Interacting with Piles of Artifacts on Digital Tables

Dzmitry Aliakseyeu[1], Sriram Subramanian[2], Andrés Lucero[1], and Carl Gutwin[2]

[1]Faculty of Industrial Design
Eindhoven University of Technology
Den Dolech 2, HG 3.51, Eindhoven, the Netherlands

{d.aliakseyeu, a.a.lucero}@tue.nl

[2]Department of Computer Science
University of Saskatchewan
110 Science Place, Saskatoon, SK, Canada

{sriram, gutwin}@cs.usask.ca

ABSTRACT
Designers and architects regularly use piles to organize visual artifacts. Recent efforts have now made it possible for users to create piles in digital systems as well. However, there is still little understanding of how users should interact with digital piles. In this paper we investigate this issue. We first identify three tasks that must be supported by a digital pile – navigation, reorganization, and repositioning. We then present three interaction techniques – called DragDeck, HoverDeck, and ExpandPile that meet these requirements. The techniques allow users to easily browse the piles, and also allow them to move elements between and within piles in an ad-hoc manner. In a user study that compared the different interaction techniques, we found that ExpandPile was significantly faster than the other techniques over all tasks. There were differences, however, in individual tasks. We discuss the benefits and limitations of the different techniques and identify several situations where each of them could prove useful.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *graphical user interfaces (GUI).*

General Terms
Measurement, Design, Experimentation, Human Factors.

Keywords
Pen input, interaction techniques, tabletop, digital piles.

1. INTRODUCTION
Most designers and architects collect sketches, drawings and photos over time and use them as inspirational material for new projects. They often flip through their collections to remind themselves how they approached an earlier project, or to find images that might inspire them for their current work. Typically, people spread out these collections on tabletop surfaces to look for useful material [5]. As a designer's collection of visual material grows, they tend to pile them into loosely structured groups and leave them on a work surface. In general, designers do not explicitly title these piles, and do not arrange the materials in

any particular order. Piles of artifacts, therefore, can create a cluttered desk – and yet, when any change is made to the apparent muddle of material, serious workflow disruptions often occur [6].

There are several advantages to piling documents. The most obvious is that piles allow designers to easily access required materials [6]: the spatial layout conveys important information about the relevance of the pile to the current task, and actively used piles are closer to the designer's active work area while piles that are rarely used are farther away. Piling also overcomes the need to explicitly classify or categorize new material. Finally, piles serve as external representations of context, reminding the designer of ongoing tasks and projects [2].

Recognizing these benefits of piles, recent digital systems have started allowing designers to pile relevant materials. For example, in the Cabinet system [5], designers are allowed to load images into the system and maintain workbooks of related images, with each workbook acting as a digital pile. However, other systems do not adequately capture the flexibility and fluidity in interaction that is evident with physical piles. For example, they do not allow users to directly and easily rearrange the elements of a pile.

2. RELEVANT WORK
2.1 Interacting with Piles
With the concept of a paperless office still remaining a distant dream many researchers have studied the organization of physical desks and the personal document management systems [2][6][8], focusing on knowledge workers [6], and more specifically on architects and designers. These latter studies have confirmed the importance of visual information and collections of different visual materials [5], such as sketches, photos and drawings which are often used by designers for inspiration and for creating collages [5]. These materials are often stored on the workplace itself, in a highly individual and (semi)-organized way [5].

2.1.1 Requirements for Pile Interaction
Based on our literature review on desk organization for knowledge workers and early stages of design we can synthesize the main requirements for design of techniques for interacting with digital piles. First, fast navigation within a pile should be encouraged [2][5][6]. Second, elements within a pile should be easily repositioned [2][8]. Third, it should be easy to reorganize elements between piles [2][8].

2.2 Interacting with Digital Piles
If users need to interact with a digital pile they need to be able to quickly assess the hidden elements of the pile and navigate through them. Several approaches have been proposed in the literature and commercial systems to address the issue of

revealing and interacting with hidden content for both desktop applications and for design specific applications. One popular approach among research systems is to use transparency to show obscured content including an idea of see-trough interface [1], a global overview of a large visual workspace shown semitransparent on top of a viewport [3], and a content aware transparency where parts of the window that are assumed to be unimportant are made transparent [4]. While some of these approaches are specific to desktop applications, the key idea here is that transparency can be used effectively to reveal hidden materials in the piles. Another approach is found on Cabinet [5] to allow users to create and maintain a collection of images. Images are kept in piles (stacks), and images are made accessible by expanding the piles and presenting them as thumbnails, using more screen space to reveal all the content to the user.

Both transparency and expand have their benefits and limitations. Using transparency allows users to perform the interaction without disrupting other parts of their workspace. It also means we can support interaction techniques that are more subtle and lightweight using pen pressure [7], hover or tilt [9] sensors. With expand, users need to explicitly initiate the interaction and the expanded pile occupies previously available portions of the workspace. This active engagement leads to a more explicit and possibly faster interaction but may require more user effort.

3. INTERACTION TECHNIQUES

The techniques described here are based on how the pile reveals its elements to the user and how the users can interact within and between piles. The first two techniques, DragDeck and HoverDeck, are based on the transparency idea. The pile opens like a partially revealing deck of cards allowing the user to change the transparency in order to view the content of the pile. Users can also directly access a partly revealed element by selecting it. The third technique, ExpandPile, is based on the idea of expanding the entire deck to reveal its elements. HoverDeck uses a lightweight gesture using the pen hover mode while the others use a more direct interaction gesture by dragging and using pen pressure to interact with the elements.

3.1 DragDeck

Users start interacting with a pile by touching the pile with the pen. Upon touching, the side closest to the pen slides open to reveal the hidden elements of the pile. By maintaining contact with the surface and moving the pen (Figure 1), users will browse in the direction that the pen is moved, making the currently visible layers become transparent to reveal hidden layers along the direction of the pen movement. After sliding open a pile the user may also quickly browse to any particular image by directly clicking on a visible part of it. By pressing the pen button a user can reposition the currently visible image to the top of the pile, and by moving the pen orthogonal to the browsing direction the visible image can be dragged out of the pile for reorganizing or active use. Users can move active images to different piles by a simple drag-and-drop. When a new image is dropped onto a pile it will be added to the top of the pile.

3.2 HoverDeck

Users open the pile by touching it with the pen and can browse through it by hovering (Figure 1) the pen on top of the pile. The hover direction decides the direction in which the hidden images become visible. When an interesting image is visible users can select the image by touching it. A selected image can be repositioned to the top of the pile by lifting the pen off the surface. The selected image can also be moved out of the pile by dragging the pen out of the pile. When the image leaves the pile it becomes an active image that can be used by the user or can be reorganized in another pile. When a new image is dragged into the pile it is placed on top of the pile.

3.3 ExpandPile

In this technique when the user touches a pile, the entire pile expands to reveal all its elements in a manner similar to the Cabinet System [5]. Elements are scaled to fit within the workspace or the designated area for the pile. The images can be collated to reform the pile by clicking on empty parts of the workspace or by clicking any of the images. In the latter case, the image that was clicked will be repositioned to the top of the pile. Users can remove an image from the pile by touching the image and dragging the pen on the workspace without lifting it. An image that is removed from the pile becomes an active image that the user can work with or can be reorganized into a new pile by dropping into the pile. When a new image is dropped onto a pile the image is placed at the top of the pile.

Table 1. Summary of interaction techniques, tasks and actions

Task	Actions	Interaction Technique		
		Drag	*Hover*	*Expand*
Navigate	Open pile	*touch with pen* (fig.2a)		
	Browse	*drag* (fig.1,2b)	*hover* (fig.1)	*look* (fig.2c)
Reposition	Put image on top	*press button on pen*	*1.touch with pen 2. lift pen*	*touch with pen*
Reorganize	Remove from pile	*move orthogonal*	*touch with pen*	
	Move to other pile	*drag*		
	Release	*lift pen*		

Figure 1. Dragging and hovering to browse. In the DragDeck (left) and HoverDeck techniques (right) users must maintain contact with the surface and hover the pen over the surface.
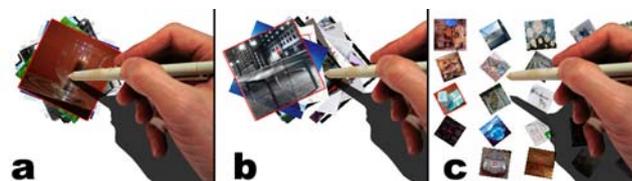
Figure 2. Different views of piles. a) Pile is closed, b) Pile is open for browsing, c) An open pile in ExpandPile.

4. EVALUATION

We compared the three interaction techniques via a user study. Three tasks (navigate, reposition and reorganize) were performed separately by our participants. We used a tabletop system consisting of a digital board with top projection.

4.1 Tasks

4.1.1 Navigating

The first task was to browse through the pile and find an image with a certain shape on it, which contained a button code (ranging from [F1] to [F6]). Participants where asked to click the corresponding button on a keyboard. Participants were informed about the button options (from [F1] to [F6]). Trials were considered successful if the correct button was pressed. We varied the buttons so that the user had to put more effort into browsing the images rather than just attempting simple pattern recognition. In most cases, users do not know exactly what they are looking for until they find it and this task reflects that situation.

4.1.2 Repositioning

The second task was to organize a pile. Two numbered images (1 and 2) were hidden in the pile. Participants were asked to find image number "1" and put it on top of the pile followed by the image with number "2" which users sometimes do to remind them of some activities. In our trials users were asked to hit the [Enter] key to complete the trial in order for them to judge that the task is finished rather than let the system make this judgment for them.

4.1.3 Reorganizing

The third task was to reorganize two piles. Participants were asked to compare two piles, find the image in common on both piles and move it from pile one to pile two so that the latter has two copies of the same image. Similarly as with the previous task, participants were asked to hit the [Enter] key to complete the trial.

4.2 Experiment Design

The experiment was conducted with 8 participants (1 female and 7 male) between the ages of 18 and 31. We had 3 left-handed and 5 right-handed participants who used their preferred hand to control the pen. All subjects had previous experience with graphical interfaces and were either professional designers or students from an industrial design department. All users were tested individually. The experiment used a 3x3x2x3 within-participants factorial design with a variety of planned comparisons. The factors were Technique (DragDeck, HoverDeck, ExpandPile), Task (sort, reorganize, navigate), Size of the pile(s) (15 images, 45 images), and Location of pile (top left, top right and center)

The number of trials per technique, task, size and location was different depending on the task. This was done to reduce the overall time needed to complete the experiment to one hour. For the first task participants completed one training and five test trials. In the second and third tasks participants completed one training and three test trials, for a total of 54 training trials and 198 test trials. The order of techniques, location and size of piles was mixed to balance any learning effects. The task order was navigating, repositioning and reorganizing. Two performance measures were used for the evaluation – mean completion time, and subjective preference scores, as rated by participants in a questionnaire which also included comments on the techniques.

5. RESULTS

5.1 Time

5.1.1 Overall Performance

The overall mean completion times across all conditions was 9.920 seconds (standard deviation = 8.643 seconds). One-way repeated-measures ANOVA showed that interaction technique had a significant effect on the trial completion time ($F_{2,69}$=11.228, p<0.001). ExpandPile was significantly faster than DragDeck followed by HoverDeck. There was no significant difference between the last two techniques.

5.1.2 Navigating

The mean completion time for navigating was 7.911 seconds (standard deviation = 7.999 seconds). One-way repeated-measures ANOVA showed that the interaction technique did not have a significant effect on the trial completion time for navigating task ($F_{2,21}$=0.703, p<0.506). ExpandPile was the fastest technique, followed by DragDeck and HoverDeck. The differences were not significant (Figure 3).

5.1.3 Repositioning
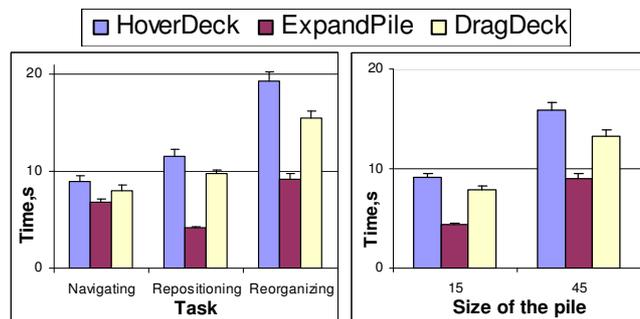
The mean completion time for repositioning task was 8.518 seconds (standard deviation = 6.149 seconds). One-way repeated-measures ANOVA showed that the interaction technique had a significant effect on the trial completion time for repositioning ($F_{2,21}$=12.339, p<0.001). As seen in Figure 3, ExpandPile is significantly faster than other techniques, followed by HoverDeck and DragDeck, with no significant difference between them.

5.1.4 Reorganizing

The mean completion time for reorganizing was 14.660 seconds (standard deviation = 9.943 seconds). One-way repeated-measures ANOVA showed that the interaction technique had a significant effect on the trial completion time for reorganizing task ($F_{2,21}$=11.961, p<0.001). As can be seen in Figure 3, ExpandPile was the fastest technique, followed by DragDeck and HoverDeck.

5.1.5 Effect of pile size

One-way repeated-measures ANOVA showed that the size of pile had an overall significant effect on the trial completion ($F_{1,14}$=13.737, p<0.001). Separate analysis of each technique also showed the significant effect of pile size (ExpandPile – $F_{1,14}$=20.170, p<0.001, DragDeck – $F_{1,14}$=12.180, p<0.004, HoverDeck – $F_{1,14}$=7.226, p<0.018) as can be seen in Figure 4.

Figures 3 and 4. Mean trial completion times with standard error for navigating, repositioning and reorganizing tasks (left) and for different pile sizes (right).
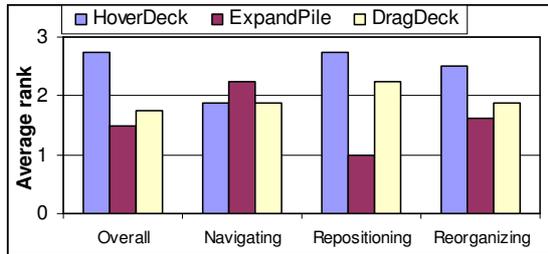
Figure 5. Mean values for the preference ranking of each technique in overall and for each task separately.

5.2 Subjective Preference

Participants ranked each technique on a scale of 1 to 3 (where 1 is best and 3 is worst) based on perceived control, tiredness, speed, overall preference and preference for each task. ExpandPile and DragDeck were ranked first by 4 participants while none ranked HoverDeck first. However, individually per task, for navigating, 8 participants preferred HoverDeck most, while DragDeck and ExpandPile only had 2 preferences. For repositioning, ExpandPile was ranked first by all participants. For reorganizing ExpandPile and DragDeck were ranked first by 4 participants.

6. DISCUSSION

6.1 Lightweight vs. Heavyweight Interaction

ExpandPile is a heavy weight interaction technique meaning it requires users to move their focus-of-attention around to various (nearby) spatial regions to effectively browse through a pile. This becomes harder when there are more elements in a pile and less space to expand them to, as opposed to both DragDeck and HoverDeck which are lightweight interaction techniques. However, for DragDeck user have to actively engage in an explicit manner (the pen has to move on the table) whereas for HoverDeck users can easily browse by just waving the pen close to the tabletop. We believe this explains why users preferred it over the other two techniques even tough it was on average slower (not significantly) than the other techniques. There are some clear, but difficult to quantify, benefits of lightweight interaction techniques in such tasks and there is a greater need to study them carefully.

6.2 Effect of Size on Performance

ExpandPile, while still being faster than other techniques, suffered most from increasing the pile size (Figure 3). Increasing the number of images decreases the size of each thumbnail in ExpandPile which makes it harder to recognize the images. For example, in the navigation task average times for ExpandPile with 15 images was 3.59 s and with 45 images it was 9.86 s. For the deck techniques the size of the pile affects browsing speed. The deck opens by a fixed amount irrespective of the number of images in it, so moving the pen 1 cm in a deck of 45 images results in browsing through more images than on a 15 image deck, thus making it harder to select images. Using the HoverDeck technique has the added disadvantage that when bringing the pen down to select an image the user might displace the pen horizontally beyond the preset threshold value. This can result in the user browsing through the image unintentionally just before selecting it. These problems can be easily addressed by incorporating a smart algorithm to couple the threshold value based on the speed of pen movement in the vertical direction.

6.3 Design Recommendations

We propose a list of recommendations for the design of digital piles. First, for effective use of digital piles designers should allow users to navigate, reposition and reorganize. Second, when supporting Navigation, it is worthwhile to consider lightweight techniques like HoverDeck. Users prefer HoverDeck and it is not significantly slower than ExpandPile. Third, when supporting techniques for repositioning and reorganizing elements of a pile, ExpandPile is a powerful technique to consider. Fourth, if it is important to give users a feeling of greater control over the interaction, techniques like DragDeck should be considered.

7. CONCLUSION

This paper investigated interaction techniques for supporting tabletop piles. Based on the analysis of relevant literature, we synthesized a set of tasks – navigate, reposition and reorganize – and developed three interaction techniques to support them – DragDeck, HoverDeck and ExpandPile. Through a user study we identified the benefits and limitations of each technique. We found that even tough ExpandPile was significantly faster than other techniques for reorganizing piles it was not the most preferred technique. Similarly, even tough HoverDeck was on average slower than other techniques for browsing/ navigating it was the most preferred technique. Based on the results we make recommendations for future designs of digital pile interaction techniques. Future work includes evaluating these techniques using other performance measures such as engagement and effort that might better quantify the users' preference for different techniques. Other subtle cues to create lightweight interaction techniques could be introduced such as tilt and pressure sensors.

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