Adaptive Control Elements for Navigation Systems

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Abstract. 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 impairments interaction with the interface, e.g. indication of directions 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 and enables the user to experience a more immersive way of interaction.

Keywords: control elements, adaptive control elements, navigation interface, visually impaired people, user centered interface design, multimodal interaction.

1 Motivation

To improve the life of people with visual impairments a continuous development of assistive technology is essential to facilitate the mobility. 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 a safe and efficient interaction can be ensured.

The present paper presents the development of a navigation interface with additional haptic support. This idea was realized during the research project "Hard- and Software Interface development of map-based haptic orientation and navigation systems for people with visual impairments". The project is carried out by the University of Stuttgart in cooperation with the industrial partner Handy Tech Elektronik GmbH and funded by the German Federal Ministry of Economics and Technology. 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 which is mainly in charge of the interface focuses on the development of ergonomic devices. VIS realizes the software of the system.

C. Stephanidis (Ed.): Posters, Part I, HCII 2013, CCIS 373, pp. 473–477, 2013.

2 State of Technology and Research

Navigation systems which help people with visual impairments have been commercialized for about four years. At this point nearly all commercialized stand-alone GPS navigation systems just use acoustic output.

This shows that there is potential for improvement. Therefore, the concept of multimodal interaction can be chosen as a basic approach to improve the usability of navigation systems. Schomaker et al. [1] 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 [2] the user's capacity of perception is enhanced through the distribution of data via multiple modalities. People with visual impairments 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.

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 [3]. As a consequence the user is being relieved in situations of complex information input.

3 Method

3.1 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. According to [4] control elements can be arranged based on the anticipated rate of use. Therefore those control elements were divided into a key field with three main areas, a primary, a secondary and a tertiary area. The nine keys of the primary area are expected to be used frequently and situated in direct space of reach. The two keys of the secondary area will be used less and are placed above the primary area. The last key is expected to be used least frequently and therefore located in the tertiary area. 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. Figure 1 illustrates the final arrangement of the twelve control elements according to their absolute rate of use including the adaptive control elements.

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 the user that he is in navigation mode. While entering a particular destination a homogenous key field is desirable being achieved by lowering the bridge elements.

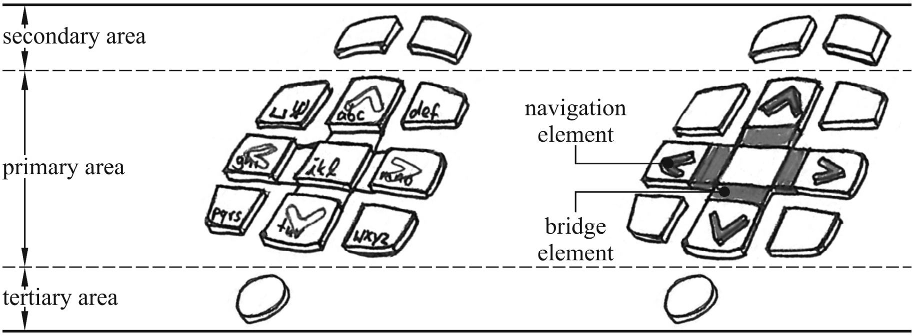

Fig. 1. Conceptual design of the interface

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.

3.2 Haptic Specifications

To develop an ergonomic device a centripetal user centered design approach is suggested. 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 [5], the absolute threshold of haptic perception due to deflection of human skin of the fingertip is 10 µm (3.93×10^{-4} in). For the design of haptic devices Kern [6] suggests a maximum height of 1 mm (3.93×10^{-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. In this context measurements published in standard DIN 33411 [7] 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.

4 Design of the Device

To enable both, the bridge and navigation elements being lifted and retracted drive elements are necessary. While all four bridge elements must be connected in parallel since they either 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 considering 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. The key field consisting of button caps and switches is placed on a circuit board. For support of the circuit board a support frame was designed. Below the key field four electrical drives are arranged ringlike 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 being pushed down with the affected keys which they are integrated into. This mechanism prevents the navigation element from causing exceeding 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. This support frame with all functional units is integrated into an ergonomic housing. Figure 2 shows the assembled digital mock-up with the adaptively variable key field and the housing.

Fig. 2. Perspective view of assembled digital mock-up

5 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 impairments 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 even though the basic approach of adaptive control elements is not only restricted to navigation systems. It can also be adapted to other types of assistive technology.

Acknowledgements. This project is supported by the German Federal Ministry of Economics and Technology on the basis of a decision by the German Bundestag.

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