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A METHOD FOR DETERMINING THE PROPERTIES OF MULTI-SCREEN INTERFACES

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An important aspect of screen design is aesthetic evaluation of screen layouts. While it is conceivable to define a set of variables that characterize the key attributes of many alphanumeric display formats, such a task seems difficult for graphic displays because of their much greater complexity. This article proposes a theoretical approach to capture the essence of artists' insights with seven aesthetic measures for graphic displays. The formalized measures include symmetry, sequence, cohesion, regularity, homogeneity, rhythm, and order and complexity. The paper concludes with some thoughts on the direction which future research should take.

Keywords: screen design, interface aesthetics, aesthetic measures, aesthetic characteristics, multi-screen interfaces

1. Introduction

The role of aesthetics in human affairs has been widely documented (e.g. Maquet, 1986). Certainly, it is related to our appreciation of computer systems as well. However, some (e.g. Foley *et al.*, 1990; Marcus, 1992) warn against a tendency among designers to emphasize the aesthetic elements of the user interface, because these might degrade usability. In fact, interface aesthetics plays a greater role in affecting system usability and acceptability than we might be willing to admit. Careful application of the following aesthetic concepts can be helpful:

- Acceptability. Two recent studies (Kurosu and Kashimura, 1995; Tractinsky, 1997) show that very high correlations were found between users' perceptions of interface aesthetics and usability.
- Motivation. Toh (1998) found that aesthetically pleasing layouts have a definite effect on the student's motivation to learn.
- Learnability. Aspillaga (1991) found that good graphic design and attractive displays help contribute to the transfer of information.

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- Comprehensibility. Tullis (1981) found that redesigning a key display from a system for testing telephone lines resulted in a 40% reduction in the time required by the users to interpret the display. In a study of 500 displays, Tullis (1984) found that the time it took users to extract information from displays of airline or lodging information was 128% longer for the worst format than for the best.
- Productivity. Keister and Gallaway (1983) found that redesigning a series of screens resulted in a 25% reduction in total processing time and a 25% reduction in error rates.

Although knowledge of the users' tasks and abilities is the key to designing effective screen displays, an objective, automatable metric of screen design is an essential aid. Tullis (1988) developed four metrics for alphanumeric displays: overall density, local density, grouping, and layout complexity. Streveler and Wasserman (1984) proposed an objective measure for assessing the spatial properties of alphanumeric screens. Sears (1993) developed a task-dependent metric called layout appropriateness to assess whether the spatial layout is in harmony with the users' tasks. Layout appropriateness is a widget-level metric that deals with buttons, boxes, and lists. In this paper, we attempt to synthesise the guidelines and empirical data related to the formatting of graphic displays into a well-defined framework. (This paper is extended from (Ngo, 1994; 1998).) We develop seven aesthetic measures for graphic displays: symmetry, sequence, cohesion, regularity, homogeneity, rhythm, and order and complexity. The measure of order and complexity is derived based on the work of Birkhoff (1933). The paper begins with an introduction to the aesthetic model, and then summarises and reviews the contributions.

There are four basic ways to use windows (Arlov, 1997):

- Multi-window interfaces: Examples are the IBM OS/2 operating system, most UNIX X-windows applications, and now Microsoft Windows 98;
- Multi-document interfaces: For example, Microsoft Word or Excel;
- Multi-pane interfaces: Microsoft Paint and Netscape Navigator are examples;
- Multi-screen interfaces: Mostly found in One-time GUIs and wizards, and multimedia applications.

This article addresses primarily multi-screen interfaces which may contain any combination of text, graphics and image items. With some modification, some of the techniques presented can also be used for other screen types. Keep in mind that the following discussion focuses on the perception of structure created by drawing a rectangle around each element on the screen, including captions, controls, headings, data, title, etc.

2. Aesthetic Measures

Many noteworthy texts discuss theories of design in both fine and commercial art. Arnheim (1954) and Dondis (1973) are good examples. From the literature on screen design, Galitz's book (1997) on design and layout presents an extensive list of very specific guidelines for the design of screens. This article relies heavily on this and other similar works (e.g. Reilly and Roach, 1984) to help demonstrate our approach. Observe that the range of the following measures is between 0 (worst) and 1 (best).

2.1. Measure of Symmetry

Symmetry is axial duplication: A unit on one side of the centre line is exactly replicated on the other side. Vertical symmetry refers to the balanced arrangement of equivalent elements about a vertical axis, and horizontal symmetry about a horizontal axis. Radial symmetry consists of equivalent elements balanced about two or more axes that intersect at a central point.

Symmetry, by definition, is the extent to which the screen is symmetrical in three directions: vertical, horizontal, and diagonal and is given by

$$\mathrm{SYM} = 1 - \frac{1}{3}\Big(\mathrm{SYM}_{\mathrm{vertical}} + \mathrm{SYM}_{\mathrm{horizontal}} + \mathrm{SYM}_{\mathrm{radial}}\Big) \in [0,1]\,, \qquad (1)$$

where $\mathrm{SYM}_{\mathrm{vertical}}$, $\mathrm{SYM}_{\mathrm{horizontal}}$, and $\mathrm{SYM}_{\mathrm{radial}}$ are, respectively, the vertical, horizontal, and radial symmetries,

$$\begin{aligned} \mathrm{SYM}_{\mathrm{vertical}} = \frac{1}{12}\Big(& |X'_{\mathrm{UL}} - X'_{\mathrm{UR}}| + |X'_{\mathrm{LL}} - X'_{\mathrm{LR}}| + |Y'_{\mathrm{UL}} - Y'_{\mathrm{UR}}| \\ & + |Y'_{\mathrm{LL}} - Y'_{\mathrm{LR}}| + |H'_{\mathrm{UL}} - H'_{\mathrm{UR}}| + |H'_{\mathrm{LL}} - H'_{\mathrm{LR}}| \\ & + |B'_{\mathrm{UL}} - B'_{\mathrm{UR}}| + |B'_{\mathrm{LL}} - B'_{\mathrm{LR}}| + |\Theta'_{\mathrm{UL}} - \Theta'_{\mathrm{UR}}| \\ & + |\Theta'_{\mathrm{LL}} - \Theta'_{\mathrm{LR}}| + |R'_{\mathrm{UL}} - R'_{\mathrm{UR}}| + |R'_{\mathrm{LL}} - R'_{\mathrm{LR}}| \Big), \end{aligned} \qquad (2)$$

$$\begin{aligned} \mathrm{SYM}_{\mathrm{horizontal}} = \frac{1}{12}\Big(& |X'_{\mathrm{UL}} - X'_{\mathrm{LL}}| + |X'_{\mathrm{UR}} - X'_{\mathrm{LR}}| + |Y'_{\mathrm{UL}} - Y'_{\mathrm{LL}}| \\ & + |Y'_{\mathrm{UR}} - Y'_{\mathrm{LR}}| + |H'_{\mathrm{UL}} - H'_{\mathrm{LL}}| + |H'_{\mathrm{UR}} - H'_{\mathrm{LR}}| \\ & + |B'_{\mathrm{UL}} - B'_{\mathrm{LL}}| + |B'_{\mathrm{UR}} - B'_{\mathrm{LR}}| + |\Theta'_{\mathrm{UL}} - \Theta'_{\mathrm{LL}}| \\ & + |\Theta'_{\mathrm{UR}} - \Theta'_{\mathrm{LR}}| + |R'_{\mathrm{UL}} - R'_{\mathrm{LL}}| + |R'_{\mathrm{UR}} - R'_{\mathrm{LR}}| \Big), \end{aligned} \qquad (3)$$

$$\begin{aligned} \mathrm{SYM}_{\mathrm{radial}} = \frac{1}{12}\Big(& |X'_{\mathrm{UL}} - X'_{\mathrm{LR}}| + |X'_{\mathrm{UR}} - X'_{\mathrm{LL}}| + |Y'_{\mathrm{UL}} - Y'_{\mathrm{LR}}| \\ & + |Y'_{\mathrm{UR}} - Y'_{\mathrm{LL}}| + |H'_{\mathrm{UL}} - H'_{\mathrm{LR}}| + |H'_{\mathrm{UR}} - H'_{\mathrm{LL}}| \\ & + |B'_{\mathrm{UL}} - B'_{\mathrm{LR}}| + |B'_{\mathrm{UR}} - B'_{\mathrm{LL}}| + |\Theta'_{\mathrm{UL}} - \Theta'_{\mathrm{LR}}| \\ & + |\Theta'_{\mathrm{UR}} - \Theta'_{\mathrm{LL}}| + |R'_{\mathrm{UL}} - R'_{\mathrm{LR}}| + |R'_{\mathrm{UR}} - R'_{\mathrm{LL}}| \Big). \end{aligned} \qquad (4)$$

Here $X'j$, $Y'j$, $H'j$, $B'j; \Theta'j$, and $R'j$ are, respectively, the normalised values of the following quantities:

$$X_j = \sum_i^{n_j} |x_{ij} - x_c|, \tag{5}$$

$$Y_j = \sum_i^{n_j} |y_{ij} - y_c|, \tag{6}$$

$$H_j = \sum_i^{n_j} h_{ij}, \tag{7}$$

$$B_j = \sum_i^{n_j} b_{ij}, \tag{8}$$

$$\Theta_j = \sum_i^{n_j} \left| \frac{y_{ij} - y_c}{x_{ij} - x_c} \right|, \tag{9}$$

$$R_j = \sum_i^{n_j} \sqrt{(x_{ij} - x_c)^2 + (y_{ij} - y_c)^2}, \tag{10}$$

for $j = \mathrm{UL}, \mathrm{UR}, \mathrm{LL}, \mathrm{LR}$, where UL, UR, LL, and LR stand for upper-left, upper-right, lower-left, and lower-right, respectively; (x_{ij}, y_{ij}) and (x_c, y_c) stand for the co-ordinates of the geometrical centres of object i on quadrant j and the frame; b_{ij} and h_{ij} denote the width and height of the object, respectively; n_j is the total number of objects on the quadrant.

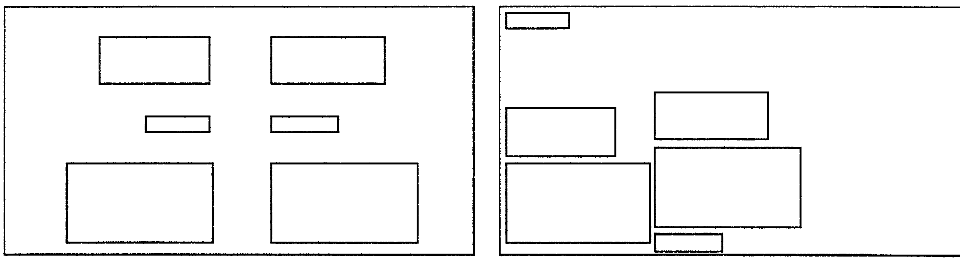
The normalisation of a component is performed by dividing its initial value by a maximum value, e.g.

$$X'_j = \frac{X_j}{\max\{X_{\mathrm{UL}}, X_{\mathrm{UR}}, X_{\mathrm{LL}}, X_{\mathrm{LR}}\}}, \quad j = \mathrm{UL}, \mathrm{UR}, \mathrm{LL}, \mathrm{LR}. \tag{11}$$

Figure 1 presents 'good' and 'bad' screens in our symmetry study. In Fig. 1(a) symmetry is achieved by replicating the elements on the left and right of the screen with respect to the centre line ($\mathrm{SYM} = 0.847$). Figure 1(b) presents an asymmetrical design ($\mathrm{SYM} = 0.402$).

2.2. Measure of Sequence

A sequence in design refers to an arrangement of the objects in a layout such that it facilitates the movement of the eye through the information displayed. Normally the eye, trained by reading, starts from the upper left and moves back and forth across the display to the lower right. Perceptual psychologists have found that certain things attract the eye. It moves from big objects to small objects.



(a) (b)

Fig. 1. Two screens in a symmetry study: (a) a symmetrical screen with SYM = 0.847; (b) an asymmetrical screen with SYM = 0.402.

The sequence, by definition, is a measure of how information in a display is ordered in relation to a reading pattern that is common in Western cultures and is given by

$$\mathrm{SQM} = 1 - \frac{1}{8} \sum_{j=\mathrm{UL,UR,LL,LR}} |q_j - v_j| \in [0,1] \tag{12}$$

with

$$\{q_{\mathrm{UL}}, q_{\mathrm{UR}}, q_{\mathrm{LL}}, q_{\mathrm{LR}}\} = \{4, 3, 2, 1\}, \tag{13}$$

$$v_j = \begin{cases} 4 & \text{if } w_j \text{ is the largest in } w, \\ 3 & \text{if } w_j \text{ is the 2nd largest in } w, \\ 2 & \text{if } w_j \text{ is the 3rd largest in } w, \\ 1 & \text{if } w_j \text{ is the smallest in } w, \end{cases} \quad j = \mathrm{UL, UR, LL, LR}, \tag{14}$$

with

$$w_j = q_j \sum_i^{n_j} a_{ij}, \quad j = \mathrm{UL, UR, LL, LR}, \tag{15}$$

$$w = \{w_{\mathrm{UL}}, w_{\mathrm{UR}}, w_{\mathrm{LL}}, w_{\mathrm{LR}}\}, \tag{16}$$

where a_{ij} is the area of object i on quadrant j. Each quadrant is assigned a weight q_j.

Figure 2 presents 'good' and 'bad' screens in a sequence study. In Fig. 2(a) a sequence is achieved by arranging elements to guide the eye through the screen in a left-to-right, top-to-bottom pattern (SQM = 1.0). The eye starts from the upper left and moves back and forth across the display to the lower right. The opposite is true for Fig. 2(b), where an arrangement and flow cannot be detected (SQM = 0.25).

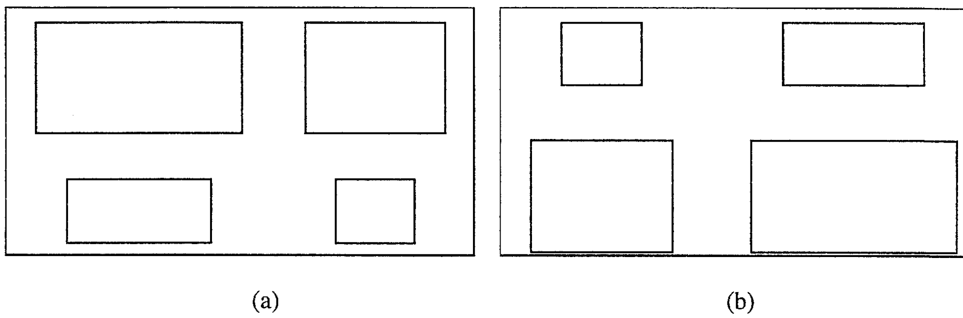


Fig. 2. Two screens in a sequence study: (a) a sequential screen with SQM = 1.0; (b) a random screen with SQM = 0.25.

2.3. Measure of Cohesion

In screen design, similar aspect ratios promote cohesion. The term 'aspect ratio' refers to the relationship between the width and height. Typical paper sizes are greater than they are wide, while the opposite is true for typical VDU displays. Changing the aspect ratio of a visual field may affect eye movement patterns sufficiently to account for some of the performance differences. The aspect ratio of a visual field should stay the same during the scanning of a display.

Cohesion, by definition, is a measure of how cohesive the screen is and is given by

$$\mathrm{CM} = \frac{1}{2}(\mathrm{CM}_{\mathrm{fl}} + \mathrm{CM}_{\mathrm{lo}}) \in [0,1]\,, \tag{17}$$

where $\mathrm{CM}_{\mathrm{fl}}$ is a relative measure of the ratios of the layout and screen,

$$\mathrm{CM}_{\mathrm{fl}} = \begin{cases} t_{\mathrm{fl}} & \text{if } t_{\mathrm{fl}} \le 1, \\ 1/t_{\mathrm{fl}} & \text{otherwise,} \end{cases} \tag{18}$$

with

$$t_{\mathrm{fl}} = \frac{h_{\mathrm{layout}}/b_{\mathrm{layout}}}{h_{\mathrm{frame}}/b_{\mathrm{frame}}}. \tag{19}$$

Here $\mathrm{CM}_{\mathrm{lo}}$ is a relative measure of the ratios of the objects and layout, i.e.

$$\mathrm{CM}_{\mathrm{lo}} = \frac{1}{n}\sum_{i}^{n} f_i \tag{20}$$

with

$$f_i = \begin{cases} t_i & \text{if } t_i \le 1, \\ 1/t_i & \text{otherwise,} \end{cases} \tag{21}$$

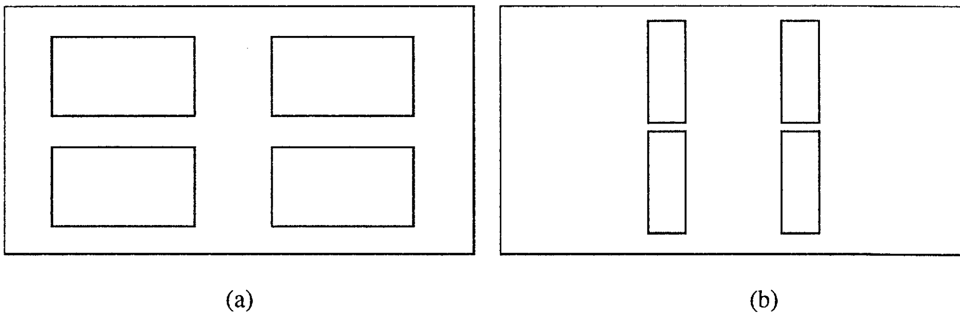


Fig. 3. Two screens in a cohesion study: (a) a cohesive screen with CM = 0.959; (b) a fragmented screen with CM = 0.453.

and

$$t_i = \frac{h_i/b_i}{h_{\text{layout}}/b_{\text{layout}}} \tag{22}$$

where b_i, h_i, b_{layout}, h_{layout}, b_{frame} and h_{frame} are the widths and heights of object i, the layout and the frame, respectively. Moreover, n is the number of objects on the frame.

Figure 3 presents 'good' and 'bad' versions in our cohesion study. In Fig. 3(a) cohesion is achieved by maintaining the aspect ratio of the visual field (CM = 0.959). The use of the screen in Fig. 3(b) may be affected by an inconsistent aspect ratio of screen elements (CM = 0.453).

2.4. Measure of Regularity

Regularity is a uniformity of elements based on some principle or plan. Regularity in screen design is achieved by establishing standard and consistently spaced horizontal and vertical alignment points for screen elements, and minimising the alignment points.

Regularity, by definition, is a measure of how regular the screen is and is given by

$$\text{RM} = \frac{1}{2}\Big(|\text{RM}_{\text{alignment}}| + |\text{RM}_{\text{spacing}}|\Big) \in [0,1]\,, \tag{23}$$

where $\text{RM}_{\text{alignment}}$ is the extent to which the alignment points are minimised,

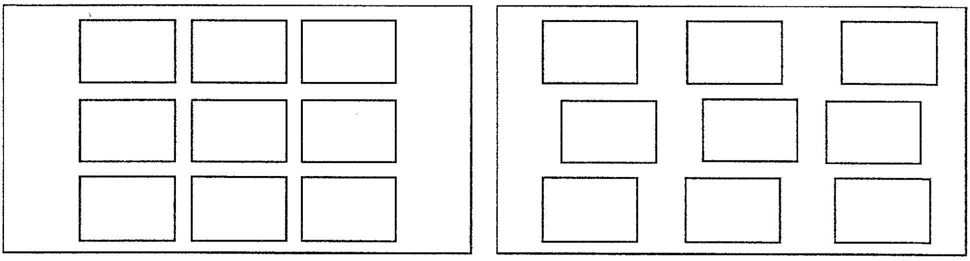
$$\text{RM}_{\text{alignment}} = 1 - \frac{n_{\text{vap}} + n_{\text{hap}}}{2n}\,, \tag{24}$$

$\text{RM}_{\text{spacing}}$ is the extent to which the alignment points are consistently spaced,

$$\text{RM}_{\text{spacing}} = \begin{cases} 1 & \text{if } n = 1, \\ 1 - \dfrac{n_{\text{spacing}} - 1}{2(n-1)} & \text{otherwise,} \end{cases} \tag{25}$$

n_{vap} and n_{hap} are respectively the numbers of vertical and horizontal alignment points and n_{spacing} is the number of distinct distances between column and row starting points.

Figure 4 presents 'good' and 'bad' screens in a regularity study. In Fig. 4(a) regularity is achieved by establishing standard and consistently spaced horizontal and vertical alignment points (RM = 0.802). The items in Fig. 4(b) are unequally spaced (RM = 0.358).



(a) (b)

Fig. 4. Two screens in a regularity study: (a) a regular screen with RM = 0.802; (b) an irregular screen with RM = 0.358.

2.5. Measure of Homogeneity

Entropy was developed in physics in the 19th century and was applied later in astronomy, chemistry and biology. Entropy influenced almost every science. We interpret the statistical entropy concept for screen design. The entropy equation is given by

$$S = k \log W, \tag{26}$$

where S is the entropy of the screen, k is a constant, known as Boltzmann's constant, and W is a measure of the degree of homogeneity.

Since increases or decreases in W are equivalent respectively to increases or decreases in S, we can conveniently work with W below, rather than with S. The relative degree of homogeneity of a composition is determined by how evenly the objects are distributed among the four quadrants of the screen. The degree of evenness is a matter of the quadrants that contain more or less nearly equal numbers of objects.

Homogeneity, by definition, is a measure of how evenly the objects are distributed among the quadrants and is given by

$$\text{HM} = \frac{W}{W_{\text{max}}} \in [0, 1], \tag{27}$$

where W is the number of different ways a group of n objects can be arranged for the four quadrants, i.e.

$$W = \frac{n!}{\prod_{j=UL,UR,LL,LR} n_j} = \frac{n!}{n_{\mathrm{UL}}!\,n_{\mathrm{UR}}!\,n_{\mathrm{LL}}!\,n_{\mathrm{LR}}!}. \tag{28}$$

W is maximum when the n objects are evenly allocated to the quadrants of the screen, as compared to more or less uneven allocations among the quadrants, and thus

$$W_{\max} = \frac{n!}{\frac{n}{4}!\,\frac{n}{4}!\,\frac{n}{4}!\,\frac{n}{4}!} = \frac{n!}{\left(\frac{n}{4}!\right)^4}, \tag{29}$$

where n_{UL}, n_{UR}, n_{LL}, and n_{LR} are the numbers of objects on the upper-left, upper-right, lower-left, and lower-right quadrants, respectively.

Substituting (28) and (29) in (27), we obtain after a rearrangement

$$\mathrm{HM} = \frac{\left(\frac{n}{4}!\right)^4}{n_{\mathrm{UL}}!\,n_{\mathrm{UR}}!\,n_{\mathrm{LL}}!\,n_{\mathrm{LR}}!}. \tag{30}$$

Note that real numbers are rounded down to the nearest integer based on the value of the fractional part of the number.

Figure 5 presents 'good' and 'bad' screens in a homogeneity study. In Fig. 5(a) homogeneity is achieved by evenly distributing the objects among the four quadrants of the screen (HM = 1.0). The items in Fig. 5(b) are not evenly distributed (HM = 0.222).

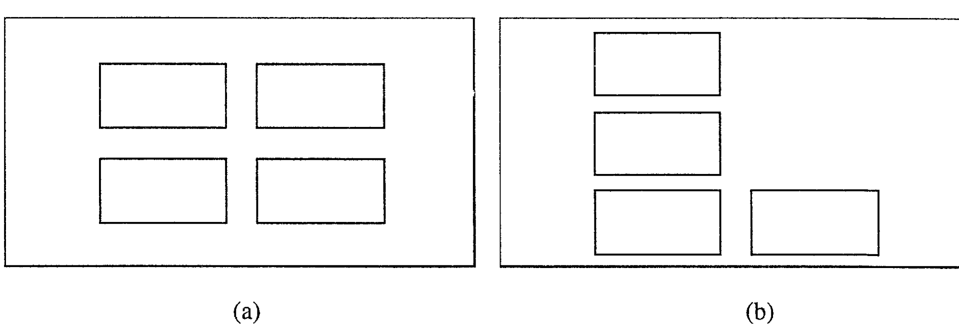


Fig. 5. Two screens in a homogeneity study: (a) a homogenous screen with HM = 1.0; (b) an uneven screen with HM = 0.222.

2.6. Measure of Rhythm

Rhythm in design refers to regular patterns of changes in the elements. This order with variation helps to make the appearance exciting. Rhythm is accomplished through variation of the arrangement, dimension, number and form of the elements.

The extent to which rhythm is introduced into a group of elements depends on the complexity (the number and dissimilarity of the elements).

Rhythm, by definition, is the extent to which the objects are systematically ordered and is given by

$$\mathrm{RHM} = 1 - \frac{1}{3}\Big(\mathrm{RHM}_x + \mathrm{RHM}_y + \mathrm{RHM}_{\mathrm{area}}\Big) \in [0,1]\,. \tag{31}$$

The rhythm components are

$$\begin{aligned}\mathrm{RHM}_x &= \frac{1}{6}\Big(|X'_{\mathrm{UL}} - X'_{\mathrm{UR}}| + |X'_{\mathrm{UL}} - X'_{\mathrm{LR}}| + |X'_{\mathrm{UL}} - X'_{\mathrm{LL}}| \\ &\quad + |X'_{\mathrm{UR}} - X'_{\mathrm{LR}}| + |X'_{\mathrm{UR}} - X'_{\mathrm{LL}}| + |X'_{\mathrm{LR}} - X'_{\mathrm{LL}}| \Big),\end{aligned} \tag{32}$$

$$\begin{aligned}\mathrm{RHM}_y &= \frac{1}{6}\Big(|Y'_{\mathrm{UL}} - Y'_{\mathrm{UR}}| + |Y'_{\mathrm{UL}} - Y'_{\mathrm{LR}}| + |Y'_{\mathrm{UL}} - Y'_{\mathrm{LL}}| \\ &\quad + |Y'_{\mathrm{UR}} - Y'_{\mathrm{LR}}| + |Y'_{\mathrm{UR}} - Y'_{\mathrm{LL}}| + |Y'_{\mathrm{LR}} - Y'_{\mathrm{LL}}| \Big),\end{aligned} \tag{33}$$

$$\begin{aligned}\mathrm{RHM}_{\mathrm{area}} &= \frac{1}{6}\Big(|A'_{\mathrm{UL}} - A'_{\mathrm{UR}}| + |A'_{\mathrm{UL}} - A'_{\mathrm{LR}}| + |A'_{\mathrm{UL}} - A'_{\mathrm{LL}}| \\ &\quad + |A'_{\mathrm{UR}} - A'_{\mathrm{LR}}| + |A'_{\mathrm{UR}} - A'_{\mathrm{LL}}| + |A'_{\mathrm{LR}} - A'_{\mathrm{LL}}| \Big).\end{aligned} \tag{34}$$

X'_j, Y'_j and A'_j are, respectively, the normalised values of

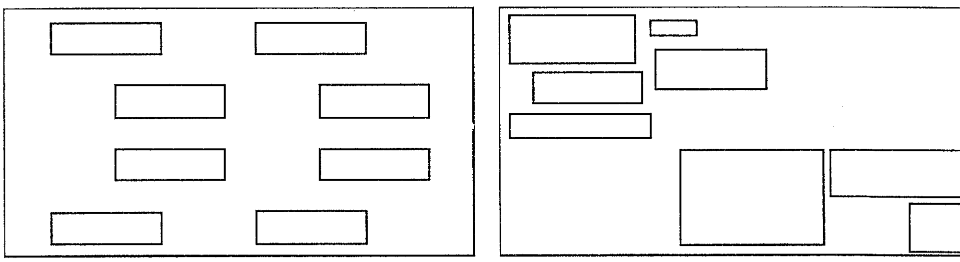
$$X_j = \sum_i^{n_j} |x_{ij} - x_c|, \tag{35}$$

$$Y_j = \sum_i^{n_j} |y_{ij} - y_c|, \tag{36}$$

$$A_j = \sum_i^{n_j} a_{ij}, \tag{37}$$

where $j = \mathrm{UL}, \mathrm{UR}, \mathrm{LL}, \mathrm{LR}$. The normalisation of a component is calculated by dividing its initial value by the maximum value. The approach is similar to (11).

Figure 6 presents 'good' and 'bad' screens in a rhythm study. In Fig. 6(a) rhythm is achieved by variation of arrangement, dimension, number and form of the elements ($\mathrm{RHM} = 0.999$). The elements in Fig. 6(b) constitute a chaotic, confusing, disorganised appearance ($\mathrm{RHM} = 0.38$).



(a) (b)

Fig. 6. Two screens in a rhythm study: (a) a rhythmic screen with RHM = 0.999; (b) a disorganised screen with RHM = 0.38.

2.7. Measure of Order and Complexity

The measure of order and complexity is written as an aggregate of the above measures for a layout. The technique is a modification of a measure of aesthetic value given by Birkhoff (1933). In its simplest form, the technique is defined as a linear combination of all six measures.

The linear summation of the weighted measures designated by OM is given by

$$\mathrm{OM} = \frac{1}{6}\sum_{i}^{6} \alpha_i M_i \in [0,1], \quad 0 \le \alpha_i \le 1 \tag{38}$$

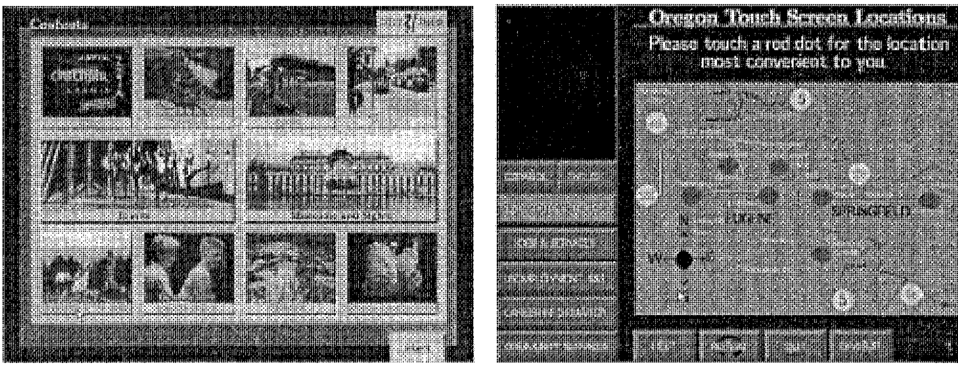
with

$$\{M_1, M_2, M_3, M_4, M_5, M_6\} = \{\mathrm{SYM}, \mathrm{SQM}, \mathrm{CM}, \mathrm{RM}, \mathrm{HM}, \mathrm{RHM}\}. \tag{39}$$

Each aesthetic measure M_i has its own weighting component α_i which is assumed to be a constant. (Determining weights is one of the multi-dimensional optimisation problems that are application specific. A paper presenting a hybrid model of neural networks and genetic algorithms is under review at the present time.)

Figure 7 presents two actual 'good' and 'bad' screens in an order and complexity study. Table 1 presents the element configurations of the screens, and their aesthetic values, according to our formulae, are summarised in Tab. 2. (All values are provided in pixels.) To perform OM calculations for the screens, all weighting components are set to 1, assuming that these measures are equally important to prospective viewers.

As indicated by the overall measure OM in Tab. 2, Fig. 7(a) is measured high (OM = 0.933), whereas Fig. 7(b) is rated low (OM = 0.379). The former is rated more positively than the latter. As Tab. 2 shows, the aesthetic values (of all six measures) are substantially better for Fig. 7(a) than for Fig. 7(b). As a result, the overall rating (using all six measures) is better for Fig. 7(a) than for Fig. 7(b). The homogeneity rating is substantially worse for Fig. 7(b) than for Fig. 7(a): 0.007 vs. 1.0, while the two figures do not differ dramatically on cohesion (a difference of 0.074).



(a) (b)

Fig. 7. Two screens in an order and complexity study: (a) the main menu of the CITY-INFO kiosk (OM = 0.933); (b) a regional map showing Oregon Employment Division kiosk locations (OM = 0.379).

Tab. 1. Summary of layout properties.

Layout	Object	X	Y	Width	Height
Fig. 7(a) (320×240)	1	23	29	64	58
	2	93	29	64	58
	3	163	29	64	58
	4	233	29	64	58
	5	23	91	134	58
	6	163	91	134	58
	7	23	153	64	58
	8	93	153	64	58
	9	163	153	64	58
	10	233	153	64	58
Fig. 7(b) (320×240)	1	94	2	220	44
	2	0	104	84	136
	3	94	50	226	160
	4	94	218	176	22

A viewer can make a subjective evaluation of aesthetic preference between the two designs. Figure 7(a) shows strong aesthetic and organisational qualities. It is aesthetically balanced with well-defined areas, multiple columns of graphics, and with white space that is around the exterior screen margins. The other screen shows two characteristics that are viewed negatively: individual screen controls and groups of controls are not perceptually distinct, and the screen is unbalanced and unattractive, with large areas of white space and a disorganised appearance.

Tab. 2. Computation of the aesthetic value for two layouts.

	Fig. 7(a)	Fig. 7(b)
SYM	0.99850	0.44697
SQM	1.00000	0.25000
CM	0.80116	0.72686
RM	0.79722	0.37500
HM	1.00000	0.00714
RHM	0.99840	0.46527
OM	0.93255	0.37854

3. Conclusions and Future Work

In this article, we have studied a computational theory of evaluating interface aesthetics. This study has suggested some improvements to enhance its usability. We can increase the scope to include the colour, tone and shape of objects in sequence, for example. Perceptual psychologists have found that certain things attract the eye. It moves from big objects to small objects, from bright colours to subdued colours, from colour to black and white, from irregular shapes to regular shapes, and from moving objects to still objects (Galitz, 1997). By manipulating eye attractors, one can plan how the information in a display will be ordered for use.

There are many interesting research topics involving the computation and use of our formulae. First, experiments must be conducted to provide additional empirical validation of the formulae and conventions. It should be emphasized that we have had to make two assumptions, namely (a) that the interaction between the selected characteristics is linear, and (b) that all these characteristics are equally important. Future research should focus on investigating the interplay between the selected characteristics, which, contrary to our original assertion, may be nonlinear. Additional research is also necessary to evaluate the effects of different weighting strategies. (Weighting deals with the problem that we care about some characteristics more than about others.) The characteristics that are common to the feeling which gives one an aesthetic experience should not be limited to the few, and more accordant ordering principles with appropriate design conventions must be found if this approach is to be improved.

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