

Personalized Wearable Interactions with WearSkill

Ovidiu-Andrei Schipor

MintViz Lab, MANSiD Center
Ștefan cel Mare University of Suceava
Suceava, Romania
ovidiu.schipor@usm.ro

Laura-Bianca Bilius

MintViz Lab, MANSiD Center
Ștefan cel Mare University of Suceava
Suceava, Romania
laura.bilius@usm.ro

Ovidiu-Ciprian Ungurean

MintViz Lab, MANSiD Center
Ștefan cel Mare University of Suceava
Suceava, Romania
ungurean.ovidiu@gmail.com

Alexandru-Ionuț Șiean

MintViz Lab, MANSiD Center
Ștefan cel Mare University of Suceava
Suceava, Romania
alexandru.siean@usm.ro

Alexandru-Tudor Andrei

MintViz Lab, MANSiD Center
Ștefan cel Mare University of Suceava
Suceava, Romania
tudor.andrei@usm.ro

Radu-Daniel Vatavu

MintViz Lab, MANSiD Center
Ștefan cel Mare University of Suceava
Suceava, Romania
radu.vatavu@usm.ro

ABSTRACT

WearSkill is our web-based application for personalized input with wearables that acts as a middleware to control connected devices that support Wi-Fi and WebSocket communications, e.g., control the smart lighting system with the smartwatch. WearSkill primarily addresses users with upper-body motor impairments, for whom it enables personalized recommendations for input modalities (touch, motion, and voice) and three categories of wearables (smartwatches, rings, and glasses) based on users' self-reported motor impairments.

CCS CONCEPTS

• Human-centered computing → Accessibility technologies.

KEYWORDS

Wearables, motor impairments, accessibility, middleware

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1 INTRODUCTION

The global market size for wearable devices was of USD 40.65 billion in 2020, according to an October 2021 Grand View Research Report.¹ This increased interest for wearables is motivated by the many applications and services they enable, such as for personal health and fitness tracking and integration with connected devices, but also their always availability coupled with the diversity of form factors and locations on the body where to wear them; see Seneviratne *et al.* [4] for a survey.

¹www.grandviewresearch.com/industry-analysis/wearable-technology-market

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1.1 Accessibility Challenges

Interactions with wearables that are not designed within an accessibility first culture² lead to accessibility challenges because of the assumptions that are made implicitly about users' abilities [8]. For example, most of the interactions with smartwatches and glasses use touch and gesture input, which may prove challenging for users with upper-body motor impairments. Different types of motor impairments determine different motor abilities to use the fingers, wrist, arm, and neck muscles to control wearable devices. For instance, people with Spinal Cord Injury (SCI) at vertebra C7 can move their arms and some of the fingers and, thus, may find viable gesture input on smartglasses, watches, or rings. SCI located at vertebrae C5/C6 render finger movements impossible, but arms can be controlled to operate smartwatches with motion gestures. People with SCI at C4 have lost their ability to move their arms, but can still perform movements of the head, which the IMU sensors from smartglasses can pick up and recognize. People with muscular dystrophy, who have also lost the ability to move their arms because of the large muscle groups being affected, can still control the small muscles in their fingers and, thus, smart ring input might be viable. In this context, personalization of input modalities is key for accessible interactions with wearables. Our WearSkill application, presented next, was designed and developed in this mindset.

2 WEARSKILL

WearSkill has been a two-year effort that involved documenting, running studies, and software development. In the following, we present our approach (Subsection 2.1) and the technical implementation (Subsection 2.2) and features (Subsection 2.3) of WearSkill.

2.1 Approach

We adopted a systematic approach consisting of four steps: (1) analysis of the state of the art in accessible wearable interactions for users with motor impairments, (2) user studies to understand input performance with and preferences for wearables, (3) software development, and (4) open source initiative, described next.

2.1.1 In-depth analysis of the state of the art. In a systematic literature review of wearable interactions for users with motor impairments [5], we found limited research available on this topic

²<https://devops.com/how-to-build-accessibility-first-design-culture>

(e.g., only four papers on smartwatch input), a disproportionate interest for hand gestures compared to other input modalities, and little involvement of participants with motor impairments in studies about wearable interactions (Mdn=6.0, M=8.2 participants per study). Based on our findings, we proposed four WISE recommendations to increase the accessibility of wearables: (W) diverse designs of wearables, (I) new input modalities and techniques, (S) more user studies, and (E) extending wearable interactions with other devices.

2.1.2 Understanding user input performance with wearables and preferences for wearables. In a first study [7] with N=14 participants with upper-body motor impairments, we examined touchscreen stroke-gestures and mid-air motion-gestures articulated with devices worn on the wrist, finger, and head. We found that users with upper-body motor impairments took twice as much time to produce stroke-gestures on wearable touchscreens compared to users without impairments, but articulated motion-gestures equally fast and with similar acceleration characteristics. In a second study [6], we elicited N=21 people with upper-body motor impairments for their preferences to use wearables to access diverse applications and services of ambient intelligence environments, including control of electronic devices and home appliances. We found high preferences for smartwatches for the control of smart homes and for rings and bracelets for making payments and interacting with public systems.

2.1.3 Design and development of WearSkill. In the context set by our WISE framework [5] and our empirical findings [6,7], we designed WearSkill as a middleware web-based software for personalized input with wearables; see details in Subsections 2.2 and 2.3.

2.1.4 Open source. Our plan is to release WearSkill as an open-source software to foster further developments in the community.

2.2 Technical Implementation

WearSkill is a web-based application compatible with the WISE framework [5] that leverages the ISO/IEC 25010:2011 SQuaRE model,³ from which it adopts six quality requirements directly relevant to wearables (i.e., modularity, reusability, interoperability, replaceability, appropriateness, and learnability) and uses three technological approaches (web-based design, JavaScript language and supporting platforms, and HTTP and WebSocket as communications protocols) [2,3]. We developed the UI on top of Vue.js,⁴ a progressive JavaScript framework that enables clear separation between views and view-models, while the back-end models run on Node.js.⁵

2.3 Features

WearSkill implements personalized input with wearable devices that have built-in Wi-Fi and support WebSocket communications. Personalization means (i) flexible associations between wearables and input modalities, e.g., use motion input for the smartwatch and voice input for smartglasses, (ii) custom associations between input commands and system functions, e.g., directional swipes on the smartwatch for controlling the TV audio volume, and (iii) personalized recommendations for input modalities based on users' self-reported impairments, for which we employed the eleven categories

from [1], i.e., slow movements, spasms, low strength, tremor, poor coordination, rapid fatigue, difficulty gripping, difficulty holding, lack of sensation, difficulty controlling direction and distance, respectively. In a study with N=21 people with motor impairments [2], we found that recommendations provided by WearSkill matched 85.3% of users' preferences for input modalities and wearables. In its current implementation, WearSkill supports stroke gestures (e.g., symbols drawn on the touchscreen of a smartwatch, such as letter "M" to effect "Menu"), motion gestures (e.g., movements of the head), and voice input (that can be captured, for instance, with the microphone embedded in a pair of glasses).

2.4 Demonstration

WearSkill supports integration of connected appliances, e.g., smart lighting for the home, that have built-in Wi-Fi and come with a programmable platform supporting WebSocket communications. When these conditions are met, WearSkill acts as a middleware platform and triggers a system function on the connected appliance following input on the wearable. To test WearSkill, we developed client web applications for three wearables: Samsung Galaxy Watch 3, Gear Fit 2 (which we mounted on a custom 3D printed support to be used as a smart ring [7]), and the Vuzix Blade smartglasses. We also developed two applications for controlling YouTube (laptop connected to a large TV set) and the Philips Hue Go smart lights (Android app on a smartphone). A video demonstration of WearSkill is available here: <https://www.youtube.com/watch?v=sZECuT2bSo8>. Future work envisions integration of other wearables and connected appliances. To foster such developments in the interested community, we plan to release WearSkill as open-source software.

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³<https://www.iso.org/standard/35733.html>

⁴<https://vuejs.org>

⁵<https://nodejs.org/en>