MobiTouch: Enhancing Pneumatic Wearable Haptics with Vibrotactile Actuation

Mark Kruijthoff
Delft University of Technology
Delft, Netherlands
kruijthoffmark@gmail.com

Abdallah El Ali
Centrum Wiskunde & Informatica (CWI)
Amsterdam, Netherlands
aea@cwi.nl

Himanshu Verma
Delft University of Technology
Delft, Netherlands
h.verma@tudelft.nl

Sebastian Günther
Urban Software Institute
Darmstadt, Germany
research@sebastian-guenther.com

Kaspar Jansen
Delft University of Technology
Delft, Netherlands
k.m.b.jansen@tudelft.nl

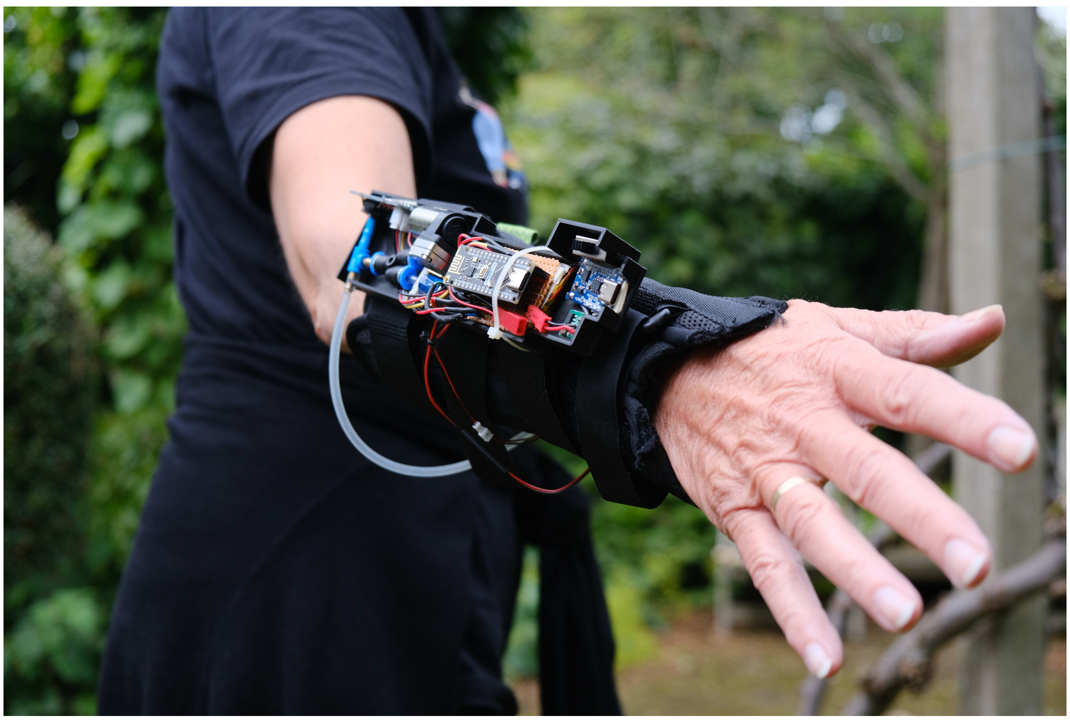

Figure 1: MobiTouch prototype on the wrist.

Abstract

MobiTouch is a wearable haptic device that integrates pneumatic and vibrotactile technologies to enhance touch sensations. The system addresses the slow responsiveness of small pneumatic components by compensating with vibrations, allowing for more diverse touch patterns. The wrist prototype operates wireless, is powered by a rechargeable battery, and features customisable touch patterns through an external controller. MobiTouch's design improves portability and responsiveness for haptic pneumatic wearables, offering potential applications in affective touch and wireless tactile transmission.

CCS Concepts

• **Human-centered computing** → **Mobile devices**; **Haptic devices**.

Keywords

Haptic, Wearable, Pneumatic, Vibrotactile, Wireless

MUM '24, December 01–04, 2024, Stockholm, Sweden

ACM ISBN 979-8-4007-1283-8/24/12
https://doi.org/10.1145/3701571.3703370

ACM Reference Format:
Mark Kruijthoff, Abdallah El Ali, Himanshu Verma, Sebastian Günther, and Kaspar Jansen. 2024. MobiTouch: Enhancing Pneumatic Wearable Haptics with Vibrotactile Actuation. In *International Conference on Mobile and Ubiquitous Multimedia (MUM '24), December 01–04, 2024, Stockholm, Sweden.* ACM, New York, NY, USA, 3 pages. https://doi.org/10.1145/3701571.3703370

1 Introduction

Wearable technology can serve various purposes, from basic time-keeping to advanced functions like enhancing our surroundings through head-mounted displays. One specific area that has captured the attention of researchers is haptic pneumatic wearable technology. Pneumatic technology utilises pressurised air for inflation or movement, offering wearables flexibility, comfort, and versatility. Unlike many commercially available wearables that may feel rigid and unnatural over time, pneumatic technology enables more life-like behaviour, such as mimicking touch or hugs in affective touch applications that leverage a range of modalities (from vibration to pneumatic to thermal feedback) [1, 3–9].

However, integrating this technology into fully wearable devices has proven difficult due to the lack of responsiveness with smaller pneumatic components, which limits the range of effective touches that can be portrayed [3, 6, 11]. To address this issue, we propose a system that enhances pneumatics with vibrotactile technology. By compensating for the inflation time of the pneumatic component with vibrations, the system's responsiveness is increased, allowing for the creation of more varied touch patterns. This allows a haptic pneumatic system to be fully tetherless and for field-testing, as opposed to testing in pre-defined situations [2, 3].

2 MobiTouch Prototype

2.1 Wrist Prototype

MobiTouch is a fully wearable system designed to deliver touch sensations to the wrist through a combination of pneumatic and vibrotactile actuation (see Figure 1). In this prototype, a pneumatically actuated airbag, vibrotactile motor, and force-sensing resistor (FSR) sensor are integrated into a stack positioned on the wrist inside a sleeve. When the airbag inflates, it applies pressure to the wrist, simulating touch, which is detected by the FSR sensor (see Figure 2). The sensor's output is inverted to drive the vibrotactile actuator, meaning that when the airbag exerts minimal force, the vibrations are at their strongest. Consequently, as the pressure in the airbag increases, the vibration intensity decreases, effectively compensating for the slower responsiveness of the pneumatic component.

This allows the creation of more varied touch patterns ranging from long presses to short taps while retaining portability with small pneumatic components.

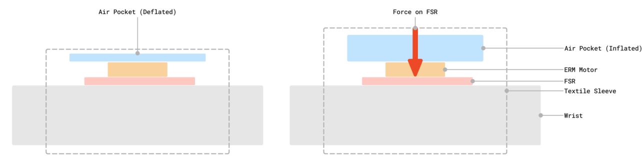

Figure 2: Airbag inflation resulting in changing FSR-values, which is used to drive the vibrotactile actuator and accurately compensate for pressure exerted by the pneumatic system.

In this design (see Figure 3), a small air pump (RS PRO Gas Compressor Pump 702-6898) and a valve (DC 5V One Way Exhaust Valve) were used for inflating and deflating the 40 x 40 mm airbag. To establish wireless communication for transmitting touch, an NRF24L01 module integrated with an Arduino Nano was utilised on both the wrist prototype and the external controller. An air pressure sensor was used to measure the internal air pressure, preventing the system from over-inflating. This sensor alongside the FSR could be used to register user touch inputs, potentially allowing for bi-directional tactile communication. Additionally, to make the device fully wireless, it is powered by an 800 mAh Li-Po battery, which can be recharged using a TP4056 USB-C module. The battery (3.7 V) powers the Arduino by raising its voltage to 5 V using an MT3068 step-up module.

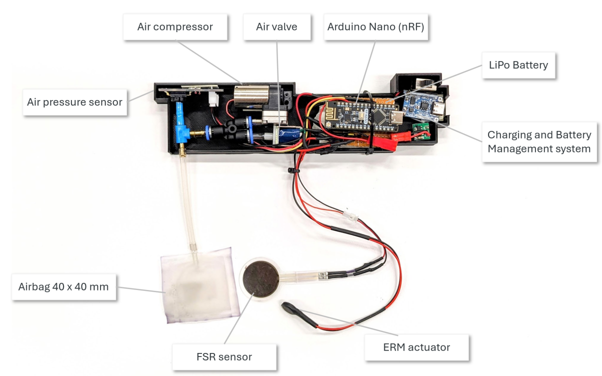

Figure 3: Component Overview of the Wearable Device.

2.2 Wireless Controller

A wireless controller was developed that allows for programming touch patterns and directly transmitting touch wirelessly to the wearable device (see Figure 4).

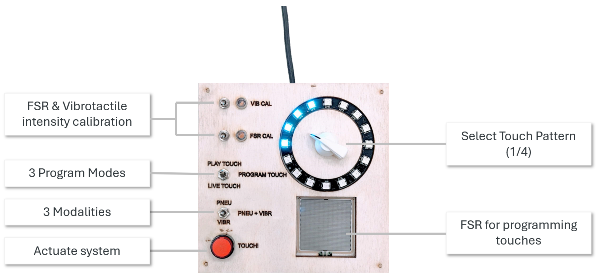

Figure 4: Wireless Controller able to program and directly transmit touches to the wrist-wearable.

2.2.1 *Programming of Touch Patterns.*

The controller offers three program modes: play, program touch, and live touch. The play mode plays the selected pattern, program touch is used to create a touch pattern, and live touch allows the user to directly transmit a simulated touch by pressing the onboard FSR.

2.2.2 *Calibration Steps.*

For the device to perform correctly, two calibration steps are needed. Firstly, users must match the vibrotactile actuator's intensity to the airbag's pneumatic inflation using a potentiometer to ensure one modality does not overpower the other. These settings are influenced by personal preferences as well as external factors such as pressure applied from clothing [10, 12]. A second calibration step is required to map the minimum and maximum FSR values while being respectively fully deflated and inflated.

2.2.3 *Modality Selection.*

The lower switch allows users to choose from three different modalities: pneumatic only, pneumatic plus vibrotactile, and vibrotactile only. This enables users to experience the various modalities offered by the system.

3 Conclusion

By integrating both pneumatic and vibrotactile components, this system is tetherless and addresses the limitations of responsiveness inherent in smaller pneumatic devices. The combination of these technologies allows for a broader range of tactile experiences, from subtle taps to longer presses, while maintaining portability and wireless functionality. MobiTouch provides a valuable tool for researchers conducting in-field testing in areas like wireless touch transmission and affective touch applications.

References

[1] Yu Chen, Yiduo Yang, Mengjiao Li, Erdong Chen, Weilei Mu, Rosie Fisher, and Rong Yin. 2021. Wearable Actuators: An Overview. *Textiles* 1, 2 (2021), 283–321. https://doi.org/10.3390/textiles1020015

[2] Kyung Yun Choi, Jinmo Lee, Neska ElHaouij, Rosalind Picard, and Hiroshi Ishii. 2021. Aspire: clippable, mobile pneumatic-haptic device for breathing rate regulation via personalizable tactile feedback. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems.* 1–8.

[3] Alexandra Delazio, Ken Nakagaki, Roberta L Klatzky, Scott E Hudson, Jill Fain Lehman, and Alanson P Sample. 2018. Force jacket: Pneumatically-actuated jacket for embodied haptic experiences. In *Proceedings of the 2018 CHI conference on human factors in computing systems.* 1–12.

[4] Abdallah El Ali, Xingyu Yang, Swamy Ananthanarayan, Thomas Röggla, Jack Jansen, Jess Hartcher-O'Brien, Kaspar Jansen, and Pablo Cesar. 2020. ThermalWear: Exploring Wearable On-chest Thermal Displays to Augment Voice Messages with Affect. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '20).* Association for Computing Machinery, New York, NY, USA, 1–14. https://doi.org/10.1145/3313831.3376682

[5] Hesham Elsayed, Martin Weigel, Florian Müller, Martin Schmitz, Karola Marky, Sebastian Günther, Jan Riemann, and Max Mühlhäuser. 2020. VibroMap: Understanding the spacing of vibrotactile actuators across the body. *Proceedings of the ACM on Interactive, Mobile, Wearable and Ubiquitous Technologies* 4, 4 (dec 2020), 1–16. https://doi.org/10.1145/3432189

[6] Sebastian Günther, Mohit Makhija, Florian Müller, Dominik Schön, Max Mühlhäuser, and Markus Funk. 2019. PneumAct: Pneumatic Kinesthetic Actuation of Body Joints in Virtual Reality Environments. In *Proceedings of the 2019 on Designing Interactive Systems Conference.* ACM, New York, NY, USA, 227–240. https://doi.org/10.1145/3322276.3322302

[7] Sebastian Günther, Florian Müller, Dominik Schön, Omar Elmoghazy, Max Mühlhäuser, and Martin Schmitz. 2020. Therminator: Understanding the Interdependency of Visual and On-Body Thermal Feedback in Virtual Reality. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems (CHI '20).* ACM, New York, NY, USA, 1–14. https://doi.org/10.1145/3313831.3376195

[8] Sebastian Günther, Dominik Schön, Florian Müller, Max Mühlhäuser, and Martin Schmitz. 2020. PneumoVolley: Pressure-based Haptic Feedback on the Head through Pneumatic Actuation. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems (CHI EA '20) (CHI '20).* ACM, New York, NY, USA, 1–10. https://doi.org/10.1145/3334480.3382916

[9] Alice C Haynes, Annie Lywood, Emily M Crowe, Jessica L Fielding, Jonathan M Rossiter, and Christopher Kent. 2022. A calming hug: Design and validation of a tactile aid to ease anxiety. *Plos one* 17, 3 (2022), e0259838.

[10] Jihong Hwang and Wonil Hwang. 2011. Vibration perception and excitatory direction for haptic devices. *Journal of Intelligent Manufacturing* 22 (2011), 17–27.

[11] Henning Pohl, Peter Brandes, Hung Ngo Quang, and Michael Rohs. 2017. Squeezeback: Pneumatic compression for notifications. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems.* 5318–5330.

[12] Ying Zheng and John B Morrell. 2012. Haptic actuator design parameters that influence affect and attention. In *2012 IEEE Haptics Symposium (HAPTICS).* IEEE, 463–470.