A MODEL FOR DEVELOPING CONSUMER ARTITIFCIAL INTELLIGENCE PRODUCT

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Abstract - To provide innovative consumer AI products that can satisfy the newly-developed interests of consumers, firms must perform a comprehensive new product development (NPD) process that can fulfill the demands on human-machine interaction, quality, performance, innovativeness, and cost, etc. A NPD model is constructed for facilitating the development of a consumer AI product. The AI applications, such as speech recognition, pattern recognition, automation, computer vision, virtual reality, diagnosis, image processing and intelligent agent, that can be beneficial to consumers are considered. Other customer attributes (CAs) and engineering characteristics (ECs) in the house of quality (HOQ) can be generated too. A quality function deployment (QFD) model integrated with fuzzy analytic network process (FANP) is constructed to facilitate the NPD process of the AI product. Since people are not willing and capable to handle comparisons properly when there are too many factors, fuzzy Delphi method (FDM) is used to limit the number of factors included in the model. Fuzzy decision-making trial and evaluation laboratory (Fuzzy DEMATEL) is used to analyze the relationship among the factors. The importance weights of theECs are generated through FANP, and a fuzzy failure mode and effects analysis (fuzzy FMEA) is adopted. Mathematical programming models can also be applied to consider additional goals.

Keywords - Artificial intelligence (AI); Consumer AI; New product development (NPD); Quality function deployment (QFD); Failure mode and effects analysis (FMEA)

I. INTRODUCTION

Artificial Intelligence (AI) is "the science concerned with the creation of machine intelligence which is able to perform tasks heretofore only performed by people" (Fox, 1986). Kaplan and Haenlein (2019) defined AI "as a system's ability to correctly interpret external data, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation." Basically, AI "deals with computer program that possess own decision making capability to solve a problem of interest" and concerns with "creation of computational system that imitates the intelligent behavior of expertise" (Kumar, 2017).

An AI system may perform actions, including "perception, interpretation, reasoning, learning, communication and decision making similar to human being to arrive solution for the given problem" (Kumar, 2017). AI has adopted basic techniques from various fields, such as logic, probability and statistics, optimization, photogrammetry, neuroscience, and game theory (Olley, 2018). AI clusters around the areas of search and optimization, fuzzy systems, natural language processing and knowledge representation, computer vision, machine learning and probabilistic reasoning, planning and decision making, and neural networks (Olley, 2018).

The application of AI includes speech recognition, pattern recognition, automation, computer vision, virtual reality, diagnosis, image processing, nonlinear control, robotics, cybersecurity, automated reasoning, bioinformatics, data mining, process planning, intelligent agent and control, manufacturing, healthcare, etc. (Kumar, 2017; Olley, 2018).

Consumer AI could change many of the things we do every day in the future. Daily tasks such as driving, food production, food preparation, cleaning, paying bills, construction, gardening will be augmented or replaced by AI.

In this paper, a NPD model for developing a consumer AI product is proposed. Based on the expertise of experts in the field, the FDM will be used to extract factors for the house of quality (HOQ) in quality function deployment (QFD). The demands of consumers, for example, human-machine interaction, can be fulfilled by the AI technology. Fuzzy DEMATEL is used to analyze the relationship among customer attributes and engineering characteristics in the HOQ.

The FANP is applied to calculate the importance of the ECs. A fuzzy failure mode and effects analysis is applied, and mathematical programming models can also be used to consider other goals.

II. PROPOSED MODEL

A NPD model is constructed for facilitating the development of a consumer AI product. The flowchart of the proposed model is as shown in Fig. 1. The steps are as follows:

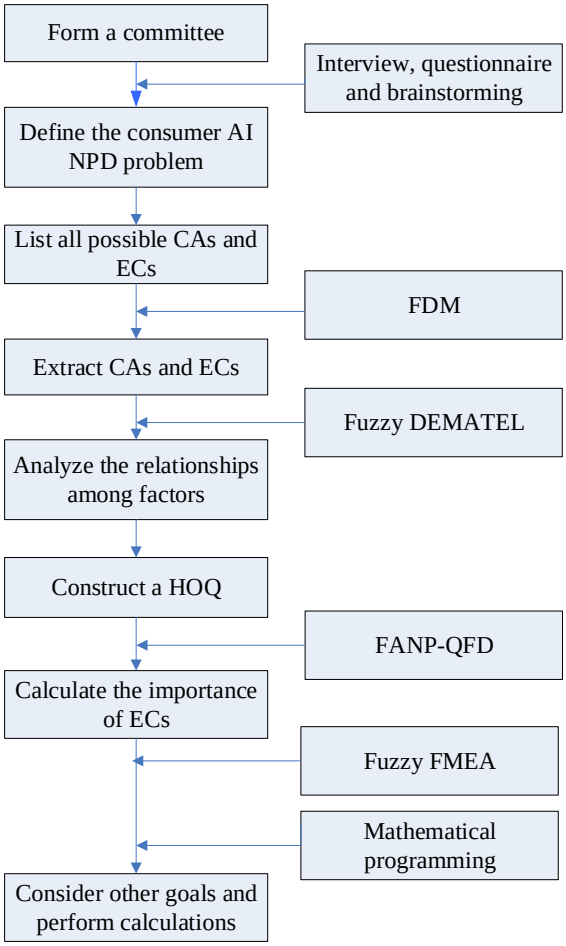


Fig.1. Flowchart of the proposed model

1. Study methodologies, including the QFD and mathematical programming, that have been applied or could be applied in the product development problem. Find new methodologies, and/or construct a new methodology to solve the problem.
2. Interview with experts in a firm, which is considering developing a consumer AI product, and form a committee of experts to define the problem. Prepare a list of CA candidates and a list of EC candidates.
3. Apply the FDM to extract CAs and ECs from the candidate lists. Some CAs that are AI-related and may be important in the selected consumer AI product may be speaking multiple languages, recognizing the user through image, recognizing the user through voice, following voice command, performing online search, unlock only by the specific user, safe from hackers, etc. Some ECs that are AI-related may be speech recognition, pattern recognition, automation, computer vision, image processing, cybersecurity, etc. Common CAs for a product also need to be included, such as durability, quality, price, size, etc. The procedure of the FDM are as follows(Lin and Lee, 2008).

3.1 A questionnaire is prepared to evaluate the importance of CAs (ECs), and experts are invited to fill out the questionnaire.

3.2 A group average is obtained for each of l_{ik} and u_{ik}, and the abnormal value, which is outside of two standard deviations, is deleted.

3.3 The geometric mean of the pessimistic (l_m^i) and the optimistic (u_m^i) importance of each CA (EC), gray zone interval value g^i and consensus significance value (s^i) are generated.

3.4 Determine the threshold value for CA (EC) subjectively, and the CA (EC) with a consensus significance value larger than or equal to the threshold value is selected.

4. Apply the fuzzy DEMATEL to analyze the inner dependence among CAs and among ECs and the interrelationship among CAs and ECs. The steps for the fuzzy DEMATEL are follows.

4.1 A questionnaire is prepared to ask the relationship of one CA (EC) to another CA (EC).

4.2 The linguistic variables are transformed into triangular fuzzy numbers.

4.3 Aggregated fuzzy direct relation matrix is prepared.

4.4 The defuzzified initial direct relation matrix is calculated.

4.5 After obtaining the initial influence matrix, the total influence matrix and the final total influence matrix are calculated sequentially.

4.6 By summing up the rows and the columns of the total influence matrix, a causal diagram can be depicted, and the interrelationship among CAs and ECs can be analyzed.

5. Prepare a house of quality (HOQ). A HOQ is constructed based on the output from Step 4. A HOQ can be depicted as in Fig.2 (Hauser and Clausing, 1988, Karsak *et al.*, 2002; Lee *et al.*, 2010).
6. Implement the FANP-QFD. Based on the HOQ, a QFD network can be prepared. An example can be as shown in Figure 3. A questionnaire with pairwise comparison can then be prepared, and experts are invited to fill out the questionnaire. The consistency property of each matrix of each person is examined to ensure the consistency of judgments in the pairwise comparison. The scores of pairwise comparison are then transformed into linguistic variables based on Table 1 (Lin and Lee, 2008). Fuzzy positive reciprocal matrices are formed, and geometric mean is adopted to integrate the fuzzy positive reciprocal matrices of decision makers. Centroid method is used to defuzzify the fuzzy numbers of the aggregate fuzzy positive reciprocal matrices (Lin and Lee, 2008). Eigenvector of each crisp-valued aggregate positive reciprocal matrix is obtained, and is putthe right position in the unweighted supermatrix. Weight the unweighted supermatrix first, and the weighted supermatrix is then raised

to limiting powers to ensure a convergence (Lin and Lee, 2008). The importance weights can be obtained as a result.

7. Construct a fuzzy failure mode and effects analysis (fuzzy FMEA). FMEA is often applied to assess the risk in the product design by calculating risk priority number (RPN), which is a product of the severity (S), occurrence (O) and detection (D) ratings, i.e. RPN=S × O × D (Almannai *et al*., 2008; Lin *et al.*, 2015). Severity (S) ratings are often linked to the ability to provide quality products to the customer. Occurrence (O) ratings provide an indication of the frequency of the problem. Detection (D) ratings estimate the effectiveness of problem prevention (Lin *et al.*, 2015). Ineach category, the rating is scaled from 1 to 10 (Lin *et al.*, 2015). A questionnaire is prepared to collect the information, and the fuzzy set theory is used to obtain the fuzzy FMEA outcomes.
8. Incorporate mathematical programming approach, such as zero-one goal programming and fuzzy multiple objective programming, to consider other factors such as cost budget and other goals into the QFD system.
9. Consider other phases of the QFD. In addition to the first phase, the HOQ, the other three phases, i.e. parts deployment, process planning and production planning, can also be studied in a similar way.
10. Analyze the results, and provide references to the firm for developing the specific AI product.

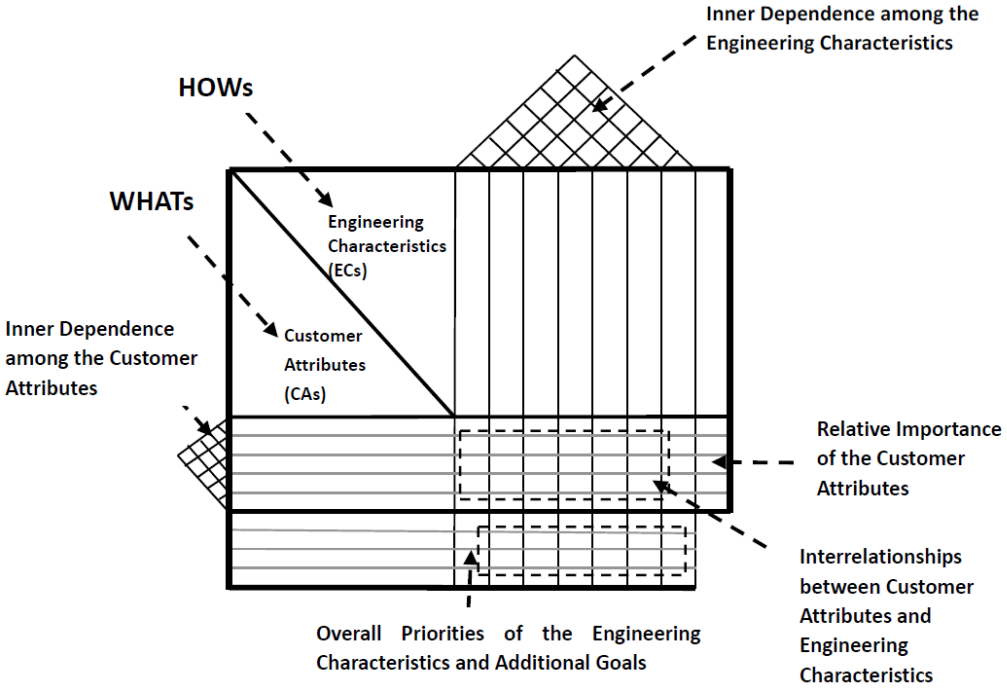


Fig.2. House of Quality (Hauser and Clausing, 1988, Karsak *et al.*, 2002, Lee *et al.*, 2010)

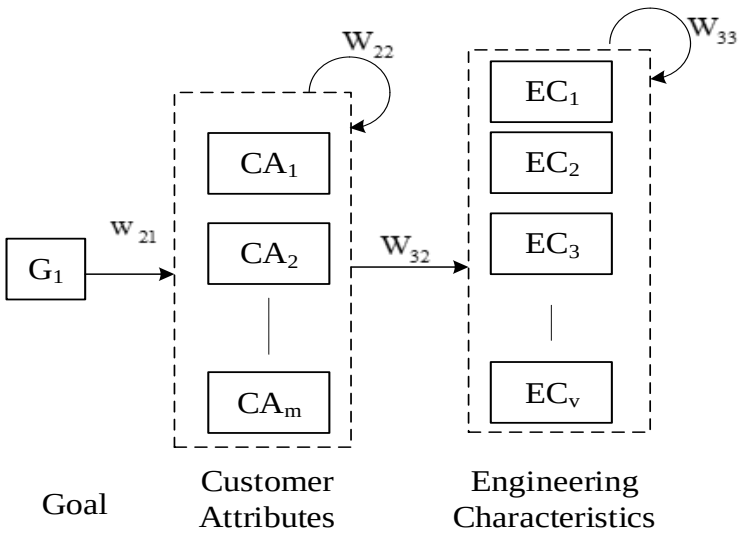


Fig.3. A QFD network structure (Lee *et al.*, 2010)

Fuzzy number	Linguistic variable	Membership function of fuzzy number
$\tilde{1}$	Equally important	(1, 1, 3)
$\tilde{3}$	Moderately important	(1, 3, 5)
$\tilde{5}$	Important	(3, 5, 7)
$\tilde{7}$	Very important	(5, 7, 9)
$\tilde{9}$	Extremely important	(7, 9, 9)

Table1: Characteristic function of the fuzzy numbers(Lin and Lee, 2008)**.**

III. CONCLUSIONS

This research aims to build an NPD model to facilitate the development of consumer AI products. Consumer AI applications, such as automation, computer vision, virtual reality, diagnostics, speech recognition, pattern recognition, image processing, and intelligent agents can be considered. Customer attributes (CAs) and engineering characteristics (ECs) in the house of quality (HOQ) are taken into consideration. A quality function deployment (QFD) model integrated with the fuzzy analytic network process (FANP) is applied to facilitate the NPD process of AI products. Because of the unwillingness and inability to handle comparisons properly when there are too many factors, a fuzzy Delphi method (FDM) is used to limit the number of factors included in the model. The relationships among factors are analyzed using fuzzy decision-making trial and evaluation laboratory (Fuzzy DEMATEL). The importance weights for ECs are generated by FANP. a fuzzy failure mode and effects analysis (fuzzy FMEA) can be adopted. Mathematical programming models can also be used to consider additional goals.

For future research direction, a case study of a firm in developing a new consumer AI product will be presented to examine the practicality of the proposed model. The results shall provide a comprehensive framework and guidance to firms interested in developing AI products.

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