An Evaluation of One-handed Techniques for Multiple-target Selection

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Abstract

Recent research has revealed that a large population of mobile users usually use one hand when interacting with mobile devices. However, very few techniques have been developed to support multiple-target selection. In this paper, we introduce *Burst* and *ZoomTap*, two techniques that aim to facilitate accurate and fast multiple-target acquisition with one-handed thumb operation on touch-based mobile devices. We compare our two techniques to *Shift* in a controlled experiment. The results show that for multiple-target selection, *Burst* and *ZoomTap* can outperform *Shift*; also according to the questionnaire, participants prefer *Burst* and *ZoomTap* to *Shift*.

Keywords

Mobile devices, touchscreens, input technique, multiple target selection, one-handed interaction

ACM Classification Keywords

H.5.2. [Information interfaces and presentation]: User Interfaces

Introduction

In recent years we have seen a new class of mobile devices, including the Apple iPhone, Blackberry Storm, and Google Android. These new devices rely on direct touching on the screen for primary interaction.

According to Karlson et al. [2], users prefer and more frequently engage in one-handed operation for most tasks on mobile touch-screens. With the rapid development of these new touch-screen displays, it is likely that users will increasingly rely on one-handed operation using their thumb. However, thumb operation has two problems: (1) screen accessibility, and (2) visual occlusion. According to Perry and Hourcade [4], targets on the edge and corner are difficult to reach and are physically uncomfortable to access. According to Vogel and Baudisch [6], such interactions suffer from the "fat-finger" problem, in which the user's fingers cover small targets, making them difficult to select. These two problems prevent users from performing fast and accurate selection.

Researchers have developed several techniques that address the two issues described above. Vogel and Baudisch [6] developed a technique called *Shift* that places an unoccluded callout showing a copy of the occluded area. The *Escape* technique developed by Yatani et al. [7] uses a disambiguating gesture to select a target with a unique beak-like cue. Roudaut et al. [5] proposed the *TapTap* technique that requires two taps. The first tap zooms in the touching area and the second tap selects the desired target. Although these techniques can offer good accuracy and resolve the occlusion problem to some degree, they are primarily developed for single target selection. It is unknown how those techniques perform in the task of selecting multiple targets.

We have designed *ZoomTap* and *Burst* to allow users to perform multiple-target selection using only their thumb with minimal screen accessibility and occlusion problems.

ZoomTap

ZoomTap is inspired by the *TapTap* technique developed by Roudaut et al [5]. It helps make selection easier by providing a zoomed view of the targets the user wishes to select.
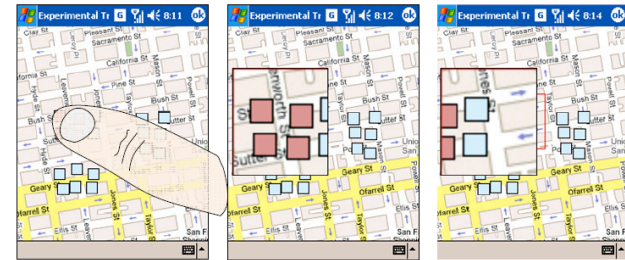

Figure 1. *ZoomTap* walkthrough: (1) User taps on the area to zoom in. (2) User taps targets in the zoom to toggle them. (3) User uses flicking gestures to change the focus of the zoom. The focus area is reflected by a red square on the background. (4) User closes the zoom area by taping outside it.

Similar to *TapTap*, *ZoomTap* prevents visual occlusion by providing a zoomed view. Unlike *TapTap*, the zoomed view will not close until the user taps outside of it. The user can select any number of targets in the zoomed view. Moreover, the user can change the focus of the zoomed view by using a gesture on the screen. The user can press their finger on the screen and slide it in one of four directions (up, down, left, and right). The program will pan the focus a fixed distance in that direction and update the zoomed view correspondingly.

Burst

Burst is inspired by *Shift* [6]*, Escape* [7], StartBurst [1] and Mizobuchi and Yasumura's [3] *Circling* technique. Figure 2 illustrates its operation.
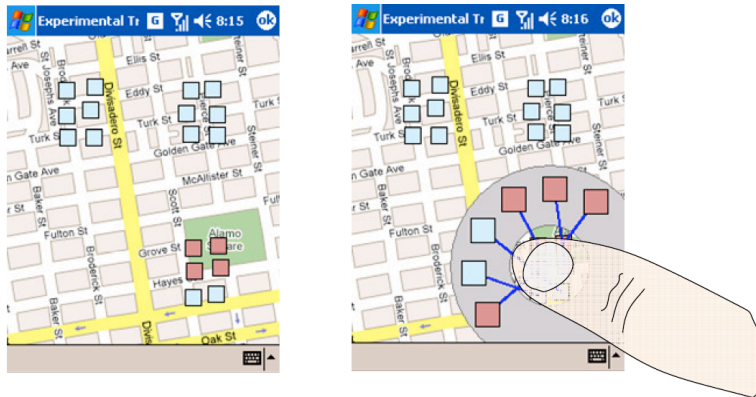
Figure 2. *Burst* places enlarged copies of the occluded targets in a ring around the user's finger.

The user presses their thumb on the screen to activate the technique. The program picks the six selectable targets that are closest to the touch point, creates enlarged proxy copies of them and arranges a ring around the user's finger. The targets are laid out to avoid edges and corners as much as possible. Blue lines connect the proxies and the actual targets. In order to select the targets, the user keeps their finger pressed on the screen and slides it over the targets to toggle them. The ring of proxies disappears when the user lifts off the finger.
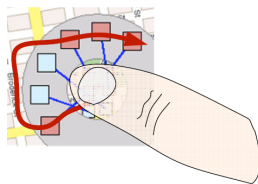

Figure 3. Keeping the finger pressed on the screen. A target is selected when the user slides their finger over it.

Similar to *Shift*, *Burst* solves the occlusion problem by displaying occluded targets in an offset location. Unlike *Shift, Burst* does not rely on a cursor to aim at a target and complete a selection.

Shift

Our version of Vogel and Baudisch's *Shift* technique [6] uses a callout circle 65 pixels in diameter. The callout is offset 65 pixels up from the cursor location. Using a finger to operate a touch screen results in random jitter in the reported touch location – we use a rolling average of the last five locations to smooth the values. With our smoothing algorithm users do not experience the random jitter when touching the screen surface.

Experiment

We conducted a controlled experiment to compare *ZoomTap* and *Burst* to *Shift* for one-handed multiple target selection. Direct tapping is still the primary technique used for multiple-target selection. Vogel and Baudisch's [6] studies show that *Shift* outperforms direct tapping for single target selection. Therefore, we chose *Shift* for our baseline comparison. Our experimentation focuses on the task of selecting multiple targets with only the thumb. In constrast to Vogel and Baudisch's [6] experiment, the user holds and operates the device with one hand. Based on the properties of our techniques introduced previously, we hypothesized the following:

1. *ZoomTap* and *Burst* would achieve a faster selection time than *Shift*
2. *ZoomTap* and *Burst* would have a lower error rate than *Shift*
3. Participants would prefer *ZoomTap* and *Burst* to *Shift*.

Subjects
We recruited eighteen volunteers ranging between 20 and 35 years of age. Seven participants are students from a local university, and eleven participants are professionals at a local company. None of them is a frequent mobile device user. All participants used their right hand. None of the participants reported having color-blindness and mobility issues with their thumb.

Apparatus
The experimental application was developed in C# using the .Net Compact Framework 3.5 and ran on a Dell Axim X30 with Windows Mobile 2003.

Independent variables
For this initial investigation we did not manipulate target size, grouping of targets and inter-target spacing. We restricted this primary investigation to only two independent variables:

- Selection technique: *Shift*, *ZoomTap* and *Burst*
- Location of targets: edge/corner, and center

Hence, our experiment resulted in a 3x2 within-subject factorial design with 3 techniques and 2 locations. All subjects performed each condition with 15 trials, yielding 90 trials for each subject. Participants were provided practice trials to the point that they felt sufficiently comfortable with the techniques and ready to start the experiment. With 18 participants, we collected a total of 18x90 or 1620 trials.

Task
To test our hypotheses, we developed a prototypical map-based program. The user must select the four red targets positioned on the map. In a real-life scenario these red targets could represent restaurants that a user wishes to select for comparison. We also placed two distracters around the four targets.

Experimental setup
The program displays three groups of six square targets (each target is 14x14 pixels). The groups of targets are randomly positioned in pre-defined starting locations. Six starting locations are located along the edges of the screen, while the other six are located in the center. The location independent variable determines which set will be used for the trial.

The program randomly chooses one of the target groups and colours four of the targets red in a tetromino configuration (tetromino is defined as a geometric shape composed of four squares, which are usually connected orthogonally). To complete a trial, participants must select all four red coloured targets. If a non-desired target is selected, the user must deselect it in order to complete a trial. The program provides feedback when the user has selected a target by bolding its edge and automatically starts the next trial after all desired targets are selected.

The trials are grouped together by technique, and the order of presentation is counterbalanced between participants in a Latin Square order. At the start of each group of techniques, the program displays a brief instruction screen and provides the user three training trials. Each subject was given a short introduction and demonstration of the three different techniques. An instruction sheet provided to the subjects acted as a reference for using the techniques. We instructed each subject to hold the device with one hand and operate it with the thumb of the same hand.

Measures

We collected the trial completion times and the error rates. Trial completion time was computed from the time the user touched the *Begin* button to the user selected all four targets. Errors were recorded if the user accidentally selected a distracter or if the user lifted their finger without selecting anything. For example, in ZoomTap, after the user activates the zoom view, presses their finger inside the view and lifts it, but does not select a target, this will be considered as an error. Upon completing the experiment, we asked each participant to fill out a simple questionnaire. The participants ranked the three techniques according to *preference*, *speed*, *simplicity*, *pleasantness*, *accuracy*, and *ease of learning*.

Results and Discussion

We present the results for Completion Time and Error Rates separately. We used the univariate ANOVA and Tamhane post-hoc pair-wise tests (unequal variances) for all our analyses with subjects as random factors. Figure 4 shows the average completion time and error rate for each technique and location.

Completion Time

There was a significant effect of *technique* ($F_{2,34}$ = 35.426, p<0.001) and *location* ($F_{1,17}$ =22.639, p<0.001) on completion time. We also found a significant interaction between these two factors ($F_{2,34}$ =17.021, p<0.001). Post-hoc pair wise comparisons reveal significant differences between all three techniques, with users performing on average the fastest with ZoomTap (4235 ms, 144.6 s.e.), then Burst (5248 ms, 144.6 s.e.) and slowest with Shift (9546 ms, 144.6 s.e.).

Error Rate

There was a significant effect of *technique* ($F_{2,34}$ = 63.065, p<0.001) but not of *location* ($F_{1,17}$ =4.28, p=0.054) on error rate. We found a significant interaction between these two factors ($F_{2,34}$ =4.430, p<0.05). Post-hoc pair wise comparisons reveal significant differences between all three techniques, with users performing on average the fewest errors with Burst (7%, 1.8 s.e.), then with ZoomTap (41.9%, 1.8 s.e.) and finally were more error prone with Shift (55.9%, 1.8 s.e.).
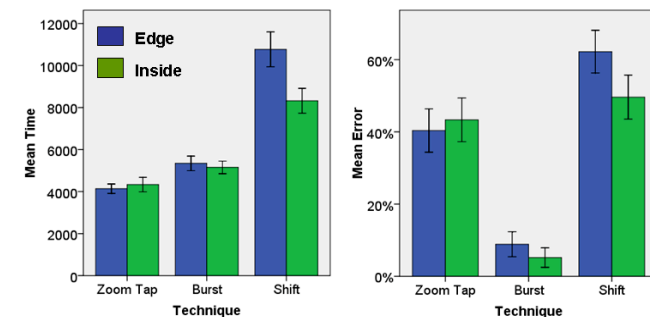

Figure 4. (left) Average completion time is msec and (right) average error rate in %, for each technique by location.

Preferences

Based on participant ratings, participants overall preferred ZoomTap, then Burst and finally Shift.

Discussion

In summary, the study results support all three hypotheses. Participants acquired multiple targets using *ZoomTap* and *Burst* faster and with a lower error rate than using *Shift*. *Shift* results in a higher completion time and a higher error rate because users can only

select a single target at a time and also users had a difficult time selecting targets on the screen edge.

Even though our two new techniques both ranked favorably, participants seem to prefer *ZoomTap* due to its simplicity and speed. However, we found one user with a large thumb had difficulty using *ZoomTap,* which resulted in many errors. To our surprise, the trial logs reveal that participants seldom used the gestures. Some of them even felt confused of the gesture direction. For example, when a user wanted to move the focus upward, he applied a downward gesture.

Burst yielded a lower error rate because in most cases, once the technique is activated and as long as the user keeps their finger pressed on the screen, the user is selecting only six separate targets without any other distraction. *Burst* can achieve good completion time because a user can complete multiple-target selection in one stroke, but its complexity in comparison to *Shift* and *ZoomTap* resulted in it ranking as less preferable. We observed that some participants with smaller hands had a difficult time maintaining contact with the screen for the entire selection task. Some participants had to adjust their grasp of the PDA after a few trials of Burst. Another limitation of *Burst* is it can still cause occlusion, especially when targets are at the upper edge, *Burst* must display the proxy below the touch point, which results in the user's thumb occluding some proxies.

We will address these limitations in our future work. We also believe *Burst* could perform well in the overlapped target scenario. To further verify our results, we also intend to improve our implementation of *Shift* so that it more closely matches the original by Vogel and

Baudisch [6]. Improvements to the filter and the callout position algorithms are necessary

Conclusion and Future Work

Our study is an initial step toward the design of multiple target selection techniques using one-handed thumb operation of touchscreen based mobile devices. The results of the experiment show our two designs result in faster selection time and increased accuracy compared to the *Shift* technique. Through participant feedback we have identified a number of potential improvements that we can make. We also plan to evaluate *Burst* and *ZoomTap* with overlapped targets.

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