Selection of Representative Kansei Adjectives using Cluster Analysis: A Case Study on Car Design

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***Abstract*— *This study aims to select the representative Kansei adjectives or words in Kansei engineering methodology. This study used the passenger car design as its experimental case study. A two-stage cluster analysis was carried out for selecting the representative Kansei adjectives. The selection process of the representative Kansei adjectives was determined based on the smallest distance of individual Kansei adjective to the centroid of each cluster. Thus, the results indicated that 'modern', 'elegant, 'sporty', and 'youthful' were thereupon selected as appropriate adjectives to represent the initial set of Kansei adjectives. As a conclusion, the cluster analysis method was able to systematically select the representative Kansei adjective and easily interpretable for Kansei engineering.*

Keywords*— *Consumers' emotional perception, product form, car design, Kansei engineering.

I. INTRODUCTION

It is generally known that products should be designed to fulfil consumer needs. Product designs which are primarily based on the functionality of the product is inadequate to attract consumers to buy the product. When it comes to buying decisions, consumers tend to follow their feelings, emotions and perceptions, and search for something *more* than what product designers think. Hence, the appearance of a product is one of the crucial factors which influence the buying decision of consumers.

A number of systematic product design studies have been carried out over the years in order to attain a better understanding on the subjective perception of consumers. Kansei engineering has been one of the prominent studies in product design [1, 2], as it is considered as one of the most reliable and useful methodologies in dealing with the emotional needs of consumers. *Kansei* is a Japanese word, which can be literally translated as feeling, image, emotion, affection, sense and impression [3]. Kansei engineering is a methodology that unites Kansei with the engineering discipline, a field in which the development of products that bring happiness and satisfaction to humans is performed technologically, by analyzing human emotions and incorporating them into the product design [4]. In recent years, Kansei engineering has been proven and successfully adopted in various design fields, such as a telephone [5], a mobile phone [6], machine tools [7], trade show booth [8], PET bottle [9] and urban planning [10].

One of the challenges of Kansei engineering involves selecting representative Kansei adjectives that will best describe the consumers' perception towards the product during initial stage of Kansei engineering. Delin *et al*. [11] selected representative Kansei adjectives by proposing a manual methodology based on a set of predefined rules specified by experts. However, their methodology possesses the main drawback the information of the extracted representative Kansei adjectives and their set of original ones are not presented quantitatively.

Several attempts have been made to select representative Kansei adjectives that support quantitative information. Consumers were requested to evaluate product samples using specific Kansei adjectives in the semantic differential (SD) experiments [12]. Factor analysis (FA) was used to extract and analyze the evaluation scores obtained from semantic differential experiments. The factor loading for each Kansei adjective was determined from the factor analysis. Following this, similar Kansei adjectives were extracted and merged into factors based on the consumers' perception. The appropriate Kansei adjectives were then determined by examining and interpreting the factor loadings of the original Kansei adjectives for each factor.

A number of studies have been carried out to correlate consumers' emotional needs with Kansei adjectives using factor analysis. Such studies include Petiot and Yannou [13], Alcantara *et al*. [14], Hsiao and Chen [15], You *et al*. [16]. Although the methodologies presented in these studies reduce the Kansei adjectives to fewer dimensions, the methodologies are incapable of determining representative Kansei adjectives. The factor loadings generated do not provide a direct criterion to select representative Kansei adjectives. The highest factor loading appears to be a reasonable criterion in selecting Kansei adjectives. However, it shall be highlighted that this approach may yield undesirable results in selecting Kansei adjectives that best represent the consumers' perception, specifically when several adjectives possess the same factor loadings in a a particular factor.

In order to address the above problem, this study is aimed to devise a systematic methodology, in which representative Kansei adjectives are selected based on predefined criteria using cluster analysis.

A car design is used as the experimental case study to demonstrate the applicability of the cluster analysis in selecting representative Kansei adjectives. As a brief background, the automotive industry is becoming one of the most important and strategic industries in the Malaysian manufacturing sector. The Malaysian Automotive Association [17] forecasted that there is an increasing trend in market share for automobiles between 2011 and 2016 with a growth of 11.6%. This will be a very challenging period for the automotive industry, in which passenger cars have the biggest market share. Although Proton and Perodua national cars dominate the current Malaysian automotive market, the steady increase of imported European and Japanese cars will eventually result in a decline in national car sales. This scenario reflects that the automotive industry is a highly competitive market, and therefore this reflects that automotive market is extremely competitive and therefore only automobiles with high appeal to consumers will thrive in such a market. A number of manufacturers are moving towards a consumer-oriented approach in automobile design due to increased competition.

It is anticipated that the results of this study will be useful for future studies to develop emotionally attractive passenger cars, specifically for the Malaysian automotive industry. This paper is organized as follows. A brief background on Kansei engineering and its relevance to product design, the Malaysian automotive industry, as well as the motivation and objective of this study is presented in the 'Introduction' section. The methodology and experimental design adopted in this study are presented in the "Research Method" section. The findings of this study are presented and discussed in detail in the "Results and Discussion" section. Finally, conclusing remarks are given in the "Conclusions" section.

II. RESEARCH METHOD

The cluster analysis is used to select the most appropriate adjectives in Kansei engineering and is elaborated in detail in this section. The methodology consists of the following stages: (1) Preparation of stimuli; (2) Preparation of the initial Kansei adjectives; (3) Experimental design for semantic differential evaluation; (4) Analysis of the initial Kansei adjectives using factor analysis; and (5) Selection of the representative Kansei adjectives using cluster analysis.

2.1 Preparation of Stimuli

A total of 76 product samples are gathered based on the various passenger cars sold in the Malaysian automotive market between year 2007 and 2012. However, the number of product samples is too large for semantic differential measurements. Hence, representative product samples are selected by consulting three experts having an automotive and product design background, in which the product samples are evaluated and classified based on the degree of similarity between the products.

A total of 12 representative product samples are finally selected as the set of stimuli used to evoke the consumer's emotional perception for the semantic differential survey as shown in Fig. 1.

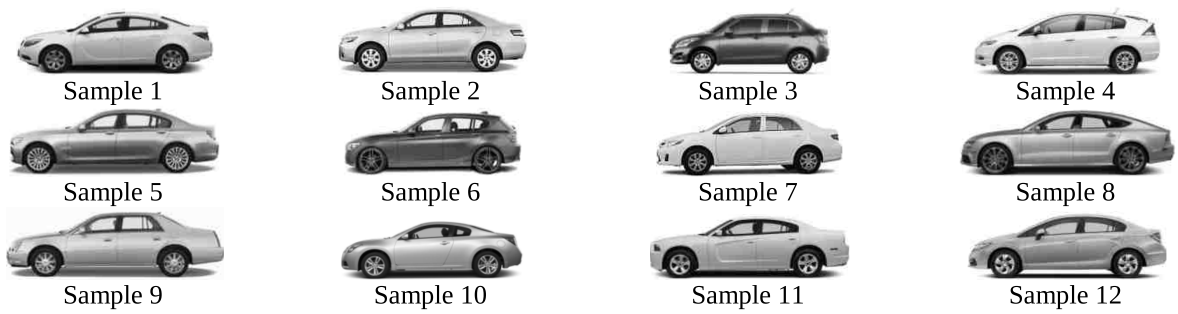


Fig. 1: 12 representative product samples used as a set stimulus for the semantic differential survey

2.2 Preparation of the Initial Kansei Adjectives

A total of 16 initial Kansei adjective pairs are collected in order to describe the emotional perception of consumers towards car design as shown in Table 1. These adjective pairs are selected by eliminating adjectives gathered from relevant Kansei engineering literatures, car magazines and the Internet based on the relationship and similarities in the definitions (i.e. synonyms). The selected Kansei adjectives are expected to represent the complete semantic description as much as possible.

2.3 Experiment Design for Semantic Differential Evaluation

The experimental design involves combining the stimuli and Kansei adjectives for semantic differential evaluation. A survey is conducted to gather the consumers' semantic differential data, in which 112 subjects (56 males and 56 females) participated in a subjective evaluation of 12 product samples using 16 initial Kansei adjective pairs on passenger car design. The subjects are requested to evaluate each product sample in the survey questionnaire, whereby each Kansei adjective pair is rated using a 5-point Likert scale [12]. In this manner, the subjects can express their subjective perception for each product sample by rating each Kansei adjective pair. For example, consider the Kansei adjective pair 'elegant – not elegant' shown in Fig. 2. If the subject evaluates the product sample by giving a score of 1, this indicates that the consumer strongly perceives that the product sample is 'not elegant'. Likewise, if the subject gives a score of 5, this indicates that the subject strongly perceives that the product sample is 'elegant'. The subjects' evaluation scores for each product sample and initial Kansei adjective pairs are averaged to obtain a final utility rating.

Table 1: Initial Kansei adjective pairs used in this study

No.	Kansei adjective pairs	No.	Kansei adjective pairs
1	Elegant–Not elegant	9	Cute–Not cute
2	Stylish–Not stylish	10	Sporty–Not sporty
3	Youthful–Oldish	11	Formal–Not formal
4	Sleek–Not sleek	12	Grand–Not grand
5	Modern–Not modern	13	Streamlined–Not streamlined
6	Powerful–Not Powerful	14	Classic–Not classic
7	Rugged–Not rugged	15	Bold–Plain
8	Spacious–Confined	16	Masculine–Feminine

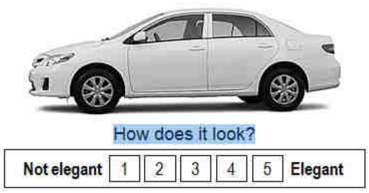


Fig. 2: Example of semantic differential questionnaire: 'Not elegant – Elegant' adjective pair

2.4 Analysis of Initial Kansei Adjectives Using Factor Analysis

The semantic differential measurement data of emotional perception are analyzed to extract the initial Kansei adjective pairs using factor analysis. Factor analysis with varimax rotation is carried out to obtain the Kansei structure, in which the emotional perception is described by factor loadings. The number of factors is determined by the following criterion, i.e. the eigenvalues must be greater than 1. The proportions of variability explaining the factor contribution are obtained after varimax rotation. The data are then analyzed for sampling adequacy and reliability. The adequacy of the sample structure is analyzed using the Kaiser-Meyer-Olkin (KMO) statistic, whereas the reliability of internal consistency between the Kansei adjectives is evaluated using Cronbach's alpha.

2.5 Selection of Representative Kansei Adjectives Using Cluster Analysis

Cluster analysis is performed to select representative Kansei adjectives once the Kansei structure is obtained. The process of selecting representative Kansei adjectives that combines hierarchical and non-hierarchical procedures is known as two-stage cluster analysis [18].

In the first stage of the two-stage cluster analysis, the hierarchical procedure is employed to determine the number of clusters. Agglomerative clustering is performed using the Ward's method in order to compute the sum of squared distances within the clusters and aggregate clusters having a minimum increase in the overall sum of squares. The elbow rule is used to define the number of clusters [19] as it has been proven to be a better rule than other statistical methods [20].

In the second stage, the non-hierarchical procedure (*k*-means cluster analysis) is employed to classify homogeneous Kansei adjective pairs into clusters and select representative adjective pairs for each cluster. Each cluster can be considered as a representative group of Kansei adjectives. For this purpose, the squared Euclidean distance is used to calculate the distances between each Kansei adjective pair and its centroid for each cluster. Kansei adjective pairs with the shortest distance to the centroid of each cluster are selected as the representative adjective pairs for the cluster.

III. RESULTS AND DISCUSSION

A semantic differential survey is carried out to gather data of evaluation scores, as described in the 'Research Method' section. The evaluation scores for each subject are then analyzed using the Statistical Package of the Social Science (SPSS) Version 19.0 software.

3.1 Factor Analysis Results

Factor analysis is performed using the data gathered from the survey to determine the consumers' emotional perception on passenger car design. The factor analysis results after applying the maximum variance of orthogonal (varimax) rotation are presented in Table 2. The results show that the Kansei variables constitute three factors, which explains 39.04%, 37.08% and 20.45% of the variance, respectively. It is interesting to note that Factors 1 and 2 denote more than half of the variability or the percentage of variance. This shows that both factors contribute a majority of the factor contribution, indicating that these factors have a dominant effect on Kansei adjectives. When Factor 3 is included, the proportion of variance increases to explain most of the factor contribution. From Table 2, it can be seen that the total cumulative percentage of three factors represent 96.57% of the total explained variance, which indicates that the three factors extracted from factor analysis are quite acceptable. Consequently, the proportion of variance explained by the remaining factors can be considered insignificant, with a value less than 3.43%. The KMO (Kaiser-Meyer-Olkin) statistic is found to be 0.818, as shown in Table 2. In terms of sampling adequacy, a KMO statistic of over 0.5 indicates that the data is adequate in order to proceed with a satisfactory factor analysis. Since the KMO statistic is 0.818 (which exceeds a value of 0.5), this indicates that the sampling of consumers' emotional perception is adequate for factor analysis. The Cronbach's alpha value is determined to be 0.908, with a range between 0.889 to 0.928 for the 16 Kansei adjective pairs, as shown in Table 2. Cronbach's alpha is a coefficient of internal consistency, and is used as an internal consistency estimate of the reliability of scores in a construct. Indicators with unsatisfactory values will be deleted based on a reliability indicator of 0.7 [21]. The results show that the Kansei adjective pairs have a Cronbach's alpha value greater than 0.7. This indicates that all items of the Kansei construct are indeed reliable.

Furthermore, Table 2 shows the factor loading score for each Kansei adjective pair in a descending order. Adjective pairs with high factor loading scores are perceived as significant factors in passenger car design. A variable must have a factor loading score greater than 0.60 in order to qualify as a significant factor, based on the criterion recommended by Hair *et al*. [22]. The results reveal that the 16 emotional perceptions of car design are structured by three factors, which explain 95.67% of the total data. The first factor consists of 9 impression adjective pairs, whereas the second and third factors consist of 5 and 2 impression adjective pairs, respectively. The impression adjectives 'sleek', 'modern', 'stylish', 'classic', 'streamlined', 'youthful', 'sporty', 'cute' and 'elegant' belong to the first factor, whereas the impression adjectives 'rugged', 'masculine', 'powerful', 'bold' and 'grand' belong to the second factor. The impression adjectives 'formal' and 'spacious' make up the third factor.

Table 2: Factor loadings for 16 Kansei adjective pairs for three factors

No	Kansei adjective pairs	Factor 1	Factor 2	Factor 3	Cronbach's alpha
4	Sleek – Not sleek	*0.915*	0.343	0.041	0.898
5	Modern – Not modern	*0.912*	0.372	0.074	0.894
2	Stylish – Not stylish	*0.868*	0.473	0.096	0.928
14	Classic – Not classic	*-0.847*	0.258	0.402	0.915
13	Streamlined – Not streamlined	*0.837*	0.487	0.166	0.892
3	Youthful – Oldish	*0.792*	-0.071	-0.593	0.901
10	Sporty – Not sporty	*0.775*	0.463	-0.409	0.893
9	Cute – Not cute	*0.666*	-0.458	-0.493	0.923
1	Elegant – Not elegant	*0.632*	0.610	0.472	0.897
7	Rugged – Not rugged	0.221	*0.954*	0.108	0.898
16	Masculine – Feminine	0.077	*0.946*	0.266	0.892
6	Powerful – Not powerful	0.241	*0.918*	0.302	0.899
15	Bold – Plain	0.301	*0.898*	0.191	0.893
12	Grand – Not grand	0.303	*0.684*	0.625	0.889
11	Formal – Not formal	-0.201	0.226	*0.947*	0.916
8	Spacious – Confined	-0.030	0.612	*0.764*	0.903
Final statistics:					
Eigenvalue		6.25	5.93	3.27	
Percentage of variance		39.04	37.08	20.45	
Cumulative percentage		39.04	76.12	96.57	
KMO (Kaiser-Meyer-Olkin) = 0.818 Cronbach's alpha = 0.908					

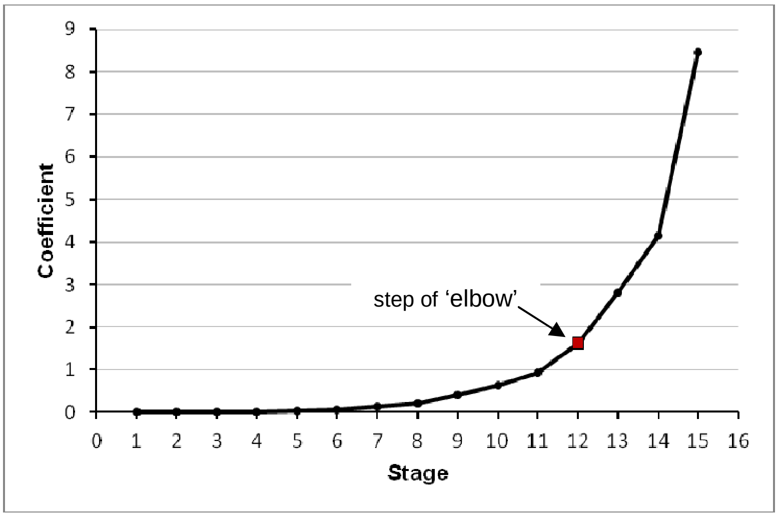
Values in italic correspond to the groups of Kansei adjectives related to Factors 1–3.

3.2 Selection Process of Representative Kansei Adjectives Using Cluster Analysis Results

The 16 initial Kansei adjective pairs are extracted from the factor analysis, in which the factor loadings are classified into three factors for two-stage cluster analysis. The factor loadings for the three factors are first analyzed by hierarchical procedure to determine the number of clusters. The elbow rule is used as the criterion to determine the number of clusters. The number of clusters is determined by identifying the "distance coefficients" that create a bigger jump where the elbow appears in the scree plot. The results of the hierarchical procedure are presented in Fig. 3. From the table in Fig. 3(a), a bigger jump occurs between stages 11 and 12, with a difference in agglomeration coefficient value of 0.692 (i.e. 1.622 – 0.930). Hence, an elbow forms at stage 12, as indicated by the red quadrangle in Fig. 3(b). From the scree plot in Fig. 3, the number of clusters can be calculated by subtracting the number of cases (Kansei adjective pairs) using the step of the 'elbow', i.e. 16 – 12 = 4. Thus, the number of clusters is 4, as determined from the hierarchical cluster analysis.

Stage	Coefficients
1	0.001
2	0.003
3	0.008
4	0.020
5	0.043
6	0.070
7	0.127
8	0.220
9	0.402
10	0.642
11	0.930
12	1.622
13	2.821
14	4.156
15	8.447

(a)



(b)

Fig. 3: Results of the hierarchical cluster analysis: (a) table of agglomeration coefficients, (b) scree plot of coefficients and stage

Table 3: Euclidean distance between Kansei adjective pairs and their centroid for cluster 1–4

Cluster	No.	Kansei adjective pairs	Euclidean distance
1	5	*Modern – Not modern*	0.108
1	14	Classic – Not classic	0.111
1	4	Sleek – Not sleek	0.116
1	2	Stylish – Not stylish	0.179
1	13	Streamlined – Not streamlined	0.412
2	1	*Elegant – Not elegant*	0.192
2	15	Bold – Plain	0.249
2	6	Powerful – Not powerful	0.313
2	12	Grand – Not grand	0.322
2	8	Spacious – Confined	0.388
2	7	Rugged – Not rugged	0.408
2	16	Masculine – Feminine	0.456
2	11	Formal – Not formal	0.805
3	10	*Sporty – Not sporty*	0.206
3	9	*Cute – Not cute*	0.206
4	3	*Youthful – Oldish*	0.000

The italic Kansei adjective pair indicates the representative Kansei adjective pairs within the cluster 1–4.

Following this, the non-hierarchical procedure (*k*-means clustering method) is implemented to classify homogeneous Kansei adjective pairs into four clusters. The squared Euclidean distance concept is applied to extract one Kansei adjective pair from each cluster by computing the centroid of each cluster. The distance between each Kansei adjective pair and its centroid for each cluster is computed and the representative Kansei adjectives are selected based on those with the smallest Euclidean distance. The Euclidean distance for each Kansei adjective pair and its centroid for each cluster is tabulated in Table 3. Table 3 shows that Clusters 1, 2, 3 and 4 consist of 5, 8, 2 and 1 Kansei adjective pairs, respectively. It is evident that the following adjective pairs with the shortest distance are selected as representative Kansei adjectives: 'modern–not modern' for Cluster 1 (distance: 0.108), 'elegant–not elegant' for Cluster 2 (distance: 0.192), 'sporty–not sporty' or 'cute–not cute' for Cluster 3 (distance: 0.206), and 'youthful–oldish' for Cluster 4 (distance: 0.000).

From Table 3, it can be noted that the adjective pairs for Cluster 3 have an equal Euclidean distance, whereby the distance for adjective pairs 'sporty–not sporty' and 'cute–not cute' is 0.206. Consequently, this poses a problem in deciding which Kansei adjective pair is most representative of consumers' emotional perception. It may be possible that both adjective pairs should be selected or either one should be selected to be representative of Cluster 3. However, this problem may still be solved by considering the factor loading of each Kansei adjective pair from factor analysis. From Table 2, the Kansei adjective pairs 'sporty–not sporty' can be selected as a representative Kansei adjective of Cluster 3 because it has a factor loading higher than 'cute–not cute', i.e. 0.775>0.666. Accordingly, if facing these drawbacks, the selection of representative Kansei adjectives is not as simple to be overcome by using cluster analysis, but should also take into account the highest factor loading criteria of factor analysis into cluster analysis.

IV. CONCLUSION

The process involved in selecting Kansei adjectives which best represent the emotional perception of consumers with respect to product samples is difficult to obtain and are often unsystematic. To address this problem, a systematic methodology is devised using cluster analysis to select Kansei adjectives which are most representative of the consumers' emotional perception for passenger cars. Based on the results obtained from the survey, it is evident that cluster analysis is capable of selecting representative Kansei adjectives in a systematic and efficient manner, and the methodology is easily interpretable for Kansei engineering. The Kansei structure is first formed by evaluating the factor loadings of each adjective pair using factor analysis. The Euclidean distance between each adjective pair and its centroid for each cluster is computed, and the representative Kansei adjectives for each cluster are selected by extracting those with the minimum distance. The representative Kansei adjective pairs are found to be 'modern–not modern', 'elegant–not elegant', 'sporty–not sporty', and 'youthful–oldish' for Clusters 1, 2, 3 and 4, respectively. However, this methodology possesses the drawback that it is difficult to select representative Kansei adjectives when there are several adjectives having the same Euclidean distance. Hence, to overcome this drawback, it is critical to take into account the highest factor loading as criteria.

The results and analysis presented in this study serve as a useful reference for future studies in designing emotionally attractive passenger cars, particularly for the Malaysian automotive industry. It shall be highlighted however, that this study is constrained within a specific number of subjects, which is assumed to be representative of the actual market segment.

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