MultiBand: Adding Multi-Touch to the Smartwatch Wristband for Extended Interaction

David Petersen
Technische Hochschule Köln
Cologne, Germany
david.petersen@th-koeln.de

Marvin Reuter
Technische Hochschule Köln
Cologne, Germany
marvin.reuter@th-koeln.de

Matthias Böhmer
Technische Hochschule Köln
Cologne, Germany
matthias.boehmer@th-koeln.de

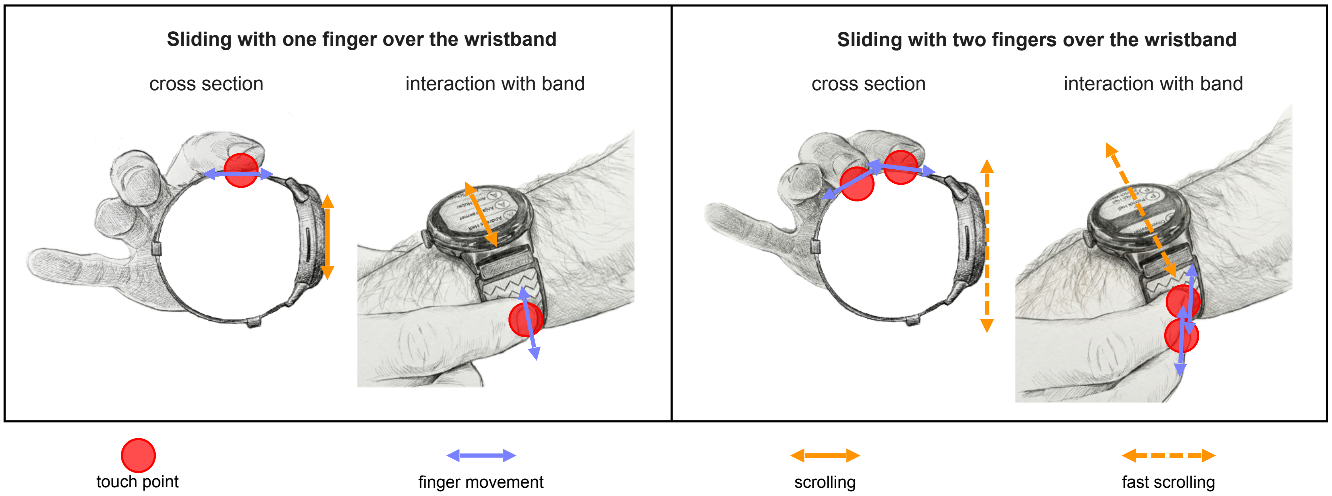

Figure 1: MultiBand extends the smartwatch interaction space by adding multi-touch to the wristband. This enables interactions based on the specific usage, such as a one-finger swipe (left) and a two-fingers swipe (right).

Abstract

The small screen size of smartwatches presents input challenges due to the limited touch surface and screen occlusion. To expand the input space and mitigate the fat finger problem, extensive research has explored various strategies for improving smartwatch interaction design. While wristband-based input has also been studied, there is a lack of research on multi-touch interaction and gestures performed directly on the band. To address this gap, we present MultiBand, a functional prototype that expands smartwatch input capabilities by leveraging capacitive touch sensors around the wristband. Our prototype enables users to execute different functions on a smartwatch based on how they place their fingers on the wristband. Our implementation distinguishes between two types of finger interactions to trigger different scrolling techniques when navigating a contact list. We contribute the software and hardware of our prototype as well as first insights from preliminary user tests.

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CCS Concepts

• **Human-centered computing** → **Interaction techniques**; *Interaction devices*; *Gestural input*.

Keywords

Smartwatch, wristband, input, multi-touch, capacitive sensing

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1 Introduction

Smartwatches have evolved over time, resulting in larger and brighter screens, better sensors and better chip performance. However, other than buttons, crown and bezel input, the input space for consumer devices has not changed dramatically, as the touch screen remains the primary input device for smartwatches. Thus, occlusion and the fat finger problem are still relevant today when interacting with apps. Research has covered different approaches to improve the interaction space of smartwatches to address these problems. Work in this area ranges from extending mechanical input functionality [1, 14, 16, 20] to recognizing mid-air gestures [6, 7, 25, 27]. However, investigating the development of wristbands seems particularly practical, given that they are an essential component of every wristwatch and provide an additional surface area for interaction. Research in this direction demonstrates interesting ways to interact with wristbands, thereby enhancing their functionality and expanding the smartwatch's interaction space. However, these prototypes are often limited to single-touch functionality or conceptual ideas. There is a gap investigating multi-touch on smartwatch wristbands. Therefore, we introduce *MultiBand*: a functional prototype for smartwatch bands capable of detecting multi-touch events along the wristband. MultiBand allows users to utilize the wristband as a multi-touch surface that enables occlusion-free input on a smartwatch.

In this poster paper we contribute the concept, hardware and software components, early learned lessons of preliminary tests and discuss possible relevant applications and limitations of a multi-touch wristband.

2 Related Work

The limited screen size of smartwatches introduces occlusion and the fat finger problem, motivating research into extending the interaction space.

Prior research has explored the space around the device to address these limitations. Approaches range from mid-air gesture recognition [6, 7, 25, 27] or finger identification [10, 17] to utilizing the skin as an input surface [8, 11, 13, 15, 22, 28]. While effective, these methods are often not self-contained and rely on external hardware like tracking systems.

To keep the interaction self-contained, research has focused on the watch itself. Mechanical inputs like digital crowns or rotatable bezels are interaction methods for occlusion-free scrolling, yet they offer limited degrees of freedom [3, 9]. Work by Neshati et al. [16], Kumar et al. [14], and Reuter et al. [20] enhanced bezel interactions, while others extended input to the smartwatch case [4, 24, 26] or added additional functionality to the digital crown [1, 23]. However, these surfaces are inherently limited by the form factor of the smartwatch (case) and its mechanical input methods (bezel, crown).

The wristband offers a naturally large surface area for interaction and extending the input space. Prior work by Perrault et al. [18] introduced WatchIt, demonstrating wristband interaction. Similarly, Funk et al. [5] utilized a touch-sensitive band for text entry, and Saviot et al. [21] combined buttons and touchpads. Klamka et al. [12] added a display into the wristband.

While these works demonstrate the utility of the wristband, they often rely on resistive sensors, potentiometers, or discrete pressure sensors, limiting them to single-touch or pseudo-multi-touch interactions. Furthermore, prototypes often cover only specific (e.g. user-facing) parts of the wristband or are limited by a predefined and small number of touch-sensitive zones. Building upon these works, we introduce a continuous capacitive multi-touch surface along the wristband. This enables true multi-touch gestures and extends the interaction vocabulary.

3 Concept

Standard smartwatch interactions are constrained by the small display size and the screen occlusion. Physical mechanisms like the digital crown offer precision but have a limited input space. To address these limitations, we developed MultiBand, a concept that utilizes the smartwatch wristband as an extended, multi-touch surface.

We were inspired by Petersen et al. [19], Reuter et al. [20] and Stanke et al. [24] to apply touch-sensing technology to surfaces that usually do not sense touch. We use the same idea to utilize the band of a smartwatch as an input device, as already addressed in research [2, 5, 12, 18], but aimed to achieve full multi-touch along the band surface. By integrating capacitive sensing into the wristband, we expand the interaction space beyond the device's boundaries without obscuring the screen. A key aspect of our concept is the use of multi-touch sensing to enrich touch input on watches. This enables users to utilize the band as a touch surface and execute different functions based on grasp patterns or the number of fingers applied.

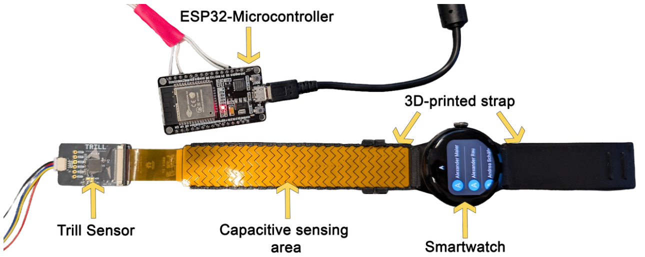

Figure 2: MultiBand prototype with custom-designed strap including capacitive sensing.

3.1 Prototype

To detect the number of fingers interacting with the smartwatch's wristband, we developed a functional prototype comprising a custom-built wristband and a companion smartwatch application.

3.1.1 Hardware Design. We designed a custom 3D-printed strap using PLA to ensure wearability while integrating the capacitive sensing. The strap is made of two parts. The longer strap (115mm x 24mm x 1.5mm) mounts a capacitive sensor with 30 distinct channels (Trill Flex by Bela[1]). The shorter one (69mm x 24mm x 0.5mm) features no technology and is used to connect to the longer strap. This design ensures the sensor remains fixed in position while allowing the strap to conform to the bending of the wrist. The sensor is wired to an ESP32 micro-controller and mounted on a Google Pixel Watch 2. The prototype is shown in Figure 2.

3.1.2 Software. The software consists of two main components: an ESP32 firmware and an Android smartwatch application developed using Jetpack Compose[2].

The micro-controller reads the capacitive sensor data via I2C. To ensure low-latency interaction, the ESP32 acts as a WiFi access point, processes the capacitive data, and transmits touch coordinates via UDP. The system achieves a stable transmission rate of 120 packets per second. Although the current Google Pixel Watch 2

[1] https://learn.bela.io/using-trill/working-with-trill-flex/
[2] https://github.com/moxdlab/MultiBand

display updates are limited to 30Hz, our implementation supports future smartwatch displays (up to 120Hz) without modification.

4 Preliminary Tests

To evaluate the feasibility of the MultiBand concept, we conducted preliminary user tests. The preliminary tests had the primary goal to evaluate the prototype, to find out whether participants can wear the watch with our custom wristband and successfully complete tasks that involve touching the MultiBand. We did no quantitative analysis on how well participants performed due to the early-stage prototype.

We adopted a sorted list task design similar to Perrault et al. [18] and Stanke et al. [24]: participants were required to select a specific target within an alphabetically sorted and grouped list.

4.1 Task and Procedure

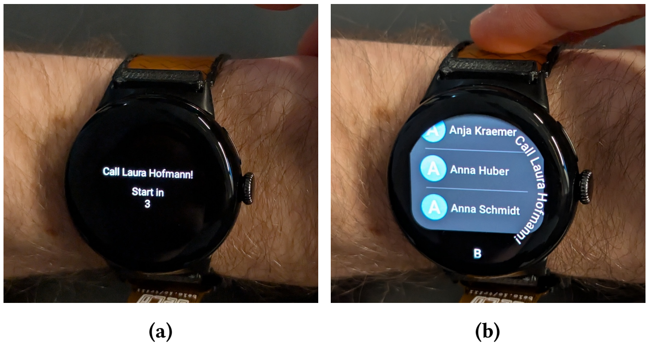

Figure 3: The task interfaces. The preparation screen (a) displays a countdown and the target task prompt. The task execution screen (b) shows the scrollable contact list with a visual cue on the side indicating the target.

Participants were seated at a table with their arm resting comfortably to ensure free movement of the wrist. The task required selecting a specific target contact within a mock contact list application containing 92 entries grouped alphabetically (see Figure 3). To navigate the list, participants utilized the MultiBand with two distinct scroll modes: Moving a single finger on the sensor mapped 1:1 to pixel movement on the screen, allowing for fine-grained control. Using two fingers triggered a *section-scroll*, which allows the user to fast-scroll between grouped sections (e.g., A to B in an alphabetized list) for rapid navigation. The participants could freely choose to use one or two fingers while solving the tasks. Each participant completed 30 tasks.

4.2 Insights

Before conducting the study, ethical screening was completed in accordance with local institutional regulations (formalized self-check). We then invited 18 participants (8 female) ranging in age from 15 to 52 years ($M = 24.6, SD = 8.2$), who were recruited by convenience sampling. 17 of them were right handed while 1 participant was left handed. 5 reported that they use a smartwatch on a daily basis. All participants provided informed consent. On average, participants completed the tasks within 35 minutes.

The tests revealed first insights for using MultiBand in scrolling tasks. One user reported that they generally like using the wristband (P16) and another reported that the "two-finger scroll works very well for faster scrolling" (P1). Additionally, another user mentioned that they prefer MultiBand over a crown because a crown can be "too small to use without effort" (P8).

However, these tests also highlight areas for improvement. The touch surface currently has a fixed length, which results in a surface that is too short or too long for wrists with a very large or very small diameter. A flexible sensor strap needs to be designed, which draws questions for a buckle and holes in the wristband or stretchable sensors. Moreover, the current sensor design utilizes a one-dimensional sensing axis, which makes two-finger input sensing impossible for certain finger placements.

Our test application currently has no visual or haptic feedback as soon as one or two fingers are placed on the band. Users receive visual feedback only after moving their fingers far enough to trigger visual changes. Also, our implementation disables input for other modalities such as the screen or crown input. For our preliminary tests this was intended, but it seems that users could benefit from multi-modal input, e.g. one user reported that they would like to "combine crown (fine-tuned interaction) and band (faster interaction)" (P1).

5 Discussion

Our early work on MultiBand and the preliminary user tests revealed that extending the interaction space to the wristband by adding multi-touch is a promising concept.

5.1 Applications for MultiBand

Beyond simple scrolling, we envision two primary categories of application scenarios: system-wide shortcuts and context-specific interactions.

5.1.1 System-wide Interactions. For global control, the MultiBand can utilize the number of detected fingers to trigger immediate shortcuts, reducing the need to navigate through menus on the small screen.

- **Global Shortcuts:** A multi-finger gesture, such as placing four fingers on the band, could launch frequently used or favorite apps like the contact list or music player services.
- **App Switching:** Compound gestures could facilitate multitasking. For example, holding one finger as an anchor point while sliding a second finger could cycle through active applications.

Since a wristband is exposed to constant contact with the body or environment, distinguishing intentional input is crucial. Mechanisms such as unlock gestures or a unique tapping pattern could serve as a safety lock to prevent unintended triggers.

5.1.2 Context-specific Interactions. Inside specific applications, MultiBand can offer context-specific control that avoids screen occlusion.

- **Media control:** As explored in previous work by Reuter et al. [20], gestures can map to media functions. A three-finger tap could toggle play/pause, while a two-finger slide

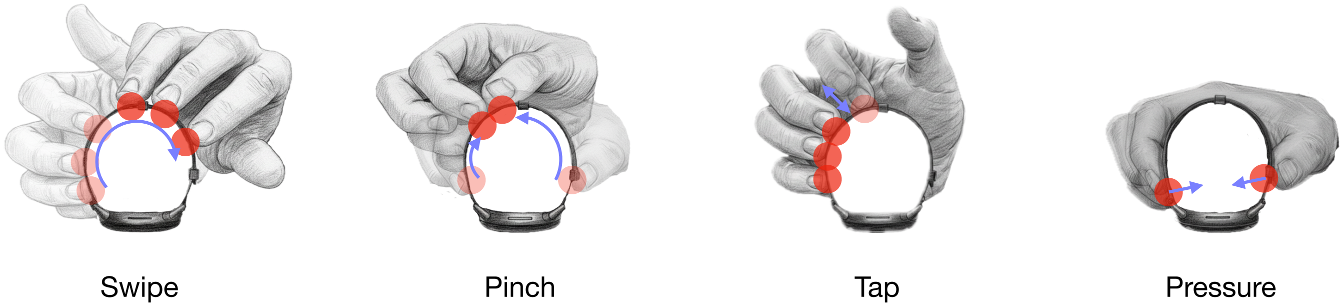

Figure 4: Types of gestures that the MultiBand hardware is capable to recognize.

gesture controls volume and a one-finger slide gesture seeks through a track.

- **Multi-Parameter Control:** In a timer or alarm application, the number of fingers could determine the granularity of the adjustment. A one-finger slide could adjust minutes, while a simultaneous two-finger slide adjusts seconds. This allows users to modify multiple parameters without using the screen.
- **Scrolling in lists:** In lists, the number of fingers can determine the scrolling speed or granularity. A one-finger slide could scroll through a list at a normal pace, while a two-finger slide accelerates the scrolling. In grouped lists, a two-finger slide could jump directly to the next section header, whereas a one-finger slide scrolls through the individual items.
- **Absolute Mapping:** While not related to multi-touch, the physical length of the wristband allows for absolute mapping. The start and end of the band could map directly to the start and end of a linear list or volume slider. This would enable users to instantly jump to coarse values (e.g., around 50% volume or letter M) which could reduce scrolling fatigue.

5.2 Possible Future Gestures for MultiBand

Beyond the proposed applications, the prototype hardware is capable to detect a different number of gesture types and their combinations. While currently not fully implemented in the software stack of the watch application, the prototype can technically distinguish the following types of gestures, see Figure 4: *Swipe:* Move any number of fingers along the touch surface. *Pinch / Spread:* Move two or more fingers closer to / farther away from each other. *Tap:* Place any number of fingers on the band and shortly touch the band with another finger (or multiple ones). *Pressure:* Apply pressure on the sensor with two or more fingers.

Combining and sequencing those gestures further expands the set of possible interactions with MultiBand. For instance, sequencing multiple different tapping gestures enables a PIN-like input for authentication applications. Furthermore, derived gestures are feasible. For example, rotating the wrist along a conductive surface (e.g. the user's arm or leg) allows executing rotational swipe inputs.

5.3 Limitations and Future Work

The preliminary tests revealed some limitations of MultiBand, which we will address in future work. The touch area of our wristband is attached to the longer part of the wristband. This limits the maximum possible length of our wristband: For very large wrist circumferences, the touch-area does not span the entire distance between the watch lugs. The prototype needs to be iterated so that the wristband has touch areas on both parts of the wristband. This will however result in overlapping capacitive touch stripes. Additional engineering is required to make the overlapping parts not activating them-self, while making sure that the wristband is able to be used on all wrist sizes.

Additionally, the capacitive sensor should be able to detect two fingers on both the x- as well as the y-axis of the sensor. In the current implementation, a two-finger touch is recognized only if multiple channels around one axis are activated. Two fingers side-by-side cannot be recognized in the current prototype. To enable two-dimensional touch recognition, a custom flex-PCB is needed, as the stock Trill Flex sensor, used in our prototype, only has single-dimensional capabilities. Future hardware iterations should also consider utilizing a smaller, battery-powered micro-controller which enables evaluation in more versatile contexts (e.g. for walking and running).

To evaluate the scrolling performance using MultiBand, future work needs to incorporate a performance study. Results of Kerber et al. [9] show that users prefer the crown of a smartwatch for list scrolling tasks, making it a good contender for a baseline variant. The application itself should be improved to incorporate haptic as well as visual feedback, because a two-finger scroll currently has no direct feedback, besides scrolling far enough to trigger a visual jump in the contact list. In addition, future studies should evaluate whether one or two fingers are more sufficient for a faster or slower scroll on the wristband. Furthermore, applications like the ones we mentioned, as well as unlock mechanisms to prevent accidental touch, should be studied.

6 Conclusion

In this work we present MultiBand, a capacitive wristband for smartwatches which allows multi-touch input that extends around the wrist. This enables users to perform occlusion-free touch input that was not possible before: multi-touch gestures performed on the wristband of a smartwatch.

We contribute the soft- and hardware components, first insights of using MultiBand in a scrolling task and potential application areas for multi-touch capable wristbands.

Acknowledgments

All images were originally created by the authors. Google Nano Banana was utilized in Figures 1 and 4 to apply a sketch filter to hand photographs.

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