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Utilizing Text Mining and Kansei Engineering to Support Data-Driven Design Automation

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Abstract. With the rapid expansion of Web 2.0, more and more people express their views and comments about products online. To understand and satisfy customer requirements, designers need to find out helpful information from online reviews and design a new one as fast as possible. It's an important phase to identify customer requirements in product development process. However, popular products can get hundreds of reviews, designers often spend a lot of time on identifying customer needs. Therefore, to meet customer requirements and speed up product development process, this research proposes a data-driven design method which combines text mining and Kansei engineering. Text mining is dedicated to capture and analyze the key words from customer reviews. Kansei engineering aims to translate customer needs into the product development domain. According to the result of Kansei Engineering, a CAD model will be generated to visualize prototype. Moreover, a case study of bike is provided to demonstrate the practical viability of proposed method. Under the trend of data-driven design, this is the first study that integrates text mining and Kansei engineering in product development process.

Keywords. Text Mining, Kansei Engineering, Product Development Process, Design Automation, Data-driven Design

Introduction

Recently, product development has emphasized on user-oriented design and the user experience. In order to find solutions for existing problems and meet customer needs, companies or designers nowadays must make clear understanding and insight of the actual needs of customers. Kansei Engineering (KE) was founded about 20 years ago. [1] defined KE as "translating the customer's Kansei into the product design domain." The Kansei means the customers' physical and psychological responses to the properties and characteristics of a product. To make customers be more satisfied with the new product, designers should consider customers' feelings in new product development. Thus, the success rate of new product development is expected to be increased.

With the rapid expansion of Web 2.0, more and more people express their opinions and comments to various products on the Web. Online reviews are generated from time to time and presented in various forms. Such opinion information reveals the evaluation

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of a product from netizens. Online reviews are not only useful for potential customers to make a decision but also critical for designers to develop a new product or a next generation of existing product. In the procedure of next-generation product development, designers have to extract current customer preferences from online reviews to satisfy customer needs accurately. Therefore, this study aims to propose a method to analyze customer reviews and extract customer requirements by integrating text mining and Kansei engineering for data-driven design. Text mining is dedicated to capture and analyze the key concepts from customer reviews. Kansei engineering intends to translate customer semantic meaning into the subsequent product design. Based on the Kansei engineering, a CAD model is generated to visualize the prototype.

1. Literature Review

1.1. Text Mining

Source [2] firstly introduced text mining is a technique for knowledge discovery from unstructured texts, especially social media data are usually large, noisy and unstructured [3]. Due to the increasing accessibility of textual data, the algorithms of text mining are developed and contribute in different fields. Source [4] proposed a heuristic two-phase model for authority and authentication sequence determination of technical documents via keyword extraction and document categorization. Source [5] applied K-means clustering and support vector machine classification to develop the text mining algorithm which effectively detected online hotspot forums. This technique has become mature and available due to scholars' effort and hard work.

With the help of text mining, many scholars have engaged in analyzing product reviews, which possess critical information with regard to customers' opinions and their experience with the product [6]. Enterprises always want to find customer opinions about their products and services. Potential customers also want to know the opinions from existing users before they pay for a service or a product [7]. Source [8] proposed a method for mining and summarizing online product reviews from Amazon. Each word is identified as part-of-speech and semantic orientation to decide customer preferences. The procedure of text mining is (1) mining product features that have been commented on by customers; (2) identifying opinion sentences in each review and deciding whether each opinion sentence is positive or negative; (3) summarizing the results. According to this method, customers enable to make an informed decision from a lot of reviews, which are long and only contain a few decisive sentence. Source [9] performed a competitive analysis through text mining approach with a case of pizza industry to obtain essential information for marketing and competitiveness comparison. The process includes pre-processing, applying text mining, and evaluating the mining results and recognize actionable. Moreover, SPSS Clementine text mining tool were used to facilitate the mining and analysis for the data on Twitter and Facebook. A system for summarizing product reviews and customer opinions is usually proposed with different methods [10-15]. According to the above literatures, previous researchers have applied text mining to understand the consumer behavior and addressed the challenge of huge reviews overload facing product designers.

To sum up, previous studies employed text mining to deal with natural language in various fields. However, previous studies almost proposed a method for potential customers to speed-up their decision process. Text mining is seldom utilized to support

product development process. Therefore, this paper uses text mining to collect customer reviews of products and try to find customers' potential needs.

1.2. Data-driven Design (D3)

With the trend of Internet of Thing (IoT) is come, the massive data generated by human and machine can create the opportunity in advancing the application of Data-driven Design (D3) for product, system and service [16]. Traditionally, researchers utilized questionnaire survey or focus group interviews to collect customer needs in the initial procedure of product design. However, these tools are costly and time consuming, and the size of available data is usually small scale[17]. Therefore, D3 for product design is proposed to collect extensive and realistic customer data, to interpret the relationship between customer data, and to guide new product design process. Source [18] presented a design method that significantly enhances the product portfolio design process, especially in the search of all possible product concepts. By using data-driven decision tree classification, a set of product concepts is generated and the feasibility is validated by multilevel optimization techniques. From a data-driven perspective, trend mining can address the challenges of capturing changes in consumer preferences that enable design engineers to forecast next generation product features [19]. Many D3 methods have been developed for identification of current customer requirements from online reviews. According to the collected and analyzed customers' product reviews, we are able to obtain current customer requirement. Then, based on the customer requirement and image, the new product development can accurately satisfy customer's demand. Source [20] translated customers' reviews into engineering characteristics in quality function deployment, which clearly understand how customer need is utilized by designers. Moreover, source [21] developed a framework to deal with big consumer data for market-driven product design. To help designers to understand the changes of customer requirements and their competitive advantages, the product features and sentiment polarities are employed to forecast the customer requirement. Source [22] proposed a method for enterprises to quickly understand customer-preferred product functions and features that are derived for product redesign and improvement.

1.3. Kansei Engineering

Source [23] developed Kansei Engineering as a consumer-oriented method for new product development in 1995. It is defined as a "translating technology of a consumer's feeling and image for a product into design elements". "Kansei" is a Japanese word which means a consumer's psychological feeling regarding a product. KE has be introduced in various distinct fields, such as automotive industry, construction, electric home appliance, office machine, etc. Several studies in the literature have utilized KE on the development of new product design. KE supports designer to develop a new product based on the consumer's feeling. Source [24] provided a design element analysis to extract important parameters such as color and shape that support the detailed design. The design element analysis is drilled down from the concept which is decided by initial concept classification. Source [25] apply KE in styling and design the speedometer and steering wheel of car interiors. Subjective evaluations were carried out by semantic differential scale and analyzed by multivariate analysis. Source [26] presented a decision support framework for an optimal design of bottle. Source [27] has reported an ergonomic toilet design which considering elderly people's needs. The

new toilet was tilted forward for elderly people's standing-up behaviors. Source [28] examined the relationships between appearances of watch and consumers' emotions to demonstrate that the product appearance would influence consumer involvement, emotion and even purchase intention.

Based on the existing literature, KE can be developed to serve as an elemental design support tool for a new product or an improvement for existing product. In the KE process, questionnaire is usually used to catch customer requirement. However, previous studies seldom applied text mining for online review to realize data-driven design.

2. Methodology

With the rapid expansion of e-commerce and online forums, more and more consumers buy products on shopping sites, discuss their personal experiences in forums, and comment products online. While customers want to buy a bike, it's reasonable that they would browse bike forums and related reviews before buying a bike. According to reading customer reviews, not only the customer evaluations of current product enable to be understood, but also the customer experiences and requirements can be captured. However, manually browsing through these reviews one by one requires a lot of time. Therefore, to investigate and analyze customer reviews original from the E-commerce Web site, the leading tool in text mining technique, SPSS Modeler, is conducted to facilitate the mining and analysis. After text mining, the KE is applied to translate customer reviews into design elements. Finally, a new product is designed based on the concept of design automation and data-driven design. Figure 1 expresses the architecture of this study. There are three major parts in the architecture: text pro-processing, text analysis and Kansei engineering. These parts are discussed step-by-step with the following contents.

2.1. Text Pre-processing

To make the results of text mining make be more representative of the population, the number of collected customer reviews should be as many as possible. Therefore, there are some pre-processing before text analysis. First, after selecting the target product, this study widely browses through shopping sites to collect representative product samples. Generally, a popular merchandise can get hundreds of reviews. Therefore, if the amount of the comments on the product is more than 100, then the product is considered as the candidate in this study. A customer review can be an article, a short comment, a discussion, or an experience to the similar products. To make the result of text mining reflect customers' Kansei image, this study only focuses on the text contents, exclusive the information of user name, date, rating and image of items. The customer reviews from shopping sites are manually collected as input information for subsequent analysis.

Second, raw data is a complete review which may contain the positive and negative comments. However, these raw data shouldn't be directly analyzed by SPSS Modeler, which mix the positive and negative comments in the same review would lead the mean of original reviews distorted. Therefore, to let each review indicate purely positive or purely negative comments, the next step is to transform complete review into several

sentences as input information. Moreover, the URL, video and other information that may impact the result of text mining are removed in this step.

Third, to discover and invent all the possible solutions for new product development, the analysis of the product design elements is conducted by morphological analysis, which is a method developed by source [29] to classify the target in each design element and help the designers recognize significant opportunities. To expand the area of possible solution, morphological analysis divides the research object into several design elements, and deal with these elements individually to form the overall solution. Morphological analysis aims to find the possible solutions from existing product that may generate a variety of solutions. Therefore, based on customer reviews, we expect to scale down the number of solutions and find the final design.

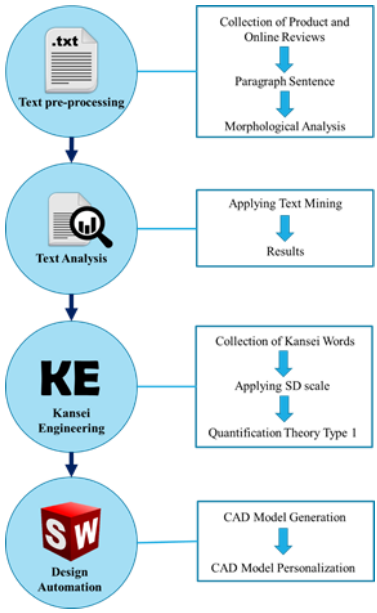

Figure 1. Research Architecture.

2.2. Text Analysis

This study applied SPSS Modeler's text analysis methods to extract key concepts from product reviews, generate categories which are composed of the extracted concepts, and help to gain insights from the unstructured text data. By following the four steps, we are able to identify popular product attributes and consumers' images of product from the collected reviews.

Step 1. Converting source data to a standard format.

The collected reviews is converted into a standard format that can be used for subsequent analysis. This conversion is conducted internally and does not change the original textual data.

Step 2. Analyzing converted data with the linguistic resources.

In this step, we utilizes the linguistic resources to extract concept terms and generate categories. The linguistic resources are core and internal components of the extraction engine in SPSS Modeler. They exist in the form of templates, libraries, and compiled resources. During the concept extraction, the linguistic resources are used every time to identify concept terms. The result of concept extraction contains the number of review sentence in which the concept appears, the number of occurrences of this concept, and the type to which the concept is assigned.

Step 3. Identifying equivalence classes and integration of synonyms.

After concepts are identified, the software uses a normalization dictionary to identify equivalence classes. An equivalence class is a base form of a phrase or a single form of two variants of the same phrase. The purpose of assigning phrases to equivalence classes is to ensure different synonyms are not treated as two concepts. For example, "Excellent" and "Perfect" are treated as one concept.

Step 4. Assigning category.
Next, category are assigned to extracted concepts. A category is a semantic grouping of concepts. Categories would include components, positive and negative words, opinion words, and more. Linguistic systems are knowledge sensitive that means the more information contained in the dictionaries, the higher the quality of the results. Modification of the dictionary content, such as synonym definitions and assigned category, can simplify the resulting information.

2.3. Kansei Engineering and Quantification Theory Type 1

After text mining, we are able to determine the Kansei words according to the frequency of all the words in relation to the overall online reviews. A word which frequently appear in customer reviews can express most consumers' image of product. Thus, this study captures the frequent opinion words as Kansei words. Semantic differential (SD) scale is a type of a rating scale to measure the semantic meaning of products. Visual-Analogue Scale (VAS), one of SD scales, is accustomed to handle a psychometric response scale which is used in questionnaires. According to the result of quantifying the semantic meaning for each sample, we can construct the matrix of design element and semantic evaluation. The relationship between the representative Kansei words and the design elements is found by the Quantification Theory Type 1 (QT1) which is usually applied in Kansei engineering.

The purpose of QT1 is to establish mathematical relation between Kansei words and design elements. Product designers usually implement QT1 in questionnaire analysis or customer needs analysis to determine the importance of each design element. QT1 is a multivariate regression analysis for categorical data with one dependent variable (quantitative) and several independent variables (qualitative). The quantitative variables determines what factor affect the importance. The qualitative variables are dummy variables that take the value 0 or 1 to indicate the absence or presence of some categorical effect. Each qualitative item is composed of several categories. A product sample must contain each item, and selects one category from each item. This concept is similar the morphological analysis (Table 1). Based on these data, a multiple regression table can be established in Excel to calculate partial correlation coefficient for each item and category score. Moreover, a regression equation is able to forecast the dependent variable depend on particulars of each design element.

2.4. Design Automation

The research proposes a way to visualize the new product by the CAD model of Solidworks based on the result of QT1. There are two major phases of design automation [30]. First, a prototype is generated according to the standard specifications [31]. This prototype is the as-is model to the specific product and the to-be model will be generated in next step [32]. Second, the to-be CAD model is generated by modifying each design element which is determined based on the result of QT1. For instance, the prototype of the product is made in steel. Nevertheless, according to the analysis, it is indicated that aluminium is preferred by the customers. Thus, the material is modified from steel to aluminium in to-be model.

3. Case Study

3.1. Text Pre-processing

In this research, customer reviews are mainly collected from Amazon.com which is the most popular E-commerce Web site and represent a large sample of online customers. Moreover, only the customers who have purchased specific products at Amazon can leave comments to the products. This research selects several types of road bike as a specific products in the case study. The reviews pages in each website which sells specific bike are used as the textual data for analysis. In the reviews pages, the research manually captures the opinion text content, exclusive of user name, date, rating and image of item, to make the result of text mining reflect customers' Kansei image. In the preliminary research, we collect 331 customer reviews of Takara Kabuto Single Speed Road Bike which written on Amazon.com. All textual rata are exported to txt-file for subsequent text mining. Moreover, to accurately obtain customers' opinion, the reviews which contain the positive and negative comments are paragraphed into several sentences, and the contents include URL, video and picture, are removed to avoid the error of text mining. After conducting above steps, original 331 reviews are transformed into 2,623 sentence as the input data of text mining.After collecting the reviews of different road bikes, to discover all the possible solutions for new product development, the design elements of bicycle is discovered by morphological analysis. As shown in Table 1, the design element can be divided into 5 category, and each category has several type. These differences is selected based on the survey of road bikes.

Table 1. Morphological analysis of bike.

Item	**Category**		
Handlebar (d_1)	Flat (d_{11})	Drop (d_{12})	Bullhorn (d_{13})
Frame material (d_2)	Steel (d_{21})	Carbon (d_{22})	Aluminum(d_{23})
Saddle (d_3)	Thin (d_{31})	Middle(d_{32})	Wide(d_{33})
Wheels (d_4)	Aluminum(d_{41})	Alloy(d_{42})	
Derailleur (d_5)	Single Speed (d_{51})	21 Speed(d_{52})	

3.2. Text Analysis and Kansei Engineering

In the preliminary research, we take the sample No.1 as an example. The result of text mining can capture the frequency of each word in customer reviews. We extract the adjectives which often are used to express customers' opinion, and the bipolar adjectives are also extracted for subsequent Kansei engineering.

Table 2. Kansei semantic set.

Kansei semantic set	**Similar Kansei words**
Overall Impression	Excellent (296), Good (255), Like(130), Bad (85), Dislike (34)
Usability	Easy (59), Difficult (51)
Riding Experience	Comfortable (46), Not comfortable (14)
Weight	Heavy(62), Light (22)

According to the result of text mining, we select 11 adjectives which frequently appear in customer reviews as Kansei words that express most consumers' image of product. These Kansei words can be divided into 4 semantic sets, include overall impression, usability, riding experience and weight (Table 2). The overall impression indicates the comprehensive evaluation of customers to this bike. The usability represents the difficulty of the customer in assembling the bike. The riding experience often means the feeling when customer riding this bike. The weight obviously mentions the weight of this bike. The right column records the times of appearance of each bipolar adjective. In the preliminary research, we only collect one sample to test the result of combining text mining and Kansei engineering. According to the morphological analysis and the calculation of VAS, the result can be summarized into the Table 3.

Table 3. Matrix of design element and semantic evaluation.

Sample	Design element					Kansei Image Evaluation Value			
	d_1	d_2	d_3	d_4	d_5	Bad-Good	Difficult-Easy	Not comfortable - Comfortable	Heavy-Light
No.1	2	1	2	2	1	0.8224	0.5364	0.7667	0.2619

3.3. Design Automation

On the basis of the selected design element, several design elements are shown in Figure 2. The design elements are visualized by Solidworks that can assemble different components and the parameter of component is adjusted by designers. Based on the analysis of Kansei engineering, the handlebar is drop style, the frame is made of steel, and the wheel is made of alloy. Overall, the CAD models are not the final design scheme, but are the design propositions that considering customer requirements for designer to subsequent adjust [33]. According to these propositions, the new product will be conformed to consumers' requirements.

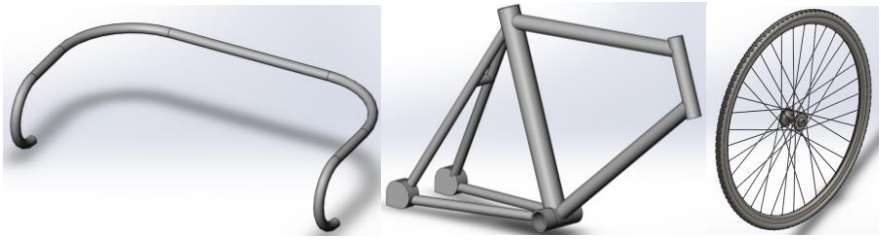

Figure 2. CAD model of handlebar, frame and wheel.

4. Conclusion

This study proposed a data-driven design method that combine text mining and kansei engineering. A case study of bike is applied to demonstrate the feasibility of this method. Text mining is dedicated to extract the feeling of existing products from customer reviews in Amazon. Kansei engineering intends to determine customer requirements and quantify customer's semantic feeling by using QT1. According to the result of Kansei engineering, the score of each design element is calculated for

determining the final appearance. Finally, each design element is visualized by solidworks to realize design automation. The result is the preliminary design in order to save designer's time to analyze customer requirements. The quality of text mining and Kansei engineering will be increased by gathering more samples and customer reviews for future work.

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