Bounded Swipe: Swipe Gesture Inside a Target

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ABSTRACT

Touch input has the problem that the input vocabulary is limited. In this paper, we propose the bounded swipe as a new touch gesture for solving this problem. In the bounded swipe, which extends the commonly used swipe action, the start and end points are inside a target. To test the feasibility of this gesture, we first investigated whether a bounded swipe is ever performed accidentally when a user swipes normally on a target; in 99.2% of swipes performed, the end point of the swipe was outside the target. Under the bounded swipe, the success rate was 96.7%. Therefore, the bounded swipe is a touch gesture that does not conflict with the conventional swipe.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; *Interaction techniques*; Gestural input;

KEYWORDS

crossing, input vocabulary, touch gesture, touch screen

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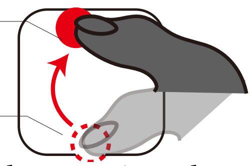

Figure 1: Bounded swipe. In this gesture, the start point and end point of the swipe are inside the target.

1 INTRODUCTION

Although the touch screen has become the dominant interface for mobile devices and has the advantage of enabling the selection of targets by direct touch, the vocabulary of touch input is limited. In an attempt to resolve this, many researchers have proposed techniques for extending input vocabulary [1–6, 8, 10–18].

In this paper, we address this issue by focusing on the swipe gesture, a frequently used action for manipulating graphic user interfaces such as soft keyboards and pie menus. The user performs this gesture by sliding a finger in any direction after selecting a target by touch. Here we propose the *bounded swipe* as a gesture that extends the conventional swipe action. A bounded swipe is a swipe whose start point, where the touch-down event occurs, and end point, where the touch-up event occurs, are inside a target (Figure 1). When the end point of the swipe is outside the target, the swipe is considered a conventional swipe (referred to as a *flick*). A bounded swipe can be distinguished from a flick by observing the end point of the swipe. Therefore, implementing a bounded swipe does not require any additional devices other than the built-in touch screen.

The bounded swipe design is based on the assumption that when the user swipes on a target without considering the end point of the swipe (i.e., flicks casually), the end point is always outside the target. If this assumption is correct, a bounded swipe can extend a swipe on a target without conflicting with a flick. In this paper, we first clarify the probability of accidental occurrences of a bounded swipe. Then we investigate the performance of a bounded swipe. In addition, if the target is small, there is a possibility that a tap will conflict with a bounded swipe; therefore, we investigate finger movement distance during a target tap.

The contributions of this paper are twofold in that we show that 1) the end point of a swipe is outside the target when the user swipes on a target, and 2) a bounded swipe is a useful gesture, based on the results of our experiments.

2 RELATED WORK

Many researchers have proposed techniques that extend the vocabulary of touch input. Many such techniques combine touch-related information with a touch position. For example, the touch area [1], the touch force [6, 8, 13], the generated sound [4], and the angle [17, 18] of the touched finger have been used. In addition, techniques that identify touch by the palm [11], touch finger [2, 3], and hand gestures [12] have been proposed. These expand the vocabulary by changing performed actions according to identified results. Although these techniques use touch-related information other than touch position, a bounded swipe can be implemented using only the touch position, because the bounded swipe can be distinguished from a flick by just observing the end point of the swipe. Moreover, a bounded swipe can coexist with these techniques, further extending the vocabulary of the touch input.

Techniques that use touch gestures that are less likely to occur accidentally have also been proposed (e.g., swipes from the bezel of the device [10, 15], consecutive distant taps [5], thumb-rolling gestures [16], and a continuous tap with two fingers [14]). Similar to the gestures used in these techniques, a bounded swipe is an action that is less likely to occur accidentally.

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3 EXP1: INVESTIGATION OF THE CONVENTIONAL SWIPE

We conducted an experiment (EXP1) to investigate the behavior of a conventional swipe on a target.

3.1 Setup

Eight participants (seven males, mean age = 22.3, six right handed) who usually used their smartphones with their right hands took part in this experiment. The average smartphone usage time of the participants was 8 years and 8 months. The device used in this experiment was the iPhone 6s (iOS 12, 138 mm × 67.1 mm).

A total of 28 targets were arranged on the screen. The targets were located in the same positions as the icons (4 columns × 7 rows) on the home screen of an iPhone 6s at the default setting, as shown in Figure 2. The size of the target was the same as that of the icon displayed on the home screen (9.3 mm × 9.3 mm). We used this size as the target size, considering the example applications of a bounded swipe from pie menus and keyboards, in which a swipe on a target is a common user interface. During the task, one randomly selected target was filled in with blue, along with the text, to instruct the user of the swipe direction on the target (upward, downward, left, or right); the other targets disappeared.

3.2 Task

The task was to swipe on targets in the instructed direction. Participants were first asked to sit on a chair. Then they were directed to swipe from the filled target on the screen in the instructed direction. Note that no instruction was given regarding the speed or distance of the swipe, as the purpose of the experiment was to investigate the behavior of a conventional swipe on the target.

One trial involved swiping on a target in the instructed direction. One session consisted of 28 trials (one for each target). If the start point of the swipe was outside the target or the swipe direction was wrong, the target remained unchanged; that is, the trial was repeated. Participants completed four sessions using each of the two grips of the smartphone: two handed (TH) and one handed (OH). With TH, participants were asked to held the smartphone vertically (i.e., in portrait orientation) in the left hand and swiped with the index finger of the right hand. With OH, participants were asked to held the smartphone vertically in the right hand and swiped with the thumb of the right hand. The order of the grips was counterbalanced: four participants performed four sessions with TH first; the others performed four sessions with OH first. Participants were required to take 1 min break after each session. In the four sessions with each grip condition, participants swiped in four directions for all targets. The experiment took approximately 30 min. After all sessions were completed, each participant received 830 JPY as a reward.

In the following description, *grip* denotes the grip condition (TH and OH), and *direction* denotes the swipe direction (upward, downward, left, and right).

3.3 Results

We collected a total of 1,792 swipes (8 participants × 28 trials × 4 sessions × 2 grips). Of all of the performed swipes, 14 swipes (0.8%) had end points inside the target (i.e., 14 swipes were identified as bounded swipes), as shown in Table 1.

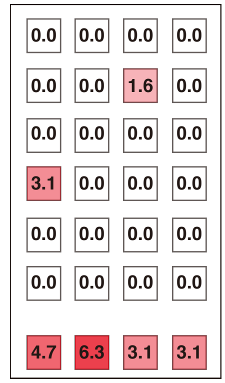

Figure 2: Probability of accidentally performing a bounded swipe for each target in EXP1 (%).

Table 1: Probability of accidentally performing a bounded swipe with respect to *direction* and *grip* in EXP1 (%).

grip \ *direction*	upward	downward	left	right
One-Handed (OH)	0.0	1.3	0.9	0.0
Two-Handed (TH)	0.4	3.1	0.4	0.0

We further analyzed the probability of accidental occurrence of a bounded swipe using a two-way repeated measures ANOVA (RM-ANOVA) with *grip* and *direction* as the independent variables. *Direction* had a significant main effect ($F_{3,18} = 23.28, p < .001$). However, Tukey's HSD post hoc pairwise comparisons showed no significant difference (all $p > .05$). Figure 2 shows the probability of accidentally performing a bounded swipe for each target; the results show that a user is likely to perform bounded swipes accidentally for the lowermost targets. On closer examination, we found that 11 bounded swipes were performed accidentally on the lowermost target, and 10 of the 11 were downward swipes. Therefore, a design that uses a downward bounded swipe on a target at the bottom of the screen should be avoided. Overall, these results show that a bounded swipe as a gesture does not conflict with a flick.

The swipe distance was 20.1 mm, which was roughly 215% of the target length. We also analyzed the swipe distance using a two-way RM-ANOVA. Our results showed that *direction* had a significant main effect ($F_{3,18} = 23.28, p < .001$). Tukey's HSD post hoc pairwise comparisons indicated a significant difference between downward and right ($p < .05$), upward and left ($p < .001$), and upward and right ($p < .001$). That is, upward swipes (18.4 mm) were longer than left (15.8 mm) and right (15.0 mm) swipes, and downward swipes (17.2 mm) were longer than right swipes. This is attributable to the screen orientation of the smartphone, which is longer in the vertical direction.

A total of 198 swipes (11.05%) had distances less than the target length. However, only 14 of these were bounded swipes. This suggests that users tend to continue swiping until the finger moves outside the target, regardless of the swipe distance.

The time taken to swipe (swipe time) was 0.175 s (SD = 0.09 s). A two-way RM-ANOVA results for swipe time, indicated that *direction* had a significant main effect ($F_{3,18} = 11.13, p < .001$). Tukey's HSD post hoc pairwise comparisons showed significant differences between downward and left ($p < .001$), right and downward ($p < .01$), right and left ($p < .001$), upward and left ($p < .001$), and right and upward ($p < .05$). That is, right swipes (0.16 s) were faster than swipes in the other three directions (upward: 0.17 s, downward: 0.18 s, and left: 0.19 s), and left swipes were slower than upward and downward swipes. This is most likely because the right swipe distance was the shortest distance, followed by the left swipe distance; however, these differences were small.

4 EXP2: INVESTIGATION OF BOUNDED SWIPE

We conducted an experiment (EXP2) to investigate the performance of the bounded swipe.

4.1 Setup and Task

Eight participants (all males, mean age = 21.0, all right handed) who usually used their smartphones with their right hands and who had not participated in EXP1, took part in this experiment. The average smartphone use time among participants was 7 years and 6 months. The smartphone and the application used in this experiment were the same as those in EXP1.

The assigned task consisted of performing bounded swipes on targets in the instructed direction. Participants were first asked to sit on a chair. Next they were asked to perform a bounded swipe on a filled target in the instructed direction. The experimental conditions were the same as in EXP1. That is, each participant performed four sessions each of TH and OH. Participants were required to take 1 min break after each session. This experiment took approximately 30 min. After completing all sessions, each participant received 830 JPY as a reward.

4.2 Results

We collected a total of 1,792 swipes (8 participants × 28 trials × 4 sessions × 2 grips). Of the swipes, 1,733 were successful bounded swipes (success rate: 96.7%). Table 2 shows the success rate of each *grip* (TH and OH) and *direction* (upward, downward, left, and right). A two-way RM-ANOVA with *grip* and *direction* as the independent variables showed no significant main effect on the success rate (all $p > .05$). Figure 3 shows the success rate for each target, in which the lowermost targets on the screen were lower than the other regions. EXP1 showed that the number of accidental bounded swipes was large for the lowermost targets. Therefore, participants may have had difficulty adjusting the end point of a bounded swipe when choosing a target in the lower region of the screen.

The swipe distance was 3.2 mm (SD = 1.0 mm), which was roughly 33.8% of the target size. A two-way RM-ANOVA showed that *direction* had a significant main effect ($F_{3,18} = 8.18, p < .01$). Tukey's HSD post hoc pairwise comparisons showed significant differences between upward and downward ($p < .001$) and upward and left ($p < .05$) swipes; upward bounded swipes (0.34 mm) were slightly longer than downward (0.30 mm) and left bounded (0.31 mm) swipes, by 0.03 mm or less. Therefore, participants moved their fingers a distance of about 30% that of the target size when performing a bounded swipe, regardless of the swipe direction. However, it is necessary to investigate whether the distance of a bounded swipe is 30% of the target size or is always about 3.2 mm.

Table 2: Success rate with respect to *direction* and *grip* in EXP2 (%).

grip \ *direction*	upward	downward	left	right
One Handed (OH)	96.9	93.3	99.1	99.6
Two Handed (TH)	94.6	91.1	100.0	99.1

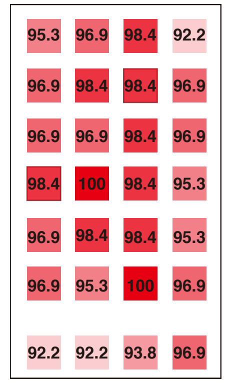

Figure 3: Success rate of bounded swipes for each target in EXP2 (%). The effects of the target position are small.

The bounded swipe time was 0.33 s (SD = 0.17 s). A two-way RM-ANOVA showed no significant main effect (all $p < .05$). Welch's t-test results revealed that the bounded swipe time was longer than the swipe time in EXP1 ($t_{2860.6} = 33.496, p < .001$); thus, a bounded swipe may require more careful finger movement than a flick for participants. As for the time required to perform other gestures, the wait time of a double tap is 0.25 s and that of a long tap is 0.50 s on an iPhone. Therefore, a bounded swipe can be performed faster than a long tap and as fast as a double tap.

5 EXP3: INVESTIGATION OF TAP BEHAVIOR

The results of EXP1 showed that a bounded swipe does not conflict with a flick. However, if the finger movement distance is large when the user taps a target, a bounded swipe may conflict with a tap. Therefore, we conducted another experiment (EXP3) to investigate finger movement distance while tapping a target.

5.1 Setup and Task

Four volunteers (all males, mean age = 21.75, all right handed) in our laboratory who usually used their smartphones with their right hands and had not participated in EXP1 or EXP2 took part in this experiment. The smartphone and application used in this experiment were the same as in EXP1 and EXP2.

We asked the participants to sit on a chair. Then, we instructed them to tap on the filled target. The target size and location were the same as in EXP1 and EXP2. Each participant tapped all 28 targets using each *grip* (TH and OH). This experiment took approximately 5 min.

5.2 Results

We collected a total of 224 taps (4 participants × 28 trials × 2 grips). The finger movement distance was 0.01 mm (SD = 0.04 mm), which was much shorter than the distance of the bounded swipe in EXP2

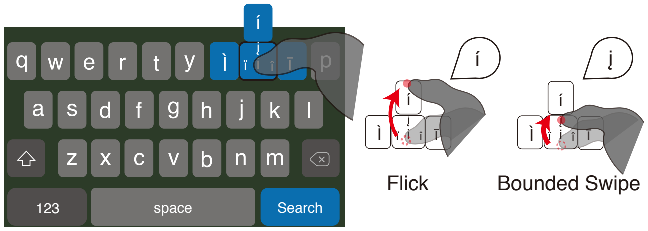

Figure 4: A keyboard shortcut using a bounded swipe.

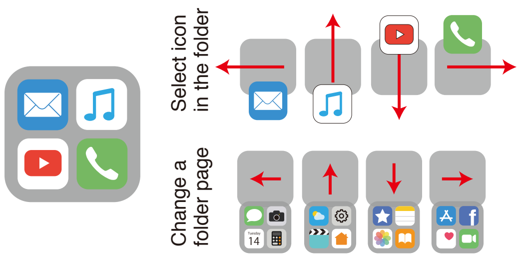

Figure 5: Shortcuts to an icon folder.

(0.26 mm). Furthermore, the time of the tap was 0.08 s (SD = 0.02 s), which was also much less than the time of the bounded swipe. Both were significantly different according to Welch's t-test (distance: $t_{2034.6} = 59.5, p < .001$, time: $t_{1016.8} = 54.8, p < .001$). Therefore, from these results, it can be concluded that a bounded swipe does not conflict with a tap.

6 EXAMPLE APPLICATIONS

A bounded swipe can extend a swipe on a target. In this section, we show example applications of a bounded swipe.

6.1 Shortcut on Keyboards

On the built-in English keyboard on the iPhone, the user long-taps a key to display a list of characters related to the key. For example, if the user presses and holds the “i” key, “ì”, “į”, “ī”, “í”, “ï” and “î” keys are displayed. Then the user can input a character by tapping a key in the list. This input requires a tap in addition to the long tap; thus, this input tends to take more time. By using a bounded swipe for shortcuts, the user can input these characters using a single swipe (i.e., a flick or a bounded swipe), as shown in Figure 4.

6.2 Shortcut to an Icon Folder

On smartphones, to make it easier to launch frequently used applications, users can place an icon on the home screen for each application. If the user has many icons to place on the home screen, the user may combine several icons into a folder (Figure 5 left). However, as the number of icons in the folder increases, the number of pages in the folder increases. In this case, to launch the application in the folder, the user must tap to open the folder and then search for the target icon and tap it again. This process tends to be inefficient.

The bounded swipe can be used to remedy this problem. The user can launch an application in an icon folder without opening the folder, by selecting the icon in the folder with a flick and changing the folder page with a bounded swipe (Figure 5 right).

7 DISCUSSION AND FUTURE WORK

Although the results of our experiments show the potential of the bounded swipe, more investigation is necessary to better understand its characteristics.

7.1 The Impact of Target Size

Performance of the bounded swipe can be considered to be affected by the size of the target. In our experiments, we used the same target size (9.3 mm) as the icon on the home screen of iPhone because we thought that the target size in our example application on an icon folder is similar to this size. However, we need to investigate the success rate and time when the user performs a bounded swipe on various sizes of a target such as the minimum target size (6.9 mm × 6.9 mm) described in Apple's guidelines [7] or the icon size (11.0 mm × 11.0 mm) when a display setting of the iPhone is changed to “zoom”.

7.2 The Bounded Swipe on Smartwatch

In this study, we investigated performance of the bounded swipe on a smartphone. We are also interested in investigating whether users can perform a bounded swipe on a smartwatch, where the input vocabulary is severely limited because of the small screen size. In EXP2, the distance of the bounded swipe was 3.2 mm (SD = 1.0 mm). Because this distance is shorter than the icon size on a smartwatch (e.g., 38.0 mm on the home screen of the Apple Watch [9]), it should be possible for users to perform bounded swipes on a smartwatch. However, it is necessary to determine whether the end point of a swipe would be within the target range, as the posture for using a smartwatch differs from that assumed for the experiments in this study.

7.3 Target Adjacent to Bezel of a Device

Our current implementation uses only the position of the end point of a swipe to distinguish a bounded swipe from a flick. However, this implementation cannot determine whether swiping on a target contacting the bezel of a screen is a bounded swipe or a flick. To address this issue, we examined data from EXP2 and found that the distance between the end point of a bounded swipe and the target edge in the swipe direction was 1.9 mm (SD = 0.8 mm). Therefore, it may be possible to use a bounded swipe when a target makes contact with a bezel by implementing an additional detection algorithm that also uses the distance between the end point of the swipe and the bezel.

8 CONCLUSION

In this paper, we proposed a bounded swipe as a new touch gesture. A bounded swipe is a swipe whose start point and end point are inside a target. We conducted three experiments to investigate the feasibility and performance of the bounded swipe. The first experiment showed that 99.2% of swipes performed on a target ended outside the target; that is, the probability of accidental occurrence of a bounded swipe was only 0.08%. The second experiment showed that the success rate of bounded swipes was 96.7%. Moreover, the third experiment showed that a bounded swipe does not conflict with a tap. From these results, it can be concluded that a bounded swipe is a gesture that can only be performed when a user intends to do so.

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