Consideration of the Experiences of Blind People Using Four User Interfaces for Independent Editing of Tactile Graphics

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Abstract

Blind people are able to access visual information if the information is expressed by tactile graphics; however, it is almost impossible that blind people express their ideas or opinions by visual information such as diagrams, if they do not have any help from sighted people. So, in this paper, we discuss the experiences of blind people using four user interfaces for independent editing of tactile graphics. We first introduce the four tactile graphics creation systems with refreshable braille displays; the user interfaces are designed so that blind people are able to edit tactile graphics by themselves. Usability of each system is discussed based on the subjective evaluation of the blind participants.

1 Introduction

We have many systems for editing tactile graphics, but most of them have been designed for sighted users. This means that for blind people it is not easy to express their ideas and opinions by using visual information such as diagrams; however, some of blind people really need to create graphics by themselves. For example, a blind physics teacher edits teaching materials for his lecture, the teaching materials include figures. For this reason, we are studying tactile graphics editors available for blind people [6].

Watanabe et al. [2] and Morii et al. [3] have studied tactile graphics editors for blind users. Watanabe's system is the first tactile graphics editor which is able to redraw and erase tactile graphics. Morii has then improved some of the drawbacks of Watanabe's system. Both of the editor systems consist of refreshable braille displays to present, redraw and erase tactile graphics, and the systems make blind users edit tactile graphics, but they are not still practical use, because the user interfaces are weak for blind users to edit tactile graphics easily. In this paper, we discuss user interfaces of tactile graphics editors available for the blind. We introduce the four tactile graphics editor systems, and usability of each editor system is discussed based on the subjective evaluation of the blind participants.

2 Outline for Our Systems

Our systems consist of the following devices (see Figure 1): a refreshable braille display (DV2 produced by KGS Corporation), a webcam for detecting the position of a fingertip, a graphics tablet for measuring the position of the braille display, a table with rails for sliding the braille display on the x-y plane, a USB keyboard, and a software program which controls all the devices.

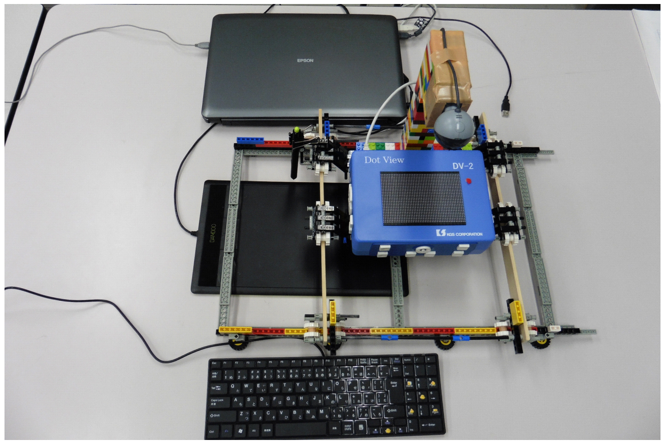


Figure 1: Overview of the System

The webcam is set above the braille display in order to detect the position of a fingertip. To detect a fingertip, a felted fabric marker is put on the nail of the index finger. We detect the coordinate of the center of gravity of the marker region, and we then estimate the position of the index finger on the braille display. This function makes blind users draw lines, simultaneously touch them. Furthermore, the braille display is put on the table, and users are able to slide the braille display freely on the x-y plane.

2.1 Input Methods for Elementary Plane Shapes

In this study, we first select several basic plane shapes, called objects, and our systems are expected to draw a figure which is able to express by a combination of these objects. We select four objects: rectangle, rhombus, arrow, and straight line. A user draws these objects on the braille display, rearranges them, and finally completes drawing the target figure. The aim of this study is to clarify an efficient drawing method for blind people, and therefore, we introduce two different methods for inputting objects and two different methods for expressing figures. In this section, we first describe the two object input methods.

The first input method uses a fingertip. This input method first requires time sequence patterns which are trajectories of a user's fingertip. Dynamic programming is applied to find a standard pattern close to the input pattern. After detecting the standard pattern, its corresponding object is presented on the braille display, the size of the object is arranged in order to circumscribe the bounding box of the input pattern.

The second input method uses a keyboard. We assign every object to a key of the keyboard, and a blind user can choose an object by pushing the key assigned the object. Then, the object pattern is presented on the center of the braille display, the size of the object is determined so that the object is inscribed in the rectangle of the size 15×16 dots.

2.2 Scrolling Methods

Two scrolling methods are described in this section. The size of DV2 is 48×32 dots; this is very small to draw figures. So, we get the drawing area in the computer memory in order to expand the small drawing size of DV2. The size of the drawing area is enlarged into the size

Table 1: Four Systems for Usability Evaluation

Scrolling \ Input	Fingertip	Keyboard
Button	System 1	System 2
Physical	System 3	System 4

Table 2: Characteristics for the Blind Participants

Sub.	Age	Age at Onset of Blindness	Tactile Graphics	DV2	PC
A	22-year-old	13-year-old	4	4	5
B	21-year-old	Born	5	5	5
C	21-year-old	2-year-old	6	6	6
D	52-year-old	45-year-old	2	1	5
E	48-year-old	12-year-old	6	4	6

Items “Tactile Graphics”, “DV2”, and “PC” stand for experience on tactile graphics, DV2, and PC, respectively. For these items, the blind participants gave one of the six grades from 1 to 6 to answer each question. The grades mean that the larger the value is, the more experience the participant has.

of 96 dots by 64 dots. Because of this expansion, every object is not always presented on the braille display. So, we need scrolling functions so that a user can touch an object when it is not presented on the braille display. We introduce two scrolling methods: the first method fixes the braille display, but scrolling the drawing area by pushing some buttons on the braille display; the second method fixes the drawing area, but scrolls the braille display directly by blind users. In the following, the first method is called button scrolling method, and the second method physical scrolling method. Physical scrolling method needs a graphics tablet to measure the position of the braille display, and then the corresponding area is presented on the braille display. To slide the braille display, we need the table with rails.

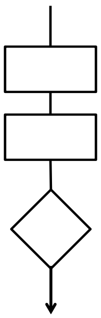
3 Experiments

We have designed a usability evaluation to examine which object input method is efficient for blind users, and which scrolling method is useful for blind users. The evaluation has been conducted by interviewing the blind participants. We have introduced the following four systems to carry out the experiments (see Table 1).

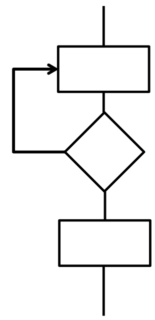
We determined flowcharts as the target figures because a flowchart can be expressed by a combination of the elementary plane shapes. Five blind people have participated to our experiment, and the characteristics for the five participants are summarized in Table 2. Participant D has lost his sight when he was 45-year-old. Therefore, he has less experience for reading tactile graphics and operating DV2. On the other hand, the other participants have enough experience for reading tactile graphics and operating DV2. All the participants are familiar with operating computers.

4 Workflow of the Experiments

First, we conducted an instruction session, in which we gave verbal instruction for the operations of the four systems. In this instruction session, every participant asked to draw the flowchart



(a) Flowchart for Instruction Session



(b) Flowchart for Evaluation Experiment

Figure 2: Flowcharts

in Figure 2 (a) by using the four systems; a tactile graphic of the flowchart was presented to the participants, and they were permitted to touch the tactile graphic during the instruction session. After the instruction session, the participants were asked to draw the flowchart in Figure 2 (b); a tactile graphic of the flowchart was presented to the participants, and they were permitted to touch the tactile graphic during drawing.

We asked the participants the following 5 questions after every completing the flowchart.

Q1: When you inputted an object, were you able to insert the object in the position where you wanted?

Q2: After inputting an object, were you able to resize and move the object easily?

Q3: Were you able to easily comprehend the structure of the whole figure?

Q4: Were you able to easily show the area where you wanted to touch?

Q5: Were you able to draw the flowchart as you wanted?

Furthermore, after completing all the four experiments, we asked the following 4 questions to the participants.

Q6: Were you able to easily use fingertip input method?

Q7: Were you able to easily use keyboard input method?

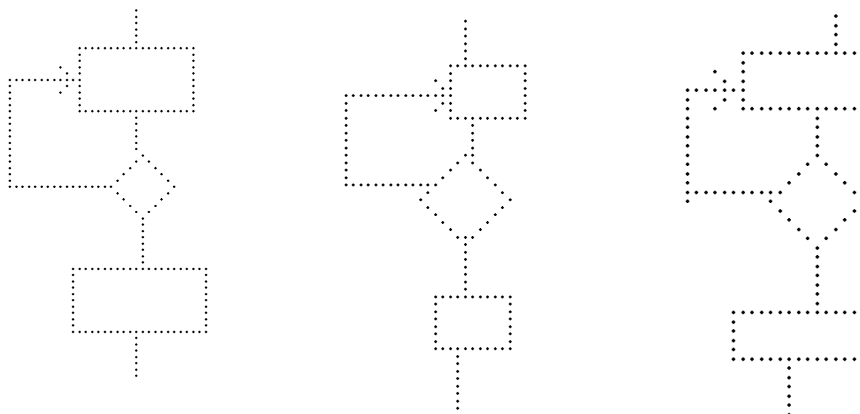
Q8: Were you able to easily use button scrolling method?

Q9: Were you able to easily use physical scrolling method?

Each participant answered each question by giving a grade from 1 to 6; the higher the grade is, the more positive the participant thinks. Moreover, we asked every participant to give an order of the four systems which expresses the participant's preference on the systems from the viewpoints of convenience and practicable for use. The results are shown in Table 3.

Table 3: Preference Order of Four Systems

Sub.	1st	2nd	3rd	4th
A	System 3	System 1	System 4	System 2
B	System 4	System 3	System 2	System 1
C	System 1	System 3	System 4	System 2
D	System 3	System 1	System 4	System 2
E	System 4	System 2	System 3	System 1



(a) Participant B (b) Participant C (c) Participant D

Figure 3: Tactile Graphics Produced by the Blind Participants

5 Experimental Results

The flowcharts of Figure 3 have been created by three of the blind participants; it is confirmed that the blind participants are able to create tactile graphics of the flowchart that sighted people can visually understand.

In the following, we first describe the results for questions from Q6 to Q9, and then show the results for questions from Q1 to Q5.

5.1 Results for Questions from Q6 to Q9

Questions Q6 and Q7 ask which input method, fingertip or keyboard, is easy to input objects. On the other hand, questions Q8 and Q9 ask which scrolling method, button or physical, is easy to present the area where the participant wanted to touch. Figure 4 shows the mean grades for questions from Q6 to Q9. A t-test has been applied to the two groups Q6 and Q7, and we have had the result that a p-value equaled to 0.545, which means that there was no significant difference between the two means. Furthermore, we have had a p-value equaled to 0.359 from a t-test of the two groups Q8 and Q9; this result also means that there was no significant difference between the two means of Q8 and Q9.

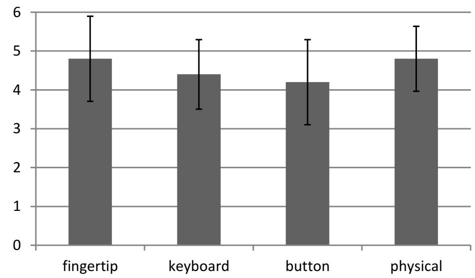


Figure 4: Mean Grades of Questions from Q6 to Q9: The error bars express the standard deviations. fingertip, keyboard, button, and physical stand for Q6, Q7, Q8, Q9, respectively.

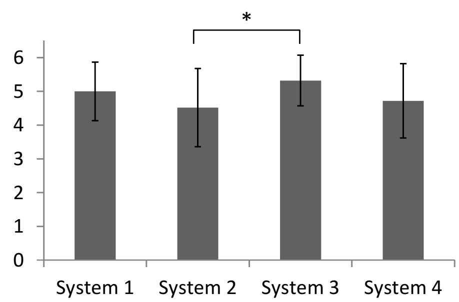


Figure 5: Mean Grades of Questions from Q1 to Q5 ($*p < 0.05$): The error bars mean the standard deviations.

5.2 Results for Questions from Q1 to Q5

Figure 5.2 shows the mean grades of questions from Q1 to Q5. We have conducted a one-way ANOVA, and we had the result that the F-statistic was $F(3, 96) = 3.130$ with a p-value equaled to 0.029. We clearly reject the null hypothesis of equal means for all four groups. We have then conducted a Tukey's honestly significant difference test to determine which pairs of the means are statistically significant. The result showed that the pair of System 2 and System 3 is statistically significant with a p-value equaled to 0.025.

Next, we have examined if there is a significant difference across the means of the four groups. As a result, for only Q3, we found that there was a significant difference between a pair of the means. So, below we describe only the result from Q3. Figure 4 shows the mean grade of question Q3. We have conducted a one-way ANOVA, and had the result that F-statistic was $F(3, 16) = 5.455$ with a p-value equaled to 0.009. We have then conducted a Tukey's HSD test to determine which pairs of the four means are statistically significant. The result showed that the pair of System 2 and System 3 is statistically significant with a p-value equaled to 0.007.

6 Conclusions

In this paper, to develop a computer-aided system that assists blind users to draw figures, we have introduced the two input methods and the two scrolling methods. We have conducted the

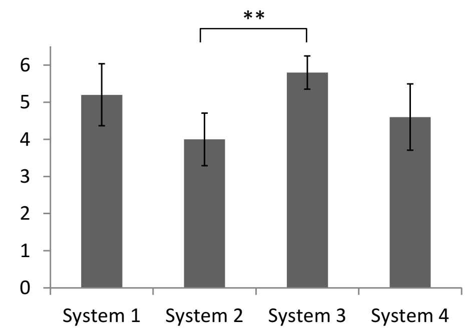


Figure 6: Mean Grades of Question Q3 (**$p < 0.01$): The error bars mean the standard deviations.

usability evaluation with the five blind participants to clarify the usability for the four methods, but we could not conclude which method is convenient for blind users. However, physical scrolling method takes some advantage from button scrolling method from the viewpoint of comprehensibility of the overall figure. Further, fingertip input method takes some advantage from button input method, this means that even blind users may want to draw figures by hand.

Acknowledgement

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