TaskHerder: A Wearable Minimal Interaction Interface for Mobile and Long-lived Task Execution

Florian Heller
florian.heller@uhasselt.be
Hasselt University - tUL - Flanders Make
Expertise Centre for Digital Media
Diepenbeek, Belgium

Kris Luyten
kris.luyten@uhasselt.be
Hasselt University - tUL - Flanders Make
Expertise Centre for Digital Media
Diepenbeek, Belgium

ABSTRACT

Notifications have become a core component of the smartphone as our ubiquitous companion. Many of these only require minimal interaction, for which the smartwatch is a helpful companion device. However, its design and placement is influenced by its traditional ancestors. For applications where the user is constrained because of a specific usage situation, or performs tasks with both hands simultaneously, interaction with the smartwatch can be cumbersome. In this paper, we propose a wearable armstrap for minimal interaction in long-lived tasks. Placed around the elbow, it is outside the hands' proximal working space which reduces interference. Its flexible e-ink display provides screen space to provide overview information at minimal energy consumption for longer uptime. We designed the wearable for a professional use-case, meaning that is can easily be placed above protective clothing as its flexible round shape easily adjusts to various diameters. Capacitive touch sensing allows gesture input even under rough conditions, e.g., with gloves.

CCS CONCEPTS

• **Human-centered computing → Interaction devices**; **Mobile devices**; *Ubiquitous and mobile computing systems and tools.*

KEYWORDS

Mobile interaction, e-paper, wearables

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1 INTRODUCTION

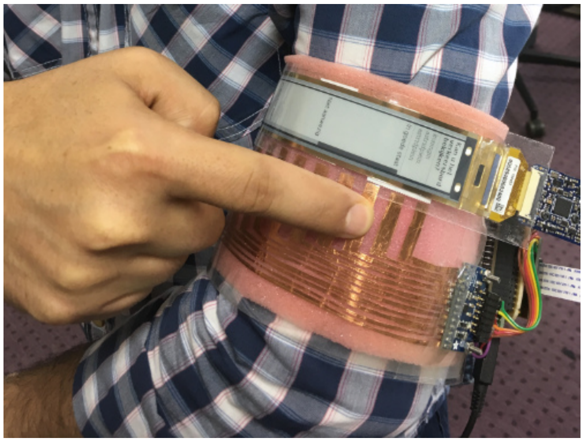

Figure 1: Our wearable minimal interaction display. The flexible e-ink display is at the top, the sensing lines for the capacitive touch input are at the bottom.

In nowadays work environments, the worker has to react to various notifications, many of which only require a simple acknowledgement or a selection from a list of items. The smartwatch seems like a predestined candidate, but has some important limitations, such as a limited display size, limited battery lifetime for continuous usage, and a display that is located at the wrist can be hard to access when performing manual tasks. Based on an existing study of possible placements for wearable devices [5], we designed and developed a device that offers an alternative to the wrist-located ones for informing and interacting with workers that perform manual labor tasks.

In this paper we present *TaskHerder*, a wearable interface specifically targeted towards minimal interaction over a long

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period of time, such as providing information on upcoming tasks. Its flexible e-ink display adapts to the body shape and provides more screen space than a typical wearable device without the discomfort of attaching a fixed, rigid screen on the arm. *TaskHerder* combines a flexible e-ink display with a custom-made 12-channel capacitive touch sensor that enables input in form of basic taps and simple gestures, even when wearing gloves. By placing it higher on the arm, close to the elbow, it is outside the hands proximate working space, reducing potential conflicts with a manual task to be executed.

TaskHerder is designed as a companion device to be used while performing a manual primary task. For example, we have designed this device in a context where mailmen use it to answer simple questions on their current surroundings while on their delivery round, capturing subjective environmental information not accessible to IoT sensors. An assembly line worker might use it to confirm the completion of a specific step and move on to the next instruction. In both cases, the hands are occupied with a primary task and interruptions to this task should be kept to a minimum.

2 RELATED WORK

While commercial products mostly focus on the form factor of a watch placed around the wrist, the research community has investigated the arm as a potential interaction surface. Harrison et al. [5] explored various display placements on the body, and draw up a design space of suitable and less suitable display placements. It clearly shows the upper arm has a lot of potential for deploying interactive displays.

On the input side, Weigel et al. [11] and Nittala et al. [8] propose a technology to add custom capacitive sensing areas directly onto the skin. Protective clothing, as used in our industrial use-cases, might interfere with such interaction surfaces. The GestureSleeve [10] provides a large, flexible resistive touchscreen that covers the lower arm. With its 16×16cm input area, it is designed to extend the touch sensing area which is very limited in case of touch interaction on a smartwatch. Pinstripe [7] builds on two affordances inherent in fabric: grabbing and rolling. The user activates the textile sensor by grabbing a fold into it. Subsequent rolling of the fold is mapped to relative changes in linear values, e.g., the volume of your MP3-player. Grabrics [4] is an extension of this concept to two dimensions. The resistive sensor can detect the angle of the fold relative to the arm, which can be used as an additional input-parameter, e.g., to change the value of various parameters.

LumiWatch [12] extends the interaction space of a smartwatch onto the lower arm. A micro-projector can show additional content while an array of time-of-flight sensors detects touch interaction on the arm itself. Similarly, Skinput [6] turns the user's arm into an interactive surface by projecting the user interface onto it and sensing finger input using sound propagation. Both systems, however, only work on the bare skin, making their application in an outdoor environment difficult.

3 DESIGN RATIONALE

The design of our wearable device is heavily influenced by the primary task of the mailmen, which is to deliver mail. Depending on the area, this task is either accomplished by foot, by bicycle, by scooter, or by car. In the case of the car, the device used for the crowdsourcing assignments can be mounted inside, and thus does not require our special attention. In the other cases, however, at least one hand is occupied, either by holding a stack of mail to deliver, or by the handle of the scooter or bike. We focus specifically on the pedestrian mailmen, nevertheless, our work also applies to the other means of transportation.

The pedestrian mailmen carry a pile of magazines, envelopes, and other items to deliver on their non-dominant arm. This situational impairment influences the possible interactions for the secondary task of completing the crowdsourcing requests. Currently, the mailmen are equipped with a mobile terminal that consists of a ruggedized smartphone which could serve the purpose as data entry terminal, but interacting with it means that it needs to be picked up from the holster. A potentially ruggedized smartwatch would be an ideal companion device, but interacting with it is difficult as the arm holding the stack of mail items would need to be turned such that the smartwatch faces the user. With our wearable interface we aim at overcoming the limitations of the smartwatch for this special application purpose.

Requirements

To give the mobile workers the means to plan their crowdsourcing tasks, the device should show a list of the upcoming ones. This gives the workers the opportunity to make informed decisions on where to park their trolly or their bike when delivering mail to a series of households. For this purpose it should be well visible and readable while performing the primary task. The interface should also support answering simple multiple-choice questions directly on the device, making it unnecessary to pick up the mobile terminal. This feature needs to work under rough environmental conditions, meaning that it should be useable with gloves.

Based on these requirements and previous work on the visibility of wearable displays [5], we decided to add a display with a capacitive touch sensor near the elbow, either on the lower upper arm or on the upper lower arm. In order to provide enough screen space to show overview information, the display should be flexible to adapt to the arm's surface. As it is supposed to continuously show information during the mailman's round, power consumption needs to be taken into consideration. We found plastic e-paper displays an interesting solution that fit our requirements. Their flexibility is sufficient to be wound around the arm and its bi-stable technology only requires power when the screen content is updated.

4 IMPLEMENTATION

For our prototype, we used a flexible 4.9inch Lectum e-paper display (EPD) from Plastic Logic [9] with a resolution of 720 × 120 pixels. It uses an Epson S1D13541 power control circuit directly attached to the display on a SD-card sized PCB. This controller is connected to a PocketBeagle [1] board that runs the EPD software needed to update the content of the display. In the spirit of reproduceable research, we have made our modified version of the software which is adapted to the pinout of the PocketBeagle, available on GitHub[1]. Figure 2 shows the schematics connecting the PocketBeagle to the EPD control circuit. 15 pins of the PocketBeagle are connected to a 24-pin FPC connection to the display controller board. As the PocketBeagle does not provide a sufficient power supply to drive the display, we connected it directly to the 5V main power supply.

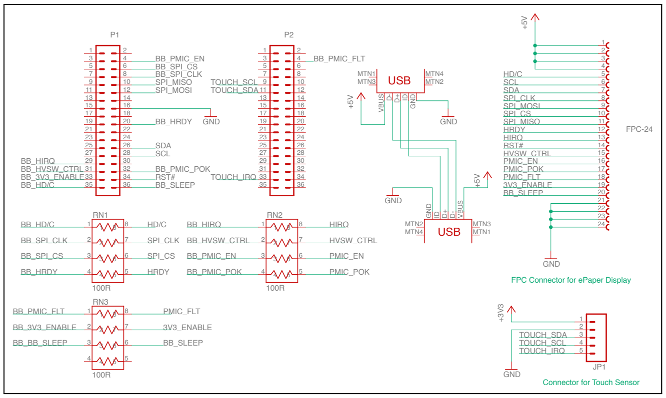

Figure 2: Compared to the original Plastic Logic Ruddock board, we adapted the wiring to the pinout of the PocketBeagle, added the USB-Connection to tap onto the 5V power supply, and added a 5-pin connector for the touch sensor.

Capacitive touch is provided by means of an NXP MPR121 12-channel touch sensor. The touch electrodes are made of copper tape and are placed right next to the right side of the display. The side on which the touch electrodes are placed should be adapted to the handedness of the user to avoid occlusions of screen content by the hand. The MPR121 is directly connected to an i2c-bus of the BeagleBone and a dedicated interrupt pin. This interrupt pin is pulled high by the MPR121 whenever it detects an event, which reduces the necessary communication to a minimum and saves power.

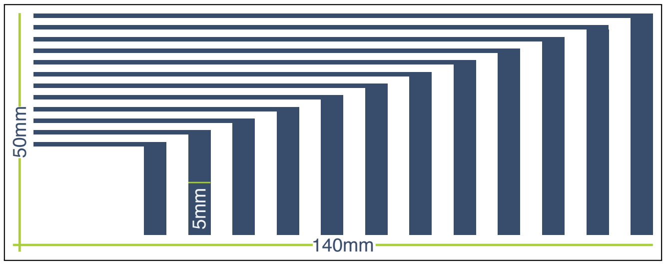

Figure 3: The touch electrodes we cut out of copper tape. The connector was directly soldered to a pin header to connect it to the breakout board.

The PocketBeagle with its Linux operating system made it easy to prototype the functionality and the necessary communication. However, the current consumption in idle state is 200mA at 5V, which is too high for a wearable device. When moving to a production-level implementation, the PocketBeagle should, therefore, be replaced with a suitable platform targeted towards mobile applications.

Software

The software stack, written in Python, consists of four components: an HTTP-server to take requests and return responses, a gesture recognizer that interprets the data from the touch sensor, a converter to turn text-based content into images to be shown on the display, and a manager that checks wether the entire screen or only part of it has to be updated.

Communication. Tasks can be transmitted to the device by means of HTTP POST-requests that hand over an XML-file with all specifics of the task. In our example use-case with the mailmen, this includes the question to be answered, the possible answers, the timeframe during which the question is valid, and the associated geographical area. Answers to the tasks are stored as XML files that can be retrieved once the mobile worker returns to the delivery center after her round.

Image Conversion & Display. Whenever a question is to be answered, the image conversion unit takes the textual information and turns it into a series of images that can be shown on the display. This includes a full-screen image with the question and the answers, as well as subsegments that indicate the selection of a certain answer. This segmentation is useful as updating part of the EPD is faster than updating it on the entire surface. An EPD can be updated in two ways: either by setting the affected pixels to their designated value directly, or by cycling through a series of black/white changes. Setting the values directly is faster, but during this

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[1] https://github.com/florianheller/pl-bb-epd

fast update, residual images from previous content can remain visible. From time to time, it is therefore necessary to cycle through a series of full color changes to remove these artifact.

The impact of these artifacts is dependent on the content elements affected. For example, we indicate a selection using a black rectangle along the selected answer. This minimizes the affected area to be updated once a selection changes, and the artifacts that remain after fast updates only consists of a small halo around the rectangle. This does not affect the readability of the on-screen text while the selection state remains clearly visible.

Touch/Gesture Recognition. A third component analyses the touch signals as reported from the touch sensor and reacts accordingly. Based on informal trials, we reduced the input alphabet to two gestures: tapping for selection and a grab-gesture to confirm. For the tapping, the 12 input electrodes are grouped based on the number of possible answers. To confirm the selection and log the answer, the users grabs around the armstrap, covering 8 of the 12 electrodes. The two-step selection serves to prevent accidental input. First, because interactions with wearable sensors are subject to more errors than regular touchscreen interactions. The movement, placement and type of usage can lead to sensing errors or noise in the sensing data. Second, because the sensing area is continuously exposed and input could thus be triggered by unintended contacts, initiated by the user or other bystanders.

5 DISCUSSION & FUTURE WORK

In this paper we presented *TaskHerder*, a wearable device for minimal interaction during long-lived tasks. Its design is based on a flexible e-Paper display that allows to present constant information, in different light conditions and over a long period of time with minimal power consumption. Capacitive touch input allows for simple gesture input directly next to the display, and allows us to avoid the "fat-finger"-problem. *TaskHerder* is outside the working area of the hands, which reduces the risk of injury or accidents in contrast to, e.g., a smartwatch.

TaskHerder has been validated for long-lived tasks in which the hands of the user are often occupied. We used *TaskHerder* in a context where it was used to give mailmen the means of completing mobile crowdsourcing tasks without major interference to their primary task of delivering mail. Our validation showed that this kind of interface is suitable for a number of other contexts where the user has to achieve a task that occupies both hands, and in different light conditions. Our setup will be further refined for assembly line operators in a factory setting, to inform and guide them through sets of complex assembly tasks.

Future work includes validations of this interaction concept in a wider variety of contexts. We ran interaction studies to validate the use of our armstrap while carrying bulky items and as control interface for AR visualization in an assembly line task. The results showed that interaction with the armstrap is on par with the smartwatch regarding visibility and access times, and even better in the cases where people have to handle large items. This means that we can move the user interface, and thus the interactions, away from the traditional placement on the wrist. As the display wraps around roughly the half arm, small pieces of content could be moved on screen according to the arm's orientation to ease reading [2].

The hardware needs to be further optimized for professional usage. Our goal was to create a prototype setup to explore the use of sleeve-based displays for long-lived tasks that occupy at least one and often both hands in different conditions. A future version of our prototype should be run on a more energy-efficient platform to take advantage of the low-power components we currently use. MicroPython [3] is a microcontroller optimized port of the Python3 language that can be used to accelerate the transition from prototype to final product. The EPD-driver is also available for the MSP430 microcontroller platform. Furthermore, the effect of using a curved E-ink display on the type of information that can be conveyed to the user needs to be explored.

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