CornerPen: Smart Phone Is the Pen

Bong-gyu Jang, Myonghee Lee, and Gerard J. Kim

Digital Experience Laboratory
Korea University, Seoul, Korea
gjkim@korea.ac.kr

Abstract. The use of finger on the touchscreen is one of the most prevalent forms of input on mobile devices. However, due to the size of the finger tip, precise input is difficult and the presence of the finger on the touchscreen can often occlude the content in interaction. In this paper, we propose to install a sensor in the corner of the mobile device (e.g. smart phone) and transform the mobile device into a digital pen for making input for itself or other external devices. The system, dubbed "CornerPen" has many potential advantages in addition to those of the traditional pen-based input (vs. finger based) such as less occlusion, leveraging on tactile memory, and larger interaction surface. We have implemented and experimentally tested the CornerPen against the nominal finger-based touchscreen input system using two tasks, namely, flick-based icon browsing (search) and selection and free-form text input. Our results showed while the subjects did acknowledge the problem of occlusion with finger-based input on the touchscreen, the CornerPen approach still was not particularly effective nor preferred for the intended purpose, i.e. making precise input, and only exhibited comparable performance for simple flick/tab like input actions.

Keywords: Mobile interaction, Optical tracking, Tactile memory, Pen-based interaction, Finger touch, Icon selection, Usability.

1 Introduction

Making input using a pen-like device (e.g. stylus, digital pen) is one of the most natural and precise interaction methods. As such, many realizations of pen-like and "direct"[1] input methods have been developed such as the light pen, digital pen, stylus-touchscreen, and finger-touchscreen[2]. In particular, many mobile devices use the touchscreen and its finger/pen based input generally suffers from the occlusion problem (the finger/hand occluding the display). The finger touch input also often fails to provide relatively high precision input [1][2].

[1] The mouse can be thought of as a generalization of a pen, but implemented as an indirect interaction device. Digital tablet uses a pen that provides indirect control of a cursor. Note that a pen-like device can carry out virtually all the input possible with the mouse, but usually with higher precision (due to the nature of the grip).

[2] Using the finger is not exactly a pen based interaction but thought to be sufficiently similar to it in nature.

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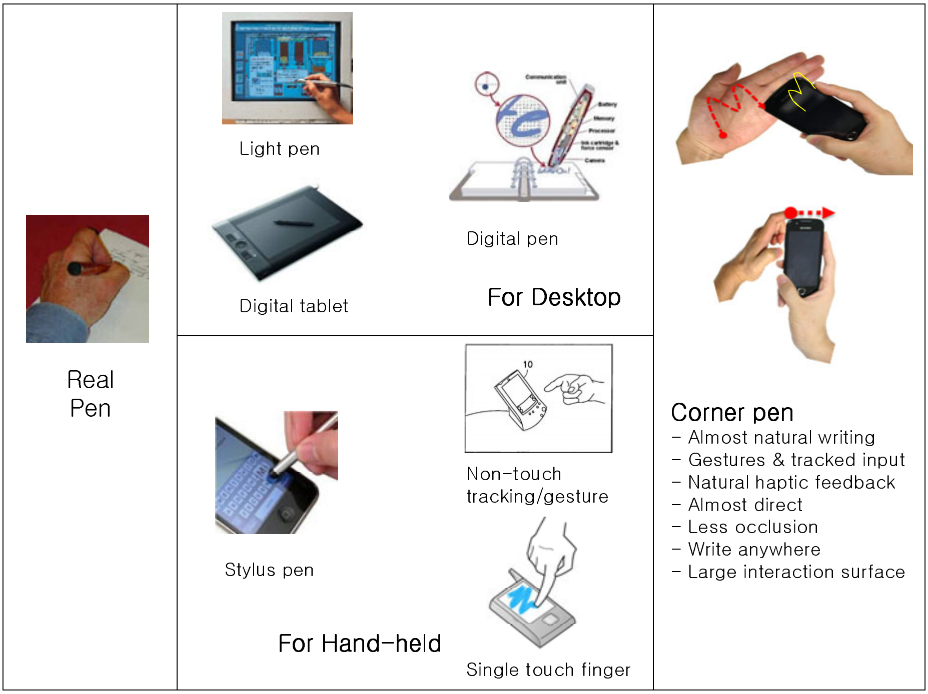

Fig. 1. Evolution of the pen-based interaction: from an actual pen to CornerPen

In this paper, we introduce the "CornerPen" in which a sensor is attached to the corner of the hand-held device (e.g. smart phone) to allow pen-based interaction using the hand-held device itself as the pen. CornerPen is a natural evolution of the pen-like input devices and has several added advantages (see Figure 1 and Section 3). Harrison and Hudson have recently introduced a very similar concept called the "Minput" in which an optical sensor was installed on the back of a small mobile device and demonstrated how simple interactions can occur through directional flick and twisting of the device [3]. Minput is particularly useful for very small mobile devices where the objects on the touchscreen are difficult to select due to their sizes relative to that of the finger tip. In our case, we are expanding the idea to a larger but still mobile device like the smart phone, *which can be held in a similar fashion to a pen (to take advantage of the precise pen-based input)*. We have implemented the proposed concept and experimentally tested its usability through two tasks, flick based icon selection (e.g. 2D menu) and free form text input, against the nominal finger driven touchscreen system.

2 Related Work

While great for direct and fast interaction, touchscreens for small mobile devices are known to have usability problems such as low precision and screen obstruction (by user's hand/finger) [1][2][3]. Thus, recent smart phones, equipped with increasingly many sensors (such as the GPS, tilt sensor, accelerometer, digital compass, camera), may offer alternative input methods. For example, many interfaces taking advantage of these sensors have appeared for recognizing gestures and tracked input in the mid-air (3D space) [4][5][6][7] but require relatively large movement of the hand-held device and thus, user is not able to see the visual output on the hand-held screen. Such input method is only suitable for non-visual applications or for controlling other external systems (e.g. interactive TV).

For relatively precise input, pen-based interface has been widely used on the desktop computing environment, for instance (e.g. especially in the design domain) either in the direct (touchscreen) or indirect (tablet) form. Similarly, for mobile devices, the stylus-touchscreen (resistive) was somewhat popular but soon replaced by the finger-touchscreen (capacitive) due to the nuisance of the stylus (or people would strive to use their finger on the resistive touchscreens).

The digital pen is a specialized device that has the same form factor as the traditional pen, but with capabilities to capture various output in digital form (e.g. text, drawings). However, it usually requires special paper and has not found widespread use. Instead, several researchers have investigated ways to use the body of the mobile device as an input medium. The use of shake or bump gestures is one such example [7][8]. Schmidt et al. developed "PhoneTouch" where phones themselves can be used for directly interacting with the objects on the touchscreen [9]. However, their system assumes the sensing to on the part of the screen or interaction surface and the interaction was devoted for objects on the system external to the phone.

3 CornerPen

3.1 Interaction Possibilities

Since the CornerPen effectively can take the same role as the stylus pen (for mobile devices) or the mouse (for desktop situation), it has a wide range of interaction applicability. The most typical interactive application would be for free form writing, being an evolution of a pen based interface. The size and form factor of today's hand-held devices make writing/manipulation almost as easy and natural as actual pen based writing/manipulation. The same task on the touch screen with the finger is much more difficult due to the relative wide touch area of the finger tip. The user is able to accomplish this task without directly using and even looking at the touch screen. While it may not replace button/key based text input, it can still find good usage for entering short memo and hand drawings.

Moreover, the input can be used for the hand-held device itself, and also for others (e.g. as a mouse for desktop computing, surface computing); that is, the CornerPen can "write" on almost any surface (e.g. palm, wall, table, forearm). Both gestures and tracked input can be realized depending on the fidelity of the sensors employed. Like the usual pen based interaction, it provides natural tactility or passive haptic feedback and even isometric input is possible with added pressure sensors. The input made (e.g. writing profile) is immediately visible through the screen and the hand make less occlusion against the hand-held screen. Alternatively, tactile or short term memory can be taken advantage of; for instance, when writing on a palm or empty surface [invisible].

Fig. 2. Few samples of interaction techniques possible with the CornerPen (from the top, gesture/character recognition, free form drawing input, tap-like input)

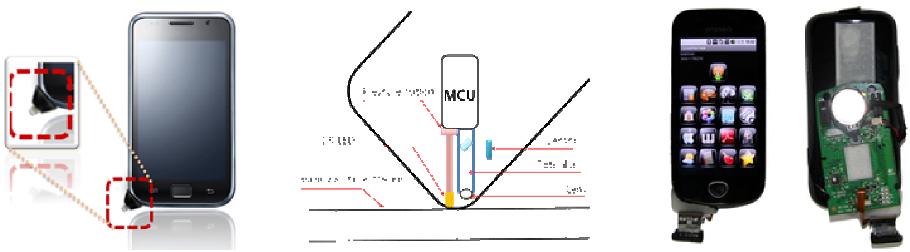

Fig. 3. The concept of the CornerPen with an optical sensor in the lower left corner of the hand-held (left). The internal architecture (middle). The actual implementation (our current version does not include the pressure sensor).

Aside from writing, as a tracking and discrete event generator, 2D gestures (e.g. simple flicker), rubber banding, drag and drop, button simulation (click/double click) are all possible in a natural fashion (Figure 2).

3.2 Implementation

In our case, we have implemented the ConerPen by adding an optical sensor (used in a standard mouse) to the lower left corner (another candidate was the upper left corner) of a smart phone. We thought making input as shown with the sensor at that location (as shown in Figure 3) was more natural and induced the phone to face the user for the display screen to be upright and visible. The optical sensor senses the infra-red light reflected by the surface and computes the relative movement of the hand-held device. The embedded MCU processes and sends (e.g. using Bluetooth communication) the sensed data to the mother hand-held device (in the actual current implementation, the sensed data is sent to a PC then back to the hand-held device).

4 Experiment

To validate the effectiveness of the proposed mobile interaction using the CornerPen, we have compared the task performance and usability between the CornerPen and the conventional touch screen based input. Two tasks were tested: (1) icon browsing (search) and selection and (2) free hand writing/drawing. The hypothesis was that the CornerPen would be superior in performance due to less occlusion (e.g. faster search) and higher precision (e.g. understandability of the drawing or writing).

Note the difference from the study of Minput [3] in that we are targeting to use CornerPen as an alternative interaction medium for general smart phone usage (rather for mere directional menu item movement in "very small" devices like a MP3 player). We hypothesized that the CornerPen would be more effective than the Finger-touch in both icon searching and making precise input due to the elimination of the occlusion problem and having a sharper contact area than the finger tip.

4.1 Experiment Design

The sole factor in the experiment was the type of the interface (ConerPen or Finger-touch) and several dependent variables were measured. The first task presented the user with several flickable (left or right) layers of icon grids (see Figure 4) from which the user was to search, find and activate an icon. Using the CornerPen, the user could flick using the corner of the hand-held device while holding the device in a way to see the whole screen without any obstruction. In case of the Finger-touch, the user would simply flick on the touchscreen to flip around the icon grid pages to search and activate the designated icon. For this task, the task completion time was measured.

The second task asked the user to enter free-form text using the two interfaces. Using the CornerPen, the user would have to hold the device and write the text as if using a pen (and see the one's own results on the hand-held screen). As for the Finger-touch, the user uses one's finger to write out the text directly on the screen (see Figure 5). For this task, self evaluated legibility (e.g. the user evaluated one's own writing in the Likert scale) was used as the dependent variable. A qualitative survey asking general preference and usability was also taken after the user tried out both treatments (1x2 Factor repeated measure).

4.2 Experiment Process

While easy enough to use, still due to the unfamiliarity, the subject was given a period of training to use the CornerPen. The subject then carried out the two tasks using the two interfaces in a balanced order. Sixteen subjects participated in the experiment (14 men and 2 women, average age: 23). The subject was first given a brief period of training to get oneself familiarized to the CornerPen interface (the touchscreen input was easy enough).

As for the first task (icon search), there were total of 64 icons divided into 4 layers (16 icons per layer) from which to find the designated icon (by flicking the layers (pages) left and right. The icon finding task was carried out for a total of 48 times in three stages (to see if there were any learning effect). The target icon and the pool of icons were all chosen and laid out in a balanced fashion.

Fig. 4. The task of browsing (searching) and selecting an icon using the Finger-touch and CornerPen

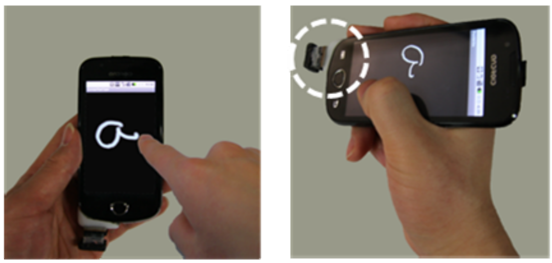

Fig. 5. The task of inputting free form text using the Finger-touch and CornerPen

As for the second task (free form writing), the subject was asked to write the seven letters ("a," "b," "c," "u," "1," "2," and "3"), 4 times for each letter. The quantitative variables were measured automatically through the task software and the survey was taken after the subject had finished testing the two interfaces.

5 Experiment Results

Figure 6 (left) shows the experiment results for the task performance between the Finger-touch and CornerPen (accumulated time for each stage, 16 times). As the graph clearly shows, the Finger-touch was far superior (with statistical significance) than the CornerPen, contrary to our hypothesis. Among many possible factors, despite prior training with the CornerPen, subjects felt much more comfortable with the usual touchscreen finger input method. The task was simple enough, despite the occasional occlusion problem with the touchscreen input, such that the CornePen did not exhibit any advantage. Further explanation is possible from the responses to the survey (later part of this section). No training effect, over the three stage trials, was found.

As for the second task, again, subjects evaluated the Finger-touch method to be much more precise with a statistical significance (Figure 6, right) due to similar reasons as from the results of the first task.

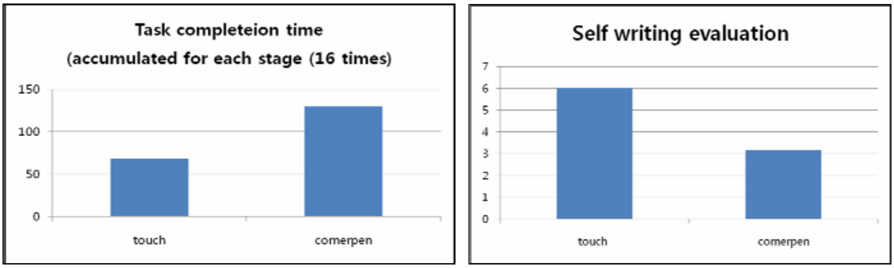

Fig. 6. The task completion time for icon search task (left) and self evaluation of the free form writing task (right) using the Finger-touch and CornerPen

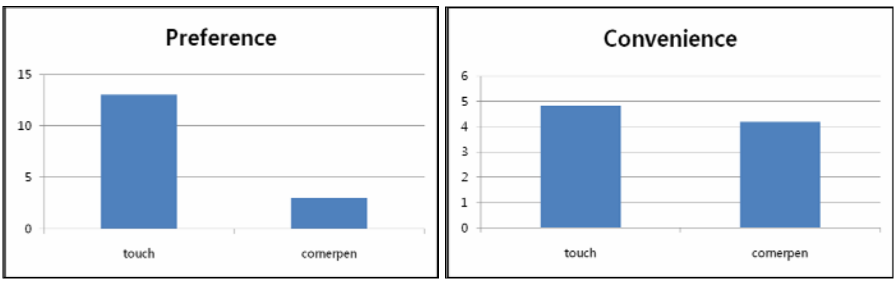

Fig. 7. User preference and ease of use responses in using the Finger-touch and CornerPen

Figure 7 shows few notable results from the survey. The subjects much preferred the familiar Finger-touch method over the CornerPen, even though convenience-wise, they were rated to be competitive (no statistically significant difference). The survey also asked of the negative influence to each input method, namely, the occlusion effect with the Finger-touch and the awkward grip needed to ensure clear visibility to the screen with the CornerPen (Figure 4 and 5). Although difficulty to directly compare, the subjects both to be problems about to the same degree.

6 Conclusion

Differently from the case of Minput [3] in which the mobile device was too small to interact with a Finger-touch, enacting the device itself as a mean for interaction was shown not to be effective when applied to a nominally sized mobile device. The naturalness and familiarity with the touchscreen outweighed the occlusion and "fat" finger tip problem. While the participants in our study reported and complained of the imperfect implementation of the CornerPen (e.g. high sensitivity and odd position of the sensor), the results indicate other solutions to these touchscreen problem might be more proper (e.g. dynamically reconfiguring the screen content according to the finger position).

In this paper, we have introduced the CornerPen in which a tracking/pressure sensor is attached to the corner of the hand-held device (e.g. smart phone) to allow the hand-held device to behave like the pen itself. While the CornerPen did not exhibit any clear advantage over the traditional Finger-touch for the typical input for the nominally sized hand-held device (e.g. smart phones), for selected tasks, it could still find good uses for, e.g. non-visual input and relative positional input for large virtual interaction space.

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