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Abstract

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Under My Finger: Human Factors in Pushing and Rotating Documents Across the Table

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Abstract. When passing a document to someone across a table, the person passing the document often rotates it to face the receiver. In this paper, we present the results of a user evaluation of three *Push-and-Rotate* schemes that offer different underlying control semantics for how an electronic document can automatically rotate as it is pushed across an interactive tabletop surface. The effects of document size are also discussed.

1 Introduction

Moving digital documents on vertical displays, such as desktop monitors or electronic white boards, involves dragging operations with only two degrees of freedom in the XY plane. Vertical displays rely on everyone sharing a common “up” vector with the display; digital documents that are translated are still readable. However, no such assumption can be made for horizontal displays because a horizontal display may be viewed simultaneously by many people sitting around it. Thus, a multi-user digital tabletop that aims to support around-the-table collaboration with digital documents must support not only the positioning, but also the orientation of documents [4].

Simultaneously moving and rotating a digital document is the subject of this paper. Specifically, we focus on techniques that map the 3 DOF into one single control point (thus requiring only one finger). Although multi-finger and multi-hand techniques can also be developed [5], by combining movement and rotation into a single finger operation, designers can use the more sophisticated gestures for issuing other commands.

There are two approaches for single-finger tabletop document repositioning and reorientation. One is to decompose the interaction into two steps by providing separate widgets for each of the tasks (such as a title bar for movement and rotation handle). An alternative approach that more naturally matches a user’s basic perceptual structure of the task [1] would be to integrate the two together in a single step. With one action, the user can push and rotate a document to the desired location and orientation [2][3]. In our system, the orientation of a document is a function of the point where a user touches the document and the position of the document with respect to the table’s center. The directness of under-the-finger manipulation leads to a high sensitivity to subtle variations in the constraint function. In building [4], we developed a number of functions, three of which, shown in Figure 2, are described below.

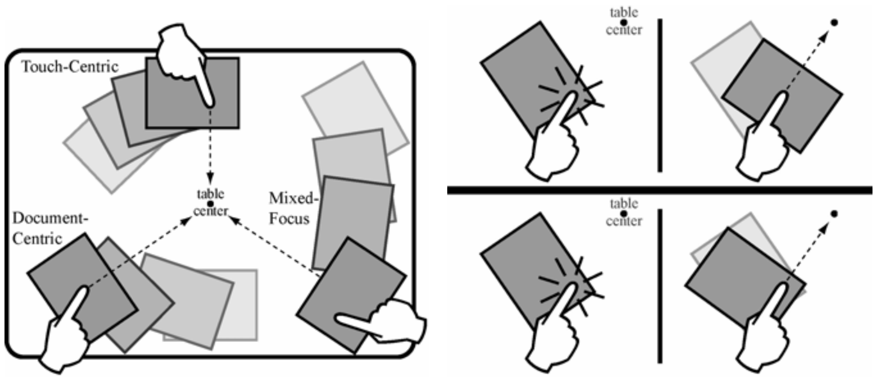

Fig. 2. (*on the left*) The three constraint functions differ in how documents follow the finger and how they auto-orient. (*on the top-right*) When touched, Document-Centric documents "slide" to center themselves with the touch point. (*on the bottom-right*) Touch-Centric documents "slide" when touched to constrain their orientation with a line between the touch point and the table center

Document-Centric. When the user touches a document, it instantly slides to center itself on the touch point, as shown in Figure 2 (*top-right*). As the finger drags the document on the table, the document continues to center itself to the touch point and the document's orientation is constrained by lining up the center of the document, the center of its top edge, and the center of the table, as shown in Figure 2 (*left*).

Touch-Centric. When the user touches a document it instantly constrains its orientation using a line between the touch point and the center of the table that is perpendicular to the document's top edge, as shown in Figure 2 (*bottom-right*). As the finger moves around the table, the document orients itself using this line and moves itself so that the initial touch point is always under the finger, as shown in Figure 2 (*left*).

Mixed-Focus. This function is a hybrid of the other two techniques. It is touch-centric for movement, and document-centric for rotation. When the user touches a document, it follows the movement of the user's finger relative to where it was first touched; however, the document orients itself using a line between the center of the table and the center of the top edge of the document, as shown in Figure 2 (*left*).

2 User Evaluation

Our hypotheses were:

H1. Subjects will be able to position documents at a desired location on the tabletop *faster* using some techniques as compared to others.

H2. The size of a document will influence the *speed* with which subjects reposition it on the tabletop.

H3. Subjects will be able to *more accurately* position documents at a desired location on the tabletop using some techniques as compared to others.

H4. The size of a document will influence the *accuracy* with which subjects reposition it on the tabletop.

Fourteen subjects (5 female, 9 male) participated, and none had experience using digital tabletops. The task consisted of a document and a target appearing on the DiamondTouch input surface. The document always appeared in the same position in front of the subject; the target appeared randomly among four positions on the opposite side of the table, all of which were equidistant from the initial document location. Subjects were asked to move the document to the target as quickly and as accurately as possible. Each subject completed 32 trials (4 document sizes * 4 equidistant target positions * 2 repetitions) using each of the 3 conditions; a total of 1344 trials. The order of the three conditions was randomized, and the first repetition of each task was discarded.

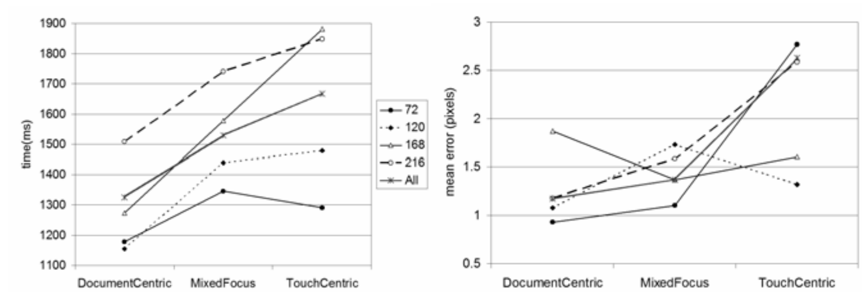

Fig. 3. (*on the left*) Task time by technique and document size. Smaller documents tend to lead to shorter times. (*on the right*) Task error by technique and doc size

2.1 Results

Our experimental data confirmed all four hypotheses.

H1: For each trial, the testing application recorded the speed with which subjects moved a document to the target position. A repeated measures ANOVA of the recorded data suggests that the technique used significantly affected the task time ($F(2,13)=13.75$, $p=0.003$, $d=0.92$). The average task times for the three techniques were 1.32, 1.67, and 1.53 seconds for Document-Centric, Touch-Centric, and Mixed-Focus respectively. The relative task times for all document sizes are shown in Figure 3.

H2: The size of the documents significantly affected the speed with which subjects repositioned them ($F(2,13)=42.99$, $p<0.001$, $d=1.0$). In general, the smaller the document, the faster the subjects were able to reposition it. Furthermore, there was a significant interaction between document size and condition ($F(6,12)=5.20$, $p=0.042$, $d=0.55$).

H3: At the end of each trial, the testing application recorded the distance in pixels between the document center and the target center. The constraint function used significantly affected this task error ($F(2,13)=13.6$, $p=0.004$, $d=0.92$). The average errors for the three techniques were 1.95, 3.54, and 2.13 pixels for Document-Centric, Touch-Centric, and Mixed-Focus respectively. Figure 3 shows the mean task errors broken down by the four document sizes.

H4: The size of the documents significantly affected the accuracy with which subjects repositioned them ($F(2,13)=3.9$, $p=0.045$, $d=0.53$). Again, in general subjects performed better with smaller documents. There was a significant interaction between document size and condition ($F(6,12)=7.19$, $p=0.02$, $d=0.69$).

After each session, we asked subjects which of the three techniques they preferred the most and the least. As a whole, subjects disliked the Touch-Centric condition, expressing that it was hard to predict the orientation of the document as it moved across the table. While they (correctly) felt that they performed well with the Document-Centric technique, many subjects disliked the initial "sliding" of the document in this condition. Most subjects named Mixed-Focus as their favorite of the three.

3 Discussion and Design Recommendations

While Document-Centric was the fastest and least error prone, it received the lowest user preference score. We are left with the question, "What is the appropriate measure for comparing these types of tabletop interaction techniques?" Future study is needed to help decide if the modest performance gains outweigh user satisfaction.

With all 3 techniques, smaller documents lead to quicker and more accurate results. We speculate that this may be because larger documents are more sensitive to small changes in angle and that this made adjustment more difficult (i.e. a small change in angle resulted in greater displacement of pixels). This led us to look at the relationship between performance and the position where the subject touched the document. In the Mixed-Focus and Touch-Centric conditions, the distance between the center of the document and the touch point was correlated with the task time and error. Therefore, a title bar that runs along the full length of the document may not be the optimal design. Rather, a design that encourages the user to touch near the center of the document when repositioning it could be a better alternative. This specific example provides weight to the argument that the design of many desktop GUI components should be scrutinized before they are brought to tabletop interfaces.

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