Smartwatches + Head-Worn Displays: the 'New' Smartphone

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Abstract
We are exploring whether two currently mass marketed wearable devices, the smartwatch (SW) and head-worn displays (HWDs) can replace and go beyond the capabilities of the mobile smartphone. While smartphones have become indispensable in our everyday activities, they do not possess the same level of integration that wearable devices afford. To explore the question of whether and how smartphones can be replaced with a new form factor, we present methods for considering how best to resolve the limited input and display capabilities of wearables to achieve this vision. These devices are currently designed in isolation of on another and it is as yet unclear how multiple devices will coexist in a wearable ecosystem. We discuss how this union addresses the limitations of each device, by expanding the available interaction space, increasing availability of information and mitigating occlusion. We propose a design space for joint interactions and illustrate it with several techniques.

Author Keywords
Smartwatch; Head-worn display; Wearable interaction; Input techniques; HMD; New smartphone.

ACM Classification Keywords
H.5.2. Information interfaces and presentation: Interaction.

Figure 1. Input on the watch controls the HWD content.

Figure 2. The HWD camera can sense the direction of finger landing on the smartwatch for multi-user sensing.

Introduction

While current advances in wearable computing bring us closer to the coveted goal of ubiquitous computing, major interaction limitations need to be overcome. Two major wearable devices that show promise in allowing productive work include the smartwatch and head-worn displays. These devices are relatively light, are becoming sleeker, provide an always available display, and can give access to information without requiring much effort (i.e. they do not have to be removed from a pocket). However they also are limited in several ways. Smartwatches have limited display and input, suffer from occlusion and the fat finger problem. Head-worn displays (HWDs), suffer from a limited or awkward available surface space for input and from contrast issues due to transparent displays. Both, are designed for single-user use and how they can support collaborative scenarios is vastly unclear.

Conversely, they both offer numerous complementary benefits. Smartwatches are good for viewing fine-grained information, have touch capabilities and can be used for sharing content with others. HWDs allow quick-access to display content and allow device recognition using the embedded camera. These devices are currently designed in isolation of one another and it is unclear if they are best used together. We propose combining smartwatches and HWDs to expand the joint interaction space that can eventually limit our reliability on smartphones and bring about the emergence or a 'new' smartphone form factor.

Previous work

Our previous experience in the field has mainly focused on exploring the design space of HWDs. We proposed using hand-to-face gestures to overcome the HWD limited input interaction problem [7]. We also presented a design framework for 2D information spaces to assist the design of UIs for HWDs [2]. To overcome the various limitations of smartwatches, previous work has extended the output space by joining multiple displays [5]. To improve input limitations solutions range from using the wristwatch [6] or adding mechanical capabilities such as pan, twist or tilt [8]. Previous work has also explored joint interactions between smartwatches and smartphones [1]: Duet is an interactive system using the devices' spatial configuration as well as coordinated touch and motion to extend phone-based interactive tasks.

Design space

To inform our design process for enabling joint HWD + smartwatch interactions, we introduce a design space organized by the possible combinations of input and output on both devices. Within this framework, we can coarsely classify a wide variety of techniques (Table 1).

Table 1. Joint interaction design space.

	HWD INPUT	**HWD OUTPUT**
SW INPUT	Proxemic interactions Inter-device mode sensing	SW as an auxiliary input SW as handheld always-available camera ("third eye")
SW OUTPUT	Around device input Multi-user sensing	Information overlay Around device content

Figure 3. Combining both displays can extend the overall display space of the devices.

Figure 4. Spatially arranging the displays allows for semantic presentation of content.

Interaction techniques

We explore the above introduced design space and present the potential for different interaction techniques for each aspect of the design space. To implement these techniques, we propose to apply three types of egocentric tracking by means of the head-mounted camera: Smartwatch tracking (Position and orientation in the FoV), Body tracking (Fingers, hand and arm) and Environment tracking (Other people faces, objects, surfaces).

a) SW Input + HWD Input

By combining sensor input from both devices, each device is able to maintain awareness of the others' relative position and orientation. This allows several advances interactions; for example *proxemic interactions* can allow the devices to apply common operations implicitly, for instance by turning on the watch display when it is facing the user or moving content into off-screen space when the user's finger approaches the watch. Similarly, *inter-device mode sensing* can determine if one device is off or not present, thus altering the resulting display method.

b) SW Input + HWD Output

An obvious combination of a smartwatch is as *auxiliary input* to interact with the HWD display content. For instance, the user can swipe on the watch to scroll an image carrousel on the HWD (Figure 1). Similarly, using input from the smartwatch camera and the HWD gives the user a "third eye" capability, enabling her to see, in live anything pointed by his arm. For instance, when looking for something under a desk.

c) SW Output + HWD Input

Using the HWD-mounted camera, we can detect around-watch gestures and use these as input for interaction with the watch to avoid occlusion of the display. The HWD can also enable sensing and registering multiple users touching the smartwatch (Figure 2), for instance to discriminate between touch input provided by each user on the watch touchscreen.

d) SW Output + HWD Output

Combining both displays allows extending the limited display of the smartwatch. For instance while the smartwatch displays a notification, one could see on the HWD a history of previous notifications (Figure 4). Similarly, while the smartwatch can display a portion of the list of contacts, the HWD can be used to display a larger section of the list (Figure 4). Both displays can be spatially arranged to enable around-watch viewing (Figure 5). For instance in the previous examples the history of notifications could be displayed on top of the watch to add a semantic meaning to its position.

All these and additional techniques in this design space are depicted in figure 5 below.

Conclusion

We propose possible joint interactions between a smartwatch and a HWD. We organize the possible interactions in our design space, which helps us analyze the available possibilities and describe the possible designs. In our continued work we strive to implement an array of demonstrable techniques using only the available onboard sensors to detect and track the pose of each device, the user's body and other people and objects in the surrounding environment.

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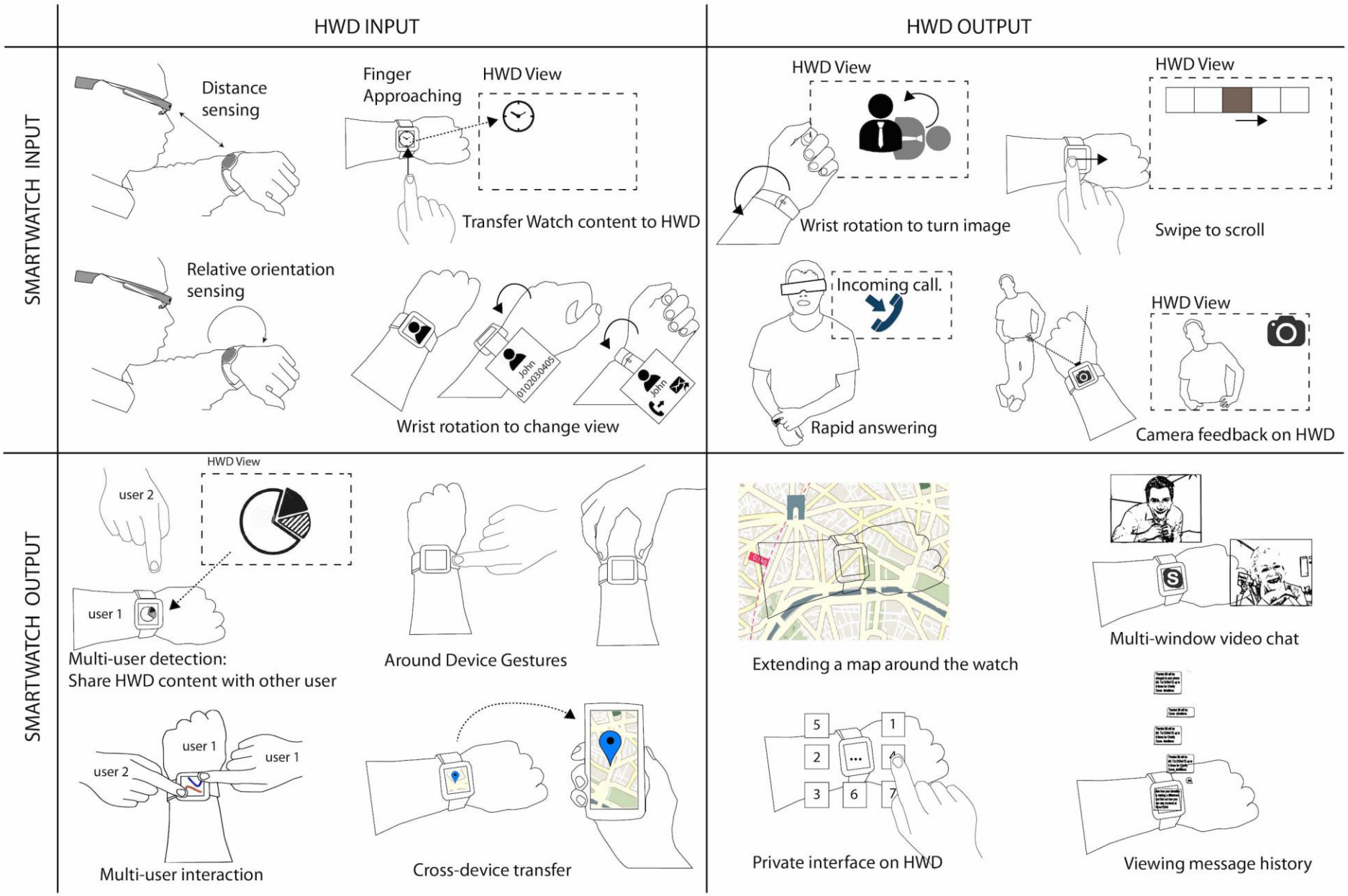

Figure 5. Design space for HWD + SW interaction techniques.