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A Conceptual Design Specification Based on User Aesthetic Information Analysis and Product Functional Reasoning

Huicong Hu [1], Ying Liu [2], Xin Guo [3,*] and Chuan Fu [4]

1 Department of Design, Harbin Institute of Technology (Shenzhen), Shenzhen 518000, China
2 Department of Mechanical Engineering, School of Engineering, Cardiff University, Cardiff CF24 3AA, UK
3 School of Mechanical Engineering, Sichuan University, Chengdu 610065, China
4 Informatization Office, Shanghai University of Finance & Economics, Shanghai 200433, China
* Correspondence: guoxin@scu.edu.cn

Abstract: User satisfaction with a product plays a direct role in the purchasing decisions. With the enrichment of material life and the growth of individual requirements, this satisfaction is derived from the requirement for functionality to aesthetics. Conventional product design methods normally focus on achieving the required functions where its design specifications are mainly related to certain functional or usability requirements. In recent years, researchers have made efforts to develop methods for supporting aesthetic design activities during the product conceptual design phase. However, most of these methods hardly consider product aesthetics or the consumers' emotional needs. Therefore, this study proposed a user-driven conceptual design specification integrating functional reasoning with aesthetic information analysis. The method consisted of two tasks, the construction of a mapping model and the implementation of the mapping model. Firstly, the mapping model was constructed for capturing the relationships between initial design specifications and user experience (UX). Secondly, the proposed design specifications were selected, refined, and optimized based on the mapping model. A case study on digital camera design was carried out to demonstrate the feasibility and effectiveness of the proposed method. The results showed that, compared with the initial design specification candidates, the UX was enhanced by applying the improved design specifications.

Keywords: product design; user experience; design specification; aesthetic design; functional design

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1. Introduction

For today's consumer products, functions are no longer the only factors that lead to a user's purchasing decision. With the core technologies of a product becoming mature in the market, the aesthetic aspect of a product becomes another determinative factor for companies to raise their product's competitiveness. In recent years, many researchers started to propose methods to support the aesthetic design activities during the product conceptual design phase. However, few studies could guide integrating aesthetic and functional information in their applications. In most conceptual design studies, the functional aspect and the aesthetic aspect of design information are usually considered separately. In fact, product aesthetics and its practical functions are usually closely related to each other. The internal structures of a product associated with its supported functions largely determine the product form. In industrial design, appearance design, and other design processes, users' needs for aesthetics are often perceptual and descriptive. These descriptive needs are summarized into qualitative, descriptive information as design specs (as opposed to quantitative function and usability specifications). For novice designers, the transition from qualitative design requirements to design shapes is difficult. The transition between them often relies on the designer's subjective judgment in combination with his own experience. Therefore, a holistic consideration is required to improve the conceptual design with integrated functional and aesthetic information.

1.1. Motivation

Integrating functional and aesthetic information in conceptual design is not an easy task. The first mission is to quantify both the functional and aesthetic design information. In general, functional design information is relatively easy to be formed into technical descriptions or values of certain functions. There are plenty of studies that focused on the representation of function and structure elements [1–5]. In comparison, quantifying aesthetic design information would be more difficult. Some studies used basic geometric dimensions to describe a product's form [6–8]. However, such a way of description could only be able to indicate the physical information of a product's aesthetics. The psychological aspect of a product including both the implied emotions that are conveyed in the product appearance and the design aesthetics of arranging design elements in the visual design composition could hardly be represented. These approaches are more applicable to the engineering research paradigm and less applicable to the aesthetic design practice. In industrial design practice, stylists often have disciplinary backgrounds in design and art. Their design thinking often revolves around theories related to aesthetic laws, with less awareness of geometric parameters and other descriptions. In an attempt to translate users' feelings towards product form elements, Kansei Engineering [9] has been proposed. In Kansei Engineering, Kansei adjectives are used to indicate certain emotions on a product. Semantic differentials (SD) [10] are implemented to quantify the degree that users would perceive the corresponding emotions from the product's appearance. However, Kansei Engineering could not support the descriptions on the arrangement of design elements, especially the use of aesthetic design principles on product form design composition. The aesthetic design principles are well-recognized design fundamentals that provide strategies for visual design compositions [11–14]. They are commonly applied by designers to choose and arrange design elements, assisting in the creation of art forms, buildings, and commercial products [15,16]. Hence, it would be necessary to include the information of applying aesthetic design principles to represent aesthetic design information.

The second mission is to compare and select functional and aesthetic information. In this mission, design trade-offs would be made among the information of function, usability, and aesthetics. For example, how to balance the smart and slim appearance of a laptop against its functionality structures such as a built-in DVD drive or a large hard drive. To handle this issue, comprehensive evaluation criteria are required to cover both the functional and aesthetic design aspects. User experience (UX) is a broad term that could reflect all aspects of the interaction between a user and a product [17–20]. Different from the concept of usability, UX covers a wider field including function, emotion, affect, hedonism, aesthetics, etc. [21–23]. This suggests that UX includes both the functional and aesthetic aspects of design information. Thus, employing UX could be practicable for the integration of functional and aesthetic design.

1.2. Objective

Based on the above considerations, the objective of this study is to propose a novel method that combines Kansei engineering and aesthetic design principles to quantify aesthetic design specs to improve design specifications by integrating functional and aesthetic information based on UX. The proposed method is designed for consumer products, such as mobile phones, digital cameras, and other electronic products, which are already mature in the market. For these products, function, usability, and aesthetic aspects are vitally important. In product conceptual design, design specifications are established with a set of precise descriptions of product requirements in terms of function, usability, and aesthetics. The proposed method mainly focuses on the activity of establishing design specifications to evaluate and generate improved design specifications for further development.

1.3. Contributions

The main contributions of the methods proposed in this paper are as follows: (1) The user driven conceptual design specification proposed in this paper is oriented toward consumer product design and can realize the integration of aesthetic information analysis and functional reasoning. (2) Based on combining function, usability, and aesthetic information, this method pays attention to emotional response and aesthetic rules of design elements and establishes design specifications through user experience, which makes up the gap between user experience and conceptual design.

1.4. Structure of the Paper

The remainder of the paper is organized as follows: Section 2 provides an introduction to product design specifications, in terms of function, usability and aesthetics, and user experience. Section 3 describes the proposed framework of integrating functional and aesthetic design specifications. Section 4 presents the implementation procedure for the proposed method with a camera design case study. Section 5 gives brief conclusions and several future suggestions for this study.

2. Related Works

2.1. Product Conceptual Design

2.1.1. Function and Usability Related Conceptual Design

The process of conceptual design includes activities of identifying customer needs, establishing design specifications, concept generation and downstream conceptual design activities (concept selection, evaluation, and validation) [24]. During the conceptual design process, customer needs are collected from target customers and formulated into a hierarchy of primary, secondary and (if necessary) tertiary needs. The weighting of each need will also be established. Based on the identified customer needs, design specifications will be determined by the design team using precise descriptions of what the product has to have to satisfy the customer needs. The downstream conceptual design activities will begin with a set of customer needs and design specifications and result in a set of design concepts from which the design team will make a final selection, evaluation, and validation. In general, most studies about user requirement analysis and design specification establishment are usually related to functional and usability information and do not combine the functional and aesthetic aspects of design information. For example, the Kano model [25–29], Quality Function Deployment [27,30,31], Needs-metrics [24], Affinity Diagram [32], Conjoint Analysis [33–35], etc.

2.1.2. Aesthetics Related Conceptual Design

Studies on supporting the aesthetics of conceptual design based on the evaluation criteria for product appearance can be classified into the group that focuses on emotional responses and the group of the aesthetic rules of design elements constitution.

To handle users' emotional responses, Kansei engineering is one of the methodologies. It is defined as "translating technology of a consumer's feeling (Kansei) of the product to the design elements" [9,36,37]. Three important issues are addressed in this method: (1) how to capture user's affective needs of the product, (2) how to analyse captured data, trying to find mappings between products and affective needs, (3) how to interpret captured data and improve product design in the following design processes. To acquire the user's emotional needs, the Semantic Differential (SD) is used as the main method with a number of collected Kansei words. A survey or an experiment is then conducted to find the mappings between physical design elements and Kansei words. Various kinds of attempts have been made to extend the Kansei Engineering approach. Chen and Chuang [38] proposed to integrate robust design method and Kano model into Kansei Engineering to enhance the subjective quality of aesthetics and user satisfaction. Smith and Smith [39] implemented the Latent Semantic Engineering approach to create a semantic space model that improves the matching accuracy between users' Kansei requirements and product designs. To adjust the inconsistency between different users' understanding of Kansei tags, Huang et al. [40] proposed a basic-emotion based SD method to obtain data for establishing the mapping between products and Kansei tags. Yang and Shieh [41] implemented support vector regression to map the relationship between user affective responses and product form features. Considering the social, environmental and economic performance, Hartono [42] developed a modified Kansei Engineering-based approach to understand and satisfy customers' emotional needs. Kansei Engineering is successfully in identifying user-preferred design elements, however, may not be very usefully in placing and arranging design elements. Some other studies have also explored to deal with user's emotional responses, such as integrating affective design with defining engineering specifications [43], affective computing [44–46], emotional and cognitive design for mass personalization [47]. The way of arranging and placing design elements is already decided following that of the original design samples selected by the design team. However, few studies considered the way of combining functional and aesthetic design.

The subject of beauty in placing and arranging design elements has been studied for centuries. Certain lines, proportions, shapes and colours were regarded to be inherently beautiful according to human cognition [48]. Many design theories influenced the notion of design beauty has been built such as the golden section. One famous pioneer of product design is the Bauhaus' teaching theory which is embraced Gestalt psychology and attempted to build a new sensitivity based on design elements such as line, colour, text, etc. [11,49,50]. In Gestalt psychology, scholars believed that "the perception of the whole is greater than a sum of individual parts", meaning that things that are orderly, balanced, unified exuding an overall sense of feeling will be more preferred by people to perceive [51–53]. Referred to the perspective of Gestalt psychology, many aesthetic design principles were developed to aid the placing and arranging of design elements for pleasing design production. Stebbing [54] summarized the most-mentioned terms related to aesthetic design principles and recognized that Contrast, Rhythm, Balance, and Proportion (CRBP) are basic design principles on visual composition. Nonetheless, aesthetic design principles lack the consideration of expressing emotional information like metaphors and feelings in design forms [15].

2.2. User Experience

2.2.1. Concept of UX

The concept of user experience (UX) emerged in the field of Human-Computer Interaction. It is defined as "a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service [55]". It is an elaborated form of satisfaction [56,57]. Law and van Schaik [56] interpreted UX that it constructs as a user's perceived hedonic quality, pragmatic quality, aesthetics and overall goodness of the product. Tractinsky and Hassenzahl [58] defined UX scope into perspectives beyond the instrumental, emotion and affect, and the experiential, and suggested UX as an outcome of the user's internal state, designed characteristics, and use of context. Crilly et al. [59] claimed that users' personal characteristics, cultural background, and life experience influence the user's cognitive process (semantic interpretation and symbolic association), as a consequence, influence user's affect and behaviour. Benyon [60] considered that all the sensations, feelings, thoughts, and actions of engaging in activities are included in UX.

To achieve the ultimate goal of UX research—finding ways of improving UX of products or services, many studies have been conducted. Basically, the motivations of UX research can be classified into three groups: defining UX, evaluation methods, UX prediction. The research goal of defining UX usually is aimed at understanding the fundamental concepts of UX. They designate evaluation methods to explore the nature and dimensions of UX. For example, through a survey evaluation method, Law et al. [61] came up with the conclusion that UX is dynamic, subjective and context-dependent; Park et al. [62] proposed three main elements of UX, including usability, affect, and user's subjective value (user value) and their correlated sub-elements for mobile phones through in-depth interview and evaluation; Battarbee and Koskinen [63] evaluated UX data from a real case of the service company to illustrate their argument of co-experience—the social interaction effects on UX. Yang et al. [64] defined UX that it includes users' affective and cognitive perspectives.

In this work, a faceted conceptual model is proposed to explain and illustrate the crucial factors of UX.

The second group, the evaluation methods, focuses on the methodology that is being applied to data acquisition and analysis of UX evaluation [65,66]. Kujala et al. [67] proposed a UX curve as a method for modelling and evaluating long-term UX by recording the chronological order of UX. Liang et al. [68] tried to minimize and structure online review statements into a facet UX model as well as to evaluate each aspect of the model. Xu, Zhou et al. [69] chose fuzzy Petri Nets to build an activity-based UX model for evaluating the causal relations between users' affective responses and cognitive processes.

The third group emphasizes the prediction of UX. Law [70] organized UX prediction into two types: UX-behaviour-loop and UX-factor-quality-loop. The former aims to predict the acceptance of a specific set of user experiences of the product, which indicates the probability that the user is willing to buy the product. This type of prediction is usually appropriate for relative matured or ready-to-market products. For example, Staiano et al. [71] proposed an automatic system for predicting user behaviour through UX assessment of tracking users' facial expressions. The type of the latter allows people to predict UX qualities that are preferred among users by specifying certain UX factors, in other words, to elicit requirements and establish criteria for conceptual design. Bargas et al. [72] conducted empirical studies of UX and found that only a smaller group of publications have covered this research field. A similar conclusion has also been made in Vermeeren, Law et al. 's study [56]. Souza et al. [73] used mouse-tracking and artificial intelligence techniques to evaluate UX. Similar studies can be found in [74].

Current research on UX mainly targets understanding UX features and undertaking UX evaluation of existing products. Little attention has been paid by researchers to develop a UX integration method for conceptual design stages [56,75–77]. Additionally, in the research of UX prediction, most of the publications focused on the user need and imagined applications of product concepts, i.e., the evaluation and validation of product concepts [72]. Few studies explored ways to support the establishment of design specifications through the assessment of UX. This suggests a significant gap between current UX evaluation and the process of deriving a product concept.

2.2.2. UX Measurement for Products

To reveal how products provide the user experience of people, the hedonic/pragmatic model proposed by Hassenzahl [78] is one common recognized UX model. It is a content-oriented model of user experience. In this model, two dimensions of product quality are addressed that will influence people to perceive interactive products, namely pragmatic quality and hedonic quality. Pragmatic quality refers to the product qualities that support the achievement of intended action by using a product, which is related to the utility and usability of products. Hedonic quality emphasized the pleasures and satisfactions brought by achieving an intended action, which focusses on the question of why people own and use a certain product. The two dimensions were suggested to be independent by Hassenzahl and Monk's study [79].

To measure the performance of user experience under the UX model, Hassenzahl et al. [80] advocated that needs fulfilment can act as a major source of good experience with interactive products. Through experiments on ten psychological needs proposed by Sheldon et al. [81], they found a clear relationship between the degree of need fulfilment and positive affect. Following this idea, Korber et al. [82] presented a measurement method of UX relying on the fulfilment of psychological needs and conducted three online surveys based on the method. Besides, Laugwitz et al. [83] developed a user experience questionnaire (UEQ) constructed from attractiveness, pragmatic quality (perspicuity, efficiency, dependability) and hedonic quality (stimulation, novelty). The UEQ scale has been successfully applied to measure UX in different scenarios [84–86]. Minge et al. [87] introduced a new questionnaire, called meCUE (components model of user experience), to measure UX. This questionnaire has four modules for validation, including user emotions, instrumental and non-instrumental product perceptions, consequences of usage, and an overall judgment of attractiveness. However, the above studies mainly focus on the measurement and quantifying of user experiences, and do not include the improvement of product quality based on UX measurement results.

In summary, few studies integrate both functional and aesthetic aspects of design information in product conceptual design. In studies of UX, few studies address the UX evaluation method for conceptual design stages, especially on supporting the establishment of design specifications through UX assessment.

3. Methodology

A framework for the proposed method is presented in this section. The main purpose of the method is to improve the design by integrating functional and aesthetic design specifications based on the user experience of target users. Figure 1 illustrates the proposed framework consisting of two tasks. The first task aims to develop a mapping model that captures the relationships between initial design specifications and UX of existing design samples. The second task focuses on implementing the mapping model, i.e., to integrate and refine proposed function and aesthetic design specifications to select and improve design specifications. It is important to note that the aesthetics here emphasizes the design method of product design, which is mainly concerned with the design of physical, shaped products, and emphasizes the appearance design and hardware and software configuration of products more than the internal design of the product, such as the GUI.

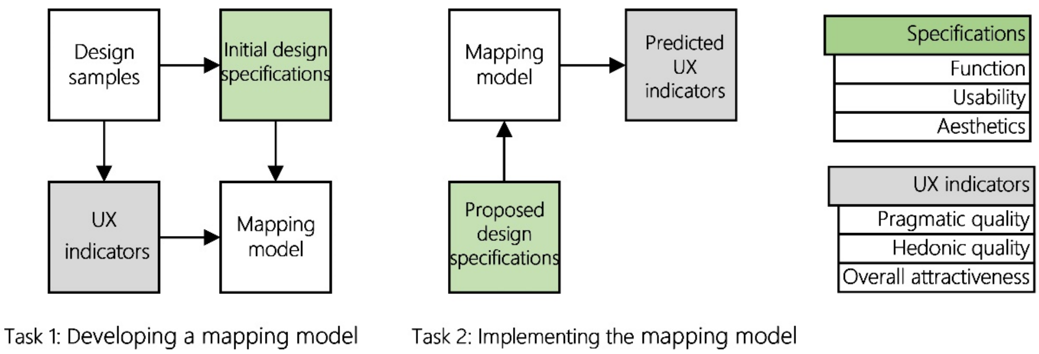
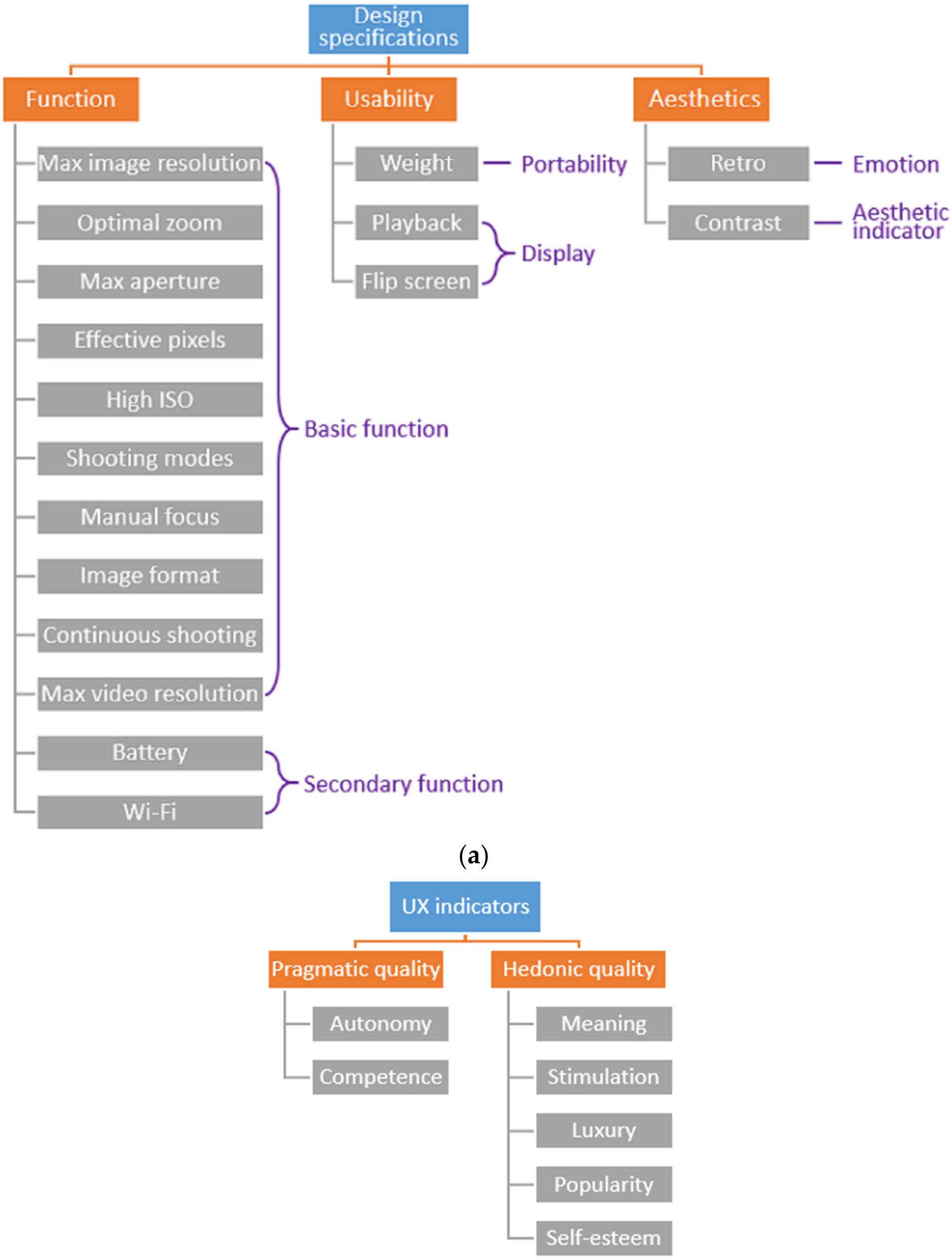


Figure 1. A User-driven Conceptual Design Specification.

3.1. Developing a Mapping Model

In the first task, three variables which are design samples, initial design specifications, and UX indicators, would contribute to the mapping model. Design samples are usually selected from existing design cases with different attributes of design specifications. Design specifications contain a list of design attributes and values that indicate the design requirements. For design samples of the same product type, their design attributes would be the same while the design values may be different depending on the design samples themselves. Concerning today's consumer products, such as electronic products, the design attributes can be classified into function, usability, and aesthetics [88,89] with respect to describing the functional, ergonomic, and aesthetic aspects of design requirements. Figure 2a shows an example of the design specifications of the compact digital camera. To obtain the values of design specification attributes from design samples, function and usability specifications which contain technical descriptions usually can be collected directly from design documents. However, appearance specifications would be hard to acquire. Appearance specifications could be classified into aspects of emotion and aesthetic indicators. Emotion reflects the expression of implied emotions in the product aesthetics. For example, a product in pink colour communicates more feelings of "feminine" than a grey-coloured product and is usually designed for the ladies. Aesthetic indicator describes the arrangement of design elements regarding implementing aesthetic design principles in the visual design composition. For instance, if the aesthetic indicator "contrast" is suggested to be low then the designer may like to avoid the use of conflicting or opposite colour combinations in colour design.



(**a**) (**b**)

Figure 2. Design specifications (**a**) and UX indicators (**b**) of the compact digital cameras.

In the proposed method, the collection of aesthetic information relies on the involvement of both users and designers. Experimental studies are conducted to acquire information of emotion and aesthetic indicators from users and designers. Emotion adjectives and aesthetic design principles are applied as criteria for users and designers to evaluate and quantify the information of emotion and aesthetic indicators, respectively. UX indicators help designers to measure the performance of UX with certain UX dimensions. Existing UX studies hold the assumption that need fulfilment could be viewed as a major source of good UX [80]. For example, "making a call" may offer a satisfying experience for a person who likes to contact their friends. Some UX studies also suggested that investigating need fulfilment could be implemented to measure UX and generate UX indicators [49,83,84].

Hence, UX indicators are derived from psychological need-satisfaction items with values indicating satisfactory levels. UX indicators, based on their definitions, can be divided into need fulfilment of the pragmatic quality and hedonic quality of a product. Pragmatic quality refers to the user-perceived ability to achieve the intended action, such as the ability to "reach a destination". Hedonic quality focuses on a higher-level perception. It underlines the pleasures and satisfactions that are bought out by achieving the action. For example, "reach a destination by a luxury car" and "reach a destination by a rusty car" may offer people different levels of satisfaction that result in different hedonic qualities. Following the studies of UX measurement (Section 2.2.2) and based on the scenario of the conceptual design of electronic products, the attributes of UX indicators are derived from the fulfilment of seven psychological needs regarding the pragmatic aspect and hedonic aspect of product quality (Figure 2b). In the evaluation of need fulfilment, users would indicate their satisfaction level of each psychological need. The satisfactory level is then converted to the value of the corresponding UX indicator attribute.

The mapping model is constructed with the input of design specifications and the output of UX indicators. UX indicators could be viewed as the criteria to compare and evaluate design specifications. As UX indicators are not equivalent and make different contributions to the assessment of design specifications, the relationship between design specifications and UX indicators would be non-linear. Additionally, design specifications and UX indicators may contain many attributes resulting in a large variation in data composition. Thus, a relatively large amount of data is required. To increase the efficiency of mapping model construction, pre-processing on reducing data dimensions to identify crucial design variables would be required.

3.2. Implementing the Mapping Model

The second task addresses the implementation of the mapping model constructed in the first task to improve design specifications. Candidates of design specifications are firstly proposed by the design team for improvement. In the activity of establishing design specifications, based on the collected user requirements, the design team lists the idea and marginally acceptable design values for each design specification feature. According to these values, the design team proposes several combinations of design specifications as design specification candidates that would contribute to different potential design concepts.

3.2.1. Evaluating and Selecting Design Specifications

Two scenarios are considered to improve the proposed specifications. The first scenario (Figure 3a) is to evaluate and select the proposed design specifications based on predicted UX indicators. To improve the proposed design specifications, trade-offs would be made between function, usability, and aesthetic specifications. The mapping model could help the design team to make decisions by predicting the user experience of the proposed design specifications. From the mapping model, the corresponding UX indicators of the proposed design specifications could be calculated. The predicted UX indicators could serve as the benchmark for the design team to select the proposed design specifications for further development.

3.2.2. Optimizing Design Specifications

The second scenario (Figure 3b) is to optimize the proposed design specifications that would result in better UX. To accomplish the optimization, genetic algorithm (GA) which is a preferred optimization search tool for design parameter optimization could be used to find the optimal design specification combinations with enhanced UX indicators based on the mapping model. Optimizing design specifications to improve UX is among the more complex nonlinear optimization problems. In recent years, heuristic optimization algorithms have performed very well in solving many complex optimization problems. The optimization process begins with an initial design specification population containing the parameter sets of the proposed design specifications to be improved. On the initial loop of the search, the mapping model is used to generate corresponding UX indicators of the proposed design specifications. The evaluation function is used to evaluate the overall UX performance based on UX indicators. The evaluation function could be determined by the design team to reflect the weighting of each UX indicator. The evaluation results are used to calculate the fitness values for each design specification. The fitness value directs GA to find optimal design specification combinations and determines the probability that a design specification will be selected as a parent for reproduction. After the fitness values of all the initial design specification populations are calculated, GA operators which consist of selection, crossover, and mutation are performed to gradually improve the performance of the population. The optimization process will repeat until a termination condition is satisfied. The termination condition could be a specific number of generations or the minimum amount of change in fitness values from one generation to the next. In this way, the improved design specification combinations could be found with enhanced UX.

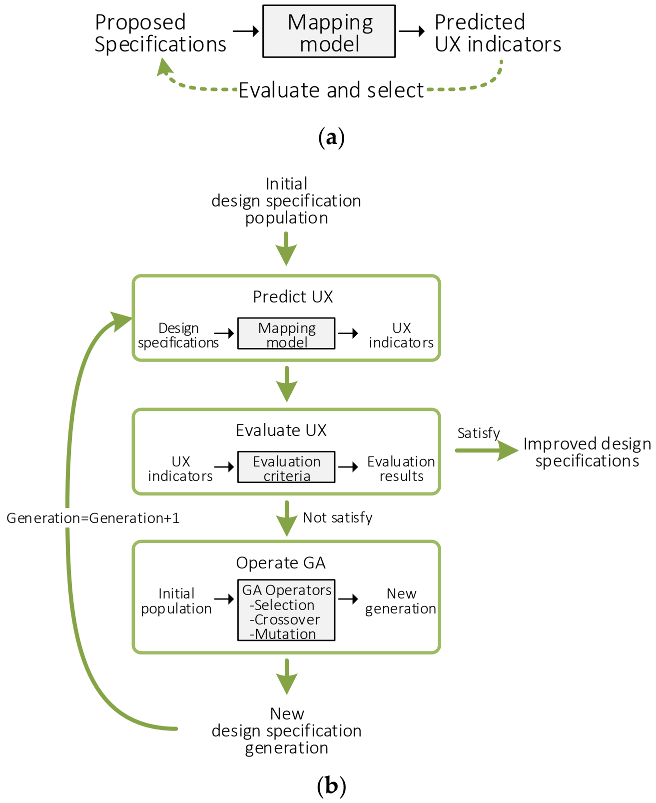


Figure 3. Implementation scenarios of the mapping model. (**a**) Evaluate and select the proposed design specifications. (**b**) Optimize the proposed design specifications.

4. Case Study

In this section, a case study is provided to exam the feasibility of the proposed method for improving design specifications based on UX. The detailed procedure of this case study is presented as follows.

4.1. Problem Statement

The case study was about the conceptual design of the compact digital camera. The goal was to establish improved design specifications of both function, usability, and aesthetics for the compact digital camera design. Based on the proposed method, the first task was to construct the mapping model. The second task was to implement the mapping model, i.e., to improve design specifications with integrated functional and aesthetic information.

4.2. Data Acquisition

To construct the mapping model, the first step was to select design samples and collect data of design specifications and UX indicators. Twenty-eight popular compact digital cameras with various design features were chosen from the market.

The next step was to decide the design attributes of camera design specifications. The main design attributes of function, usability, and aesthetics were determined and are presented in Figure 4. The design values of function and usability specifications were obtained from the camera manufacturer websites. Based on the attributes of function, usability and aesthetics, the values of basic function, secondary function, portability, and display were obtained. To access the aesthetics design specifications, surveys were conducted among users and designers. The user survey aimed to capture user-perceived emotions from product forms. The user survey was conducted online and consisted of an introduction, questions on demographic information and semantic differential scales to investigate user perception of the emotional adjective "Retro". The emotional adjective "Retro", which indicates what the aesthetics style looks like from the recent past, was selected from advertisements and magazines as the emotional adjective. The four views (front, top, left and 3D) of design samples were presented to the participated users. Figure 5 shows the survey question (one question) on "Retro" presented to the participants. Totally, 46 sets of valid data were obtained from the user survey. The designer survey was similar to the user survey for most parts. The difference was that the designer survey aimed to investigate design intentions on applying the aesthetic design principle. The principal attribute "Contrast" means that the juxtaposition of relative different elements to create a visual discord in composition was chosen for evaluating digital cameras. Fifteen designers participated in the survey and eight sets of valid data were collected from them.

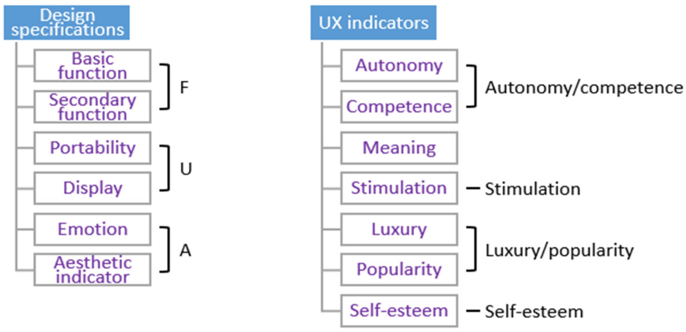


Figure 4. Main attributes of camera design specifications.

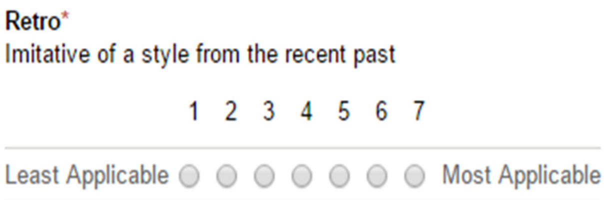


Figure 5. Survey question of "Retro".

To measure UX of selected design samples, the attributes of UX indicators for evaluating the compact digital camera were determined (Figure 4).

To measure the UX of selected design samples, user experience indicators for evaluating digital cameras should be determined. Based on the need-satisfaction items proposed by Sheldon et al. [81] and the camera design scenarios, "Autonomy", "Competence", "Meaning", "Stimulation", "Luxury", "Self-esteem", and "Popularity" were selected as UX indicators. A six-month UX evaluation survey was published on Amazon Mechanical Turk to collect UX metric values for a sample of 28 designs (we prepared 40 design samples but ended up keeping 28 designs because some sample cameras did not receive enough responses). Survey participants were required to have experience with at least one camera from the provided list to be eligible to participate and were asked to respond only to cameras with which they had experience. The survey asked the participants to indicate how they agree that the descriptions of each UX indicator could reflect their own experience of using one of the sample cameras with semantic differential scales. The UX survey for the 28 design samples yielded 300 valid responses. All 300 responses were manually checked to eliminate any obvious errors (e.g., responses where all respondents selected the same option, responses with omitted choices, etc.)

4.3. Mapping Model Construction

4.3.1. Pre-Processing by PCA

After the step of data acquisition, the mapping model was ready to be constructed. The mapping problem is between multiple inputs and outputs among a relatively large number of attributes. Thus, pre-processing for reducing the data dimensions was required in this case study. Principle component analysis (PCA) was frequently used to handle complex multivariate data and provide a compact representation of the data [90]. It obtains a linear combination of attributes (refer to the principal components) with a lower-dimensional space that reveals the data structure. In PCA, data reduction is accomplished by neglecting the less important vector directions in which the variances of the design sample are not significant. In general, PCA could not provide well interpretable components. However, to facilitate the interpretation, rotation of the components could be performed once the number of principal components is decided. Varimax rotation [91,92] is one of the popular rotation methods. It simplifies the interpretation and provides clear insights into how the attributes make up each component. In the case study, PCA with Varimax rotation was implemented to reduce the dimensions of UX indicators. Four principal components that accounted for 90.17% of the design samples' total variance were extracted from UX indicators. Table 1 shows the total variance explained of PCA results of the seven UX indicators. Table 2 illustrates the Varimax rotation results of the four principal components of UX indicators. UX indicator attribute "meaning" which loaded on two components higher than 0.50 without clear primary components was suggested to be removed. Attribute pairs "autonomy and competence" and "luxury and popularity" were found that largely loaded on the second and the first principal components, respectively. They were suggested to be merged into two combined attributes. The final four attributes for UX indicators were "autonomy/competence", "stimulation", "luxury/popularity", and "self-esteem" (Figure 4).

Table 1. Total variance explained of PCA results.

Component	Initial Eigenvalues		
	Total	**% of Variance**	**Cumulative %**
1	3.882	55.458	55.458
2	1.413	20.189	75.647
3	0.616	8.802	84.449
4	0.401	5.723	90.172

Table 2. Varimax rotation results of principal components of UX indicators.

	Component			
	1	**2**	**3**	**4**
Autonomy	0.354	**0.806**	0.246	0.154
Competence	−0.050	**0.895**	0.132	0.307
Meaning	**0.715**	**0.540**	0.023	0.190
Stimulation	0.125	0.424	0.255	**0.840**
Luxury	**0.812**	0.233	0.370	−0.119
Self-esteem	0.305	0.227	**0.869**	0.255
Popularity	**0.915**	−0.072	0.167	0.177

4.3.2. Proposed Model for Construction

Facing the problem of multiple variable modelling, artificial neural networks (NN) are commonly adapted in design studies. It is a well-known data processing system that contains many simple, highly interconnected processing elements which are called neurons in an architecture inspired by the structure of the human brain. As the nature of the neural network in the brain is nonlinear, the NN can be used to derive non-linear mappings between a set of input and output variables. In the case study, considering the relatively large number of input variables, an integrated model using multiple linear superposition and NN was proposed. Figure 6 presents the proposed model for the case study. The input attributes were simplified into 3 variables (F (function), U (usability), and A (aesthetics)) by constructing a multiple linear superposition between F, U, A and their attributes (design specification attributes F1, F2, F3, . . . , U1, U2, U3, . . . , A1, A2, A3, . . .). An NN model was then constructed with the input of F, U, and A and the output of the UX indicators. GA was applied to search for the optimal values of the unknown parameters (a1, a2, a3, . . . , b1, b2, b3, . . . , c1, c2, c3, . . .) in the multiple linear superpositions. In the GA optimization, the mean squared error of the NN model was used to determine the optimal value of the unknown parameters. To avoid the overfitting problem, 3-fold cross-validation (CV) was employed to train the NN model and obtain suitable parameters for the multiple linear superpositions.

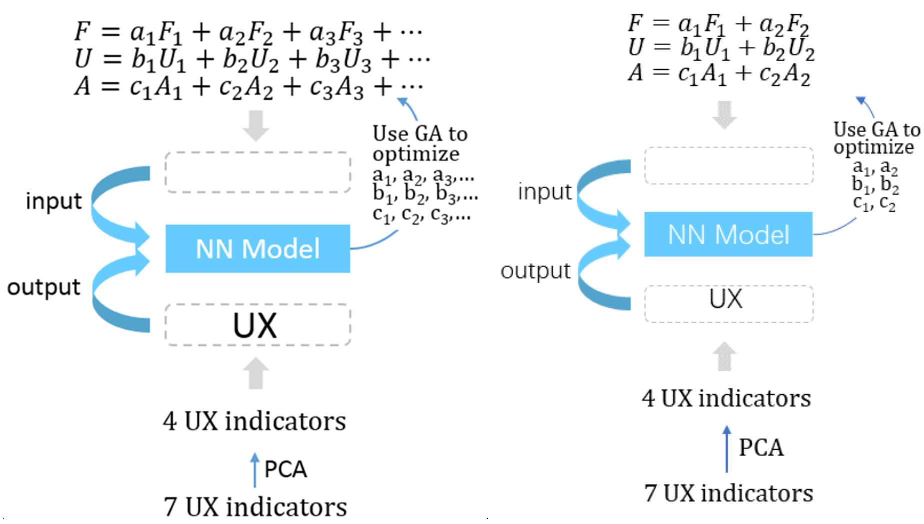


Figure 6. Proposed model with multiple linear superposition and NN.

4.3.3. Experimental Results

The NN model was constructed with two layers. The NN structure was defined to contain three neurons in the input layer, four neurons in the hidden layer, and four neurons in the output layer. The training algorithm was set as Levenberg-Marquardt backpropagation. Figure 7 shows the GA optimization results on selecting the optimal parameters of the multiple linear superposition. Parameters with larger values reflected greater importance of design specification attributes in calculating function, usability, and appearance. For example, “portability” with the parameter value of 0.83 was more important than “display” with the parameter value of 0.17 in determining usability. Based on the optimized parameters of the multiple linear superpositions, the NN model was constructed. To train the NN model, 80% of the total data was defined as the training data and the other 20% data was used as the testing data. The mean squared error of the testing results for the NN model was 0.0687.

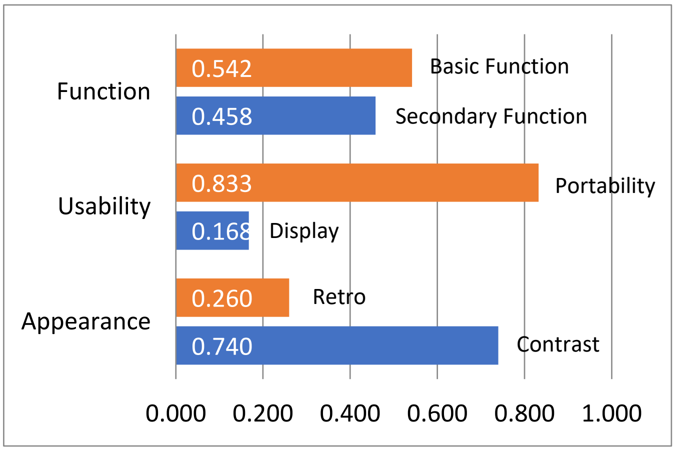


Figure 7. Optimized parameters of multiple linear superposition.

4.4. Mapping Model Implementation

In the case study, two scenarios for implementing the mapping model were presented. The first scenario was to select camera design specifications among three design specification candidates that were proposed by the design team. Table 3 presents the values of the three design specification candidates for selection. From the mapping model, the corresponding UX indicators were predicted and illustrated in Figure 8. Among the three candidates, Candidate 1 had the highest values on "autonomy/competence", "stimulation", "self-esteem", and "average UX (mean value of the four UX indicators)" compared to Candidate 2 and Candidate 3. However, for "luxury/popularity", Candidate 1 had a relatively lower value than Candidate 2. The results suggested that Candidate 1 would result in the best UX performance. However, Candidate 1 needed to be further improved to raise the value on "luxury/popularity".

Table 3. Proposed design specification candidates for selection.

	Basic Function	Secondary Function	Portability	Display	Retro	Contrast
Candidate 1	0.231	0.283	1.000	0.000	0.300	0.607
Candidate 2	0.346	0.914	0.800	1.000	0.524	0.214
Candidate 3	0.398	0.478	0.415	0.000	0.567	0.393

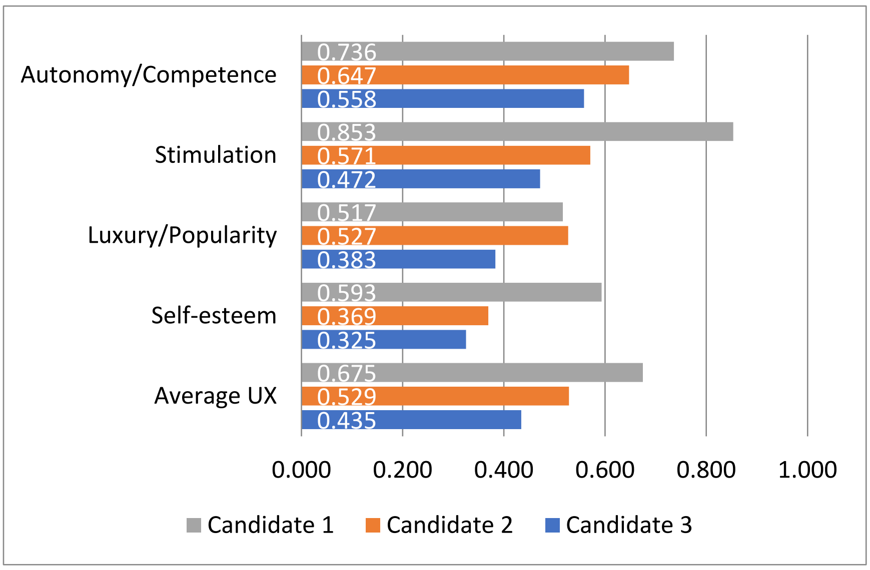


Figure 8. Predicted UX indicators of design specification candidates.

The second scenario was to perform optimization of design specification candidates. Candidate 1 was chosen for further improvement in this scenario. GA was implemented to improve the design specifications of Candidate 1. The search mechanism began with an initial population containing design specification values of Candidate 1. The parameters of GA mainly include selection using stochastic uniform random uniform distribution, crossover using scattered crossover function, and mutation using Gaussian mutation operation. The constructed mapping model (NN model) was applied to evaluate each generated chromosome. The weightings to calculate the fitness value were defined as 0.15, 0.15, 0.4 and 0.3 for UX indicators "autonomy/competence", "stimulation", "luxury/popularity", and "self-esteem" accordingly. GA iterations were then performed. The results of the GA optimization are presented in Figure 9. Based on the improved specifications, the value of "average UX" was increased from 0.675 to 0.787. The value of "luxury/popularity" was increased from 0.517 to 0.641.

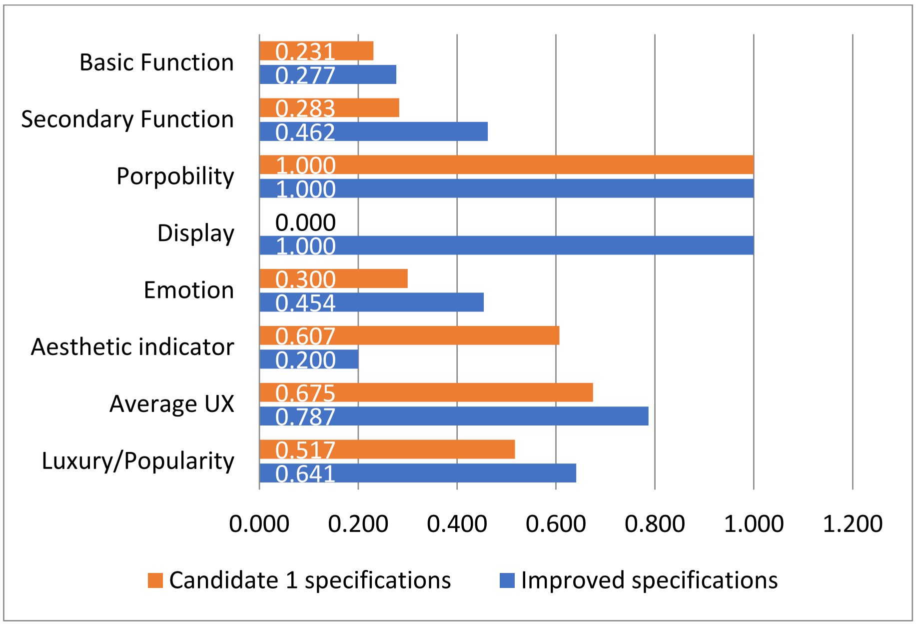


Figure 9. GA optimization results of design specification candidate.

4.5. Discussion

This case study focused on the conceptual design problem of compact digital cameras. In the case study, the proposed approach to improve design specifications with integrated functional and aesthetic information is demonstrated. An integrated model with multiple linear superpositions and NN was proposed to construct the mappings between initial design specifications and UX indicators of cameras. GA was applied to search for the optimal parameters of the multiple linear superpositions. Based on the constructed mapping model, three proposed candidates of camera design specifications were evaluated. One candidate was selected and further improved through GA optimization. The value of "average UX" was increased from 0.675 to 0.787, which proved the improved design specifications were feasible and effective. In addition, we also realized in the case that there are many other algorithms besides GA that can achieve the same purpose, and we will try to use other algorithms for further optimization in the future.

5. Conclusions

In this study, a method was proposed to improve design specifications integrating functional and aesthetic design information based on UX. The method consisted of the development of a mapping model and the implementation of the mapping model. The relationships between initial design specifications including function, usability, and aesthetics and UX were constructed in the mapping model. The implementation of the mapping model included the selection and optimization of proposed design specifications. The proposed method was demonstrated by a camera design case study. The proposed method makes an early attempt to improve design specification with integrated functional and aesthetic information. It combined function, usability, and aesthetic aspect, focusing on both the emotional response and the aesthetic rules of design elements constitution in the aesthetic aspect. The method bridges the gap between UX and conceptual design by applying UX to support establishing design specifications of conceptual design. In future research, studies on the improvement of design concepts such as forms and structures based on UX could be considered.

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References

1. Chakrabarti, A.; Bligh, T.P. An approach to functional synthesis of solutions in mechanical conceptual design. Part I: Introduction and knowledge representation. *Res. Eng. Des.* **1994**, *6*, 127–141. [CrossRef]
2. Dahmus, J.B.; Gonzalez-Zugasti, J.P.; Otto, K.N. Modular product architecture. In Proceedings of the International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Baltimore, MD, USA, 10–13 September 2000; Volume 35142, pp. 225–235.
3. Komoto, H.; Tomiyama, T. A framework for computer-aided conceptual design and its application to system architecting of mechatronics products. *Comput.-Aided Des.* **2012**, *44*, 931–946.
4. Umeda, Y.; Ishii, M.; Yoshioka, M.; Shimomura, Y.; Tomiyama, T. Supporting conceptual design based on the function-behavior-state modeler. *Ai Edam* **1996**, *10*, 275–288.
5. Cao, G.; Sun, Y.; Tan, R.; Zhang, J.; Liu, W. A function-oriented biologically analogical approach for constructing the design concept of smart product in Industry 4.0. *Adv. Eng. Inform.* **2021**, *49*, 101352. [CrossRef]
6. Kelly, J.C.; Maheut, P.; Petiot, J.-F.; Papalambros, P.Y. Incorporating user shape preference in engineering design optimisation. *J. Eng. Des.* **2011**, *22*, 627–650.
7. Orsborn, S.; Cagan, J.; Boatwright, P. Quantifying aesthetic form preference in a utility function. *J. Mech. Des.* **2009**, *131*, 061001. [CrossRef]
8. Fischer, M.S.; Holder, D.; Maier, T. Analysis of Geometric Features of 3D Shapes on Perception of Product Appearance for Visual Brand Affiliation. In Proceedings of the Congress of the International Ergonomics Association, Online, 13–18 June 2021; pp. 31–38.
9. Nagamachi, M. Kansei engineering: A new ergonomic consumer-oriented technology for product development. *Int. J. Ind. Ergon.* **1995**, *15*, 3–11. [CrossRef]
10. Osgood, C.E.; Suci, G.J.; Tannenbaum, P.H. *The Measurement of Meaning*; University of Illinois Press: Champaign, IL, USA, 1957.
11. Kim, N. A history of design theory in art education. *J. Aesthetic Educ.* **2006**, *40*, 12–28. [CrossRef]
12. Kumar, M.; Garg, N. Aesthetic principles and cognitive emotion appraisals: How much of the beauty lies in the eye of the beholder? *J. Consum. Psychol.* **2010**, *20*, 485–494. [CrossRef]
13. Huicong, H.; Wen-Feng, L. Design specification representation for intelligent product appearance design. In Proceedings of the E3S Web of Conferences, Henderson, NV, USA, 17–21 May 2020; p. 02004.
14. Liang, L. Research on Educational Practice of Innovative Packaging Structure Design. In Proceedings of the 4th International Conference on Culture, Education and Economic Development of Modern Society (ICCESE 2020), Moscow, Russia, 13–14 March 2020; pp. 1034–1040.
15. Wallschlaeger, C.; Busic-Snyder, C.; Morgan, M. *Basic Visual Concepts and Principles for Artists, Architects, and Designers*; Wm. C. Brown Publishers: Dubuque, IA, USA, 1992.
16. Teng, J.; Wang, X.; Lu, K.; Qiao, X.; Hao, N. Domain-specific and Domain-general Creativity Differences between Expert and Novice Designers. *Creat. Res. J.* **2021**, *34*, 55–67.
17. Alben, L. Quality of experience: Defining the criteria for effective interaction design. *Interactions* **1996**, *3*, 11–15. [CrossRef]
18. McNamara, N.; Kirakowski, J. Functionality, usability, and user experience: Three areas of concern. *Interactions* **2006**, *13*, 26–28.

19. Berni, A.; Borgianni, Y. From the definition of user experience to a framework to classify its applications in design. *Proc. Des. Soc.* **2021**, *1*, 1627–1636. [CrossRef]
20. Renaud, J.; Houssin, R.; Gardoni, M.; Armaghan, N. Product manual elaboration in product design phases: Behavioral and functional analysis based on user experience. *Int. J. Ind. Ergon.* **2019**, *71*, 75–83.
21. Gross, A.; Bongartz, S. Why do I like it? Investigating the product-specificity of user experience. In Proceedings of the 7th Nordic Conference on Human-Computer Interaction: Making Sense Through Design, Copenhagen, Denmark, 14–17 October 2012; pp. 322–330.
22. Park, J.; Han, S.H.; Kim, H.K.; Oh, S.; Moon, H. Modeling user experience: A case study on a mobile device. *Int. J. Ind. Ergon.* **2013**, *43*, 187–196.
23. Shin, D.; Zhong, B.; Biocca, F.A. Beyond user experience: What constitutes algorithmic experiences? *Int. J. Inf. Manag.* **2020**, *52*, 102061.
24. Ulrich, K.T. *Product Design and Development*; Tata McGraw-Hill Education: Columbus, OH, USA, 2003.
25. Matzler, K.; Hinterhuber, H.H.; Bailom, F.; Sauerwein, E. How to delight your customers. *J. Prod. Brand Manag.* **1996**, *5*, 6–18. [CrossRef]
26. Shi, Y.; Peng, Q. Enhanced customer requirement classification for product design using big data and improved Kano model. *Adv. Eng. Inform.* **2021**, *49*, 101340.
27. Ishak, A.; Ginting, R.; Suwandira, B.; Malik, A.F. Integration of Kano Model and Quality Function Deployment (QFD) to Improve Product Quality: A Literature Review. In Proceedings of the IOP Conference Series: Materials Science and Engineering, Medan, Indonesia, 3–4 September 2020; p. 012025.
28. Kang, X.; Qu, M. Multi-Kansei Qualities Optimization Design of Products Combined with Refined Kano Model and QFD. *Comput.-Aided Des. Appl.* **2021**, *18*, 954–969.
29. Liu, H.; Ren, Z.; Li, Y. Research on the Evaluation of Customer requirement Importance of Smart Products Based on Online Comments and Improved Quantitative Kano Model. *CONVERTER* **2021**, *2021*, 382–392.
30. Hauser, J.R.; Clausing, D. The house of quality. *Harv. Bussines Rev.* **1988**, 63–73.
31. Kang, X. Aesthetic product design combining with rough set theory and fuzzy quality function deployment. *J. Intell. Fuzzy Syst.* **2020**, *39*, 1131–1146. [CrossRef]
32. Holtzblatt, K.; Beyer, H. *Contextual Design: Defining Customer-Centered Systems*; Elsevier: Amsterdam, The Netherlands, 1997.
33. Barone, S.; Lombardo, A.; Tarantino, P. A weighted logistic regression for conjoint analysis and Kansei engineering. *Qual. Reliab. Eng. Int.* **2007**, *23*, 689–706. [CrossRef]
34. Aydin, N.; Seker, S. Assessing Customer Preferences on a New Design of Refrigerator Using Conjoint Analysis. In *Customer Oriented Product Design*; Springer: Cham, Switzerland, 2020; pp. 417–428.
35. Backhaus, K.; Erichson, B.; Gensler, S.; Weiber, R.; Weiber, T. Conjoint Analysis. In *Multivariate Analysis*; Springer: Berlin/Heidelberg, Germany, 2021; pp. 531–598.
36. Nagamachi, M. Kansei engineering as a powerful consumer-oriented technology for product development. *Appl. Ergon.* **2002**, *33*, 289–294. [CrossRef]
37. Ismail, N.N.N.N.; Lokman, A.M. Kansei engineering implementation in web-based systems: A review study. In Proceedings of the International Conference on Kansei Engineering & Emotion Research, Tokyo, Japan, 7–9 September 2020; pp. 66–76.
38. Chen, C.-C.; Chuang, M.-C. Integrating the Kano model into a robust design approach to enhance customer satisfaction with product design. *Int. J. Prod. Econ.* **2008**, *114*, 667–681. [CrossRef]
39. Smith, G.C.; Smith, S. Latent Semantic Engineering–A new conceptual user-centered design approach. *Adv. Eng. Inform.* **2012**, *26*, 456–473. [CrossRef]
40. Huang, Y.; Chen, C.-H.; Khoo, L.P. Products classification in emotional design using a basic-emotion based semantic differential method. *Int. J. Ind. Ergon.* **2012**, *42*, 569–580. [CrossRef]
41. Yang, C.-C.; Shieh, M.-D. A support vector regression based prediction model of affective responses for product form design. *Comput. Ind. Eng.* **2010**, *59*, 682–689. [CrossRef]
42. Hartono, M. The modified Kansei Engineering-based application for sustainable service design. *Int. J. Ind. Ergon.* **2020**, *79*, 102985.
43. Jiang, H.; Kwong, C.K.; Liu, Y.; Ip, W. A methodology of integrating affective design with defining engineering specifications for product design. *Int. J. Prod. Res.* **2015**, *53*, 2472–2488.
44. Guthier, B.; Dörner, R.; Martinez, H.P. Affective computing in games. In *Entertainment Computing and Serious Games*; Springer: Berlin/Heidelberg, Germany, 2016; pp. 402–441.
45. Zhou, F.; Kong, S.; Fowlkes, C.C.; Chen, T.; Lei, B. Fine-grained facial expression analysis using dimensional emotion model. *Neurocomputing* **2020**, *392*, 38–49. [CrossRef]
46. Hsiao, S.-W.; Chiu, F.-Y.; Chen, C.S. Applying aesthetics measurement to product design. *Int. J. Ind. Ergon.* **2008**, *38*, 910–920. [CrossRef]
47. Zhou, F.; Ji, Y.; Jiao, R.J. Affective and cognitive design for mass personalization: Status and prospect. *J. Intell. Manuf.* **2013**, *24*, 1047–1069. [CrossRef]
48. Ralls, K. But is it Science? *Conserv. Biol.* **1995**, *9*, 983–984. [CrossRef] [PubMed]
49. Köhler, W. *Gestalt Psychology: An Introduction to New Concepts in Modern Psychology*; WW Norton & Company: New York, NY, USA, 1970; Volume 18.

50. Dresp-Langley, B.; Reeves, A. Color for the perceptual organization of the pictorial plane: Victor Vasarely's legacy to Gestalt psychology. *Heliyon* **2020**, *6*, e04375. [CrossRef] [PubMed]
51. Katz, D. *Gestalt Psychology: Its Nature and Significance*; Ronald Press: New York, NY, USA, 1950.
52. Chang, D.; Nesbitt, K.V. Identifying commonly-used gestalt principles as a design framework for multi-sensory displays. In Proceedings of the 2006 IEEE International Conference on Systems, Man and Cybernetics, Taipei, Taiwan, 8–11 October 2006; pp. 2452–2457.
53. Steiner, C.M.; Nussbaumer, A.; Neville, K.; Albert, D. A psychological framework to enable effective cognitive processing in the design of emergency management information systems. *Electron. J. Inf. Syst. Eval.* **2017**, *20*, 39–54.
54. Stebbing, P.D. A universal grammar for visual composition? *Leonardo* **2004**, *37*, 63–70. [CrossRef]
55. Organización Internacional de Normalización. *Ergonomics of Human-System Interaction: Human-Centred Design for Interactive Systems*; ISO: Geneva, Switzerland, 2010.
56. Law, E.L.-C.; Van Schaik, P. Modelling user experience–An agenda for research and practice. *Interact. Comput.* **2010**, *22*, 313–322. [CrossRef]
57. González-Pérez, L.I.; Ramírez-Montoya, M.-S.; García-Peñalvo, F. User experience in institutional repositories: A systematic literature review. In Digital Libraries Institutional Repositories: Breakthroughs in Research Practice; edited by Information Resources Management Association, IGI Global, 2020. pp. 423–440. Available online: https://repositorio.grial.eu/bitstream/grial/1062/1/garcia-penalvo%20article%20IJHCITP%209%281%29-RepositoryAuthorizedVersion.pdf (accessed on 24 August 2022).
58. Hassenzahl, M.; Tractinsky, N. User experience-a research agenda. *Behav. Inf. Technol.* **2006**, *25*, 91–97. [CrossRef]
59. Crilly, N.; Moultrie, J.; Clarkson, P.J. Seeing things: Consumer response to the visual domain in product design. *Des. Stud.* **2004**, *25*, 547–577. [CrossRef]
60. Benyon, D. *Designing User Experience*; Pearson: London, UK, 2019.
61. Law, E.L.-C.; Roto, V.; Hassenzahl, M.; Vermeeren, A.P.; Kort, J. Understanding, scoping and defining user experience: A survey approach. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Boston, MA, USA, 4–9 April 2009; pp. 719–728.
62. Park, J.; Han, S.H.; Kim, H.K.; Cho, Y.; Park, W. Developing elements of user experience for mobile phones and services: Survey, interview, and observation approaches. *Hum. Factors Ergon. Manuf. Serv. Ind.* **2013**, *23*, 279–293. [CrossRef]
63. Battarbee, K.; Koskinen, I. Co-experience: User experience as interaction. *CoDesign* **2005**, *1*, 5–18. [CrossRef]
64. Yang, B.; Liu, Y.; Liang, Y.; Tang, M. Exploiting user experience from online customer reviews for product design. *Int. J. Inf. Manag.* **2019**, *46*, 173–186. [CrossRef]
65. Lewis, J.R.; Sauro, J. Usability and user experience: Design and evaluation. In *Handbook of Human Factors Ergonomics*; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2021; pp. 972–1015.
66. Guerino, G.C.; Valentim, N.M.C. Usability and user experience evaluation of conversational systems: A systematic mapping study. In Proceedings of the 34th Brazilian Symposium on Software Engineering, Natal, Brazil, 21–23 October 2020; pp. 427–436.
67. Kujala, S.; Roto, V.; Väänänen-Vainio-Mattila, K.; Karapanos, E.; Sinnelä, A. UX Curve: A method for evaluating long-term user experience. *Interact. Comput.* **2011**, *23*, 473–483. [CrossRef]
68. Liang, Y.; Liu, Y.; Loh, H.T. Exploring online reviews for user experience modeling. In Proceedings of the 19th International Conference on Engineering Design (ICED13), Design for Harmonies, Vol. 7: Human Behaviour in Design, Seoul, Korea, 19–22 August 2013; pp. 237–246.
69. Xu, Q.; Zhou, F. Affective-cognitive modeling for user experience with modular colored fuzzy petri nets. *J. Comput. Inf. Sci. Eng.* **2011**, *11*, 011004. [CrossRef]
70. Law, E.L.-C. The measurability and predictability of user experience. In Proceedings of the 3rd ACM SIGCHI Symposium on Engineering Interactive Computing Systems, Pisa, Italy, 13–16 June 2011; pp. 1–10.
71. Staiano, J.; Menéndez, M.; Battocchi, A.; De Angeli, A.; Sebe, N. UX_Mate: From facial expressions to UX evaluation. In Proceedings of the Designing Interactive Systems Conference, Newcastle Upon Tyne, UK, 11–15 June 2012; pp. 741–750.
72. Bargas-Avila, J.A.; Hornbæk, K. Old wine in new bottles or novel challenges: A critical analysis of empirical studies of user experience. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Vancouver, BC, Canada, 7–12 May 2011; pp. 2689–2698.
73. Souza, K.E.; Seruffo, M.C.; De Mello, H.D.; Souza, D.d.S.; Vellasco, M.M. User experience evaluation using mouse tracking and artificial intelligence. *IEEE Access* **2019**, *7*, 96506–96515. [CrossRef]
74. Čegan, L.; Filip, P. Advanced web analytics tool for mouse tracking and real-time data processing. In Proceedings of the 2017 IEEE 14th International Scientific Conference on Informatics, Poprad, Slovakia, 14–16 November 2017; pp. 431–435.
75. Javahery, H.; Deichman, A.; Seffah, A.; Taleb, M. A user-centered framework for deriving a conceptual design from user experiences: Leveraging personas and patterns to create usable designs. In *Human-Centered Software Engineering*; Springer: Berlin/Heidelberg, Germany, 2009; pp. 53–81.
76. Vermeeren, A.P.; Law, E.L.-C.; Roto, V.; Obrist, M.; Hoonhout, J.; Väänänen-Vainio-Mattila, K. User experience evaluation methods: Current state and development needs. In Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries, Reykjavik, Iceland, 16–20 October 2010; pp. 521–530.
77. Märtin, C.; Bissinger, B.C.; Asta, P. Optimizing the digital customer journey—Improving user experience by exploiting emotions, personas and situations for individualized user interface adaptations. *J. Consum. Behav.* **2021**. [CrossRef]

78. Hassenzahl, M. Experience design: Technology for all the right reasons. *Synth. Lect. Hum. -Cent. Inform.* **2010**, *3*, 1–95.
79. Hassenzahl, M.; Monk, A. The inference of perceived usability from beauty. *Hum. –Comput. Interact.* **2010**, *25*, 235–260. [CrossRef]
80. Hassenzahl, M.; Diefenbach, S.; Göritz, A. Needs, affect, and interactive products–Facets of user experience. *Interact. Comput.* **2010**, *22*, 353–362. [CrossRef]
81. Sheldon, K.M.; Elliot, A.J.; Kim, Y.; Kasser, T. What is satisfying about satisfying events? Testing 10 candidate psychological needs. *J. Personal. Soc. Psychol.* **2001**, *80*, 325. [CrossRef]
82. Körber, M.; Eichinger, A.; Bengler, K.; Olaverri-Monreal, C. User experience evaluation in an automotive context. In Proceedings of the 2013 IEEE Intelligent Vehicles Symposium Workshops (IV Workshops), Gold Coast, QLD, Australia, 23–23 June 2013; pp. 13–18.
83. Laugwitz, B.; Held, T.; Schrepp, M. Construction and Evaluation of a User Experience Questionnaire. In *HCI and Usability for Education and Work*; Holzinger, A., Ed.; USAB 2008. Lecture Notes in Computer Science; Springer: Berlin/Heidelberg, Germany, 2008; Volume 5298.
84. Schrepp, M.; Hinderks, A.; Thomaschewski, J. Applying the user experience questionnaire (UEQ) in different evaluation scenarios. In Proceedings of the International Conference of Design, User Experience, and Usability, Heraklion, Greece, 22–27 June 2014; pp. 383–392.
85. Klein, A.M.; Hinderks, A.; Schrepp, M.; Thomaschewski, J. Measuring User Experience Quality of Voice Assistants Voice Communication Scales for the UEQ+ Framework: Voice Communication Scales for the UEQ+ Framework. In Proceedings of the 2020 15th Iberian Conference on Information Systems and Technologies (CISTI), Seville, Spain, 24–27 June 2020; pp. 1–4.
86. Paramitha, A.I.I.; Dantes, G.R.; Indrawan, G. The evaluation of web based academic progress information system using heuristic evaluation and user experience questionnaire (UEQ). In Proceedings of the 2018 Third International Conference on Informatics and Computing (ICIC), Palembang, Indonesia, 17–18 October 2018; pp. 1–6.
87. Minge, M.; Thüring, M.; Wagner, I.; Kuhr, C.V. The meCUE questionnaire: A modular tool for measuring user experience. In *Advances in Ergonomics Modeling, Usability & Special Populations*; Springer: Berlin/Heidelberg, Germany, 2017; pp. 115–128.
88. De Angeli, A.; Sutcliffe, A.; Hartmann, J. Interaction, usability and aesthetics: What influences users' preferences? In Proceedings of the 6th Conference on Designing Interactive Systems, University Park, PA, USA, 26–28 June 2006; pp. 271–280.
89. Lee, S.; Koubek, R. Users' perceptions of usability and aesthetics as criteria of pre-and post-use preferences. *Eur. J. Ind. Eng.* **2012**, *6*, 87–117. [CrossRef]
90. Naik, G.R. *Advances in Principal Component Analysis: Research and Development*; Springer: Berlin/Heidelberg, Germany, 2017.
91. Kaiser, H.F. The varimax criterion for analytic rotation in factor analysis. *Psychometrika* **1958**, *23*, 187–200. [CrossRef]
92. Acal, C.; Aguilera, A.M.; Escabias, M.J.M. New modeling approaches based on varimax rotation of functional principal components. *Mathematics* **2020**, *8*, 2085. [CrossRef]