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# Assisting people with visual impairments in aiming at a target on a large wall-mounted display☆

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ABSTRACT

Large interactive displays have become ubiquitous in our everyday lives, but these displays are designed for the needs of sighted people. In this paper, we specifically address assisting people with visual impairments to aim at a target on a large wall-mounted display. We introduce a novel haptic device, which explores the use of vibrotactile feedback in blind user search strategies on a large wall-mounted display. Using mid-air gestures aided by vibrotactile feedback, we compared three target-aiming techniques: Random (baseline) and two novel techniques – Cruciform and Radial. The results of our two experiments show that visually impaired participants can find a target significantly faster with the Cruciform and Radial techniques than with the Random technique. In addition, they can retrieve information on a large display about twice as fast by augmenting speech feedback with haptic feedback in using the Radial technique. Although a large number of studies have been done on assistive interfaces for people who have visual impairments, very few studies have been done on large vertical display applications for them. In a broader sense, this work will be a stepping-stone for further research on interactive large public display technologies for users who are visually impaired.



## 1. Introduction

With considerable progress in display technologies and interaction techniques, we are observing increasing affordability and availability of large interactive displays in our everyday lives. The rapid growth of such large public displays allows us to access a wide range of information in diverse places and the contents are now much more interactive. However, the proliferation of large interactive displays also creates great challenges for people with visual impairments who require equal access to information on displays that are predominately visual. Accommodating the special needs of people with visual impairments is not only socially valuable but also produces more effective and widely useful interfaces for everyone (ACM Code of Ethics and Professional Conduct, 2015).

Assistive technology research has come a long way and has yielded many effective interfaces. Nevertheless, assistive technology for *large vertical displays* is still sparse and poorly supported in part due to the lack of a good understanding of the challenges faced by *people with visual impairments*. This paper investigates how to facilitate a target-aiming task on a large wall-mounted display by people with visual impairments. The ability to correctly select a target on an interface is the first step toward further manipulation and it is fundamental in most modern graphical user interfaces. Specifically, we present three target-aiming techniques – Random, Cruciform, and Radial – using natural gesture input aided by directional vibrotactile feedback. In all three techniques, our users with visual impairments point their hands at the large wall-mounted display, and this mid-air, non-contact gesture is tracked by a computer vision system and mapped to a cursor position onto the screen like a mouse using ray-casting (Fig. 1). To determine the best search direction, vibrotactile stimuli are delivered by means of a mobile phone held in the pointing hand. The three target-aiming techniques differ in the geometric path along which the search is performed and the way vibrotactile stimulus is provided for guidance. In Experiment 1, we evaluated three target-aiming strategies with eleven visually impaired participants to find out which search strategy was the best. In Experiment 2, we compared haptic feedback efficiency and speech feedback efficiency, which were used in our target-aiming

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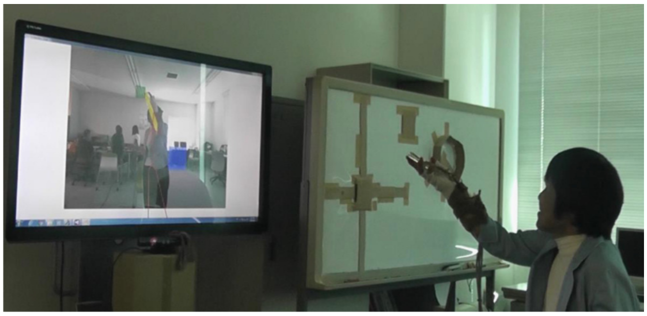

**Fig. 1.** A user with visual impairments aims towards a target on the display using the Radial technique.

strategies. The task was finding a bus schedule available on a large vertical digital display. According to the Royal National Institute of Blind People report (Pavey et al., 2009), the information on bus and train station boards is generally inaccessible for people with visual impairments, and this greatly affects their day-to-day mobility and freedom outside the home. We studied whether our novel vibrotactile target-aiming system enables participants with visual impairments to access train schedule information on a large vertical display, so providing equal access to the information. Both experiments were conducted with people with visual impairments. The present study is, to the best of our knowledge, among very few of its kind in that it is concerned with the use of a large vertical display by people with visual impairments. Our lightweight, low-cost interface allows people with visual impairments to dynamically access targets on a large vertical display in a 3D environment. The findings of our two experiments will serve as an initial step towards enhancing the interactivity of large vertical displays for people with visual impairments, with an ultimate goal of granting them equal access to public displays that are currently accessible almost exclusively to sighted people.

## 2. Related work

This section reports the results of a literature survey of existing assistive technologies for people with visual impairments in order to identify cases relevant to large vertical displays. Its emphasis was on devices, the types of sensory feedback, and eyes-free target selection.

### 2.1. Assistive device/display types

Interactive devices for assisting people with visual impairments have various form factors. Small, portable ones include wearable widgets such as a vibrotactile glove (Krishna et al., 2010) and a wearable camera (Jeon et al., 2012; Shilkrot et al., 2015); handhelds such as a pen (Evreinova et al., 2013), a PDA (Ghiani et al., 2009; Sanchez et al., 2008), a smartphone (Azenkot et al., 2011, 2013; Southern et al., 2012), force disk (Amemiya and Sugiyama, 2009) as well as Wii Remote (Morelli et al., 2010); and an electronic white cane (Astler et al., 2011; Fernandes et al., 2009). Large displays like tabletops (Kane et al., 2011, 2013b; Manshad et al., 2013) have also been used.

The form factor appears to be correlated to the nature of the task involved. For example, FingerReader (Shilkrot et al., 2015) was implemented in a small finger-worn device to support the blind in reading printed text by scanning with the finger and hearing the scanned words through synthesized speech. This system utilized computer vision algorithms, along with audio cues (e.g., a simple utterance of “up” or “down”) and tactile cues (e.g., a gradually increasing vibration to indicate vertical deviation from the line) to indicate in which direction the finger should move. StickGrip (Evreinova et al., 2013) provided a motorized pen grip, which was sliding up and down in relation to the distance from the pen tip to the virtual surface being explored, so that a user could explore complex topographic and mathematical onscreen images or virtual surfaces. In their experiment, blindfolded subjects relied mainly on the proprioception and kinesthetic sense in the fingers.

To assist blind users with photo taking and photo sharing, smartphones have become very popular devices. EasySnap (White et al., 2010) and Accessible Photo Album (Harada et al., 2013) were developed for the Apple iPhone by employing iOS's VoiceOver screen reading functionality. PortraitFramer (Jayant et al., 2011) on Android phones explored the usefulness of haptic and audio cues for proper people positioning in group photos. The portability of the embedded camera and smartphone made them useful as mainstream crowdsourcing devices for collecting information regarding everyday visual challenges faced by people with visual impairments (Bigham et al., 2010; Brady et al., 2013). In addition, BrailleTouch (Southern et al., 2012) implemented a six-key chorded Braille soft keyboard on iPod touchscreen with keyclick audio feedback to support eyes-free text entry. While braille has been often used in today's note-taking systems, the standard Perkins Brailler encodes only 63 ($2^6-1$) characters on a $3\times2$ binary matrix, with the dots numbered one through six in column-major order, and its use for graphical content is a challenge.

On the other hand, large tabletop displays were used for collaborative learning or target acquisition by people with visual impairments. For example, Trackable Interactive Multimodal Manipulatives (TIMMs) provided multimodal feedback (e.g., speech, sound/music, vibration/force feedback) to enable collaborative learning between sighted and blind students (Manshad et al., 2013). Access Overlays (Kane et al., 2011) and Touchplates (Kane et al., 2013b) supported easy target selection on a tabletop, e.g., selecting a location on a map, by providing speech or tactile feedback.

### 2.2. Sensory feedback types

In most of the assistive technologies we reviewed, the auditory and/or haptic channels are the de-facto channels for providing sensory feedback. Audio feedback, such as text-to-speech, is quite effective for communication between systems and people with visual impairments. For example, Blobby (Nicolau et al., 2009) used familiar and easily understandable speech, behaving like a blind companion, to help people with visual impairments navigate through unfamiliar places. Auditory icons, or earcons, are also useful. DigiTaps (Azenkot et al., 2013) presented an eyes-free number entry method for touchscreen devices, which required minimal audio feedback. It provided haptic and optional audio feedback, vibrating and speaking each digit when a gesture was entered on the screen. Their experimental results showed DigiTaps with audio feedback was slower but more accurate than with no audio feedback after each input.

Audio feedback has often been augmented with haptic feedback. It was shown that people with visual impairments could perceive an audio-based representation of a bar graph using a pointing device if provided with adequate tactile feedback (Wall and Brewster, 2006). Haptic feedback presented by a tactile array can enable people with visual impairments to perceive graphical information and form a mental model for visual imagery. For example, GraVVITAS demonstrated that the combination of a touch sensitive tablet and a data glove with vibrating actuators could be an effective technique for representing tactile graphics to users with visual impairments (Goncu and Marriott, 2011). Ghiani et al. (2009) also showed that vibrotactile feedback enhancement for vocal comment in mobile guides was particularly useful to