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Designing motion marking menus for people with visual impairments

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ABSTRACT

Current smartphone accessibility for people with visual impairments relies largely on screen readers and voice commands. However, voice commands and screen readers are often not ideal because users with visual impairments rely mostly on hearing ambient sound from the environment for their safety in mobile situations. Recent research has shown that marking menus in mobile devices provide fast and eyes-free access for sighted users Francone et al., 2010; Oakley and Park, 2007, 2009. However, the literature is lacking design implications and adaptations that meet the needs of users with visual impairments. This paper investigates the capabilities of visually impaired people to invoke smartphone functions using marking menus via 3D motions. We explore and present the optimal numbers of menu items (breadth) and menu levels (depth) for marking menus that people with visual impairments can successfully adopt. We also compared a marking menu prototype to TalkBack™ which is an accessibility menu system in Android smartphones. The experimental results show that our participants could perform menu selections using marking menus faster than when using TalkBack. Based on the study results, we provide implications and guidelines for designing marking menus and motion gesture interfaces for people with visual impairments.

1. Introduction

Even though some accessibility issues remain with smartphones, the reliance of visually impaired people on smartphones has been increasing (Ye et al., 2014). Although smartphones support screen readers, such as VoiceOver™ and TalkBack™ (WebAIM, 2015), and voice commands, these features can be inefficient in noisy environments and inappropriate in quiet public environments. These systems enable users to browse menu items on touchscreens using speech feedback. However, they require users to perform long sequences of touch gestures to browse the menus. This might result in increased user fatigue and dissatisfaction. There is an increasing need for more efficient interaction techniques as supplements or alternatives to the accessibility features that are currently available for users with visual impairments.

Marking menus allow fast and eyes-free menu selections. In marking menus, menu items are arranged in certain directions (north, south, west, east, and so on). Users perform menu selections by drawing marks in the direction of the desired menu item without the need of visual attention. Recently, marking menus have been adapted to mobile devices because they offer fast and eyes-free interaction (Oakley and Park, 2007; 2009). This means marking menus may offer significant benefits to the users with visual impairments via eyes-free mobile interactions. Thus, we propose marking menus working together with motion gestures to provide users with fast access to smartphones using only one hand. Adequate motion sensors are now available on most common mobile devices (Negulescu et al., 2012), and we developed 3-D space motion gesture-based marking menu selection called Motion Marking Menus (MMM) which offer users with visual impairments ready access to smartphone menus (Fig. 1).

In spite of the need and potential, the capability of people with visual impairments to perform motion marking menus has not been investigated until now. A thorough understanding of such capabilities will help in the design of more efficient and accessible interfaces. We provide valuable design implications regarding the spatial ability of smart phone users to navigate motion marking menus, and more especially to apply the benefits of this work to people with visual impairments.

Research questions include: Q1. How many directions can people with visual impairments distinguish? In other words, we wanted to determine how many user-discernable directions there are at each level of efficient marking menus. Q2. How many hierarchic levels can people with visual impairments navigate in marking menu selections? Q3. How receptive are users with visual impairments to motion marking menu systems?

To answer the aforementioned research questions, we performed two user studies. In Study 1, we investigated Q1 and Q2. In Study 2, we in-

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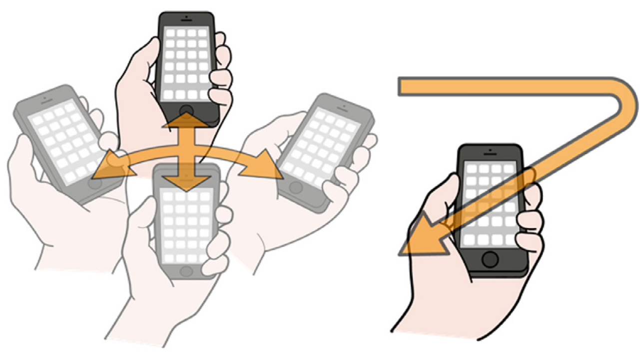

Fig. 1. Motion Marking Menu (MMM) interfaces in smartphones. Menus are assigned according to the movement of the device in certain directions (e.g., the Phone-call menu is assigned to appear at the right side) and users perform menu selections by moving the phone in the direction of the desired menu. Submenus are assigned in the same manner. Users select a submenu by continuously moving the hand in the direction of the main menu, then in the direction of a submenu (e.g. move hand to the right, then to down directions).

vestigated Q3. To understand the relative efficiency of motion marking menu systems, we compared the efficiency of our marking menu prototype to TalkBack^{TM}, an accessibility menu system currently available on Android smartphones.

2. Related work

Related work includes marking menus for mobile devices, non-visual interactions with menus and mobile spatial interactions.

2.1. Marking menus on mobile devices

Kurtenbach (1993) introduced marking menus that allow users to perform fast, eyes-free menu selections. According to Kurthenbach and Buxton's case study of marking menus in a real-world situation, marking makes interaction more efficient, easier to learn, and faster than selection using the menu (Kurtenbach and Buxton, 1994). Recently, marking menus have been adapted to mobile devices. Jain and Balakrishnan (2012) developed a marking gesture based mobile text entry system which requires less visual attention from users. pieTouch (Ecker et al., 2009) is a marking gesture based vehicle information system designed to reduce visual demand. Francone et al. (2010) presented touch-based marking menus for navigating data hierarchies on mobile phones. Also, Oakley et al. (Oakley and Park, 2007; 2009) demonstrated a marking menu based eyes-free menu system with 3D rotational strokes. Their system deviated from the traditional marking menu system which was one dimensional and involved dividing a 90 ° portion of rotational space into three targets of 30 degrees each. Bauer et al. (2013) presented a marking menu system for eyes-free interactions with a large display using smartphones and tablets. In their study, a marking menu was placed on the touch screen of a smartphone or tablet so that the user could remotely interact with a large display.

Despite the fact that marking menus are promising for eyes-free input, questions about the capability of people with visual impairments to navigate marking menus has not been investigated.

2.2. Non-visual interactions with menus

Research studies have attempted to provide more accessible interfaces for users with visual impairments. Kane et al. (2008) presented a specialized touch-based interface for menu selections called Slide Rule. Slide Rule is a set of audio-based multi-touch interaction techniques that enable people with visual impairments to access smartphone functions including making phone calls, mailing, and music performance functions. Zhao et al. (2007) developed EarPod using touch input and sound feedback for eyes-free menu selections. Audio-based text entry systems were also developed by Sánchez and Aguayo (2007) and Yfantidis and Evreinov (2006). These systems used multi-tap, directional gestures and audio feedback, to enable users to enter text on touchscreens. On the other hand, Oliveira et al. (2011) showed that spatial ability plays an important role in the blind user's ability to use and perform accurately with touch-based text-entry methods.

The literature has demonstrated several accessibility features on mobile devices that utilized touch-based gestures and speech feedback. In mobile situations, people with visual impairments usually have one hand occupied with a cane or a guide dog leash (Ye et al., 2014), while touch-based interfaces may require users to use both hands, one hand to hold the phone and the other to perform gestures. Although touch-based interfaces enable one hand operation using the thumb, user performance in thumb-based interactions greatly relies on several factors such as surface size, hand size and hand posture (Bergstrom-Lehtovirta and Oulasvirta, 2014). For the purpose of use "on the go", 3D motion gestures are suitable because they provide fast access and enable users to operate the system with only one hand (Negulescu et al., 2012; Ruiz et al., 2011).

Some researchers studied the design space of motion gestures for non-visual interfaces (Wolf et al., 2011) and other researchers validated body-space gestures with a view to improving on-the-move interaction performance (Guerreiro et al., 2008). Also, a previous study has reported that motion gesture interfaces were efficient and well received by users with visual impairments (Dim and Ren, 2014). Some previously developed motion gesture interfaces in (Dim and Ren, 2014) were based on linear gestures performed to the left or to the right, e.g., to select a contact, users repeated the gesture, to the left for the previous contact and right for the next contact, until they found the desired contact name in a list.

To increase efficiency of motion gesture interfaces for users with visual impairments, we propose motion marking menus (MMM). MMM allow users to perform menu selections by drawing marks in the direction of the desired menu with six degrees of freedom in 3D space.

2.3. Mobile spatial interactions

Recently, there has been a growing interest in research regarding input techniques in mobile devices that allow spatial input. For example, SideSight (Butler et al., 2008) allows multitouch interactions around the device. HoverFlow (Kratz and Rohs, 2009) and Abracadabra (Harrison and Hudson, 2009) provided spatial interactions in mobile devices using motion input in space around the device. Minput (Harrison and Hudson, 2010) is also a spatial interaction that allows users to manipulate the whole device for input. On the other hand, Skinput (Harrison et al., 2010) provides spatial input by allowing users to appropriate the body for finger input. Peephole displays (Yee, 2003) offered spatial input that maps physical movements of a device to movements in a virtual world. VirtualShelves (Li et al., 2009; 2010) extends these techniques by treating the space around the user as a discrete set of regions (shelves), so that the user can access contents on these virtual shelves. Gustafson et al. (2010) presented Imaginary Interfaces i.e., spatial interactions that occur only in the user's imagination. Oh et al. (2013) proposed and evaluated a gesture sonification interface which generates various sounds based on finger touches, creating an audio representation of gesture.

Romano et al. (2015) conducted a preliminary elicitation study to understand the preferences of blind people with respect to touch and motion gestures on mobile devices. In addition, several studies have demonstrated spatial interaction in mobile devices as a promising eyes-free input modality.

Our study investigates the spatial ability of people with visual impairments to perform motion marking menus for eyes-free input in mobile phones. MMM differ from other solutions such as VirtualShelves in that MMM inherit the advantages of traditional marking menus: