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Integrating comprehensive customer requirements into product design

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ABSTRACT

Identification of customer needs is the starting point of design process. Most of design methodologies focus on technical domains to define customer requirements. However, the success of product design nowadays goes beyond technical features; it often depends heavily on multi-facets of customers' needs including various business parameters. Moreover, the qualitative and subjective factors such as affection, aesthetic appearance, user friendliness and brand loyalty are essential to the ultimate acceptance of a new product. This paper presents a probabilistic approach to elicit, characterize the qualitative customers' latent and subjective preferences and incorporate them into product design.

1. Introduction

A successful product design today has to provide the necessary functions, to offer sufficient business returns, to generate enthusiasm in the market and to comply with various regulatory standards such as sustainability and safety. In fact, product design has long been considered as a fusion of different disciplines and a multiple dimensional task, involving the participation of engineers, industrial designers, and business managers along with customers' participation. The interdisciplinary nature of design cutting across diverse fields in engineering, business, science and arts has become more prominent than ever. However, because engineering, business and art are three distinctive academic areas, most education programs cannot address the design issue in a holistic manner. In lieu of a common foundation to address the design issues, it is unavoidable that there are disconnections behind the knowledge, education, tools and skills of design. The disconnections in these three areas, technical, business and aesthetic can sometimes become extremely difficult to overcome in theory and practice.

To achieve a holistic design with the consideration of design from all three areas of engineering, business and art, it is imperative to incorporate comprehensive customer requirements and preferences into design [1]. Traditional engineering design methodologies focus more on technical requirements which are often represented in quantitative and explicit form. On the other hand, customers' perceptions and preferences like appearance, aesthetics, affection, usability and comfort of products are considered as subjective, and hence called subjective characteristics. They often are ignored in the technical design literature. The inability to include the subjective and qualitative customer preferences has limited the progress of holistic design methodology. To certain extent, it can be attributed to the gap between theory and practice. This is particularly true in today's dynamic marketplace. The success of product design cannot depend only on technical merits or business analysis. Instead, the qualitative and subjective factors such as affection, aesthetic appearance, and easy-to-use can be just as important, if not more. Thus, it becomes imperative that design methodology should include not only quantitative data but also subjective customer preferences.

2. Customer requirements elicitation in design task

In the research of product design, the understanding of comprehensive consumer requirements and preferences becomes more critical because customer centric product design and manufacturing has become the mainstream in academia and industrial practice [2].

In engineering design, customer preferences are expressed in functional requirements or design parameter language. Customer preferences elicitation task can be considered as the specification definition procedure, i.e., customers only need to specify the alternative of each product attribute. This process is also referred to as product configuring, with the purpose of translating subjective customer needs into tangible specifications. However, the configurator based customer needs elicitation system requires customers to express their needs in a specific design parameter domain. The methods cannot capture customers' perceptions and preferences on the subjective characteristics.

Kansei engineering is another stream on preferences elicitation from engineering design perspective [3]. It originated in Japan from the beginning of 1970s and tries to leverage customers' psychological feelings, such as emotions, moods, impressions and needs to improve the quality of products/services design. However, it can be difficult to capture customers' subjective feeling due to the different behaviour and psycho physiological settings.

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Customer preferences elicitation and modelling is also an active research topic in marketing science. Conjoint analysis is perhaps the most widely used tool to elicit customer preferences. It is commonly adopted to determine how people value different features which constitute an individual product [4]. In this method, the respondent is required to express his preference or choice among products shown to him. Then conjoint analysis estimates psychological tradeoffs that the respondent makes when evaluating several attributes together by the revealed preferences. However, conjoint analysis focuses more on products' physical attributes since they are well defined and the same for every customer. Thus, it is hard to directly elicit customers' subjective preferences.

3. Comprehensive customer requirements

Unlike most physical phenomena, the goal of meeting customer needs often can hardly be expressed in objective and quantitative terms, which restricts the possibility of exploring, assessing, and optimizing different alternatives. In the mean time, it has been acknowledged that the key to product success relies on better understanding of the voice of the customer and on better links between the preference of the customers, including artistic appreciation, sensory feedbacks, and value judgement with the capability of the companies. These preferences often have to be expressed in subjective and qualitative terms. It is obvious that there is a need to discover new ways to characterize and incorporate customer needs, particularly, subjective characteristics of customers' preferences like aesthetics, user friendliness, comfort, etc. In business, the widespread acceptance of products like Apple iPhone has been considered as a testimony of design being able to master the fusion of technology, business and arts in one product.

However, integrating the comprehensive customer requirements into design can be a challenging task due to the following reasons [5];

1) The difficulty of characterizing the customer subjective preferences: product subjective characteristics are not as well defined as components or tangible attributes. Each individual customer's perceptions to the product depend largely on complicated internal and external factors and differ from person to person. For example, when selecting a cell phone, different customers may have totally different perceptions of aesthetics, comfort and easy-to-use to the same product. The levels of subjective preferences and the corresponding scales may vary significantly across customers.
2) The wide variation complexity of customer preferences: customer preferences and requirements are context-dependent [6]. Customers may vary in their preferences and decision making criteria due to the purchase situation changes. The external factors like mood, emotion or impulsive feeling can also affect their preferences and requirements.
3) The difficulty of eliciting and integrating the subjective preferences into design: one of the reasons that design teams remain to be disconnected lies in the difficulties in eliciting customer needs towards product's subjective characteristics which are usually latent, as opposed to known function-based physical requirements. Although various techniques such as weighting ratio and data mining can identify personal profiles based on previous purchasing history and personal backgrounds to extrapolate personal preferences, however, these approaches tend to be heavily skewed towards product functional attributes. Thus, the links between customer needs and products' subjective characteristics often become disconnected. Though the design research has recently been getting attention, the established research on product design focuses primarily on engineering design and business strategy perspectives. There still lacks efficient ways of incorporating subjective and qualitative design parameters into the design process.

To this end, this paper is to address the major barrier for integrating subjective and qualitative customers' preferences into product design. Although a customer's preferences to subjective characteristics are hard to describe objectively, his final purchasing choice will indicate his subjective preferences to some extent. Links are built to connect customers' final purchasing choices and their potential subjective preferences via a Naïve Bayes structure which is constructed based on existing survey or transaction data. The Naïve Bayes structure will be deployed to incorporate new customers' subjective preferences into their customized product design task. The approach will leverage engineering design and industrial design in product design practice and tries to strike a balance between these two.

4. A Naïve Bayes based comprehensive representation of customer preference

4.1. Customers' preferences representation

Customer preferences solicitation and modelling is the basic step for acquiring customers' needs for product design. During this stage, not only a complete description of a product's tangible attributes or components should be provided, but also customers' preferences and perceptions to subjective characteristics need to be addressed. This section aims to include comprehensive customer preferences, particularly those subjective and qualitative characteristics, as an important decision making factor, since there is a clear recognition that customers' behaviour has to be considered in the early stage of design process.

In this paper, a product is modelled as a combination of attributes $\{C_1, C_2, \ldots, C_n\}$ where C_i represents the ith attribute of the product. C_i takes on values from its choices set $c_i = \{c_{i1}, c_{i2}, \ldots, c_{im_i}\}$ with m_i being the number of choices of C_i. All the possible combinations of attributes alternatives determine the complete set of product designs. Customers' functional requirements to the product can be met by the realization of the attribute set, i.e., the specifications to the attributes which can be captured directly from existing specification definition methods [6].

A customer's technical requirements to a product are represented by a set of variables $\{X_1, X_2, \ldots, X_n\}$ where each variable X_i represents a technical functional requirement, like a car's power, a camera's lens requirements, etc. Each X_i is associated with a set of possible values $x_i = \{x_{i1}, x_{i2}, \ldots, x_{in_i}\}$ where n_i is the number of choices of X_i. It should be noted that the functional requirements are functions of the attributes set $\{C_1, C_2, \ldots, C_n\}$. In many design methodologies, a product design task is often considered as a mapping between customers' functional requirements to design parameters, i.e., the realization of tangible attributes [7].

Similarly, a customer's subjective preferences to a product are represented by a set of variables $\{Y_1, Y_2, \ldots, Y_n\}$ where each variable Y_i represents a subjective preference, like appearance, friendliness, ease of use, etc. Each Y_i is also associated with a set of possible values $y_i = \{y_{i1}, y_{i2}, \ldots, y_{ik_i}\}$ where k_i is the number of choices of Y_i. The values can be either qualitative or quantitative. Usually, the subjective preferences cannot be obtained easily as the specifications to well defined attributes. In the research of marketing, it has been acknowledged that camera-ready prototypes are necessary for customers to articulate their subjective preferences [1]. In the case study of this paper, we also use camera-ready prototypes to capture customers' subjective preferences.

4.2. Integrating comprehensive customers' preferences into design via Naïve Bayes

Customers' functional requirements and subjective preferences have been considered as the main factors in determining their