Intelligent Human Systems Integration (IHSI 2023), Vol. 69, 2023, 704–713
https://doi.org/10.54941/ahfe1002893

The Influence of Background, Layout and Colour Elements on the Beauty Index of Search Engine Interface

Haoyue Dai and Chengqi Xue

School of Mechanical Engineering, Southeast University, Nanjing, China

ABSTRACT

It is well known that the aesthetics of interface design are often evaluated in various qualitative or quantitative ways. As a quantitative index, interface beauty has been widely used in the evaluation of interface aesthetics. Search engines are the first choice for users to quickly obtain information. Improving their interface design based on quantitative evaluation can effectively enhance the aesthetics of the interface design and enhance the user experience. This paper selects six basic beauty indicators: sense of order, sense of association, simplicity, sense of union, intensity and sense of regularity, to evaluate the beauty of the layout and background elements of the search engine interface, and to study its impact on the influence of interface beauty. In addition, by introducing the colour balance index, the influence of background elements of different levels on the beauty of search engine interface under different colours is evaluated. The result shows that background pictures can improve the beauty of interface, and the lower the beauty without background, the higher the degree of improvement. There is no significant difference in the improvement of beauty between different backgrounds, indicating that the layout of elements has a greater impact on the beauty of the interface than the background image.

Keywords: Aesthetic measures, Subjective evaluation, Interface layout design, Interface beauty

INTRODUCTION

The value of current interface aesthetics is not only reflected in the beauty itself, but also has important contributions in the field of human-computer interaction and ergonomics. An interface with high aesthetics can not only achieve faster user visual search response time (Salimun et al., 2010) but also help users learn knowledge through the interface (Zain et al., 2011).

As a method of objectively evaluating the aesthetics of interface design, interface beauty calculation has been widely used in various types of interfaces. Essentially, the search engine interface can be regarded as an interface with elements superimposed on the background, and it can also be evaluated by the method of beauty calculation.

Regarding interface beauty, Ngo et al. proposed a method to objectively measure interface beauty by combining user visual aesthetics with design feature elements (Ngo et al., 2003). There are a total of 14 beauty standards in its calculation model, and their impact on the overall beauty has

© 2023. Published by AHFE Open Access. All rights reserved.

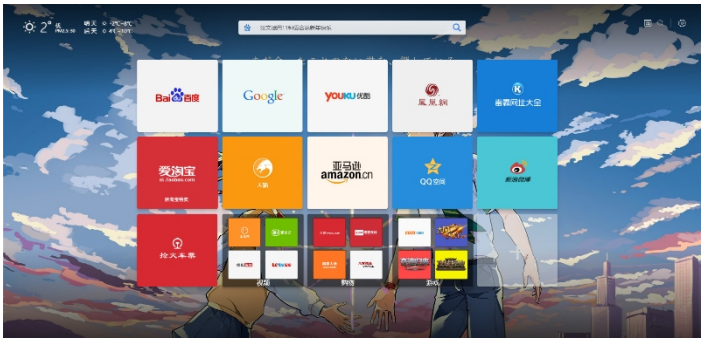

Figure 1: Search Engine Interface.

different priorities. Purchase et al. quantified the layout features of web pages according to fourteen different indicators, and proposed an aesthetic evaluation tool. The tool was used to evaluate a variety of web interfaces, and the results showed that users' judgments of aesthetic appeal and perceived usability matched numerical measures (Purchase et al., 2011).

However, for interfaces of different natures, not all of the 14 beauty indexes are applicable. Therefore, in many studies of beauty calculation, different interface types are often evaluated by different types of beauty indexes. For example, Miniukovich et al. proposed 8 GUI beauty indicators that can be effectively and reliably applied to desktop web pages and mobile applications(Miniukovich & Angeli, 2015). Six beauty indicators that affect the aesthetics of the interface, including proportion, simplicity, order, rhythm, density and balance, can be extracted by the factor analysis method, and constructe a computing system for the aesthetics of computer interface layout (L. Deng and Wang, G, 2020).

At the same time, the coverage of the 14 indicators in the Ngo model is limited, and many researchers have also proposed new indicators of beauty. For example, the effect of colour on beauty is not considered in the Ngo model. In the study of Lai et al., a method of beauty calculation was proposed in terms of colour balance and symmetry (Lai et al., 2009). Tsai et al. proposed a computational model for calculating the beauty of text overlay images (Tsai et al., 2014). Combined with the above research, this paper proposes a method to calculate the beauty of elements superimposed on the background image by using the AHP method, and evaluates the selected search engine interfaces.

METHODOLOGY

In this study, according to the initial layout characteristics of the search engine interface, 6 of Ngo's 14 beauty indexes are selected: sense of order, sense of association, sense of union, simplicity, density and sense of regularity. On this basis, the background is added to the interface, and the method of Lai et al. is used to calculate the interface colour balance when the interface elements have the same colour. The 7 indicators are quantitatively analysed by the analytic hierarchy process, the weight of each indicator is obtained, and the comprehensive beauty of each initial interface is calculated for analysis and comparison.

Measure of Sequence

The sense of order refers to the arrangement of elements in the interface, and the arrangement should help the eyes to move in the displayed information. Therefore, the sense of order refers to the relationship between displayed information and human visual patterns. The calculation formula is:

$$
\begin{aligned}
SQM &= 1 - \frac{\sum_{j=\mathrm{ULUR,LLLR}} |q_j - v_j|}{8} \in [0,1] \\
&\quad \{q_{\mathrm{UL}}, q_{\mathrm{UR}}, q_{\mathrm{LL}}, q_{\mathrm{LR}}\} = \{4,3,2,1\} \\
v_j &= \begin{cases} 4 \textit{ if } w_j \textit{ is the biggest in } w \\ 3 \textit{ if } w_j \textit{ is the 2nd biggest in } w \\ 2 \textit{ if } w_j \textit{ is the 3rd biggest in } w \\ 1 \textit{ if } w_j \textit{ is the smallest in } w \end{cases} \\
j &= UL, UR, LL, LR \\
w_j &= q_j \sum_{i}^{n_j} a_{\mathrm{ij}} j = \mathrm{UL, UR, LL, LR} \\
w &= \{w_{\mathrm{UL}}, w_{\mathrm{UR}}, w_{\mathrm{LL}}, w_{\mathrm{LR}}\}
\end{aligned}
$$

In the formula, UL, UR, LL, LR represent the upper left, upper right, lower left, and lower right areas of the interface, and weights are assigned to the visual importance of each area. A_{ij} is the area of the interface element i in this quadrant j.

Measure of Cohesion

The sense of association helps to partition the functions of different interface elements, and the reasonable function partition helps users locate quickly and improve the efficiency of interface operations. Similar aspect ratio can improve cohesion, and the calculation formula is:

$$
\begin{aligned}
CM &= \frac{|\mathrm{CM_{fl}}| + |\mathrm{CM_{lo}}|}{2} \in [0,1] \\
\mathrm{CM}_{f1} &= \begin{cases} c_{f1} & \text{if } c_{f1} \le 1 \\ \frac{1}{c_{f1}} & otherwise \end{cases} \\
c &= \frac{h_{layout}/b_{layout}}{h_{frame}/b_{frame}} \\
\mathrm{CM_{lo}} &= \frac{\sum_i^n t_i}{n} \\
t_i &= \begin{cases} c_{\mathrm{i}} & \text{if} c_i \le 1 \\ \frac{1}{c_i} & otherwise \end{cases} \\
c &= \frac{h_i/b_i}{h_{layout}/b_{layout}}
\end{aligned}
$$

The h_i, b_i, h_{layout}, b_{layout}, h_{frame}, and b_{frame} in the formula represent the length and width of each layout element, including the length and width of the largest rectangular box containing all interface elements and the length and width of the outer border.

Measure of Unity

After partitioning the functions through the sense of association, the elements in each area are united together, resulting in a sense of union, making the overall interface layout orderly. The sense of unity refers to the degree to which screen elements belong to a whole, and its calculation formula is:

$$\begin{aligned} \mathrm{UM} &= \frac{\left|UM_{form}\right| + \left|UM_{space}\right|}{2} \in [0,1] \\ \mathrm{UM}_{form} &= 1 - \frac{n_{size} - 1}{n} \\ \mathrm{UM}_{space} &= 1 - \frac{a_{layout} - \sum_i^n a_i}{a_{frame} - \sum_i^n a_i} \end{aligned}$$

In the formula, a_{layout} and a_{frame} respectively represent the area of the largest rectangular frame containing the entire interface element and the area of the product outline, n_{size} represents the number of dimensions used in the interface element, and ai represents the area of each component element in the interface.

Measure of Simplicity

A concise interface can make the content of the interface easier to understand. The calculation formula is:

$$SMM = \frac{1}{n_{vap} + n_{hap} + 3} \in [0,1]$$

Among them, n_{vap} and n_{hap} represent the number of alignment points in the horizontal and vertical directions respectively, and n represents the number of elements in the entire interface layout.

Measure of Density

Intensity refers to the extent to which the interface is covered by interface elements, and is related to the area and number of interface elements. Intensity is achieved by limiting the screen density level to an optimal percentage. The calculation formula is:

$$\mathrm{DM} = 1 - 2\left|0.5 - \frac{\sum_{\mathrm{i}}^{\mathrm{n}} \mathrm{a_i}}{\mathrm{a_{frame}}}\right| \in [0,1]$$

where a_i and a_{frame} are the area of element i and the interface; n is the number of elements on the interface.

Measure of Regularity

Regularity is the consistency of elements based on a certain principle or plan. By establishing standard, equally spaced horizontal and vertical alignment points for screen elements, and minimizing the alignment points, the regularity of screen design can be achieved. The calculation formula is:

$$RM = \frac{\left|\mathrm{RM}_{alignment}\right| + \left|\mathrm{RM}_{spacing}\right|}{2} \in [0,1] \quad (1)$$

$$\mathrm{RM}_{\mathrm{alignment}} = \begin{cases} 1 & \text{if } n = 1 \\ 1 - \frac{n_{\mathrm{vap}} + n_{\mathrm{hap}}}{2n} & \text{otherwise} \end{cases}$$

$$\mathrm{RM}_{\mathrm{spacing}} = \begin{cases} 1 & \text{if } n = 1 \\ 1 - \frac{n_{\mathrm{spacing}}-1}{2(n-1)} & \text{otherwise} \end{cases}$$

Measure of Color Balance

In interface design, all elements are arranged on the background of the page, regardless of whether the background is a solid colour or a picture. Therefore, the colour of the background contrasts with the elements and affects the beauty of the page. According to the research of Lai et al., the format of the picture can be converted to HSV, and the colour balance in the horizontal and vertical directions can be calculated on this basis. Calculated as follows:

$$\Delta C = \frac{1}{\sqrt{4}}\sqrt{(V_1 - V_2)^2 + (V_1 S_1 \cos H_1 - V_2 S_2 \cos H_2)^2 + (V_1 S_1 \sin H_1 - V_2 S_2 \sin H_2)^2}$$

Calculate the vertical and horizontal colour weight:

$$W_i = \sum_{j=1}^{h} \Delta C_{ij-B}$$
$$W_j = \sum_{i=1}^{w} \Delta C_{ij-B}$$

Calculate the vertical and horizontal colour balance x_b and y_b:

$$\sum_{i=1}^{w} W_i(i - x_b) = 0$$
$$\sum_{j=1}^{h} W_j(j - y_b) = 0$$

Calculate the beauty of colour balance:

$$B_H = 1 - |2 \times \frac{x_b}{w} - 1| \qquad B_V = 1 - |2 \times \frac{y_b}{h} - 1|$$

$$CBM = \frac{B_H}{w/(w+h)} + \frac{B_V}{h/(w+h)}$$

Sample Selection

The sample selected is the search engine interface of several mainstream browsers that are frequently used in the Windows, including IE, Cheetah, Sogou, Aoyou, 360, as shown in Figure 2.

Import the initial page into Adobe Illustrate and simplify the elements on the page into rectangles and outline the outline with vector tools. Use the

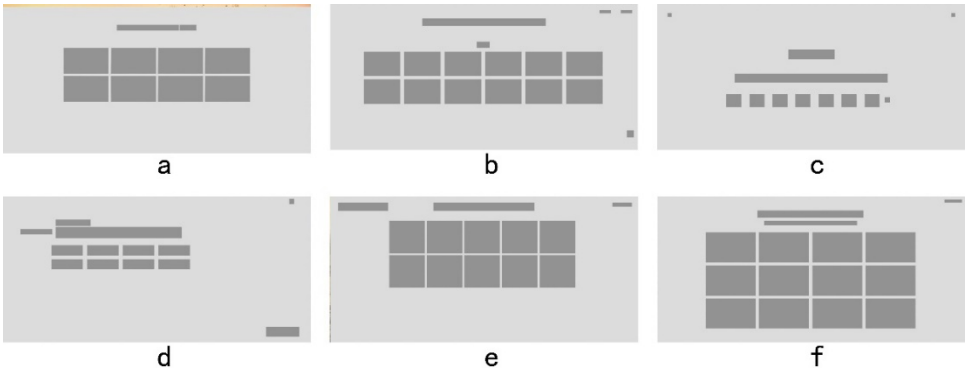

Figure 2: Interface extraction map.

information reading tool in the software to obtain the data of the height and width of each rectangle and the relevant coordinate points required for calculation in pixels. The size of the page is 1920*910 px.

BEAUTY CALCULATION

Calculation of Beauty Index Without Background

Substituting the coordinates in Table 1 into the beauty calculation code written by Matlab, the calculated values of 6 beauty indicators are shown in table 2.

Calculation of Colour Balance Index

As shown in Figure 3, add five different backgrounds for each interface and calculate the colour balance index. The calculation results are shown in Table 3.

AHP to Calculate Comprehensive Beauty

Considering the first six beauty indicators except the background, the weight vector is [0.2105, 0.1053, 0.0526, 0.1579, 0.2105, 0.2632]. Then, the weight vector is sorted and checked for consistency. The result of the test is that the consistency index CI is close to 0, and there is satisfactory consistency; at the same time, the consistency ratio CR is less than 0.1, and the inconsistency of the paired comparison matrix is within the allowable range. The calculation results are shown in Table 5.

When including the background image and considering 7 beauty indicators, the weight vector is [0.1538, 0.0769, 0.0385, 0.1154, 0.1538, 0.1923]. Then, the weight vector is sorted and checked for consistency. The result of the test is that the consistency index CI is close to 0, and there is satisfactory consistency; at the same time, the consistency ratio CR is less than 0.1, and the inconsistency of the paired comparison matrix is within the allowable range. The calculation results are shown in Table 5.

Table 1. Page layout element information.

	Element	X	Y	Width	Height
360	1	712	110	385	36
	2	1102	110	104	36
	3	380	255	280	160
	4	675	255	280	160
	5	970	255	280	160
	6	1265	255	280	160
	7	380	430	280	160
	8	675	430	280	160
	9	970	430	280	160
	10	1265	430	280	160
Aoyou	1	210	297	228	152
	2	462	297	228	152
	3	714	297	228	152
	4	966	297	228	152
	5	1118	297	228	152
	6	1370	297	228	152
	7	210	470	228	152
	8	462	470	228	152
	9	714	470	228	152
	10	966	470	228	152
	11	1118	470	228	152
	12	1370	470	228	152
	13	576	88	770	47
	14	915	234	80	38
	15	1681	38	70	20
	16	1814	38	70	20
	17	1850	787	45	45
Edge1	1	64	55	25	25
	2	1832	55	25	25
	3	816	282	288	63
	4	483	433	952	57
	5	430	562	94	80
	6	574	562	94	80
	7	718	562	94	80
	8	862	562	94	80
	9	1006	562	94	80
	10	1150	562	94	80
	11	1294	562	94	80
	12	1416	582	34	34
Edge2	1	50	39	310	50
	2	642	39	630	50
	3	1759	39	122	25
	4	368	151	222	202
	5	602	151	222	202
	6	836	151	222	202
	7	1070	151	222	202
	8	1304	151	222	202
	9	368	366	222	202
	10	602	366	222	202

(Continued.)

Table 1. *(Continued.)*

	Element	X	Y	Width	Height
	11	836	366	222	202
	12	1070	366	222	202
	13	1304	366	222	202
Cheetah	1	624	87	660	46
	2	1792	17	107	21
	3	664	153	580	25
	4	302	224	312	188
	5	633	224	312	188
	6	964	224	312	188
	7	1295	224	312	188
	8	302	429	312	188
	9	633	429	312	188
	10	964	429	312	188
	11	1295	429	312	188
	12	302	634	312	188
	13	633	634	312	188
	14	964	634	312	188
	15	1295	634	312	188
Sogou	1	1786	16	30	30
	2	330	144	218	39
	3	109	202	200	32
	4	330	191	785	69
	5	303	304	196	65
	6	526	304	196	65
	7	749	304	196	65
	8	972	304	196	65
	9	303	390	196	65
	10	526	390	196	65
	11	749	390	196	65
	12	972	390	196	65
	13	1643	814	205	60

Table 2. The beauty index score of each interface.

	(SQM)	(CM)	(UM)	(SSM)	(DM)	(RM)
360	1	0.7764	0.8332	0.1579	0.4304	0.6083
Aoyou	1	0.8291	0.5413	0.0882	0.5265	0.5313
Edge1	0.5	0.5340	0.5478	0.1034	0.1459	0.3277
Edge2	1	0.4862	0.6964	0.1250	0.5706	0.6218
Cheetah	1	0.8252	0.6317	0.1071	0.8596	0.6048
Sougou	0.75	0.7622	0.3893	0.1071	0.2108	0.4615

CONCLUSION

In the case of no background addition, the search engine interface ranking of each browser is Cheetah, 360, Edge2, Aoyou, Sogou, Edge1. The number one is Cheetah, and the last one is Edge1. From the perspective of sense of

Figure 3: Background.

Table 3. Color balance beauty (CBM).

	360	Aoyou	Edge1	Edge2	Cheetah	Sogou
1	0.9366	0.9366	0.9527	0.9327	0.9097	0.9639
2	0.9504	0.9520	0.9626	0.9673	0.9382	0.9482
3	0.9508	0.9516	0.9653	0.9527	0.9316	0.9783
4	0.9098	0.9165	0.9261	0.9089	0.8788	0.9299
5	0.9957	0.9909	0.9858	0.9822	0.9708	0.9576

Table 4. AHP pairwise comparison matrix.

	SQM	CM	UM	SMM	DM	RM
SQM	1	2	4	4/3	1	4/5
CM	1/2	1	2	2/3	1/2	2/5
UM	1/4	1/2	1	1/3	1/4	1/5
SMM	3/4	3/2	3	1	3/4	3/5
DM	1	2	4	4/3	1	4/5
RM	5/4	5/2	5	5/3	5/4	1
CBM	7/4	7/2	7	7/3	7/4	7/5

order, Sogou and Edge1 have more elements in the lower half, which do not conform to the reading habits of human from upper left to lower right; Cheetah, Edge2 and 360, the element blocks in these interface are relatively similar, with a good sense of simplicity and regularity; Considering the cluster density, the coverage of elements in Edge1 interface is too small, while the coverage of elements in Sogou interface is too large, so they rank last.

Table 5. Comprehensive beauty of each interface.

background	360	Aoyou	Edge1	Edge2	Cheetah	Sogou
no	0.6117	0.5909	0.3236	0.6019	0.6877	0.4414
1	0.6992	0.6840	0.4930	0.6909	0.7474	0.5820
2	0.7029	0.6881	0.4956	0.7002	0.7551	0.5778
3	0.7030	0.6880	0.4964	0.6963	0.7533	0.5859
4	0.6920	0.6785	0.4858	0.6845	0.7391	0.5729
5	0.7151	0.6986	0.5019	0.7043	0.7639	0.5803

By adding background to calculate colour balance, the comprehensive beauty of each interface has been significantly improved. This shows that adding background can significantly improve the comprehensive beauty of the interface. In addition, the degree of beauty improvement of the interface with low beauty after adding background is more significant than that of the interface with high beauty. However, the ranking of search engine interface scores of each browser remains unchanged. At the same time, the scores of the same interface under different backgrounds are basically no significant difference. This indicates that the main factor determining the beauty of this type of interface is the arrangement of elements rather than the colour of the background. The reason for this result may be that when users use this type of interface, their main attention resources will be placed on the element block without paying too much attention to the background. The specific reasons need further exploration.

REFERENCES

Deng, L., & Wang, G. (2020). Quantitative Evaluation of Visual Aesthetics of Human-Machine Interaction Interface Layout. Computational Intelligence and Neuroscience, 2020.

Lai, C., Chen, P., Shih, S., Liu, Y., & Hong, J. (2010). Computational models and experimental investigations of effects of balance and symmetry on the aesthetics of text-overlaid images. *Int. J. Hum. Comput. Stud., 68*, 41–56.

Miniukovich, A., & Angeli, A.D. (2015). Computation of Interface Aesthetics. Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems.

Ngo, D.C., Teo, L.S., & Byrne, J.G. (2003). Modelling interface aesthetics. *Inf. Sci., 152*, 25–46.

Purchase, H.C., Hamer, J., Jamieson, A., & Ryan, O. (2011). Investigating Objective Measures of Web Page Aesthetics and Usability. AUIC.

Salimun, C., Purchase, H.C., Simmons, D.R., & Brewster, S.A. (2010). The effect of aesthetically pleasing composition on visual search performance. *NordiCHI*.

Tsai, M., Wang, K., Liu, Y., & Hong, J. (2014). Perceived Visual Aesthetics of Text-Overlaid Images: Computational Models and Experimental Research for White-Space Fraction. *International Journal of Human–Computer Interaction, 30*, 1–23.

Zain, J.M., Tey, M., & Goh, Y.S. (2011). Does Aesthetics of Web Page Interface Matters to Mandarin Learning? ArXiv, abs/1101.1608.