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LETTER

BackAssist: Augmenting Mobile Touch Manipulation with Back-of-Device Assistance

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SUMMARY Operations, such as text entry and zooming, are simple and frequently used on mobile touch devices. However, these operations are far from being perfectly supported. In this paper, we present our prototype, BackAssist, which takes advantage of back-of-device input to augment front-of-device touch interaction. Furthermore, we present the results of a user study to evaluate whether users can master the back-of-device control of BackAssist or not. The results show that the back-of-device control can be easily grasped and used by ordinary smart phone users. Finally, we present two BackAssist supported applications – a virtual keyboard application and a map application. Users who tried out the two applications give positive feedback to the BackAssist supported augmentation.

key words: *mobile devices, mobile interface, back-of-device interaction, text input, zooming operation*

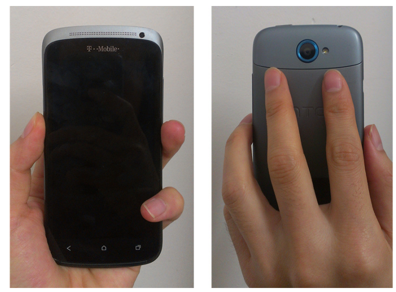

Fig. 1 A normally used holding posture for smart phones.

1. Introduction

Mobile touch devices have already ubiquitously penetrated into people's daily lives. Direct touch interaction gains its popularity among users because it enables them to interact with their mobile devices with easy-to-use, natural and intuitive gestures comparing to previously used techniques, e.g. keypad-based and joystick-based ones.

Although well accepted by end users, mobile direct touch manipulation still has many limitations needing further amelioration from HCI (Human Computer Interaction) researchers' point of view, especially on some frequently used simple operations, such as zooming, switching between different pages of a virtual keyboard, and so on. Taking mobile text entry for example, users switch between different keyboard pages primarily through pressing dedicated keys, e.g. the shift key, which is cumbersome and error-prone. As for zooming, although pinch and stretch gestures are considered to be natural and intuitive, they cause more finger occlusion. Therefore, how to further improve these simple and frequently used operations should be focused and explored.

Back-of-device interaction has become a hot research area in mobile interaction. Originally, it was mainly explored for addressing the occlusion problem and fat finger problem in mobile touch input [1]–[3]. Later research work extended its usage for many other mobile manipulations, such as text entry [4]–[6], one-handed manipulation [7], smartphone authentication [8], 3D model manipulation [9], UI (user interface) layout adjustment [10], landscape-orientation grip manipulation [11], and so on. On the other hand, we observe that many smart phone users usually operate their phones with the holding posture as shown in Fig. 1. The work by Li et al. [12] also reports this posture as a typical grip. With such a holding posture, users are able to freely lift up and land back their fingers on the rear of the device without weakening a firm grip. Inspired by these research work, we explore making use of the combination of the on and off states of the two fingers behind a device for promoting the abovementioned frequently used operations.

In this paper, we present our prototype BackAssist for augmenting front-of-device touch interaction through back-of-device input. The results of a user study indicate that the back-of-device control of BackAssist can be easily mastered and operated by normal smart phone users. In addition, we present two BackAssist augmented applications. Users who tried out the applications show a preference for the BackAssist supported virtual keyboard and the zooming operations for a map application.

2. System Implementation

2.1 Hardware

The hardware of our prototype is built by adhering two smartphones back-to-back. Each smartphone possesses a 1.5 GHz CPU and 1GB RAM. The in-built screen of the smartphone is 4.3 inches. We make use of a modified phone case for covering the bottom half of the touch surface of the phone on the backside of our prototype. Therefore, only the top half of the rear surface can be used for generating back-

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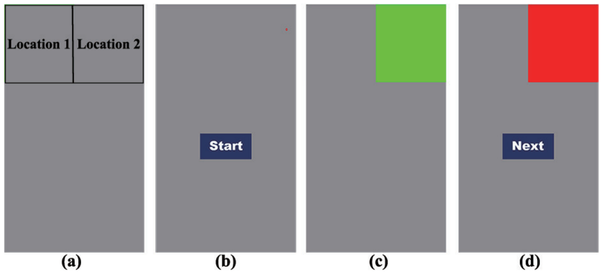

Fig. 2 Appearance of the task in our user study.

Table 1 The states generated by the two fingers.

	Zone 1 without index finger on	Zone 1 with index finger on
Zone 2 without middle finger on	State 1	State 2
Zone 2 with middle finger on	State 3	State 4

of-device input. Data transmission between the two phones is via Bluetooth.

2.2 BackAssist

The motivation of developing BackAssist is to utilize the two fingers of the holding hand, usually just resting on the rear of a mobile device and doing nothing, to generate back-of-device input for facilitating front-of-device interaction. The rear touch sensitive surface is logically divided into two zones (Zone 1 and Zone 2) by the central vertical line. Zone 1 and Zone 2 are respectively beneath Location 1 and Location 2 in Fig. 2(a). If a user holds the device with his or her left hand as Fig. 1 illustrates, the index finger and middle finger of the holding hand will rest on Zone 1 and Zone 2 respectively. We can make use of the combination of on and off states of the two fingers (see Table 1), except for the State 1, for switching modes of front-of-device input, e.g. from lowercase page to uppercase page of a virtual keyboard, or directly generating back-of-device commands, e.g. zooming operations for a map application.

In the early days of this study, we used to attempt to employ the State 1 for interaction, too. However, during the research, we found that lifting up the index and middle fingers simultaneously from the backside (the State 1) might cause the device to jitter or even tilt backward, which weakened a firm grip of the device. Without a firm grip, our goal of utilizing back-of-device input to augment front touch interaction would be undermined. Therefore, we chose not to use the State 1 in the final implementation of BackAssist.

3. User Study

The intention of developing BackAssist is to make use of back-of-device assistance to promote present touch manipulation on mobile devices. However, whether ordinary smart phone users are able to efficiently and accurately use BackAssist's back-of-device control as we expected is still an open question. To verify it, we conducted a user study to primarily answer the following questions.

1. How long does it take to lift a desired finger off the back surface?
2. How often do participants make mistakes?
3. Can participants land their finger back to the right zone on the back surface?

In order to answer the abovementioned questions, target acquisition times, errors, coordinates of finger contacts (both lifted ones and non-lifted ones) were all recorded by the experiment program during the study.

3.1 Participants and Apparatus

Ten participants were recruited as volunteers in the local university. All participants were graduate students with an average age of 24.7 (SD=2.21). They were all right-handed people with sufficient experience in manipulating mobile touch devices. None of them had used neither back-of-device nor dual-surface interfaces before our study.

The experiment program, which was written in Java and Android SDK, ran on the two-surfaced prototype mentioned in Sect. 2.

3.2 Tasks and Procedure

During the study, each participant was required to sit in a chair and hold the device with the posture demonstrated in Fig. 1 using the left hand. Interactions with the back surface were conducted by the index finger and middle finger of the holding hand while interactions with the front touch screen were conducted by the index finger of the other hand.

A target acquisition task was designed for the study. Each trial was activated by tapping the start button on the front touch screen (Fig. 2(b)). 500 milliseconds after that, a green rectangle target which measured 300 * 270 pixels would be rendered in either Location 1 or Location 2 (Fig. 2(c)) randomly. The participant was instructed to acquire the green target as accurately and quickly as possible by lifting the finger, which was right beneath the green target, off the back touch surface. The green target would turn red the moment any finger on the back surface was lifted up. If the wrong finger was lifted or the right finger was lifted from the wrong zone, an error sound would be played to remind the participant to be more careful and this trial would be marked as an error trial. The participant moved back the lifted finger on the back surface and tapped the next button on the front screen to enter the next trial (Fig. 2(d)).

Before the study, each participant was first asked to complete a pre-study questionnaire for gathering some personal information. Then the experimenter gave each participant a brief introduction of BackAssist as well as a teaching session of how to use it to perform the target acquisition tasks. After that, each participant was required to perform at least one block of trials for mastering the technique. When he or she felt experienced enough, ten blocks of trials were given to the participant to complete. A post-study questionnaire was asked to be filled out at the end of the study for collecting users' feedback.

3.3 Experiment Design

There were totally ten blocks of trials for each participant to finish in our study. In each block, there were 20 trials of two types – green targets rendered in Location 1 (Trial Type I) or in Location 2 (Trial Type II), with ten trials in each type. The sequence of the trials in each block was generated randomly. The whole experiment design could be summarized as follows:

10 (participants) * 10 (blocks) * 2 (types) * 10 (trials) = 2000 trials in total.

Averagely, it took about 30 minutes for each participant to finish all the trials. During the study, participants were allowed to rest when timing was not activated.

3.4 Results

3.4.1 Target Acquisition Time Analysis

Target acquisition time is the time which is taken between the appearance of the green target and the departure of a finger from the back surface. Before we calculated the average target acquisition time, we first removed the trials marked as error ones from the dataset. The average time for acquiring green targets was 0.438 second (SD = 0.096 second), with 0.443 second (SD = 0.103 second) for trials rendered in Location 1 and 0.437 second (SD = 0.097 second) for trials in Location 2.

3.4.2 Error Rate Analysis

There are two types of acquisition errors which may occur during the experiment. The first type (Error Type I) happens when a participant lifts up the wrong finger on the rear. The second type (Error Type II) occurs when the right finger is lifted up but the recorded coordinates are in the wrong zone which indicates that the finger landed back onto the wrong zone in the last trial.

By analyzing the collected records, we found a total of 11 errors, three of which fell into Trial Type I. That was, a very low error rate of 0.55%. In addition, all errors belonged to Error Type I, which meant that all participants could land back their fingers to the right zone on the back surface during the whole study. Furthermore, we found that five participants completed all trials with no errors.

We also calculated the average target acquisition time of the erroneous trials. The result was 0.29 second (SD = 0.069 second), indicating that these errors were mainly caused by the participants' intention to quickly finish these trials.

3.4.3 Coordinates Analysis

Figure 3 and Fig. 4 respectively illustrate the coordinates of the finger contacts on the back surface for each participant and for the whole study. From Fig. 3, we can see that although the patterns of the finger contacts vary from person to person which may be related to participants' hand size, an overwhelming majority of the finger contacts are not close to the line which divides the back surface into two zones. Therefore, the possibility of committing errors in Error Type II is tiny which means that participants can land back their fingers to the right zone on the back after each trial.

3.4.4 User Feedback

The summary of the results of post-study questionnaires is illustrated in Fig. 5. From the feedback, we can see that overall the participants subjectively believed that they could conduct the tasks easily, quickly and correctly.

By synthesizing the quantitative and subjective findings, we can conclude that the back-of-device control of BackAssist can be easily mastered and efficiently and accurately used by ordinary mobile device users. Accordingly, BackAssist has a great potential of being used for promoting

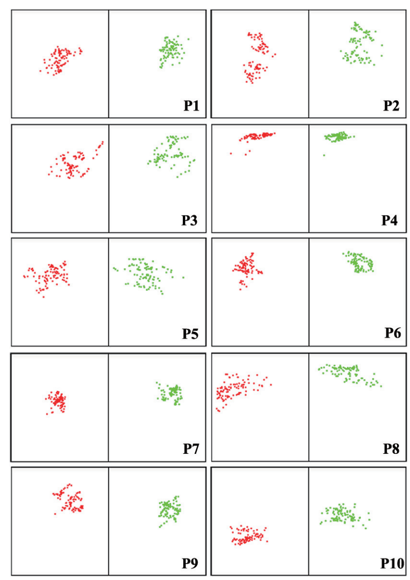

Fig. 3 Finger contacts of each participant on the back surface.

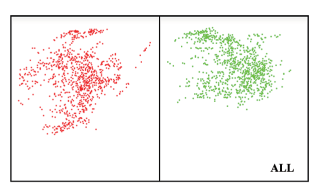

Fig. 4 Finger contacts of all participants on the back surface.

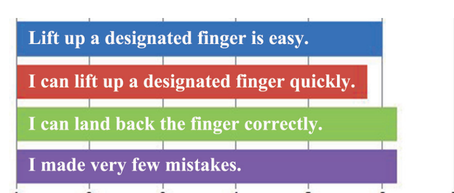

Fig. 5 The summary of answers of post-questionnaires in our user study.

current mobile touch interactions.

4. Applications

BackAssist can support many operations on a mobile device. Here, we present two very frequently used mobile applications which can leverage the back-of-device augmentation.

The first application is a BackAssist supported virtual keyboard which makes use of back-of-device input for switching between different keyboard pages. It saves the time for achieving the same function by pressing specific keys on the front display. As shown in Fig. 6(b), the lowercase page is shown when the two fingers respectively rest on Zone 1 and Zone 2. The user switches the keyboard to uppercase page by lifting up the finger previously on Zone 1 (see Fig. 6(a)); he or she can also switch the keyboard to the page of numbers and symbols by lifting up the finger on Zone 2 (see Fig. 6(c)).

The second one is a map application which utilizes back-of-device input for zooming operations and front touch input for panning operations. A user lifts up the index finger on Zone 1 to trigger a zoom-in operation, as shown from Fig. 7(b) to Fig. 7(a). He or she can also lift up the middle finger on Zone 2 to trigger a zoom-out operation, as shown from Fig. 7(b) to Fig. 7(c).

We let the ten participants, who took part in the user study, to try out the two BackAssist supported applications for getting preliminary subjective feedback. Overall, we got very positive feedback on both applications. On one hand, eight participants preferred BackAssist supported virtual keyboard over the traditional ones. On the other hand, all participants favored the technique of using back-of-device input for zooming operations. Note that, our current hardware prototype is thicker and heavier than most off-the-shelf smartphones. In the future, with a thinner and lighter prototype, BackAssist may receive even better user feedback.

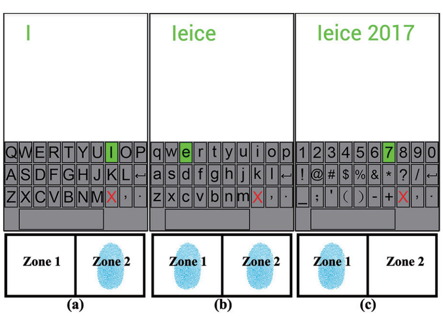

Fig. 6 The BackAssist supported virtual keyboard.

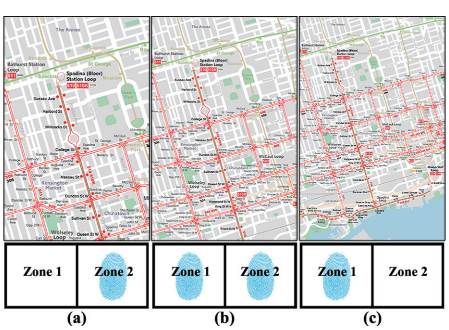

Fig. 7 The BackAssist supported map.

5. Conclusion and Future Work

In this paper, we explore making use of back-of-device input for augmenting front-of-device touch manipulation. We present our prototype BackAssist as well as two applications supported by BackAssist. Encouragingly, we find that users can master and use the back-of-device control with ease. They also respond very positive feedback to the BackAssist supported applications. In the future, we will do further user studies on BackAssist supported applications to get a deeper understanding of BackAssist's impact on user performance and experience.

Acknowledgements

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