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Data-driven innovation to capture user-experience product design: An empirical study for notebook visual aesthetics design

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ABSTRACT

Visual aesthetics is a critical factor of new product design to capture customer attention and create positive emotional reaction to enhance the customer satisfaction. Understanding user preferences in terms of product visual aesthetics and the factors affecting user experience (UX) is crucial for the product designers to enhance customer satisfaction. However, few studies have been done to identify the relationship between product characteristics of visual aesthetics and the UX reaction. This study aims to propose a framework of data-driven product design for capturing product visual aesthetics UX to effectively identify the useful design concepts from consumer preferences to consumer response. In order to validate the proposed framework, an empirical study in cooperation with a world leading electronics manufacturing service (EMS) company was conducted. The derived rules can assist the designers to design notebook visual aesthetics and develop promotion strategies to corresponding segments of different customers. The results have shown the practical feasibility of the proposed framework that has been implemented in this case company.

1. Introduction

With the emergence of rapidly developed technology and the extensive application of that technology, several products have been launched for different purposes within different customer segments. Within the consumer electronic product industry, the notebook computer product design and manufacturing is one of the most competitive domains. To gain the competitive edge, delivering product designs that meet the customer needs is the key to succeed in the turbulent global market. Thus, consumer electronics manufacturers attempt to customize the design of the notebook product to satisfy a wide array of customer needs. Among the substantial impact elements of product design, product visual aesthetics is highly relevant to product performance and users judgment (Hoegg & Alba, 2011). In general, users evaluate the novelty of the product and get their first impression from the product's visual aesthetics before accessing the functional aspects of products (Radford & Bloch, 2011). In addition, purchasing decisions are typically made regarding to the users' judgment of visual novelty and the distinctiveness of products. Accordingly, visual product newness has become a central determinant of new product adoption. To compete in the evolving market, notebook products should differentiate their visual aesthetics according to UX. UX is the reaction of emotions, demands and feeling of users with the respect to the use of the product in various scenarios and screenplay (Creusen, 2011; Hassenzahl & Tractinsky, 2006). Users' sensation feedback after adopting products contributes their inclination of satisfactory products (Chien, Lin, & Yu, 2014; Sundar, Bellur, Oh, Xu, & Jia, 2013). Thus, referring UX during the new product design process can deliver the product in line with the expectation of users.

Focusing on the realistic need, this study aims to develop a data-driven product design framework for capturing product visual aesthetics UX. The derived information regarding UX and important product characteristics of visual aesthetics can assist product designer to identify potentially successful product visual aesthetics concepts. Furthermore, the clarified factors may help the manufacturers to target specific customer segment to better cater to the needs of the segment and gain the core competence. However, in the notebook manufacturing companies, product designers often encounter the pressure of time to market, and thereby rely on their own experience and the market report provided by the upstream brand name firms to design the products. In this case, product designers face challenges to find appropriate

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visual aesthetics design concepts effectively. Thus, it is crucial to identify positive UX toward product visual aesthetics in order to obtain potentially useful information from customer voices to assist timely decision-making, especially for short life cycle products and in the severe competitive consumer electronics industry. However, collecting customer voices through the investigation of questionnaires is hard to elicit UX. In order to obtain the critical insight of customer voices, a systematic method to extract the important rules is required for the data analysis. Data mining is the multidisciplinary tool for discovering relation between users' sensation and the factors by deriving simple rules to discover valuable patterns driven by data. In particular, rough set theory (RST) (Pawlak, 1982) has been proposed to apply in the field of product design (Chien et al., 2014; Shao, Wang, Li, & Feng, 2006; Shi, Sun, & Xu, 2012; Zhai, Khoo, & Zhong, 2009). This approach can be applied specifically when the characteristic of information is imprecise, uncertain, and vague (Yang, Yang, Wu, & Yu, 2008). However, little research has been conducted for product visual aesthetics and consumers' purchase intention. In particular, RST was developed to explore the data of customer voices and detect the relationship hidden in data for decision makers to evaluate various products appearance features in the product design and prototype stage. To evaluate the validity of the proposed approach, an empirical study was conducted for a leading consumer electronics manufacturing company in Taiwan to demonstrate the practical feasibility of this framework.

The rest of this paper is organized as follows. Section 2 describes the fundamentals of this approach and reviews related studies. Section 3 addresses the proposed approach. Section 4 evaluates this approach with the empirical data for validation. Section 5 provides the discussion of this study. Section 6 concludes with contributions and future research directions.

2. Fundamentals

2.1. Data mining and RST

As the development of information technology, a massive amount of data has been collected automatically or semi-automatically as the resources for data mining and knowledge discovery. Data mining is an approach that combines several branches of learning expertise for discovering potentially useful patterns (Berry & Linoff, 2004). Decision makers may find valuable knowledge concealed in the raw data to enhance their decision quality. Many studies have been done to develop data mining methodologies to solve various problems in different domains, including yield enhancement (Chien, Hsu, & Chen, 2013; Chien, Wang, & Cheng, 2007; Hsu, Chien, Lin, & Chien, 2010), manufacturing management (Chien & Hsu, 2006; Kuo, Chien, & Chen, 2011; Kusiak, 2006), personnel selection (Chen & Chien, 2011; Chien & Chen, 2008; Strohmeier & Piazza, 2013), customer behavior analysis (Altintas & Trick, 2014; Baumann, Elliott, & Burton, 2012; Chen, Chiu, & Chang, 2005), marketing (Ayetiran & Adeyemo, 2012; D'Haen, Van den Poel, & Thorleuchter, 2013; Khan, 2014), and product design (Li, Nahar, & Fung, 2015; Okudan, Chiu, & Kim, 2013; Sangelkar, Cowen, & McAdams, 2012; Sangelkar & McAdams, 2013; Song & Kusiak, 2009; Tucker & Kim, 2009).

In terms of product design, data mining techniques have been applied to improve the product design quality and extracting the prototype features. The comparison of data-mining techniques and relevant studies for data mining in design were shown as Table 1.

However, only few studies have been undertaken to develop an assessment system for evaluating product features and UX based on data mining approach. In particular, Chien et al. (2014) employed rough set theory to propose a UX- based data mining model for tablet operation system design. Lin, Chien, and Kerh (2016) proposed UNISON framework for data-driven innovation to extract UX and conducted an empirical study for wearable devices product design. Feng, Yangjian, and Jiao (2014) also developed a UX decision-making model for aircraft cabin interior design based on hierarchical Bayesian analysis.

The RST is an approach of data mining which extracts association rules to support decisions with simple, understandable, and practical rules under uncertainty and vagueness. Apart from the traditional statistical methods, the unneeded assumption of variables independence and the data distribution normality is the advantage of RST. In addition, the "IF-THEN rules" are easy to interpret and understand practically, and can be applied forthright to categorical type of data. Thus, RST is particularly suitable and useful for the applications of product design features decision. RST has been applied in several fields such as manufacturing management (Hou & Huang, 2004; Hsu et al., 2010; Kusiak, 2001; Zhai, Khoo, & Fok, 2002), medical decision making (Kusiak, Kern, Kernstine, & Tseng, 2000), fault location identification (Peng, Chien, & Tseng, 2004), talent recruiting (Chien & Chen, 2007), marketing and customer research (Li, Tang, Chin, Han, & Luo, 2012; Liou & Tzeng, 2010; Thanh-Trung, Viet-Long Huu, & Phi-Khu, 2012), and product features design (Shao et al., 2006; Shi et al., 2012). However, little research has been done for the design of product visual aesthetics. The definitions of terminology and notations for RST are described as follows.

2.2. Information system

In the concept of RST, each row stands for an object (e.g. UX data for product visual aesthetics) and each column stands for an attribute in a decision table. The attributes can be further classified into the attributes of condition and decision. User information and cognition that have conceivable association with user's decisions were contained in the condition attributes. Hence, insights were depicted in the information system S, and can be defined as follows:

$$S = (U, A, V, f) \tag{1}$$

Table 1
Comparison of data-mining studies for design.

Approach	Research aims	Authors (year)
Association rules	Identified product configurations to control product diversity and complexity	Song and Kusiak (2009)
	Created design guidelines	Liao, Hsieh, and Huang (2008) and Sangelkar et al. (2012)
	Customized design features	Li et al. (2015)
Decision tree	Optimized new product portfolio design	Tucker and Kim (2009) and Bae and Kim (2011)
Statistical hypothesis	Obtained engineering specifications	Kang, Kang, and Hong (2014)
Rough set theory	Developed a model based on rough set theory to compare various operating systems of different tablets to derive user preference	Chien et al. (2014)
Text mining	Constructed a knowledge-based system to support notable product features design and development process	Tuarob and Tucker (2015)