

論文内容の要旨

ABSTRACT

Although some interfaces have been developed for people with visual impairments, this demographic remain unable to fully access technology. This is because there is still very little understanding of user capabilities that would facilitate interactions with technology, appropriate design approaches, and guidelines for designing successful technology for this user group. Lack of these fundamental knowledge results in the existing technologies less efficient or unable to engage users.

To increase the interaction bandwidth, and to address the aforementioned problems, this dissertation proposes *motion gesture interfaces* for visually impaired people. Motion gesture interfaces are users' movements of body parts or devices (including tilting, translating) in three dimensions, to invoke system commands. We studied (1) user gestures and their rationale, (2) user capabilities to perform motion gestures, and (3) participatory design approaches for gesture design.

Based on understanding of user gestures and capabilities, we developed and evaluated two interaction techniques: (i) motion gesture interfaces and (ii) motion marking menus in smartphones.

The outcomes of this dissertation are:

1. understanding of user gestures, gesture rationale and taxonomies
2. new interaction techniques
3. a hybrid participatory design approach
4. theoretical explanation and design guidelines

In summary, this dissertation contributes to the field of assistive technologies for visually impaired people, in the view of gesture based interactions. The conclusion drawn and methodologies proposed will benefit future research studies that explore gesture-based interaction techniques and scientific foundations of assistive technologies for people with visual impairments.

DISSERTATION OUTLINE

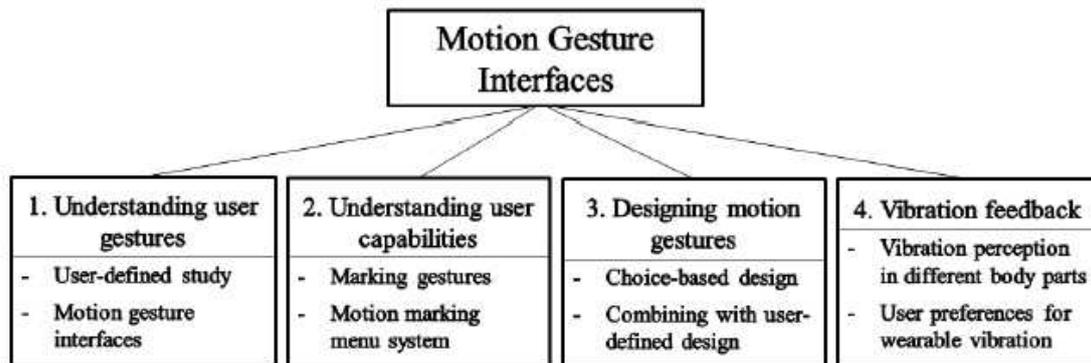


Figure 1. Outline of dissertation

1. To understand user gestures and their rationale, we conducted a user-defined study. Using the gesture set and design heuristics from the user study, we implemented and evaluated motion gesture interfaces.

2. To increase the bandwidth of motion gesture interfaces, we proposed motion marking menus, and studied user capabilities. Then we developed and evaluated a motion-based marking menu system.

3. A participatory design process is essential for developing successful assistive interfaces. We evaluated a user-defined and a choice-based design method, and proposed a hybrid participatory design approach which is particularly suitable for visually impaired people.

4. To support the gesture inputs, we studied design guidelines of vibration feedback, especially for wearable vibration systems.

1. UNDERSTANDING USER GESTURES

Gesture-based interactions have become one of the major techniques for natural user interfaces. Studies investigated user gestures for different applications and presented gesture taxonomies. However, motion gestures of visually impaired people and their gesture taxonomies were not systematically studied. Thus, we studied gesture taxonomies, their rationale and usability of motion gestures for

visually impaired people.

Study 1: User-defined Motion Gestures

A user-defined study was conducted to elicit user behaviors to enhance the design process. During the study, we explored motion gestures from 13 visually impaired participants. The participants were asked to perform motion gestures that could be used to command the available functions on a smartphone. We presented 15 tasks to the participants. The participants were asked to use a think-aloud method and to perform gestures in think-aloud protocol. They were also asked to supply subjective preference ratings for each gesture they performed. All the sessions were video-recorded and each session took approximately one hour to complete.

After the user study, we made clustered quotes of each participant from the video transcript. A careful analysis was then performed to classify each motion gesture designed by the participants. Each gesture was labeled with a corresponding rationale and each was generalized to identify common characteristics shared by the participants. For this purpose, we adopted a bottom-up inductive analysis approach where we analyzed the specific cases of each participant to identify common themes.

Findings: We analyzed the motion gestures and grouped the gestures into 4-fold taxonomic themes. The themes include natural and intuitive gestures, real-world metaphors, natural consistent mappings, and arbitrary gestures. Gesture generation by visually impaired people was primarily influenced by metaphors from daily life which were greatly different from sighted people. Regarding the physical characteristics of gestures, we found that our participants used large movements to generate gestures so that their gestures were recognizable enough.

Study 2: Motion Gesture Interfaces in Mobile Phones

We evaluated the usability of motion gesture interfaces implemented using the gestures that were suggested in Study 1. The study was motivated by three research questions: 1) Do motion gesture interfaces provide more efficient use of smartphones compared to traditional feature phones? 2) What do visually impaired users actually experience when using motion gesture interfaces? 3) What design implications can be learned for smartphone assistive interfaces?

In this study, the participants used both a smartphone with a motion gesture interface and a feature phone with a button interface, to browse contacts and make calls.

Findings: We found that motion gesture interfaces are more efficient than traditional button interfaces. Also, motion gesture interface gained more positive comments from the participants. Through the study results, we provided implications for designing smartphone interfaces.

2. UNDERSTANDING USER CAPABILITIES

While our studies showed the benefits of motion gesture interfaces for visually impaired users, it is difficult to use motion gestures for some commands. To increase the bandwidth of motion gesture interfaces, we proposed motion marking menus. The

literature has shown that spatial memory is a great aid in many situations (e.g., locating and finding objects they daily use) of visually impaired people. Leveraging such capabilities will facilitate eyes-free interactions in various applications. Thus, we studied user capabilities to perform motion marking menus with which users can exploit their spatial abilities for interactions.

Study 3: User Capabilities to Perform Motion Marking Gestures

The literature has shown the potential of marking menus for eyes-free interactions. However, user capabilities to perform marking menus were not studied. Our research questions include: 1) How many menu items can there be at each level? In the other words, we wanted to determine how many directions visually impaired people can distinguish to successfully perform with marking menus. 2) How deep or how many hierarchic levels can visually impaired people go before marking menu performance drops off? 3) Is wider breadth better than deeper depth in marking menus, or vice versa?

To answer the aforementioned research questions, we performed a user study. In the study, experimental trials to establish the number of items (breadth) and number of levels (depth) were designed as within-subject repeated measurements. The participants performed menu selections in 12 menu configurations of four breadths (angular width 90 degree), six breadths (angular width 60 degree) and eight breadths (angular width 45 degree) crossed with depths from 1 to 4 levels. User performances in terms of menus selection time

and errors were recorded.

Findings: Results indicated that people with visual impairments were able to perform directional motion gestures in up to 8 directions. The results also suggested that hierarchic levels for marking menus are efficient up to 4 levels for 4-item menus, up to 2 levels for 6-item menus and up to 3 levels for 8-item menus.

Study 4: Motion Marking Menus in Smartphones

To understand user impressions on motion marking menus systems, we developed and evaluated motion gesture-based marking menus in 3D space, which is called Motion Marking Menus (MMM). To understand the relative efficiency of motion marking menu systems, we compared the efficiency of our marking menu prototype to TalkBack, an accessibility menu system that is currently available on Android smartphones.

Findings: Results indicated that motion marking menus were faster than the TalkBack menu system. Also, we found that our participants were very receptive to the motion marking menu systems on smartphones. Through the analyses of qualitative data, we provided design guidelines for motion marking menus.

3. PARTICIPATORY GESTURE DESIGN

While understanding users and user capabilities promise more usable interfaces, user participation is also essential for designing and developing any successful assistive interfaces. Thus, for gesture design of visually impaired users, we studied effectiveness and guidelines for participatory design approaches: user-defined and choice-based design.

Study 5: Choice-based Gesture Design

User-defined approach is commonly used in the design of gestures. However, the user-defined approach may not always be appropriate, particularly when users have little idea of the design space. We proposed a novel choice-based elicitation approach for gesture design for visually impaired people, i.e., an approach where users are given a list of gesture choices to select from. To examine the relative

effectiveness, we compared choice-based approach and user-defined approach for gesture design.

During the study, participants were asked to define gestures for 15 TV commands in randomized order. Response time, i.e., the time between command instruction and gesture execution, was recorded. After each group of commands was defined (each group contains approximately 5 commands), participants were asked to evaluate their gestures, in terms of suitability, easiness and fatigue. After all commands were defined, 20 minutes break was provided. After the break, we asked participants to recall the gestures they performed in a randomized order. Recall time and recall errors were recorded.

To make the results of the two gesture design comparable, the same 12 visually impaired participants were recruited and a choice-based design study was conducted. To minimize the effect of user-defined gesture on their choices, we recruited the participants 3 weeks after the user-defined study.

Findings: Choice-based design approach outperformed the user-defined approach in agreement scores, response time, recall time and errors, and subjective assessments. The choice-based elicitation approach also confirmed that there is indeed some agreement of choice among the participants. This indicated that the participants had agreed mental mappings between the gesture choice and the given command, which can be better observed when all participants are equally informed about the design space.

Our studies also showed that it is possible to gain design insights by analyzing the gestures and mental mappings of users. By understanding what gestures users are familiar with (user-defined set), and what gestures they prefer (choice-based set), it helps to better determine what are the suitable and intuitive gestures. Thus we proposed a new participatory design approach which is a hybrid combination of user-defined and choice-based methods.

4. VIBRATION FEEDBACK

Motion gestures were the most effective when feedback was provided. In particular, spatial vibration feedbacks can support user's spatial ability to perform motion gestures. Moreover, visually impaired people are in a unique position to appreciate and make functional use of vibration devices. Thus, we studied design guidelines for vibration feedback to support motion gesture interfaces.

Study 6: Vibration Perception in Different Body Parts

Previous research has shown that vibration in different body positions were more efficient than vibration in a single body position device. Also, wearable vibration devices are gaining increasing interest. Thus, we conducted user studies to determine the most suitable body sites for wearable vibrations and to provide design guidelines. For the study, we proposed 15 vibration positions (ears, neck, chest, waist, wrist, hand, finger, ankles and feet). We also studied the most suitable vibration intensity for different posture (static, walking and fast walking). User perception ratings and errors were recorded. The studies were conducted in real mobile environments.

Regarding the proposed vibration positions, our design was based on careful consideration as to whether vibrations are easier to perceive in particular positions, whether vibrators can be easily integrated into clothing or accessories, and whether vibrations in those positions are wearable in the long-term in real-world settings.

Findings: The ears, neck, waist and fingers had the highest perception ratings in all conditions. The chest, ankles and feet had the lowest perception ratings, and these positions were the most effected by motion. In terms of preferences to wear, the wrists and the waist had the highest score, followed by the neck, hands and ears. The feet had the lowest score.