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Unmanned Vehicles' Message Display Optimization for IoT

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Abstract. The rapid development of Internet of Things (IoT) has drawn much attentions. Recently, the unmanned vehicles-based application for the IoT is widespread. With the unmanned vehicles, the human-machine display design of the unmanned vehicle instrument panel is very important. To rapidly and precisely obtain the comprehensive message through the unmanned vehicle message display, the message display optimization is important. In this paper, we proposed the fuzzy analytic hierarchy process evaluation approach for the optimization of the unmanned vehicle message display. The results of the experiment verified that the proposed method could quantitatively analyze the design consideration factors, and the proposed approach could improve the usability and appeal of the message display for unmanned vehicles.

Keywords: IoT; Unmanned Vehicle Message Display; fuzzy analytic hierarchy process; Evaluation Approach; Appeal.

1. Introduction

Due to the lightweight requirement for unmanned vehicles, the unmanned vehicle message display must achieve the visual performances of both visibility and readability, and the unmanned vehicle message display's space would concurrently be reduced. Whether the person can intuitively judge the message displayed on the screen while driving is related to the comprised elements on the unmanned vehicle display, the special arrangement of the elements, the size and proportion. With respect to the design of the unmanned vehicle message display, good visibility, wonderful visual appeal, a small size and lightweight requirements should all be taken into consideration.

The display modes on the unmanned vehicle message display could be flexible. Many message elements on the unmanned vehicle message display may be represented with new forms and increasingly more message can be added to the unmanned vehicle message display. An important problem that should be studied is that the unmanned vehicle message display design should accord with the personal customs and characteristics of the unmanned vehicle. With some new unmanned vehicles, the imitated traditional design should be not continued. Additionally, even with the existing unmanned vehicle, the unmanned vehicle message display design should also be adjusted to meet users' preferences.

In this paper, we proposed the fuzzy analytic hierarchy process evaluation approach for the optimization of the unmanned vehicle message display. The results of the experiment verified that the proposed method could quantitatively analyze the design consideration factors, and the proposed approach could improve the usability and appeal of the message display for unmanned vehicles.

2. Related Work

To meet the customized requirements of the display, several common techniques (including Evaluation Grid Method(EGM) [1] and the Kano model [2]) have been proposed to reduce the gaps between customer requirements and unmanned vehicle varieties. Professor Cheng Jianxin proposed "intuitive semantics" [3]. Yadav et al. [4] combined Fuzzy Kano Modeling with Quality Function Deployment to study priorities in the esthetic attributes of cars. Ahmed and Yannou [5] proposed that the design attributes of unmanned vehicles and the users' perceptions are intertwined and correlated with each other. They also proposed that Japanese researchers used the scientific research methods of Kansei Engineering to study the correlation between an unmanned vehicle display's physical attributes and perceptual attributes. For example, Tomio Jindo and Kiyomi Hirasago[6] divided the components of the display into the following factors: the type of unmanned vehicle, the character pattern, the shape of the pointer and the type of the dimension. Authors in [7] explored the relationships between the presentation image designs of a unmanned vehicle display and personnel's Kansei responses. They built a prediction model that described the relationships between the representative Kansei factors and physical image design properties of the unmanned vehicle display for the future user-centered presentation image design of unmanned vehicle displays. The authors in[8] stated the design strategy for the attractiveness of display, and the authors in [9] presented the evolution of preference-based design.

The largest advantage of the Evaluation Grid Method is that the structure of users' preferences can be elicited [11, 12]. The repertory grid method developed by Kelly [10] can capture the mechanism of people's comprehension and recognition of their environments, especially in human relationships. This method was conducted by means of interviewing and asking what the similarities and differences between the two objects were [10]. Sanui[13] advanced it into the evaluation of the grid method in two processes. This method mainly discusses the similarities and differences among the objects to sort out the target object of individual qualities through personal interviews and the paired comparison between objects A and B [13]. The qualitative EGM of Miryoku Engineering can structure the abstract feelings of interviewees to a kind of real feeling [14]. The results are expressed using the hierarchical diagram of the appeal factors for evaluation [14]. By researching the attractive factors of app icons, Chun-Heng Ho found that the EGM is a quantitative method that is used to analyze the influence of design factors [14]. Park et al. [15] disclosed the relationship between specific attributes and ultimate value when using a mobile hospital application by conducting an evaluation grid method based on in-depth interviews with people of various ages.

3. The Fuzzy Analytic Hierarchy Process Evaluation Approach

The attraction is a strength that draws the will of the people and puzzles us. It is the force that causes people to become puzzled, and it may cause people to produce some behaviors, such as consumption and decision-making. This is the subjective selection of the consumers, and it is closely and directly related to the consumer's values. From the view of the designer, the attract extraction is the element many designers devote their efforts to seek.

To capture the attractiveness, the hierarchical diagram of the attractiveness factors for the display of the unmanned vehicle would be built by the evaluation phase. This phase mainly reflect inner feelings of the users. Then user's preferences and the exact factors affecting everyone's decisions can be obtained.

While the factors attained through the evaluation phase constituted the basic evaluation, the in-between importance ordering and the quantitative weight-factors are unclear. The 'upper-level' factors attained by the evaluation phase would be implemented into a quality continuous fuzzy approach to compute the quantitative attributes.

To ensure the evaluation, the study will apply the Fuzzy Analytic Hierarchy Process (FAHP) to make the analysis. The FAHP consists of the following steps:

Step 1. Build up Fuzzy Pairwise Comparison Matrix $\widetilde{A}$: based on the fuzzy number a_{ij} by a pair of evaluation project, we can build up the Fuzzy Pairwise Comparison Matrix. When *i* is not equal to 1, $\tilde{a}_{ij}$ is equal to $\tilde{a}_{ij}^{-1}$.When *i* is equal to *j*, $\tilde{a}_{ij}$ is equal to (1,1,1).

$$\widetilde{A} = [\tilde{a}_{ij}];\ i=1,2\ldots,n, j=1,2,\ldots,n \tag{5}$$

Step 2. Calculate fuzzy weight vector $\widetilde{w}$: Because the fuzzy positive reciprocal matrix is an irreducible matrix with positive values, the standardized relative weight values of each criterion can be calculated through a standardization process. The research adopts Column Vector Geometric Mean.

$$Z_i=(a_{i1}\otimes a_{i2}\otimes\ldots\otimes a_{in})^{1/n} \tag{6}$$

$$W_i= Z_i\oslash(Z_1\oplus Z_2\oplus\ldots\oplus Z_n) \tag{7}$$

$$\tilde{W}=(W_L,W_M,W_U);\ i=1,2,\ldots,n \tag{8}$$

Step 3. Fuzzy maximum eigenvalue $\tilde{\lambda}_{\max}$: Fuzzy maximum eigenvalue $\tilde{\lambda}_{\max}$ of fuzzy pairwise comparison matrix $\tilde{A}$ can be calculated as follows:

$$\tilde{A}\tilde{W}=\tilde{\lambda}_{\max}\tilde{W} \tag{9}$$

Fuzzy maximum eigenvalue $\tilde{\lambda}_{\max}$ of pairwise comparison matrix can also be defined in triangular fuzzy numbers:

$$\tilde{\lambda}_{\max}=(\lambda_L^0\,max,\ \lambda_M^1 max,\ \lambda_U^0\,max) \tag{10}$$

$\lambda_L^0 max$: Maximum eigenvalue of Matrix λ_L that refers to value on the left of integrated expert fuzzy evaluation values.$\lambda_M^1\ max$: Maximum eigenvalue of Matrix λ_M that refers to value in the middle of integrated expert fuzzy evaluation values.$\lambda_U^0 max$: Maximum eigenvalue of Matrix λ_U that refers to value on the right of integrated expert fuzzy evaluation values.

Step 4. Consistency verification: Consistency Index (C.I.) is defined to confirm the rationality of the comparative matrix of the subject's reply result. It is recommended by Saaty that C.I.≤0.1, it is acceptable error, the maximum permissible range is C.I. ≤0.2, and the formula is as follows:

$$C.I.=\frac{\lambda max-n}{n-1}\text{, } n\text{: number of the evaluation factors} \tag{11}$$

λmax is the maximum eigenvalue of the comparison matrix. If this value is closer to the n (The number of elements in the matrix), it has more consistence. Consistency Ratio (C.R.) orders that the ratio of the values of C.I. and R.I. under the same matrix order is called the Consistency Ratio (C.R.).

$$C.\ R.=C.I./R.I. \tag{12}$$

If C.R. is less than or equal to 0.1, the assessed values of matrix have consistence, and every comparison matrix can correspond to the random index (Random Index, R.I.) according to the number of elements, that is, the order (n), as shown in the following figure:

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.4	1.49	1.51	1.48	1.56	1.57	1.59

Figure 1. Random index

Step 5. This study is the comparison convenient for the final evaluation value, simple center-of-gravity method is applied to convert the fuzzy weight of each initial criterion $\widetilde{W_i}$ into single value DF_i, and its calculation method is as follows:

$$DF_i = \left[\left(W_{Ui} - W_{Li}\right) + \left(W_{Mi} - W_{Li}\right)\right]/3 + W_{Li} \quad (13)$$

In which DF_i: the defuzzification value, $\widetilde{W_i}$: the ith fuzzy weight vector, W_{Ui}: the maximum value of the triangle fuzzy number of the ith fuzzy weight vector, W_{Mi}: the median of the triangle fuzzy number of the ith fuzzy weight vector, and W_{Li}: the least value of the triangle fuzzy number of the ith fuzzy weight vector.

The Fuzzy Analytic Hierarchy Process is used to obtain the weights of criteria. The weight adjustment of the factors can be calculated as follows:

$$w_{i\_ad\,j} = \frac{W_i E_i}{\sum_{i=1}^{n} W_i E_i} \quad (14)$$

In the equation, w_{i_adj} is the weight value adjusted for the ith element, W_i stands for the weight of the ith element, i =1,2,...,n, and E_i is determined by the two-dimensional quality. The priority of attractive factors is determined using the weight adjustment method.

4. Experiment and the Result Discussion

4.1 The Course of the Experiment and Results

We conduct the experiment on the unmanned vehicle message display optimization as an example. The reason for adopting the e-scooter display as the experimental subject is that the users are commonplace and the experiment would be facilitated.

4.1.1 Stage I: The Evaluation Phase

Apart from the commonly used display elements, the current message displays also have intelligent display elements supported by wireless sensing technology. Intelligent e-scooters are equipped with built-in unmanned vehicles, through which the data can be displayed on the message display and synchronized on smartphones. With the advancement of Internet technology, message display elements are also updated, such as Bluetooth or the 4G mobile network signal. Furthermore, the message display could also include social networks and smart traffic network message. The message in the display has become more complex, and users can choose models for their personal customized message display style.

4.1.2. Stage II: The Fuzzy Computing Phase

In the fuzzy computing phase, we could utilize the two-way questionnaire and the attribution judging matrix to analyze the trustees' responses in the case of sufficient or insufficient factors for each kind, and then judge the quality attributes of each factor.

Table 1. Fuzzy Computing Table

Functional	1. How would you feel if the message on the surface of instrument of the E-scooter is easily recognizable?
	Dislike, Live With, Neutral, Expect, Enjoy 1 .3 .5 .7 2 .3 .5 .7 3 .3 .5 .7 4 .3 .5 .7 5
Dysfunctional	2. How would you feel if the message on the surface of instrument of the E-scooter isn't easily recognizable?
	Dislike, Live With, Neutral, Expect, Enjoy 1 .3 .5 .7 2 .3 .5 .7 3 .3 .5 .7 4 .3 .5 .7 5
Weight	3. How important is it to you that the message on the surface of instrument of the E-scooter is easily recognizable?
	Not Important Very Important 1 2 3 4 5 6 7 8 9

Table 2 provides the fuzzy computing analysis of the results. As shown in Table IV, according to the results of the fuzzy computing classification, the attractive qualities of 'Easy to Recognize', 'Concise and Easily Displayed Visuals' and 'Distinct Difference between the Primary' yielded high EI values, whereas the other attractive qualities yielded low EI values. Thus, the designers may prefer to integrate the attractive qualities with high EI values into the design.

Table 2. Attribute Priorities of Factors

	C-FKM		FAHP	Adjusted	Normalized	Priorities
Kansei Word	EI	Category	Weight Values	Weights	Weights	
Precise	0.083503	Indifferent	0.03260	0.00272	0.01095	7
Distinct Difference between the Primary and Secondary	0.259018	Attractive	0.28510	0.07385	0.29708	2
Futuramic	0.105071	Attractive	0.04857	0.00510	0.02053	6
Striking	0.122861	Attractive	0.08690	0.01068	0.04295	5
Concise and Easy, Displaying-Visual	0.201006	Attractive	0.20093	0.04039	0.16248	3
Easy to Recognize	0.289993	Attractive	0.31327	0.09085	0.36547	1
Relaxing	0.197391	Attractive	0.12660	0.02499	0.10053	4
Note:	EI: Mean of the satisfaction of all participants for the demands of a specific consumer					

5. Conclusion

In this paper, the unmanned vehicle message display design for the unmanned vehicles was studied, in order to rapidly and precisely obtain the comprehensive message. We proposed the fuzzy analytic hierarchy process evaluation approach for the optimization of the unmanned vehicle message display. In the experiment, from the two perspectives of the attractiveness of usability of the unmanned vehicle message display and the visual attractiveness of the unmanned vehicle display, we considered the font of the display of the unmanned vehicle, content arrangement, electric quantity, the types of speedometers and the amount of message on the unmanned vehicle message display. Then, 20 experimental samples were constructed to conduct the dynamic simulated experiment. In the evaluation phase, we obtain the statistical analysis results of users' preferences. Then, in the fuzzy computing phase, we conduct the more precise analysis to obtain the preference factors of testees. By the results obtained from computing results, researchers can evaluate the quality category of the factor and determine the extent to which it contributes to people's satisfaction. Designers might combine the perpetual request of attractive type into their design according to the rank ordering of the EI values.

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