Using a Touch-Sensitive Wristband for Text Entry on Smart Watches

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Abstract
The ongoing miniaturization of computing devices enabled smart watches with capabilities almost on par with smart phones. Due to immanent size restrictions smart watches require specifically designed input and output techniques. In particular, entering text is often needed when interacting with computers but the watches' small size excludes common input techniques. In this paper we propose a text entry technique using a touch sensitive wristband. Using the wristband requires no screen space besides displaying the current character and might enable cheaper devices. In an experiment we compare a linear keyboard and a multitap keyboard layout. We show that users type faster and make fewer errors using multitap. We argue that the inexpensive sensors enable the integration in low cost wearable watches that require text entry occasionally.

Author Keywords
smart watch; keyboard; text entry; wristband;

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H.5.m. [Information Interfaces and Presentation (e.g. HCI)]: Miscellaneous

General Terms
Human Factors; Design; Measurement.

Introduction

Without doubt mobile phones became the most ubiquitous computing devices. They are always with the user and provide access to a very wide range of services. While mobile phones are highly portable they are typically carried in pockets and bags [18]. To provide the user with almost instant access to digital services smart watches have been proposed. Commercially available smart watches are either just extensions of mobile phones and mainly used to present information or very bulky. An input technique that is required to make smart watches independent of a hosting phone is the ability to enter text. Text entry is required for a very wide range of even the most basic tasks. Writing a short message, entering passwords, or searching for content are just some examples.

With the proliferation of smart phones with touch screens, research effort has been invested in providing a high text entry performance using touch typing on QWERTY soft keyboards. Recently it has even been proposed to use virtual QWERTY keyboards on very small touchscreen devices such as smart watches [13]. On-screen keyboards, however, require not only precious screen space but equipping smart watches with touch screens also increases their cost. Further, users face the fat finger problem and occlusion. A number of other text entry techniques have therefore been proposed. In this paper we propose an alternative text-entry technique that exploits touch-sensitive wristbands. Previous work already showed that the touch-sensitive band can be used for selection and scrolling [15]. In contrast, we used the surface of the band for text entry. We propose two different approaches for text entry, sliding and multi-tapping. The assessment of both techniques reveals that users are able to enter text faster with a lower error rate using a multitap wristband keyboard.

Related Work

Various approaches for interacting with very small devices such as smart watches have been investigated in various research projects. Baudisch and Chu proposed to use the rear of very small device for interaction [4]. However, the rear surface is unavailable for wristwatches. Lyons et al. presented Facet, a wrist worn device with a multitouch display [12]. It supports multi-segment touch, resulting in a rich set of touch input techniques. Ashbrook et al. also used a touchscreen and studied the errors when interacting with buttons placed around the rim of the watch [2]. Blasko and Feiner used tactile landmarks on a watch's bezel [5]. Using such a tactile feedback decreases the dependence of the watch interface on the visual display. A strand of work investigated interaction around the watch using different sensors. Harrison and Hudson presented Abracadabra a watch with an integrated magnetometer [8]. By moving a magnet around the watch, the user is able to interact with it. Ashbrook and Baudisch also used a magnetometer to track the rotation of a finger ring around the finger [1]. An array of proximity sensors also used to detect movement around the device [6, 11].

A particular focus of previous work has been text entry on small devices. One approach explored is tilting the device for text entry [14, 16]. Researches also tried to shrink down a QWERTY keyboard layout to fit on very small devices and uses a touchscreen for interaction. Kim et al. used one key together with the QWERTY layout [10]. The keyboard uses the position of the fingertip at the time of the touch event and determines the character entered. Oney et al. used a QWERTY keyboard layout for text entry and developed a soft keyboard, called ZoomBoard [13]. They used iterative zooming to enlarge keys. QWERTY-based approaches have the advantage that the layout is instantly familiar to the users. However, using these techniques on very small devices such as a watch with very small screens is not practical due to the number of keys and the fat finger problem. In particular, approaches relying on the touch screen of a smart watch require parts of the already sparse screen space.

Previous work also explored using watches' wristbands for interaction. The main advantage of using a touch sensitive wristband is that it does not require screen space. Thus, the screen can be used for presenting actual content. As the surface of the wristband is typically larger than the screen of a watch it can also reduce the fat finger problem. Perrault et al. presented WatchIt that uses the surface of wristband as an input for selection and scrolling [15]. We extend their work by investigating alternatives for text entry using touch sensitive wristbands. We compare two promising keyboard layouts and show that a multitap keyboard outperforms simpler linear keyboards.

Text entry with a touch-sensitive wristband

To avoid occluding large parts of smart watches' small screens we developed two techniques for text entry using a touch-sensitive wristband. The cheap off-the-shelf components that we use could also enable text entry for watches that are only equipped with a simple display and not a more expensive touchscreen.

Design constraints

Due to the affordance of a wristband we chose to use a vertical representation of the characters. One cannot easily touch all around the wrist while looking at the watch. Therefore, we chose to mainly use the side of the wristband which faces the body. Through informal pre-tests we determined that the wristband can be easily

Figure 1: The prototypes with the two keyboard layouts. The multitap layout is shown on the left and the linear keyboard is shown on the right.

seen and touched on a length of around 5.2cm. The width of the sensor is 7.2mm. Pressing a button is recognized when 0.6 to 1.5N are applied to the sensor. Tactile feedback for the buttons is not used. For the wristband, we tried different materials like rubber, velcro and steel. In the prototype, we used a steel wristband, because the linear touch sensor that we use, a Spectrasymbol SoftPot potentiometer, was most responsive.

Input techniques

We implemented two keyboard layouts for text entry on a wristband. Both keyboard layouts include 26 characters, a delete key, an enter-button and a space-button. All buttons are 10mm wide and are located in the middle of the sensor. Although, the sensor's width is only 7.2mm the buttons are responsive even on the outside. The first layout implements multitap [7] on a wristband. The keys are grouped together as depicted in Figure 1 (left). The groups are vertically aligned on the wristband. To select

Figure 2: The text entry test application used in the study running on a Nexus S.

the first character the user has to tap the group once, for the second character twice, and so on. The current character is shown on the watch's display. Each key for a group of characters is 5.5mm high. A 12mm high space-button and a 16mm high enter-button are placed at the back of the wristband. Through the larger size we made the two buttons accessible without looking at them. The delete button is placed at the top of the layout and 3.6mm high.

In the second layout, the linear keyboard, the keys are vertically aligned as shown in Figure 1 (right). While the wristband is touched the user can select the character and refine it by sliding. When the user lifts up the finger the character is entered. The character keys are 1.8mm high. The delete key, the enter-button and the space-button have the same size as in the multitap layout.

Implementation

We use a Spectrasymbol SoftPot potentiometer, which is connected to an Arduino microcontroller via an electical circuit to make the wristband touch-sensitive. The location of the touch is determined by the change in the resistance of the sensor. The value is streamed to a computer through a serial port. The entered key is determined on the connected computer according to the current keyboard layout. The key is transmitted to an Android application using WiFi. The entered character is appended to a textfield. The currently selected character is displayed below the textfield.

Evaluation

We conducted a controlled experiment to compare the two keyboard layouts for touch-sensitive wristbands. In the experiment, participants had to enter phrases using both keyboard layouts.

Method

We conducted the experiment using a repeated measures design with the keyboard layout as the only independent variable. Every participant used both techniques in counterbalanced order to reduce sequence effects. We used objective and subjective measures as dependent variables. As objective measures we used words per minute (WPM), keystrokes per character (KSPC), and minimum string distance (MSD) as proposed by Soukoreff and MacKenzie [17]. To determine the KSPC we consider an entered character as a keystroke even it might require tapping the wristband multiple times to enter a character in the multitap condition. In addition, we collected quantitative subjective feedback using the NASA TLX [9] and the SUS [3] questionnaire. Additional qualitative feedback has been provided through informal feedback from participants.

The prototype of the two keyboards described above has been used to enter text. We simulated an actual smart watch through a mobile phone to be able to present phrases that participants should enter next to the watch. Participants entered the text using the custom text entry test application shown in Figure 2. It presents phrases on the left half of the screen that participants are supposed to copy. An image of a watch is presented on the right side of the screen. The upper part of the watch's display show a text field and the lower part shows the character that is currently entered. During the test, the application was running on a Google Nexus S that we attached to the participant's arm above the wristband.

We conducted the evaluation in a calm office environment. After welcoming a participant we explained the purpose of the study and the procedure. Afterwards, we attached the prototype to the arm which the

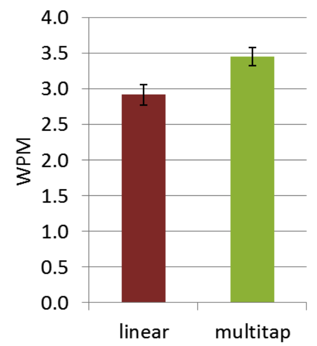

Figure 3: The average WPM for the two keyboard layouts. The error bars show the standard error.

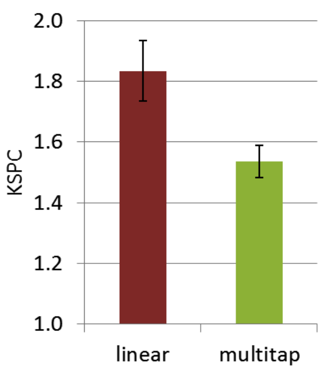

Figure 4: The average KSPC for the two keyboard layouts. The error bars show the standard error.

participant is typically using to wear a watch. All participants were asked to enter five phrases with each input technique. After completing all phrases with one technique they were asked to fill the two questionnaires. We repeated the procedure with the other input technique and asked for qualitative input.

We recruited 4 female and 6 male participants. Participants were between 22 and 41 years old (M=26.9, SD=5.4). Most participants were students in a variety of majors, e.g., informatics, mechanics, design, economy. Two participants were left-handed. We compensated participants with 5 Euro.

Results

Including welcoming the participant, a short introduction, and a debriefing the study took around 45 minutes per participant. The results for WPM and KSPC are shown in Figure 3 and 4. On average, participants entered the phrases with 2.91 WPM (SD=0.99) using the linear keyboard and 3.45 WPM (SD=0.93) using multitap. A t-test shows that the keyboard layout had a significant effect on the WPM (p=0.02). The average MSD between the given phrases and the submitted phrases was 3.17 (SD=14.71) using the linear keyboard and 2.58 (SD=13.70) using multitap. A t-test revealed no significant difference between the conditions (p=0.84). The KSPC using the linear keyboard was 1.83 (SD=0.71) and 1.54 (SD=0.37) for multitap. The difference between the conditions is significant (p=0.01).

The average Nasa TLX score using the linear keyboard is 57.5 (SD=24.2) and 48.4 (SD=19.9) using the multitap keyboard. The difference between the two keyboard layouts was not significant (p=0.40). The average SUS score for the linear keyboard is 56.4 (SD=22.1) and 65.3 (SD=14.6) for the multitap keyboard. However, the difference is also not significant (p=0.31). The qualitative feedback revealed that a gap between the first letter and the delete-key could result in fewer falsely deleted characters. Participants also stated that the lower letters are harder to reach than the ones on top because they had to rotate their arms and were not able to watch the display anymore. Two participants felt more comfortable using multitap on the wristband because they used to write text messages on mobile phones using multitap.

Overall, the objective results show that using the multitap keyboard results in a significantly higher speed. In addition, the significantly lower KSPC for the multitap keyboard shows that participants made fewer corrected errors. While subjective measures revealed no significant difference, the average scores suggest the same trend that is also reflected in their qualitative feedback. Participants achieve a higher performance with the multitap keyboard and they also prefer this layout.

Conclusion

In this paper we proposed using a touch sensitive wristband to enter text on smart watches. Using the wristband instead of a touch screen requires less screen space and has the potential to use cheaper displays. We developed a low-cost protoype and designed two different keyboard layouts. Through a controlled experiment we showed that users type faster and with fewer errors using a multitap keyboard compared to a linear one.

In the conducted study we only assessed the keyboard layouts' pickup usability. While this is the most important factor for predicting user adoption a long term study could reveal the performance of trained users. Another direction for future work is to design a complete user interface that can be controlled using the wristband.

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