Using Perceptual Grouping for Object Group Selection

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Abstract
Modern graphical user interfaces support the direct manipulation of objects and efficient selection of objects is an integral part of this user interface paradigm. For the selection of object groups most systems implement only rectangle selection and shift-clicking. This paper presents an approach to group selection that is based on the way human perception naturally groups objects, also known as the "Gestalt" phenomenon. Based on known results from perception research, we present a new approach to group objects by the Gestalt principles of proximity, curve-linearity, and closure. We demonstrate the results with several examples.

Keywords
Perceptual grouping, Gestalt laws, Proximity, Curve-Linearity, Object grouping

ACM Classification Keywords
H.5.2 User Interfaces: Graphical User Interfaces, I.2.10 Vision and Scene Understanding: Perceptual reasoning

Introduction
Perceptual grouping is one of the main categories of perceptual organization that can be defined as the

ability to detect structural layout on visual items. Other perceptual organization phenomena are perceptual coupling, multi-stable figures, and figure-ground segregation, but are outside the scope of this work.

The first and most fundamental approach for perceptual grouping is the Gestalt view, introduced by Koffka, Kohler, and Wertheimer (see e.g. [CITATION e.g. to PALMERbook]). It states: "the whole is different than the sum of its parts", which means that elementary parts (or sensations) will interact non-linearly in perception. This is specified in the Gestalt laws of perception, which are perceptual principles for grouping visual items. Proximity, Good Continuation, and Common Regions are among most important Gestalt laws. Proximity, the most fundamental principle, states that "Being all other factors equal, the closer two elements are to each other the more likely they are to be perceived as belonging to the same form". Good Continuation states that "co-linear or nearly co-linear visual items tend to be grouped". This law is applied at a local level (such as intersection of lines or contours) with little regards for the consequences at more global levels. Common Region states that "all else being equal, elements will be perceived as grouped together if they are located within a connected enclosing contour".

The Gestalt psychologists approach was almost entirely based on the method of demonstration where observers were asked to view a stimulus and to describe its apparent organization. Hence, no quantifiable data was obtained. Moreover, when there was more than one principle involved the Gestalt laws cannot predict which principle would prevail and how they would weaken or strengthen each other.

To the best of our knowledge, the Gestalt principles have been only applied at the dot and contour levels. In this paper, we can utilize low-level grouping models to detect structures at the object level, based on the premise that similar mechanisms work at this level. We apply two of the existing models for Proximity and Good Continuity to detect groups in a set of objects of square shapes. As the selection and manipulation of groups of objects are critical tasks in many applications including any kind of drawing programs and design systems, this will be beneficial for many user interfaces. Most of the existing drawing and design systems require users to manually perform several extra steps to select and manipulate groups. These extra steps, such as shift-clicking, are often time consuming, tedious, and error-prone. Similarly, rectangle selection works only well for horizontally and vertically arranged groups. A system that automatically recognizes how humans perceive a layout can leverage this to implement new interaction techniques.

Related Work:

Koboyy and Wagemen presented a quantified model of how humans group dots by proximity [1], which is basically a decaying exponential function of inter-dot distances. Graph theoretical approaches were proposed to detect and describe Gestalt clusters [2,3]. Zahn [3] proposed an algorithm based on minimum spanning trees to detect and describe Gestalt clusters but did not use a model of proximity. Taxmap [4], a clustering algorithm, attempts to imitate the procedure used by a human observer for grouping objects based on their distances. However, this method cannot deal with overlapping objects and other common cases. Feldman et. al. [5,6] introduced a measure of curve-linearity among 3 or 4 dots as a function of inter-dot angles

(angles between lines connecting the successive dots). Using different combinations of inter-dot distance (e.g. same-same-same or same-different-same in the 4-dot case), the authors experimentally showed that equal spacing of dots has the highest preference for curve-linearity but they did not provide a metric correlation between inter-dot distance and angles.

In computer field, the closest work to ours is Igarashi's et. al.[6] work on the recognition of structures in arrangements of boxes. The authors proposed a system that creates virtual links between objects and assigns them heuristic strength factors depending on how strongly they are perceptually grouped. This approach also adds interaction criteria to change the strength factors of neighboring links. Finally, a threshold is used to cull "weak" links. This approach reliably detects only perceptual organizations: horizontal and vertical lists as well as clusters. Moreover, the system needs to be adapted to each individual user, as it is based on heuristics. This is clearly undesirable.

Grouping Objects by Gestalt Laws

In our approach, we first construct two different kinds of groups: proximal groups (grouped by Proximity), and regular groups (grouped by Curve-linearity). Each group is assigned a quantitative coefficient indicating how strong the members are grouped together. Then we group by Common Region and handle interactions between groups.

Proximal Groups

The area around each object is divided into eight regions (horizontal, vertical, and the 4 diagonals). Each object and its closest neighbor in each region form a proximity group of two objects. Applying an methods similar to Kobovy[1], we use a decaying exponential function to model the relative strength of each group. The proximity coefficient between two objects *xi* and *xj* is defined as $PC = 1 - \exp(alpha(d_{ij} - 1))$, where d_{ij} is the Euclidean distance between x_i and x_j, and *alpha* is an experimentally determined constant. Then, two objects form a group if their proximity coefficient is less than a threshold. All groups are merged afterwards by detecting common item(s).

Regular groups

We construct regularity sets based on groups of four neighboring objects *(sq1, sq2, sq3, sq4)* and calculate the regular coefficient as follows:

$$RC = [e^{-\frac{1}{2s^2(1+r)}} * (a1 + a2)^2] * f(L1, L2) * f(L2, L3).$$

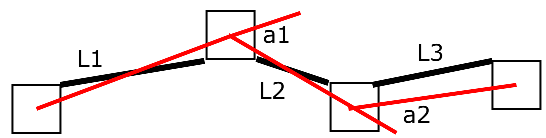

Figure 1. Coefficients *a1* and *a2* approximate the curvatures between the lines connecting successive square(red lines). *L1*, *L2* and *L3* (black lines) model the distances between squares.

The first term in the equation is based on Feldman's model [5] for consecutive dots. It approximates the curvature between lines connecting centers of objects (*(a1,a2)* in Fig.1). The coefficients s and r are the standard deviation and correlation coefficient as in [5]. f is a decaying exponential function of the relative distance among three successive objects (e.g.L1 and L2 in Fig. 1). In an extra step, we merge the primary regularity sets and use a threshold to keep only strong ones. To group objects with only two neighbors we used another model presented by Feldman [6].

Closure and Common-region:
An algorithm to detect closed contours is applied to the extracted curve-linear groups. Objects inside closed structures form a group based on the common-region principle and are considered part of the closed structure

Interaction between proximal and regular groups
In our system, Proximity and Regularity interact in two ways:

- For each regular group, we calculate the average proximity among the successive items. The final regularity coefficient of the group is the multiplication of the regularity coefficient and the average proximity. We eliminate groups with weak regularity with a threshold.

- If two regular groups *R1* and *R2* contain two the same proximal objects *P1* and *P2* such that *R1 - R2 = {p1}* and *R2-R1 = {p2}* then only the group with higher regularity coefficient is retained. This is illustrated in the right side of Fig. 1., where there are two regular groups: the stronger one labeled *G1 (*represented by the solid line), and the weaker one represented by the dashed line. The proximal group G2 consists of 2 objects.

Overlapping objects are grouped together by default. Hence, if two regularity groups R1 and R2 contain two overlapping objects P1 and P2 such that R1 - R2 = {p1} and R2-R1 = {p2} only the strongest one is kept (see left side of Fig. 2).

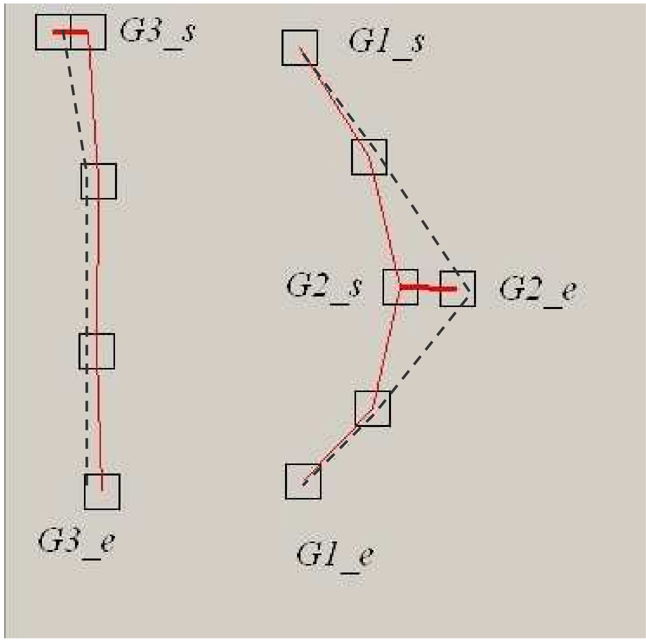

Figure 2. Proximity and overlap may eliminate regular groups. Strongly regular groups are visualized by solid lines, weak groups by dashed lines, and proximal/overlapping groups by thick solid lines. **Left**: Overlapping objects are grouped, which causes only G3 to remain. **Right:** proximal group *G2* causes the weaker regular group to be discarded.

Experimental Result

Figures 3 to 6 show some of our current results. Fig. 3 shows several examples of proximal and regular groups. Fig. 4 shows groups with common objects. Fig. 5 illustrates an example of the Closure and Common Region principles. The group of overlapping objects and the single object in the middle of the diagram form another group *G2*. Fig. 6 again visualizes group strength via line thickness. Note that the visually most salient groups (the diagonal groups) cannot easily be selected via rectangle selection.

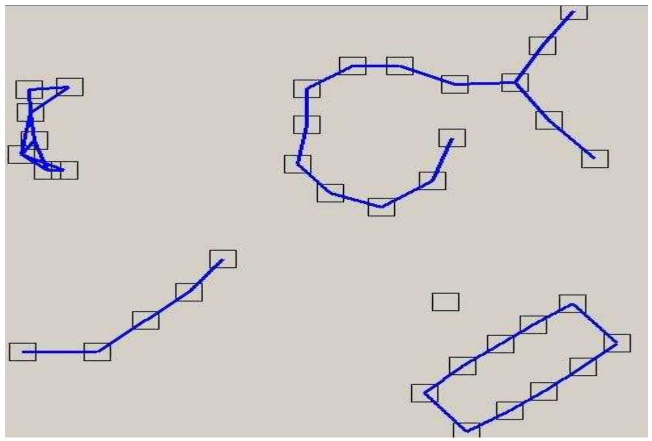

Figure 3. Several proximal and regular groups.

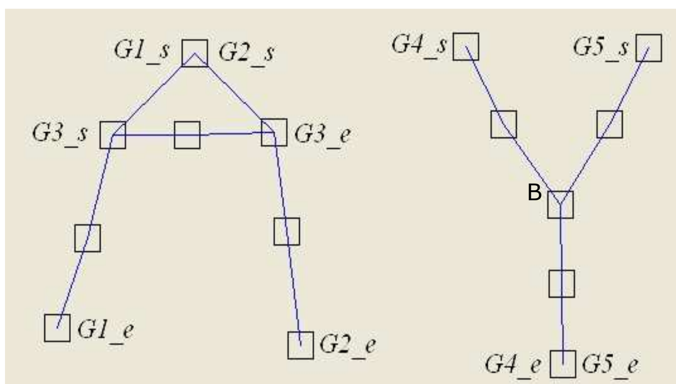

Figure 4. Two groups with common objects.

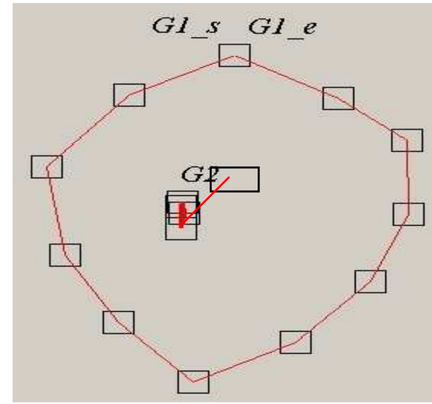

Figure 5. Objects inside a closed contour are grouped to the contour (Common Region law).

Interaction with Gestalt groups

If the user double-clicks on an object in a group, the whole group as visualized by the links in the images is selected and can be manipulated further. If the user double-clicks on an object common to multiple groups, all groups sharing are selected. For example, double-clicking on object *B* in Fig. 4 selects group *G4* and *G5*. Similarly, in Fig. 5., the selection of *G1* will select the inner group, too.

Finally, in Fig. 6, double-clicking on a rectangle will first select one of the 2 diagonal rows, triple-clicking the other diagonal and quadruple-clicking will select the whole group (i.e. all 16 objects). Note that in this case it is impossible to infer which diagonal group the user intends to select, hence the only alternative is to let the user cycle through the possibilities.

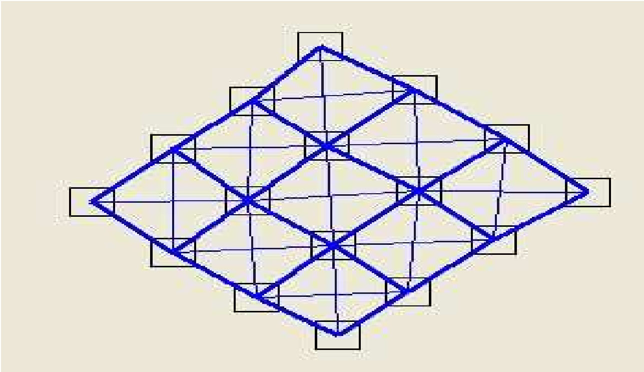

Figure 6. Line thickness visualizes group strength. Note that rectangle selection of visually strong groups is not viable here.

Future work

In our current implementation, the proximity threshold is not scale-invariant, which contradicts perception results. This will be fixed in future work. Other thresholds may also have to be adapted depending on scale, but as there are no results about this from perception research we cannot predict if this will be necessary.

Humans are perceptually sensitive to circular configurations. In future work, we will add curve-circularity and investigate its interaction with proximity and curve-linearity.

In almost all previous work on quantifying Gestalt principles, dots were used as visual items. Since they convey no directionality, changes on their relative positions provides different kinds of interpretations. Our current system uses (modified versions of) these models, which seems to work fine with the examples we have investigated. However, we need to validate our method with bigger examples and user studies.

Reference:

[1] Kubovy, M., Holcombe, A. O, & Wagemans, J. "On the lawfulness of grouping by proximity". Cognitive Psychology, 35,1998, 71–98.

[2] N. Ahuja and M. Tuceryan, "Extraction of Early Perceptual Structure in Dot Patterns: Integrating Region, Boundary, and Component Gestalt,'' *Computer Vision, Graphics, and Image Processing*, 48, 1989,304-356,

[3] C. T. Zahn, "Graph theoretical methods for detecting and describing gestalt clusters" IEEE Transactions on Computers, 20(1),1997:68—86.

[4] Everitt, "Cluster Analysis", 2nd ed. New York: Halsted Press. 1980.

[5] J.Feldman, " Curvilinearity, covariance, and regularity in perceptual groups", Vision Research, 37, 1997, 2835-2848.

[6] J. Feldman. *Perceptual models of small dot clusters*. In Proceedings of the DIMACS Workshop on Partitioning Data Sets. American Mathematical Society, 1993.

[7] Takeo Igarashi, Satoshi Matsuoka, Toshiyuki Masui, "Adaptive Recognition of Human-Organized Implicit Structures", Proceedings of Visual Languages, 1995