Use of Association Rules Mining and Kansei Engineering for Product Design

Yogendra Shektwat[1], Virendra Chouhan[2]
Assistant Professor[1], Student[2]
Department of Mechanical Engineering
SIET
***Email ID:** chouhanvirendra225@gmail.com[2]*

Abstract

Kansei engineering is a technique that turns human emotions into mathematical measures and assists designers in developing new goods that fulfill the expectations of customers. Many studies have discovered forward and backward links between human sensations and design features using various soft computing methodologies, which is a standard Kansei engineering procedure. In this research, we introduced the Kansei engineering framework, which links not only human sentiments and design parts, but also the entire product, by creating association rules. In this experiment, we use semantic differentials to get input from the emotion score that participants assess after they see the entire product. Then, association rules are built to determine the mix of design elements that influences human emotion. The findings of our investigation show a pattern of association of design components based on human emotions that may be obtained from the entire product.

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

INTRODUCTION

TODAY'S competitive landscape has altered dramatically. Customers' attention is no longer drawn to essential functions such as product performance. People are increasingly searching for solutions that meet not only their utilitarian but also their aesthetic demands.

As a result, good product creation has become a critical responsibility for businesses in order to thrive in such tough competition. When designing a new product, it is inevitable to pay close attention to design because it is important to the initial impression of buyers in terms of product look and experience. As a result, it is critical that designers integrate in their working method not only the functionalism ideology (form follows functions), but also the user-centric idea (form follows people) [1].

Today, different tools are available to aid designers in explicitly and implicitly capturing consumer wants. "Kansei Engineering" is a well-known technology that turns client emotion/feelings in their product perspective. Kansei Engineering is a consumer-oriented technology that assists designers in the new product development process by translating customers' emotions/feelings in response to product appearance by evaluating five human senses: sight, hearing, taste, smell, and touch and generating design specifications accordingly [2].

Kansei Engineering is used in the design process in a variety of sectors, including autos, fashion, telephones, and furniture [3, 4, 5, 6]. Various data analysis methodologies for Kansei Engineering have been created up to this point in order to optimize design aspects that best portrayed emotion [7].

However, most Kansei Engineering research is currently concentrated on monitoring emotion/feeling in reaction to product on a one-to-one basis. Because a product is made up of many little components, it necessitates a separate Kansei Engineering study for each component; these fragmented studies are then combined to form the product's outline. This method has a disadvantage in that it takes a long time and costs a lot of money. Furthermore, designers struggle to bring together the effects of each design aspect, especially when they are not properly integrated.

In this study, we suggested combining Kansei Engineering with the notion of "the Whole of its Parts" by using Association Rules Mining to discover the pattern of link between emotion/feeling and the overall product look, design features, and qualities. As a consequence, it is easier for designers to grasp the significance of the information, and it is also easier for designers to understand the results.

LITERATURE REVIEW

A. Kansei Engineering

Kansei Engineering is described as "the technology of a consumer's sentiment and image for a product translated into design aspects" [8]. It has been utilized in the process of developing new products by methodically acquiring design elements through perception experiment research, which results in a shorter product creation time and a more exact design idea for future design development. Statistical scaling, magnitude estimation, Likert scale, and the Semantic differential technique [9] have all been used to collect data in order to measure emotion using design features. The semantic differential technique, established by Osgood as a psychological evaluation employing bipolar adjective scales [10], is the most extensively utilized data gathering approach in Kansei engineering. The semantic differential technique was used to collect primary data between design features and emotion in a variety of domains, including street furniture, watches, phones, and so on [11,12,13]. Following the fundamental research from the semantic differential method, there are several approaches to analyzing data, such as the statistical approach, soft computing approach, and mathematical model approach, which are widely known in the Kansei engineering field as Kansei engineering classification types I, II, and III, respectively [8].Depending on the goal of each research, different Kansei engineering analyzing approaches have advantages and disadvantages.The categorization type I is only appropriate for small data sets with straightforward variable relationships. Several studies have effectively used type I analysis, such as the development of a design support system for an office chair and a car interior using multivariate analysis, and the development of a telephone using linear regression [6, 14, and 13].

Kansei engineering category classification type II is better suited for big data sets with more complicated and dynamic relationships among experiment variables. The soft computing approach aids in the discovery of data patterns, the matching of relationships, and the suggestion of solution patterns. Kansei engineering classification type II has been used in a variety of sectors, including studies on automated builders using self-organizing neural networks and mobile phones using fuzzy logic [15,16].

Kansei engineering classification type III is appropriate for huge data sets with highly complicated system relationships for specific purposes that can often be answered by a specific mathematical solution. Park and Han used a "fuzzy rule-based" approach to design office chairs, and Tsuchiya used a "fuzzy rule induction with genetic algorithm" technique to build autos [17,18]. Later, the concepts were extended to Virtual Kansei Engineering and Collaborative Kansei Engineering Designing by integrating users into the system over the internet.However, the majority of the strategies suggested are one-to-one, that is, one design element to one degree of emotion. People view things as a whole rather than as isolated parts of a product. As a result, the research on a single perception of the entire portion that may deduce and infer emotion with design features will be expanded as the topic of study in order to increase the degree of confidentiality, which will save time and money in conducting research.

B. Part and Whole Perception

The idea of part and whole perception has long been debated in cognitive neuroscience. The traditional perspective claimed that perception was the product of the brain processing information from human organ sensing. To describe the entire, spatial perception was formed by merging sensing of human organs. The motor theory of perception, on the other hand, maintained that spatial perception was the product of impulse stimulation rather than perception or memory [19]. However, no conclusion can be drawn about how people see the world around them. One of the long-discussed and still-current arguments is how individuals see things as a whole, or view things as discrete parts and integrate as a whole, in order to derive meaning.

The notion of whole and pieces is constantly used in Kansei engineering. The majority of Kansei engineering research was done on a one-to-one basis, generally in two ways. One method was to measure emotion in respect to each component (design element) and then merge them as a whole product. Yang used design components from a cell phone to create a new product form design [20]. Nakada investigated the impression of construction machinery controller's seats [21]. Another method was to measure emotion in connection to a whole product. Beak et al. used the full perception concept to perform an experiment on textile design [22]. Chen and Chang created a knife based on the overall product idea [23].

C. Design and Semantics

Design is a style of thinking. There are three major schools of thought: behaviorists, Gestalt school, and cognitive science approach [24]. The behaviorist school of thinking is based on internal inputs and responses. They make decisions based on gut instinct [25]. Unlike behaviorists, Gestalt concentrates on the process of reaching a solution. There is a clearly established structural process in issue solving [26]. De Groot proposed that the solution system is derived from memory [27]. The cognitive science method is based on the discipline of psychology. Short-term memory in the human brain is processed using aspects of sensory pattern, discriminating ability, language, and idea [28]. Because the human brain can be gathered as a pattern of brain performance, artificial intelligence is used to simulate the designer's brain.

Product semantics falls under the second school of thinking, which holds that humans respond to products based on their individual and cultural meanings. It is one of the design viewpoints that focuses on the human perception of objects based on personal experience. Rein hard Butter and Klaus Krippendorf developed and initially proposed the idea of product semantics in 1989. They defined "Product Semantics" as "a systematic investigation into how people attribute meaning to artifacts and interact with them accordingly," as well as "a vocabulary and methodology for designing artifacts in light of the meanings they could acquire for their users and the communities of their stakeholders" [29]. The foundation of semantic product design is based on analyzing and comprehending objects through interaction. There are three routes of gaining meaning from objects, according to Krippendorf: meaning in usage, meaning in lives, and meaning in language. First, the meaning in use approach acknowledges that individuals perceive objects differently depending on their history and experience. Second, the approach to meaning in lives demonstrates that meaning is a lifelong learning process. Because certain items take time to develop, often longer than a person's lifespan, the changes along the development must be given meaning in order to communicate. Finally, the meaning in language method demonstrates that the meaning may be described verbally as the focal point of communication. Among these three ways, language is the most successful in deriving sentiment and expression since it can explain clearly in specifics without indicating or inferring.They felt that based on the product semantic notion, each person understands things differently based on their experience. Something's interpretation or meaning can differ. The famous study "Seeking the Ideal Shape: Product Design and Consumer Response" by Peter H. Bloch outlines the elements that determine product form, the perception process, and consumer responses [30]. The product shape is constrained by design goals and limitations such as performance, ergonomics, production/cost, regulatory/legal, marketing programme, and design. Individual likes and preferences, as well as situational conditions, influence psychological responses to product shape, resulting in behavioral responses. As a result, design is more than simply a solution provided to clients; it is the entire process of communication experience that design must maintain as a foundation in design.

D. Association Rules Mining

Association rules mining is defined as "a data mining strategy for discovering interesting associations or correlations between a large group of data elements" [31]. Association rules mining is distinguished by its ability to "discover common patterns, connections, correlations, or causal structures among groupings of items or objects in transactional databases, relational databases, and other information repositories" [32]. This approach is commonly used in market basket data analysis, cross-marketing, and catalogue design to identify patterns of customer behaviors, particularly in consumer purchasing decisions. The notion of data mining has been employed in Kansei engineering to reduce the workload associated with calculating and determining relationships between variables. Yang et al. used association rule mining to map emotion with design aspects for a Volvo truck cab [33].

METHODOLOGY

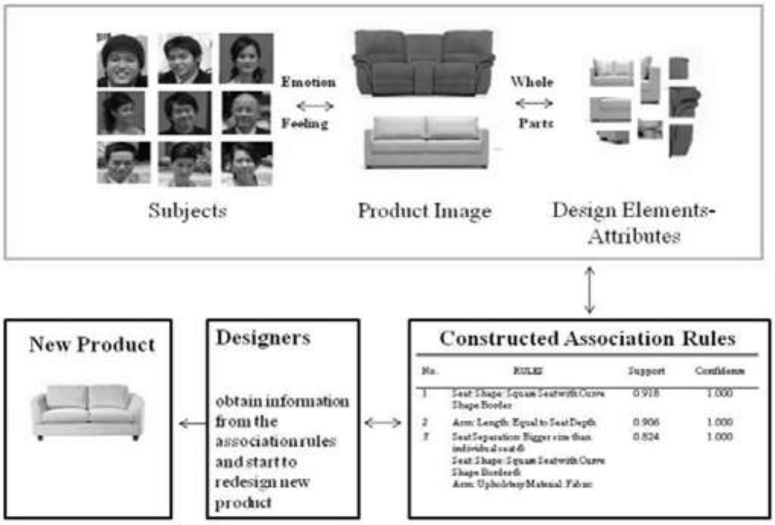

Fig. 1 Research Framework

The core principle of this study is to comprehend consumer perception as a whole rather than in parts, and to identify the sequence matching pieces in order to build and form a new product that meets the expectations of the customer. As a result, product perception will be assessed by inferring the link between subjects, product, design features, and design qualities. Following that, the suggested Kansei engineering-association rules mining integration gained from this study will be used to examine the relationship and search for the combination of design elements-attributes that represents the degree of emotion when people view the image. Designers will be able to use this knowledge to optimize the design of new Products in accordance with client expectations in a substantially shorter development period. Figure I summarize the general premise of this work.

In this study, the experiment is separated into three phases:

1. Data preparation,
2. Data collecting,
3. Data analysis.

Data preparation in the first step comprises choosing objects of study, categorizing design aspects, classifying design qualities, and deriving relevant adjectives that reflect object samples. In the second step, data collecting procedures such as sampling and collection are used. The last phase, data analysis, comprises data analysis using the association rules mining approach in order to understand results. Because the purpose of this study is to assess the level of perception to product appearance, the sofa is thought to have refined details of design elements and is used as the object of this study to demonstrate how the integration of Kansei Engineering technology with applied association rules mining technique can be optimized.

Data Preparation Phase

In this phase, four variables were required to be prepared in order to develop a semantic database: sofa picture (total product image), sofa design elements, sofa design characteristics, and adjectives (emotion/feeling in reaction to the product).

Couch Image (Whole Product Image): The objects of research were sofa images that represented the notion of the whole of its pieces. Between 2010 and 2011, a hundred couch photos were gathered from five top Thai furniture and design publications. A4 paper cards with hundreds of couch photos printed in gray scale were created. Two male and one female furniture designers with more than five years of expertise in the field of sofa design were invited to evaluate the couch picture cards in this study. The designers compared the similarities and contrasts in terms of exterior look, and eventually chose ten couch photos to represent this study. Figure II depicted the final set of couch photos.

Sofa Design Elements and Sofa Design Attributes: Sofa design elements are generated from sofa design patterns,
Which are often employed in the manufacturing process? Because the approach for defining sofa design patterns differed somewhat between companies, in-depth interviews with three sofa production managers were undertaken to extract sofa design components and sofa design characteristics for each selected sofa image. Three male managers with more than 10 years of expertise in couch manufacturing comprised the three sofa production managers. The interviews sought to identify a standard approach for extracting sofa design features and sofa design characteristics based on couch pattern and material utilization. All conceivable couch design features and qualities were recorded and classified in a tabular format. Following the completion of the table of sofa design components and characteristics, the ten selected sofa photos were submitted to the managers for matching the entire sofa images with the appropriate sofa design elements and attributes.

Fig. 2 Ten Selected Sofa Image

Finally, 10 couch pictures were created, each containing twenty sofa design elements and eighty eight sofa design features. Table I contains a collection of design components and design qualities.

Adjectives (Emotion/Feeling to Product Image): In order to communicate with the respondents in this study, the emotion/feelings in reaction to the sight of the sofa wereexpressed by 10 pairs of antonym adjective. The semanticdifferential approach using a five-point Likert scale was used to assess the degree of emotion toward product appearance. Three sofa designers, two male and one female, with more than five years of experience in sofa design, and three sofa salespersons, one male and two female, with more than three years of experience in sales and marketing of the sofa product category, were invited to brainstorm and choose the represented adjectives in this study.

Table 1. 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, Un shown Sewing Stitching –Straight Line, Un shown Sewing Stitching – Curve, Chester field 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 no number of seater	More than, equal to, separation

30-33	Seat Cushion: Shape	Square, Square with Border Curve, Circle, Triangle
34-36	SeatCushion:Sewing Pattern	Shown Straight Stitching, Shown Curve Stitching, Unsown
37-40	SeatCushion: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, Circle
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 late 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	SofaLeg:Height	Very High, Medium, saw able Short, Unsalable Short, No Leg, Metal Recycling 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 initial in-depth interview sessions were held independently in order to collect as many descriptors on the impression of couch image as feasible. The second in-depth interview session was done by grouping all participants and asking them to group comparable meaning adjectives based on their comprehension. The adjective group was created and named after the best-represented adjective in the same category. The antonym adjectives were paired with the chosen adjectives. Following that, three designers and three sales people collaborated to establish

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which adjective pairs should be paired to characterize the sofa's perspective. As a consequence, the 10 adjective pairs were chosen as the measuring scale. Table II has a list of 10 pairs of adjectives.

Data Collection Phase

The goal of this step was to assess how respondents felt when they saw the chosen couch photos. Quota sampling was used to choose 50 respondents for this investigation. The subjects were 22 males and 23 females ranging in age from 25 to 40 years old and living in the Bangkok region. The semantic differentials approach was used as a tool to assess individuals' perceptions of couch pictures. The five-point semantic differentials scale was created using 10 bipolar adjective pairings on ten couch photos.The negative meanings of selected adjectives were placed to the left, while the counter meaning adjectives were placed to the right. The subjects were asked to rate their reactions to each couch image displayed during the trial. The score was assigned a value between 1 and 5, with 1 representing themost negative connotation on the left and 5 representing the most positive meaning on the right. Figure III depicts the questionnaire. Individual questionnaires were obtained by asking each participant to respond to each couch image and score selected bipolar adjectives on the semantic differentials scale according on 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 2. 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

A. Data Analysis Phase

Table 3. 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

During this stage, the acquired data was examined using the association rules mining approach. First, the data was entered into a database and linked to the relationship between couch photos, sofa design elements, sofa design qualities, and adjectives. The database was analyzed to determine the pattern of relationship between full product photos, design features, design qualities, and adjectives, which resulted in the association rules.

The association rules suggested a link between the mix of design components and qualities and the degree of emotion. The experiment's results were reported in tabular style. The regulations of the association were outlined together with the amount of support and confidence. The association rules are made up of design elements-attributes that are ranked from the greatest to the weakest relationship to the chosen level of emotion. The result can be retrieved for any degree of selected adjectives. The experiment's outcomes might vary based on the degree of adjective used.

The combination of design elements-attributes created by the term "most beautiful" was depicted in table III. They proposed ten most connected rules with adjectives based on the results of the experiment. With a support degree of 0.918, the "Seat Shape that has Square Seat with Curve Shape Border" is the design element-attribute that had the highest association with "Most Beautiful" from the subjects' point of view. With a support degree of 0.906, the second most connected to "Most Beautiful" was "Arm Length that Equals Seat Depth." The third most related resulted in a support degree of 0.824 as a combination of "Seat Separation that has larger size than individual seat", "Seat Shape that has Square Seat with Curve Shape Border" and "Arm Upholstery Material is Fabric".

RESULTS AND DISCUSSIONS

The rules or list of combinations of design elements-attributes in connection to adjectives were proposed by the experiment under the integrated Kansei Engineering and the association rules mining in the context of "Wholes of its Parts." Designers may use this approach to get such principles from experiments, evaluate such data, and use it as critical knowledge in developing new products. The tool was tested with designers to determine its effectiveness by using the keyword "Most Beautiful" as the required design concept.

The designers were able to collect design elements- characteristics relating to this term that were recommended by the combined Kansei Engineering and association rules mining approach. According to the results, the designers created a fresh design prototype. According to the results of the testing, the designers were able to save time while gathering reference pictures and selecting materials. In the five sofa factories studied, the average time spent creating a couch prototype by five professional designers was 2 hours and 12 minutes. The average time for creating a couch prototype was lowered to 1 hour 56 minutes by applying the integrated Kansei Engineering with association rules mining tool created. The combination of Kansei Engineering and the association rules mining approach reduced design time by roughly 16 minutes in this trial.

CONCLUSION

Kansei Engineering is a technology that supports designers in producing innovative goods that suit the emotional needs of customers. The majority of Kansei engineering research has focused on measuring emotion in response to product on a one-to-one basis, which is costly and time-consuming in the new product development process. By utilizing the association rules mining approach, this study suggested Kansei Engineering integrating with the notion of "the Whole of its Parts." By improving the rules proposed by the association rules mining approach, this work condensed design element-based tests into a single whole-product experiment. The outcome indicated a collection of design features and qualities that significantly and consistently corresponded with the intended emotion judged relevant to customers' expectations in reaction to the thing to be developed. Designers were able to extract relevant design elements-attributes from such information. According to research, designers were able to reduce design time when producing new products.

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