Intelligent Object Group Selection

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Abstract
Current object group selection techniques such as lasso or rectangle selection can be time consuming and error prone. This is apparent when selecting distant objects on a large display or objects arranged along curvilinear paths in a dense area. We present a novel group selection technique based on the Gestalt principles of proximity and good continuity. The results of a user study show that our new technique outperforms lasso and rectangle selection for object groups in (curvi)linear arrangements or clusters, i.e. groups with an implicit structure.

Keywords
Proximity, Good continuity, Perceptual Object grouping,

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

Introduction
Object group selection is an integral part of almost all graphical user interfaces. Most systems implement rectangle or lasso selection in which a rectangle or a loop is dragged around targets. Current pen-based systems offer also auto-complete lasso technique: the system actively connects the current last point of the lasso to the start point as the user draws a loop around targets. With this, the user does not have to close the loop, which often speeds up selection [1].

Although quite simple and powerful, these techniques can be time consuming and error prone if the distance the mouse has to be moved is large (e.g. distant objects on a large display) or targets are placed in a dense area. Rectangle selection requires only traversal of the diagonal of the region. However, it works only well for horizontally and vertically aligned arrangements.

In this paper, we present a novel perceptual-based approach for group selection that addresses the above-mentioned drawbacks. Our approach is based on Gestalt principles of proximity and good continuation. Proximity law states that *"spatially close objects are perceived as a group"*. Good continuity law states that *"linear objects tend to be grouped"*.

Related Work:

A substantial body of research in human perception has focused on measuring the strength of proximity [2,3,4] and good continuity [6,7] in dot patterns. Contour grouping has also been studied extensively in the context of ink drawings [9,5,8]. However, not much research is known for *object* groupings.

Spatial parsers employed in hypertext systems are the most related works. They detect horizontal lists, vertical lists, and clusters of objects [10,11,12]. However, they are based on heuristic functions with many parameters. Moreover, they provide only multi-click interaction technique (for hierarchical group selection). In ambiguous cases where there is more than one interpretation, they present only the best interpretation and do not allow interaction or selection of secondary groups. The FLAPS [11] system is an exception and permits cycling through alternatives.

Previously, we presented a perceptual-based system that detects good-continuity groups (i.e. linear and curvilinear arrangements in arbitrary orientations) and proximity with the need of only two global parameters [13]. In this paper, we improve our system in various aspects: we utilize a scale-invariant proximity model, introduce novel interaction techniques, and conduct a formal user study.

Group Detection

In our system, we use the same techniques to detect good continuity groups as in [13]. However, we greatly improved proximity group detection by utilizing a perceptual-based scale-invariant technique, CODE [3].

As in CODE [3], the grouping strength of each object exerted onto the others is modeled in our system by a normal distribution function. That function is centered at each object and the standard deviation is half of the distance between the object and its closest neighbor. The strength of a group is defined as the summation over all individual functions. When the strength of a region surpasses a threshold, all objects in that region are grouped.

USER INTERACTION WITH GESTALT GROUPS

Proximity Group Selection*:* Similar to spatial parsers, a click on an object selects it, a double-click selects the object cluster, and successive clicks extend the selection to closest clusters.

Good Continuity Group Selection*:* Single clicking on an object selects it and visualizes its good continuity group via colored links between successive objects. Double clicking selects the detected group. If the object is part of multiple groups, all these groups are selected (see Fig. 1)

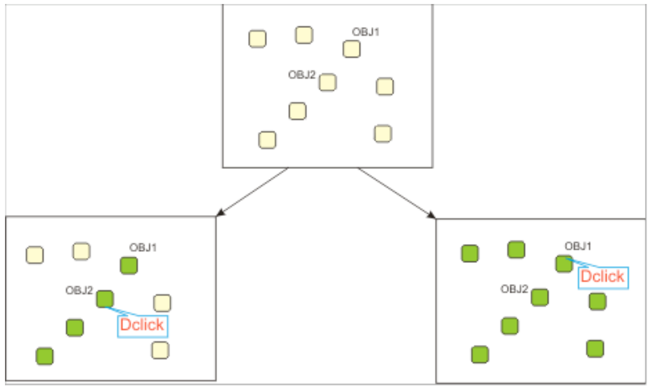

Figure 1: Selecting Good Continuity groups. Given the layout shown on the top, double-clicking OBJ2 selects the line (left), Double-clicking OBJ1 selects both the line and the arc (right).

Partial Good Continuity Group selection*:* To select a subgroup, the user first selects the whole group by double-clicking on one of its objects (called anchor). Then, she clicks on the first non-target object closest to the anchor while holding the Alt key down. Any object on the path from the anchor beyond this point is then de-selected (see Fig. 2)

Resolving Ambiguity in Clusters: Grouping by proximity may not result in a unique grouping configuration. For example, three different configurations can be seen in Fig. 3: five small groups, two large groups, or one whole group. The CODE algorithm can detect all these configurations using different thresholds. We introduce here a novel interaction technique to automatically change this threshold: subsequent clicks on the same object while holding *Shift (Alt)* key changes the threshold and selects groups at a larger (smaller) scale (see Fig. 3).

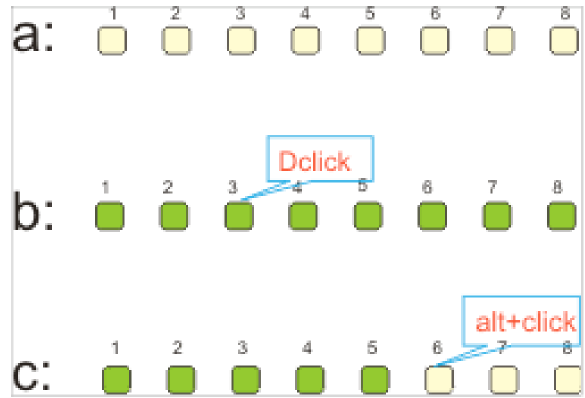

Figure 2: Partial selection of a Good Continuity group. Top: a collinear layout. Middle: Clicking on an object selects the group. Bottom: Alt-clicking on object 6 deselects objects 6,7,8.

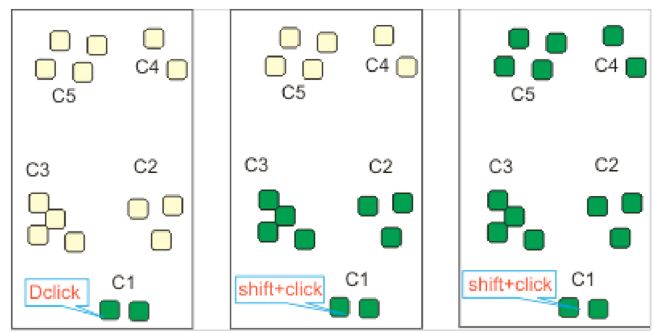

Figure 3: Resolving proximity ambiguity. Left: double-clicking on any object in C1 selects C1 i.e. the first hierarchy level. Middle: a Shift-click adds C2 and C3 to the selection (the next level). Right: the next Shift-click select all the clusters (the top level). At any level, an Alt-click moves a level down in the hierarchy, i.e. one image left.

Resolving Ambiguity in good continuity groups: As mentioned before, double-clicking an object selects all the groups sharing it. If only one of the groups is desired, the rest can be deselected similarly to partial group selection (i.e. Alt-clicking the closest non-desired objects). See Fig. 4.

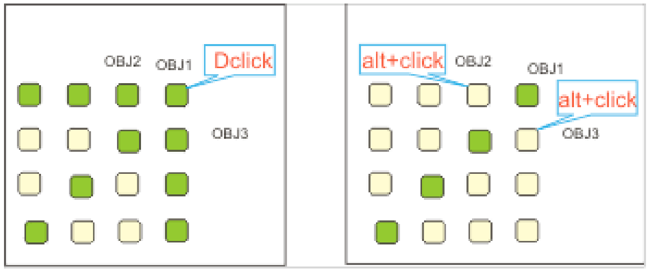

Figure 4: Resolving ambiguity. Left: double-clicking on OBJ1 selects three groups shown in green. Right: clicking on OBJ2 and OBJ3 while pressing the Alt-key de-selects both groups.

Experiments

We conducted a within subject study to assess the efficiency of our technique in comparison to rectangle selection and auto-complete lasso.

TASKS AND STIMULI

In each task, participants saw layouts and were asked to select a target group with various techniques. Targets were displayed in Green and the rest in Black. The bounding box of target objects contained no distracters. Therefore, for all three techniques no subsequent selection or de-selection was required. If the target group was selected correctly, the software advanced to the next task, with a different layout. Selection time was measured starting from the first mouse click after the layout was displayed to the time when only the whole target group was selected. The number of selection cancellations (i.e. clicks on an empty area) was also recorded.

EXPERIMENTAL DESIGN

We used a repeated measure within subject design. The independent variables were: selection technique (Gestalt-based, auto-completed lasso, or rectangle), group arrangement (linear, arc, or cluster), size (small, medium, or large), and orientation (horizontal, vertical, diagonal 45, and 135). Size was defined by the diameter of the bounding box of the target group (small ≈250 pixels, medium ≈450, and large ≈750). Horizontal and vertical orientations had a bounding box with a significant difference in height vs. length (at least 4 to 1 ratio); whereas the diagonal arrangements were aligned roughly at 45 or 135 degrees.

Dependant variables were selection time and error rate. We used a 3x3 Latin Square to counter balance the order of techniques across participants. Participants were trained by performing various selections on 12 practice layouts in advance.

The experiment design was as follows: 3 arrangements X 3 selection techniques. Overall there were 3 sizes X 4 orientations X 3 repetitions X 11 participants, so totally 3564 selections were performed.

Apparatus: The experiments were conducted on a Pentium M 1.6 Ghz computer with 1GB memory. Screen resolution was set to 1024x768.

Participants: Eleven students from a local university campus were recruited. None of them had used Gestalt technique before. Most of them had not used the lasso.

Hypotheses: we hypothesized that for selection of clusters or good-continuity groups, Gestalt technique is faster and more accurate than rectangle and lasso.

Results and Discussion

Selection Time: The repeated measure ANOVA revealed that technique have a strong main effect on selection time ($F_{2,20} = 40.31$, $p \ll 0.001$) (see Fig. 5). A Tukey-Kramer test reveals that all three techniques are different. Orientation and shape have no significant effect on selection time, but size had a significant effect ($F_{2,20} = 98.86$, , $p \ll 0.001$).

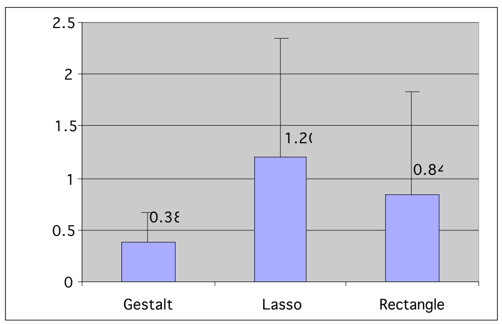

Figure 5: Comparing selection times among techniques.

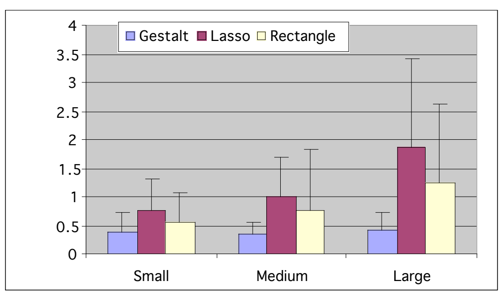

Figure 6: Interaction between size and technique.

There is a strong interaction between technique and size of the layout ($F_{4,20} = 34.39$, $p \ll 0.001$). While size has no effect on Gestalt technique, it affects selection time for lasso and rectangle (Fig. 6).

Cancellation: There is not significant difference between the cancellation rates (Fig. 7).

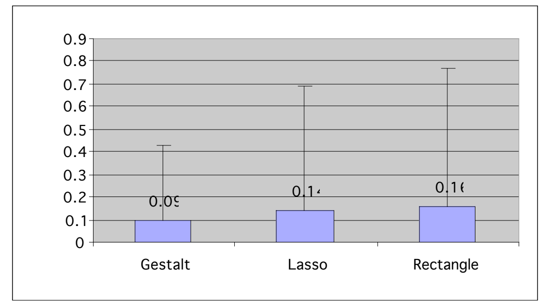

Figure 7: Average cancellation rate for different techniques.

Repetition: We analyzed learning within the techniques by plotting selection time vs. repetitions for each technique. The Gestalt-based technique showed no change over time, but participants got moderately faster with lasso and rectangle (Fig. 8).

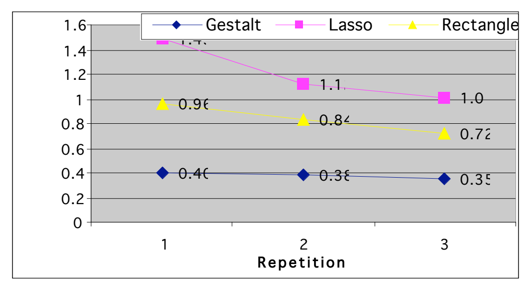

Figure 8: Repetition vs. selection time (learning effect).

Discussion: In terms of speed, the new technique is about 2.3 times faster than rectangle selection and 3.2 times compared to lasso. This is even more interesting as the layouts used were equally suited for rectangle and lasso selection, i.e. there were no nearby distracters. If distracters existed, we would expect that each technique would be affected differently (e.g. rectangle selection by non-axis aligned structures, lasso by narrow tunnels, Gestalt by ambiguous clusters). Our new Gestalt-based selection technique is very well suited for all forms of groups with a curvilinear layout (i.e. 1D arrangements), while still being competitive for the layouts where conventional selection techniques work well. Hence, we believe the new technique nicely complements rectangle and lasso selection techniques.

Conclusion

We presented a new perceptual-based approach to object group selection. Based on known models from perception research, we presented a new approach to automatically detect salient perceptual groups with the Gestalt principles of proximity and good-continuity. We introduced a new, simple, yet efficient, interaction technique to select and de-select such Gestalt groups. The results of our user study show that our technique is faster and more accurate than lasso and rectangle when selecting object groups with implicit structures.

Future work

We plan to investigate techniques that enable users to select perceptual groups in very dense configurations. Furthermore, we will investigate how other Gestalt principles can be used to further facilitate group selection.

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