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Application of Kansei Engineering and Association Rules Mining in Product Design

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***Abstract*—**The Kansei engineering is a technology which converts human feelings into quantitative terms and helps designers develop new products that meet customers' expectation. Standard Kansei engineering procedure involves finding relationships between human feelings and design elements of which many researchers have found forward and backward relationship through various soft computing techniques. In this paper, we proposed the framework of Kansei engineering linking relationship not only between human feelings and design elements, but also the whole part of product, by constructing association rules. In this experiment, we obtain input from emotion score that subjects rate when they see the whole part of the product by applying semantic differentials. Then, association rules are constructed to discover the combination of design element which affects the human feeling. The results of our experiment suggest the pattern of relationship of design elements according to human feelings which can be derived from the whole part of product.

***Keywords*—**Association Rules Mining, Kansei Engineering, Product Design, Semantic Differentials

I. Introduction

TODAY's competitive environment has changed tremendously. The basic function such as product performance can no longer catch the attention of customers. People are now looking for products that not only response to their functional requirements, but also to their aesthetic needs.

Therefore, successful product development becomes a crucial duty for companies in order to survive in such fierce competition. It is unavoidable to pay great attention to design when developing new product as it is critical to the first impression of customers in terms of product appearance and experience. Therefore, it is vital that designers include in their working procedure by taking into account that not only the functionalism ideology (form follows functions) is the design goal, but also the user-centric notion (form follows users) [1].

Today, there are various technologies available to assist designers in capturing customer needs explicitly and inexplicitly. One of the well known technologies, which converts emotion/feelings of customers in their perception towards products, is "Kansei Engineering." Kansei Engineering is a consumer-oriented technology to assist designers in new product development process, it translates customer's emotion/feeling in response to product appearance by evaluating five human senses, which are sight, hearing, taste, smell, and touch and generates design specifications accordingly [2].

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Kansei Engineering is applied in the design process in different industries such as automobiles, fashion, telephone, furniture, and so on [3,4,5,6]. Until now, various data analyzing techniques for Kansei Engineering have been developed to optimize design elements that best represented emotion [7].

However, at present, most researches on Kansei Engineering are focusing on measuring emotion/feeling in response to product on the one-to-one basis. As a product is composed of many small components, therefore, it requires separated Kansei Engineering study conducted on each component, these fragmented studies are later combines as the outline of the product. This approach has its drawback as it takes long time and costs substantially. Furthermore, it is difficult for designers to bring together the results of each design elements especially when they are not appropriately combined. In this paper, we proposed the integration of Kansei Engineering with the concept of "the Whole of its Parts" by applying Association Rules Mining in order to find the pattern of relationship between the emotion/feeling and the whole product appearance, its design elements, and attributes. Thus, it is more effective for designer to interpret the meaning of the information and it is easier also for designer to understand the results.

II. Literature Review

A. Kansei Engineering

Kansei Engineering is defined as *"translating technology of a consumer's feeling and image for a product into design elements"* [8]. It has been used in the process of designing new product by systematically obtaining design elements through perception experiment research, which yields benefits in terms of shorten product development time and more precise design concept for further design development. To quantify emotion with design elements, there are several approaches that have been used in order to gather the data, such as statistical scaling, magnitude estimation, Likert scale and Semantic differential method [9]. The most widely used data collection method in Kansei engineering is semantic differential method, which was introduced by Osgood, as a psychological measurement by using bipolar adjective scales [10]. The semantic differential method was applied in order to collect primary data between design elements and emotion in various fields, such as street furniture, watches, telephone and etc [11,12,13]. There are also several approaches in analyzing data after conducting the fundamental research from semantic differential method, such as statistical approach, soft computing approach, and mathematical model approach, which are widely known in Kansei engineering field as Kansei engineering classification type I, II and III respectively [8].

There are advantages and disadvantages among different Kansei engineering analyzing techniques, depending on the objective of each study.

The classification type I is suitable only for small data set with simple relationship among variables. There were several researches applying type I analysis successfully, such as development of design support system for office chair and car interior by multivariate analysis, telephone by linear regression [6,14,13].

Kansei engineering category classification type II is more suitable for large data set with more complex and dynamic relationship among variables in experiment. The soft computing technique assists in finding the pattern of data together with matching the relationship and finally suggests the pattern of solution. Kansei engineering classification type II was applied in various fields such as researches in automatic builder by self-organizing neural networks, and mobile phones by fuzzy logic [15,16].

Kansei engineering classification type III is suitable for large data set with extremely complex system relationship for particular purpose, which can normally be solved by particular mathematic equation. Park and Han applied "Fuzzy rule-based" technique in office chair design, and Tsuchiya applied "Fuzzy rule induction with genetic algorithm" in automobiles [17,18]. In later years, the techniques were invented further to Virtual Kansei Engineering, Collaborative Kansei Engineering Designing by integrated user into system via internet.

However, most techniques mentioned are based on one-to-one basis, which is between one item of design element to one degree of emotion. In reality, people perceive things as a whole rather than individual part of product. Therefore, the research on one single perception of whole part that can derive and infer the emotion with design elements shall be enhanced as the focus of study in order to elevate degree of confidential level, which in turn would save time and cost in conducting research.

B. Part and Whole Perception

The concept of the part and whole perception has long been discussed in the field of cognitive neuroscience. The conventional view proposed that the perception was a result from the brain processing information from sensing of human organs. The space perception was derived from combining sensing of human organs together to explain the whole. In contrast, the motor theory of perception argued that the space perception was a result from the stimulation of impulses, rather than from perception or memory [19]. However, there is no conclusion on how people perceive things around them. One of the debates that have long been discussed and still remains in the spotlight is on how individuals perceive things as a whole, or perceive things as an individual part and combine as a whole, in order to make a meaning out of it.

In Kansei engineering, the concept of whole and parts are always applied. Most of researches under Kansei engineering were conducted experiment on one-to-one basis usually in two approaches. One was by quantifying the emotion in relation to each part (design elements) and then later combined them as a whole product. Yang extracted design elements of mobile phone in order to develop new product form design [20].

Nakada studied the perception of controller's seat for construction machinery [21]. Another was by quantifying emotion in relation to a product as a whole.

Baek et al. conducted an experiment on textile pattern by applying the whole perception concept [22]. Chen and Chang developed a knife from the whole product concept [23].

C. Design and Semantics

Design involves way of thinking. There are three main theories of thinking, which are the behaviorists, the Gestalt school and the cognitive science approach [24]. The behaviorist's school of thought believes in the inner stimuli and response. They trust in basic instinct for any decision making [25]. Totally opposite from behaviorists, the Gestalt focuses on the process in obtaining solution. There is a clear defined structure process in solving problem [26]. De Groot suggested that the system of solution is derived from memory [27]. The cognitive science approach has grounded from psychology field. Human brain is processed from short-term memory with elements of perception pattern, discrimination ability, language, and concept [28]. As the human brain can be collected as pattern of brain performance, the use of artificial intelligence is employed to imitate designer's brain.

The product semantics is categorized in the second school of thought, which believes that humans response to products according to their individual and cultural meanings. It belongs to one of the design perspectives focusing on the human interpretation of object based on individual experience. The concept of product semantics was discovered and firstly introduced by Reinhard Butter and Klaus Krippendorf in 1989. They defined "Product Semantics" as "*A systematic inquiry into how people attribute meanings to artifacts and interact with them accordingly*" and "*A vocabulary and methodology for designing artifacts in view of the meanings they could acquire for their users and the communities of their stakeholders*" [29]. The fundamental of semantic product design weights on interpreting and understanding of object through interaction. According to Krippendorf, there are three approaches in obtaining meaning from object, which are meaning in use, meaning in lives, and meaning in language. First, the meaning in use approach addresses that individuals have their own way in interpretation according to their background and experience on object association. Second, the meaning in lives approach illustrates that the meaning is a lifetime learning process. Since some objects take time to be developed, which sometimes take more than a person lifetime, therefore, the changes throughout the development must be given the meaning in order to communicate. Lastly, the meaning in language approach shows that the meaning can be described in verbal form as the center of communication. Among all these three approaches, the most effective way in deriving feeling and expression is through language as it can explain directly in details without implying or inferring.

From the product semantic concept, they believed that each person interprets things differently according to their experience. The interpretation or meaning of something can be varied. The classic paper of Peter H. Bloch on "Seeking the Ideal Form: Product Design and Consumer Response," illustrates the factors that influence product form, the process of perception and consumer responses [30]. The product form is subjected to the design goals and constraints, which are performance, ergonomic, production/cost, regulatory/legal, marketing program and design. The individual tastes and preference together with situation factors affect the psychological responses to product form, which finally resulted in behavioral responses. Therefore, the design is not just a solution providing to customers, but rather the whole process of communication experience that design have to keep as a fundamental in design.

D.Association Rules Mining

Association rules mining is *"a data mining method to find the interesting association or correlation among a large set of data items"* [31]. The unique characteristics of association rules mining is *"finding frequent patterns, associations, correlations, or causal structures among sets of items or objects in transactional database, relational databases, and other information repositories"* [32]. This technique is frequently applied in doing market basket data analysis, cross-marketing, and catalog design, in order to obtain pattern of consumer behaviors, especially in consumer buying decision. The concept of data mining has been applied in Kansei engineering in order to ease the work load in calculating and find relationship among variables. Yang et al. applied association rule mining to map the emotion with design elements for Volvo truck cab design [33].

III. Methodology

The underlying concept of this research is to understand consumer perception as a whole rather than partial and to find the sequence matching elements to develop and form a new product that suitable for customer's expectation. Therefore, the perception of product will be evaluated by inferring the relationship between subjects, product, design elements, and design attributes. Thereafter, the proposed integration of the Kansei engineering with association rules mining obtained by this study will be applied to analyze the relationship and search for the combination of design elements-attributes that reflects the degree of emotion when people see the image. Designers, therefore, will be able to optimize this information in the designing of new product in accordance to customers' expectation with significantly shorter development time. The overall concept of this study is summarized as in figure I.

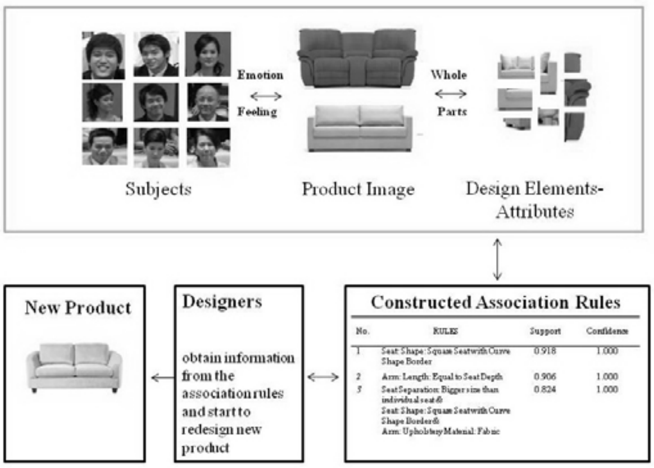

Fig. 1 Research Framework

In this research, the experiment is divided into three phases, which are 1) data preparation phase, 2) data collection phase and 3) data analysis phase.

In the first phase, the data preparation includes selecting objects of study, categorizing design elements, classifying design attributes, together with deriving appropriate adjectives that represent object samples. In the second stage, the data collection includes sampling techniques and collection technique. The last phase, the data analysis phase covers the analysis of data by applying the association rules mining technique in order to interpret results. Since this study aims to assess the perception level to product appearance, sofa is considered to have refined details of design elements and is utilized as the object of this study in order to illustrate how the integration of Kansei Engineering technology with applied association rules mining technique can be optimized.

A. Data Preparation Phase

In this phase, there were four needed variables to prepare in order to construct semantic database, these variables were sofa image (whole product image), sofa design elements, sofa design attributes, and adjectives (emotion/feeling in response to the product).

Sofa Image (Whole Product Image): sofa images, which represent the concept of the whole of its parts, were selected as the objects of study. A hundred sofa images were gathered from five leading furniture and decoration magazines in Thailand during 2010 – 2011. The paper cards of hundred sofa images printing in gray color scale in A4 size were made. The furniture designers invited to evaluate the sofa image cards in this study consisted of two male and one female furniture designers with more than five years experience in the field of sofa design. The designers compare the similarities and differences in term of external appearance, and finally selected ten sofa images that would be used as the representation of this study. The final set of sofa images was shown in figure II.

Fig. 2 Ten Selected Sofa Image

Sofa Design Elements and Sofa Design Attributes: The sofa design elements derived from sofa design pattern, which were usually used in the production process. Since the method in classifying of sofa design pattern was slightly different from company to company, in-depth interviews with three sofa productions managers were conducted to derive sofa design elements and sofa design attributes for each selected sofa image. The three sofa productions managers, were consisted of three male managers with more than ten years experience in sofa manufacturing. The interviews were aimed at finding common methodology in extracting sofa design elements and sofa design attributes according to the sofa pattern and material usage. The lists of all possible sofa design elements and attributes were listed and categorized into table form. After the table of sofa design elements and attributes were completed, the ten selected sofa images were presented to the managers to match the whole sofa images with the suitable sofa design elements and attributes. Finally, ten sofa images with twenty sofa design elements and eighty eight sofa design attributes derived. The list of design elements, design attributes were listed in Table I.

Adjectives (Emotion/Feeling to Product Image): The emotion/feelings in response to sofa appearance were represented by ten pairs of antonym adjective in order to communicate with subjects in this study. The semantic differential method with five Likert scale was applied in order to measure degree of emotion toward product appearance. Three sofa designers, which consists of two male and one female, with more than five years experience in sofa design, and three sofa salespersons, which consists of one male and two female, with more than three years experience in sales and marketing of sofa product category, were invited to brainstorm and select the represented adjectives in this study.

TABLE I
SOFA DESIGN ELEMENTS &ATTRIBUTES

Item No.	Design Elements	Design Attributes
1-3	Back Rest: Sewing Pattern	Un-foldable with Individual Seat Sewing Pattern, Un-Foldable with Seat without Sewing Pattern, Foldable with Individual Sewing Pattern
4-7	Back Rest: Shape	Square, Square with Curve Border, Circle, Triangle
8-13	Back Rest: Sewing Design	Shown Stitching – Straight Line, Shown Stitching – Curve, Unshown Sewing Stitching – Straight Line, Unshown Sewing Stitching – Curve, Chesterfield Button Sewing, No Sewing Stitching Shown
14-16	Back Rest: Separation	Bigger than number of seater, equal to number of seater, no separation
17-21	Back Rest: Thickness	Very thick with foam, thick with form, very thick with fiber cushion, thick with fiber cushion, slim
22-26	Back Rest: Additional Pillows	Large, Medium, Small, Mixed Size, None
27-29	Seat Cushion: Separation to number of seater	More than, equal to, no separation
30-33	Seat Cushion: Shape	Square, Square with Border Curve, Circle, Triangle
34-36	Seat Cushion: Sewing Pattern	Shown Straight Stichting, Shown Curve Stichting, Unshown
37-40	Seat Cushion: Thickness	Very thick with foam, thick with form, very thick with fiber cushion, thick with fiber cushion
41-43	Arm: Shape	Square, Square with curve, Circel
44-49	Arm: Thickness	Triangle, Very thick with foam, thick with form, very thick with fiber cushion, thick with fiber cushion, slim
50-55	Arm: Material	Shining Round Metal, Non-shining Round Metal, Shining Plate Metal, Non-Shining Plate Metal, Wood, Fabric/Leather
56-58	Arm: Length compared with seat depth	Equal, shorter, longer
59-63	Sofa Leg: Shape	Square, Rectangle, Round, Plate, Curve
64-69	Sofa Leg: Height	Very High, Medium, Sawable Short, Unsawable Short, No Leg, Metal Recling Leg
70-71	Sofa Leg: Color Tone	Dark, Light
72-77	Sofa Leg Material	Shining Round Metal, Non-shining Round Metal, Shining Plate Metal, Non-Shining Plate Metal, Wood, Plastic
78-80	Overall: Proportion, compared to arm height	A lot Higher, Slightly Higher, Equal to
81-84	Overall: Color Tone	Light Tone for overall, Dark Tone for overall, Light tone sofa with dark tone accessories, Dark tone sofa with light tone accessories
85-88	Overall: Material	Leather, Fabric, Fabric sofa with leather pillow, Leather pillow with fabric pillow

The first in-depth interview sessions were conducted separately in order to gather adjectives on the perception of sofa image as many as possible. The second in-depth interview session was conducted by putting all interviewees together, they were asked to group similar meaning adjectives according to their understanding. The group of adjectives were developed and named with the best represented adjective in the same category. The antonym adjectives were matched together with the selected adjectives. After that, three designers and three salespersons took parts to determine which adjective pairs should be matched in order to describe the perception of the sofa. As a result, the ten pairs of adjective were selected as the measurement scale. The list of ten pairs of adjectives was listed in table II.

B. Data Collection Phase

The objective of this phase was to measure how subjects felt when they saw the selected sofa images. There were 50 subjects recruited for this study by quota sampling. The subjects included 22 male and 23 female, with age ranges from 25-40 years old, residing in Bangkok area. The semantic differentials method was applied as the tool to measure the perception from subjects when they saw sofa images. The five-point semantic differentials scale was developed with ten bipolar pairs of adjectives on ten sofa images.

The negative meanings of selected adjectives were set on the left and the counter meaning adjectives were set on the right. The subjects were asked to score how they felt to each sofa image shown during the experiment. The score was ranked from 1 for the most negative meaning on the left and 5 for the most positive meaning on the right. The questionnaire is shown in figure III. The questionnaire was collected individually by asking each subject to response to each sofa image and score on the semantic differentials scale of selected bipolar adjectives according to their emotion/feelings.

Ugly	1	2	3	4	5	Beautiful
Uncomfortable	1	2	3	4	5	Comfortable
Hard	1	2	3	4	5	Soft
Bulky	1	2	3	4	5	Slim
Unrefined	1	2	3	4	5	Elegant
Old Fashion	1	2	3	4	5	Modern
Formal	1	2	3	4	5	Casual
Fragile	1	2	3	4	5	Durable
Worthless	1	2	3	4	5	Valuable
Extremely Dislike	1	2	3	4	5	Extremely Like

Fig. 3 Questionnaire

TABLE II
TEN SELECTED ADJECTIVE PAIRS

Beautiful – Ugly	Comfortable – Uncomfortable
Soft - Hard	Slim - Bulky
Elegant - Unrefined	Modern – Old Fashion
Casual - Formal	Durable - Fragile
Valuable - Worthless	Extremely like – Extremely dislike

C. Data Analysis Phase

In this phase, the collected data were analyzed by applying association rules mining technique. Firstly, the collected data was transferred into the database and linked to the relationship between sofa images, sofa design elements, sofa design attributes and adjectives together. The database was processed in order to find the pattern of relationship between whole product images, design elements, design attributes and adjectives, the result as the association rules. According to this, the association rules inferred the relationship of combination of design elements and attributes with the degree of emotion. From the experiment, the result was presented in the table format. The association rules were listed with the support level and confidence level. The association rules comprised of design elements-attributes ranking from the strongest to the weakest relationship to the selected degree of emotion.

The result can be retrieved for any degree of selected adjectives.

TABLE III
ASSOCIATION RULES CONSTRUCTED FOR WORD: "MOST BEAUTIFUL"

No	Rules	Support	Confidence
1	Seat: Shape: Square Seat with Curve Shape Border	0.918	1.000
2	Arm: Length: Equal to Seat Depth	0.906	1.000
3	Seat Separation: Bigger size than individual seat & Seat: Shape: Square Seat with Curve Shape Border & Arm: Upholstery Material: Fabric	0.824	1.000
4	Seat: Separation: Bigger size than individual seat & Arm: Upholstery Material: Fabric	0.824	1.000
5	Seat: Shape: Square Seat with Curve Shape Border & Arm: Upholstery Material: Fabric	0.824	1.000
6	Arm: Upholstery Material: Fabric	0.824	1.000
7	Back Rest: Shape: Square with Curve Shape Border & Seat: Shape: Square Seat with Curve Shape Border	0.824	1.000
8	Back Rest: Shape: Square with Curve Shape Border	0.824	1.000
9	Seat: Separation: Bigger size than individual seat & Seat: Shape: Square Seat with Curve Shape Border	0.824	1.000
10	Seat: Separation: Bigger size than individual seat	0.824	1.000

The results from the experiment can be varied depending on the selected degree of adjective. The table III illustrated the combination of design elements-attributes generated from the word: "Most beautiful." According to the result from experiment, they suggested ten most related rules with adjectives. The "Seat Shape that has Square Seat with Curve Shape Border" is the design element-attribute that had the most relationship with "Most Beautiful" from the subjects' point of view with the support degree of 0.918. The second most related with "Most Beautiful" was "Arm Length that Equal to Seat Depth" with the support degree of 0.906. The third most related yielded the result as a combination of "Seat Separation that has Bigger size than individual seat", "Seat Shape that has Square Seat with Curve Shape Border" and "Arm Upholstery Material is Fabric" with the support degree of 0.824.

IV. RESULTS AND DISCUSSIONS

From the experiment under the integrated Kansei Engineering and the association rules mining in the context of "Wholes of its Parts", suggested the rules or the list of combinations of design elements-attributes in relation to adjectives. With this technique, the designers are able to obtain such rules from experiment, interpret such data and utilize them as essential information in designing new product. Testing of the tool with designers was conducted in order to evaluate the efficiency of this tool by choosing a keyword "Most Beautiful" as the requested design concept.

The designers were able to gather design elements-attributes related to this keyword, which were suggested from the integrated Kansei Engineering and the association rules mining technique. The designers developed new design prototype according to suggested results. The tests revealed that the designers were able to reduce time in gathering reference images and selecting materials. The normal average time in designing sofa prototype by five experienced designers in the five sofa factories observed was 2 hours 12 minutes. By utilizing the integrated Kansei Engineering with association rules mining tool developed, the average time in designing sofa prototype was reduced to 1 hour 56 minutes. The integrated Kansei Engineering with association rules mining technique helped reducing time in designing approximately 16 minutes from this experiment.

V. Conclusion

The Kansei Engineering is a technology that assists designers in developing new products that meet customer's requirement in term of emotion. Most of researches on Kansei engineering aimed on measuring emotion in response to product on one-to-one basis, it is costly and time-consuming in new product development process. This paper proposed the Kansei Engineering integrating with the concept of "the Whole of its Parts" by applying association rules mining technique. This study reduced design element-based experiments into one whole-product experiment by optimizing the rules suggested from association rules mining technique. The result revealed the combination set of design elements and attributes that significantly and reliably matched with the targeted emotion deemed relevant to customers' expectation in response to the object to be designed. From such information, designers were able to obtain suitable design elements-attributes. Research provides evidence that designers were able to shorten designing time in developing new product.

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