

A Comparison of User Interfaces for Panning on a Touch-Controlled Display

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ABSTRACT

An experiment was conducted to determine which of several candidate user interfaces for panning is most usable and intuitive: panning by pushing the background, panning by pushing the view/window, and panning by touching the side of the display screen. Twelve subjects participated in the experiment, which consisted of three parts: 1) subjects were asked to suggest panning user interfaces that seemed natural to them, 2) subjects each used three different panning user interfaces to perform a structured panning task, with experimenters recording their performance, and 3) subjects were asked which of the three panning methods they preferred. One panning method, panning by pushing the background, emerged as superior in performance and user preference, and slightly better in intuitiveness than panning by touching the side of the screen. Panning by pushing the view/window fared poorly relative to the others on all measures.

KEYWORDS

Touch display, touchscreen, panning, scrolling, navigation.

INTRODUCTION

Often, computer-based displays provide views of a scene or information that is too expansive (wide or tall) to be shown in its entirety. A common solution is to provide a panning or scrolling function, allowing users to control which portion of the subject is visible in the display. If such a function is provided, a user interface -- a way for users to invoke and control panning -- must also be provided.

Panning user interfaces for touch-displays have not been studied much, if at all. Some work has been done on scrolling techniques for more conventional input devices. Informal (and unpublished) investigations at Xerox in the late Seventies focused on whether scrollbars in the Star user interface should treat the document as moving under the window, or the window as moving over the document. Star's designers chose the former [14], but the marketplace for mouse-controlled graphical user interfaces eventually

settled on the latter. Bury *et al.* [3] compared scrolling user interfaces for keyboard-controlled character-display terminals and found that subjects performed best when keys indicated the direction of movement of the *viewing area* (e.g., the "up" key moved it upward in the document and hence the document content downward). Beard *et al.* [1] and Glassner [5] described panning and scrolling user interfaces for specific task-domains. Beck and Elkerton [2] compared user interfaces for traversing long lists. MacLean *et al.* used panning user interfaces as an example in their analysis of how to compare alternative user-interface designs rationally [8]. However, all of this work has focused on user interfaces controlled through keyboards and indirect pointing devices such as mice, not touch-displays.

Though empirical studies of touch-display interfaces have been performed [10, 11, 12], these have not included studies of panning and scrolling. Several ways of using touch-displays have been proposed [13] but panning through a flat information space is not among them. Recently, a product that incorporates a user interface for controlling panning has appeared in the marketplace [15], but nothing describing how that design was validated has been published.

The goal of the current study was to determine the best -- meaning most easily used -- user interface for panning and scrolling in a simulated physical world displayed on a touch-controlled display.

Initial experience at FirstPerson (a Sun subsidiary) with a prototype information-space controlled by a touch-display raised in a new form the old issue of whether the scene should be treated as moving under the view-window or the window as moving over the scene. The prototype had been designed such that swiping one's finger across the display caused the scene to shift. The issue was: What should the relationship be between the direction of the swipe and how the scene shifts? Is the user's finger swipe best regarded as pushing the scene background or pushing the "camera" that is viewing the scene? With a Push Background user interface, users swipe in the direction they want the scene to go. This seems completely natural until one considers previous findings on scrollbars and scrolling keys, as well as the fact that to bring information onto the screen that is off-screen left, users would swipe towards the right. With a Push Camera user interface, users swipe in the direction of the off-screen information. This, too, seems natural until one

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considers that the physical display doesn't actually move, so it is the scene that shifts -- in the opposite direction as the swipe. Of course, both interfaces can't be "natural," since they have opposite effects.

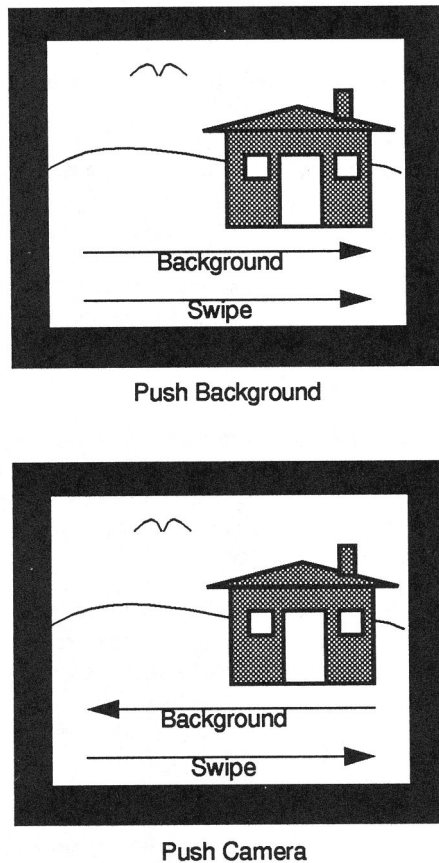


Figure 1. Two contrasting panning methods.

The correct interface depends on how users think about it: do they view themselves as shifting the background or panning the camera? Therefore, the right way to resolve the issue is via user testing. The designers of the initial prototype chose the Push Camera approach, based on an informal paper-and-pencil test they conducted using a few co-workers as subjects. However, experience with the prototype suggested that a significant number of users considered its panning user interface to work "backwards" from what they expected.

In an attempt to resolve this issue, a more formal study was devised, using subjects from outside the company who had no experience with the existing prototype and so were not already familiar with its user interface for panning. The idea of the study was that subjects would first be asked -- before they had tried or seen any panning user interface -- to describe one that would seem natural to them. Subjects would then perform a panning accuracy test with different panning user interfaces. Finally, they would be asked to say which panning user interface they preferred of those they had tried.

As the study was being designed, it was decided that panning user-interfaces other than Push Background and

Push Camera should be considered. One plausible alternative to panning by swiping a finger is panning by touching the sides of the touch-display. In fact, this user-interface for panning was already used in the prototype in certain situations. When a user is dragging an object to a new location that is off-screen, it is impractical to have to drop it, pan the scene, pick the object up, and resume dragging. Therefore, in the prototype, when a user drags an object to a side of the display and holds it there, the "camera" pans towards that side. It is reasonable to consider having panning work that way *all* the time rather than only when the user is dragging something. This interface is best regarded as Touch Edge Camera because the user feels as if hitting an edge of the display pushes the "camera" or "viewing window" in that direction. This interface was added to the set to be compared.

Another possible panning user interface is the opposite of Touch Edge Camera: users press on the side of the display they want the background to move towards. However, because this interface -- referred to herein as Touch Edge Background -- is in the author's experience very counter-intuitive and also seems incompatible with the goal of having panning work well with dragging, it was not included in the comparison.

Regarding the first part of the study, when subjects would be asked to suggest a panning method, it is clear that the appearance of the touch-display can influence what people suggest. This is what Gibson [4] and, later, Norman [9] refer to as an "affordance": when an aspect of an artifact's design suggests how it is to be used. We thought that adding a brightly colored border around the displayed image might suggest "touch here" to users, and might therefore suggest Touch Edge panning (camera or background). We therefore designed the study so that in the initial (elicitation) phase of the study, half of the subjects would see such a border, and half would see the "normal" display (with the displayed scene taking up the entire screen).

METHOD

Subjects

The subjects were six males and six females, ranging in age from 18 to 65 years old. The distribution of subject ages was similar across gender. Subjects were recruited by company employees, and were paid \$15 for the one-hour test session. The subjects' occupations include student, homemaker, retiree, clerical, salesperson, and business planner. None are computer engineers, but some do use computers.

Design

The experiment consisted of three tests: Panning Elicitation, Panning Accuracy, and Panning Preference. Since gender differences have occasionally been observed in studies involving hand-eye coordination [7], all three tests were designed to allow gender effects to be distinguished from individual differences.

Panning Elicitation Test

The six subjects of each gender were randomly assigned to one of two display types -- plain or bordered -- in such a

way that three subjects of each gender had each display type. The dependent measure was the type of panning user interface the subject suggested (see Procedure and Materials), i.e., a categorical variable. However, as is described in the Analysis and Results section, the response categories were not predetermined, but rather emerged as the study was conducted.

Panning Accuracy Test

Because high intersubject variability was expected in the panning accuracy task, a within-subject design was used for that part of the experiment. Each subject was tested with all three panning user interfaces (Push Background, Push Camera, and Touch Edge Camera), with the order of presentation of the interfaces counterbalanced across subjects both within gender and overall. For each panning user interface, there were twenty-three trials (see Procedure). The following dependent measures were taken on each trial: time, number of moves, and whether the subject started by shifting the scene in the wrong direction (direction errors). Thus, the design of the panning accuracy test was a three (panning user interface) by two (gender) design, with panning user interface varied within subject.

Panning Preference Test

The panning preference test was a very simple design: Ask all 12 subjects (six of each gender) which panning user interface they preferred of the three they had tried, to determine whether any interface is systematically favored or disfavored.

Procedure and Materials

The display was a small (15 cm diagonal) color liquid-crystal screen mounted in a flat case. The case added about 2 cm of border to each edge of the display. A transparent touch-pad was affixed to the front of the display. The display housing was mounted on a pedestal, which held the display about four inches above the surface of a desk (see Figure 2). The display and touch-pad were connected to a Sun™ Sparcstation™ 2 workstation.

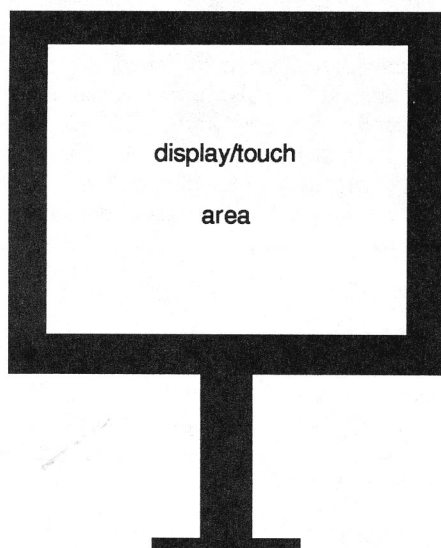


Figure 2. Touch-display apparatus.

Subjects participated in the study individually. A video camera was focused on the display for the entire session, recording what happened on the display as well as the subject's hand when near or on it. Each session was conducted by an experimenter and an assistant (to operate the camera and a timer).

Subjects were told at the start of the session that we (the experimenters) "are testing various design ideas for our product, to make the product easy to use." The experimenter explained that some aspects of the prototype might be hard to use, but if so, that indicated a bad design rather than anything wrong with the subject. Subjects were seated in front of a prototype touch-sensitive display, and their attention was directed to it. The session consisted of three phases: Panning Elicitation, Panning Accuracy, and Panning Preference.

Panning Elicitation

A cartoon scene of a living room was visible on the display. For half of the subjects, the living room display occupied the full area of the display; for the other half, the display had a quarter-inch, bright blue border that decreased the area available for the living room scene.

Subjects were shown that the living room scene was wider than the display (by panning the scene remotely via keyboard commands to the right and then back to the initial position). In other words, they were shown the panning function without being shown a panning user interface. They were then asked to show and tell how they would expect to operate the touch-display to "bring that other part of the scene back into view." Words such as "pan" that might suggest a particular mental model or user interface were intentionally not used in the instructions. Subjects' responses were categorized (see Analysis and Results).

Panning Accuracy

In this phase of the study, the experimenter placed a sticker on the display's bottom bezel that marked three horizontal positions: "A", "B", and "C". Then the experimenter started a program that changed the displayed image from the living room scene to a set of evenly spaced vertical lines, each labeled by a number (0 - 10 from left to right) at its top end (see Figure 3). The experimenter directed the subject's attention to the numbered lines and said that in this part of the test, he would ask the subject to shift the scene so that certain numbered lines were over specified letters. The experimenter explained that the subject would be timed while shifting the scene to the target letter. The experimenter continued: "We'll do that several times, then I'll change the way the scene is shifted and ask you to shift it some more, then we'll change it again and I'll ask you to shift it some more." The subject was reminded that we were testing our designs, not the subject.

The experimenter then demonstrated to the subject how to operate the first of the three panning user interfaces. Subjects were not allowed to practice panning before starting the timed trials. Subjects were instructed to move the line given on each trial to the indicated letter position, and once the line was positioned to his or her satisfaction, to

say "OK" so that the assistant would know when to stop the timer. The next trial began after a brief pause, with the scene positioned where it had been left by the previous trial. Twenty three panning trials followed (i.e., all lines moved to all reachable targets) in which the experimenter stated the line number and target letter, the assistant timed the trial, and the experimenter recorded the time on a data sheet. All trials were videotaped to allow rechecking of the times and collection of other data.

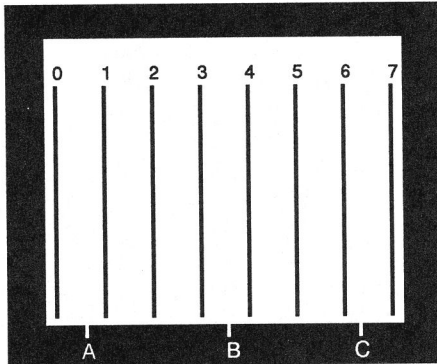


Figure 3. Panning accuracy test display.

After the first set of panning accuracy trials, the experimenter changed the panning method, demonstrated the new panning method, and commenced a second set of trials with a different panning user interface. These were followed by a set of trials with a third panning user interface.

Panning Preference

After completing all three sets of panning accuracy trials, subjects were asked "Which of the three shifting methods do you like best?" Their answers were recorded, both on the data sheet and on videotape.

ANALYSIS AND RESULTS

Panning Elicitation

When subjects were asked to indicate how they would operate the touch-display to bring into view the part of the living room scene that was off-screen-right, they gave a variety of responses. Note that at this point, subjects had not yet seen any actual panning method for the prototype display (though some had used scrolling mechanisms on computers). All they had seen was that the living room scene was wider than could be seen in the display at once, and that the off-screen portion was the right side of the scene. Thus, their responses may be considered to be based upon their prior experience and whatever the prototype display suggested to them.

Subject responses were grouped into five categories, corresponding to the four panning methods under consideration plus an Other category. The panning categories were:

- Push Background: finger motion on screen, shifting the background.

- Push Camera: finger motion on screen, panning the viewer/camera.
- Touch Edge Camera: press edge of screen that camera is to pan towards.
- Touch Edge Background: press edge of screen that background is to shift towards.
- Other: anything else, e.g., scrollbar, physical scrolling buttons on the case.

Six (i.e., half) of the twelve subjects indicated by their actions and words that Push Background was the panning method they first thought of when faced with the prototype touch-display. Three subjects suggested Touch Edge Camera. The remaining three subjects suggested methods that were classified as Other. A statistical test of the skewedness of the observed distribution requires a null hypothesis specifying what distribution would be expected by chance. Because a null hypothesis of equal category probabilities seems naive and no other chance distribution seems any more plausible, a statistical test wasn't feasible. Nonetheless, it is notable (if not "significant" in the formal sense) that half of the subjects suggested Push Background, and that no subject suggested Push Camera or Touch Edge Background (see Figure 4).

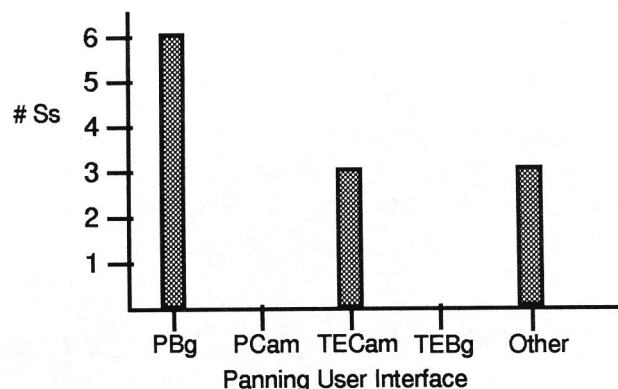


Figure 4. Panning elicitation results.

The foregoing analysis treated all 12 subjects as one group. However, the scene shown to half of the subjects had a bright blue border, which might suggest a Touch Edge panning user interface. Also, orthogonally to this grouping, half the subjects were of each gender. Neither the presence/absence of a blue border nor gender appeared related to subjects' suggested panning user interfaces.

Panning Accuracy

Each subject's time scores were averaged over each trial block, yielding, for that subject, an average time for each of the three panning user interfaces. Similarly, each subject's moves scores were averaged for each of the panning user interfaces. Direction errors were summed for each panning user interface. Tables 1, 2, and 3 show each subject's aggregated data for the time, moves, and error measures, respectively. Note that though treatment means are included in the tables for informal comparison purposes, the table

columns are not independent: all three scores in each table-row are from the same subject.

For each dependent measure, a Friedman ranks test for matched scores [6] was used to test for an effect of panning user interface type.¹ To perform this test, each subject's three scores on a given measure were ranked, then the rank scores were submitted to a formula that yields a chi-squared statistic indicating whether any interface had more low or high ranked scores than would be expected by chance.

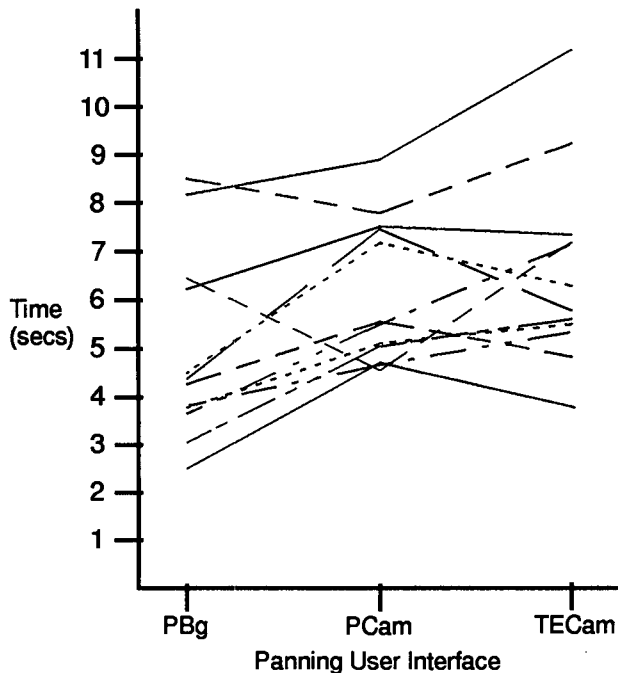


Figure 5. Panning accuracy: time data.

Subject	Age	Gender	PBg	PCam	TECam
1	21	M	3.06	5.03	5.66
3	43	"	6.48	4.66	7.18
7	29	"	4.58	7.16	6.33
8	26	"	6.29	7.48	7.35
9	65	"	8.14	8.90	11.22
12	45	"	4.44	7.45	5.83
2	23	F	4.27	5.69	4.91
4	65	"	8.57	7.88	9.20
5	18	"	3.88	4.07	4.57
6	39	"	3.71	5.49	7.08
10	50	"	3.81	4.65	5.29
11	19	"	2.53	4.79	3.88
Mean			4.98	6.10	6.54

Table 1. Panning accuracy: time data (avg. over trials).

1. The Friedman test was used in preference to a within-subject ANOVA because of controversy regarding the degrees of freedom for within-subject ANOVAs.

For all three measures, a significant effect of interface type was observed (time: $\chi^2(2) = 13.17$, $p < .01$; moves: $\chi^2 = 12.17$, $p < .01$; errors: $\chi^2 = 15.79$, $p < .01$; see Figures 5-7). With the Push Background panning user interface, subjects took less time, required fewer moves, and made fewer direction errors than with the other two panning user interfaces. The effect was particularly strong for the direction-errors measure: when using the Push Background, subjects made almost no direction errors, in sharp contrast to the other two panning user interfaces (see Figure 7). A *post-hoc* t-test of difference scores between the Push Camera and Touch Edge Camera interfaces showed no significant difference between those two interfaces for any of the dependent measures.

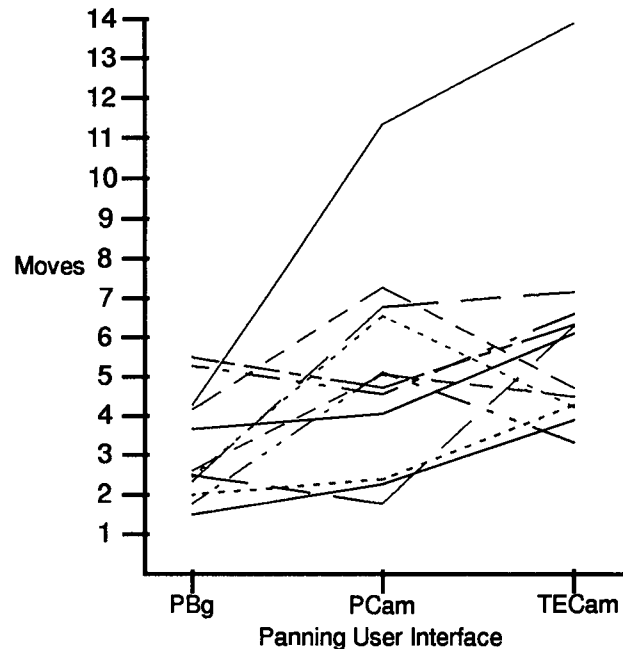


Figure 6. Panning accuracy: moves data.

Subject	Age	Gender	PBg	PCam	TECam
1	21	M	1.48	2.26	3.96
3	43	"	2.57	1.74	6.26
7	29	"	2.39	6.87	7.13
8	26	"	4.26	11.35	13.96
9	65	"	5.57	4.70	6.30
12	45	"	2.43	6.61	4.22
2	23	F	4.13	7.30	4.70
4	65	"	5.22	4.61	6.65
5	18	"	3.74	4.04	6.13
6	39	"	2.57	5.09	4.57
10	50	"	2.09	2.39	4.30
11	19	"	1.87	5.09	3.30
Mean			3.19	5.17	5.95

Table 2. Panning accuracy: moves data (avg. over trials).

No gender differences appeared on any measure, either for overall performance or effect of panning user interface type.

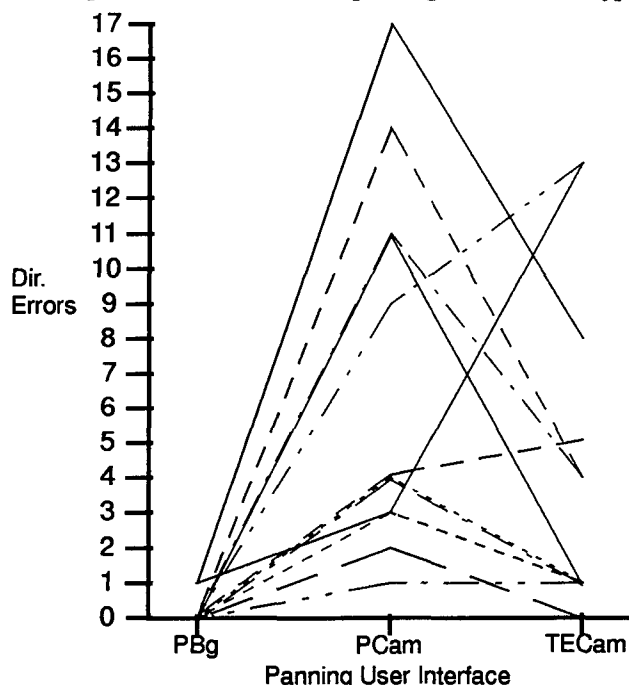


Figure 7. Panning accuracy: error data.

Subject	Age	Gender	PBg	PCam	TECam
1	21	M	0	4	5
3	43	"	0	3	1
7	29	"	0	11	1
8	26	"	1	17	8
9	65	"	0	4	1
12	45	"	0	2	0
2	23	F	0	11	4
4	65	"	0	1	1
5	18	"	0	4	1
6	39	"	1	3	13
10	50	"	0	9	13
11	19	"	0	14	4
Mean			1.67	6.92	4.33

Table 3. Panning accuracy: error data (sum over trials).

One possibility worth checking is that the three panning user interfaces might differ in how performance improves with practice. For example, performance with one user interface might start out worse than with others, but improve faster. Learning effects were examined by comparing, for each subject, performance in the first half of the trials with that in the second half. Since each user-interface-block of trials consisted of an odd number (23) of trials, the "first half" was defined as trials 1-11, and the "second half" was defined as trials 13-23. Trial 12 was ignored.

Overall, there was clear evidence of learning over the trial blocks. Superimposing the trial blocks for the three panning user interfaces, performance in the second half of the trials in a block almost always exceeded that in the first half. Simple sign tests were significant for all three performance measures: time ($p < .01$), number of moves ($p < .05$), and direction errors ($p < .01$).

Since the distance from the starting position to the target position differed from trial to trial, a performance difference between the first and last half-blocks could result from a difference in the distance panned in the two half-blocks. In this case, that explanation can be ruled out, because the distance subjects had to pan in the two half-blocks was almost equal (averaging 102.4 pixels/trial for trials 1-11 vs. 103.2 pixels/trial for trials 13-23) and was greater in the second half-block anyway.

To determine whether the learning rate depended on the panning user interface, subject's difference scores (first half-block minus second half-block) were submitted to a Friedman ranks test. For all three performance measures (time, moves, and direction errors), the test showed no significant difference in learning between the three interfaces.¹

Another possibility worth checking is whether panning time and number of moves depends on the distance panned, and whether the dependency is affected by the panning user interface. It might be, for example, that panning time is directly proportional to distance for one panning user interface but not for another. For each subject, regressions were computed for panning distance vs. time and distance vs. moves for each of the three panning user interfaces.

Overall, both time and number of moves were positively related to the panning distance. This was determined by a simple sign test on the regression scores: many more of them were positive than would be expected by chance ($p < .01$). On the other hand, Friedman ranks tests applied to the regression scores showed no effect of panning interface type on the strength of the relationship between distance and either time or number of moves.

Panning Preference

Two of the twelve subjects, one male and one female, were accidentally not asked which of the panning user interfaces they preferred of those they had tried. Of the ten remaining subjects, eight preferred Push Background panning, two preferred Touch Edge Camera panning, and none preferred Push Camera panning. A multinomial calculation showed that this distribution is significantly skewed ($p < .01$).

The subjects who preferred Touch Edge Camera panning were subjects 4 and 8. Since neither of these subjects (in fact, no subjects at all; see Tables 1-3) performed better using Touch Edge Camera than with Push Background,

1. A learning-based decrease in direction errors was not possible with the Push Background user interface, because direction errors were almost nonexistent.

performance cannot be an explanation for their divergent preference.

Of the ten subjects who were asked to state a preference, five were male and five were female. The distribution of preference scores was exactly the same for males as for females: four out of five preferred Push Background, one out of five preferred Touch Edge Camera. Thus, no gender difference in preference was observed.

DISCUSSION AND CONCLUSIONS

Although the methodology used in the Panning Elicitation test was less formal than that used in the rest of the study, it seems safe to say that Push Background is the most common way people expect to pan a touch display given that they know nothing else about it. Even putting a visible border around the image did not seem to raise the likelihood that subjects would suggest Touch Edge panning instead of Push Background panning.

A possible follow-up to the Panning Elicitation test would be to show subjects a panning scene (without showing them a panning *user interface*, as in the present study) and then ask them: "How do you prefer to think of what just happened: Did the room shift to the left or did the camera view shift to the right?" In other words, subjects would be given a forced choice between two ways of thinking of panning instead of an open-ended question.

Push Background panning was the clear winner of the accuracy test: it resulted in faster times, fewer corrective movements, and fewer initial direction-errors than the other two panning methods tested. This seems to contradict the findings of Bury *et al.* [3] for scrolling keys and the eventual "decision" of the marketplace for scrollbars. Are touch-displays so different from mouse- and keyboard-controlled displays that opposite results make sense? It seems more likely that the important distinction is *not* whether panning/scrolling is controlled *via* keyboard, mouse, or touch. For example, in a touch-controlled system that provided scrollbars or on-screen scrolling "buttons," moving the view might well be more intuitive than moving the background, congruent with the findings of Bury *et al.* In the FirstPerson prototype, there was no separate scrolling control; subjects panned by swiping directly over the displayed scene. Perhaps scrollbars or scrolling keys "afford" camera/view panning (even in touch-displays), while on-scene panning "affords" background panning. Following up on this speculation would be a useful direction for future research.

Even when panning works by swiping directly on the scene (i.e., there is no separate panning/scrolling controller), the intuitiveness and efficiency of the panning user interface presumably depends on other aspects of the application's design, e.g., its user interface for moving displayed objects. Thus, the optimality of Push Background panning may also depend on other elements of the application's gesture-set. This is another possible topic for future study.

Finally, Push Background was the preferred panning method for most subjects. Though subjects' preference must be influenced by their experience in the Panning Accuracy test,

the fact that two of ten voiced preferences that disagreed with their performance shows that preference for Push Background panning is not based purely on performance.

One advantage of Touch Edge panning (despite poorer performance) is that it requires less hand motion than Push panning does: users can just leave their hands poised above the edges of the screen. It is also possible that Touch Edge Camera wouldn't do so badly against Push Background if the task were grosser, e.g., just moving something offscreen on, or just moving something to the left half of the screen. Touch Edge (Camera or Background) may just be a difficult user interface for panning to an exact position. A less exact panning task is thus a good candidate for a follow-up study.

Touch Edge Background (i.e., touch the side that you want the background to move towards) was not included in this study because informal experience with scrollbars suggested (at least to the author) that it is counter-intuitive. However, the number of direction errors made with Touch Edge Camera and some subjects' comments that it is "backwards" suggest that not everyone would find Touch Edge Background to be a counter-intuitive panning method.

Overall, Push Background seems to be the best of the three panning user interfaces examined in this study. Based on these results, subsequent prototypes developed at FirstPerson used Push Background panning.

This study has shown that it is possible to design an intuitive, highly usable panning user interface for a touch-controlled display without using scrollbars or scrolling keys. Furthermore, the study's results suggests that for such touch-displays, Push Background panning is the right user interface to use unless a strong case can be made for an alternative.

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