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Application of Kansei engineering and data mining in the Thai ceramic manufacturing

Chaiwat Kittidecha[1] · Koichi Yamada[2]

Abstract

Ceramic is one of the highly competitive products in Thailand. Many Thai ceramic companies are attempting to know the customer needs and perceptions for making favorite products. To know customer needs is the target of designers and to develop a product that must satisfy customers. This research is applied Kansei Engineering (KE) and Data Mining (DM) into the customer driven product design process. KE can translate customer emotions into the product attributes. This method determines the relationships between customer feelings or Kansei words and the design attributes. Decision tree J48 and Class association rule which implemented through Waikato Environment for Knowledge Analysis (WEKA) software are used to generate a predictive model and to find the appropriate rules. In this experiment, the emotion scores were rated by 37 participants for training data and 16 participants for test data. 6 Kansei words were selected, namely, attractive, ease of drinking, ease of handing, quality, modern and durable. 10 mugs were selected as product samples. The results of this study indicate that the proposed models and rules can interpret the design product elements affecting the customer emotions. Finally, this study provides useful understanding for the application DM in KE and can be applied to a variety of design cases.

Keywords Kansei engineering · Data mining · WEKA · Ceramic

Introduction

Nowadays, the product design and development has become more complexity and fast changes (Yang et al. 1999). Every company competing in market has to focus on this issue, and they have improved their products to enhance consumer satisfaction. A product with aesthetic design that matches with customer preference was chosen especially when product alternatives are similar in terms of functions and price (Tang et al. 2013). According to product design and development, Kansei Engineering (KE) has been used to fulfill subjective needs and preferences of customers. KE methodology aims to translate human psychology, such as feelings and emotions, into appropriate

product design attributes, such as size, shape and other engineering characteristics (Nagamachi 2001). This method has ability to test the different feeling and shows their relation with characteristics of real productions requirements (Huang et al. 2012). It has been successfully applied in various design domains, such as running shoes (Shieh and Yeh 2013), chocolate snacks (Schütte 2013), E-commerce sunglasses (Chuan et al. 2013), beverage bottle (Luo et al. 2012) and booth show (Huang et al. 2011). However, because a product is composed of many elements, it requires separated KE study conducted on each component. Consequently, it takes long time and extreme costs (Pitaktiratham et al. 2012). Data mining is one of the "Knowledge Discovery in Databases" processes. DM can be used to explore numerus volumes of data to discover the hidden patterns and the interactions of highly complex dataset (Zayed et al. 2013). This technique has been used widely in the areas of science and engineering and it has been called as a modern analysis methodology (Natek and Zwilling 2013); e.g. an intelligent system for complex process monitoring (Rezki et al. 2016), a maintenance

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policy (Faghihinia and Mollaverdi 2012) and future behavior of stock price (Mehmanpazir and Asadi 2017). The concept of DM has been applied in KE such as truck cab design (Yang et al. 2008), sofa (Pitaktiratham et al. 2012) and mobile phone (Jiao et al. 2003). In this study, we proposed the integration of KE and DM in order to find the relationships between the emotions and the product attributes. Ceramic is one of most consumer perception product that plays a vital role in design development. Many Thai ceramic companies are attempting to know the customer needs and perceptions for making favorite products, but lacking of formal methodology. The purpose of this study is to determine user feelings related to the features of ceramic design in the Thai manufacturing by KE and DM as a primary study. The findings from this research would increase customer satisfaction and help product designers.

Theoretical background

Kansei engineering

KE is known as "translating technology a consumer's feeling and image for a product into design elements" (Nagamachi 1995). KE is performed by Kansei and the engineering field to evaluate human sensibility and produce the product that customers need and satisfy (Nagamachi 2007). The aim of KE is method to develop new product design according to consumer feeling or emotion. KE System is used to analyze the product attributes that influence on the customer emotion as shown in Fig. 1. Consequently, the features of products can be designed regarding to the emotion and feeling. KE has been applied in various industries in supporting designers to understand consumer. KE is obtained through experiments on customer emotions and feelings affected the physical product and finding the interaction between the psychological feeling and the product element.

Data mining

DM can use to explore, analyze and discover the structure and rules from tremendous volumes of data (Berry and Linoff 1997). Data mining is generally used for prediction 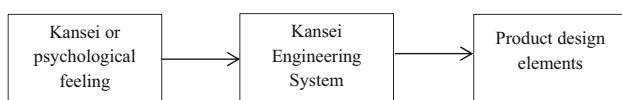and description. There are many data mining tools such as classification, clustering, association rule mining, attribute selection and visual interactive page (Kaya et al. 2014).

The J48 algorithm

The J48 decision tree is one of classified tools by creating a decision tree using the attribute values. J48 algorithm is a modified version of C4.5 and ID3 algorithm implemented through Waikato Environment for Knowledge Analysis (WEKA) software works with discrete and continuous variables and generates the trees (University of Waikato 2015). Decision trees summarize the relationship between attributes and the class of an object in a branching tree structure. The tree consists of decision nodes, chance nodes and end nodes. At each node in the decision tree, the estimation criteria are used to select relevant input variables for prediction (Wikipedia 2015a).

Association rule mining

Association rules mining is "a data mining method to find the interesting association or correlation among a large set of data items" (Jiao et al. 2003). It is used to identify the significant rules in databases using the support and confidence measurements. The support and confidence are used to select interesting rules (Wikipedia 2015b). The support reveals how of frequently the items appear in the database. The confidence reveals the number of times the true statements. Apriori algorithm is the best-known algorithm and widely used in association algorithm. Class association rule (CAR) is one of tools in association rule mining with the specified classes (Lia et al. 2002). CAR was used instead of general association rules in this study.

Confusion matrix

A confusion matrix is a table with each column represents the instances in a predicted class, while each row represents the instances in an actual class (Wikipedia 2015c). Each cell in the table represents the number of true positives (TP), false negatives (FN), false positives (FP) and true negatives (TN) as shown in Table 1. From the confusion matrix the accuracy was calculated as follows.

Fig. 1 A diagram of a process of Kansei engineering system (Nagamachi 2007)

Table 1 Confusion matrix

Actual class	Predict class	
	Yes	No
Yes	TP	FN
No	FP	TN

$$\text{Accuracy} = \frac{TP + TN}{TP + TN + FP + FN}. \qquad (1)$$

Methodology

This study applied KE and Data mining based on model procedure as presented by Schütte and Eklund (2005). The procedures of this study represented in Fig. 2. This procedure is presented as follows.

Choice of domain

A mug was selected as the product domain. The sample size of the study was 37 participants for training set (67% of all the data) and 16 participants for test set (33% of all the data). The ratio 70-30 is often used in data mining for split of the data set (Analysis Services 2017). The participants were Thai people who used the mug for a long time.

Span the semantic space

Kansei words were collected from advertisements, internet videos, magazines, literature reviews. In the initial stage, a total of around 170 different words describing could be extracted. Some of unclear words were omitted in the screening step. After discussions with the professionals and experts in product design from Rajamangala University of Technology Lanna (Thailand), 6 words highly relevant were finally determined, namely, attractive, ease of drinking, ease of handing, quality, modern and durable.
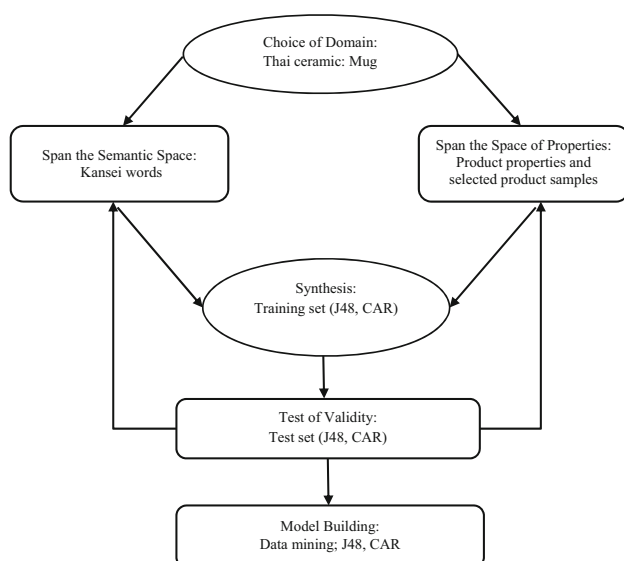

Fig. 2 Research methodology

Span the space of properties

We conducted an interview with 3 ceramic manufacturing experts to obtain complete description of the mug appearance. The external feature of mug can be deconstructed as 6 design attributes or items, namely, body, handle, foot, lip, color and pattern. For spanning the space of properties, 6 different aspects with 24 different properties in total, which are enough to represent the whole mug designs, were identified as shown in Table 2. Finally, a total of 10 mug sample images which would cover the whole design space were selected as the product image questionnaires as shown in Fig. 3. Table 3 shows the product properties of the mug samples. For example, Mug 1 has cylinder body, loop handle, non-foot, non-lip, pain color and non-pattern.

Synthesis

Data collection process

Firstly, the questionnaire is constructed by using the 5 score Likert scale which ranged from 5 that means strongly agree, 4 means agree, 3 means undecided, 2 means disagree and 1 means strongly disagree. Constructed questionnaires were used to perform a survey. The participants were given a brief introduction about how to fill in the survey and described about the meaning of Kansei words. They were asked questions: How do you feel about the sample ''x'' for Kansei word ''x''? The product samples images were ordered randomly.
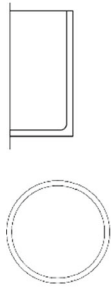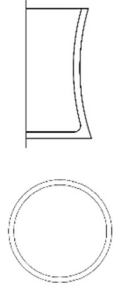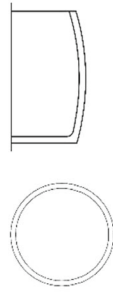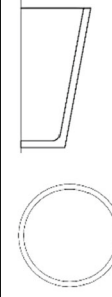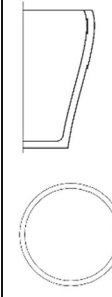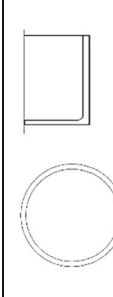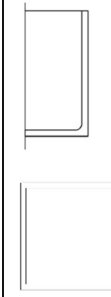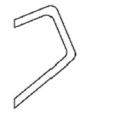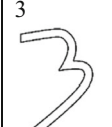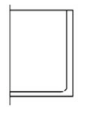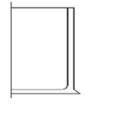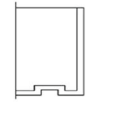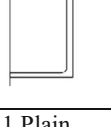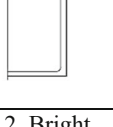
Synthesis

WEKA freeware developed by the University of Waikato was conducted to analysis the DM Technology. We also used the decision trees technique J48 and CAR as best suited for data analysis. Using the tenfold cross validation method in WEKA, the data was analyzed by each of the models, and the best one was chosen. Each model was evaluated on a training set. The accuracy is calculated for J48, whereas the support and confidence are used for CAR.

Test of validity

To validate the relationships between Kansei words and product properties, a separate data was used on the test set. The available data will divide into two sets: a training set and a testing set. Training set is the one that is used for the training of the algorithm. These are 370 for each kansei word, which are the questionnaire results for 10 sample mugs by 37 participants. A test set is only used to test the performance of a trained model. The test data are 160 for

Table 2 Product properties identified

Item	Category						
1.Body	1.Cylinder	2.Inward Curve	3.Barrel	4.Cone	5.Curved Cone	6.Short	7.Square
2.Handle	1.Loop	2. Square	3.Geometric	4.Number 7	5. Number 3		
3.Foot	1.Non Foot	2.Foot	3.Slot Foot				
4.Lip	1.Non Lip	2.Lip					
5.Color	1.Plain	2. Bright	3. Dark				
6. Pattern	1.Non Pattern	2.Cartoon	3. Image	4.Alphabet			

Fig. 3 Mug samples selected for evaluation. Top row from left: Mug 1–5. Bottom row from left: Mug 6–10

each kansei word, which are the questionnaire results for 10 sample mugs by 16 participants. The evaluation measures were evaluated again.

Model building

The data acquired from the synthesis step are presented in a relational model. Models are proposed that relate between each of Kansei words and product attributes. The most important factor among product attributes was determined as the decision tree by J48 algorithm. Normally, the decision tree is graphically revealed with hierarchical structures that include a root node, branches, and leaf nodes. Each Kansei word is set as the decision attribute and the product properties (items and categories) are set as conditional attributes. In the analysis by J48, the most important factors were determined by the leaf nodes that are the high degree of emotions (from agree to strongly agree level). CAR was used to understand the relationships between product attributes and emotions from the strongest to the weakest relationship for each of Kansei word. The most important

Table 3 The product properties of the mug samples

Product sample	Product properties											
	Body							Handle				
	Cylinder	Inward Curve	Barrel	Cone	Curved Cone	Short	Square	Loop	Square	Geometric	Number 7	Number 3
Mug1	x							x				
Mug2					x							x
Mug3							x		x			
Mug4			x					x				
Mug5				x							x	
Mug6		x						x				
Mug7						x		x				
Mug8					x				x			
Mug9				x				x				
Mug10	x									x		

Product sample	Product properties											
	Foot			Lip		Color			Pattern			
	Non Foot	Foot	Slot Foot	Non Lip	Lip	Plain Color	Bright Color	Dark Color	Non Pattern	Cartoon	Image	Alphabet
Mug1	x			x		x					x	
Mug2	x			x		x				x		
Mug3	x				x		x					x
Mug4		x			x		x		x			
Mug5	x			x		x			x			
Mug6	x			x			x			x		
Mug7		x		x				x	x			
Mug8	x			x				x	x			
Mug9			x	x				x	x			
Mug10	x			x			x		x			

rules also determined by the high degree of emotions (from agree to strongly agree level). Product designers can design product attributes related to the customer emotions which are retrieved from these results. For example, the combination of product attributes that modeled for the emotions or Kansei word of attractive.

Results and discussion

In this study, J48 classifier technique and CAR are proposed for evaluating the relationships between Kansei words and product properties. All the models are trained and tested, the results obtained are recorded. Firstly, we selected the best decision tree structure for each emotion

Table 4 Training and test data decision tree with different confidence factors

Model	Confidence factor	Accuracy (%)					
		Attractive	Ease of drinking	Ease of handing	Quality	Modern	Durable
Training data 1	0.25	34.59	31.08	27.84	36.22	30.27	34.59
Training data 2	.04	34.59	28.38	26.76	36.22	29.73	34.95
Training data 3	0.6	35.40	28.65	26.49	36.22	29.73	37.03
Test data		35.00	38.75	36.25	37.27	36.25	40.00

model as shown in Table 4. The training and test data were 370 and 161 instances, respectively. Training data1 was selected for predictive model ease of drinking, ease of handing and modern, whereas training data3 was selected for model of attractive and durable because theirs accuracy were the best. The effects of product properties on customer emotion were mapped as shown in Figs. 4, 5, 6, 7, 8 and 9. For example, Fig. 4 shows the map indicates that the product properties such as pattern, body and handle affect the emotion of attractive results significantly. Table 5
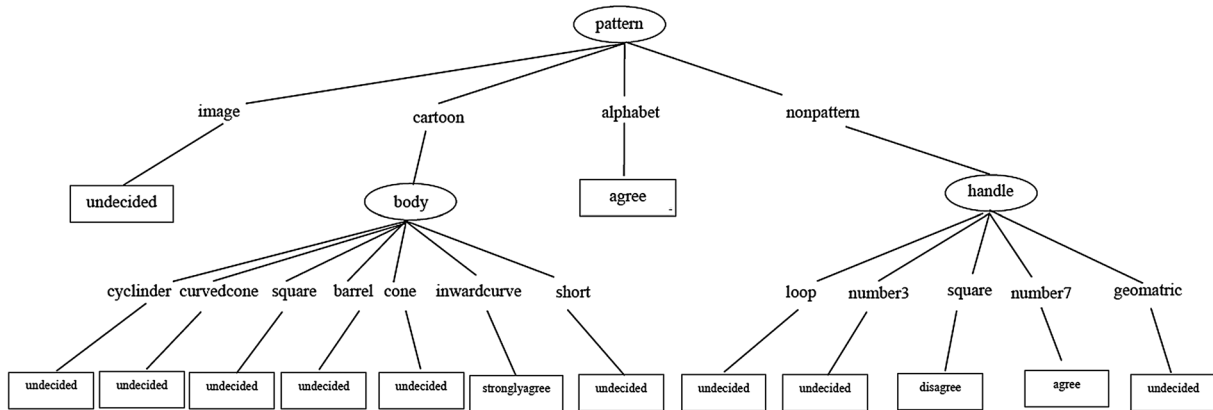

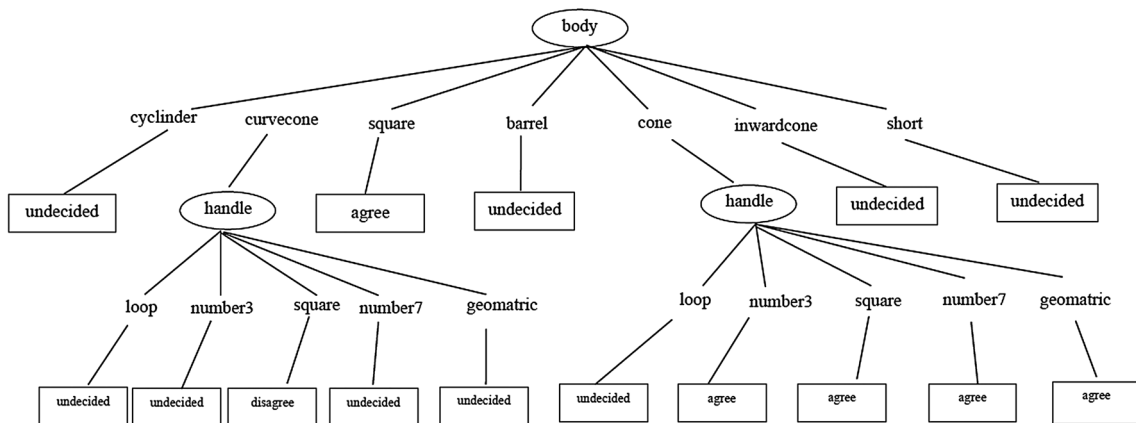**Fig. 4** Decision tree classifier for the emotion of attractive

Fig. 5 Decision tree classifier for the emotion of ease of drinking
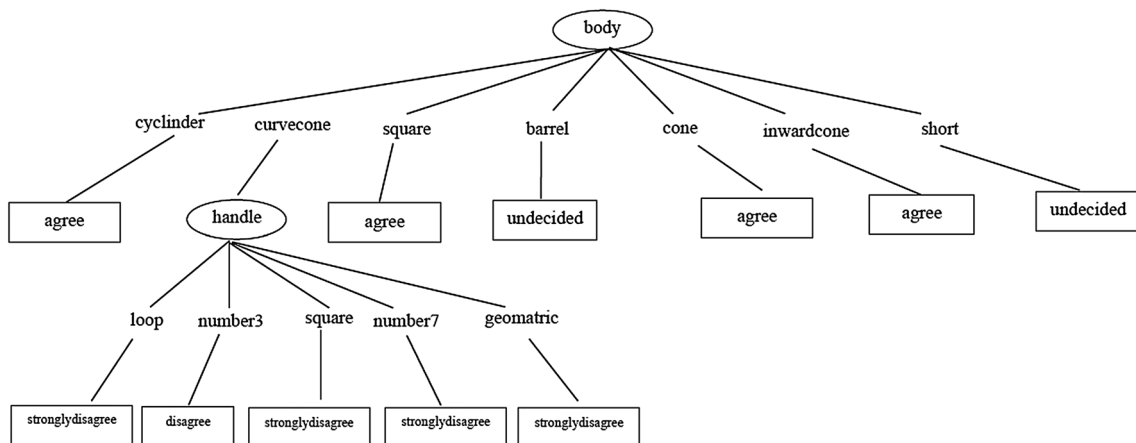

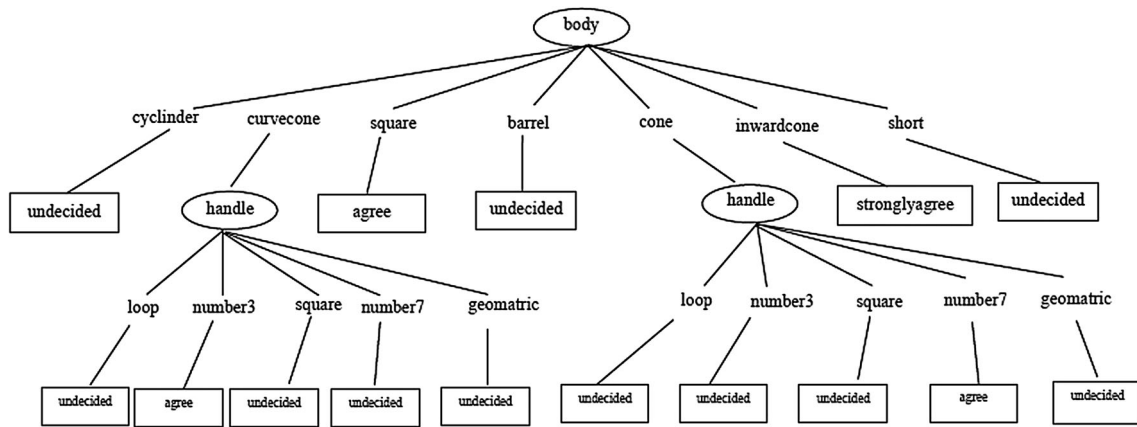**Fig. 6** Decision tree classifier for the emotion of ease of handing

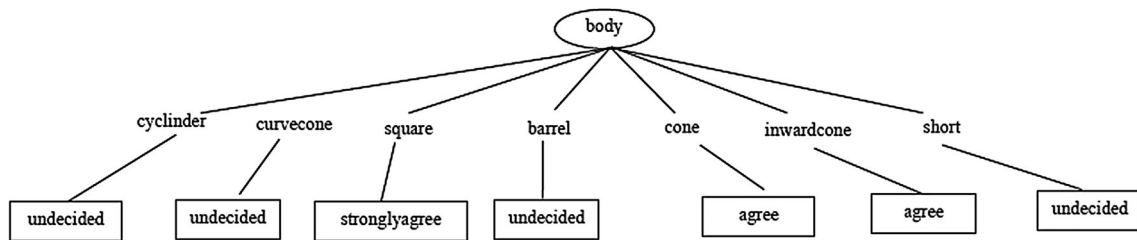**Fig. 7** Decision tree classifier for the emotion of modern

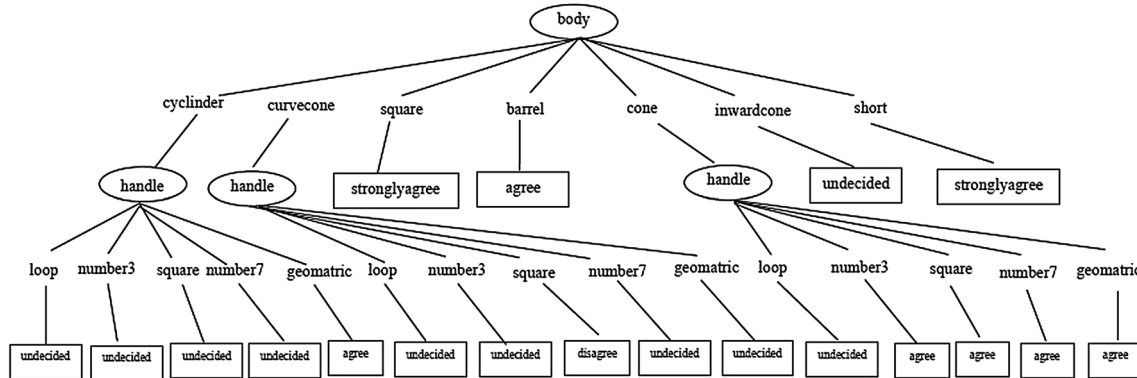**Fig. 8** Decision tree classifier for the emotion of quality

Fig. 9 Decision tree classifier for the emotion of durable

shows the most important category of mug that affecting the high degree of emotions/Kansei words (from agree to strongly agree level).

For CAR, the minimum of confidence value and the support value were determined as 0.1. According to the high degree of emotion (from agree to strongly agree level), the most important rules are show in Table 6. For example, the bright color of mug is the design attribute that had the most relationship with the emotion of attractive with the confidence degree of 0.28. The second most relation was the non-foot mug with the confidence degree

of 0.24. The non-pattern mug was the third most related this emotion with the confidence of 0.23.

From the results of J48 and CAR, we found the difference of the predictive model of product property that affecting the emotions. For example, the most important properties of mug that affecting the emotion of attractive by J48 was body, handle and pattern whereas the most important properties by CAR was foot, lip, color and pattern. The non-pattern appearance was significant both of models, therefore the designers were able to design this attribute related to this customer emotion. Similarly, the

Table 5 The most important category of mug for the high degree of Kansei words by J48

No.	Attractive	Ease of drinking	Ease of handing	Modern	Quality	Durable
1	pattern = alphabet ==> attractive = agree	body = square ==> ease of drinking = agree	body = cylinder ==> ease of handing = agree	body = inward curve ==> modern = strongly agree	body = cone ==> quality = agree	body = square ==> durable = strongly agree
2	pattern = cartoon body = inward curve ==> attractive = strongly agree	body = cone handle = number3 ==> ease of drinking = agree	body = square ==> ease of handing = agree	body = square ==> modern = agree	body = inward curve ==> quality = agree	body = short ==> durable = strongly agree
3	pattern = nonpattern handle = number7 ==> attractive = agree	body = cone handle = number7 ==> ease of drinking = agree	body = cone ==> handing = agree	body = curved cone handle = number3 ==> modern = agree		body = barrel ==> durable = agree
4		body = cone handle = square ==> ease of drinking = agree	body = inward curve ==> ease of handing = agree	body = curved cone handle = number7 ==> modern = agree		body = cylinder handle = geometric ==> durable = agree
5		body = cone handle = geometric ==> ease of drinking = agree				body = cone handle = number3 ==> durable = agree
6						body = cone handle = number7 ==> durable = agree
7						body = cone handle = square ==> durable = agree
8						body = cone handle = geometric ==> durable = agree

Table 6 The most important rules for the high degree of Kansei words by CAR

No.	Rules of attractive	Rules of ease of drinking	Rules of ease of handing	Rules of modern	Rules of quality	Rules of durable
1	color = bright color ==> attractive = agree conf:(0.28)	foot = non foot color = bright color ==> ease of drinking = agree conf:(0.33)	foot = non foot color = bright color ==> ease of handing = agree conf:(0.4)	foot = non foot ==> modern = agree conf:(0.28)	color = bright color ==> quality = agree conf:(0.27)	handle = loop pattern = non pattern ==> durable = agree conf:(0.35)
2	foot = non foot ==> attractive = agree conf:(0.24)	color = bright color ==> ease of drinking = agree conf:(0.3)	color = bright color ==> ease of handing = agree conf:(0.36)	foot = non foot lip = non lip ==> modern = agree conf:(0.27)	pattern = non pattern ==> quality = agree conf:(0.26)	pattern = nonpattern ==> durable = agree conf:(0.32)
3	foot = non foot lip = non lip ==> attractive = agree conf:(0.22)	foot = non foot ==> ease of drinking = agree conf:(0.29)	foot = non foot ==> ease of handing = agree conf:(0.3)	color = bright color ==> modern = strongly agree conf:(0.26)	foot = non foot lip = non lip ==> quality = agree conf:(0.26)	color = bright color ==> durable = agree conf:(0.32)
4	pattern = non pattern ==> attractive = agree conf:(0.2)	foot = non foot lip = non lip ==> ease of drinking = agree conf:(0.27)	handle = loop lip = non lip ==> ease of handing = agree conf:(0.29)	color = bright color ==> modern = agree conf:(0.26)	handle = loop ==> quality = agree conf:(0.26)	lip = non lip pattern = non pattern ==> durable = agree conf:(0.32)
5	lip = non lip ==> attractive = agree conf:(0.2)	lip = non lip ==> ease of drinking = agree conf:(0.25)	handle = loop ==> ease of handing = agree conf:(0.29)	lip = non lip ==> modern = agree conf:(0.24)	color = bright color ==> quality = strongly agree conf:(0.26)	handle = loop ==> durable = agree conf:(0.31)
6	foot = non foot ==> attractive = strongly agree conf:(0.16)	handle = loop ==> ease of drinking = agree conf:(0.23)	lip = non lip ==> ease of handing = agree conf:(0.27)	foot = non foot ==> modern = strongly agree conf:(0.22)	foot = non foot ==> quality = agree conf:(0.25)	handle = loop lip = non lip ==> durable = agree conf:(0.3)
7	lip = non lip ==> attractive = strongly agree conf:(0.16)	pattern = non pattern ==> ease of drinking = agree conf:(0.21)	foot = non foot lip = non lip ==> ease of handing = agree conf:(0.27)	foot = non foot lip = non lip ==> modern = strongly agree conf:(0.22)	lip = non lip pattern = non pattern ==> quality = agree conf:(0.25)	lip = non lip pattern = non ==> durable = agree conf:(0.28)
8		foot = non foot ==> ease of drinking = strongly agree conf:(0.17)	pattern = non pattern ==> ease of handing = agree conf:(0.25)	lip = non lip ==> modern = strongly agree conf:(0.21)	lip = non lip ==> quality = agree conf:(0.24)	handle = loop lip = non lip ==> durable = strongly agree conf:(0.27)
9		lip = non lip ==> ease of drinking = strongly agree conf:(0.14)	lip = non lip ==> ease of handing = strongly agree conf:(0.17)	pattern = non pattern ==> modern = agree conf:(0.2)	foot = non foot ==> quality = strong ly agree conf:(0.18)	foot = non foot ==> durable = agree conf:(0.27)
10			foot = non foot ==> ease of handing = strongly agree conf:(0.15)			foot = non foot lip = non lip ==> durable = agree conf:(0.26)

designers should develop the new product design by the suggested results for the other emotions. However, this study still in the initial step and there are various decision variables of Data Mining to be depth study such as algorithms (Support vector machines, Naive Bayes, k-means) and quality measures (conciseness, coverage, reliability). In addition, more the study on the psychological effect is needed.

Conclusions

Even though several popular techniques in product design and other related research theories are very helpful for designers in considering customer needs and evaluating design alternatives, they may not have efficiency and effectiveness. It might be due to current product design decisions in most industries still continue to be based on the experiences of designers. This study is investigated the product properties affecting the customer emotions by using KE, classification and association rule which are data mining methods. Decision tree J48 and CAR which are the most popular data mining methods are used to generate a predictive model and to find the appropriate rules. The results will be important not only for the mug design that affecting the customer emotions but also for other products in applying data mining methods in product design and development.

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