2004

Aesthetic measures for automated document layout

Steven Harrington

Fernando Naveda

Rhys Price Jonesq

Paul Roetling

Aesthetic Measures for Automated Document Layout

Steven J. Harrington
Xerox Corporation
800 Phillips Rd. MS 128-27E
Webster, NY 14580
sharrington@crt.xerox.com

J. Fernando Naveda
Rochester Institute of Technology
One Lomb Memorial Drive
Rochester, NY 14623
jfnics@rit.edu

Rhys Price Jones
Rochester Institute of Technology
One Lomb Memorial Drive
Rochester, NY 14623
rpjavp@rit.edu

Paul Roetling
Roetling Consulting
illusion@rochester.rr.com

Nishant Thakkar
Rochester Institute of Technology
knetzar@charter.net

ABSTRACT
A measure of aesthetics that has been used in automated layout is described. The approach combines heuristic measures of attributes that degrade the aesthetic quality. The combination is nonlinear so that one bad aesthetic feature can harm the overall score. Example heuristic measures are described for the features of alignment, regularity, separation, balance, white-space fraction, white-space free flow, proportion, uniformity and page security.

I.7.2 [**Document Preparation**]: Algorithms – *aesthetics, document, layout*

1. INTRODUCTION
Technology offers automated systems for document creation and a diversity of presentation methods that make the single fixed output appearance obsolete. To produce documents that look good, one needs methods to quantify document aesthetics.

Efforts to quantify aesthetics are known in other design domains including graph layout and bridge design. In the document domain, Goldenberger [3] considered automatic layout with the minimization of white space and overall aspect ratio. Giegel and Loui [2] describe automatic layout of a photo album where the fitness criteria include balance and spacing, but also include elements for chronology, emphasis and unity that match the layout to expectations and provide comfort and ease of use.

Our own interest in aesthetics originated in our attempts to define, analyze and measure document intents [4]. The aesthetic measure has since been applied to automatic document layout [5, 6] where it serves as one component of a fitness function.

2. AESTHETICS
Aesthetics is one of the values generally accepted as important to document layout. There are design rules that can be found in graphic arts books [1, 7, 8] that caution against practices that can ruin the design aesthetics. Such measures enable preserving a fair amount of freedom in the style and layout choices that can support further decision criteria.

3. COMBINING MEASURES
Each rule has been defined to produce a value ranging from 0 (bad) to 1 (good). Rules are defined for a page, and the individual page measures are combined to form a document measure. Since a bad contributor can ruin the document quality no matter how good the others are, a nonlinear combination is used.

An effective method is:

$$V = \left(\sum w_i (d + V_i)^{-p}\right)^{-1/p} - d.$$

The w_i factors are the weights that specify the relative importance of each rule and should sum to one. The parameter d is slightly larger than 0 and 'p' introduces a non-linearity.

4. ALIGNMENT
The content objects should be displayed in an aligned pattern. The alignment might be for all left edges to have the same horizontal position value or to share the same centerline. If right edges are aligned as well as left ones, this is better still. Similarly, rows of objects should share a vertical position. A method for calculating an alignment measure that can be applied to an object's edges and centerlines will be described. Each application yields a different alignment measures, which are then all combined.

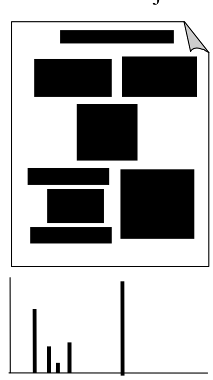

Figure 1: A histogram of left edge positions

First, a histogram of edge (or center) positions is created. Alignment will result in most positions contributing to the same histogram element.

The alignment measure depends on the distances between neighboring entries in the histogram. The closer together the entries the higher the score. The non-linear function used for entries separated by a distance z is: A / (A + z) where A is a constant that controls how fast values fall away from 1 as the distance between entries increases. If two edges are aligned and the distance separating them is z=0 then this yields 1. If a position has n edges contributing then a contribution of n-1 is included. We divide by one less than the number of objects to normalize the score so that the final result ranges between 0 and 1. An overall alignment measure for a page can be defined as a weighted sum of the horizontal and vertical contributions.

5. REGULARITY

The algorithm described for measuring alignment can be extended to calculate the regularity of object placement. The regularity rule suggests that it is best to space alignment positions in a regular fashion. For example, it is better if rows and columns of a table have relatively the same heights and widths.

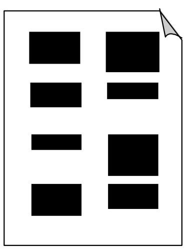

Figure 2: Regular positioning

Regularity might be calculated from the distance between corresponding edges of the object and its neighbors. But because the identification of neighbors can be expensive, a simpler approximation is to examine the distances between alignment positions. The alignment positions are the peaks identified in the edge alignment histogram constructed for the alignment measure. The distances between alignment peaks are stored them in a new histogram. The new histogram is processed in the same way as the original alignment histogram, with the exception of normalizing by the number of peak separations instead of the number of edges. Because western languages read from left to right, top to bottom, peak separation in the left alignment histogram is preferred for determining horizontal regularity and peak separation in the top alignment histogram is used for finding vertical regularity.

6. UNIFORM SEPARATION

A uniform separation between objects can be calculated in a manner similar to alignment and positional regularity. However, a histogram of spacing values between objects is used.

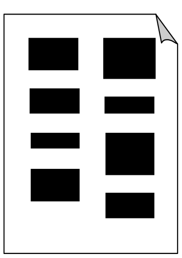

Figure 3: Uniform separation

An approximation using edge arrays is used to avoid the search for object neighbors. For each right edge position, determine the first left edge to the right of this location. The separation value becomes the distance between the right and left edge positions. To account for the possibility that more than one object may have an edge at these locations, we enter into the histogram the product of the count of edges from the right and left edge histograms at these locations. The sum of these products is then used to normalize the final result. For vertical separations the calculation is analogous using top and bottom edge values.

7. BALANCE

A major factor in layout aesthetics is balance. There are at least two ways of defining balance, *centered balance,* where the center of visual weight is at the visual center of a page, and *left-right balance*, where the weight of an object on the left side of the page is matched by the weight of an object at the same vertical position on the right side of the page. The centered balance is calculated by determining the center of visual weight and noting how much it differs from the visual center of the page. This is a simple calculation of moments, but it requires the definition of the two terms "visual weight" and "visual center". The visual weight of an object, to first order, is defined as the object's area times its optical density. The optical density is the common log of the inverse of the reflectance or normalized luminance. The visual center lies halfway between the left and right edges of the page but it is not halfway between the top and bottom [8]. Typically, the visual center is taken to be offset a twentieth of the page height towards the top from the geometric center.

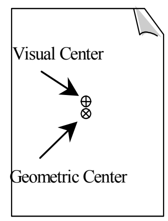

Figure 4: Visual center

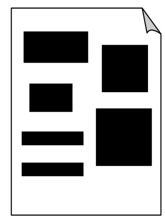

Figure 5: Centered balance

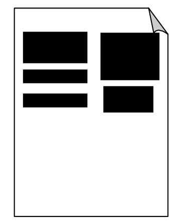

Figure 6: Left-right balance

If the visual weight of an object i is M_i and the object's center is positioned at (x_i, y_i) then the center of visual weight for the page layout is at (x_m, y_m) where

$$x_m = \sum x_i M_i / \sum M_i \quad \text{and} \quad y_m = \sum y_i M_i / \sum M_i$$

and the sums are over all objects on the page. Objects refer to paragraphs, pictures, graphics, etc. If the visual center of the page is at (x_c, y_c) and the maximum x and y distances an object can be from the visual center are d_x and d_y then a balance value is calculated as:

$$V_{cb} = 1-[(((x_m-x_c)/d_x)^2+((y_m-y_c)/d_y)^2)/2]^{1/2}.$$

For left-right balance, the center of visual weight for the x component is calculated as given above. However, for the y component what is desired is that the left and right halves have the same position rather than the total being centered. This is done by calculating the center of weight for the left and right sides as:

$$y_{Lf} = \sum y_i M_i / \sum M_i \quad \text{and} \quad y_{Rt} = \sum y_i M_i / \sum M_i$$

summing over the portions with $x_i < x_c$. and $x_i > x_c$ respectively. If a content object spans both the left and right sides of the page then, for the purposes of this calculation, the object is divided along the vertical centerline of the page. The left and right divisions of the object are then entered into the left and right sums, respectively. If the page height is d_h then a left-right balance value is:

$$V_{LR}=1-[(((x_m-x_c)/d_x)^2+((y_{Lf}-y_{Rt})/d_h)^2)/2]^{1/2} .$$

Balance measures should be combined before they contribute to the page aesthetics. One approach to combining is:

$$V_{bl}= u-[w_{cb} (u-V_{cb})^{-q}+w_{LR} (u-V_{LR})^{-q}]^{-1/q}.$$

The weights w_{cb} and w_{LR} give the relative importance of the two balance approaches and should sum to 1.

8. WHITE-SPACE FRACTION

Another design rule is that white space (including margins) should total about half of the total page area. The non white-space area can be estimated by totaling the areas of the content objects. An expression capturing this rule for a page of area A_p is:

$$V_{ws} = 1 - 4\,((\sum A_i / A_p) - 0.5)^2.$$

9. WHITE-SPACE FREE-FLOW

For good design, white-space should always be connected to the margins. We determine all white-space that can be accessed directly from the margins, add this to the area of the content and the difference from the page area is the trapped white-space.

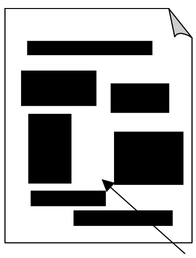

Figure 7: Trapped white space

Four profiles of white space accessible from the four margins of the document are constructed. Total white-space area connected to the page edges is found by examining the entire page at coarse resolution and checking each point position against the profile arrays. A sum of all points that lie between a page edge and the corresponding profile boundary is computed. The area of the content is added and the difference from the page area is determined.

10. PROPORTION

Certain proportions are more pleasing than others. The "golden" ratio between width and height of $R = 2/(1 + \sqrt{5}) = 0.618\ldots$ is often considered ideal. The ratio of width and height Z_i of the major content elements and groups of elements on a page is determined and compared to this ratio. The absolute difference from the ideal ratio R and scale can be determined to get a number between 0 and 1 as follows:

$$V_{ar} = 1 - | Z_i - R | / R.$$

The ratios of the considered content elements and groups can be combined to give an overall proportion measure for the page.

11. UNIFORMITY

For aesthetics, it is preferred to have content objects distributed uniformly over a page. Non-uniformity is defined herein as the variance of the visual density. For each object a visual density is determined as its visual weight divided by its area such that:

$$D_i = M_i / A_i.$$

An average page density is the sum of the visual weights for all page objects divided by the page area excluding margins.

$$D_{av} = \sum M_i / A_{pi}.$$

A non-uniformity value, calculated as by comparing an object's visual density to the average page density. The ratio of the two densities R_i is calculated, but in order to confine the result to the [0 to 1] interval, the ratio is formed by dividing the small density by the larger.

A weighted average of the density ratios is calculated where the weights are proportional to the object areas.

12. PAGE SECURITY

It is better if small objects are not positioned at or near the edge of a page as they appear insecure and could fall off. To quantify the page security of an object, the distance from its center to each of the page edges is determined. The distance may be weighted by which edge is used since an object may appear less secure near a bottom edge than at the top edge. If the object center is at (x_i, y_i) and the page size is defined by width andheight (d_w and d_h,) then for each object, calculate:

$$ps_i = \min(s_L\, x_i,\ s_T\, y_i,\ s_R\,(d_w - x_i),\ s_B\,(d_h - y_i))$$

where s_L, s_T, s_R, and s_B are the left, top right and bottom edge weights. An overall page security value can be defined as the minimum of the values.

13. CONCLUSION

A practical measure of document layout aesthetics has been described. The approach has been to collect and combine heuristic rules for factors that can harm the aesthetics. While measures for several primary rules have been discussed, there is no claim of completeness and additional rules could easily be added. There is also no claim of correctness in either the detail behavior or the implemented heuristics or their method of combination. It is claimed only that the implementations are relatively efficient and have yielded good results when applied to the problem of automatic document layout. The search for further heuristics and their quantification through the measurement of human responses are seen as opportunities for further research. The approach, however is seen as a fruitful one, yielding a practical measure for aesthetics and applicable to other document intents

14. REFERENCES

[1] Collier, D., *Collier's Rules for Desktop Design and Typography*, Addison-Wesley 1991

[2] Geigel, J., and Loui, A., Automatic Page Layout Using Genetic Algorithms for Electronic Albuming, *Proceedings of Electronic Imaging 2001*, (Jan 2001) available on-line at http://www.jogle.com/Research/publications/spieFinal.pdf.

[3] Goldenbert, E., *Automatic layout of variable-content print data*, MSc Dissertation, School of Cognitive & Computing Sciences, University of Sussex, Brighton, UK May- August 2002.

[4] Harrington, S.J., Naveda, J. F., Price Jones, R., Towards a Science of Document Intent, *ICDAR 1st International Workshop on Web Document Analysis*, (Seattle, WA September 2001) 63-66.

[5] Purvis, L., A Genetic Algorithm Approach to Automated Custom Document Assembly, *Proceedings of the 2nd International Conference on Intelligent Systems Design and Applications (ISDA'02)* (Atlanta, GA, August 2002).

[6] Purvis L., Harrington S., O'Sullivan B., Freuder E., "Creating Personalized Documents: An Optimization Approach", *Proceedings of the ACM Symposium on Document Engineering*, (Grenoble France, 2003).

[7] Topping, S. M. Graphic Design and Color in Today's Office, *Kodak Publication W-628*, 1990.

[8] Turnbull, A. T., and Baird, R. N., *The Graphics of Communication*, Holt, Rinehart & Winston, NY 1964.