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Towards Error Recovery Microstrategies in a Touch Screen Environment

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Abstract

Touch screens have seen widespread adoption in the last decade due to the rise of smartphones, tablets, and touch screen laptops. While interface designs for this new interaction paradigm have improved, errors cannot be eliminated. Using an unmodified tablet and an infrared eye tracker, this paper identifies microstrategies that occur naturally during error recovery and evaluates their occurrences in low, medium, and high error environments. Cognitive modelers interested in touch screen interactions can use this information to better simulate real human performance.

Keywords: microstrategies; strategies; error; touch;

Introduction and Related Work

Current Computer Science research in touch screen errors can be broadly categorized into two areas: guideline solutions and auxiliary solutions. Guideline solutions focus on using a design that minimizes the occurrence of errors (Ng, Brewster, & Williamson, 2014) while auxiliary solutions compensate for an error after it occurs (Rudchenko, Paek, & Badger, 2011). Psychologists have used fMRIs to see what parts of the brain are involved in error recovery (Garavan, Ross, Murphy, Roche, & Stein, 2002), but to our knowledge, there is no research on the behavioral steps a person takes to recover from common errors.

Microstrategies are the low-level processes that describe the interactive behavior between the design of the available artifacts, and the cognitive, perceptual and motor processors (Gray & Boehm-Davis, 2000). When multiple strategies can be employed, the space of microstrategies can be explored to find the best explanation of human performance (Zhang & Hornof, 2014). This paper enumerates microstrategies observed during error recovery.

Microstrategies are well suited to be modeled in CPM-GOMS, because it has a straight forward notation that allows the model to be implemented more easily than it would be in a cognitive architecture like ACT-R, EPIC, or SOAR. We used a performance calculator called Cogulator (Corporation, 2014) for preliminary modeling. Like SANLab-CM (Patton & Gray, 2010) or Apex (John, Vera, Matessa, Freed, & Remington, 2002), Cogulator creates CPM-GOMS models to estimate performance.

Two new technology trends have converged in the past few years: mobile touch devices in wide use, and eye tracking technology becoming smaller and inexpensive. Modeling researchers have recently begun to explore this intersection, building and validating models of users as they carry out tasks on mobile devices. We set forth an experimental apparatus that can identify areas of interest within one degree of visual angle during bi-manual touch interactions on an unmodified tablet and an infrared eye tracker.

Methodology

Task Ten men and three women between the ages of 16 and 34 were recruited by word of mouth or volunteered at an open house. No compensation was offered to participants. Three trials were thrown out (all male) because the eye tracker's calibration did not last through the entire experiment. All glasses or contacts were removed before beginning.

Participants were told that this experiment focused on how users perceive error on a touch screen device. When the program started, a start button appeared. Once pressed, they would see five red targets to select with touch input. When a target was successfully selected, it turned grey. When all targets were selected, the screen cleared itself. After each screen, participants were asked to guess the total error rate for that screen. When a screen had been successfully cleared, ten buttons appeared with decile percentages. Participants selected the button corresponding to what they felt was the closest value. The start button then reappeared, and the process repeated for a total of 21 screens.

In this task, there were two possible kinds of errors: real target selection errors, and introduced errors. During the experiment, the system manipulated the perceived error rate. For example, if the system introduced 10% error, 1 out of 10 successful touches was ignored, simulating a missed touch.

No participant made a real target selection error. This could be because we disclosed that we were studying errors in the instructions which made people more careful, or because targets were large and spread out. Thus, all errors discussed are artificially introduced.

Experimental Apparatus Our experimental apparatus consisted of the EyeTribe eye tracker attached to the bottom-front of the Surface Pro 2 tablet using the EyeTribes proprietary harness and connected with a short cord in the USB on the left side. Both devices were attached to an adjustable height tripod with a universal 10" tablet tripod mount. The neck of the tripod was adjusted to the participant's height as needed. Participants held their hands on the side of the tablet and used their thumbs and index-finger for interactions.

This experiment followed two pilot studies that reduced noise in the eye tracking data. Like all the other eye trackers in this price range, the EyeTribe eye tracker must be placed below the screen to avoid eye lash occlusion. Some webcam-based solutions also require the tablet to be flipped so that the camera is below the screen (Wood & Bulling, 2014). Our setup specifically minimized hand occlusion during interaction. Following the examples of related work (Holland & Komogortsev, 2012), the setup was fixed on a tripod.

Microstrategies

Event logs were graphed on a timeline and patterns were found first by manual review and later parsing the log files. We divided our task into three distinct stages. We found three reoccurring microstrategies in each stage as described below.

Stage 1. Searching for target

Visual-Search (VS) Consists of multiple fixations in a row with no touch input. This microstrategy is indicative of some cognitive decision making about what action to perform next. VS occurs in 50% of all screens, and the number of fixations in the search versus its occurrence decreases in a logarithmic pattern. It is not correlated with error rate.

No-Visual-Search (NVS) Defined as the absence of *VS*.

Peripheral-Focus (PF) Consists of a single, unmoving fixation in the center of the screen during multiple touch-events. Unlike the other microstrategies, this is likely a conscious strategy by the user to keep their eyes still and only use their peripheral vision. Seen in "twitch" gaming, the user is trying to minimize reaction time by eliminating eye movement. It was only used by one participant three times, all in low-error situations. The *PF* microstrategy in Stage 2 is a continuation of this one.

Stage 2. Shifting attention away from target

No-Visual-Feedback (NVF) Consists of fixation-start, fixation-end, touch event. Both successful and unsuccessful touches are grouped together in this strategy, because they are cognitively the same action. The user anticipates the completion of a touch action without waiting for visual feedback on its success. It is seen most in low-error environments, used approximately 20% of the time.

With-Visual-Feedback (WVF) Consists of fixation-start, successful-touch, fixation-end, or fixation-start, unsuccessful-touch, repeat-touch, etc. This microstrategy is by far the most common one identified in all error levels. It occurs in 96% of all screens.

Peripheral-Focus (PF) Shift of attention is entirely cognitive, and the eyes do not move. Can result in either *NVF* or *WVF*.

Stage 3. Choosing next action

Success-With-Feedback (SWF) Consists of fixation-start, successful-touch, fixation-end. In this case, there is no need for error recovery, and the user will either return to Stage 1 to choose the next target or the task will end.

Delayed-Error-Recovery (DER) Consists of unsuccessful-touch, fixation-end, ..., touch on different target. This microstrategy is defined by some indication that the user has noticed the error but has chosen to move on and come back to it later. It is seen most in high-error environments, used 34% of the time.

Immediate-Error-Recovery (IER) In this microstrategy, fixations can be in many places. Therefore, it is only defined by an unsuccessful-touch followed by another touch on the same target indicating that they saw the error and attempt to fix it immediately. This strategy is used twice as often as *IER*, and is most seen in high-error environments and accounts for 66% of all error recoveries.

Discussion

This experiment was exploratory to identify microstrategies that occur naturally. Future studies will be designed to isolate a microstrategy to define what conditions make it more likely to occur and its duration under those circumstances.

Microstrategies and full models of some trials have been implemented in Cogulator. If the length of each fixation is specified, performance time is overestimated by roughly 10% for low-error environments. Variation increases with error rate and will be explored more in the future.

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