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Braille Pad Project: Proposal of a Braille Education Support System using a Tablet Device

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Abstract
In this study, as teaching materials of early Braille education for visually-impaired children, we propose a Braille learning support system, which they play touching Braille by using tablet devices. The proposed system provides auditory and tactile feedback in conjunction with finger movement touching Braille, relying on placing conventional Braille teaching materials on the touchscreen surface of a tablet device. In doing so, the system is effective in point of making user to touch and trace Braille actively and accurately, linking own finger movement with sound. Also, we entertain that the system can be used as motivational teaching material in early stage of Braille education. In addition, because that consists of the system is simplified based on product on products for sale generally and widely distributed in Braille education, the system is estimated using widely. In this paper, we describe about the process of development, system, and consideration through exhibition of the system.

Keywords: Braille education, accessible, tablet device

1 Introduction

Visually-impaired children use Braille habitually as a way of learning. Therefore, in education for visually-impaired children, it is important to nourish the ability to read and write Braille effectively. In Braille education, it is hard to learn how to read and write Braille. Hence, it is necessary to use support devices to make learning Braille more efficient. Previously, refreshable Braille displays, which can create tactile outputs by connecting personal computers, Braille keyboards, which can enter text, and Braille typewriters, which can print Braille documents; were all commonly used. In recent years, information technology has made it possible to read and write Braille easily, meaning there is ample research and development [1][2][3][4]. However, these works focus on supporting to distinguish Braille characters on the monitor using vibration or audio feedback, and do not give much thought to experience of touching Braille physically. Especially, in the early stage of Braille education, it is important to touch Braille physically. Through this physical experience, visually-impaired children, who have underdeveloped tactile sense, can become familiar with Braille, improve their awareness of tactile sense, and practice how to touch Braille to read it in an efficient way. For such occasions, we consider teaching materials necessary to make visually-impaired children actively and physically touch Braille.

On the other hand, tablet devices, such as the Apple iPad have become common in recent years. Tablet devices are expected to be widely used for supporting education, for the reason that they have high functionality yet low cost compared with personal computers, and are portable [5]. Tablet devices make it possible to detect several fingers' location and movement simultaneously on a touchscreen within a high degree of accuracy. In addition, these devices provide visual and auditory feedback in response to users' touch actions instantaneously. For these distinctions, tablet devices have the induction of touching action. Thus, we assert applying tablet devices to early Braille education by incorporating the physical experience of touching Braille with touch interaction provided by the tablet's touchscreen.

In this study, we propose a Braille learning system, which provides effective support to visually-impaired children in the early stage of Braille education by using a tablet device and tangible Braille objects [Figure 1]. The system consists of a tablet device affixed to a custom wooden case that allows for sheets of Braille to be placed over the tablet's touchscreen. The movement of the finger tracing the Braille is detected via the touchscreen. The user, while tracing the Braille sheet, receives auditory feedback. The system can make the user touch Braille actively, and use it as motivational teaching material in the early stage of Braille education. In addition, the user links their own finger movements with sound, meaning they can focus on movements, improving sharpness and awareness of their tactile sense. We set out to implement this system in an education setting, and become widely-used in Braille education. For this reason, the constitution of the system is based on products that are widely available. Also, in the process of developing the system, we added audio functionality for teachers in special needs school which correspond to the special needs of those undertaking Braille education. In this paper, we describe related research and our own research agenda. Then we describe the system overview based on survey results and the system detail. Finally, in light of user feedback through exhibitions of the system, we further explain the system.

2 Related research

Braille characters are defined uniquely by a pattern formed in a rectangular space divided into six parts. Each character is distinguished by the presence or absence of dots represented in each divided region. In recent years, there are many works to develop accessible systems, where users can learn to read and write Braille characters by using the concept of Braille and various technologies.

"VBraille" by Jayant et al. [1], is a system where a user can read Braille characters by using a mobile device's touchscreen and vibration. The screen is split into six parts in the style of Braille regions. By controlling the vibration of the device's touchscreen (depending on the area touched), a user can read the Braille characters on the screen. Rantala et al. also developed a system that communicated Braille via a touchscreen with vibration [2]. They adapted the vibration method of the touchscreen to convey Braille characters, which change at regular intervals. For example, the alphabetical character "C" has dots in the first and fourth cells, if it is expressed in Braille. In this system, vibration is provided strongly in the first and fourth cells, and weakly in others, so a user can determine the existence of a dot. Frey et al. developed "BrailleTouch": a mobile-friendly Braille character input method that does not rely on visual feedback [3]. There are six keys on the touchscreen of a mobile device, corresponding to the six dots of Braille. By taking hold of a mobile device, turned around on the screen, a user can place six own long fingers on each keys and enter dot by touching each keys. Also, users can enter several dots in real-time. After entering them, users can get auditory feedback. While these aforementioned examples used ready-made touchscreen devices, Seim et al. used a custom-made device [4]. Their system supports learning to read and write Braille based on "Passive Haptic Learning". This device consists of a vibrating wearable glove device, and a button device, connected to a personal computer. By controlling vibrations based on Braille phrases, users can read and write Braille on the screen.

The systems described above, by controlling vibration and audio, can support learning Braille. However, they generally focus on recognising Braille characters on the screen, and do not consider recognition of physical Braille characters. In the early stage of Braille education, it is important that a child can use tactile sense actively and touch Braille physically. Hence, these systems can not be used as teaching materials for visually-impaired children.

Fig.1 Example of Using System

3 System requirements based on Braille education survey

In our study, we focus on providing auxiliary learning materials concentrated on the physical experience of early stage Braille education for visually-impaired children. It is important that these materials are suitable for special needs in Braille education, and have the potential to be widely used in schools. By canvassing teachers in a special needs school, we defined requirements below that our system needs to fulfill.

1. Encouraging the user to touch Braille actively.

Since the early stage of Braille education is aimed at visually-impaired children who have an underdeveloped tactile sense and have not learned the basics of Braille, it is important to create an independent-minded learning environment by making them to be interested in Braille, and to use the tactile sense of own fingers actively. Furthermore, it is necessary that visually-impaired children can learn independently without a teacher's support.

2. Acquiring basic finger movements for effective touch-reading of Braille.

In the early stage of Braille education, before learning the language system of Braille, it is important that visually-impaired children practice to acquire basic finger movements for effective touch-reading of Braille. This basic movement consists of a fine motion, forward and left-to-right scanning movement, and cooperative movement of hands. For learning these, it is necessary to encouraging users to trace Braille, and improve sharpness and cleverness of their tactile sense.

3. Ease of implementation in schools and ability to be used widely.

Generally, supporting devices for special needs is expensive because they require a long time to develop. Furthermore, they often require special equipment. For this reason, it is hard to introduce such devices in schools or for them to be used widely. Therefore, it is necessary that the constitution of a system is simplified, and is based on products that are widely

available. Also, it needs to promote the use of existing devices already used in schools generally.
Based on these four requirements, here we introduce an overview of our system.

4 System

4-1. System overview

In this study, we propose a tactile Braille learning system for early stage education of visually-impaired people, to provide effective support using a tablet device and tangible Braille objects. The proposed system relies on placing conventional Braille teaching materials on the touchscreen surface of a tablet device. By touching the Braille on the sheet, touch interaction is detected via the touchscreen, making it is possible to obtain feedback through sound. Therefore, the system encourages the user to actively engage with the Braille and undertake self-motivated learning (requirement 1).
In addition, by working with a teacher in a special needs school, we made several Braille patterns, which consist of simple figures based on line shapes, and have start and end points [Figure 2]. The shapes offer finger movement directions: these Braille patterns encourage users to trace Braille. There are also many kinds of shapes, such as lines, curves and angles, which create several kinds of tracing movements. Braille patterns become more complex as page numbers increase. Users can therefore practice in accordance with children's stage of learning and development. Additionally, aural feedback is provided as finger positions and movements change, so users can correlate finger movements with sound and condition their fingers appropriately. For this reason, users can trace Braille finely without moving away from it. By detecting via a multi-touch screen, users can use multiple fingers. For these reasons, the system encourages users to improve the sharpness and cleverness of their tactile sense, and acquire basic movement of fingers for effective touch-reading of Braille (requirement 2).
Braille sheets, which are used in our system, are commonly used in Braille education. Teachers can create and edit Braille sheets using authoring software or a Braille printer, which are used in schools generally. If the sheets become dirty or dots become flat from repeated use, teachers can simply print new Braille sheets. Desideratum the system needs else is only tablet devices and case. For these reasons, the system can be used widely in schools (requirement 3).

4-2. System configuration

The system consists of an Apple "iPad Air 2" affixed to a custom wooden case that allows for sheets of Braille to be placed over the iPad's screen [Figure 3]. These Braille sheets come in three thicknesses: 90g, 110g and 135g: for the purpose of touch accuracy, we are using 90g. These sheets are a standard size of 258mm by 196.5mm, and have binding holes on both sides. On the other hand, the "iPad Air 2" is 240mm by 191mm. Braille sheets are placed over the iPad, and the binding holes of sheets are laterally placed on the iPad. We use these holes to affix the case. Thus, the Braille sheets are fixed firmly on the iPad's touchscreen, and the makes possible that detecting finger positions or movements on Braille sheets via the touchscreen. Also, the user can set this interactional sequence without visuals, because the binding holes of the sheets and the case's pegs are tangible.

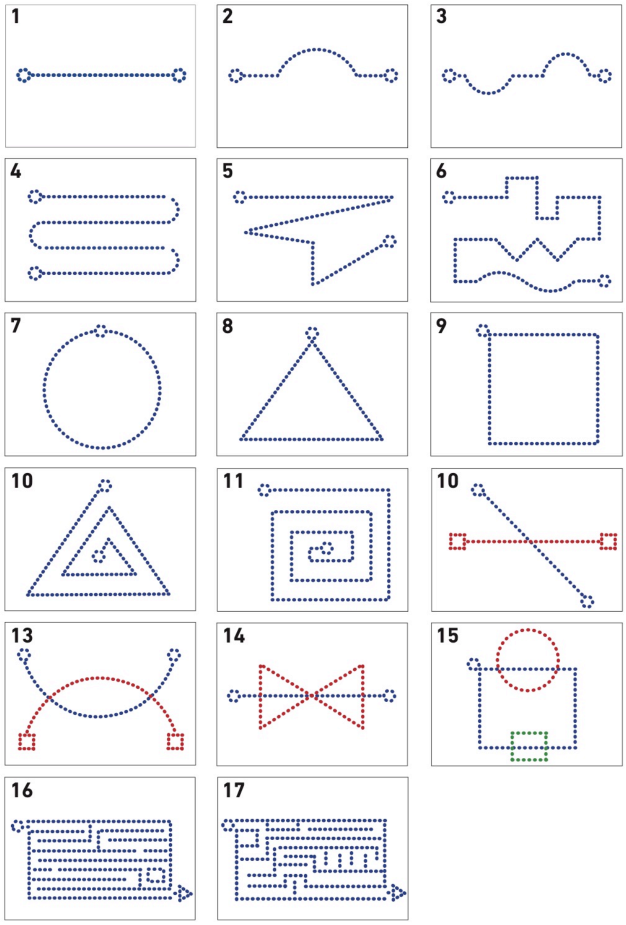

Figure 2: Graphics of Dot Pattern

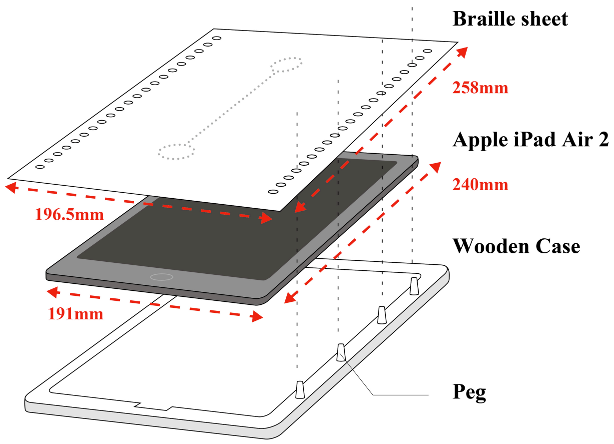

Figure 3: System configuration

Case has a figure that will accommodate the iPad, including its speaker. Thus, the sounds described in the previous section are outputted through the iPad's speaker, which then vibrates the case. To test which material propagated vibrations strongly, we made cases with plastic, acrylic and wood. Consequently, we selected a wooden case, which propagates vibration strongest [Figure 4].

4-3. Application

The application runs on a conventional iPad. The application was developed in JavaScript, using jQuery and P5.js JavaScript libraries. The application is divisible into two modes according to execution through a program.

4-3-1. Lock-mode (Initial state)

This mode is the initial state when the application runs. Generally, visually-impaired need to grasp the overall structure and layout of Braille spatially, before they read its details. If auditory feedback is provided while they do so, it can be confusing. Hence, in the initial state of application, if a user touches the Braille, no feedback is provided.

4-3-2. Trace-mode

The mode makes a transition from lock-mode to trace mode if the user taps the start button. In this mode, a user can get auditory feedback along with finger movements. If a user changes a page, the mode changes to lock-mode.

4-4. Framework of application

The application consists of four parts, 1) Collision detection, 2) Page switching control, 3) Setting of touch determination, 4) Auditory feedback control.

4-4-1. Collision detection

The application needs to load two lots of graphic data in advance with each page. One is the graphics, which matches the Braille pattern [Figure 5]. It is displayed for sighted-people. The other shows collision detection between finger and Braille [Figure 6], which is not displayed. Each area of the graphics is color-coded according to its subject. The application recognises each functional area, start button, end button, page switching button, area of touching detection. From these colors, the application can then execute collision detection. Here we introduce each function and color data.

1. Start button: Red (255, 0, 0)
2. End button: Blue (0,0,255)
3. Page switching button: white (255, 255, 255)
4. Area of touching detection: Green (0, 255, 0)
5. Area not applicable: Black (0, 0, 0)

The area of touching detection establishes how strictly to judge the accuracy of tracing movements. To ascertain the area of touching detection, which is suitable for learning, we experimented with two teachers (one is sighted, one is visually-impaired) and one visually-impaired student. As a result, if the area is narrow, it is too difficult for users to trace. Conversely, if the area is too wide, it is determined that the user has traced the object successfully even if they have not traced it correctly. We increased the area in steps of 5 pixels. Through feedback from the three aforementioned people, we found that 25 pixels is the optimal area for learning.

Figure 4: Wooden Case

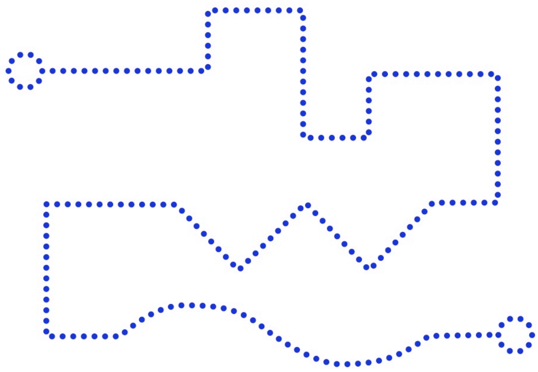

Figure 5: Example of Dot Pattern Graphics

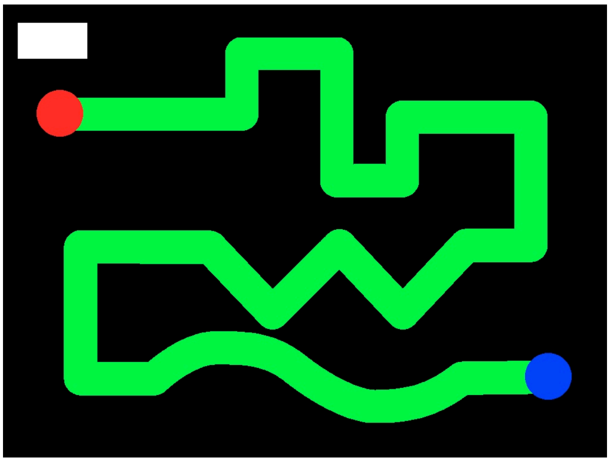

Figure 6: Example of Collision Detection Graphics

4-4-2. Page Switching Control

Each dot pattern and Braille sheet is numbered [Figure 2]. When the application runs, the first page is displayed. If a user taps the page switching button once (white [Figure 6]), the next page is displayed. Pressing the page switching button on the final page returns users to the first page.

4-4-3. Setting of touch determination

In this application, touched Braille are recognised by detecting when a finger touches the iPad's screen. In Braille education, for effective touch-reading of Braille, bimanually touch-reading is recommended. In bimanually touch-reading, one finger is primarily used, with the second finger and fourth finger also used. However, when it shifts emphasis from the first finger to others, fingers are often disengaged from Braille. Therefore, even if a finger is disengaged, it is necessary to detect other fingers touching Braille at one time. While the program is running, the application observes this alteration constantly (up to ten fingers), by using multi-touch technology. Thus, it detects touching data for all fingers, and program is implemented in line with the collision detection graphics displayed at that time. For this reason, aural feedback is provided as an auxiliary function to finger touching.

4-4-4. Auditory feedback

While a user's finger is touching any Braille on the sheet, continuous electronic aural feedback is provided. In this application version, the change rate of the pitch depends on the rate of tracing. For this, when the Braille object is being traced, a transmutative pitch will sound. The range of this pitch is 55.00Hz –3520.00Hz (six octaves), which is within the range of human hearing. It makes users become more aware of changes in their finger movements. Towards the upper-right corner of the screen, the pitch becomes increasingly higher, while in the lower-left, it becomes increasingly lower. This variation in tone is in a seamless manner, as opposed to twelve distinct tones. Users can feel the pitch shifting more clearly, which sharpens their focus on tracing. Users can correlate finger movement with sound, and adjust their own finger appropriately. Thus, it improves the sharpness and cleverness of a user's tactile sense. This sound feedback is ongoing while any finger is touching Braille, from the start button point to the end point. If the user keeps their finger on the screen and successfully traces the object in the correct sequence, a sound will inform them once the end of the object is reached. Hence, a user can trace Braille finely without moving away from Braille, in the lead up to end point from the start button.

5 User feedback

To examine the effects that the system had on users, we collected user feedback and observed people using the system. The current system was presented at the exhibition "Digital Contents EXPO 2015", at the Japan National Museum of Emerging Science and Innovation in October 2015. It was also presented at the "20th General Japan Information Processing Society of Japan –Interaction 2016" exhibition at the Japan Science Museum in March 2016. Initial user testing was undertaken in the form of experiments and interviews with more than one hundred people in each exhibition. The subjects were fully-sighted adults who conducted the testing while their vision was blocked.

Some comments from these subjects included: "tracing is a simple way of facilitating the recognition of Braille" and, by obtaining feedback via sound and vibration it "can be expected to improve the autonomy of Braille learning". We also often observed several users playing, where they repeatedly practiced tracing the Braille until completion – even when their finger moved away from Braille. We observed that most users explored the system independently without specific instructions.

6 Discussion, future work

Through observations and user feedback, we determined that the proposed system allowed users to enjoy touching Braille, by encouraging them to actively trace Braille using their own tactile sense. In addition, we find that the system provides fully-sighted a good opportunity to become interested in Braille. Hence, our system is predictably effective for fully-sighted people to come closer towards knowing and understanding the experience of being visually-impaired. In future work we will undertake a quantitative study with visually-impaired children. About improved performance, we would like to explore how to adjust the page displayed on the screen automatically, when users fix a Braille sheets on the tablet surface. Additionally, it is necessary to examine how electronic sounds as a feedback mechanism can be designed adequately for visually-impaired children and Braille education.

7 Conclusion

In this study, by providing effective support to early-stage Braille learning, we proposed a system that places emphasis on the experience of touching and using Braille, by combining a touchscreen tablet device with conventional teaching materials. We implemented the functionality of providing tactile and auditory feedback, triggered by touching Braille. Early testing of the system with fully-sighted subjects suggested that the system is effective at allowing the user to touch and trace Braille effectively. In the future, we plan to undertake multiple rounds of testing with visually-impaired subjects to analyse the usefulness of the system proposed here. Additionally, we will test variations of our tactile and auditory feedback in order to strengthen the cognitive links between the Braille sheet and the application. In doing so we will further examine the possibilities of utilising touchscreen tablet devices in the education of those with visual impairment.

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References

[1] Chandrika, J., Christine, A., William, A. J., Janet, H. and Richard, E. L., *VBraille: Haptic Braille Perception using a Touch-screen and Vibration on Mobile Phones*, Proceedings of the 12th international ACM SIGACCESS conference on Computers and accessibility, ACM, pp. 295-296, 2010.

[2] Jussi, R., Roope, R., Jani, L., Veikko, S., Jukka, R., Katri, S., Toni, P. and Arto, H., *Methods for Presenting Braille Characters on a Mobile Device with a Touch-screen and Tactile Feedback*, IEEE Transactions on Haptics, Vol.2, Issue No.01, IEEE Computer Society, pp. 28-39, 2009.

[3] Frey, B., Southern, C. and Romero, M., *Brailletouch: mobile texting for the visually impaired*, Proceedings of the 6th International Conference on Universal Access in Human-Computer Interaction. Context Diversity, pp. 19-25, 2011.

[4] Seim, C., Chandler, J., DesPortes K., Dhingra S., Park M. and Starner, T., *Passive Haptic Learning of Braille Typing*, Proceedings of the 2014 ACM International Symposium on Wearable Computers, pp. 111−118, 2014.

[5] Murphy, G. D., *Post-PC devices: A summary of early iPad technology adoption in tertiary environments*, e-Journal of Business Education & Scholarship of Teaching, Vol. 5, Iss. 1, pp. 18−32, 2011.