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A linguistic representation based approach to modelling Kansei data and its application to consumer-oriented evaluation of traditional products

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A B S T R A C T

This paper aims at introducing a new method for Kansei data modelling, which is basically based on the linguistic interpretation of Kansei data and the probabilistic semantics of fuzzy sets. We first interpret a semantic differential scale used in Kansei experiment as a linguistic variable and then propose a new method of how the Kansei value of products can be represented as a probability distribution on the set of Kansei linguistic labels of the linguistic variable. We further extend this Kansei data modelling approach to the cases where the Kansei value is imprecisely given as an interval or a fuzzy number. Furthermore, the proposed approach for modelling Kansei data will be used to develop a target-based model for consumer-oriented evaluation. Finally, a case study for consumer-oriented evaluation of hand-painted Kutani cups, a traditional product in Ishikawa, Japan, is conducted to show the applicability of the proposed Kansei data modelling approach.

1. Introduction

Kansei engineering (KE) has been developed as a new product development methodology to "translate the technology of a consumer's feeling and image for a product into the design elements of the product" [26], and successfully applied to a variety of industries [32]. Kansei is a Japanese term reflecting a multifaceted expression that is closely connected to Japanese culture and so has no direct corresponding word in English or other languages. As quoted from [31], Kansei is an individual subjective impression from a certain artifact, environment or situation using all senses of *sight, hearing, feeling, smell, taste* [and *sense of balance*] as well as their *recognition*.

Typically, the main aim of KE is to develop new product prototypes that generate specific aesthetics of products so as to improve their attractiveness. It usually utilizes multivariate analysis techniques, such as principal component analysis and regression analysis, in order to discover the relationships between design elements (physical attributes, e.g., size and shape) and Kansei attributes (bipolar pairs of Kansei words). It has also been shown in many studies of *Kansei design* [5,20,35,40,41] that the aesthetic quality of a design can greatly enhance the desirability of a product and influence consumer satisfaction in terms of perceived product quality. Simultaneously, from the viewpoint of consumers, it is also important for them to care about the aesthetic aspect of products when making their purchasing decisions. Therefore, it is necessary to develop *consumer-oriented Kansei evaluation* [12] that aims at capturing consumers' Kansei preferences in support of their decision making. In practice, purchase decisions are sometimes made by consumers according to their Kansei preferences toward products, therefore such an evaluation will be helpful for the purposes of marketing and recommendation [15,19,38,39]. In a broader context, recommender systems have been widely applied in e-commerce applications [3,8,42], and the Kansei evaluation method proposed in this research could be also applied in the development of fuzzy linguistic recommender systems [14,21] for traditional products.

In research of Kansei engineering and evaluation, a Kansei experiment is usually conducted in advance to build the Kansei database of products in which products are assessed according to a predefined set of their Kansei attributes from a population of subjects, typically by means of the semantic differential (SD) method [29]. The Kansei database is then used to generate so-called *Kansei*

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profiles of products [12,31,38,39], which will eventually serve as the knowledge for the purpose of Kansei design or consumer-oriented evaluation. Basically, there are two main approaches to modeling Kansei data for generating Kansei profiles. In many KE studies, especially where statistical analysis techniques are employed, Kansei data is usually treated as numerical data in which Kansei judgement is viewed as a crisp score and the average of scores given by a population of subjects is defined as Kansei profile of products [4,16,19,27,35]. Alternatively, the authors in [38] and [12] have recently proposed a voting statistics based approach to generating Kansei profiles in which Kansei judgment is viewed as categorical data. It is worth noting here that both the mentioned approaches of Kansei data modelling do not take the fuzziness inherent in Kansei attributes into account.

So far, numerous fuzzy linguistic approaches have been developed for dealing with linguistic information in decision making [6,25,33,45]. In this paper, in order to capture fuzziness inherent in human judgments regarding Kansei attributes due to their qualitative and ambiguous nature, we first propose a new linguistic representation approach to modelling Kansei data based on the linguistic interpretation of Kansei data and the probabilistic semantics of fuzzy sets. Then, we introduce a method for generating Kansei profiles of products making use of the proposed approach of Kansei data modelling. Eventually, this newly introduced method for generating Kansei profiles is integrated into the target-based decision model in order to develop a consumer-oriented evaluation model for personalized recommendation in traditional products.

The rest of the paper is organized as follows. Section 2 briefly presents the necessary and preparatory Kansei experiment in KE studies. Based on a linguistic interpretation of Kansei data, Section 3 proposes a new approach to generating Kansei profiles involving the partial semantic overlapping of Kansei judgments, which are represented as probability distributions on the set of Kansei linguistic labels. Section 4 presents a target based model for consumer-oriented evaluation problem based on the proposed Kansei data modelling approach and target-based decision analysis. In Section 5, a case study for evaluation of hand-painted Kutani cups, a traditional product of Ishikawa prefecture, Japan, is conducted to illustrate the applicability of the developed approach and evaluation model. Finally, some concluding remarks are given in Section 6.

2. Kansei experiment

The first step in Kansei experiment is to select a product domain and collect product samples, which are representative experimental samples representing the product domain. Depending on particular product domain, the number of product samples can vary from 15 to 112, e.g., [7,16,19,30,40,43]. Let $\mathcal{O} = \{O_1, O_2, \dots, O_M\}$ be a set of representative products to be evaluated.

The next step is to identify Kansei attributes which are often used by people to express their psychological feelings of products. Usually, Kansei attributes are identified by a panel of experts who are familiar with KE and the product domain via a brainstorming process [31]. In our research each Kansei attribute is defined as a bipolar pair of (adjectival) Kansei words as done in [12]. In particular, let $\mathcal{A} = \{A_1, A_2, \dots, A_N\}$ be the set of Kansei attributes, in which each Kansei attribute A_n is defined by a bipolar pair of opposing Kansei words, denoted by $< \mathbf{w}_n^-, \mathbf{w}_n^+ >$. For example the Kansei attribute of *fun* determines the pair of Kansei words of *solemn* and *funny*. Also, let us denote $\mathbf{W}$ the set of all bipolar pairs of Kansei words, i.e. $\mathbf{W} = \{< \mathbf{w}_n^-, \mathbf{w}_n^+ > | n = 1, \dots, N\}$.

Having determined the set of Kansei attributes, the semantic differential (SD) method [29] is then used to design a questionnaire consisting of listing N Kansei attributes, each of which corresponds to a bipolar pair of Kansei words with a G-point qualitative

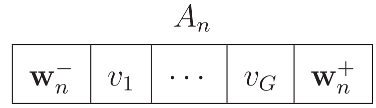

Fig. 1. Qualitative G-point scale for gathering Kansei data.

Table 1
Kansei database of product O_m on N Kansei attributes.

Subjects E	Kansei attributes $\mathcal{A}$			
	A_1	A_2	…	A_N
e_1	$x_m^1(e_1)$	$x_m^2(e_1)$	…	$x_m^N(e_1)$
e_2	$x_m^1(e_2)$	$x_m^2(e_2)$	…	$x_m^N(e_2)$
⋮	⋱	⋮	⋱	⋮
e_K	$x_m^1(e_K)$	$x_m^2(e_K)$	…	$x_m^N(e_K)$

scale denoted as

$$\mathcal{V} = \{v_1, v_2, \dots, v_G\} \quad (1)$$

where $\mathbf{w}_n^-$ and $\mathbf{w}_n^+$ are respectively placed at the ends v_1 and v_G as illustrated in Fig. 1. Guided by the rule of seven plus or minus two [23], 5-point scale [28], 7-point scale [7,24,39] or 9-point scale [5] are often used in KE studies.

Finally, in order to gather Kansei data, the questionnaire is distributed to a population of subjects $\mathbf{E} = \{e_1, e_2, \dots, e_K\}$, who are invited to assess the products in $\mathcal{O}$ according to Kansei attributes in $\mathcal{A}$ by means of the G-point scale. Formally, the Kansei assessment provided by subject $e_k \in \mathbf{E}$ for product $O_m \in \mathcal{O}$ on Kansei attribute $A_n \in \mathcal{A}$ is denoted as $x_m^n(e_k)$, where $x_m^n(e_k) \in \mathcal{V}$, for $m = 1, \dots, M$, $n = 1, \dots, N$, and $k = 1, \dots, K$ as shown in Table 1. With the Kansei database obtained, we have to generate the Kansei profile for product O_m on Kansei attribute A_n.

3. A probabilistic approach to generating Kansei profiles

3.1. Linguistic interpretation of Kansei data

Conventionally, most KE studies consider the qualitative scale in Eq. (1) as crisp numeric data. However, Kansei attributes used to expressing aesthetic aspects of products are usually qualitative and ambiguous. This makes the subjective assessments provided by people are inherently varied and vague. Therefore, a more realistic approach may be to treat the qualitative scale $\mathcal{V}$ as a linguistic variable, which was introduced by Zadeh [44] as a model for reasoning and computing with vague concepts in natural language. Formally, a linguistic variable is defined as a quadruple $\langle \mathcal{L}, \mathrm{T}(\mathcal{L}), \Omega, \mathrm{S}, \mathrm{M} \rangle$ in which $\mathcal{L}$ is the name of the variable, $\mathrm{T}(\mathcal{L})$ is the set of labels or words, Ω is a universe of discourse, S is a syntactic rule for generating linguistic terms of $\mathrm{T}(\mathcal{L})$ and M is the semantic rule which associates with each linguistic label its meaning represented by a fuzzy set of Ω.

Under such an observation, we now model a G-point scale used for Kansei assessment of products according to Kansei attribute A_n as a *Kansei linguistic variable* denoted by

$$\langle \mathcal{L}_n, \mathrm{T}(\mathcal{L}_n), \Omega, \mathrm{M} \rangle \quad (2)$$

where $\mathrm{T}(\mathcal{L}_n) = \{L_1^n, L_2^n, \dots, L_G^n\}$ in which L_g^n is the linguistic value with v_g as its modal value, $\Omega = [1, G]$ and M associates each linguistic value in $\mathrm{T}(\mathcal{L}_n)$ a fuzzy set in [1, G].

With this linguistic interpretation of Kansei data, if a subject assesses product O_m on Kansei attribute A_n using v_g, it implies that the subject chooses Kansei linguistic label (or Kansei label for short) L_g^n as his/her judgment expressed by an assertion that "O_m on X_n is L_g^n". As argued in [17,18], from the philosophical viewpoint of the *epistemic stance*, humans posses some kind of mecha-