Demonstration of PocketThumb: a Wearable Dual-Sided Touch Interface for Cursor-based Control of Smart-Eyewear

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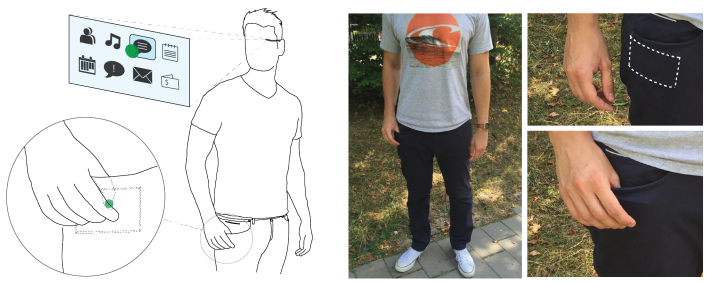

Figure 1: *PocketThumb* is a dual-sided touch interface embedded into the fabric of the trouser's front pocket. The user controls an absolute cursor with the thumb by sliding along the touch surface from within the pocket and can tap to select from outside.

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Abstract
We demonstrate PocketThumb, a wearable touch interface for smart-eyewear that is embedded into the fabrics of the front trouser pocket. The interface is reachable from outside and inside of the pocket to allow for a combined dual-sided touch input. The user can control an absolute cursor with their thumb sliding along the fabric from the inside, while at the same time tapping or swiping with fingers from the outside to perform joint gestures. This allows for resting the hand in a comfortable and quickly accessible position, while performing interaction with a high expressiveness that is feasible in mobile scenarios.

Author Keywords
Wearable input; dual-sided touch; smart-eyewear

ACM Classification Keywords
H.5.m [Information Interfaces and Presentation (e.g., HCI)]: User Interfaces. - Input Devices and Strategies.

Introduction
Smart-eyewear allows for information access and retrieval that is potentially always available and quickly accessible when the device is worn. This is envisioned to serve as an augmentation to the user's memory [7] and to enable short bursts of interaction that minimize interruption from the task at hand [1]. With current technology such as Google Glass,

Figure 2: The *PocketThumb* interface is integrated into a common pair of trousers. The dual-sided touch sensor can be reached with the thumb from within the pocket and with the rest of the hand from the outside.

however, interaction is yet a problem. Much like other wearable devices, input capabilities are negatively affected by the user's mobility, by sensing capabilities as well as by a limited input space at the device due to a desired miniaturization for wearability.

Wearable interfaces allow to quickly interact while being mobile. However due to a lack of available input space and difficulties providing hand stablization in mobile conditions, most wearable touch interaction systems provide only very limited basic gestures, such as dimensional swiping, the detection of a general finger tap or individual fixed buttons. While this can be sufficient for very narrow use cases that do not rely on many different options, such as accepting or declining a phone call, or pausing music, it does not allow for complex interfaces with many options as familiar from other mobile devices that allow to directly point at icons using a finger or indirectly using a cursor.

In this work, we show the applicability of cursor-based pointing and selection in wearable contexts. We propose to use a combined dual-sided touch interaction at the front pocket of the user's trousers. By sliding the thumb into the pocket, the hand is stabilized into position where a capacitive multi-touch sensor is embedded into the fabric (see Fig. 1). The thumb is always in contact with the interface through the fabric and serves as a pointer that is rendered into the virtual image of the wearable display. The cursor positioning is absolute, so that the whole display can be reached by sliding the thumb along the interface. Thus, it doesn't need to be lifted from the interface during interaction, which enhances comfort and hand stabilization at the pocket. The other fingers can access the dual-sided touch sensor from outside the pocket to tap for selection and to furthermore perform swiping gestures while jointly pointing with the thumb. We show that this can be used to increase the input expressiveness of wearable touch interaction.

On-Body Interaction Around the Pocket

The pocket and upper thigh area has already been of interest in the literature for wearable touch interaction [2]. Thomas et al. [8] investigated the placement of a body-attached touchpad mouse for wearable displays in terms of body position and body posture and concluded the front of the thigh to be the most appropriate position when sitting, kneeling and standing. Holleis et al. [4] built capacitive touch buttons into various garments. People most often mentioned the thigh area for where to potentially accept wearable touch controls.

Saponas et al. [6] showed that capacitive sensing through fabric is feasible. They re-calibrated a capacitive sensing grid to enable touch interaction through pockets and investigated signal strength for various fabric materials. It was shown that stroke-based gestures could be performed from outside with most fabrics. We built on top of this finding, by embedding a thin capacitive layer in-between trouser and pocket fabric to allow for sensing not only from the outside but also from the inside of the pocket for combined dual-sided interaction.

Dual-Sided Touch on a Single Capacitive Layer

PocketThumb [3] is the first dual-sided touch interface utilizing a single capacitive touch layer for sensing on both sides. The capacity intensity of finger touches is similar on both sides. Thus, the sensing grid cannot distinguish and assign its measured signal to a respective side which generates ambiguity. However, its measured intensity is additive, so that a pinch-through gesture has a high intensity that cannot be reached by only touching from one side (see Fig. 4). By this, no separating and shielding layer is required, enabling the interface to be thinner. When slid into the pocket, the thumb's surface is in contact with the touch interface, rendering a large blob into the sensor image. We use a weighted average of the bottom of the blob as the cursor position representing the tip of the thumb. As long as in pocket, the thumb remains leaning against the interface even during movement, so that it's absolute position is always rendered as an absolute cursor into the display. This way, the thumb does not need to be lifted from the interface (as required by relative touch interfaces) and can remain leaning against the fabric, which enhances hand stabilization.

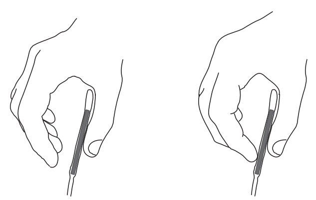

Figure 3: The thumb is leaning against the rigid touch interface (gray) from within the pocket and serves as a cursor. By tapping with the index finger from the other side, the user can perform a selection.

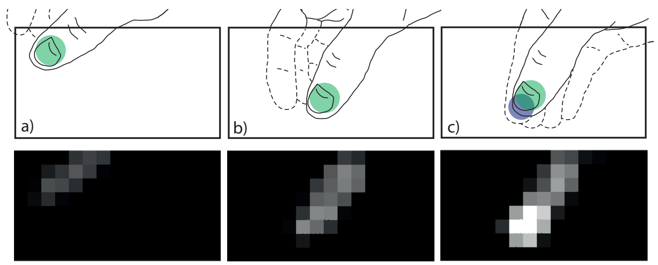

Figure 4: The thumb is sliding along the interface and by that moving the cursor at its tip (a&b). As soon as the index finger touches the interface, the pinch generates a higher capacitive intensity and can thus be detected (c).

Dual-Sided Touch Gestures

The thumb can not only be used as a cursor, but also as a spatial point of reference for the remaining hand. Hence, we want to explore the capabilities of using the thumb for pointing and the remaining fingers for jointly performed gestures. For single-sided touch interaction, the capabilities for pointing and joint gestures are very limited due to the pointing finger reducing the degrees of simultaneous movement of the remaining hand. The only finger that can independently be moved over its saddle joint is the thumb. This is utilized in current touch systems for pinch-to-zoom, where thumb and index finger are moving with a high degree of freedom. However, when other fingers are concurrently used, they are very dependent on each other and bound to move together, such as when swiping with multiple fingers into the same direction (e.g. for scrolling). This limitation in hand motion leads to users either pointing at a target with a finger or performing a complex gesture, but not doing both at the same time with the same hand. By using the thumb as a pointer in dual-sided touch interaction, the high degree of freedom of the thumb's saddle joint enables independent movement of the remaining hand and by that concurrently performed gestures. Since the thumb is opposing the other fingers, it is not obstructing their movement and can instead serve as a point of reference in the user interface. We demonstrate four gestures that utilize this interaction (see Fig. 5):

Spatial Tapping

Users can use their thumb as a proprioceptive reference for tapping with their fingers. This is used for the introduced pinching gesture, where users aim for the thumb selection. It is however also possible to aim *beside* the thumb. Users can willingly tap left or right of the pointing cursors, which can be used as an analogy to left and right clicking of a mouse to increase the expressiveness of a touch selection.

Grab-and-drag

Dragging is a basic operation in many touch-based interfaces to move a target along the display that is pinned to a pointing finger. For the dual-sided *PocketThumb* interface, a target can be grabbed from both sides and then dragged along the display. This corresponds to physical interaction, where the thumb is opposing the rest of the hand and providing force to grab and move an object.

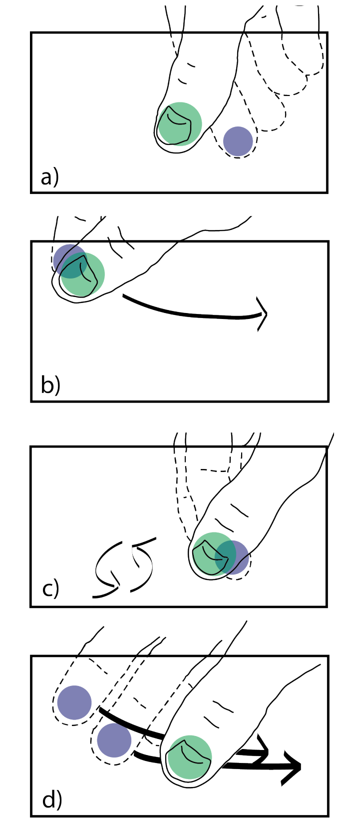

Figure 5: While the thumb is used for cusor-based pointing, the opposing fingers can be used for concurrently performed gestures: a) to commit a 'right-click', b) to drag items c) to circle through content and to d) navigate by swiping.

Pinch-and-circle
When the dominant characteristic of a human grip is precision, the gripped object is pinched between index finger and the opposing thumb [5]. This allows to flex and axially rotate both fingers and by that precise manipulations. We utilize this for a pinch-and-circle gesture where the user can pinch their thumb and then circle the opposing index finger around it for fast and precise interaction. In an user interface, this allows to rotate a virtual knob or to quickly navigate through a list by continuous circling without having to lift the finger.

Point-and-swipe
Swiping is commonly used for touch-based interaction to navigate through content such as when scrolling a page or switching through displayed interfaces. For PocketThumb users can use their fingers for swiping while pointing with the thumb to quickly navigate through complex menu structures. This can be used to switch the current application (left and right swipe) or to invoke or close menu interfaces related to a pointed target (up and down swipe).

Conclusion

PocketThumb [3] is a wearable touch interface embedded into the trousers' front pocket for combined dual-sided interaction utilizing a single capacitive touch layer for rich interaction. The thumb stabilizes the hand from inside the pocket and allows for cursor-based interaction. Furthermore, the input expressiveness can be increased by using the thumb as a spatial point of reference for finger gestures performed on the front of the interface.

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