An Information Interface Quantized Evaluation Method for Wireless Sensor Networks

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Abstract. In the global-scaled internet of things, the wireless sensor networks play an important role of collecting information. The sensors are developing towards the integrated information sensor and complex information may be displayed. To obtain the comprehensive information rapidly and precisely through the sensor information interface, the visual appeal-oriented interface is important. In this paper, we proposed a preference-based evaluation-fuzzy-quantification method (EFQM) for the optimization of sensor information interface. In this model, the evaluation analysis, the fuzzy computing and the quantitative analysis were combined to quantify the importance of design considerations for the sensor information interface respectively. The characteristic of proposed method is that the qualitative analysis and quantitative analysis are combined to overcome the respective drawbacks. The results of experiment verified the proposed method could analysis the factors of design considerations quantitatively, and the proposed approach could improve the visual appeal of the sensor information interface.

Keywords: Wireless Sensor Networks; Information Interface; Quantized Evaluation Method; Qualitative analysis; Attractiveness.

1. Introduction

To obtain the comprehensive information rapidly and precisely through the instrument interface, the visual appeal-oriented Interface design is very important, especially for the astronaut and the monitoring personnel on the ground. Due to the light-weight requirement of sensor, the sensor information interface must achieve the visual performances of both visibility and readability, and the sensor information interface's space would be reduced at the same time. Whether the person can judge the information displayed on the screen institutively while driving concerns is related to the comprised elements on the sensor interface, the special arrangement of the elements, the size and proportion, etc. With regard to the design of the sensor information interface, the good visibility, wonderful visual appeal, small-sized and light-weight requirements should be all taken into consideration.

The display modes on the sensor information interface could be flexible. Many information elements on the sensor information interface may be represented with new forms and more and more information can be added on the sensor information interface. There is an important problem should be studied is that the sensor information interface design should be accord with the personal's custom and the characteristic of sensor. With some new sensor, the imitative design of traditional design should be not continued. Also, even with the existing sensor, the sensor information interface design should also be adjusted to meet users' preferences.

In this paper, we proposed a comprehensive model for the optimization of sensor information interface in the satellite-based wireless sensor networks. In this model, the evaluation analysis, the fuzzy computing and the quantitative analysis were combined to quantify the importance of design considerations for the interface respectively. The results of experiment verified the proposed model could analysis the factors of optimization of sensor information interface considerations quantitatively, which would be accord with the feeling of human.

2. Related Work

With the modern sensor information interface become more complicated due to their new functions and elements [1], the service and information of the sensor interface, ranging from safety system to personal communication, from entertainment to locating information may not distract the personnel from their attention on the main objects. Then the designing of sensor interface should provide the correct information for the personnel, and should be clearly, readable and understandable rapidly [2, 3]. Therefore, the designing of sensorial interface should follow the principles that the personnel can understand the relevant functions rapidly. Besides, Owsley et al. [4] put forward that the reducing of contrast ratio and spatial resolution might result in the visibility-related problem while personnel reviewing the icons on the sensor interface. Gibson et al. [5, 6] argued that the effectiveness, visibility and comfortable operation are really important for the sensor interface.

Gkouskos et al. (2014) utilized conceptual vehicles to find out constructs of user needs. Through their study, nineteen need dimensions were revealed: Automation, Calmness, Comfort & Convenience, Connectivity, Control, Driver support, Trip context, Driving pleasure, Efficiency, Environmental impact, Freedom of choice, Interaction fluency, Ownership, Personalization, Safety, Self-image, Simplicity, Technology and Versatility. Chengqi,et al. [7] provided the instruction for the color saturation design of the interface. The research results of J.G Ellis & R.E. Dewar [8] suggested that people’s response to the symbolic pattern is quicker than that to the character and number, and better responses may appear in the bad audio-video circumstances. Since different design objectives should adopt different manners of presenting the information, number and character may be better for some objectives while patterns for others. The ultimate goal is allowing the users to read the information in the fastest and clearest way.

A sensor interface with better usability and visual appeal also must boost the competitiveness of sensor [9, 10]. Therefore, the designing of sensor interface is drawing more and more attention of people. Scolaro & Mclaughlin [12] put forward that the sensor interface should be equipped with better methods of designing and configuration so that the personnel may receive information easily and a great quantity of differential information on the interface may be reduced greatly, thus accomplish the purpose of increasing the safety and stability of driving. Bijuan Luo & Jing Zhu [13] put forward that people’s attention to the interface concentrated more and more on the visual comfort ability and usability of driving. By means of the reasonable designing of human-computer interface, users will be more convenient in recognition and reading, and thus the incidents of mistaken reading will be reduced and the visual comfort will be improved. Gibson et al. [14] proposed that the companies should carry out the user-centered designing and the analysis on which sensors shall meet the requirements of market and users is the key issue.

3. The Preference Based Evaluation-Fuzzy-Quantification Method (EFQM)

In this paper, we adopt “Preference-based design” as the principle. This discipline is about the method of seizing people’s cognitive concept and tidying these concepts by listing, and is also a kind of designing concept centered on the consumer, and may provide a communicating interface between the designers and the users. The designing concept is a method to look for the attraction from the user’s preference, then, capture the attractive nature of the sensors and further create a design with the attraction after disclosing the relation between the preference and the attraction.

To analyze the factors of usability and visual attractiveness for the sensor interface, we need to determine the spatial arrangement of various elements, such as the size, the font type, height, length, width and so on. We propose the evaluation-fuzzy-quantification method (EFQM) to make the analysis. Firstly the evaluation phase would be utilized to build the hierarchical diagram. The upper level of this diagram is the psychological feelings of users, the lower level being the specific characteristics of sensor interface, and the medium level the specific reasons of the attractiveness. Then in the fuzzy computing phase, the factors attained by the evaluation phase would be put forward into a quality model of continuous fuzzy model to analysis the quality attributes of factors precisely.

Eventually, in the quantitative analysis phase, the weight relationship between the upper level, medium level and lower level would be analyzed by the quantitative method.

In the proposed EFQM, we adopt the continuous fuzzy Kano model [15] which is based on the theories of the Kano model and the fuzzy Kano model. The continuous fuzzy Kano model integrates fuzzy skills and the quantitative analysis method of the Kano model. The question pair included a functional question that captured a customer's perception of whether the sensor had a certain attribute and a non-functional question that captured a customer's perception if the sensor did not have the attribute. Based on the responses, the sensor attribute can be classified into one of five categories according to the Kano evaluation table, as shown in Table 1.

Table 1. Evaluation Table

Functional	Dysfunctional				
	1. Enjoy	2. Except	3. Neutral	4. Live with	5. Dislike
1. Enjoy	Q	A	A	A	O
2. Except	R	I	I	I	M
3. Neutral	R	I	I	I	M
4. Live with	R	I	I	I	M
5. Dislike	R	R	R	R	Q
Note:	A: Attractive M: Must-be R: Reverse				
	O: One-dimensional Q: Questionable I: Indifferent				

Based on the study [15], the value of influence may be divided by its maximum value, and the matrix of the influence value here is:

$$NIV = \left(\upsilon_{ij}\right)_{5\times 5} = \begin{bmatrix} 0 & 0.200 & 0.250 & 0.300 & 0.500 \\ -0.100 & 0 & 0.050 & 0.075 & 0.900 \\ -0.125 & -0.025 & 0 & 0.100 & 1.000 \\ -0.150 & -0.038 & -0.050 & 0 & 0.800 \\ -0.250 & -0.450 & -0.500 & -0.400 & 0 \end{bmatrix} \tag{1}$$

The answer of a participant on the two-way questionnaire is employed, and the preference of a group of users may be expressed as:

$$\mu_{nij}=m(F_i)_n\times m(D_j)_n \tag{2}$$

The user satisfaction under the special user demand may be produced according to the mathematical set of the value of influence. S_n can be computed as follow:

$$S_n = \sum_{i=1}^{5}\sum_{j=1}^{5}\upsilon_{ij} \times \mu_{nij} \tag{3}$$

The participants were able to select a number from 1 to 9 as the score of the importance of each specific user demand in the questionnaire design.

The values of S_n required by every participant may be evaluated according to the different importance values given by the participants. The average of the total participant satisfaction for a specific user demand is expressed by the evaluation indicator (EI), which was employed to represent the average evaluation of all participants. Given N participants, the value of EI may be calculated as:

$$EI = \frac{\sum_{n=1}^{N} W_n S_n}{N} \tag{4}$$

Eventually the researchers conducted the statistics and analysis using the quantification theory to research the higher-ranking factors so as to find out the specific characters of interface which influence the usability and visual appeal of the sensor interface.

4. Experiment and the Result Discussion

This experiment was carried out on a wide road isolated from external interruption. The testees helped do the research by driving the samples. They followed their driving habits when scanning the information on the information interface. When the driving ends, they were requied to do the questionnaires about feelings of the information interface during their driving process. At last, the researcher made certain records and came to conclusions. 10 males and 10 females with driving licenses and experience were chosen for this evaluation research. Among them, 10 testees are designers and scholars who have been studying the interface design. One testee was been interviewed after he/she finished driving, and then he/she would continue driving the next oen. Another testee would begin to drive after the first one finished driving all the e-scooter. Each testee was asked to drive one e-scooter for several minutes and then record their feelings about the information interface during driving. They would need to mark those samples that had attractive information interface, according to their own feelings during the driving experience. Then they would also group those samples they selected by analyzing the reasons for attraction.

According to the results listed on the evaluation phase, times of mentioning the factors at the upper-level were sequenced: Concise and Easy, Displaying-Visual, Striking, Distinct difference between the primary and secondary part, futuramic and relaxing. The statistical results were shown at Table 2.

Table 2. Statistical Table of the Evaluation Phase

UPPER LEVEL **Items**		**ORIGINAL LEVEL** **Items**	
Easy to Recognize	63		
Concise and easy, displaying-visual	44		
Striking	23		15
Distinct Difference between the Primary and Secondary Parts	19	Form of electricity meter	16
Futuramic	17	Form of Speedometer	20
Relaxing	12	Relationship between the spatial positions and sizes of the speedometer and electricity meter	
Well-Regulated	8	Font of the speedometer	16
Precise	7	Aspect ratio of the font of speedometer	11
Convenient	7	Distribution of amount of information on the interface	
Practical	6		19
Compact	5		
Harmonious in the visual sense	4		

We introduced the upper-level factors attained through the evaluation phase into a fuzzy computing, precisely analyzed the consumers' comments on the quality attributes of these 6 items, and provided the priority ordering of each quality according to the results of calculating EI values.

Table 3. Attribute Priorities of Factors

Upper-Level Factors	Fuzzy Computing			
	EI	VFAA	Category	Priorities
Easy to Recognize	0.289993	0.3487	Highly Attractive	1
Distinct Difference between the Primary and Secondary Parts	0.259018	0.3385	Highly Attractive	2
Concise and Easy, Displaying-Visual	0.201006	0.2276	Highly Attractive	3
Relaxing	0.197391	0.2086	Highly Attractive	4
Striking	0.122861	0.1598		5
Futuramic	0.105071	0.1367	Attractive	6

Table 4. Quantitative Analysis Results for 'Easily Recognizable Information on the Surface of Sensor'

Item	**Attractive factor**	**CS[a]**	**PCC[b]**
A1	A11	0.8862	0.8571
	A12	0.8212	
	A13	-0.2471	
	A14	-0.4480	
A2	A21	-0.6056	0.8258
	A22	-0.3744	
	A23	0.5285	
A3	A31	0.4203	0.4692
	A32	-0.0413	
	A33	-0.0694	
A4	A41	-0.0604	0.2199
	A42	0.0511	
A5	A51	-0.0804	0.7481
	A52	0.5458	
	A53	-0.3294	
	A54	-0.3281	
	A55	0.7121	
	A56	-0.0303	
A6	A61	-0.1121	0.5545
	A62	0.2019	
	A63	-0.1801	
Constant	3.5653		
$R=0.8985$			
$R^2=0.8073$			

Note: [a] Category scores, [b] Partial correlation coefficients. *R*-Multiple correlation, R^2-Determination coefficient

The research results argued that the most major factors leading to the attractiveness of the sensor information interface include 'Easy to Recognize', 'Distinct Difference between the Primary and Secondary Parts' and 'Concise and Easy, Displaying-Visual'.

5. Conclusion

In this paper, the sensor's information interface design in the satellite-based wireless sensor networks was studied, to realize the comprehensive information obtain rapidly and precisely. We proposed a preference based evaluation-fuzzy-quantification method (EFQM) for the optimization of sensor information interface. In the experiment, from the two perspective of attractiveness of usability on the sensor information interface and the visual attractiveness of the sensor interface, we considered the font on the interface of the sensor, contents arrangement, electric quantity and types of speed per hour as well as the amount of information on the sensor information interface, then 20 experimental samples were made to conduct the dynamic simulated experiment. In the evaluation phase, we obtain the statistical analysis result of users' preference. Then in the fuzzy computing phase, we carry out the more precisely analysis to obtain the preference factors of testees. At last, we used the quantitative analysis to find out the important and specific characteristics influencing the usability and the visual attractiveness of sensor information interface.

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