# Innovative Haptic Interface for Navigation

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## Abstract

This paper presents the development of an innovative navigation interface with haptic support for people with visual impairment. Based on the idea of adaptive control elements, interaction with the interface is facilitated and haptic distinction between different menus is made possible. By integrating haptic feedback, a safer and more user-centered approach for navigation systems is introduced, which leads to a more immersive way of interaction.

## Keywords

Adaptive control elements, multimodal interaction, navigation interface, visually impaired people, user centered interface design

## Introduction

Mobility is one of the most important human basic needs. Due to high risk of injury, people with visual impairment often reduce their traveling activity to a minimum, which in the worst case can lead to isolation of the person. Therefore, continuous development of assistive technology that increases the safety level during navigation is essential. Since most navigation systems only use auditory output, there is a high chance that information is not being perceived properly, e.g., because of ambient noise. By adding an additional haptic output an efficient interaction can be ensured.

This paper presents the development of a navigation interface with additional haptic support. The idea was realized during the research project "Hard- and Software Interface development of map-based haptic orientation and navigation systems for people with visual impairment." The project was carried out by the University of Stuttgart in cooperation with the industrial partner, Handy Tech Elektronik GmbH. The University of Stuttgart is represented by the Institute for Visualization and Interactive Systems (VIS) and the Institute for Engineering Design and Industrial Design (IKTD), Research and Teaching Department Industrial Design Engineering. IKTD was mainly in charge of the interface focuses on the development of ergonomic devices. VIS realized the software of the system.

## State of Technology and Research

Navigation systems which help people with visual impairment have been commercialized for about four years. At this point nearly all commercialized stand-alone GPS navigation systems just use acoustic output. On the research and development level, there are projects going on trying to use other modes of feedback like HaptiMap, Tacit, vibro-tactile belts or vibrating compasses. To improve navigation for people with visual impairment, a holistic approach considering all channels of human machine interaction is recommended.

## Human-Product-Relation and Multimodality

The cognition of and the behavior in response to a product depend on the perception of a person. The product interacts with the user through the product gestalt, which consists of its assembly, shape, color and graphics (see Figure 1).

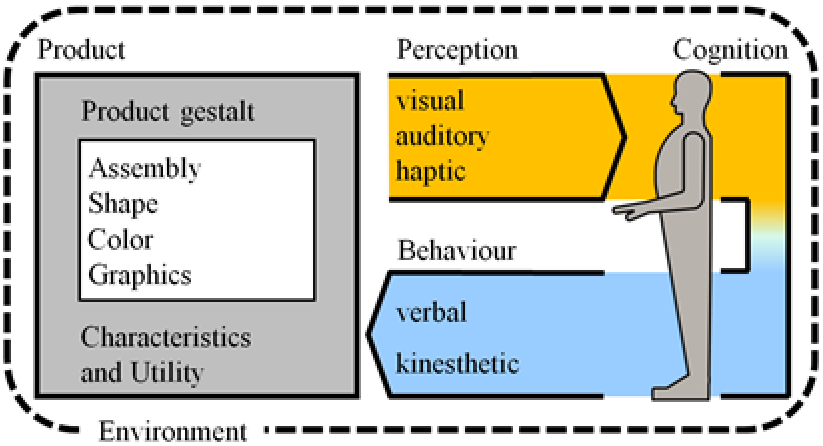


Fig. 1. Basic Model of Human-Product-Interaction

The concept of multimodal interaction can be chosen as a basic approach to improve the usability of navigation systems. Schomaker et al. define an interaction as multimodal if it is "restricted to those interactions which comprise more than one modality on either the input (perception) or the output (reaction) side." According to Schmid, Petrov, and Maier, the user's capacity of perception is enhanced through the distribution of data via multiple modalities. People with visual impairment can use two modalities (auditory and haptic). Since auditory information, like a sound, can be easily disturbed by ambient noise during navigation, there is a high chance that information is not being perceived properly by the user. By using the somatosensory modality as an additional source of input, a safe and efficient transmission of information is ensured.

## Adaptive Control Elements

An additional haptic user input for the interface of a navigation system can be made possible by the basic approach of adaptive control elements. Adaptive control elements are characterized by their ability to vary and adapt their gestalt (structure, shape) depending on the context of the human machine interaction (Petrov). As a consequence, the user is being relieved in situations of complex information input.

## Haptic Specifications

To develop an ergonomic device, the German guideline VDI 2424 suggests a centripetal user-centered design approach. In this case the design is based on the haptic requirements of the human hand, so that the tangible feedback is well received. Especially important for proper haptic perception is the tangible height of elements which leads to deflection of the human skin during contact. According to Kaczmarek and Bach-Y-Rita, the absolute threshold of haptic perception due to deflection of human skin of the fingertip is 10 µm ($3.93 \times 10^{-4}$ in). For the design of haptic devices Kern suggests a maximum height of 1 mm ($3.93 \times 10^{-2}$ in). Apart from requirements concerning the haptic perception of the human skin, a basic understanding of the exerted finger forces is essential for the choice of adequate drive elements that enable the variation of the interface gestalt. In this context, measurements published in the German standard DIN 33411 state axial forces being exerted from the index finger of 7 N maximum. Those key specifications provide a basis for the dimensions of the tangible elements.

**Arrangement of Control Elements**

Schmidtke states that control elements should be arranged according to their rate of use with the most frequently used ones being located in the most comfortable area of operation. Since the system should be used easily during navigation and a visually impaired user is expected, in addition, to carry a white cane for people with visual impairment, there is only one hand left to operate the device. Thus, single-handed use is required. To enable a sinistral and dextral operation, symmetric assembly is necessary. Therefore the interface is divided into three control element areas. Figure 2b shows the natural position of rest of the operating thumb which represents its most comfortable position, with the inclination angle of the thumb joint being minimal.

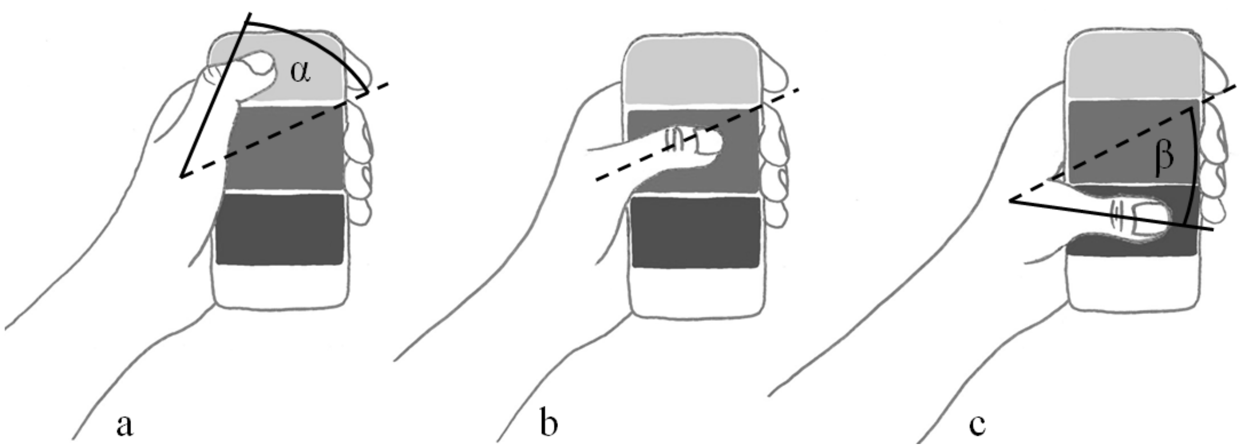


Fig. 2. Determination of Comfortable Thumb Reaching Areas for a Single-Hand Control Device

As a consequence the central area of the interface is supposed to contain the most frequently used control elements. To reach the upper area a positive inclination (α) of the thumb is implied (see Figure 2a). Speaking of comfort, this thumb movement is clearly to be preferred over the negative inclination (β) to reach the lower area (see Figure 2c). As a result, the upper area is defined to contain frequently used control elements while the lower area should only contain least frequently used elements.

## Design of the Apparatus

### *Conceptual Design*

To develop the conceptual interface design, a set of essential menu functions were derived from different user questionings. Twelve control elements were defined for an ergonomic handling of the device. Based on the anticipated rate of use, those control elements were divided into a key field with three main areas: a primary, secondary and tertiary area. The nine keys of the primary area are expected to be used frequently and situated in direct space of reach. Accordingly the keys of the secondary and the tertiary area will be used less and therefore are placed in less comfortable areas above and under the primary one. Figure 3 illustrates the final arrangement of the eleven control elements according to their absolute rate of use.

The idea of adaptive control elements was realized by two types of additional retractable and liftable tangible elements, bridge and navigation elements, permitting additional haptic information encoding.

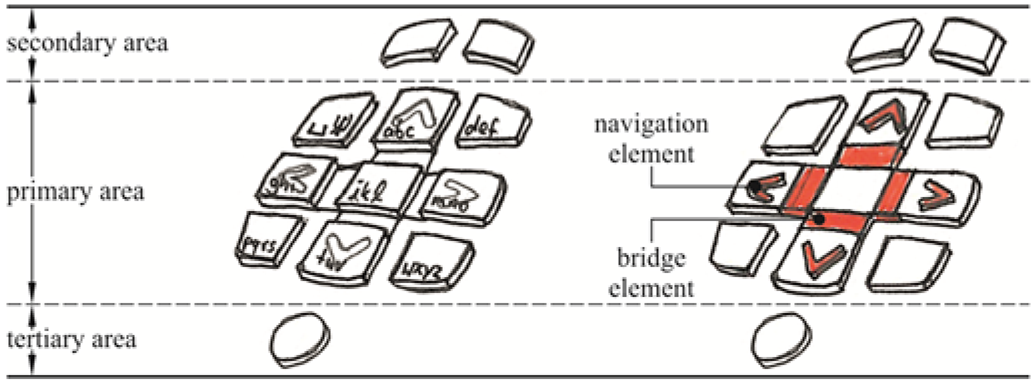


Fig. 3. Conceptual Design of the Interface with Bridge and Navigation Elements in Retracted (left side) and Lifted (right side) Position

Four movable bridge elements vary the interface gestalt of the key field and thus facilitate haptic distinction between different menus such as input / setup mode or navigation mode. By lifting all four bridge elements, the key field transforms into a cross gestalt intuitively being associated with the four cardinal directions. At the same time it indicates to the user that s/he is in navigation mode. While entering a particular destination, a homogenous key field is desirable, which is achieved by lowering the bridge elements.

Four movable tangible navigation elements provide a haptic support during navigation mode. Depending on the element being lifted the aspired direction is indicated. By varying the frequency with which the elements are lifted and retracted, the distance toward the next change of direction is encoded continuously. The higher the frequency the closer the user is to the aspired waypoint.

*Assembly*

To enable both the bridge and navigation elements to be lifted and retracted, drive elements are necessary. While all four bridge elements must be connected in parallel since they all lift or retract together, the drive unit must enable the navigation elements to lift and retract individually. A set of electrical drives was chosen with consideration to the necessary holding forces and lifting range. The drives must have sufficient power so that the adaptive elements remain lifted during haptic exploration by the user.

Figure 4 shows the CAD model with the adaptively variable key field and the main drive unit. The key field consisting of button caps and switches is placed on a circuit board. To support the circuit board, a support frame was designed. Below the key field, four electrical drives are arranged ring-like to enable the individual movements of the navigation elements. Those navigation elements form the tips of spring elements. They are necessary to allow the navigation elements to be pushed down with the affected keys they are integrated into. This mechanism prevents the navigation element from causing excessive deflection of the human skin while the adaptive control element is pushed down. A fifth electrical drive below the other four drives is connected to an upstroke mechanism. This mechanism enables the bridge elements to lift and retract. All drives are integrated into the support frame, which also serves as guidance for the upstroke mechanism.

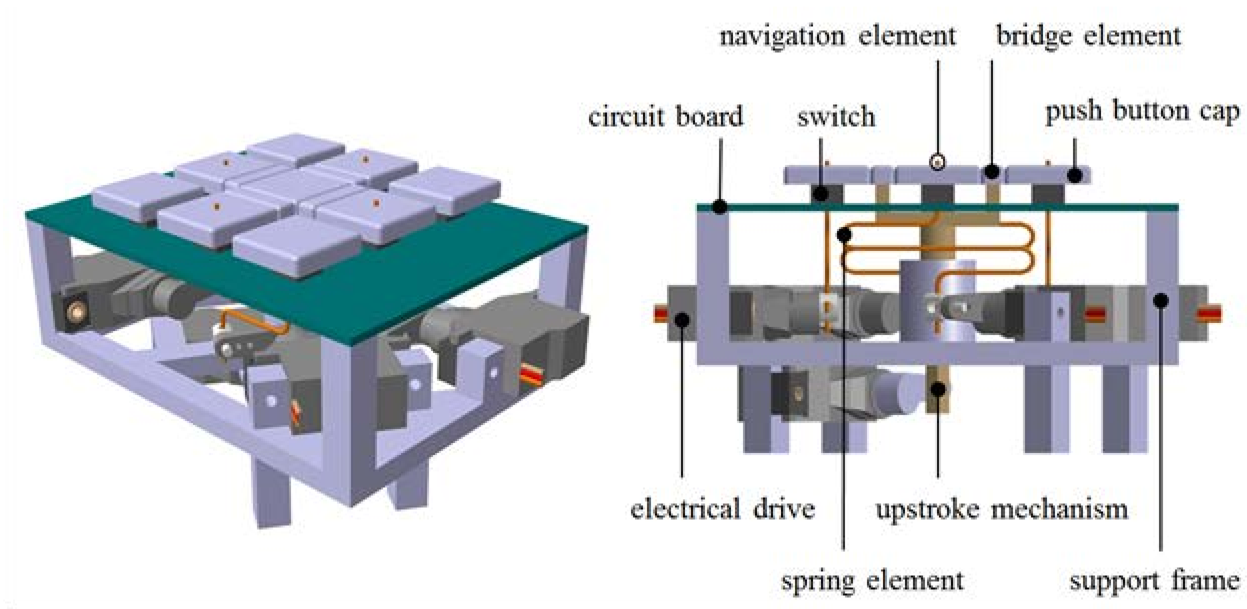


Fig. 4. Functional Components of the CAD Prototype

*Housing and Overall Shape*

Based on the CAD model, a hardware prototype was manufactured and assembled (see Figure 5). To house all functional components and facilitate single-handed use, the device has a curved shape with anthropomorphic areas. This allows the user to carry and operate the device at the same time with one hand only.

Fig. 5. Manufactured Prototype with Housing

## Conclusion

An innovative navigation interface with haptic support is developed, based on the idea of multimodal interaction and adaptive control elements. Thereby, for people with visual impairment, interaction with the interface is facilitated, and haptic distinction between different menus is made possible. Due to the additional haptic feedback, a safe and efficient transmission of information can be ensured during use. Apart from that, the use of adaptive control elements partly compensates for the lack of information based on the impaired visual channel. This leads to an enormous improvement of the device's usability and introduces a new kind of haptic esthetics in assistive technology. This navigation interface can be used both for outdoor and indoor navigation. The basic approach of adaptive control elements is not restricted to navigation systems. It can also be adapted to other types of assistive technology.

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**Work Cited**

Kaczmarek, Kurt. A., and Paul Bach-Y-Rita. “Chapter 9: Tactile Displays.” *Virtual Environments and Advanced Interface Techniques*. Ed. Woodrow Barfield and Thomas A. Furness. New York: Oxford University Press, 1995. 349-414. Print.

Kern, Thorston A. "Identifikation von Anforderungen." *Entwicklung Haptischer Geräte - Ein Einstieg für Ingenieure* (in German). Ed. Kern. Berlin: Springer, 2009. 129-32. Print.

Norm DIN 33411 Mai 1987: Körperkräfte des Menschen; Maximale statische Aktionskräfte – Teil 4 (in German). Print.

Norm VDI 2424 January 2001. Industrial Design; Grundlagen, Begriffe, Wirkungsweisen (in German). Print.

Petrov, A. *Usability-Optimierung durch adaptive Bediensysteme* (in German). Diss. Universität Stuttgart, Institut für Konstruktionstechnik und Technisches Design, Forschungs- und Lehrgebiet Technisches Design, (2012). 59-77. Print.

Schmid, Markus, Aleko Petrov, and Thomas Maier. “HMI with Adaptive Control Elements.” *ATZ autotechnology* 8 (2008): 50-55. Print.

Schmidtke, H.: *Handbuch der Ergonomie* (in German). Band 4, 2 überarbeitete und erweiterte Auflage. Bundesamt für Wehrtechnik und Beschaffung, Koblenz (1989). C 6.1.2. Print.

Schomaker, L., J.Nijtmans, A.Camurri, F. Lavagetto, P.Morasso, C. Benoit, T.Guiard-Marigny, B.Le Goff, J.Robert-Ribes, A.Adjoudani, I.Defée, S.Münch, K.Hartung, and J.Blauert. “A Taxonomy of Multimodal Interaction in the Human Information Processing System. A Report of the Esprit Project 8579 MIAMI.” Ed. L. Shomaker, S. Munch, and K.Hartung. Nijmegen: NICI, 1995. 5-6. Print.