Advanced Engineering Informatics 30 (2016) 1–15

Contents lists available at ScienceDirect

Advanced Engineering Informatics

journal homepage: www.elsevier.com/locate/aei

A Kansei evaluation approach based on the technique of computing with words

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ARTICLE INFO

Article history:
Received 29 March 2015
Received in revised form 11 October 2015
Accepted 5 November 2015
Available online 30 November 2015

Keywords:
Kansei evaluation
Preference modeling
Kansei clustering
Linguistic aggregation
Computing with words

ABSTRACT

Kansei evaluation plays a vital role in the implementation of Kansei engineering; however, it is difficult to quantitatively evaluate customer preferences of a product's Kansei attributes as such preferences involve human perceptual interpretation with certain subjectivity, uncertainty, and imprecision. An effective Kansei evaluation requires justifying the classification of Kansei attributes extracted from a set of collected Kansei words, establishing priorities for customer preferences of product alternatives with respect to each attribute, and synthesizing the priorities for the evaluated alternatives. Moreover, psychometric Kansei evaluation systems essentially require dealing with Kansei words. This paper presents a Kansei evaluation approach based on the technique of computing with words (CWW). The aims of this study were (1) to classify collected Kansei words into a set of Kansei attributes by using cluster analysis based on fuzzy relations; (2) to model Kansei preferences based on semantic labels for the priority analysis; and (3) to synthesize priority information and rank the order of decision alternatives by means of the linguistic aggregation operation. An empirical study is presented to demonstrate the implementation process and applicability of the proposed Kansei evaluation approach. The theoretical and practical implications of the proposed approach are also discussed.

1. Introduction

Successful new products contribute to financial and market performance measures and open up new opportunities for business. In today's highly competitive and uncertain market environment characterized by short product life cycles, new product strategies have transformed from a product-push type to a market-pull model [1]. Companies must develop every aspect of product quality to satisfy customer requirements and maintain market success. Previous research has argued that a better understanding of the process that designers use to incorporate customer requirements into a product design is needed [2]. However, customer requirements and preferences for a product often vary. More specifically, different groups of customers have different requirements, and even customers in the same target group frequently have distinct preferences. Customer preference is often referred to as the degree to which an individual likes a product, and is considered a psychological construct that might be composed of perceptive, affective, and behavioral dimensions [3]. Consequently, it is a challenge for companies to devise ways to identify and measure the elements of such preference decisions with any accuracy and reliability [4]. Further confounding this challenge, the psychological preferences a customer responds to are conceptually vague with uncertainty determined by his/her inner perceptions and frequently presented in linguistic forms. However, perceptions are not readily observable using external tools, and so how to precisely extract preference patterns from linguistic data as well as objectively evaluate such data is an important issue for both academia and industry.

The term "Kansei" is a Japanese word that covers the meanings of sensibility, impression, and emotion. It is related to a customer's physiological and psychological feelings and refers to the cognitive processes of human perception. Kansei engineering has been developed as a consumer-oriented technique to better understand customers' emotional responses and further translate them into the design elements of a product [5]. This technology has been widely employed in various design fields over the past few decades [6–8]. Kansei evaluation is an important step in determining and substantiating the degree of customer preferences prior to the utilization and application of Kansei engineering. Many studies have conducted Kansei evaluation in which statistical analysis associated with the semantic differential (SD) method is widely employed to quantify human perception and establish an understanding of Kansei preferences [9–12]. Conventional statistical

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http://dx.doi.org/10.1016/j.aei.2015.11.001
1474-0346/

analysis methods used with Kansei evaluation (e.g., correlation coefficient analysis, principal component analysis, factor analysis, and multiple regression analysis) assume that customer preferences increase or decrease linearly as improving or worsening product attributes. However, in many cases, these preferences can be a non-linear pattern due to uncertain, imprecise, or incomplete data caused by human error, recording error, or arbitrary guesses which may ultimately yield unreliable results. This non-linear behavior requires specific analytical techniques to identify the different effects that variations in Kansei attributes may have on customer preferences. To deal with the quantitative measures of perceptual information, a number of non-linear inference techniques have been developed and employed for modeling Kansei evaluation systems, including neural networks [13,14], fuzzy logic [15–17], and genetic algorithms [18–20].

Kansei evaluation is a systematic determination of customer preference significance using criteria against a set of Kansei attributes, where Kansei attributes refer to the criteria of emotional connotations. In practice, Kansei evaluation consists of three main operations, namely attribute classification, preference modeling, and priority analysis. A basic principle in Kansei evaluation is that valid results depend on justifying the classification of Kansei attributes extracted from a set of collected Kansei words, establishing priorities for the customer preferences of product alternatives with respect to each attribute, and synthesizing the priorities for the evaluated alternatives. Previous research has indicated that the main problem in constructing customer preference models with good predictive performance is how to deal with the inherent non-linear correlations between product attributes [15]. Kansei preferences refer to a non-quantifiable, subjective, and affective-based process involving the human perceptual interpretation of Kansei responses, which inevitably involves some imprecision or vagueness in terms of individual perceptual confidence. For example, the perceptual intensity of "very comfortable" is more than that of "comfortable", but by how much is unknown. Moreover, respondent bias occurs when customers are unable or unwilling to provide accurate answers in a Kansei evaluation survey. Fortunately, fuzzy set theory offers a powerful tool to deal with concepts and rules with uncertainty, imprecision, and non-linearity. This theory is based on the premise that the key points in human thinking are not numbers, but linguistic terms or labels of fuzzy sets [21]. Fuzzy logic incorporating computing with words (CWW) involves computers being activated by words, which are converted into a mathematical representation using fuzzy sets. These fuzzy sets are then mapped by means of a CWW engine into another fuzzy set, after which the latter is converted back into a word [22]. Over the last decade, CWW has been regarded as a very flexible technique for dealing with decision-making problems and evaluating human perceptions, and many different approaches for CWW using fuzzy sets have been proposed and used in the literature [23–28]. According to Wang and Hao [29], these approaches can be classified into three categories: (1) the Extension Principle based models, which operate on the underlying fuzzy set models of the linguistic terms using the Extension Principle [30]; (2) the symbolic model, which makes computations on the indices of the linguistic terms; and, (3) the 2-tuple representation based model, which is an improvement over the symbolic model. Franco et al. [24] indicated that CWW explores the brain's ability to handle and evaluate perceptions by means of the linguistic representation of information and knowledge. It can be used as a paradigm for developing reasoning mechanisms to improve solving processes of perception-based problems dealing with uncertainty, imprecision, and subjective vagueness [31–33]. The CWW paradigm deals with Kansei preferences through qualitative semantics instead of numbers. For Kansei evaluation situations in which customer preferences cannot be assessed precisely in a quantitative manner but can be approximated via a qualitative one, the use of the CWW paradigm is very appropriate.

With regard to existing Kansei evaluation approaches, Huang et al. [34] proposed a Kansei clustering method for Kansei attribute classification that combines the design/dependency structure matrix (DSM) with Pearson correlation analysis to measure the perceptual similarity of customers between the meanings of Kansei words. However, their method does not provide internal consistency verification for the customers' Kansei correlation matrix and also requires a heavy cognitive load to manage Kansei subsets. Although most Kansei evaluation studies have used quantification theory type I (QT1) to synthesize Kansei priority information [35], there are clear statistical limitations that can influence the synthesis results [18,36]. Based on the multi-attribute fuzzy target-oriented decision analysis, Yan et al. [17] proposed a Kansei evaluation model to improve the strength of Kansei evaluation systems. Their model uses a prioritized aggregation operator to aggregate the partial degrees of satisfaction for the evaluated alternatives. However, the prioritized aggregation includes three complex calculation processes for priority analysis and the OWA-based operator is a scoring type that focuses on the aggregation of crisp numbers rather than fuzzy numbers. Zhou et al. [37] argued that fuzzy numbers provide an efficient way of knowledge representation and can be applied to human preference modeling using linguistic terms. Accordingly, this paper presents a Kansei evaluation approach based on the CWW technique. The aims of this study were (1) to classify collected Kansei words into a set of Kansei attributes by using cluster analysis based on fuzzy relations; (2) to model Kansei preferences based on semantic labels for the priority analysis; and, (3) to synthesize priority information and rank the order of decision alternatives by means of a linguistic aggregation operation. This approach can be used to assist evaluators in assessing customer Kansei preferences of a product. The remainder of this paper is organized as follows. Section 2 introduces the theoretical fundamentals of Kansei preference modeling, Kansei clustering, and linguistic aggregation. Section 3 describes the proposed Kansei evaluation approach, while Section 4 presents an empirical study to demonstrate the implementation process and applicability of the proposed approach. A discussion is given in Section 5 and conclusions and recommendations for further research are offered in Section 6.

2. Theoretical fundamentals

In this section, some important fundamentals used in the proposed approach (see Section 3) are addressed. These fundamentals include Kansei preference modeling for the priority analysis, Kansei clustering for classifying collected Kansei words into a set of Kansei attributes, and linguistic aggregation for synthesizing Kansei priority information.

2.1. Kansei preference modeling

Kansei preferences are defined as customer preferences on a specific Kansei attribute of a product. In modeling such preferences, respondents are customarily asked in a questionnaire to indicate their appropriate choices from a set of self-report inventories. Likert-based and semantic differential-based scorings are two commonly used scales to quantify human perceptual interpretations. A Kansei attribute refers to a criterion of emotional connotation (e.g., elegant-positive feeling or inelegant-negative feeling) associated with different levels of intensity descriptors (e.g., very inelegant, inelegant, neutral, elegant, and very elegant) for quantifying customer preferences. To quantify Kansei preferences, the semantic differential (SD) method is often used. An SD consists of