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A dominance-based rough set approach to Kansei Engineering in product development

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Abstract

Keen competitions in the global market have led product development to a more knowledge-intensive activity than ever, which requires not only tremendous expert knowledge but also effective analysis of design information. Kansei Engineering as a customer-oriented methodology for product development, often has to analyse imprecise design information inherent with nonlinearity and uncertainty. This paper proposes a systematic approach to Kansei Engineering based on the dominance-based rough set theory. Two novel concepts known as category score and partition quality have been developed and incorporated into the proposed approach. The new approach proposed is able to identify and analyse two types of inconsistencies caused by indiscernibility relations and dominance principles respectively. The result of an illustrative case study shows that the proposed approach can effectively extract Kansei knowledge from imprecise design information, and it can be easily integrated into an expert system for customer-oriented product development.

Keywords: Kansei Engineering; Rough sets; Product development; Affective design; Expert knowledge

1. Introduction

The essence of product development is the process of creation, utilisation, and exploitation of design knowledge. Effective knowledge acquisition from rough design information in both designers' and customers' perspectives plays a crucial role in successful product development. In the new globalised environment, keen competitions have resulted in profuse product alternatives in the market and an increasing number of consumers like to express their individual expectations about a product. Such competitions are also compelling manufacturers to develop new products that are able to satisfy consumers' needs and tastes. Accordingly, even mass-produced products have to be adaptable to meet individual demands in terms of product functionality, product form, design style and many other aspects (Shimizu et al., 2004). In order to improve the competitiveness, a well-designed product should be able to not only meet the basic functionality requirements, but also satisfy consumers' psychological needs (or feelings). In this regard, Kansei Engineering, which was originated from Japan in the 1980s, has attracted much attention and has been successfully applied to product development. Kansei is a Japanese word which refers to the customers' psychological impressions or feelings about a product. It may be evoked by the product form, style, colour, function, price, etc. and affected by consumers' emotions and personal senses of values (Lee, Harada, & Stappers, 2002). Since its inception, Kansei Engineering has been widely regarded as an effective tool for customer-oriented product development, which is able to translate the human Kansei into the product design elements (Nagamachi, 2002).

Basically, Kansei Engineering focuses on customers' feelings and needs, viz. Kansei, about a product and converts these ambiguous expressions of the product into detailed design, through a collection of techniques such as psychological assessment, statistical analysis or artificial

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intelligence, and graphics (Nagamachi, 1991). It functions as an interface between product designers and customers and its role is twofold. Kansei Engineering can be used by designers as a design aid to develop products that are able to meet customers' Kansei. It can also be used by customers to select products based on their Kansei requirements. However, in order to realise this, the relation between the human Kansei and design details, which is one of the key issues for the implementation of Kansei Engineering, needs to be discovered. From the designers' point of view, the discovery of the relation between the two enables the bridging of designers' creativity and customers' needs, and facilitates the development of competitive new products.

The core issue of Kansei Engineering is to formalise the knowledge that relates human Kansei with product design elements (Nagamachi, 1995). Fig. 1 presents a generalised Kansei Engineering system. In the system, customers' perceptions about a set of design alternatives of a product are represented in the form of Kansei words such as "compact", "deluxe", "sporty", etc., and quantified by the degree of appreciation (semantic scale ratings). On the other hand, the design alternatives of the product can be decomposed into a set of design elements. With the assistance of appropriate mathematical tools and advanced computer technologies, the relations (Kansei knowledge) between the quantified Kansei words and design elements can be established.

Toward this end, much research work has been done to build Kansei Engineering systems using techniques such as regression analysis, quantification theory, neural networks, genetic algorithms, fuzzy logic, and rough sets (Schütte, 2005). For example, Jindo and Hirasago (1997) described the application of Kansei Engineering to the interior design of passenger cars based on semantic differential methods and multivariate analysis, which are used to gather the relationships between interior design and desirable impressions. Ishihara, Ishihara, Nagamachi, and Matsubara (1995, 1997) presented an automatic semantic structure analyser and a Kansei expert system builder using self-organising neural networks for automated rule building. More recently, Chen, Khoo, and Yan (2006) proposed a prototype system using self-organising map neural networks to consolidate the relationships between affective requirements and formal elements. Some other researchers have tried more sophisticated methods based on genetic algorithms and fuzzy logic to capture the mappings between perceptual words and design elements (Tsuchiya, Maeda, Matsubara, & Nagamachi, 1996, 1999; Yanagisawa & Fukuda, 2003). Recently, rough set theory has also been applied to Kansei Engineering due to its ability to handle vague information and uncertainty (Nagamachi, Okazaki, & Ishikawa, 2006; Nishino, Nagamachi, & Ishihara, 2001; Okuhara, Matsubara, & Ueno, 2005).

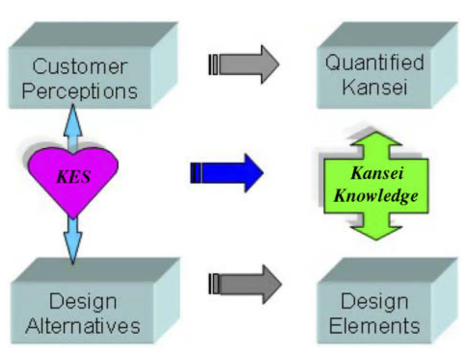

Fig. 1. Generalised Kansei Engineering systems (KES) in product design.

Among the various approaches to Kansei Engineering, statistical analysis plays an important role and is widely accepted as the most systematic tool for Kansei Engineering. For example, the linear regression model of type I quantification theory is one of the most popular tools to derive the relationships between human perceptions and product design factors (Schütte, Eklund, Axelsson, & Nagamachi, 2004). However, such statistical tools assume linear relations among the various variables used in the analysis, which may not be true in most cases. In fact, the psychological perceptions of consumers are usually fuzzy in nature and the behaviour of Kansei response is normally nonlinear (Arakawa, Shiraki, & Ishikawa, 1999; Ishihara et al., 1995; Kinoshita, Cooper, Hoshino, & Kamei, 2006; Tsuchiya et al., 1996). If non-linear characteristics exist in the system, statistical analysis will become inappropriate because it is based on the hypothesis of normal distribution (Nagamachi et al., 2006). In this regard, more sophisticated methods such as genetic algorithms, neural networks, and fuzzy logic have been developed to ensure the appropriate mappings between perceptual expressions and design properties. However, these methods are often transparent to designers and consumers (Petiota & Yannoub, 2004). Moreover, compared with the widely used statistical analysis, they lack formal frameworks when employed in Kansei Engineering applications.

This work is motivated by the need to develop a systematic approach to Kansei Engineering that is reasonably accurate in establishing the knowledge between product design elements and human Kansei, and is robust enough to handle various situations that involve nonlinearities or noises. Rough set theory as a systematic knowledge discovery tool with analytical power in dealing with rough, uncertain, and ambiguous data, is one of the most promising alternatives for solving Kansei Engineering problems (Nagamachi et al., 2006). The rest of the paper is organised as follows. Section 2 analyses the nature of Kansei Engineering problems and the feasibility of applying rough set theory in Kansei Engineering is discussed. Section 3 presents a brief introduction to the dominance-based rough set theory, which is an extension of classical rough sets. A prototype Kansei Engineering system built on the dominance-based rough set theory is proposed in Section 4. The capability of the prototype system is demonstrated using an illustrative example. Section 5 summarises the major conclusions achieved in this study.