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Release, Relocate, Reorient, Resize: Fluid Techniques for Document Sharing on Multi-User Interactive Tables

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Abstract
Group work frequently involves transitions between periods of active collaboration and periods of individual activity. We aim to support this typical work practice by introducing four tabletop direct-manipulation interaction techniques that can be used to transition the status of an electronic document from private to group-accessible. After presenting our four techniques – release, relocate, reorient, and resize – we discuss the results of an empirical study that compares and evaluates these mechanisms for sharing documents in a co-located tabletop environment.

Categories & Subject Descriptors: H5.3. Information interfaces and presentation (e.g., HCI): Group and Organization Interfaces.

General Terms: Design, Experimentation, Human Factors.

Keywords: Computer-supported cooperative work, tabletop interfaces, multi-user interfaces, access control, groupware.

INTRODUCTION

Typical meetings transition between phases of individual work and times of active collaboration among everyone present. Prior studies of group work [3, 5] have established that quick, smooth transitioning between individual and group work during collaboration is a natural skill. The importance of the ability to maintain a personal workspace during collaborative activities is reinforced by Tang's observation [12] that users of traditional (non-computational) tables often maintain distinct, individual work areas. Thompson's work [13] also highlights this fact by noting that students in a school library preferred quadrilateral, rather than round, tables because they allowed clearer demarcation of individual work areas. In their list of guidelines for the development of collaborative tabletop software, Scott et al. [7] note that the ability to support transitions between personal and group work is a desirable trait for tabletop groupware applications.

To support more fluid transitions between group and personal work around a multi-user computational tabletop, we present four interaction techniques that can facilitate changing the accessibility of electronic documents, so that items can be made accessible to all users during periods of group work, and can be returned to owner-only accessibility during individual work. These techniques can be used individually or in combination to more naturally support this existing work practice.

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FLUID DOCUMENT SHARING TECHNIQUES

We use the term "sharing" to refer to the ability to dynamically change the accessibility of a digital document by transitioning between a "personal" access control policy (whereby only the document's owner can move or alter the document) and a "public" access control policy (whereby all users at the table can move or alter the document). To support sharing we introduce four interaction techniques – *release*, *relocate*, *reorient*, and *resize*.

These interactions were prototyped using DiamondSpin [9], a Java toolkit for creating tabletop interfaces. We did our testing using a DiamondTouch table [2], a touch-sensitive, multi-user input device that uses capacitive coupling to provide user identification information along with each touch event. This identification information was necessary to enforce access control rights; other tabletop input technologies such as SmartSkin [6] or DViT [14] could support our techniques if they were augmented with cameras to provide identifying information to accompany each touch. The concept of supporting fluid transitions between group and individual work is applicable to other forms of single display groupware [10] in addition to the specific hardware and software platforms we chose to use.

Release

This technique mimics interactions with paper documents. If user A "holds" an electronic document and user B attempts to take it, then if user A continues to hold the document user B will come away empty-handed. However, if user A releases his touch from the document, user B will successfully acquire it (see Figure 1).

Relocate

We have implemented a tabletop layout in which different portions of the table can be associated with different users. Moving a document into a public region of the table transitions it to a public mode, while moving it to a user-

*This work was done while the author was an intern at MERL.

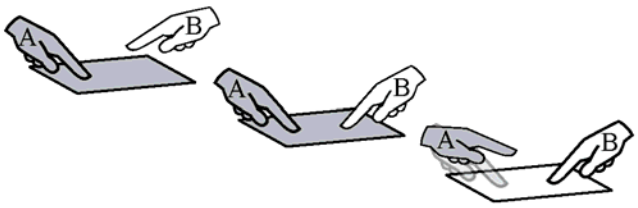

Figure 1. The "release" technique for sharing: User B attempts to take the document User A is holding. User A releases the document in order to transfer access privileges to User B.

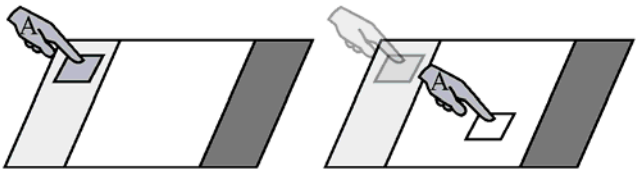

Figure 2. The "relocate" technique for sharing: When the document is in User A's private area, it is inaccessible to other users. By moving the document to the center (public) section of the table, it becomes publicly accessible.

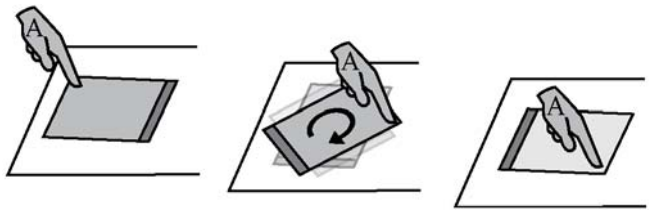

Figure 3. The "reorient" technique for sharing: When User A's document faces him it is not accessible to other users. User A rotates his document to face the center of the table in order to make it publicly accessible.

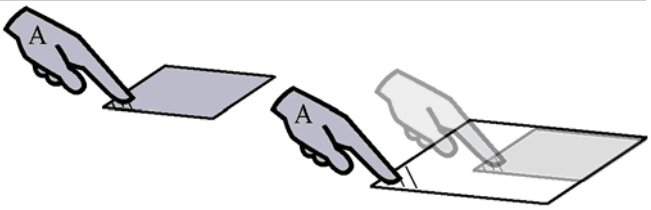

Figure 4. The "resize" technique for sharing: User A's small document is inaccessible to other users. User A enlarges his document, thereby making it public.

owned region (demarcated by color or lines) makes it private (see Figure 2). We support flexible partitioning of the work surface by initially presenting a surface that is completely public. When a user joins the group at the table, she can touch the portion of the table closest to her, thereby claiming that region as her own. That region's color changes to match the color of the user's chair in order to provide feedback that it is now a private region. If all four sides of the table are claimed as private spaces, the center of the surface still remains available as a public work area. When a user leaves the group, double-tapping her private region opens a contextual menu that presents the option of relinquishing her portion of the table to the public domain.

Although Bullock and Benford [1] propose using space to provide access control in multi-user environments, they are referring to a metaphor of space within the application (e.g., an application with different "rooms," where only some users have permission to access certain rooms), rather than referring to physically partitioning the work surface into areas with different access permissions. The UbiTable [8] also partitions a work surface to indicate access permissions, and was implemented using the DiamondSpin toolkit with our "relocate" sharing technique.

Reorient

This interaction is also inspired by observations of people's interactions with paper – Kruger and Carpendale [4] observed that people changed the orientation of physical documents on a table to indicate whether they were personal or public. We allow "sharing" of a document by orienting it toward the center of the table, while orienting it toward the outside (e.g., toward the user who owns it) transitions it back to a personal mode (see Figure 3).

Resize

With this technique, making a document smaller than a threshold size makes it private, while enlarging it opens it to public access (see Figure 4). The association of a larger size with increased access seems appropriate in light of the findings of Tan and Czerwinski [11], who observed that displaying electronic correspondence at a larger size invited more snooping.

EVALUATION

We conducted an evaluation to measure performance and qualitative differences among our four interaction techniques for sharing – releasing, relocating, reorienting, and resizing. In addition to observing subjects using these techniques, we posed the following hypotheses:

H1. Pairs of subjects would be able to exchange private documents faster using some techniques over others.

H2. Pairs of subjects would commit fewer errors while exchanging private documents with some techniques over others.

H3. Visual feedback showing the accessibility of documents would result in fewer errors.

H4. Differences in the perceived ease of use and naturalness would exist among the four techniques.

Method

Participants: Fifteen pairs of subjects (14 males, 16 females) from outside our lab participated in our study. Their ages ranged from 18 to 33 years old. All of the pairs knew each other prior to the study and none of the pairs had significant experience with tabletop interfaces.

Setup: The digital documents displayed by the test application were simple images with a clear orientation. Each document was movable, turnable, and resizable by its owner. During each trial, the application displayed which of the four techniques the pair should use. Finally, the test application logged the time pairs took to complete each task as well as the number and type of errors made.

Procedure: Pairs sat opposite from one another across the tabletop. Each session began with instructions on how to move, turn, and resize documents on the table. The tutorial then included written instructions on how to use each of the four sharing techniques to change the accessibility of a document. Subjects were given the chance to practice each of the techniques and ask questions. When they were finished practicing, pairs were asked to perform a series of simple document exchanges in which each subject had to first make their document accessible to their partner and then had to take their partner's document.

Each exchange used one of the four techniques and either provided visual feedback or did not. Visual feedback was provided in the form of colored tabs along the edge of each document. The tabs corresponded to the colors of the chairs each user sat in. If a tab was transparent, it indicated that the user in the corresponding chair could not access the document; conversely, opaque tabs indicated that the corresponding user could access the item. While we conjecture that providing such feedback is helpful in a multi-user, multi-document setting in which several different access policies are simultaneously in effect, the best way to present this visual feedback is still an open question and was not the focus of this work.

The order in which the techniques and feedback appeared was randomized to control for condition. The pairs participated in 64 such trials (4 techniques, by 2 feedback conditions, with 8 repetitions each). To balance learning effects, only the last 4 of every 8 repetitions were logged.

Questionnaire: At the end of the study, both subjects were asked to fill out a short questionnaire designed to elicit subjects' subjective preferences among the four techniques.

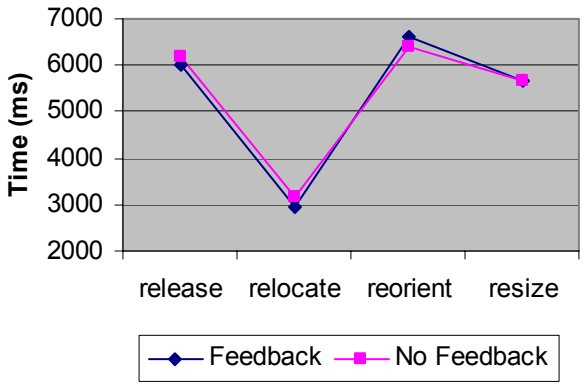

Figure 5. Sharing documents with the "relocate" technique was significantly faster than with the other three techniques.

Table 1. Error rates were lowest when using the "relocate" and "resize" techniques to share documents.

	Release	Relocate	Reorient	Resize
Mean Errors	1.45%	0.0%	1.65%	0.4%

Results

There is a significant difference among the four techniques in task times (H1). The testing application recorded the task time for every trial, measured from the moment the two documents appeared on the screen to the moment both documents had been successfully exchanged. The technique used significantly affected the task time ($F(3,117)=50.4, p<0.0001$)—relocate was more efficient than the other three techniques. The mean task times for each of the four conditions are shown in Figure 5.

There is a slightly significant difference among the four techniques in error rate (H2). For each trial, the testing application recorded how often a subject attempted to take a document that they did not have permission to take. Additionally, the application recorded unnecessary steps performed by either of the subjects (such as resizing a document when they only had to reorient it). The relocate and resize techniques seem to have slightly significantly lower error rates than the release and reorient conditions ($F(3,117)=2.34$, $p=0.07$). The error rates for each of the four conditions are shown in Table 1.

There is no significant difference between the feedback and no-feedback conditions in error rate (H3). The mean number of errors between these two conditions was indistinguishable. (on average, 0.007 vs. 0.010, $F(1,119)=0.30$, n.s.)

There is also no significant difference between the feedback and no-feedback conditions in task time. Because the overall error rate was very low for all conditions, we thought that while visual feedback did not seem to affect the error rate, it might allow pairs to perform their tasks more rapidly; however, the mean task times in the feedback and no-feedback conditions were indistinguishable (on average, 5305 ms vs. 5353 ms respectively, $F(1,113)=0.0004$, n.s.). Figure 5 shows the similarity between the averages for each technique, and the lack of a significant interaction effect. This may reflect the fact that the task involved only two documents and users at a time; visual feedback might become more useful as the number of users and/or documents increased. This is a question left for a future study. While feedback did not prove to be numerically significant, subjects strongly agreed with the

Table 2. Subjects' average rank of ease of use for each technique. Lower scores reflect easier methods.

	Release	Relocate	Reorient	Resize
Avg. Rank	2.8	1.1	2.9	3.1

Table 3. Subjects' average agreement with the statements. Higher values show more agreement.

Statement	Avg.
It's easy to share documents with Release	4.9
It's easy to share documents with Relocate	6.9
It's easy to share documents with Reorient	4.4
It's easy to share documents with Resize	4.6
The Release technique was natural to use.	3.8
The Relocate technique was natural to use.	6.8
The Reorient technique was natural to use.	3.3
The Resize technique was natural to use.	4.9

statement "The colored tabs showing ownership made it easier to share documents" (on average, 5.18 on a 7-point Likert Scale) and strongly disagreed with the statement "The colored tabs cluttered the interface" (2.58 on a 7-point scale).

There is a significant difference among the four techniques in regard to users' perception of ease of use (H4). Each subject was asked to rank the four techniques by "how easy it was to share a document with your partner," with 1 being the easiest and 4 being the hardest. There appears to be a significant difference among the four techniques, with subjects strongly favoring the relocate method ($F(3,116)=44.26, p<0.0001$). Additionally, subjects were asked to rate their agreement on a 7-point Likert Scale with statements about the ease of use and naturalness of the four techniques. The average results from the ranking and agreement are shown in tables 2 and 3.

Subjects were able to quickly learn and then successfully perform each of the four techniques. While this was perhaps an unstated hypothesis, we were pleased to see high success rates across the board. Virtually all of the trials were successful, with only 13 out of the 484 total trials being unsuccessful. Of these 13, all but 2 took place in the relocate condition and involved a subject placing a document directly in his partner's area rather than the public area in the middle of the table, a situation that we recorded as a failure since no "exchange" was made. In general, subjects seemed able to quickly learn these techniques and were able to switch between them without any noticeable trouble.

CONCLUSION AND FUTURE WORK

We introduced four tabletop interaction techniques (release, relocate, reorient, and resize) for transitioning documents between public and personal accessibility. A formal study of these techniques demonstrated that users quickly understood and mastered these four methods of sharing. This is an important step toward creating co-located groupware that supports the swift, fluid transitions between periods of individual work and active collaboration that have been observed in meetings around traditional tables.

We plan to further evaluate these four techniques in more challenging scenarios, such as tasks that involve multiple documents, and tasks that allow for choosing among the four techniques rather than limiting the user's choice to one at a time. Developing and evaluating other mechanisms to support flexible access control for co-located groupware is a rich area for further study.

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REFERENCES

1. Bullock, A. and Benford, S. An Access Control Framework for Multi-User Collaborative Environments. *Proc. Group 1999*, 140-149.
2. Dietz, P. and Leigh, D. DiamondTouch: A Multi-User Touch Technology. *Proc. UIST 2001,* 219-226.
3. Elwart-Keys, M. et al. User Interface Requirements for Face to Face Groupware. *Proc. CHI 1990*, 295-301.
4. Kruger, R. and Carpendale, M.S.T. Orientation and Gesture on Horizontal Displays. *UbiComp 2002 Workshop on Collaboration with Interactive Walls and Tables*.
5. Mandviwalla, M. and Olfman, L. What Do Groups Need? A Proposed Set of Generic Groupware Requirements. *ACM Transactions on Computer-Human Interaction*, 1(3), 245-268.
6. Rekimoto, J. SmartSkin: An Infrastructure for Freehand Manipulation on Interactive Surfaces. *CHI 2001*, 113-120.
7. Scott, S.D. et al. System Guidelines for Co-located, Collaborative Work on a Tabletop Display. *Proc. ECSCW 2003*, 159-178.
8. Shen, C. et al. UbiTable: Impromptu Face-to-Face Collaboration on Horizontal Interactive Surfaces. *Proc. UbiComp 2003*, 281-288.
9. Shen, C. et al. DiamondSpin: An Extensible Toolkit for Around-the-Table Interaction. *Proc. CHI 2004,* (to appear).
10. Stewart, J. et al. Single Display Groupware: A Model for Co-present Collaboration. *Proc. CHI 1999,* 286-293.
11. Tan, D. and Czerwinski, M. Information Voyeurism: Social Impact of Physically Large Displays on Information Privacy. *Proc. CHI 2003 Extended Abstracts,* 748-749.
12. Tang, J.C. Findings from observational studies of collaborative work. *International Journal of Man-Machine Studies*, 1991, Volume 34, 143-160.
13. Thompson, J.J. Beyond Words: nonverbal communication in the classroom. New York: Citation Press, 1973.
14. http://www.smarttech.com/dvit