

An Approach for Improving Computer Human Interaction of Visually Impaired People

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Abstract

This paper introduces two research projects about the universal designed interfaces to improve visually impaired people's computer human interaction. The one is the touch panel interaction of visually impaired people. Our final goal is to develop the universal-designed plugins that translate graphics into interactive contents with sound and touch interaction. As an instance, we proposed "One Octave Scale Interface (abbr. OOSI)" as the graphical representation. Several touch panel contents with OOSI, such as a guide maps, a concentration game, and shape recognition puzzle of symbols, have been implemented. This paper focuses on the evaluation of shape recognition puzzle by visually impaired people, and reports the implementation and evaluation of single and multi touch display contents. The other research project is a collaborative music composing application. Recently, so many people have come to enjoy computer music. But the interface of the music application is too complex for children, the elderly and the visually impaired. In this paper, our goal is to propose a universal design collaborative music application for everybody with due consideration for visually impaired people. We employed tangible interface using daily goods and stationeries with AR markers, and a dining table. We developed two prototype systems. By using the first prototype, we confirmed the effectiveness of our interface that consists of clip type objects and string type objects. It was also confirmed that the interface has an advantage in promoting collaboration between sighted and visually impaired people. To improve the multiuser collaborative functions, we developed the second prototype system with stylish daily objects and rich sound interaction.

Introduction

Toward the upcoming ubiquitous computing and networking era, the digital divide problem of visually impaired people tends to be focused on the access difficulties of graphical information today. This paper introduces our research experiences on developing two universal-designed interactive interfaces for visually impaired people. The first is a touch panel interface. The second is a music composing application with daily goods on a table.

As the touch panel interface, we have been proposing "One Octave Scale Interface (abbr. OOSI)" as a graphical representation interface on touch-panels for visually impaired people[1][2]. The OOSI is based on the view that all

shapes of graphics are able to be divided into start/goal/relay points and line/curve segments. Each line/curve is divided into eight parts to be linked to a musical scale as showed in Fig.1. When a user successfully traces a line/curve, continuous musical scale sound is played depending on the finger position. Proposed methods and interfaces are basic techniques for developing plug-ins which help blind people to use ordinary mass-produced computer devices with touch-screens, such as smartphones and tablet computers.

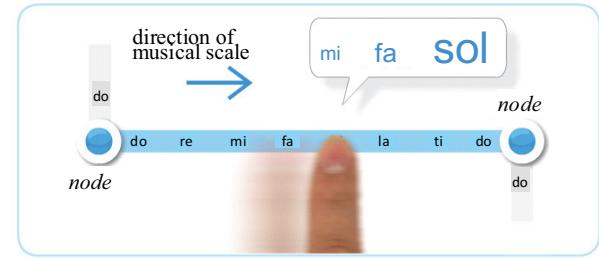


Fig. 1. The overview of the One Octave Scale Interface.

The second topic of this paper is the music composing application for visually impaired people. So many people have come to enjoy computer music recently. But the interface of the music application is too complex for children, the elderly and the visually impaired. Our goal is to propose the universal design collaborative music application for everybody with due consideration for visually impaired people. We employed tangible interface using daily goods and stationeries with AR markers, and a dining table[3]. We have developed two prototype systems. In the experimental work with visually impaired people using the first prototype, we confirmed the effectiveness of our interface which consists of clip type objects and string type objects. It was also confirmed that the interface has an advantage in promoting collaboration between sighted and visually impaired people. So, we developed the second prototype system to improve multiuser collaborative functions as showed in Fig.2. This paper reports our new system with stylish daily objects and rich sound interaction.

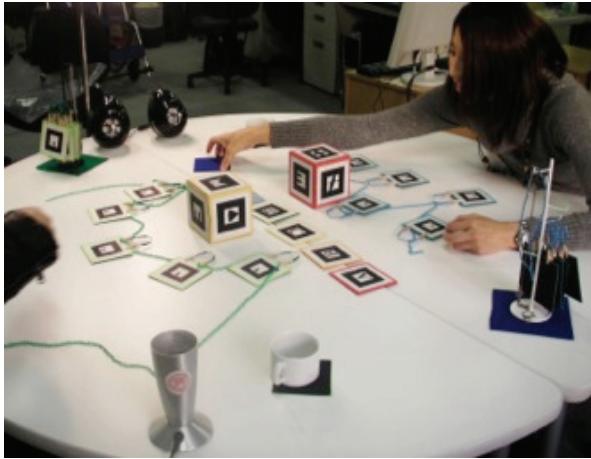


Fig. 2. The overview of the music application

Graphical Representation Interface For Visually Impaired People

Our final goal is to develop the universal-designed map and its graphical expression with due consideration for visually impaired people. Target places of the map are inner buildings and structures, such as museums, airports, and stations, whose details are not described in published paper maps and digital maps. The maps will be used in events and transit guides within buildings and structures by downloading contents of the map into smart phones, tablets, and PCs, and by contact operation of the map which is displayed in large size touch panel displays, such as wall-hanging displays and table-top displays. Recent problems which visually impaired people have pointed out are that maps in events and transit places tend to attach great importance to good-looking design, neglecting information accessibility for visually impaired people. Text reading software is highly helpful for them in text contents case. But in map contents case, recent map reading software only slices text information such as route guidance with landmarks and turning point. A lot of spatial representations in maps still remain to be unavailable for visually impaired people. The evolution of map contents shows clear-cut trend toward highly interactive approach; Google Map and Earth, for instance. Certainly the highly interactive approach will be practical and indispensable for all people except for visually impaired people to understand complex shaped multi-floor/room space with zooming, rotating and jumping to linked information. But the highly interactive approach will put more weight to visual expression and good-looking design of maps. Not to leave visually impaired people neglected, ultimate solution is to develop universal designed interactive representation of map, which cares deeply for visually impaired people and is also useful for other people. From the reasons mentioned above,

to develop universal designed interactive map is the final goal of our research. We propose a novel map expression in which sense of sight, hearing and touch are united, because touch panels are naturally attached on large size wall-hanging/table-top displays, and on small size smart phones/tablets/PCs' displays today.

One Octave Scale Interface

Our basic idea for the graphical representation of touch panel contents for the visually impaired is simple, like previous research for example, dividing graphs into start/goal/relay points and trajectories[4]. Users hear the sound/voice information when they touch the area where sound/voice are linked. There are two types of the sound and voice linked area, one is the spot type area for connecting points, end-points and landmarks, another is the line type area for paths and borderline of rooms and buildings. Users recognize spatial arrangement from the sound/voice information linked to spatial objects.

We have proposed “One Octave Scale Interface(abbr. OOSI)” in which lines are divided into eight parts which link to ‘do re mi fa sol la ti do’ sound like Fig. 1. When a user touches lines, ‘do re mi fa sol la ti do’ sound depending on finger position of a line, for example ‘sol’, is played. When a user traces a line with his/her finger, continuous ‘do re mi fa sol la ti do’ sound is played according to a speed of tracing. This will help the user’s intuitive understand of relational finger position of a line and length of lines. If no sounds are linked to spot type area at connecting points and end-points of lines in this method, users will manage to recognize the spatial relations of lines at connecting points and end-points. Because users will be able to distinguish lines from one octave difference of ‘do’ at connecting points, and ‘do re mi fa sol la ti do’ sound interval according to lengths of lines. We achieved two experiments: (1)the graphic symbol recognition experiment for evaluation of OOSI comparing a method of beep sound by two female low vision examinees with heavy impairment that only letters within 10cm distant from their eyes are illegible, but they can write letters and graphics within 10cm distant from paper to their eyes, (2)the unknown place navigation experiment for evaluation of the interactive map with OOSI by four blind people who walked the route after map reading[5].

The results of the experiments shows that OOSI is effective (1) to lead curve and oblique trace against subliminal trace of horizontal and vertical direction of touch panel displays, (2)to provide explicit information of connecting points and end-points of lines, and (3)to gives clear positional signs of points where they lost and where they recover after getting lost, include positional expressions of

length of lines. OOSI succeeded to help graphical recognition and navigation for visually impaired people.

Implementation and Evaluations on Single Touch Displays

We have been implementing and evaluating 4 following ideas to improve the performance of OOSI with visually impaired people: (1)limiting the number of nodes, (2)introducing the stereo effect of lateral direction to the expression of line, (3)adjusting the position of figures to the first touch point by users, and (4)adding interactive function of map scrolling and jumping. From these evaluation results, minimal number of nodes, with only start and end point, doesn't work in case of curved symbols, in contrast with the previous experiments mentioned in previous section, the circles with 4 nodes and more were bad recognition result. Stereo effect helps users but seems not to be indispensable, and position adjustment seems to have a strong effect for performance improvement. Map scrolling and jumping function was evaluated with a interactive map consists of 4 pages linking each other. One blind person could understands the structure of the map and successfully wrote down the whole routes of a campus guide tour of Sophia University.

For improving the shape recognition performance of the OOSI as the single-touch screen interface, further several experiments with visually impaired people were done as showed in Fig. 3 for investigating the node number effect, the stereo sound effect and the node regulation effect. Fig. 4 is the recognition results of the figures in three types of node regulation by eleven visually impaired people. In this figure, 'S' means the single-touch experiment, 'B' means the blind person, and 'L' means the masked low vision people. Despite these efforts of improving, the low recognition rate of curves still remained as unsolved problem. Looking at this problem from different angle, we decided to introduce the multi-touch screen in our development.

Shape Recognition on Multi Touch Display

To enrich the OOSI as a multi-touch screen interface, we thought that using multi timbre would provide useful clues to find the location of each finger on a displayed graphic for users. We introduced the timbre of eight musical instruments into the OOSI's representation of lines and curves as shown in Fig. 5(a). To evaluate the OOSI's multi-touch function, an application was written by Cocoa for iPad, which allowed us to develop an eleven finger multi-touch application. The application consists of a training



Fig. 3 Single Touch Display Experiment (Symbols were not displayed on the screen.)

	M	○	□	□	○	N	S	□
SBa	M	↖	□	□	○	N	↙	↗
SBb	M	○	□	□	○	N		No answer
SBc	M	↖	○	□	○	N	↙	↗
SBd	↖	○	○	□	□	□	↖	↖
SBe	↖	○	○	R	○	N	↙	□
SBf	□	○	○	D	○	N	↙	□
SLg	M	↖	↖	↖	↖	N	↖	↖
SLh	M	↖	○	□	○	N	↖	↖
SBi	○	○	○	R	○	N	↙	□
SBj	↖	○	○	↖	○	M	↙	↖
SLK	↖	○	↖	↖	○	N	↙	↖

Fig.4 Recognition Results of the Single-touch Experiment drawn by examinees

graphic in Fig. 5(b), and twelve graphics in three patterns as shown in Fig. 5(c). The size of each graphic is 10cm x 10cm as same as the previous experiments. Six blind people and five low vision people, who were staff members or former/recent students of braille training courses of Japan Braille Library, participated in our evaluation. People with low vision wore eye-masks, and all participants were given warm encouragement but no feedbacks about correct answers from examiners while evaluating. All figures were displayed in random order. Maximum time for examining one figure was strictly fixed at four minutes. After examining, the recognition result was presented by the examinee with fingertip drawing on a paper, and was traced by examiner with a pen. The recognition results by all participants are shown in Fig. 6. An example of touching display is shown in Fig. 7. By comparing the recognition results of the same figure “□” in two experiments shown in Fig. 4 and 6, the number of the perfect matching was zero in the single-touch evaluation and four in the multi-touch evaluation. The curve recognition ratio of single/multi-touch screens is compared in Table 1.

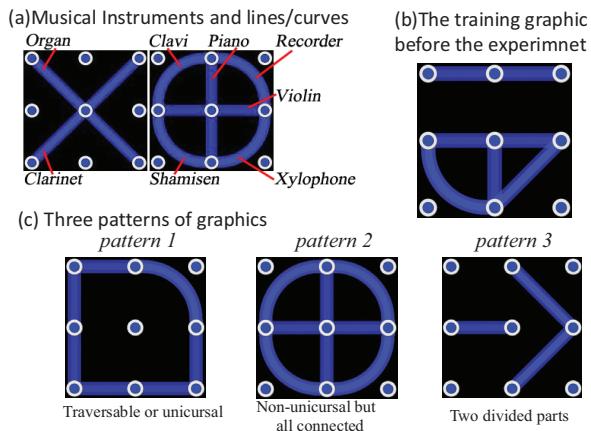


Fig. 5. (a) Sound Mapping of Figures, (b) a Figure for Training and (c) Figures for Evaluation in three patterns.

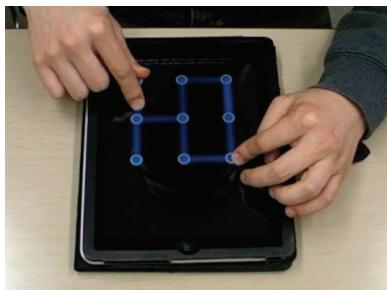


Fig. 7 Multi Touch Display Experiment
(Symbols were displayed on the screen.)

Music Application with Daily Goods and Stationeries on the Table

Recent attractive music applications, such as GarageBand on Mac and reacTable[6], could be ineffective for visually impaired people because of these rich intuitive comfortable visual interfaces and interactions. Our research goal is to propose the novel musical application using commodities at home for users even if they have visual impairments. The idea showed in Fig. 8 is so simple that string objects, such as yarn, ropes and chains, help users to trace and adjust the positions of clip objects with AR marker on the table. The positions of clip objects are equivalent to musical note, and string objects are equal to phrase. This paper introduces the universal design of the music application interface and two prototype systems. The first prototype was developed to confirm the effectiveness of the interface with string objects and clip object. Evaluations of single user composing and two users' collaborative composing with five visually impaired people are reported. From the result of the evaluation, we developed the second prototype as the universal design collaborative music application with

		Pattern 1	Pattern 2	Pattern 3
Staff Members	Ba	□ ∩ ⊚ ⊜ X ⊙ □ ⊕ - ⊙ ⊙ ⊙	□ ⊙ ⊙ X ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙
	Bb	□ ∩ ⊚ ⊜ X ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ X ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙
	Bc	□ ⊙ ⊙ ⊙ ⊙ X ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ X ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙
	Bd	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ X ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ X ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙
Former Students	Le	□ △ ▽ ▷ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙
	Bf	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙
	Lg	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙
	Lh	△ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	No Answer	No Answer
Students	Bi	△ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙
	Lj	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙
	Lk	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙	□ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙ ⊙

Fig. 6 Recognition Results of the Multi-touch Experiment drawn by examinees

Tab. 1 the Curve Recognition Ratio

	The number of lines+curves	The number of curves	Recognition ratio of curves	Misrecognition ratio of curves	Absence ratio
Single	43	7	31.2%	50.6%	18.2%
Multi-Pat1	25	7	45.5%	23.4%	31.2%
Multi-Pat2	26	6	63.6%	9.1%	27.2%
Multi-Pat3	18	2	59.1.%	31.8%	9.1%

improved usability and interactions of the interface.

Design of the Music Application

We started this research from the interviews of blind people and a teacher who developed and researched assistive applications for visually impaired students. They similarly indicated the difficulties to learn music because of the hurdle to memorize phrases or read music score with braille, and also because of the embarrassment of making strange sounds in the presence of others. The real situation seems that visually impaired people are more interested in music applications than in real musical instruments. There are few visually impaired people who master computer music applications recently. Agendas for designing the music application from the interviews are as follows; (1) composing music without memorizing or reading musical scores is a much-needed application for visually impaired people contrary to our expectation, (2) user friendly interface without making strange sounds helps visually impaired people to enjoy the music application with others without emba-

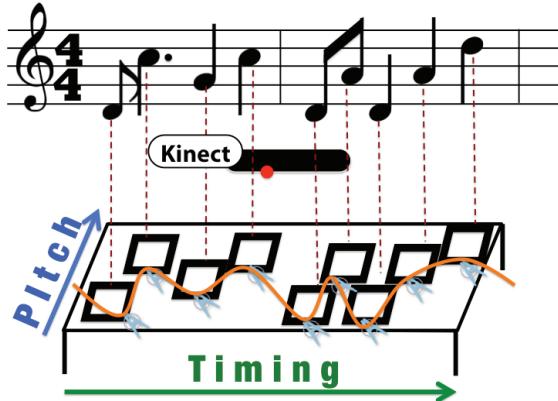


Fig.8. Overview of our music application

rassment. What is such a user-friendly interface of music composing application for visually impaired people? We have focused on the importance of their rich touch experiences. Tangible interface using graspable objects is a good idea, but gestural interface without any visual feedback could not be comfortable for visually impaired people[7]. For helping intuitive understanding of composing mechanism, we employed the method of laying out tangible objects on the table. A vision sensor detects the positions of the objects, and the detection results are directly changed into musical score as showed in Fig. 8. As the objects, daily goods and stationeries are familiar enough for users to try out the application without embarrassment. After many trials, clip objects, such as paper clips, binder clips and clothespins, with AR marker, and string objects, such as yarn, clips, and chains, to help users to trace and adjust the positions of AR markers with clip objects, are seemed to be practical and promising for our music application.

The First Prototype Development and the Single User Evaluation

The first experimental system was implemented using Kinect, ARToolkit, OpenCV and MIDI interface on Visual C++. Users can compose the piano and the guitar melody under continuous replay of the percussion sounds. To change the tempo of the percussion, users attach an AR marker with rubber band on their wrist and make waving gesture. Two male and three female blinds, aged 18 to 33, and all with some experiences of playing music, participated in the single user evaluation. The experiment was consists of three parts: (exp.1) composing without string objects within 10 minutes, (exp.2) with string objects within 20 minutes, and (exp.3) with favorite clip and string objects within 10 minutes. Fig. 9 is a comparison example of clip objects layout between exp.1 and exp.2. All examinees used wider area of the table, and were able to find more suitable melody with string objects than without them. Figure 10 is an example of a female examinee's changes of

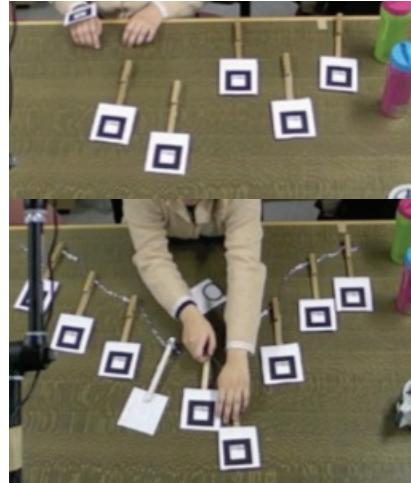


Fig. 9 The effect of string objects on clip objects,
upper: without string objects,
and lower: with string objects.

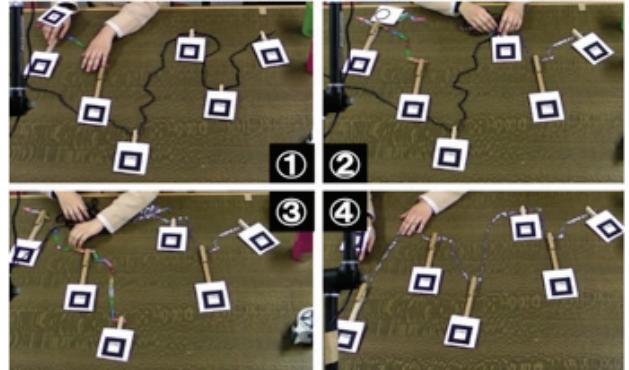


Fig. 10 Change of the string object.

string objects in exp.2. She finally chose a chain as a string object and finished composing. In exp.3, all examinees answered the chain as the best string object. Large clothespins were the best clip object for three female, and small clothespins were the best for two male. The string objects helped them a lot to find clip objects, especially the texture of the chain perfectly suited to adjust clip objects as they liked. All participants commented that the application was so simple and satisfying to compose preferable music.

Collaborative Composing Evaluation

Five blinds people mentioned previously and a sighted male aged 22 years old participated in this evaluation, and were divided in three couples of a male and a female. The experiment was to compose music with favorite clip and string objects by two users within 10 minutes. All couples chose clothespins and chains. The first couple was close friends with lively communications and influences on each behavior during the experiment. They composed two phrases of the guitar and the piano, and were satisfied with their music. The second couple was not friends but knew

each other with reserved communications. They divided composing area on the table into left and right parts and did not get involved in each other's composing. But they commented that the collaboration for composing was amusing. The third couple was first meet, and the male was the sighted. The sighted male acted naturally as a helper for the blind female with lively communications. The female commented that the communications for collaborative composing was a pleasurable experience. From this experiment, it was confirmed that our proposed interface was effective to help users' collaboration of composing music in laying out objects on the table and also in the communication.

The Second Prototype Development

The second prototype showed in Fig. 11 was developed as the universal design collaborative music application. Why we focused on the collaborative application is that music composing should be more fascinating by multiuser collaboration between visually impaired people and others as our experimental results showed. To improve the usability and interactions of the interface for multiuser composing, we have changed the basic system design for multiuser from the side-by-side design to the face-to-face design showed in Figure 11. The table is divided into two sides by the center line and the users can compose two music phrases at the same time. This simultaneous composing function is the most important function for promoting mutual communication between users. AR markers for musical notes as clip objects are redesigned. Choosing sounds of musical instruments is also a key factor of composing music. This application uses a dice like shape box with six AR markers which indicates high-pitched piano, low-pitched piano, guitar, drum kit, trumpet and violin. Users can select two instruments from two boxes. These boxes are a reused package of confectionery. When the musical instrument is changed, "glissando", continuous several octave musical scale sounds, of the selected musical instrument is played to inform users. Seven markers for base sounds are newly introduced to this prototype. Seven sounds are loop of percussion, drum, dance beat, pop beat, dance base, pop base, and shaker. Users can add the base sounds to their music by turning over AR markers. Multi base sounds duplication are allowed for users to make the rich sounds. The difference between two prototypes is the sound. The second prototype uses sound files made by GarageBand instead of MIDI interface on visual C++.

Conclusion

This paper introduced our research project about the universal designed interfaces to improve visually impaired people's computer human interaction. Recent progress of our ongoing development and evaluations were reported.

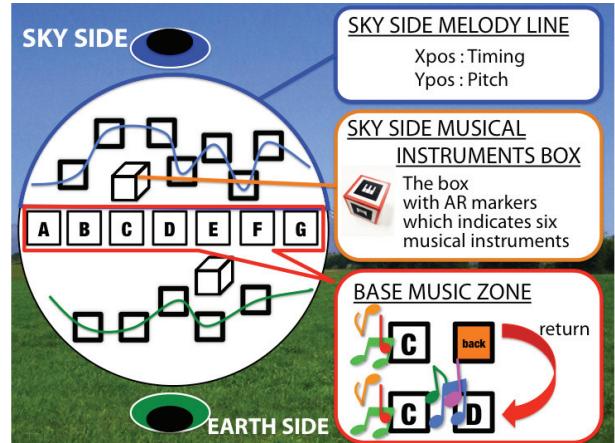


Fig. 11. Outline of the second prototype

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