a representation of design knowledge, including structures connections were proposed by Amaresh [6]. Also, with the aim of supporting the functional synthesisation, the function-behaviour-state (FBS) modeller based on knowledge representation [56] was proposed. Based on this FBS modeller, further studies on conceptual design studies were conducted [32, 48].

With the increasing life quality requirement, the main focus in terms of design information is not only on the functional aspect but also on the aesthetic aspect [58]. The definition of aesthetics is the pleasure obtained from sensory [22]. As a fundamental feature for a product, visual product aesthetics include the constitution of the form, colour, and texture of a product preference [4, 28, 59]. Therefore, visual product aesthetics is one of the most essential contributing factors of a desirable product [29].

In the field of design information representation, it is a popular research topic on the consideration of subjective requirements, especially aesthetic ones. With the aim of recognising the aesthetic aspect, it was stated [23] that there are two prominent indicators which are the inherent arrangement of visual design elements and the expression of design emotions implied in its design appearance when aesthetic information is processed. With the aim of realising positive customer satisfaction, aesthetic quality is one of the most contemptuous aspects of product development [39]. In addition, there are high correlations between the purchase decisions made by customers and the visual aesthetics design elements. It is believed that the aesthetic quality can be improved if the aesthetic needs of customers are measured and achieved through product forms design [18]. Aesthetic shapes are characterised by integrity, order, visual balance, rhythm, and appropriate size ratio in aesthetic cognition [15].

The expression of design emotions is one of the essential indicators of aesthetic information [50]. However, the understanding of design emotions expression is subjective since the unquantifiable implications or symbols implied in the product appearance were indicated. In regard to this indicator, Kansei engineering is a popular approach that assesses user-perceived emotions in design and deals with the sentiments of consumers [38]. Kansei engineering was defined as the translating approach of a consumer's psychology regarding the product to the design elements

[41]. Kansei engineering has been successfully applied in the design domain as it conveys the emotions in a design. Similar to the principle of Kansei Engineering, the quality function deployment (QFD) transforms the needs of customers into technical requirements [7]. For its applications, the customer preferences are identified using the QFD method in the quality analysis of products [33]. Based on online reviews, Jin et al. focus on engineering characters for QFD in the product design [27].

2.2 Understanding user aesthetic needs through aesthetic experience

As a concept, aesthetic experience entails a number of complex processes that are involved in the interaction with a product's visual experience. According to Leder, Belke, Oeberst, and Augustin, aesthetic experience involves perceptual analysis, comparison with previous encounters, classification, interpretation, and evaluative judgments, which eventually result in aesthetic judgments and emotions [37].

An element of visual design can have a significant impact on the aesthetic experience of a product through the expression of information implied in its appearance and its integrated arrangement of elements [23]. These conclusions can also be found in the "classical aesthetics" and "expressive aesthetics" dimensions [36] [10], as well as Crilly's conclusion concerning aesthetic impression, semantic interpretation, and symbolic associations with cognitive response [11].

Depending on the way in which design information is presented, people might understand and view the product differently [23]. Rather than considering tangible artifact characteristics, this indicator takes into account intangible properties of meanings and metaphors that are embedded in the product forms. Due to its subjective nature, this indicator depends greatly on someone's background, identity, personality, social status, or culture, etc. [11, 24]. In addition, the user-perceived attractiveness of a product may also be affected by the typicality and novelty of the product form and by the usage of certain design metaphors or expressions [23, 44].

Form, colour, texture, etc., affect a product's universal appeal as a result of its inherent arrangement in the design. The human mind will award beauty to certain geometric shapes, proportions, and colour combinations [47]. It is an objective property that affects the aesthetic experience and is considered as reflecting the inherent attractiveness that is perceived by sensors. As a consequence of the notion of design beauty being an important part of many design theories, such as the golden section [13], many have been put forward. The Bauhaus is one of the famous pioneers of the field of product design. The Bauhaus' teaching theory is often embraced in product design because it actually incorporates Gestalt psychology and tries to create a "new sense" from the design elements like line, colour, text, and so on [31]. Those who follow Gestalt psychology--which was developed in the early 1900s rather than the modern generation-believe that "there is more to an experience of the whole than its parts" [30]. As a result, people tend to perceive things that are pleasing, balanced, and unified, spreading a feeling of overall harmony [8]. In spite of this, a product considered to be too harmonious may be regarded as boring and monotonous [23]. The ability of complex and varied experiences to generate arousal can sometimes be required in some circumstances [3]. There are a number of aesthetic equilibrium theorists who suggest that this balance lies between boredom and confusion [16].

According to aesthetics, design elements are vocabularies that constitute a design form [31]. There are several commonly recognised design elements, including line, shape, colour, and texture [53]. A number of researchers have argued that an appealing psychological form is one that holds the right aesthetic balance between covenant order and complex arousal based on research findings. It is critical to apply aesthetic principles to provide a heuristic guide for users in order to be able to perceive both arousal-reducing and arousal-driving design strategies [31, 34]. The principles of aesthetic design can be defined as universally recognised compositional strategies for visual appearance. In addition to constituting and arranging the elements of visual design, they contribute to the aesthetics of the process [19]. Based on contrast, rhythm, balance, and proportion (CRBP), Stebbing enumerated the basic principles of aesthetic design on visual composition [54]. A contrast is, in this context, the juxtaposition of different elements of a composition that creates visual disunity. The concept of rhythm is based on repeated or alternative elements that are arranged with organised or defined intervals. With the aim of creating a sense of equilibrium, balance is the application of design elements. Various elements in a design must be sized and scaled so that they are proportionately large [25].

3. Overall framework

As appearance specifications are usually described as semantic requirements, which are imprecise and challenging to quantify, design specifications in conceptual design are typically composed of a collection of attributes or metrics with certain values. To describe the requirements of product appearances, a representation model of appearance specifications is first proposed in order to recognise important attributes.

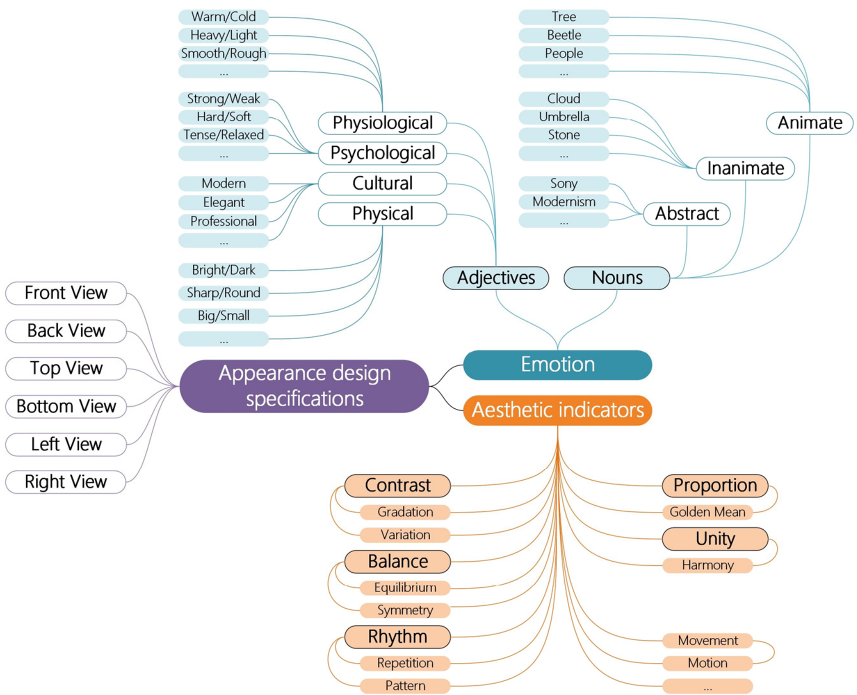

Fig. 1. Representation of appearance specifications

As illustrated in Figure 1, a representation model for appearance specifications is presented. It is useful to use appearance specifications to describe the appearance of the product from the six different points of view (front, back, top, bottom, left, and right). Within each view, two categories of appearance specification are displayed, namely emotion and aesthetic indicator. Emotions, or content meanings implied in the appearance of the product, are defined as the attributes of subjective emotions and meanings. Various emotional words are included in this product. A noun may refer to an object, or an adjective might describe certain psychological meanings. An emotional adjective is employed to evaluate the expression of design forms in this study. As stated by Dong et al. [46], four categories are used to categorise adjectival words, these categories being physiological, psychological, cultural, and physical. The adjectives in each category are each considered attributes of emotion corresponding to implied feelings associated with the product's appearance. When defining appearance specifications, the value of emotion attribute is determined as the degree to which the product appearance gives people a sense of the emotion word. In the case of the "modern" emotion attribute, values could be "very high", "high", "middle", "low", and "very low". It indicates that the product may not appear modern to people if the value of the emotion attribute "modern" is "very low = 1". It is also possible to refer to an emotion attribute as a noun, which could refer to the shape of an actual object. This could be an inanimate object like a cloud or an animate object like a beetle. An abstract notion, such as Sony or Modernism, can also be a representation of an idea. As described in the aesthetic indicator, design elements must be arranged according to specific strategies. The aesthetics of design principles determine how to arrange design elements. Aesthetic design principles are well-known and are used by designers in composing design elements, as discussed in previous chapters. They are regarded as attributes of aesthetic indicators, as described in previous chapters. According to Stebbing's study [54], the representation model contains common aesthetic design principles, such as contrast, balance, rhythm, proportion, and unity. As a result, the aesthetic indicator attribute value is determined by the degree of implementation of the corresponding aesthetic design principle in the appearance of the product.

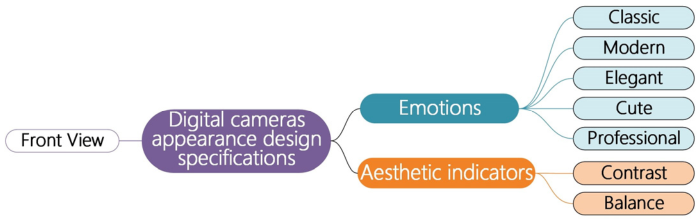

Fig. 2. Representation of digital camera appearance specifications (front view)

As shown in Figure 2, the front view of a digital camera is represented by appearance specifications. Aesthetic design principles are contrast and balance as the elements of the aesthetic design indicator, and emotion adjectives "classic", "modern", "elegant", and "cute" are selected as emotion attributes.

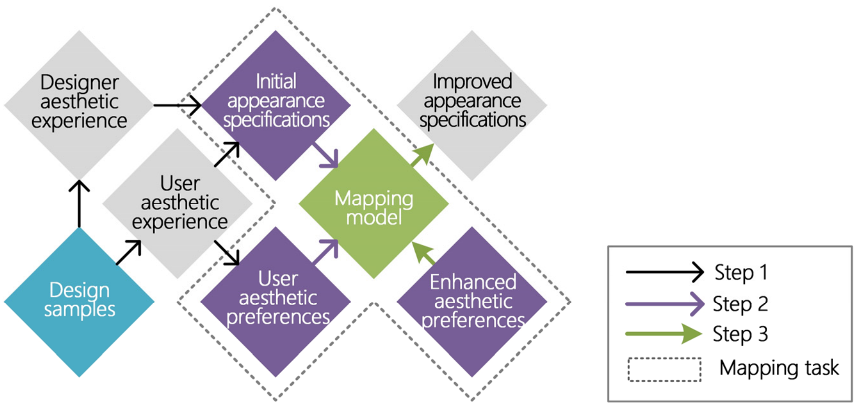

Fig. 3. The proposed method for improving appearance specifications based on aesthetic experience

Next, the overall method for improving appearance specifications is presented in Figure 3. Based on the aesthetic experience of existing design samples, a mapping task is performed to generate appearance specifications. The mapping task consists of three steps. The first step is to acquire initial appearance specifications and user aesthetic preferences of existing design samples. The values of initial appearance specifications are obtained from both evaluations of user aesthetic experience and designer aesthetic experience. In the evaluation of user aesthetic experience, the user would also indicate their aesthetic preferences of the existing design samples. Step 2 focuses on constructing a mapping model between the initial appearance specifications and the user aesthetic preferences. Step 3 is to generate improved appearance specifications based on enhanced user aesthetic preferences, which are predefined by designers.

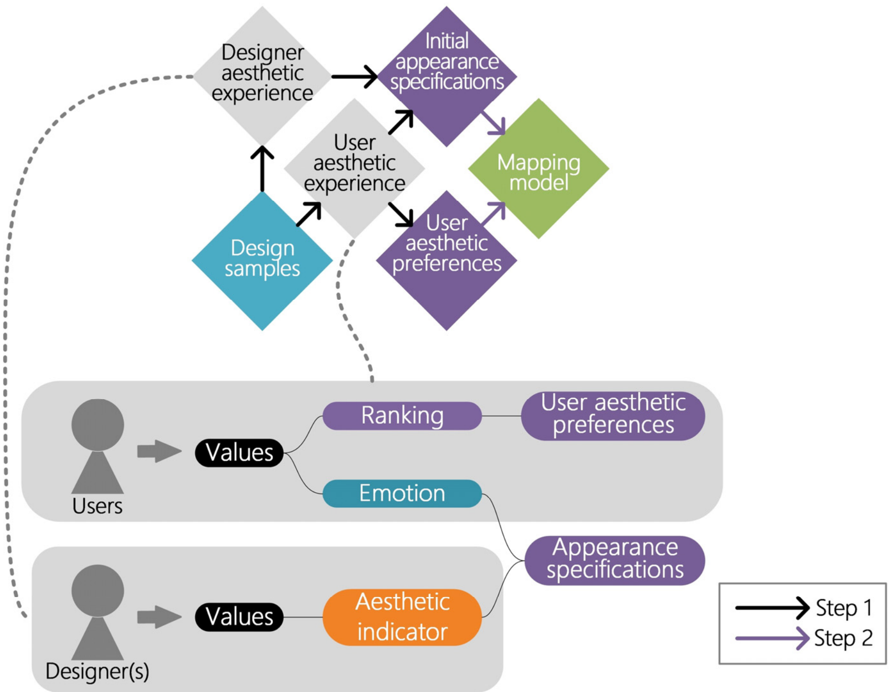

Fig. 4. Process of constructing the mapping model

Figure 4 shows the detailed process of constructing the mapping model between initial appearance specifications and user aesthetic preferences (Step 1 and Step 2). In Step 1, design samples are chosen from existing product designs or prototypes. From the design samples, the attributes of the initial appearance specification are determined based on the proposed representation model. With the aim of obtaining the values of the initial appearance specification attribute regarding design samples, user evaluation and designer evaluation are conducted. Participants of the user evaluation could be users from the target user group with defined personal backgrounds. Participants of the designer evaluation are designers with certain design experience and knowledge of applying aesthetic design principles. During the evaluation, users and designer(s) observe the appearance of design samples and gain certain aesthetic experiences. Their aesthetic experiences could be acquired from survey questions regarding each attribute of initial appearance specifications. In the user evaluation, values of the emotion attributes of initial appearance specifications and ranking values of user aesthetic preferences are obtained. In the designer evaluation, designer(s) evaluate the appearance of design samples and indicate the values of aesthetic indicator attributes of initial appearance specifications. The resulted values of both user and designer evaluations would be used for constructing the mapping model. In Step 2, the mapping model is constructed with the input of initial appearance specifications and the output of user aesthetic preferences.

Step 3 is to implement the constructed mapping model to generate improved appearance specifications. Figure 5 shows the detailed process of implementing the mapping model for the generation of improved appearance specifications. In this process, enhanced user aesthetic preferences are first defined as the target aesthetic preferences. Based on the mapping model, improved appearance specifications that result in the target aesthetic preferences could be generated.

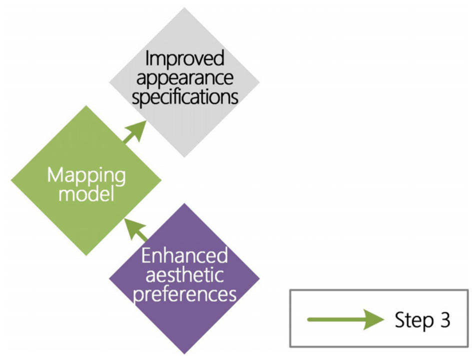

Fig. 5. Process of implementing the mapping model

4. Case Study on improving appearance specifications based on aesthetic experiences

To demonstrate the method proposed for improving appearance specifications based on the aesthetic experiences of users and designers, a case study with digital cameras was conducted. By applying fuzzy logic, a mapping model was constructed for this study. There is evidence to suggest that fuzzy logic is an excellent tool for modelling information with imprecise values that depend on their degree

[45]. Therefore, it can be used to construct mappings between original appearance design specifications and aesthetic preferences. Below is an outline of the steps involved in this case study.

1. Select design samples and attributes of initial appearance specifications for aesthetic experience evaluation
2. Determine linguistic variables for initial appearance specifications
3. Construct a fuzzy set X of initial appearance specifications
4. Determine linguistic variables for user aesthetic preferences and construct a fuzzy set Y of user aesthetic preferences
5. Construct fuzzy rules between initial appearance specification fuzzy set X and user aesthetic preference fuzzy set Y

   Rule: IF X_1 is A_1 AND X_2 is A_2 … AND X_n is A_n THEN Y is B,

   where A_1, A_2, …, A_n and B are fuzzy linguistic values, taken by the input linguistic variables X_i and the output linguistic variable Y.

6. Generate improved appearance specifications with enhanced user aesthetic preferences

This case study is to demonstrate the appearance design of the interchangeable-lens digital camera. The goal was to establish appearance specifications of the digital camera for the target users of 20-30 years olds female college students.

4.1 Acquiring initial appearance specifications and user aesthetic preferences

A total of eight interchangeable-lens digital cameras were chosen as the study's design samples. There were different combinations of styling forms, colours, and textures used to select the design samples. Aesthetic design principles "contrast" and "balance" were chosen as aesthetic indicator attributes, whereas emotion attributes "classic", "modern", "elegant", "cute", and "professional" were chosen as emotion attributes.

To determine linguistic variables for initial appearance specifications, the triangular form of the membership function, which is frequently used for representing fuzzy numbers and significantly simplifies the modelling process [26], was employed to determine approximate interval values of linguistic variables. Seven linguistic variables were chosen as criteria for appearance specification attributes (Figure 6, Table 1).

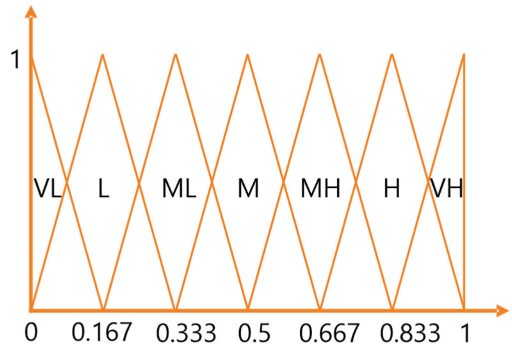

Fig. 6. Membership functions for appearance specification attributes

Table 1. Linguistic criteria for appearance specification attributes

Linguistic variable	Interval of triangular fuzzy number
Very low (VL)	[0, 0.167]
Low (L)	[0, 0.333]
Medium low (ML)	[0.167, 0.5]
Medium (M)	[0.333, 0.667]
Medium high (MH)	[0.5, 0.833]
High (H)	[0.667, 1]
Very high (VH)	[0.833, 1]

Next, the value of each attribute of appearance specifications was obtained. To construct a fuzzy set on emotion attributes, the semantic differential (SD) method, which is a self-report method using a Likert scale, was employed to evaluate design samples regarding each emotion attribute. A seven-point SD scale (1 to 7) corresponding to the seven linguistic variables (VL to VH) was employed in the user evaluation. Forty-three female college students were selected from target users for the user evaluation. The evaluation result of each emotion attribute is shown in Table 2, with the average and standard deviation values. The converted values of fuzzy sets on emotion attributes are listed in Table 3.

Table 2. Users SD evaluation results

Design sample	Classic		Modern		Elegant		Cute		Professional	
	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.	Avg.	Std.
1	2.21	1.29	5.95	0.99	5.58	1.10	4.53	1.53	4.23	1.74
2	5.91	1.03	2.56	1.33	4.40	1.50	1.98	0.90	5.14	1.39
3	2.05	0.89	5.65	1.27	3.12	1.67	5.70	1.50	3.28	1.60
4	2.91	1.51	4.56	1.56	3.07	1.59	4.30	1.59	3.42	1.50
5	5.28	1.83	3.42	1.73	4.51	1.53	2.26	1.08	5.84	1.03
6	3.81	1.79	3.23	1.87	3.05	1.49	3.21	2.03	3.98	1.80
7	3.26	1.73	4.67	1.43	4.37	1.75	3.16	1.41	4.70	1.46
8	2.88	1.50	4.88	1.83	6.21	1.05	4.16	1.74	2.95	1.70

Table 3. Values of the fuzzy set on emotion attributes

Design sample	Classic	Modern	Elegant	Cute	Professional
1	L	H	H	MH	M
2	H	ML	M	L	MH
3	L	H	ML	H	ML
4	ML	MH	ML	M	ML
5	MH	ML	MH	L	H
6	M	ML	ML	ML	M
7	ML	MH	M	ML	MH
8	ML	MH	H	M	ML

The Analytic Hierarchy Process (AHP) developed by Saaty [49] was applied to perform comparative judgments to determine the degree to which aesthetic principles were implemented in particular design samples in order to construct a fuzzy set of aesthetic indicators. Table 4 illustrates the pairwise comparisons made between design samples in regards to aesthetic design principles based on their intensity of importance, as shown in the figure. By applying local weights, each aesthetic design principle was assessed in relation to its degree of implementation. This process was performed by an aesthetic designer with over five years of experience in implementing aesthetic design principles. The resulting AHP weights are presented in Table 5. The largest weights of "contrast" and "balance" were found in Sample 3 and Sample 5, respectively. The linguistic variables regarding "contrast" for Sample 3 and "balance" for Sample 5 were determined as "VH" and "H",, respectively by the designer. The corresponding numerical values of the linguistic variables "VH" and "H" were 0.917 and 0.833, respectively, based on the defined linguistic criteria of appearance specification attributes (Figure 6, Table 1). By multiplying the resulting AHP "contrast" weights by the "Contrast" numerical values (0.917) of Sample 3, the "contrast" numerical values of other samples were obtained. The "balance" numerical values of other samples were generated in the same way. The numerical values were then converted into the fuzzy set, which consists of linguistic variables with the degree of support (DOS) based on the defined linguistic criteria of appearance specification attributes. The DOS could be regarded as the weight of the corresponding fuzzy rule for constructing the fuzzy model. Table 5 shows the AHP evaluation results of the fuzzy set on aesthetic indicator attributes "contrast" and "balance".

Table 4. The intensity of importance scale for AHP evaluation

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak importance of one over another	Experience and judgment slightly favour one activity over another
5	Essential or strong importance	Experience and judgment strongly favour one activity over another
7	Demonstrated importance	Activity is strongly favoured, and its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed

Table 5. AHP results of the fuzzy set on aesthetic indicator attributes

Design sample	Contrast				Balance			
	Weight	weight *0.917	Linguistic variable \DOS		Weight	weight *0.833	Linguistic variable \DOS	
1	0.126	0.116	L\0.70	VL\0.30	0.848	0.707	MH\0.76	H\0.24
2	0.082	0.075	VL\0.55	L\0.45	0.196	0.163	L\0.98	VL\0.02
3	1.000	0.917	H\0.50	VH\0.50	0.722	0.602	MH\0.61	M\0.39
4	0.746	0.684	MH\0.90	H\0.10	0.428	0.357	ML\0.86	M\0.14
5	0.280	0.257	ML\0.54	L\0.46	1.000	0.833	H\1	VH\0
6	0.530	0.486	M\0.92	ML\0.08	0.277	0.231	L\0.61	ML\0.39
7	0.076	0.070	VL\0.58	L\0.42	0.361	0.301	ML\0.81	L\0.19
8	0.113	0.104	L\0.62	VL\0.38	0.236	0.197	L\0.82	ML\0.18
	Inconsistency=0.04				Inconsistency=0.07			

With the aim of acquiring user aesthetic preferences, user ranking was used to represent the user aesthetic preferences. Table 6 shows the evaluation criteria for linguistic judgments of user aesthetic preferences and Figure 7 presents the membership functions for user aesthetic preferences. Table 7 shows the ranking results of the fuzzy set on user aesthetic preferences.

Table 6. Linguistic criteria for user aesthetic preferences

Linguistic variable	Interval of triangular fuzzy number
Rank 1 (R1)	[0, 0.143]
Rank 2 (R2)	[0, 0.286]
Rank 3 (R3)	[0.143, 0.429]
Rank 4 (R4)	[0.286, 0.571]
Rank 5 (R5)	[0.429, 0.714]
Rank 6 (R6)	[0.571, 0.857]
Rank 7 (R7)	[0.714, 1]
Rank 8 (R8)	[0.875,1]

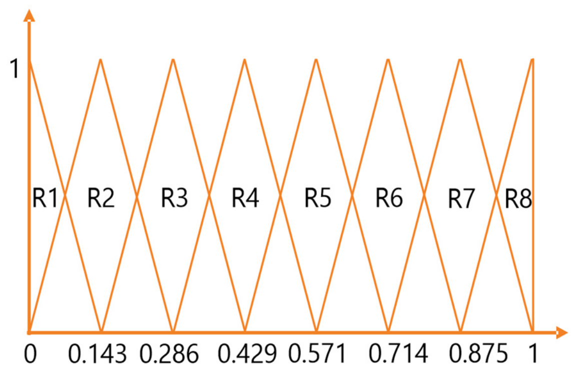

Fig. 7. Membership functions for user aesthetic preferences

Table 7. Ranking results of the fuzzy set on user aesthetic preferences

Design sample	User ranking
1	Ranking 1 (R1)
2	Ranking 5 (R5)
3	Ranking 4 (R4)
4	Ranking 7 (R7)
5	Ranking 3 (R3)
6	Ranking 8 (R8)
7	Ranking 6 (R6)
8	Ranking 2 (R2)

4.2 Constructing the fuzzy model

Based on fuzzy sets of the appearance specifications and aesthetic preferences, 32 fuzzy rules were constructed, as shown in Table 8. The weight of each fuzzy rule was determined by the DOS of the aesthetic indicator of "contrast" and "balance".

Table 8. Fuzzy rules between appearance specifications and user aesthetic preferences

	Expression					Arrangement		Weight	User preference
	Classic	Modern	Elegant	Cute	Professional	Contrast	Balance		Ranking
1	L	H	H	MH	M	L	MH	0.5320	R1
2	L	H	H	MH	M	L	H	0.1680	R1
3	L	H	H	MH	M	VL	MH	0.2280	R1
4	L	H	H	MH	M	VL	H	0.0720	R1
5	H	ML	M	L	MH	VL	L	0.5390	R5
6	H	ML	M	L	MH	VL	VL	0.0110	R5
7	H	ML	M	L	MH	L	L	0.4410	R5
8	H	ML	M	L	MH	L	VL	0.0090	R5
9	L	H	ML	H	ML	H	MH	0.3050	R4
10	L	H	ML	H	ML	H	M	0.1950	R4
11	L	H	ML	H	ML	VH	MH	0.3050	R4
12	L	H	ML	H	ML	VH	M	0.1950	R4
13	ML	MH	ML	M	ML	MH	ML	0.7740	R7
14	ML	MH	ML	M	ML	MH	M	0.1260	R7
15	ML	MH	ML	M	ML	H	ML	0.0860	R7
16	ML	MH	ML	M	ML	H	M	0.0140	R7
17	MH	ML	MH	L	H	ML	H	0.5400	R3
18	MH	ML	MH	L	H	ML	VH	0.0000	R3
19	MH	ML	MH	L	H	L	H	0.4600	R3
20	MH	ML	MH	L	H	L	VH	0.0000	R3
21	M	ML	ML	ML	M	M	L	0.5612	R8
22	M	ML	ML	ML	M	M	ML	0.3588	R8
23	M	ML	ML	ML	M	ML	L	0.0488	R8
24	M	ML	ML	ML	M	ML	ML	0.0312	R8
25	ML	MH	M	ML	MH	VL	ML	0.4698	R6
26	ML	MH	M	ML	MH	VL	L	0.1102	R6
27	ML	MH	M	ML	MH	L	ML	0.3402	R6
28	ML	MH	M	ML	MH	L	L	0.0798	R6
29	ML	MH	H	M	ML	L	L	0.5084	R2
30	ML	MH	H	M	ML	L	ML	0.1116	R2
31	ML	MH	H	M	ML	VL	L	0.0684	R2
32	ML	MH	H	M	ML	VL	ML	0.3116	R2

4.3 Establishing improved appearance specifications

The enhanced user aesthetic preferences are predefined by designers to establish improved appearance specifications based on the constructed fuzzy model. In this case study, referring to the linguistic criteria of user aesthetic preferences, the fuzzy linguistic value of enhanced user aesthetic preferences was defined as R1(Ranking 1) [0, 0.143]. Based on the constructed fuzzy model, every possible combination of appearance specifications that contributes to the enhanced user aesthetic preferences were searched and generated as improved appearance specifications. Twelve groups of improved appearance specifications that result in Ranking 1 of user aesthetic preferences were generated and are shown in Table 9. The results suggested that users would prefer designs with a lower degree of "contrast" and higher degrees of "modern" and "elegant". The values of appearance specification attributes could provide directions and insights in both aspects of emotions and the arrangement of design elements for designers to generate design concepts.

Table 9. Generated improved appearance specifications

Group	Contrast	Balance	Classic	Modern	Elegant	Cute	Professional
1	VL	MH	L	H	H	MH	ML
2	VL	MH	L	H	H	MH	M
3	VL	MH	L	H	H	MH	MH
4	VL	H	L	H	H	MH	ML
5	VL	H	L	H	H	MH	M
6	VL	H	L	H	H	MH	MH
7	L	MH	L	H	H	MH	ML
8	L	MH	L	H	H	MH	M
9	L	MH	L	H	H	MH	MH
10	L	H	L	H	H	MH	ML
11	L	H	L	H	H	MH	M
12	L	H	L	H	H	MH	MH

5. Conclusions

When it comes to increasing user satisfaction, the aesthetic aspect of product design becomes crucial. Conceptual design literature rarely addresses the information representation of appearance specifications. An information representation model of appearance specifications was proposed to address this issue. Further, a method that supports designers in improving appearance specifications based on aesthetic experience was developed. In the method, a mapping model was constructed with the input of initial appearance specifications and the output of user aesthetic preferences. From the mapping model, improved appearance specifications that result in enhanced user aesthetic preferences could be obtained. A digital camera design case study was conducted to illustrate the overall method. The case study reflected that the proposed method is effective in improving appearance specifications. It also showed that fuzzy logic is applicable to construct the mappings between appearance specifications and user aesthetic preferences.

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