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Interface Evaluation Method of Medical Equipment Based on Aesthetics Measures

Lele Duan and Xingsong Wang

School of Mechanical Engineering, Southeast University, Nanjing, China

ABSTRACT

The purpose of this paper is to provide an effective evaluation method for the interface design of medical equipment to improve user experience. In order to construct an effective evaluation system, five aesthetics measures are selected according to the principles of interface design. Ben-Bassat et al.(2006) point out that the comprehensive measures are better reflection of the system's value for the user. AHP (Analytic Hierarchy Process) was used to calculate the weight of each measure and the evaluation method is constructed through MATLAB programming to provide an objective evaluation method for the improvement of the user experience of the interface design of medical equipment. The interface of a medical slicer was selected as sample to verify that the model could benefit designer on selecting the optimal design plan and improving the efficiency of using the interface. The result is that the evaluation method can well reflect the aesthetics of the medical equipment interface design, play a guiding role in the interface design of the medical equipment.

Keywords: HCI, Medical device, Design evaluation, Aesthetic measures

INTRODUCTION

The interface design of medical equipment affects the efficiency of the doctor's work. When designing an interface, designers often rely on subjective experience to judge the quality of the interface design. The level of designers varies, and their subjective experience does not represent the opinions of most users. There have been many discussions on the evaluation criteria of design evaluation and aesthetic measures. Hentati et al. (2018) argued that the usability evaluation could be calculated on some basic usability attributes. Moshagen and Thielsch (2010) validated that aesthetics can be identified by four measures.

The German Fechner established the aesthetic theory of Experimental Aesthetics by introducing some experimental methods in the field of psychology into the field of aesthetics. Later scholars created many new domains along this path. The aesthetic measures of the interface are one of the branches. Tullis (1981) argue that the aesthetic measures are calculated by quantitative numerical calculation of the objects on an interface to analyze the relationship between interface elements and user perception. Later, Ngo et al. (2002) proposed 13 aesthetic measures based on Tullis's research.

They verified the effectiveness of the evaluation measures used to measure the aesthetic of the screen interface through experiments. However, there is a problem that the weight of each aesthetic measure in the research is the same, which is obviously not in line with human cognitive ability.

Based on the design principles of the interface and the characteristics of the interface design of medical equipment, we select several basic aesthetic measures from the evaluation system to create a measuring method of medical device interface. The Analytic Hierarchy Process (AHP) was used to assign value on each selected aesthetic measure to construct an interface design evaluation method. Quantitative evaluation of the interface design of medical equipment could help designers create better works and provide an objective evaluation basis for the interface design of medical equipment.

SELECTING AESTHETICS MEASURES

Based on five basic interface design principles, user research and experiences of professional designers five measures that are balance symmetry economy regulation and rhythm were selected from Ngo's 14 aesthetic measures for graphic displays. As the basic element of constructing the evaluation method, the selected measures are weighted and assigned to construct the evaluation system through the analytic hierarchy process.

Measure of Balance

The balance is calculated as the difference in the visual weight of the objects on both sides along the horizontal axis and the vertical axis. The formula is as follows

$$\mathrm{BM} = 1 - \frac{\left|\frac{\mathrm{W_L} - \mathrm{W_R}}{\max(|\mathrm{w_L}|, |\mathrm{w_R}|)}\right| + \left|\frac{\mathrm{W_T} - \mathrm{W_B}}{\max(|\mathrm{w_T}|, |\mathrm{w_B}|)}\right|}{2} \in [0, 1].$$

$$\mathrm{w_j} = \sum_{i}^{\mathrm{n_j}} \mathrm{a_{ij} d_{ij}} \; \mathrm{j} = \mathrm{L, R, B, T}.$$

L, R, B and T are the upper, lower, left and right regions in the figure respectively. a_{ij} represents the area of object i in region j. d_{ij} represents the distance between the central lines of the object and the frame. n_j is the total number of objects on the side.

Measure of Symmetry

Symmetry, by definition, refers to the degree of symmetry on screen in three directions: vertical, horizontal and diagonal type as shown in the following (Ngo and Byrne 2001). Bauerly and Liu (2006) proposed that users preferred symmetric over non-symmetric interfaces.

As shown in the following formula

$$SYM = 1 - \frac{|SYM_{vertical}| + |SYM_{horizontal}| + |SYM_{radial}|}{3} \in [0, 1]$$

$$SYM_{horizontal} = \frac{\begin{array}{c}|X'_{UL}-X'_{LL}| + |X'_{UR}-X'_{LR}| + |Y'_{UL}-Y'_{LL}| + |Y'_{UR}-Y'_{LR}| \\ + |H'_{UL}-H'_{LL}| + |H'_{UR}-H'_{LR}| + |B'_{UL}-B'_{LL}| + |B'_{UR}-B'_{LR}| \\ + |\theta'_{UL}-\theta'_{LL}| + |\theta'_{UR}-\theta'_{LR}| + |R'_{UL}-R'_{LL}| + |R'_{UR}-R'_{LR}|\end{array}}{12}$$

$$SYM_{radial} = \frac{\begin{array}{c}|X'_{UL}-X'_{LR}| + |X'_{UR}-X'_{LL}| + |Y'_{UL}-Y'_{LL}| + |Y'_{UR}-Y'_{LR}| \\ + |H'_{UL}-H'_{LL}| + |H'_{UR}-H'_{LR}| + |B'_{UL}-B'_{LL}| + |B'_{UR}-B'_{LR}| \\ + |\theta'_{UL}-\theta'_{LL}| + |\theta'_{UR}-\theta'_{LR}| + |R'_{UL}-R'_{LL}| + |R'_{UR}-R'_{LR}|\end{array}}{12}$$

$$SYM_{vertical} = \frac{\begin{array}{c}|X'_{UL}-X'_{UR}| + |X'_{LL}-X'_{LR}| + |Y'_{UL}-Y'_{UR}| + |Y'_{LL}-Y'_{LR}| \\ + |H'_{UL}-H'_{UR}| + |H'_{LL}-H'_{LR}| + |B'_{UL}-B'_{LR}| + |B'_{LL}-B'_{LR}| \\ + |\theta'_{UL}-\theta'_{UR}| + |\theta'_{LL}-\theta'_{LR}| + |R'_{UL}-R'_{UR}| + |R'_{LL}-R'_{LR}|\end{array}}{12}$$

X'_i Y'_i H'_i B'_i θ'_i R'_i are, respectively, the normalized values of

$$X_j = \sum_i^{nj} |x_{ij} - x_c| \ . \ Y_j = \sum_i^{nj} |y_{ij} - y_c|$$

$$B_j = \sum_i^{nj} b_{ij} \ \theta_j = \sum_i^{nj} \frac{y_{ij} - y_c}{x_{ij} - x_c} \ . \ R_j = \sum_i^{nj} \sqrt{(x_{ij} - x_c)^2 + (y_{ij} - y_c)^2}$$

$$j = UL, UR, LL, LR.$$

UL, UR, each represent upper left, upper right, LL, LR each represent lower left, lower right. b_{ij} is the width of the object and h_{ij} is the height of the object, x_{ij} y_{ij} and x_c y_c represent the co-ordinates of the centers of object i on quadrant j and the frame. n_j is the total number of objects on the quadrant. a_{ij} is the area of the element.

Measure of Economy

Economy refers to the use of small-size interface elements to convey more information as much as possible. The calculation formula of economy is as follows

$$ECM = \frac{1}{n_{size}} \in [0, 1]$$

where n_{size} is the number of sizes.

Measure of Rhythm

The calculation method of rhythm is shown in the following formula

$$RHM = 1 - \frac{\left|\begin{matrix} |X'_{UL}-X'_{UR}| + |X'_{UL}-X'_{UR}| \\ +|X'_{UL}-X'_{LL}| + |X'_{UR}-X'_{LR}| \\ +|X'_{UR}-X'_{LL}| + |X'_{LR}-X'_{LL}| \end{matrix}\right| + \left|\begin{matrix} |Y'_{UL}-Y'_{UR}| + |Y'_{UL}-Y'_{UR}| \\ +|Y'_{UL}-Y'_{LL}| + |Y'_{UR}-Y'_{LR}| \\ +|Y'_{UR}-Y'_{LL}| + |Y'_{LR}-Y'_{LL}| \end{matrix}\right| + \left|\begin{matrix} |A'_{UL}-A'_{UR}| + |A'_{UL}-A'_{UR}| \\ +|A'_{UL}-A'_{LL}| + |A'_{UR}-A'_{LR}| \\ +|A'_{UR}-A'_{LL}| + |A'_{LR}-A'_{LL}| \end{matrix}\right|}{18} \in [0, 1]$$

$$X_j = \sum_i^{n_j} |x_{ij} - x_c| \qquad j = UL, UR, LL, LR .Y_j = \sum_i^{n_j} |y_{ij} - y_c|$$

$$j = UL, UR, LL, LR. \quad A_j = \sum_i^{n_j} a_{ij} \qquad j = UL, UR, LL, LR$$

UL, UR, each represent upper left, upper right. LL, LR represent lower left, lower right. x_{ij} y_{ij} and x_c y_c represent the co-ordinates of the centers of object i on quadrant j and the frame. n_j is the total number of elements on the quadrant. a_{ij} is the area of the elements.

Measure of Regulation

The degree of regulation is usually judged by calculating the number of alignment points of the interface elements in the horizontal and vertical directions (Ngo et al., 2002).

$$RM = \frac{\left| RM_{spacing} = \begin{cases} 1 & \text{if } n = 1 \\ 1 - \frac{n_{spacing}-1}{2(n-1)} & \text{otherwise} \end{cases} \right| + \left| RM_{alignment} = \begin{cases} 1 & \text{if } n = 1 \\ 1 - \frac{n_{vap}+n_{hap}}{2n} & \text{otherwise} \end{cases} \right|}{2} \in [0, 1]$$

n_{vap}, n_{hap}, $n_{spacing}$ respectively represent the number of alignment points in the horizontal and vertical directions, and the number of starting points with different distances between rows and columns. n represents the number of elements in the entire interface layout.

CONSTRUCTION OF EVALUATION METHOD BASED ON ANALYTIC HIERARCHY PROCESS (AHP)

There are many methods for assigning weight values to measures. The analytic hierarchy process was used in the research.

Build a Hierarchical Structure Model

The judgment matrix of target layer and measure layer is constructed according to the expert scoring.

Table 1. Measures layer judgment matrix and W the weight value of each measure.

Measures	Balance	Symmetry	Economy	Rhythm	Regulation	W
Balance	1	1	3	5	4	0.2996
Symmetry	3	1	5	6	7	0.4980
Economy	1/4	1/4	1	2	1	0.0851
Rhythm	1/8	1/8	1/2	1	1/2	0.0425
Regulation	1/4	1/7	1	2	1	0.0749

First perform normalization by column and then use arithmetic average method to find W that is the weight value of each measure W according to Sipahi and Timor (2010). Make consistency judgments. The consistency ratio is

$$C.R. = C.I/R.I = 0.0499$$

C.R. less than 0.1 is acceptable.

The calculation method of the comprehensive aesthetic value of the interface is

$$S = \sum_{i}^{b,s,d,r,re} s_i W_i$$

s_i are the five aesthetic measures discussed above.

EMPIRICAL STUDY

Selecting Samples

For experimentation, we chose five different design schemes for the homepage of the operation interface, and processed the interface elements into rectangles. And get the position and area data of the rectangle through adobe xd. Frame width and frame height of samples are 656 and 392.

The weight value of each indicator has been calculated

$$W_b = 0.2996\ W_s = 0.4980\ W_e = 0.0851\ W_r = 0.05\ W_{re} = 0.0749$$

$$C_1 = 0.6297\ C_2 = 0.7499\ C_3 = 0.7204\ \ C_4 = 0.5760$$

$$C_2 > C_3 > C_1 > C_4$$

By comparison, we can see that the comprehensive C value (the comprehensive aesthetic value of each interface) in interface 2 is the highest.

Validation of the Results

The "design look" of Web sites Has clearly prominent effects on Web-site usability (Fogg, B et al. 2003). A questionnaire survey was conducted with 30 students and asked them to rank the four interface design samples above and vote in descending order from the beautiful to the ugly. The results show that

Table 2. Elements data.

Interface element data							
Interface1	R1	R2	R3	R4	R5	R6	R7
x_i	0	137	245	403	504	137	445
y_i	3	17	39	20	6	116	282
w_i	119	83	115	56	141	283	54
h_i	364	133	86	117	243	168	54
Interface2	R1	R2	R3	R4	R5	R6	R7
x_i	0	126	180	161	268	472	
y_i	0	37	51	256	256	256	
w_i	111	12	460	78	163	168	
h_i	392	331	162	112	112	112	
Interface3	R1	R2	R3	R4	R5	R6	
x_i	65	343	595	65	346	0	
y_i	44	44	7	194	194	291	
w_i	244	222	248	163	125	656	
h_i	113	113	11	42	42	101	
Interface4	R1	R2	R3	R4			
x_i	18	297	297	540			
y_i	47	53	127	7			
w_i	244	185	221	106			
h_i	109	41	41	301			

$$C_2 > C_3 > C_1 > C_4$$

The voting result is consistent with the MATLAB calculation results, which shows that the method can effectively calculate the overall aesthetics of the interface design.

CONCLUSION

The research combines the analytic hierarchy process and the aesthetic measurement method to construct the interface aesthetic evaluation method of medical equipment through MATLAB programming. An experiment was conducted to verify that people's evaluation is consistent with the score given by the method. This evaluation method can provide a quick and efficient interface evaluation feedback for the interface designer of medical equipment, and help the designer to improve the deficiencies of the interface.

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