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APPLICATION OF FUZZY LOGIC FOR CUSTOMER NEEDS ANALYSIS: A CASE STUDY ON ONE DIMENSIONAL ATTRIBUTE OF KANO MODEL

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ABSTRACT

The Kano model can be used to translate the voice of the customer (VOC) into product specifications. Kano model offers a customer-oriented approach, supporting design teams in developing new products based on an assessment of customer needs. Customer needs are translated into design attributes, which are then deployed in process and quality requirements. Normally, customer satisfaction is proportional to the level of requirements fulfilled and customers explicitly demand one-dimensional customer requirements of Kano model, (i.e. a car, the higher the gas mileage, the higher the customer satisfaction). Thus, One-dimensional attribute is more facilitated and visualized for customers than others attribute of products i.e. attractive, must-be, and indifferent of Kano model. Generic cases, probability use for uncertainty quantifies. Thus, fuzzy logic based computational intelligence is considered to quantify customer satisfaction levels in probability for product development. Hence, this probability is applied as an input of Monte Carlo-simulation method to determine virtual respondents/sample size for one dimensional attribute of Kano Model.

Keywords: Fuzzy Logic; One-dimensional Attribute of Kano Model; Respondent; Simulation.

1. INTRODUCTION

A single product development system can support a variety of purposes including project planning and control and it provides the scaffolding for knowledge management and organizational learning among numerous other uses [1]. Any organizational activity is effective for promoting utilization of tools and methods, more utilization requires any systematic promotion activity of product development [2]. Virtual interaction tools and virtual products experiences can be integrated into a company's product development process [3]. In this viewpoint, Kano model [4] can be expressed customers' latent needs to initiate or evaluate any product. In this paper, application of fuzzy logic for customer needs analysis is discussed. Thus, the fuzzy front end can be referred to product development to comply with consumer needs to increase the value, profitability or success of a product [5]. Various qualitative techniques, tools and methods [2] can be used to uncover these unspoken consumer needs, wants, likes and dislikes. Moreover, fuzzy clustering was used to cluster customers into a number of groups based on their needs and hence recommends businesses more effective strategies of customer grouping for unknown customers [6]. The customers' assessment of technical attribute is very uncertain especially at the beginning of product life-cycle, thus in Kano's model the exponents of

satisfaction functions cannot be considered as deterministic values [3]. It is considered linguistic values or answer of customer. These are attractive, one-dimensional, must-be, indifferent and reverse. Among them, an attractive relationship, increasing performance of the product in terms of the fulfillment levels can produce more customer satisfaction. The must-be relationship is described as when an essential performance of product is enough to satisfy the customers' needs [7].The maximum profit requirement is the vision from the limited resources of all enterprises. It is possible, when the product attribute, i.e. one-dimensional; linear function between performance and customer satisfaction can be included as more in the product. Hence, customer satisfaction can come automatically, it is the key element of profitability and this satisfaction is based in the designing and resources allocating process. Consequently, product attribute is consumer's needs oriented. If the manufacturer cannot meet diverse needs of the consumers, they will turn to its competing rivals. To meet this requirement of customers with product development, there is applied fuzzy clustering to analyzing consumers' needs and provided the manufacturer with useful information that can be used as guidelines, when it is planning to launch new marketing strategies to the fast changing market . In this

perspectives, one–dimensional attributes is needed to study for the customers' requests into quality measurable characteristic, and judging their rationality, productivity and adequacy to the market [8-12].

A computer system on Kano model aspect was developed to support a product development team by providing an answer to the question: minimal how many respondents [10] should be asked to determine whether or not an attribute is attractive [11], reverse [12]? In this paper, above work [10-12] is extended to determine the minimal number of respondents (sample size) can be asked to determine whether or not an attribute is one-dimensional or not.

The remainder of this article is organized as follows: section 2 describes the Kano model. Section 3 describes a Monte Carlo simulation method. Section 4 describes a proposed system of Kano model. Section 5 describes a case study for one-dimensional attribute of Kano model using fuzzy. Section 6 concludes.

2. A BRIEF DESCRIPTIONS OF KANO MODEL

Kano model defines the relationship between product attributes or Kano evaluation (KE) and customer satisfaction. Five types of product attributes of this model are: Must-be (M), One-dimensional (O), Attractive (A), Indifferent (I) and Reverse (R) as schematically illustrated in Fig.1. Beside of five types of product attribute, Questionable (Q) attribute is occurred, when one selects "Like" or "Dislike" from both FA and DFA; as a result this answer does not make any sense. It is also considered in the Kano model.
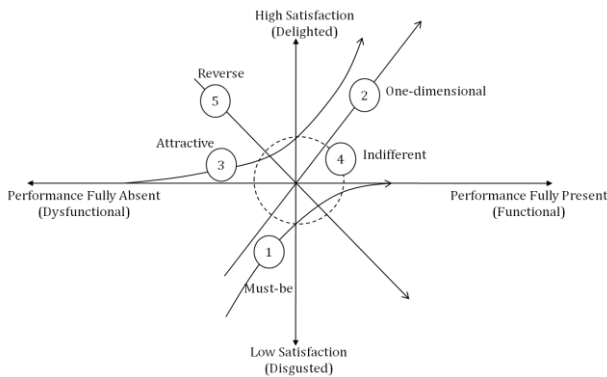

Fig 1. Kano model for customer satisfaction adapted from ullah and Tamaki, 2011[13]

Kano questionnaires the respondents are allowed to choose any combination of the answer from FE and DE. Any combination makes an attribute among, KE $\in$ {A, O, M, I, R, Q}. Thus the combination of FA and DFA is used to identify the status of the attributes (KE) in term of: M, O, A, I, R and Q.

Table 1: Kano evaluation table adapted from Berger et al. (1993) [7]

FE (x_i)	DE (y_j)				
	Like (L)	Must-be (M)	Neutral (N)	Live-with (Lw)	Dislike (D)
Like (L)	Q	A	A	A	O
Must-be (M)	R	I	I	I	M
Neutral (N)	R	I	I	I	M
Live-with (Lw)	R	I	I	I	M
Dislike (D)	R	R	R	R	Q
KE (z_k) =Attractive (A),Indifferent (I),Must-be (M),One-dimensional (O),Questionable (Q),Reverse (R)					

3. MONTE CARLO SIMULATION METHOD

This part of the article describes a technique to simulate the functional/dysfunctional answers and subsequently the Kano evaluation [15-19]. This technique is based on simulation process defined by Eq. (1), as shown as below:

Input:
$\mathbf{E} = (E_1, \cdots, E_n)$ //event vector
$\mathbf{P} = (\Pr(E_1), \cdots, \Pr(E_n))$ //probability vector
N //number of iterations

Calculate:
For $i = 1, \cdots, n$
   $\mathrm{CPr}(E_i) = \Pr(E_1) + \cdots + \Pr(E_i)$ //cumulative probability
End For

Simulate:
For $k = 1, \cdots, N$
      generate r_k //r_k is a random number in the interval $[0,1]$
         If $r_k \in [0, \mathrm{CPr}(E_1))$ Then $S_k = E_1$
         Else
         For $i = 2, \cdots, n-1$
         If $r_k \in [\mathrm{CPr}(E_{i-1}), \mathrm{CPr}(E_i))$ Then $S_k = E_i$
         End For
         If $r_k \in [\mathrm{CPr}(E_{n-1}), \mathrm{CPr}(E_n)]$ Then $S_k = E_n$
End For

Output:
$\mathbf{S} = (S_1, \cdots, S_k, \cdots, S_N)$ //simulated event vector

(1)

In this case probability is considered the relative frequency of the events. The probability of events $E_1 \ldots E_N$ in $\mathbf{S}$ denoted by $\Pr'(.)$ can be determined using the formulation defined by (2).

Input:

$\mathbf{S} = (S_1, \cdots, S_k, \cdots, S_N)$ //simulated event vector

Calculate:

For $i = 1, \cdots, n$

 $count_i = 0$

 For $k = 1, \cdots, N$

  If $S_k = E_i$ Then $count_i = count_i + 1$

 End For

 $\Pr'(E_i) = \dfrac{count_i}{N}$ //probability of E_i in $\mathbf{S}$

End For

Output:

$\mathbf{P}' = (\Pr'(E_1), \cdots, \Pr'(E_n))$ //simulated probability vector (2)

Consequently, simulation *Error* (summation of absolute difference between given and simulated probabilities of each event) can be defined by the expression in (3).

$$Error = \sum_{i=1}^{n} |\Pr(E_i) - \Pr'(E_i)| \tag{3}$$

4. A PROPOSED COMPUTER SYSTEM FOR KANO MODEL

Regard as that **FE** = (Like, Must-be, Neutral, Live-with, Dislike) [7] is a vector that contains all possible states of functional answers. For convenience, x_i will be used to denote i-th element of **FE**, $i = 1, \ldots, 5$. $\mathbf{P_{FE}}$ = (Pr (x_i) | $i = 1, \ldots, 5$) is the probability vector of the states of functional answers defined by **FE**. The corresponding cumulative probability vector is denoted by $\mathbf{CP_{FE}}$ = (CPr (x_i) | $i = 1, \ldots, 5$). In addition, consider that **DE** = (Like, Must-be, Neutral, Live-with, Dislike) [7] is a vector that contains all possible states of dysfunctional answers. For convenience, y_j will be used to denote j-th element of **DE**, $j = 1, \ldots, 5$. $\mathbf{P_{DE}}$ = (Pr (y_j) | $j = 1, \ldots, 5$) is the probability vector of the states of dysfunctional answers defined by **DE**. The corresponding cumulative probability vector is denoted by $\mathbf{CP_{DE}}$ = (CPr (y_j) | $j = 1, \ldots, 5$). Moreover, consider that Kano evaluation, **KE** = (Attractive, One-dimensional, Must-be, Indifferent, Reverse, Questionable) [7] is a vector that contains all possible states of Kano evaluations. For convenience, z_k will be used to denote k-th element of **KE**, $k = 1, \ldots, 6$. $\mathbf{P_{KE}}$ = (Pr (z_k) | $k = 1, \ldots, 6$) is the probability vector of the states of Kano evaluation defined by **KE**. A combination of functional and dysfunctional answers (x_i, y_j) corresponds to a definite Kano evaluation z_k, i.e., (x_i, y_j) $\rightarrow z_k$, in accordance with the Kano model. There are twenty five possible transformation rules (x_i, y_j) $\rightarrow z_k$ [11]. However, to simulate functional and dysfunctional answers and subsequently the Kano evaluation, a simulation process is proposed as illustrated in following Fig. 2.
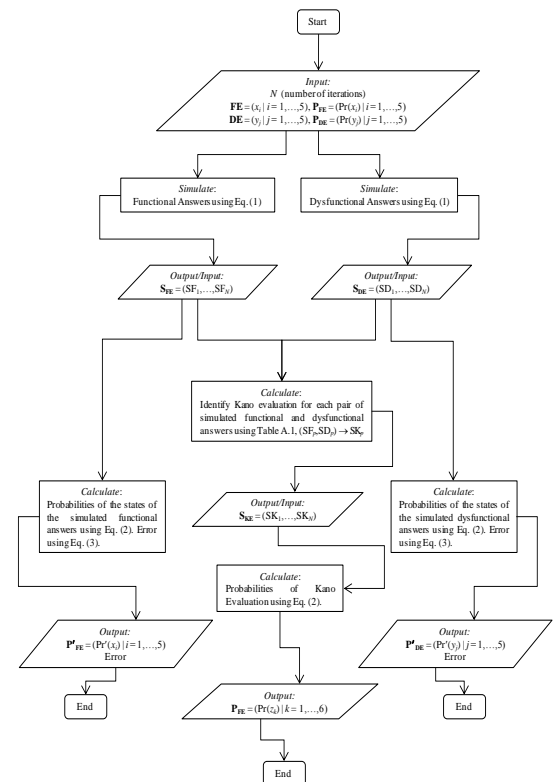

Fig 2. A Proposed Monte- Carlo Simulation method for Kano model

5. A CASE STUDY FOR ONE-DIMENSIONAL ATTRIBUTE OF KANO MODEL USING FUZZY

A case is considered in Fig. 3 for determination the number of respondents for one dimensional attribute of Kano Model. According to Fig.3, there is a questionnaire regarding a product (automobile) attribute (the gas mileage of an automobile). It is well-known that gas mileage of an automobile is "One-dimensional" attribute. Therefore, the ideal answer of a respondent would be "Like" from functional side (i.e., gas mileages of an automobile is good) and "Dislike" from dysfunctional side (i.e., gas mileages of an automobile is not good). This combination of answer (Like, Dislike) yields a "One-dimensional" attribute according to Kano Evaluation (see Table 1). In reality, respondents exhibit a rather fuzzy behavior and sometimes answer different than the ideal one. For example, see the frequency of the answers of 23 [7] respondents shown in Fig.3. This raises a fundamental question that is how many respondents should be requested to know for certain that the specified attribute is one-dimensional attribute or not. This will be also determined a specified sample size for the study one dimensional attribute.
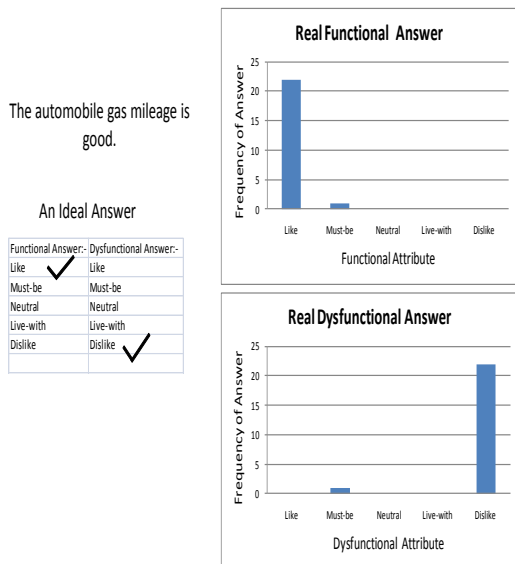
Fig 3. Real Respondents answer

This question can be answered using the developed system, which is system validity is proved [11]. For the first step is to input the probability vectors of functional answers and dysfunctional answers. To determine the probability vectors of functional/ dysfunctional answers the subsequent procedure can be used.

As it is seen from the case shown in Fig.3, from functional side, the respondents are "most-likely" to choose "Like", "less-likely" to choose "Must-be, Neutral, Live-with and Dislike". On the other hand, from the dysfunctional side, the respondents are "most-likely" to choose "Dislike" , "less-likely" to choose "Live-with, Neutral, Must-be, and Like".
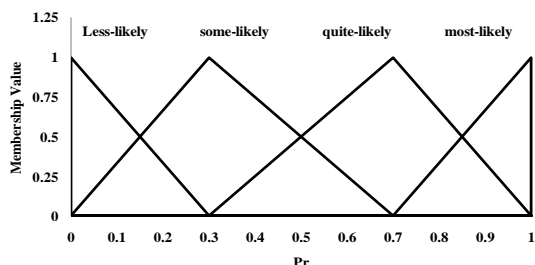

Fig 4. Defining linguistic likelihoods by fuzzy numbers adapted from Rashid et.al, 2010 [11]

These linguistic likelihoods ("most-likely", "some-likely", "less-likely", and so on) can be transformed into numerical probability using fuzzy logic. Ullah and Tamaki, 2011[13] have afforded a fuzzy logic method, which is used here. Figure 4 illustrates the fuzzy numbers defining the linguistic likelihoods "most-likely", "quite-likely", "some-likely", and "less-likely."

From the linguistic likelihoods shown in Fig.4, the average value and lower and upper limits of are determined using centroid method [14] and α-cuts at $\alpha=0.5$, respectively. The results are shown in Table 2.

Table 2: Numerical probability of linguistic likelihoods

Linguistic likelihoods	Pr		
	Lower limit	Upper limit	Average
most-likely	0.85	1	0.9
quite-likely	0.5	0.85	2/3
some-likely	0.15	0.5	1/3
less-likely	0	0.15	0.1

Table 3 shows the probabilities of functional answers for average and worst-case scenarios. For average scenario the average probabilities of linguistic likelihoods (shown in Table 2) are used. These probabilities are normalized to calculate crisp probabilities shown in 4-th column in Table 3. For worst-case scenario, the lower limit of most-likely is used and upper limits of quite –likely, some-likely and less-likely are used. These limits are normalized to calculate the crisp probabilities for worst-case scenarios, as shown in last column in Table 4.

Table 3: Probabilities of functional answers for average and worst-case scenarios

Functional Answers	Linguistic likelihoods	average scenario		worst-case scenario	
		average Pr	Crisp Pr	upper/lower limits of Pr	Crisp Pr
Like	Most-likely	0.9	0.69230769	0.85	0.5862069
Must-be	Less-likely	0.1	0.07692308	0.15	0.10344828
Neutral	Less-likely	0.1	0.07692308	0.15	0.10344828
Live-with	Less-likely	0.1	0.07692308	0.15	0.10344828
Dislike	Less-likely	0.1	0.07692308	0.15	0.10344828

Similarly the probabilities of dysfunctional answers for average and worst-case scenarios are determined and listed in Table 4.

Table 4: Probabilities of dysfunctional answers for average and worst-case scenarios.

Dysfunctional Answers	Linguistic likelihoods	average scenario		worst-case scenario	
		average Pr	Crisp Pr	upper/lower limits of Pr	Crisp Pr
Like	Less-likely	0.1	0.07692308	0.15	0.10344828
Must-be	less-likely	0.1	0.07692308	0.15	0.10344828
Neutral	Less-likely	0.1	0.07692308	0.15	0.10344828
Live-with	Less-likely	0.1	0.07692308	0.15	0.10344828
Dislike	Most-likely	0.9	0.69230769	0.85	0.5862069

The results shown in Tables 3-4 provides two sets probabilities of functional/dysfunctional answers. These probabilities are illustrated in Fig. 5. Using these probabilities a study has been carried out to determine the minimum number of respondents to conclude whether or not an attribute is one -dimensional. Figure 6 shows results for average scenario. As observed from Fig. 6, for 25 respondents there is overlap among the probabilities of attractive, one-dimensional and must-be. This means that using the results of 25 respondents it is not reliable to conclude that the attribute is one-dimensional. For the case of 50 respondents, there is no overlap among the probabilities of attractive, one-dimensional and must-be; this trend remains more or less the same for more respondents (e.g., compares the results of 50 respondents, 75 respondents and 100
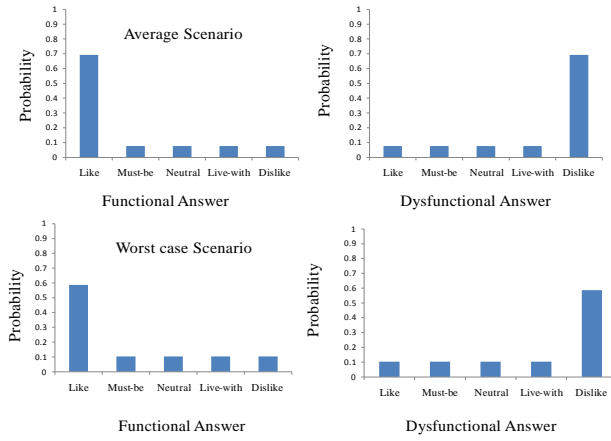
respondents shown in Fig.6).

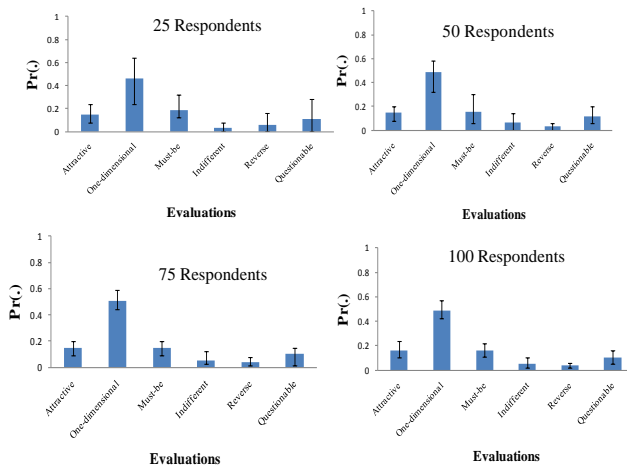Fig 5. Probabilities of functional/dysfunctional answers for two scenarios

Fig 6. Number of respondents versus Kano Evaluation for average scenario

Therefore, at least answer from 50 respondents should be collected to determine that an attribute is a one dimensional. What if the other set of probabilities (probabilities for worst-case scenario) is used? Figure 7 shows the results for the case. In that case 25 respondents it is not reliable to conclude that the attribute is a one dimensional. For the case of 50 respondents, there is no an overlap among the probabilities of attractive, one-dimensional and must-be, this trend remains more or less the same for more respondents (e.g., compares the results of 50 respondents, 100 respondents and 200 respondents shown in Fig.7).
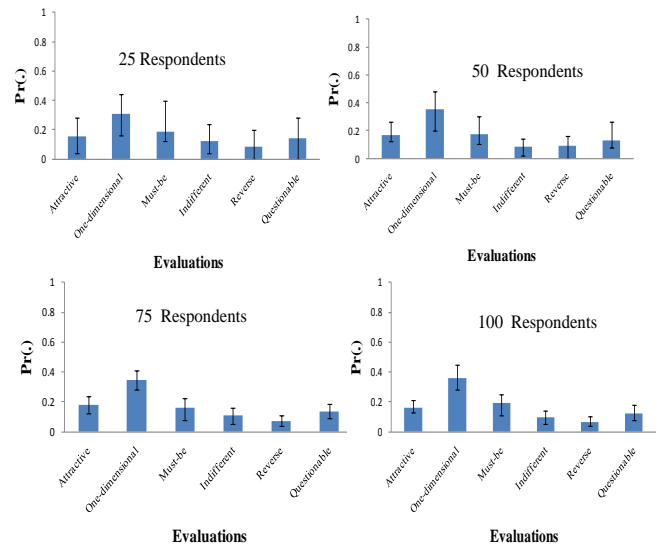

Fig 7. Number of respondents Versus Kano Evaluations for worst case scenario

According to the above results it can be completed that if the answers of at least 50 respondents should be considered the one-dimensional attribute. This working standard can be used as a guideline while distinctive the one–dimensional attribute from others attractive [11], reverse [12], must-be [20], indifferent [21] in all kinds of products.

6. CONCLUSION

Fuzzy logic can be applied, when the crisp value of a phenomenon does not exist. In our arbitrary cases gas mileages of an automobile is good, when there are no boundaries or exact values available. Besides, the statement is uncertain. The idea of fuzzy reasoning originates from human decision making process. 'If ... Then ...' is a statement that is used in human decision making. These 'If ... Then ...' statements are called rules in fuzzy theory. A fuzzy system consists of inputs, outputs, and fuzzy rules. A particular in this article linguistic likelihood is presented to inputs determination (probability) for Kano model based Monte Carlo simulation method for respondent determination of one dimensional attribute. Exactly it is found that at least 50 respondents should be requested to verify whether or not an attribute is one-dimensional attribute

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