Literature Review of Touch-Screen Research from 1980 to 1992

Technical Report · January 1993

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MeasuringU

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Technical Report

IBM

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August 20, 1993

Technical Report 54.694

Unclassified

Boca Raton, Florida

Unclassified

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Abstract

As the cost of the technology falls, touch screens are becoming more common. The purpose of this report is to document the human factors research in touch screens from 1980 to 1992. It covers the topics of touch-selection strategies, button size, touch-screen keyboards, touch-feedback strategies, mouse-emulation strategies, touch biases and screen angles. The literature review provides the basis for making recommendations to touch screen designers.

Introduction

There is a substantial body of research in the open literature on the usability of touch screens. This report is a review of the research about the design of touch screens for users from 1980 to the present (1992). It includes information about different touch-selection strategies, appropriate button sizes as a function of the touch-selection strategy, touch-screen keyboards, touch-feedback strategies, touch biases, and screen angles.

Research about the design of touch screens for users

Touch-Selection Strategies

There are a variety of ways in which a touch-screen system can interpret user input to initiate a function. The most common strategies are:

Land-on: If a selectable item is under the initial touch, it is selected upon impact with the touch surface; otherwise, nothing is selected. (This strategy is the only one available to some types of touch technologies, such as piezo-electric, which does not provide continuous touch data.)

First contact: The system enters the first selectable field that the user touches when the user's finger contacts the field.

Last contact: The system enters the last selectable field that the user has touched when the user's finger leaves the touch screen, regardless of any other selectable fields the user may have touched before breaking contact with the touch screen. (Some researchers have called this *lift-off*.)

The first-contact strategy is usually faster, but unless the display has only a few, relatively large targets, it is more error-prone than the last-contact strategy (Potter, Berman, and Shneiderman, 1989; Potter, Weldon, and Shneiderman, 1988). The last-contact strategy is a little slower, but allows the user to be acceptably accurate with very small targets (Sears and Shneiderman, 1989). The land-on strategy is the most error-prone and least-preferred (Potter, Berman, and Shneiderman, 1989; Potter, Weldon, and Shneiderman, 1988).

Button Size

For near-perfect accuracy (99% with land-on strategy), buttons should be 26 mm per side (Hall, Cunningham, Roache, and Cox, 1988; Sears, 1991).

After correcting for touch bias by shifting touchable regions slightly lower and to the left of the displayed key (on a fixed-angle display at 30 degrees), buttons 22.7 mm per side had near-perfect accuracy (99% with first-contact strategy) (Sears, 1991).

For accurate first-contact touching, targets should be at least 20 mm on a side (Beringer, 1990).

For accurate last-contact touching, targets may be as small as 1.7 mm x 2.2 mm (Sears and Shneiderman, 1989).

Note: None of the researchers who have published information on touch-screen button size studied users wearing gloves. In some application environments, such as automated teller machines located outside in winter conditions, button sizes and inter-button spacing must be large enough to allow users wearing gloves to operate the equipment.

Touch-Screen Keyboards

Touch-screen keyboards are not as fast as a standard keyboard, but are a viable alternative for limited text entry -- 25 words-per-minute (wpm) with 22.7-mm square keys (Sears, 1991) and 20 wpm on a keyboard (using a conventional QWERTY layout) that is only 70 mm wide (Sears, Revis, Swatski, Crittenden, and Shneiderman, 1991).

Lewis, Kennedy, and LaLomia (1992) investigated alternative typing layouts for typing with one finger or a stylus -- a situation that can occur with touch screens (especially small touch screens). They showed that a roughly square (5 x 5) alphabetic layout would be better than a conventional QWERTY layout because it reduces the average inter-key distance. For situations in which maximum typing productivity is an important application attribute, they used an analysis of English-language digraphs to devise a typing-key layout that (after practice) optimizes one-fingered typing productivity.

Touch-Feedback Strategies

The system can feed back the touch position with a selection pointer (for mouse emulation) or by highlighting (for example, reverse video) the object that the user has selected (Mack and Montaniz, 1991; Mann, 1990; Montaniz and Mack, 1991).

For small targets and a last-contact strategy, either (1) the touch-sensitive area should extend below the target so the user's finger does not obscure the visual feedback when he or she has selected the target, or (2) the system should display a pointer slightly above the contact point so the user can tell which target the pointer is on (Potter, Weldon, and Shneiderman, 1988).

Mouse-Emulation Strategies

Montaniz and Mack (1991) tried two ways of emulating standard mouse actions (click, double-click, and drag) with a touch screen for tasks with Microsoft Windows[1]. The 1-2-3 method used a touch area in the lower part of the screen to control a touch mode. Users changed the touch mode by touching and releasing the 1-2-3 icon. In Mode 1, the system interpreted a touch as a single click; in Mode 2 it interpreted a touch as a double-click;

[1] Microsoft and Windows are trademarks or registered trademarks of the Microsoft Corporation.

and in Mode 3 a touch started a drag operation. The second method was the "Pause Touch Control Method" (Pause). To perform a single-click, the user would touch the object for 50 ms (make event), then hold the object for an additional 150 ms, at which point the object changed state to indicate selection, and the user could remove his or her finger. To double-click (open or close), the user would touch the object for 50 ms (make event), then release the object before an additional 150 ms. To drag, the user would touch the object for 50 ms (make event). After an additional 150 ms, the object would change state to indicate selection. Then the user could drag the object, which would remain at its new location after the user removed his or her finger from the screen. Consistent with other research on interfaces that require a user to select modes (like the 1-2-3 method), Montaniz and Mack (1991, p. 293) concluded, "it is easier to control touch states with the pause method than the 1-2-3 method."

Touch Biases and Screen Angles

When displays are mounted at a fixed-angle, users tend to hit below and to the left of the center of the target (Sears, 1991).

Providing the user an orthogonal line of sight to the display surface virtually eliminates bias (Beringer and Bowman, 1989).

For fixed-angle touch screens, 30 degrees from horizontal plane is probably optimal for reducing arm fatigue (Ahlstrom and Lenman, 1990). However, this angle can result in glare problems, depending on the ambient light conditions (Pfauth and Priest, 1981). Sears (1991) found no significant difference in perceived fatigue between 30- and 45-degree angles from the horizontal, but did find that users rated a 75-degree angle as more fatiguing.

Recommendations

Designers should use the last-contact touch strategy. It allows more flexibility in usable target sizes than the first-contact strategy.

Use button sizes that are appropriate for the touch strategy. For a first-contact strategy, buttons should be at least 20 mm on a side. For a last-contact strategy, buttons may be as small as 1.7 mm x 2.2 mm.

Touch-screen keyboards may be as small as 70 mm wide, depending on the touch strategy. If users do not require a layout that maximizes typing speed, then the default typing screen should use a roughly square (5 x 5) alphabetic key layout. If the user will benefit from a layout that maximizes typing speed, then the default typing screen should use a roughly square layout based on English-language digraph analysis. Because so many users are familiar with the QWERTY layout, it should always be available as an alternative layout.

The system should clearly inform the user about the current touch position, either through target highlighting or with a selection pointer. Be sure the user's finger does not obscure the system feedback about the current touch position.

For mouse emulation, use the Pause strategy.

Touch display angles should be adjustable. If fixed, 30 degrees from the horizontal plane is probably optimal, although a 45-degree angle is acceptable. For fixed-angle displays, the setup instructions should tell the user to place the display to minimize glare from ambient lighting.

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