Handscope: Enabling Blind People to Experience Statistical Graphics on Websites through Haptics

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ABSTRACT
Statistical graphics on the web such as a tag cloud visually represent statistical data which are generated by website users. While sighted people can scan the latest information through the dynamic changes of statistical graphics, blind people, who cannot perceive them, lose opportunities to keep up to date in this quickly-changing society. In order to enable blind people to experience socially-generated statistical graphics, we propose a new assistive device, namely, Handscope, which translates statistical graphics on websites into simple height changes of its haptic pole. We conducted a two-phase user study with blind people in order to test its usability and explore its effects on the quality of blind users' web experiences. The results show the meaningful contribution of Handscope in extending the area of blind people's web experiences.

Author Keywords
Statistical graphics, haptic, blind users, web accessibility

ACM Classification Keywords
H.5.2.User Interfaces: User-centered design. K.4.2.Social Issues: Assistive technologies for persons with disabilities.

General Terms
Design

INTRODUCTION
Handscope translates *statistical graphics* on websites into haptic expressions for blind people. Statistical graphics like a tag cloud and five-star rating visually represent *socially-generated statistical data* such as popularity of search keywords or ratings of movies and books. Statistical graphics are seemingly small graphics, but very critical for users to quickly scan and fully understand the meaning of data. In addition, in the web environment, such graphics are dynamically updated by the website users, which enhance their importance for blind people, who also want to understand social trends. The screen-reading software that most blind people are using cannot enable them to either scan the information or even recognize the existence of statistical data in some cases. In other words, blind people's low accessibility to these statistical graphics on the Internet is an obstacle for their participation in this society.

Many have studied the field of haptic data visualization (HDV) of graphics that represent statistical data such as charts and graphs [3, 4]. However, not many have attempted to translate such dynamically changing information specifically to the web environment. Although Yu et al. [5] developed audio-haptic visualization of web-based graphs, they still focused on traditional types of graphs such as line graphs, pie charts and bar charts. Also, researchers have mainly focused on inventing new modeling techniques and evaluating their accuracy and efficiency. Unlike these approaches, with quality-centered design thinking, we have more interest in designing a technically simple, but sufficiently valuable assistive device and exploring its values in design for blind people.

By designing the haptic expression system of Handscope in a very simple but sufficiently clear way to deliver numerical values, we also aimed to make it intuitively and universally understandable without high-expense devices. Since Handscope expresses only the critical information in a 1-dimensional haptic model, it is much more affordable for real users compared to existing commercialized products like PHANTOM and Novint Falcon.

HANDSCOPE: STATISTICAL GRAPHICS TO HAPTICS
Before we designed the Handscope, we conducted pre-observations of five blind people in order to better understand their current experiences of web-browsing and to extract the key design requirements for blind people.

The form of Handscope was designed to be asymmetric, so that blind people can easily determine its orientation. Also, it was designed to be used with two hands, since we discovered that most of the blind participants in our pre-observation felt more comfortable when grabbing an object with two hands because they could be sure of its form.

Figure 1. Initial design of Handscope

The two wheels, which are rotatable and clickable, were designed to allow users to browse web contents. The vertical wheel is for macro browsing, which is used to look through the whole structure, and the horizontal wheel is for micro browsing, which is used to see the details of each piece of content. This two-wheel system was inspired by blind users' searching steps on the interfaces they use with the screen-reading software: for macro browsing, they use the up-and-down arrow keys; for micro browsing, they use the left-and-right arrow keys (Figure 1).

If Handscope finds a statistical graphic by using the vertical wheel, which reads block elements of HTML, it vibrates to let users know of its existence. Then, blind users can examine more details by rolling the horizontal wheel, which reads inline elements. Although the algorithms for detecting statistical graphics need to be studied further, the experts we consulted were all sure of its feasibility. With the hypothesis that the algorithm is available, we performed more exploration of new values from a design perspective.

Figure 2. HDV process of a tag cloud through Handscope

Whenever the horizontal wheel is rotated, the haptic pole, which is covered with flexible fabric, moves up and down to translate the statistical data into a tangible height. The HDV process of Handscope consists of three steps: i) It loads the HTML codes of the selected statistical graphic (Figure 2-a); ii) It extracts only the statistical data and the related words. It translates the range of statistical data into the motion range of the servomotor that moves the haptic pole. After then, the words are synthesized to voice and the translated statistical data are mapped onto the angles of the servomotor in order to create different heights of the haptic pole (Figure2-b); iii) The flexible fabric is transformed depending on the haptic pole's height and it can be touched and felt underneath the user's hand (Figure2-c).

For user studies—both the pilot study and the primary user study—, we needed to provide the same statistical graphics for all the participants so that we could compare the results in equal conditions. To do so, we devised Flash prototypes, borrowing structures and contents from existing websites instead of using actual websites that are changing in real time. We used MIDAS [1], which was developed for designers to easily prototype hardware-software integrated interactive products in a Flash environment.

PILOT STUDY

For the pilot study, we first had to figure out whether our concept of HDV would work or not. If blind people can understand the meaning of the height difference, then we would not have to display all content materials as they actually look. In addition, we were interested in seeing if our design for Handscope is ergonomically appropriate.

Study Setup

A tag cloud was selected as a Flash content because it is the best example of something that blind users do not even know the existence of. We used popularly searched tags on Flickr for the content of the tag cloud. We recruited three blind people (P1-P3) who were high school students, and who were interested in different kinds of web contents. Each participant was given a short explanation about how to use Handscope and asked to do two things: 1) explore the Tag Cloud by manipulating Handscope; 2) explain how they interpreted the meaning of the height difference either through oral explanation or by using Lego bricks. The Lego kit was used as a supporting communication tool to enable blind participants to describe their thoughts visually. The whole study process for each participant was recorded with a camcorder to observe their behavior while they were interacting with Handscope.

Study Results

Two of three participants perceived the height of the haptic pole as *a representation of size or as an amount of something related to the mapped words in the tag cloud*. P1 explained the height as the size of countries and named the tallest block he built on the Lego board as 'Japan', because the words we included in the tag cloud contained names of several countries and Japan was the most popular one (Figure 3). P3 also interpreted the meaning of height as the amount of information related to each tag.

P2, on the other hand, couldn't guess the meaning until we explained the tag cloud. This reaction seemed to reflect this participant's particular style of using the Internet. She doesn't as frequently encounter visual contents as the others do. She uses the internet for reading books and listening to lectures on an audio library; the other, however, use the internet for playing games, for browsing new digital products, and even for buying products. It might have been hard for this one participant to imagine visualized-text. However, she still understood the haptic pole's taller height as the representation of bigger size or larger amount.

From the results of each participant, we determined that the meaning of the height can be understandable if a clear explanation of what the haptic pole's height represents is given so that the blind users are sure what contents they are

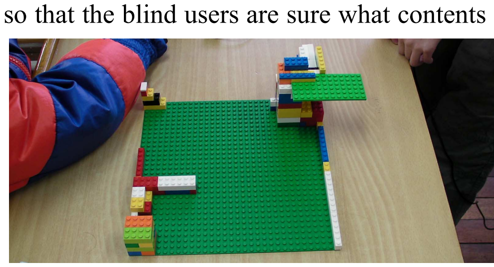

Figure 3. P1 created a Lego model in the user study. Heights of the blocks in each corner represent different sizes of tags

looking at and how to interpret the Handscope's display .

In addition, we observed interesting behavior through the video analysis. We used the wheel interface to enable the blind users to quickly browse the web. However, sometimes they rotated the wheels too quickly and were confused about how many steps they had skipped. This implies that discrete step-by-step browsing is important and more appropriate for blind people than continuous browsing. This also implies the importance of matching interactivity quality of a product with expressed meaning of information it delivers based on the types of users [2].

PRIMARY USER STUDY

Before we conducted the primary user study, we refined Handscope to improve its usability based on the findings from the pilot study (Figure 4). While keeping its basic structure, we refined the parts that had made participants uncomfortable or confused. We replaced the wheels with buttons so that users wouldn't lose their imaginary cursor, and assigned functions as tab buttons to go previous or next link. This was done because we discovered that macro browsing is more familiar and convenient for blind users when it is controlled with the keyboard, because the keyboard provides more various ways to look through the whole content structure by using keyboard shortcuts. When they encounter a statistical graphic, they will move their hands from the keyboard to Handscope to browse the detail information. We also modified Handscope's features in a way that users can grasp it more comfortably.

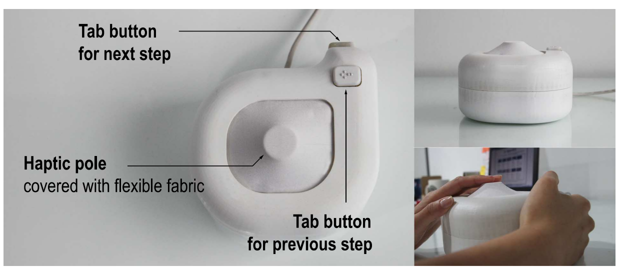

Figure 4. The refined Handscope

Regarding the flexible fabric, all participants very much enjoyed the feeling of its dynamic form changing. In addition, that unique transformation seemed to help users not misunderstand the meaning of its height. Since the pole expands as it is raised, the participants feel a larger volume on their hands compared to the case when the pole falls. Therefore, we kept this element in the second prototype.

Study Setup

In the primary user study, we aimed to explore the effects that Handscope actually had on blind users' web experiences. To determine this, we devised the experiments and Flash prototypes in two situations in order to compare the differences: with Handscope (Case A) and without Handscope (Case B).

For the contents of Flash prototypes, we selected two types of statistical graphics that contains *preattentive features* like basic shapes or colors that are instantaneously identified

Figure 5. Preattentive features in each set of content

even after a very brief exposure; blind users, therefore, have problems to scan and understand the information when they hear those contents through the screen-reading software (Figure 5). There are two types of problematic data: i) statistical data that are eliminated in the process of HDV and cannot be delivered by auditory feedback; ii) statistical data that are recognizable even without Handscope, but are ineffectively delivered because the auditory feedback delivers them in a linear manner. For the first type, we chose a tag cloud, which represents the popularity of each search-keyword with different font sizes (C1). For the second type, we selected a five-star rating for representing average ratings of movies (C2), and aligned text, which uses the text width of the recommended numbers as a preattentive feature for scanning through the width of the numerical text (C3). The content was about good places and restaurants to visit. Flash prototypes of each portion of content were devised both for Case A and Case B. We had six Flash prototypes in total (1-A, 1-B, 2-A, 2-B, 3-A, 3-B); each participant went through all of the cases. To prevent participants from being influenced by each Flash prototype when browsing the same type in Case A and Case B, we used a different set of words for each division of content.

We recruited ten blind people who were familiar with using the internet. Five of them were high school students and the others were teachers. We explained how to use Handscope and randomly provided the six Flash prototypes to each participant, and asked a question according to the content type. For the first content type, we asked participants to select the most popular word in the tag cloud in order to explore *the effect of recognizing the statistical information on one's interpretation of the content*. For the second content type, we aimed to explore *the effects of the haptic expressions* when users were asked to select a certain piece of information after browsing the content (i.e. C2 for the movie they most want to see, or C3 for the local place they most want to go), compared to the cases in which only auditory expression was given. Since statistical data of the second content type can be delivered through auditory feedback even without Handscope, we wondered what benefits Handscope can make in such a case. That's why we asked participants to select the most preferable item, instead of directly asking them which item is the most popular one, which is a type of a decision making task resulting from the information they had gathered.

Regarding the instruction about the height of the haptic display, we didn't explain this in the case of 1-A in order to explore how participants came to understand what the height means; however, we explained it for cases 2-A and 3-A because these two cases were primarily designed to explore the effects of haptic expressions by comparing results for this situation with and without Handscope.

Study Results

Regarding the effect of having statistical graphics on a blind user's understanding of content, all the participants *correctly understood the content rather than guessing or being biased* when they read the content with Handscope (1-A). None of the participants selected the word that is actually the most popular one in 1-B, and their rationales were only based on their *individual interests*; however, in 1-A, their rationales were supported by *reliable objective data*. Six of the participants selected the correct word and two of the others selected the 2nd most popular word because they were unable to distinguish the small height difference between the 1st most popular word and the 2nd most popular one. Although the other two participants F and J selected the 4th most popular word, they actually selected the most popular word from their point of view. Participant F said, "I did understand that height means the popularity, but the top three words are related to visual materials, which we cannot see, so I selected the 4th word, which is the most popular among the remaining words."

Some reactions were quite meaningful beyond the correct comprehension of information, because these participants *expressed a will to participate in generating social statistics* when using Handscope. Participant H (3-A) said, "Why this restaurant's ranking so low? I thought it was very nice. There might be some hygienic problems that I can't see. If not in the reviews, I would like to vote for this restaurant to raise the recommended number." Participant A (1-A) also had the same opinion for one of the small-sized tags—i.e. the name of a TV drama which he thought was very popular.

Regarding the effects of haptic expressions on users' selection of an item on the web, when compared to the case B, 5 to 6 *more participants did care about statistical information* when they were able to obtain the information through Handscope. Just as in previous examples, participants mentioned their opinions about the statistical graphics that Handscope displayed in 2-A and 3-A, while most of them used the information as just a reference for their selection in Case B. In addition, 4 more participants in Case A explicitly expressed that Handscope helps them *quickly scan the content*, because its multimodal interface can deliver more than single pieces of information at the same time. In Case B, everyone attempted at least one time to skip the auditory feedback even before listening to the statistical information.

We also found that Handscope's *haptic change can emphasize certain information* through which participants may give more attention to that information. Participant J said, "It commands my attention whenever the height change is big. If I hear certain words at that time, I can remember those words better." This *attention effect* has great meaning in HDV, because the state change from one to the other within one haptic pole can be understood as one step. This implies that motion translation within one haptic pole should be considered as another haptic language and should be carefully designed in order not to be confused.

CONCLUSION AND FUTURE WORKS

Our study discovered that Handscope provides valuable benefits to their understanding of web contents the quality of their web browsing. The key implication of this result is that blind people's web accessibility can be increased with a simple haptic display, such as that which Handscope provides, instead of relying on realistic representation through advanced haptic devices.

However, Handscope still has problems with the inefficient use of going back and forth between a keyboard and Handscope although it reduced the time for scanning information by letting people use its tab buttons. In order to make the haptic model of Handscope truly and preattentively perceivable, this will be the next step to be studied.

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REFERENCES

1. Introduction to MIDAS. http://cidr.kaist.ac.kr/mediawiki/index.php/MIDAS
2. Lim, Y., Lee, S. and Lee, K. Interactivity attributes: a new way of thinking and describing interactivity. In *Proc. CHI 2009*, ACM Press (2009), 105-108.
3. Wall, S.A. and Brewster, S.A. Tac-tiles: multimodal pie charts for visually impaired users. In *Proc. NordiCHI 2006*, ACM Press (2006), 9-18.
4. Yu, W., Ramloll, R. and Brewster, S.A. Haptic Graphs for Blind Computer Users. In *Proc. International Workshop on Haptic Human-Computer Interaction*, Springer-Verlag (2000), 41-51.
5. Yu, W., Reid, D. and Brewster, S.A. Web-based multimodal graphs for visually impaired people. In *the 1st CWUAAT*, Cambridge (2002), 97-108.