Research on Optimizing User Requirement of Intelligent Vehicles Based on Scenario Analysis

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Abstract: Aiming to the inaccurate definition of user requirement during the preliminary development stage of vehicle, a scenario-oriented model to evaluate vehicle intelligent function is proposed in this paper. The proposed model use scenario analysis to describe the driving status, demand tasks and response measures. KANO model is applied to screen user's requirements. In the process of requirements evaluation, the importance of each function is determined by rough set theory. The ambiguity and subjectivity of user's requirements is considered in proposed model, therfore, the accuracy of evaluation results is improved. Furthermore, a typical commute scenario is presented as an example to verify the feasibility of the model.

1. Introduction

During the preliminary development stage of vehicles, definition and acquisition of user's requirements are key steps that guide the entire development process of the product. Wiley et al [1] pointed out that more than 80% of product defects are the wrong acquisition of requirements during the product development stage. At present, in the acquisition and selection of vehicle's functions, the influence of environment and personal factors on user requirements is not considered [2,3]. The random function overlays will cause problems such as reduced user driving experience and increased product costs. Therefore, it is an urgent problem for vehicle enterprises to define user's requirements accurately and evaluate function priority.

There is a lot of research on acquiring user's requirements, Beyer et al [4] believes that scenario perception can help designers obtain enough data to provide a basis for qualitative research. Carroll [5] proposed the idea of scenario design and solved five technical difficulties in information design. Ueda et al. [6] used scenario design theory to study the innovation of products, services and systems. Horning et al [7] used a scenario-based design approach to explore the requirements of community users for Wi-Fi networks. Benabbou et al. [8] used the activity graph method to analyze the scenario factors of event trigger conditions in the activities of users, and derive user requirements.

The above research only abstractly describes the product design theory. In order to describe how to extract user's requirements through scenarios and synthesize evaluation of requirements, this paper proposes a scenario-oriented function evaluation method.

2. Scenario-based vehicle requirements evaluation model

For the proposed model, the method use scenario analysis to integrate user's requirements, and then, classification of functions based on priority and Kano model, afterwards, the rough number is applied during evaluation so as to effectively reflect the true perceptions of users and the importance of the function .The flow chart of proposed method is shown in Fig 1.

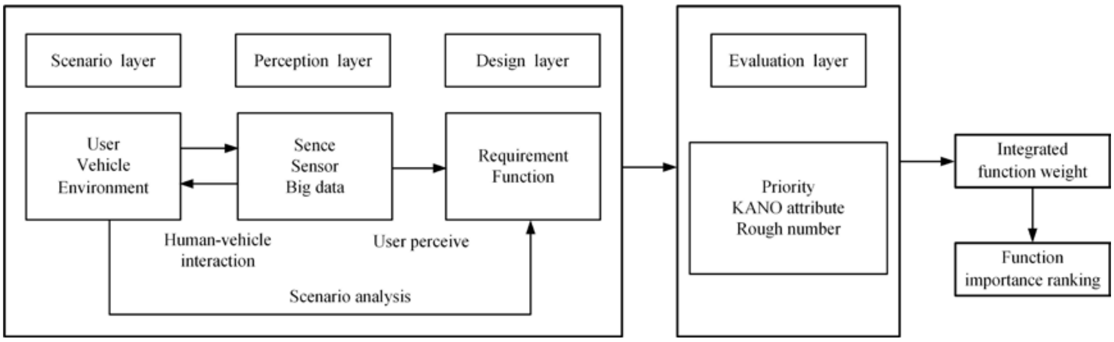

Figure 1. Flow chart of proposed method.

2.1 Scenario-based Requirement Modeling

Scenario, describes the basic elements of person or the product, as well as the current state and environment, including user's behavior, product information, environment, factors affecting the occurrence of events [9].Based on the development of sensor technology and big data, the vehicle scenario studied in this paper is composed of factors that can be monitored. The driving scenario model is constructed by the relationship among user, vehicle, environment and the three factors.

Scenario analysis describes the possible states and stages of the product during the use process. Using scenario analysis method to analyze the potential requirements that may occur at different driving stages of vehicle, and combine similar requirements to obtain a scenario-based user requirements feature set.

Counting the function set and analyzing the requirement priority. Functions that maintain normal driving behavior during driving are defined as level 1 and other functions are defined as level 2. The weight of the two evaluated by experts set as W_L , where W_{L1} = 0.6, W_{L2} = 0.4.

2.2 Definition of Demand Attributes

The Kano model is introduced to better identify the degree of user's demand for vehicle intelligent functions. Kano model is proposed by Kano, et al. [10], which classifies the quality attributes of products or functions based on user satisfaction. According to the relationship between user demand and satisfaction, it corresponds to five types of product quality attributes and five types of demand. In terms of product demand design, existing research usually eliminate indifferent demand (I) and reverse demand (R), then give priority to must demand (M), one dimensional demand (O) and attractive demand (A).

(1) Must demand (M): when this type of attribute is satisfied, user satisfaction will not rise too much, but when it is not satisfied, user satisfaction will decrease significantly;

(2) One dimensional demand (O): linear correlation with user satisfaction;

(3) Attractive demand (A): this type of attribute will greatly improve user satisfaction when it is satisfied.

The KANO model can classify functions that have a great impact on user satisfaction, which help enterprises detailed understand user's requirements and product development priority [11]. Kano questionnaire is used to investigate the types of functional requirements. Each function in the questionnaire has two direct and inverse questions, Kano gave the classification of demand attributes, as shown in Table 1.The attribute weight are shown in Table 2.The adjustment weight *K* indicates the contribution of function to the promotion of product competitiveness.

Table 1. Classification of demand attributes

Demand attributes		**Inverse question**				
		Like	**Must-be**	**Neutral**	**Live with**	**Dislike**
Direct question	**Like**	Q	A	A	A	O
	Must-be	R	I	I	I	M
	Neutral	R	I	I	I	M
	Live with	R	I	I	I	M
	Dislike	R	R	R	R	Q

Table 2. Weight of function attributes

Function Attributes	Must demand	One dimensional demand	Attractive demand	Indifferent demand	Reverse demand
Attribute weight (*K*)	1.5	1.2	1.0	Eliminate	Eliminate

2.3 Algorithm of proposed model

Since users have different requirements for functions in different scenarios, the expression of requirements information is also fuzzy. Therefore, the rough number in rough set theory [12] is applied to deal with the importance of user requirements. The requirements can be represented by a functional set,

$$CR = \{CR_1,\ CR_2,\ ...,\ CR_n\} \tag{1}$$

Suppose PC_{ij} represents the evaluation value of the user i for the function CR_j. Then the evaluation set of m tested users for function CR_j is

$$R_j = \{PC_{1j},\ PC_{2j},\ ...,\ PC_{mj}\} \qquad j=1,2,\dots,n \tag{2}$$

Set PC_{kj} represents any determined element in R_j, PL_{kj} is the number of elements in R_j no more than PC_{kj}, and PU_{kj} is the number of elements in R_j no less than PC_{kj}. Then the formulas for upper and lower limits as well as the rough number of PC_{kj} are

$$L\left(PC_{kj}\right) = \frac{1}{PL_{kj}} \sum_i PC_{ij} \tag{3}$$

Where i is all the subscript numbers of $PC_{ij} \le PC_{kj}$.

$$U\left(PC_{kj}\right) = \frac{1}{PU_{kj}} \sum_i PC_{ij} \tag{4}$$

Where i is all the subscript numbers of $PC_{ij} \ge PC_{kj}$.

$$R\left(PC_{kj}\right) = \left[L\left(PC_{kj}\right),\ U\left(PC_{kj}\right)\right] \tag{5}$$

Combining all the evaluation values of the function j, the average value of upper and lower limits of m tested users as the initial importance of the function j.

$$\left[\bar{R}_{Lj},\ \bar{R}_{Uj}\right] = \frac{1}{m}\left[\sum_{i=1}^{m} L\left(PC_{ij}\right),\ \sum_{i=1}^{m} U\left(PC_{ij}\right)\right] \tag{6}$$

Combining W_L, K and rough number, the evaluation values of m tested users are aggregated by arithmetic averaging, and the final importance of function j expressed as [13].

$$W_j = \frac{1}{2} \cdot W_I \cdot K \cdot \left[\bar{R}_{Lj} + \bar{R}_{Uj}\right] \tag{7}$$

According to formula (7), the final importance of each function is obtained, and the importance of user's requirements is compared by arranging the size of W_j .

3. Case study and discussion

According to the frequency of scenario appearance, scenarios can be divided into high-frequency scenarios and low-frequency scenarios. In this section, daily commuting scenario in high-frequency scenarios is selected as an example, which is more representative. Base on the development direction of new four modernizations of vehicle. This paper mainly analyzes the user's requirements of vehicle intelligent functions and the analysis process is shown in Fig 2.

Kano questionnaire was used to investigate the types of functional requirements. A total of 112 questionnaires were distributed. 96 valid questionnaires were collected and sorted out to ensure the validity of the questionnaire. Through the model, the function attributes are classified, the user's requirements are screened. The classification and adjustment results are shown in Table 3 below.

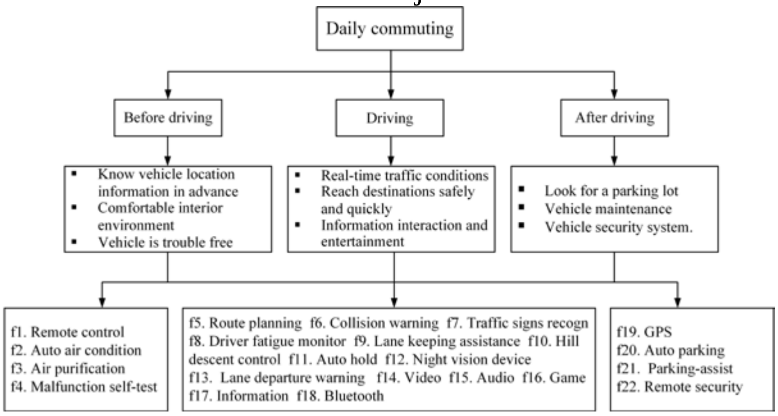

Figure 2. Commute scenario function requirement analysis process.

Table 3. Function classification and weight adjustment.

	CR_1	CR_2	CR_3	CR_4	CR_5	CR_6	CR_7	CR_8	CR_9	CR_{10}	CR_{11}
Function	GPS	route planning	air purification	collision warning	remote control	malfunction self-test	driver fatigue monitor	night vision device	automatic parking	parking-assist	remote security
KANO attributes	M	M	O	O	A	A	A	A	A	A	A
W_L	0.6	0.6	0.4	0.6	0.4	0.6	0.6	0.4	0.4	0.4	0.6
K	1.5	1.5	1.2	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Through a function set $CR = \{CR_1, CR_2, \dots, CR_{11}\}$to describe the screened results, the tested users evaluated the screening functions according to the 9-level rating scale. The user's evaluation of the importance of intelligent functions is scored according to the number 1-9. A score of 1 indicates that the function is not important, 3 indicates that it's generally important, 5 indicates that it's relatively important, 7 indicates that the function is very important, and 9 indicates that it's extremely important. 72 valid questionnaires were collected and sorted out. The evaluation data of each function is processed according to the formula (1) - (6), and the rough number of evaluation values is calculated. The evaluation values are shown in Table 4.

Table 4. Evaluation values of function

CR_1	CR_2	CR_3	CR_4	CR_5	CR_6	CR_7	CR_8	CR_9	CR_{10}	CR_{11}
[5.13,7.14]	[4.62,7.09]	[4.74,6.91]	[6.37,8.04]	[3.0,5.0]	[5.28,6.67]	[4.96,7.09]	[4.89,7.78]	[4.64,6.33]	[5.14,7.54]	[5.92,7.76]

The attribute and priority coefficients are synthesized in Table 3. Calculating the function importance according to formula (7), and normalize the results to obtain the final weight vector of function importance:

$$W^T=(0.142, 0.135, 0.072, 0.133, 0.041, 0.092,0.093,0.065,0.056,0.066,0.105),$$

According to the arrangement rule of rough number [12], the importance of each function can be compared. Ranking the importance of vehicle function is $CR_1 > CR_2 > CR_4 > CR_{11} > CR_7 > CR_6 > CR_3 > CR_{10} > CR_8 > CR_9 > CR_5$.

Furthermore, the proposed model is compared with TOPSIS [14] and rough number methods, and the evaluation results of vehicle function are shown in Fig 3. the functional importance ranking of the three methods are similar, But in the rough number model, the function importance is basically the same, In TOPSIS method, the importance of collision warning and automatic parking are much higher than the evaluation values of other two models, because the data evaluated by TOPSIS did not consider actual scenarios and requirement priority. In reality, it is the first task to arrive at the destination within the specified time on the basis of ensuring safety, which shows that the proposed method has strong practicality and the evaluation values are more discriminative compared with conventional method. Moreover, the proposed model combines the subjectivity of attributes adjustment and the objectivity of the data, which can effectively reflect the true evaluation of users.

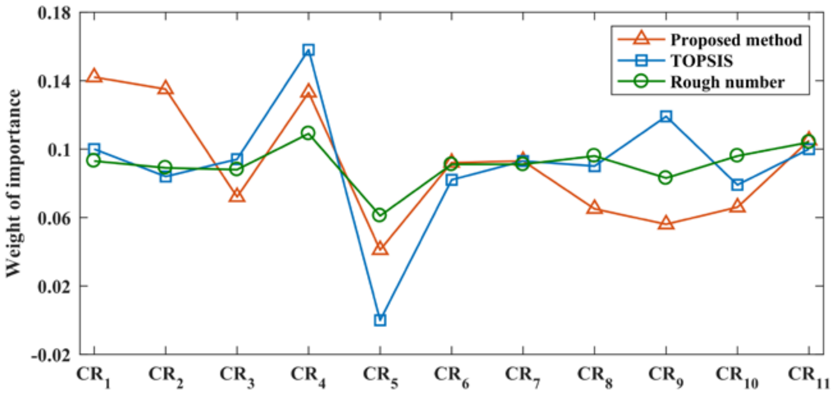

Figure 3. Comparison of three kinds of weights

In daily commuting scenario, users have higher demand for GPS and route planning, the second are the collision warning, remote security, etc. In addition, users will consider vehicle management and other auxiliary functions. The evaluation result shows that the model proposed in this paper is consistent with the actual driving behavior. According to the function screening of scenario analysis and its importance weight, vehicle designers can effectively optimize the positioning and functional design of products so as to improve the competitiveness of products and user satisfaction.

4. Conclusion

This paper proposes an intelligent function evaluation model of vehicle based on scenario analysis. Compared with other evaluation methods, the results of functional evaluation are more practical.

This paper studies the ranking of the importance of functional requirements in commuting scenarios, and provides a theoretical basis for the configuration and optimization of vehicle intelligent functions.

Though the scenario samples are large, and the user's subjective evaluation of vehicle function may not completely consistent, considering from the perspective of product development, the proposed method has a certain reference value for the preliminary design and optimization of intelligent vehicle function.

References

[1] Wiley, Deborah Lynne. "Customer-Centered Products: Creating Successful Products through Smart Requirements Management." *Insight* 3.4(2001):350-351.

[2] Zhu, Fen, M. W. Mutka, and L. M. Ni. "Service Discovery in Pervasive Computing Environments." *IEEE Pervasive Computing* 4.4(2005):81-90.

[3] Bolchini, C., F. A. Schreiber, and L. Tanca . "A methodology for a Very Small Data Base design." *Information Systems* 32.1(2007):61-82.

[4] Beyer, Hugh, and K. Holtzblatt. "Contextual Design." *Interactions* 6.1(1999):32-42.

[5] Carroll, J. M.. "Five reasons for scenario-based design." *Interacting with Computers* 13.1(2000):p.43-60.

[6] Ueda, Yoshihiro, et al. "Structured Scenario-Based Design Method for Experience Vision." *International Conference on Human-Computer Interaction* Springer, Berlin, Heidelberg, 2013.

[7] Horning, Michael A., H. R. Robinson, and J. M. Carroll. "A scenario-based approach for projecting user requirements for wireless proximal community networks." *Computers in Human*

Behavior 35(2014):413-422.

[8] Benabbou, Amel , S. N. Bahloul , and P. Dhaussy . "An Automated Transformation Approach for Requirement Specification." *Procedia Computer Science* 91(2016):891-900.

[9] Carroll, John M. "Scenarios and Design Cognition." *10th Anniversary IEEE Joint International Conference on Requirements Engineering (RE 2002), 9-13 September 2002, Essen, Germany* IEEE, 2002.

[10] KANO N, SERAKU K, TAKAHASHI F,et al. "Attractive Quality and Must be Quality ".*The Journal of the Japanese Society for Quality Control* 14.2 (1984):39-48.

[11] Matzler, Kurt , and H. H. Hinterhuber . "How to Make Product Development Projects more Successful by Integrating Kano's Model of Customer Satisfaction into Quality Function Deployment."*Technovation* 1(1998):25-38.

[12] Lian-Yin, et al. "A rough set enhanced fuzzy approach to quality function deployment."*The International Journal of Advanced Manufacturing Technology* (2008).

[13] Wang, Chih Hsuan , and J. N. Chen . "Using quality function deployment for collaborative product design and optimal selection of module mix."*Computers & Industrial Engineering* 63.4(2012):1030-1037.

[14] Yoon, Kwangsun, and C. L. Hwang. "Multiple attribute decision making: an introduction." 4.4(1995):287-288.