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A Comparison of Spatial Grouping Techniques on Interactive Surfaces

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Abstract

In this paper we report a comparative study investigating two interaction techniques for grouping items spatially on a tabletop interface. We compared a container technique with a proximity technique. The container concept was considered due to its familiarity with desktop systems, while the proximity technique is a novel organic concept based on spatial proximity. Our goal was to identify the characteristics of both techniques in regard to grouping and regrouping performance, grouping strategies as well as bimanual and multi-finger input. Our results indicate that the traditional container concept may not be an adequate fit for harnessing the benefits of interactive surfaces. Rather, our study shows that more informal spatial techniques based on proximity open up a promising design space for further investigations.

1 Introduction

Grouping and regrouping digital objects is a common task in various application domains. From creating diagrams, sorting photos to managing files, users need to move single or multiple items around for creating spatial aggregations, collections or clusters. Systems that incorporate such functionality can be found in various domains, such as creative group work (Tse et al. 2008), document analysis and management (Robertson et al. 1998) or web surfing and mind mapping (Brade et al. 2011). When engaging in such activities, virtual space is utilized for sense-making, creating representations that reveal new relations or insights. Managing and organizing digital artifacts in a manual way thereby serves as an implicit tool for filtering and synthesizing, thereby taking advantage of human spatial memory capabilities (Shipman et al. 1995).

Multi-touch interaction bears great potential for supporting the manipulation of individual items and groups of objects more efficiently than it is possible with traditional single pointer desktop interfaces. A study by Kin et al. (2009) even found that multi-target selection tasks with a single-touch interface can be performed up to twice as fast compared to mouse-based selection. The researchers account 83% of the reduction in selection time to the direct-touch nature of their interface. When the mapping between gesture and action becomes more direct, users can make more use of their spatial memory capabilities and it is easier to move objects (North et al. 2009). Nevertheless, due to the rich affordances of touch interfaces, it is possible to manipulate virtual objects and groups of objects with not only one hand, but with two hands and multiple fingers, thereby making interaction more analogous to physical interactions in the non-digital world.

In recent years, researchers have examined the characteristics of digital and physical affordances (e.g. Terrenghi et al. 2007), gestures for typical tasks and commands (e.g. Wobbrock et al. 2009) and bi-manual gestures for moving and grouping items (e.g. North et al. 2009). In our research, we build upon this work for examining the effects of *interaction techniques* for spatial grouping and re-grouping tasks in regard to direct-touch, bimanual and multi-finger input. We argue that traditional interaction techniques for grouping items based on containment (e.g. folder or pile metaphor) might not be adequate for harnessing the benefits of multitouch input. Hence, we explore the use of alternative grouping concepts, such as grouping based on spatial proximity. In the following, we will discuss related research and state-of-the-art grouping techniques typically used on interactive surfaces. We then present two exemplary interaction techniques we designed for representing the containment concept (Bin) and the proximity concept (Blub). Eventually, we describe a user study that we conducted for comparing both grouping techniques. In a discussion we focus on the differences both concepts yield in grouping and regrouping performance, use of multi-touch input as well as grouping strategies.

2 Related Work

Our research is related to studies of bimanual multitouch interaction in general as well as interaction techniques for supporting grouping tasks on interactive surfaces in particular.

Terrenghi et al. (2007) have explored the differences in affordances and physicality of manipulation of digital content on interactive surfaces and traditional physical interactions. They conclude that emulation of some of the physical characteristics in digital interfaces may lead to quite different actions and strategies. They make the point that “in order to confer the benefits of bimanual interaction, one approach is to design specific tools and techniques which more explicitly require asymmetric bimanual interaction” (Terrenghi et al. 2007). Furthermore, related to grouping tasks, they argue that “to compensate for the lack of physical constraints in the digital realm, ‘magnetic snapping’ between pieces and grouping gestures are some possible solutions” (Terrenghi et al. 2007). Wobbrock et al. (2009) studied the use of user-elicited gestures on multitouch interfaces for 27 typical tasks like moving, selecting, panning and zooming. Their conclusions show that two-handed interaction forms an important part of surface gesture design. However, their study did not include grouping tasks or the manipulation of multiple objects. North et al. (2009) closed this gap by examining the use of different multitouch gestures for manipulating multiple small items on a tabletop interface. The focus of their study however was not on grouping, but to investigate which interactions from the physical world carry over to the digital replication. They compared a mouse condition with a physical condition and a multitouch condition. Their results show that two-handed operations can be faster than mouse actions, but slower than physical operations. They also proposed a grouping gesture where users can select multiple items by defining a convex hull with three or more fingers. However, their results show that users had some difficulty with the hull system. Because there is a vast body of other work in bi-manual interaction, we refer to Kin et al. (2009) for an overview of studies in multi-finger and bi-manual gestures on touch interfaces. Based on their multi-target selection experiment they argue that a major benefit of multitouch is the ability to simultaneously select multiple targets. They propose further research in examining these characteristics for moving items into groups.

Besides the investigation of (bimanual) gestures, researchers have also created interaction techniques especially for grouping items on tabletops. Traditionally, multi-selection and grouping tasks on desktop interfaces are supported by group selection methods such as rubber banding or lasso selection, before operations (e.g. move into folder) are applied to the selected group (Watanabe et al. 2007). This method of group selection and drag & drop style operations was also carried over to interactive surfaces. Examples for this can be found in research and practice. Scott et al. (2005) presented the grouping technique “Storage Bins” that can be considered as an equivalent to folders on desktop interfaces. Items can be dragged into movable and resizable containers. Once dragged into the container, they are scaled down as to allow for space-efficient organization. Similarly, Hinrichs et al. (2005) presented “Interface Currents”, a container system that can also be attached to borders and corners of interactive tables. Items dragged into the containers are animated, flowing in streams around the container to make all items available to collaborating individuals. Both interaction techniques can be considered examples for the traditional container concept and similar techniques are now supported by most non-commercial and commercial frameworks such as Surface SDK and therefore can be considered as state-of-the-art. Some innovative concepts based on containment are interaction techniques based on piles or multimodal selection and grouping based on gestures and speech (Tse et al. 2008). We may summarize that research in interactive surfaces has not yet examined other techniques for grouping items beyond the multi-selection, drag & drop style container concept. This is especially noteworthy, since studies of bi-manual and multi-finger interaction point to a need for more informal grouping techniques that are closer to our physical interactions (see Terrenghi et al. 2007). We therefore question if the container concept is indeed the best fit for harnessing the potential benefits of multitouch and bimanual interaction.

3 Spatial Grouping Techniques

In search for alternative grouping concepts, we were inspired by an interaction technique called “Bubble Clusters” (Watanabe et al. 2007) for grouping items on a mouse-operated desktop system. It avoids the need for selecting items with rubber banding or lasso selection which is usually required before creating groups. This is achieved by a “snapping” algorithm that associated objects when they are placed in close proximity to each other, similar to a force field with magnetic properties. The force field is thereby visualized as bubbles around the associated objects and also allows users to move clusters by dragging the bubble shape.

A study by Watanabe et al. (2007) showed that their technique could improve grouping performance in a simple single-pointer icon relocation task compared to standard folders and lasso selection. We argue that such informal grouping techniques based on spatial proximity might be closer to our natural physical interactions and that these might be better suitable for harnessing the benefits of multitouch bi-manual input. We therefore think that it is valuable to explore an adaptation of this mouse-based grouping technique for use on interactive surfaces. By comparing the traditional container concept and the self-adjusting proximity-based container concept on a multi-touch system we may reveal differences in bi-manual, multi-finger input and resulting interaction performance and grouping strategies. In the following, we will describe the techniques Bin and Blub that we developed for this purpose.

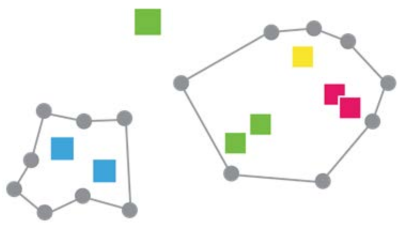

Figure 1: Bin – Grouping items by moving them into a container object.

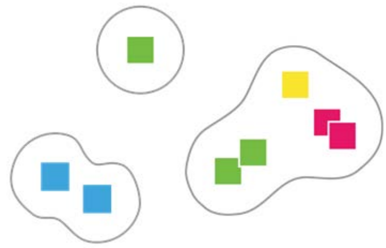

Figure 2: Blub – Grouping items by moving them in close proximity to each other.

3.1 The Bin Technique

We designed the Bin technique based on "Storage Bins" (Scott et al. 2005), a container concept for digital tabletops. Mobile and adjustable containers allow for storing and retrieving digital items on an interactive surface. Therefore, the classical concept of containment (c.f. folders) was adapted by including eight handles (size: 13 px) which allow adjusting the bin's shape (see Figure 1). Users can add items to the bin and may freely arrange them inside the bin. Users may also move the bin itself by dragging it to a new location. A bin provides several ways of interaction as described in the following: 1) *Dragging objects into a bin:* The user may either drag or toss an object directly into a bin. When the item is released inside a bin, it is resized as to show that it is now contained by the bin. Users may also select a group of objects with a lasso selection and may then move this collection into the bin. After releasing the collection, objects are added to the bin. 2) *Collecting objects:* The bin itself can also be used to collect items. Therefore, users can drag the bin directly over objects or adjust the shape of the bin by dragging its handles. After releasing the bin or its handles, objects inside the bin's boundaries are resized to visualize containment. 3) *Spreading a bin:* When objects overlap within the bin, users may use a pinching gesture for getting an overview on the bin's contents. When applying this gesture, objects are slightly moved so that no overlapping items remain.

3.2 The Blub Technique

For the Blub technique we adapted “Bubble Clusters” (Watanabe et al. 2007), an organic concept of proximity for spatial object and group manipulation on mouse-operated desktops interfaces. Therefore, each object is surrounded by a bubble, which adjusts its boundaries organically according the number and positions of objects in close proximity (see Figure 2). This bionically-inspired concept can be compared with merging water drops or colliding soap bubbles. In accordance with the Gestalt Law of Proximity, humans perceive elements, which are close together as a group or even more related. If those objects are visually connected, elements are usually interpreted as sharing one or more common attributes (Sternberg 1996). Blub utilizes these characteristics for making grouping more natural. Our multi-touch adaptation provides following interaction techniques for visually organizing items: 1) *Group by object:* Two items join one bubble if they are positioned close to each other. To do so, the user drags an object to another object and as soon as their boundaries touch each other, bubbles melt, creating a new, larger bubble. 2) *Group by bubble:* Users can move bubbles with multiple items by dragging the bubble shape to a new position. After releasing the bubble, overlapping items or other bubbles are merged, when applicable. 3) *Splitting a bubble:* Users may also split a bubble by drawing a stroke with the finger across the bubble shape. The bubble then splits and two new bubbles result. 4) *Spreading a bubble:* Similar as in the Bin technique, a pinching gesture can be used to get an overview on the bubble’s items. When applying the gesture, overlapping objects slightly move to new positions and the bubble adapts its surrounding boundary.

4 Experimental User Study

We conducted a user study for comparing our traditional container concept Bin with the organic proximity concept Blub. Our goal was to identify the differences in bi-manual, multi-finger input and resulting interaction performance and interaction strategies that are afforded by the two grouping techniques. Eventually, we also wanted to examine whether Blub as an organic concept is more natural and hence allows harnessing more of the benefits of multi-touch input in grouping tasks.

4.1 Procedure

Our controlled experiment was performed in our lab on a Microsoft Surface table, measuring 24” x 18” with 1024 x 768 px screen resolution. We collected data in the form of questionnaires, structured interviews, video-recordings and logging data for answering our research questions. Twelve participants (seven male and five female, age 21 to 39, mean: 26) were recruited for the study from the local university campus. All of the participants passed a color-blindness test. With the exception of two individuals, all participants had no background in computer science and only one had never used a touch device before. Participants were compensated for their efforts. We used a counterbalanced within-subjects design whereby each condition (Blub & Bin) was introduced to the participants prior to each test run by a description supplied on a paper sheet. Each condition was tested in sessions that lasted approximately 20 minutes. The whole procedure took around 60 minutes.

4.2 Tasks

Users were given the task to group 30 spatially distributed rectangles (size: 45 x 45 px) according to five different colors (c.f. Watanabe et al. 2007). Each task covered a grouping and a regrouping phase: 1) The rectangles appeared distributed randomly on the surface. 2) Then, users were asked to group shapes according to colors. 3) After a five second break, the colors of the shapes were shuffled (keeping their original position) and participants had to group the objects again. The whole task procedure consisted of 16 trials (4 passes x 2 interface conditions x 2 phases), whereby the first pass was excluded from data analysis as this was used for a short tutorial and free practice. In order to avoid carryover effects, six participants started with the Bin (see Figure 3) and the other six started with the Blub condition (see Figure 4).

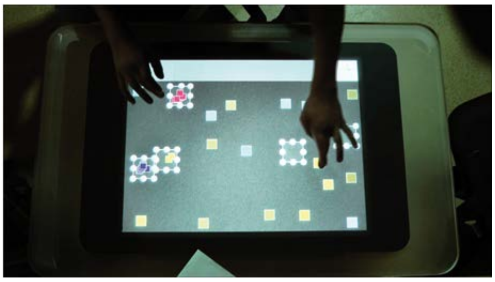

Figure 3: Interacting with the Bin technique.

Figure 4: Interacting with the Blub technique.

4.3 Results

Our data analysis focused on the differences both concepts yield in grouping and regrouping performance, user preferences as well as grouping strategies. In the following, we will describe the results from our quantitative and qualitative analysis.

4.3.1 Task Performance and Efficiency

One of our research goals was to find out, if participants can complete the grouping task with both interfaces. This was measured by logging the task completion times of each trial. 94% of all trials with the Blub Interface and 99% of all trials with the Bin Interface were successfully completed within a five minute limit. This indicates that both interfaces did work for the grouping task. Logged task completion times however differed between Bin and Blub (see *Figure 5*). Paired t-tests for the grouping phase depict significant differences between both techniques ($t(12) = 0.00063$, $p < 0.001$) with Blub being faster. Measured times for the regrouping phase demonstrate only slight variations. By interacting with the Blub technique, participants had a tendency to become faster across the passes (see *Figure 6*). We found that the average task completion times differed in 49 seconds between the first and the third pass

(31 % improvement). However, user performance remained almost constant in the Bin condition.

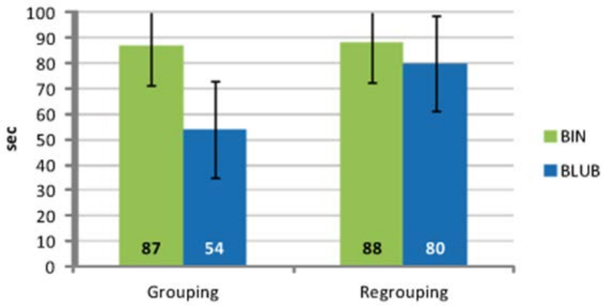

Figure 5: Average trial time and standard deviation of phases in both conditions.

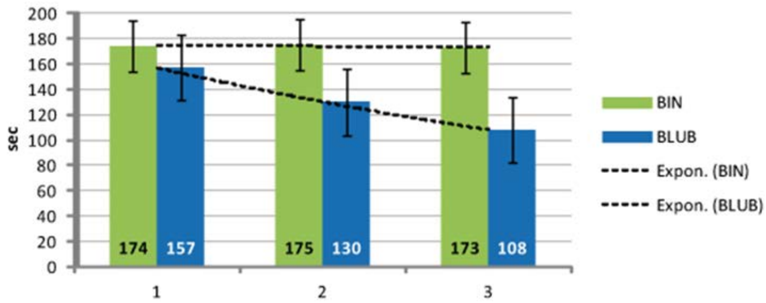

Figure 6: Average trial time, standard deviation and exponential tendency across the passes.

4.3.2 User Preferences

Based on the results of two standardized questionnaires SUS (Brooke 1996) and AttrakDiff™ [1] as well as a final interview we learned that participants clearly preferred the Blub technique. The SUS ratings show that participants would significantly ($t(12) = 0.02971$) use Blub more frequently than Bin and that the latter was significantly ($t(12) = 0.01911$) considered more cumbersome to use. The AttrakDiff™ questionnaire revealed that although Bin was described as more motivating, all but one participant would prefer Blub. Participants described the technique as more task-oriented than self-oriented (pragmatic quality). Concerning the hedonic qualities, the questionnaire revealed that users were more likely to identify themselves with the Blub technique than with the Bin technique. Although not significant, Blub consistently scored higher concerning stimulation, identity and attractiveness.

1 http://www.attrakdiff.de

4.3.3 Use of Multitouch Input

We analyzed our data as to investigate the differences concerning multi-touch input channels between the interfaces. Therefore, 71 completed trials with the Bin technique and 68 completed trials with the Blub technique were qualitatively analyzed using video material. No specific characteristics were found by examining multi-finger input and bimanual interaction separately. However, two-handed interaction combined with multiple fingers was especially applied in the Blub condition (28 trials) whereas one hand and multiple fingers (25 trials) as well as both hands with one finger each (22 trials) was more often used in the Bin condition. Another interesting aspect is that participants used multiple fingers more often in the grouping phase than in the regrouping phase in both conditions.

4.3.4 Interaction Strategies

We examined our data for differences between interaction strategies in grouping by using either the Bin or the Blub technique. Based on the log data of operations conducted with both techniques, we analyzed the observation videos and identified a variety of interaction strategies. Most strategies can be separated in two basic steps – a preparation step and a grouping step. In the Bin condition, participants often prepared the rectangles by accumulating them in small heaps by either dragging or tossing them to groups. In the regrouping phase, they often enlarged the bin and dragged overlapping shapes apart in order to get a better overview. For the grouping itself, participants dragged or tossed objects into a bin, from bin to bin or used the lasso for collecting items. Another strategy was to collect the accumulated shapes by dragging a bin over them or by adjusting a Bin’s shape to enclose objects. The proximity based concept of Blub provided less freedom in interaction as its boundaries were not adjustable. Due to that, less preparation steps were applied. For grouping, they mostly dragged objects to same-colored items in a target-oriented way or tossed them to a point at the edge of the display. A different strategy was to create a large bubble of objects and then splitting it based on colors. However, this strategy was just applied by a few participants. Participants did use the pinching gesture in order to get a better overview of overlapping objects mainly in the regrouping phase. We also analyzed our data as to investigate the differences concerning multi-touch input channels between the interfaces. Participants used multiple fingers more often in the grouping phase than in the regrouping phase in both conditions

4.4 Discussion

Our results have shown that participants were able to successfully complete the task with both interfaces. Nevertheless, by using the Blub technique the task completion time decreased across the passes. In the Bin condition, times remained nearly the same. One possible explanation is that participants understood the Blub technique better and adapted their interaction much faster. Another explanation is that the handle size in the Bin condition was too small. Hence interaction required more effort and was slower. Long term usage however could weaken this trend, because users will get accustomed to both interfaces. Blub was clearly favored by participants. We believe that this is due to its bionically inspired design, which is less complex than Bin. Because Blub lacks handles for adjusting its size, users can save one interaction step but have less freedom in interaction. In the Bin condition, participants favored creating heaps for each color. This and the use of handles for adjustment caused a greater complexity in interaction strategies, which may lead to slower task completion times. We found that the pinching gesture for spreading objects was never used in the Bin condition. We think that the reason for this is that that the mapped gesture was not appropriate or that spreading was not required for completing the tasks. By interacting with the Blub Interface, the most popular interaction strategy was to assort objects selectively. Possibly, this interaction strategy requires less skills and practice in contrast to the splitting strategy. Only two participants applied the splitting strategy, mainly in the regrouping phase. Accidental grouping occurred in both conditions, but was much easier to correct in the Blub condition due to the automatic adjustment of the bubble's contour. Our analysis concerning multitouch input shows that none of our participants had preferences for one particular combination of fingers and hands across the techniques.

5 Conclusion

In this paper we compared the container and the proximity concept for supporting grouping tasks on digital tabletops. We introduced the Bin and the Blub technique and presented a user study comparing these interfaces concerning task performance, task efficiency, user preferences and interaction strategies. The findings of our study depicted that the proximity concept is more beneficial for grouping tasks on a digital surface than the traditional container concept. All but one participant explicitly preferred this concept and on average the task completion times were faster. We consequently argue that grouping based on spatial proximity is closer to our interactions in the non-digital physical world than grouping based on containment. However, we also found that minor changes could further improve the usability of Blub. As overshooting objects is currently a problem, "Superflick" (Reetz et al. 2006), a throwing-based interaction technique, could further enhance Blub toward a more realistic feel. Moreover, when dragging a bubble, other bubbles could move apart which would make interaction more elegant (c.f. Robertson et al. 1998). We found that splitting is not mandatory on interactive surfaces as users made better use of their fingers. Removing this functionality would also reduce the complexity of the interface. We also believe that a splaying gesture instead of a pinching gesture would be more intuitive for spreading objects as it better reflects the user's intention. Another possible enhancement could be to allow users to manipulate the bubble shape in an informal way, thereby allowing more freedom of interaction to the user when necessary.

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