# Towards Understanding the Usability of Vibrotactile Support for Indoor Orientation

Giulio Mori
CNR-ISTI, HIIS Laboratory
Pisa, Italy
giulio.mori@isti.cnr.it

Fabio Paternò
CNR-ISTI, HIIS Laboratory
Pisa, Italy
fabio.paterno@isti.cnr.it

Carmen Santoro
CNR-ISTI, HIIS Laboratory
Pisa, Italy
carmen.santoro@isti.cnr.it

## ABSTRACT

This study aims to understand the potential of using vibrotactile stimulation for indoor orientation in complex, unfamiliar buildings. Four vibrotactile prototypes have been analysed and tested in initial trials in order to investigate the benefits and the problems of each solution. The main goal of this study is to reach a better understanding of the design aspects that make a vibrotactile solution intuitive and effective.

## CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)** → Interaction devices → Haptic devices

## KEYWORDS

Vibrotactile, Orientation & Navigation, Usability

## 1 INTRODUCTION

In vibrotactile user interfaces, vibrations are conveyed by actuators that transform an electrical signal into mechanical motion. The way in which vibrations can vary depends on several parameters including intensity, frequency, waveform, duration, rhythm of temporal patterns, spatial location on the body. However, the large array of vibrational cues that could potentially be afforded by combining all such parameters is in reality more limited due to some factors, including the type of vibrotactile motors actually used (especially in wearable and cost-effective solutions), and the vibrotactile sensations that in the end can actually be perceived by humans. The coding of the messages transmitted by the vibration on the skin can be pictorial (direct, self-explanatory) or codified (where the connection between the stimulus and its corresponding meaning must be learned as encoded by an alphabet) [1]. When pictorial coding is used for orientation, users can easily map vibration positions to directional concepts, so a vibration in the left or right part of the body can be intuitively interpreted as an indication to turn left or right. Since frequencies of several vibration motors could interfere with each other [2], it is recommended to place the motors at an appropriate distance to distinguish the different signals [1, 2]. Studies showed that people are able to easily locate vibrations if they are presented to the right/left, back/forward of the body [1], and vibrotactile stimuli can be well recognized by a blindfolded person guided by receiving vibrotactile stimuli applied to each actuator placed on arm by a velcro strap [3]. In [4] Van Erp proposes a solution adopted in a car seat, where a vibration on the left or right leg indicated a left or right turn, and the rhythm coded the distance. Vocal modality can be effectively integrated with haptic for encoding complex indications such as a reached target or the presence of an obstacle. However, repetition of vocal messages can be tedious in public contexts [5, 6]. One advantage of vibrotactile feedback is that it is less intrusive than other interaction modalities (e.g. vocal) in capturing user's attention, and it enables eyes-free and hands-free interaction. Thus, users can still perceive their surroundings and accomplish real world tasks [5, 6]. In our study we focus on the use of vibrotactile feedback to support orientation in complex and unfamiliar buildings (e.g. hospitals), by providing users with indications to reach a specific destination. The goal is to provide suggestions for cheap solutions easy to wear and maintain.


*AVI '18*, May 29-June 1, 2018, Castiglione della Pescaia, Italy

ACM ISBN 978-1-4503-5616-9/18/05.
https://doi.org/10.1145/3206505.3206584

## 2 VIBROTACTILE EXPERIMENTS

### 2.1 Prototypes

Within the FITS.ME project [7], authors collaborated with industrial partners for analyzing suitable solutions for indoor navigation using vibrotactile feedback. To this goal, different prototypes were built as alternative design choices. In particular, *Tertium Technology* built the Bluetooth vibrotactile prototypes, while *Virtualis* implemented a mobile application to send stimulation to the actuators (vibrating motors Parallax 9000 RPM 3VDC [8], 1cm of diameter x 0.27cm thickness). The selection of the prototypes was made taking into account some requirements, among all the need of providing a vibrotactile system that supports unambiguous guidance, can be cheap, easily worn and used in various contexts without hindering users from perceiving the surroundings and accomplishing real world tasks. At the moment we focused on flat environments, without taking into account up and down directions (e.g. multi floor buildings). In the end, four prototypes were designed: 1) two bracelets, 2) a four-engine glove with a flexible structure, 3) a four-engine glove with rigid ends, 4) one bracelet.

**Two bracelets (Figure 1)**: left and right directions are provided by vibrating left and right bracelet; forward and backward are given by simultaneously vibrating the two bracelets at different frequencies. Each bracelet contains one vibrotactile motor.

**Figure 1: The two Bluetooth vibrotactile bracelets.**

**Four-engine glove with a flexible structure (Figure 2a)**: left and right directions are given by the vibration on the little finger or on the thumb (or vice versa, depending on the used hand), while forward on the middle finger and backward on the wrist.

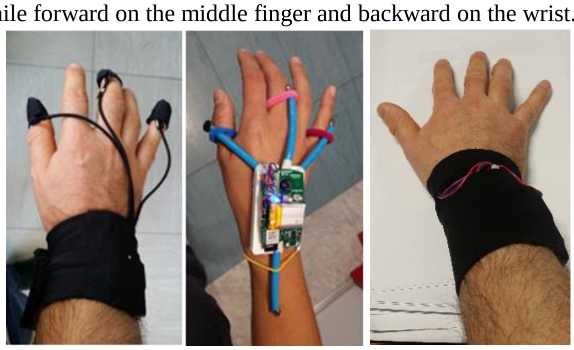

**Figure 2: The Bluetooth vibrotactile: (a) gloves with flexible structure; (b) glove with rigid structure; (c) one bracelet.**

**Four-engine glove with a rigid structure (Figure 2b)**: the indications are the same as the previous solution, but a rigid structure was used to better understand whether the perception of the vibrotactile impulses was better distinguishable on the hand.

**One bracelet with four motors (Figure 2c):** We propose a configuration with four actuators positioned on the top, bottom and sides of the wrist. The same principle could be applied to other solutions with a different form factor, e.g. a belt, a cap.

## 2.2 User Feedback

The tests were carried out using a mobile application that allowed (via Bluetooth) to control the vibrotactile motors on the prototypes, by providing the direction to take to reach the next waypoint on the route. In each experimental setup, the considered prototype was worn by a user (playing the role of *visitor*) who was guided towards an unknown destination by the directional vibrotactile impulses sent through the mobile application by another user (who thus acted as *navigator*). The prototypes have been tested by 7 participants playing the role of *visitor*. Two versions of the mobile application have been implemented. One provided impulses indicating four directions (left, right, back, forward). Another one supported eight cues, thus including diagonal directions: each diagonal was indicated by two vibrating impulses (e.g. straight and right for a right diagonal). Trials were carried out within the CNR area of Pisa to identify benefits and drawbacks of each solution, and more general principles about the vibrotactile efficiency during orientation.

Users indicated the solution based on two bracelets as the most intuitive one. Its main drawback was the weak distinction of the vibrating frequencies chosen for the forward and back directions, and the fact that it consists of two objects (bracelets) instead of one (as the glove), thus more cumbersome. The glove-based solutions have the advantage of engaging only one hand, although the hand wearing the glove could not be used for other activities (e.g. opening doors, holding bags). The 'back' direction (on the wrist) was perceived more clearly than the solution with two bracelets. However, it requires cognitive user's effort to associate the vibration received on a finger with the direction to follow. This problem is especially evident when the user changes the position of the hand and the arm. For example, depending on whether the arm is held parallel to the body or is held straight ahead of the body, and/or the palm is facing down or up, the decoding of the direction could not be always intuitive. For this reason, we discarded the glove solutions, which are also less practical to wear. The bracelet solution has been more appreciated for wearability and ergonomics aspects. In the single bracelet solution which seems anyhow promising, the users did not perceive directions in a distinguishable manner, probably because the four actuators were placed too close.

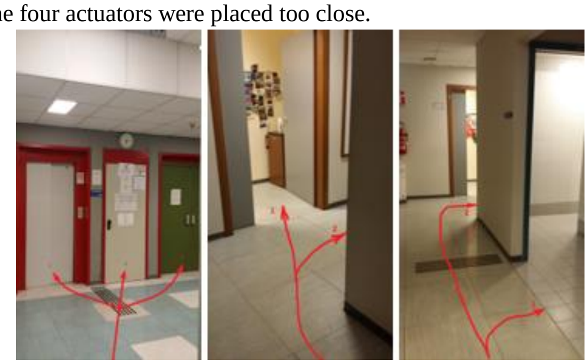

**Figure 3: Examples of ambiguous orientation perception.**

The eight directions application was implemented to identify ambiguous cases such as very close doors or entrances near a turning (Figure 3a, 3b). Detecting diagonal directions was not easy for users. As expected, early vibrotactile feedback facilitated recognition of close turns (Figure 3c).

# 3 CONCLUSIONS AND ACKNOWLEDGEMENTS

This study provided first insights on user orientation during indoor navigation, which need further investigation. Future work will focus on developing a working indoor navigation system, and on exploiting vibrotactile modality for applications that adapt according to e.g. user's emotional status.

This work has been partly supported by Tuscany Region through the FITS.ME project.

# REFERENCES


[1] L. M. Brown. 2003. *Tactons: Structured Vibrotactile Messages for Non-Visual Information Display*. Ph.D. thesis. University of Glasgow.

[2] R. W. Cholewiak, and A. A. Collins. 2003. Vibrotactile localization on the arm: Effects of place, space and age. *Perception & Psychophysics,* 65, 4 (2003), 1058–1077.

[3] T. S. Filgueiras, A. C. O. Lima, R. L. Baima, G. T. R. Oka, L. A. Queiroz Cordovil, M. P. Bastos. 2016. Vibrotactile sensory substitution on personal navigation. In *IEEE International Symposium on Medical Measurements and Applications (MeMeA)*. 1–5.

[4] J.B.F. van Erp, H. J. van Veen. 2002. Vibro-Tactile Information Presentation in Automobiles. In Proceedings of Eurohaptics 2001, 99–104.

[5] L. Chittaro. 2010. Distinctive aspects of mobile interaction and their implications for the design of multimodal interfaces. *Journal on Multimodal User Interfaces*. Volume 3, Issue 3 (April 2010), 157-165

[6] G. Ghiani, B. Leporini, F. Paternò. 2009. Vibrotactile feedback to aid blind users of mobile guides, *Journal of Visual Languages and Computing*, Volume 20, Issue 5 (October 2009), 305-317

[7] FITS.Me Project: http://hiis.isti.cnr.it/FITS.ME/index_en.html

[8] Vibration Motor Flat Coin: https://www.parallax.com/product/28821