THAI VISUALLY IMPAIRED 'S REQUIREMENTS TO ACCESS MATHEMATICS VIA AN AUTOMATIC MATH READER

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Abstract: We present the requirements to access mathematics for the Thai visually impaired students. Blind and visually impaired (VI) students agreed to participate in an interview to determine the requirements for using a text–to–speech (TTS) system with the capability to automatically read math expressions. The interview consisted of two parts: the students' background characteristics and the students' difficulties in and requirement for using TTS systems to read math expressions. Our results show that the students who are blind and visually impaired had difficulties to access mathematics. The students have basic computer skills with standard software e.g., Microsoft Word. Therefore, the findings suggest that the students desire assistant technology to better access to mathematics.

1 INTRODUCTION

Presently, blind and visually impaired (VI) students can access math documents with the help of a human reader. Unfortunately, having a human reader at their side at all times is impractical. Braille display is a more convenient way for blind and VI students to access such documents. However, not many math documents are available in Braille because of the difficulty of production. Moreover, reading mathematics in Braille requires special knowledge. Video technology is another choice. Nonetheless, blind and VI students can have difficulty obtain the main point of the story even if they listen for a very long continuous period. Audio devices e.g., Daisy books and talking books are an alternative material to provide for the blind and VI students; however these books are less prepared for math and scientific expressions. Screen readers with text–to–speech (TTS) technology can read the documents aloud. Then again, most TTS engines including Thai TTS can read only plain text from a screen. They cannot read math and scientific electronic books (e–books). All existing technologies are inadequate for assisting VI students to access math documents.

Although many math word problems are available either in printed materials or electronic forms, blind and VI students derive limited benefit from them. Blind and VI students lose an opportunity to develop their math skills and to practice on their own. Limitations in writing and reading formulas restrict blind and VI students for an efficient and complete study of mathematics.

Therefore, we are looking for a solution to help blind and VI students with as fair a chance to studying as with the sighted students. Compared to other forms of assistance, TTS systems with the capability to automatically read math expressions would serve as an educational tool for blind and VI

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students to access math documents written in Thai their convenience.

We determine the blind and VI students' background, difficulties and requirements to access mathematics by the verbal interview. With using such interviewed information from the blind and VI students, we design an automatic math expressions reader system, called MathReader, for blind and VI students to access math documents in Thai. MathReader is designed to incorporate reading Thai text and math expressions as well.

2 EDUCATIONAL TECHNOLOGIES FOR VISUALLY IMPAIRED STUDENTS

Current technologies allow blind and VI students to access to printed text via various means e.g., Braille documents (e.g., Moço and Archambault, 2004; Niyomphol, Tandayya, Nantachaipitak, and Intasoi, 2008), digital talking books (DAISY Consortium, 2008) and TTS systems. Moreover, Freitas and Kouroupetroglou (2008) reviewed speech technologies for blind and VI students to access the printed, written and visual information. With these devices, blind and VI students can maintain their independence while they are studying and practicing.

A text–to–speech (TTS) engine is computer software that can read aloud text within electronic text formats e.g., Internet Explorer, Microsoft Word, and Adobe Reader. Often this engine works with the screen reader software to have a more comfortable employment for blind and VI people. TTS system is widely used by blind and VI people to read electronic text through a computer since the sound–based representation is an important channel to access information for blind and VI people.

In Thailand, groups of researchers have researched and developed Thai TTS systems since the 1980s. Until recently, most Thai TTS systems generate Thai speech from Thai text with high accuracy of pronunciation and high quality of natural sound (Wutiwiwatchai and Furui, 2007). However, the important problems in developing Thai TTS system are the ambiguity of segmentation and pronunciation, and unnatural sound of continuous synthetic speech.

At present, to enhance the access to educational math materials, a few TTS based systems were developed to read math expressions in many languages, e.g., A_ST_ER, MathTalk, and MathPlayer in English (Raman and Gries, 1995; Stevens and Edwards, 1994; Soiffer, 2005); AudioMath in European Portuguese (Fereira and Freitas, 2005); and Math Genie in English, French, and German (Karshmer, Bledsoe and Stanley, 2004; Gillan, Barraza, Karshmer, and Pazuchanics, 2004). In addition, some systems presented output in both audio format and Braille e.g., TRIANGLE, REMath-Ex and LAMBDA (Gardner, Lundquist and Sahyun, 1998; Pavel, 2002; Schweikhardt, Bernareggi, Jessel, Encelle, and Gut, 2006). Also, the mutimodality accessibility of math expressions was proposed to support individual preferences. This mutimodal provided output in audio, tactile and visual forms (e.g., Tsonos, Kaccori, and Kouroupetroglou, 2009).

The TTS system with the capability to read math expressions has continuously been developed and researched to assist blind and VI people in accessing math documents the same as for sighted people. With the potential of TTS system, blind and VI students have valuable tools to help them learn science and mathematics. However, none of Thai TTS systems has the capability to read math expressions.

3 METHODOLOGY

The requirements for using a TTS system with the capability to automatically read math expressions were determined. The analyzed results will contribute in designing TTS system with the capability to automatically read math expressions in Thai.

3.1 Participants

The participants are students in secondary schools (Grade 7–9) for the blind and VI students. The study is developed with 20 blind and VI students ranged in age from 14 to 20 (*mean* = 16.8, *sd* = 1.6). The participants consisted of ten blind students (seven male and three female) and ten visually impaired students (five males and females) from two schools for blind and VI students in Thailand. All of them agreed to participate in the verbal interview.

3.2 Interview

The Thai semi–structured interview was prepared for surveying the blind and VI students' difficulties and requirements of TTS with the capability to read math expressions. The interview consisted of two parts (see Appendix). Part 1 requested the students' background characteristics: personal information and their ability to use the computer including their

experiences with computer software and aspects of using the Internet. Part 2 covered the students' difficulties in using existing TTS systems to read math expressions, and the students' requirements for using TTS systems with the capability to read math expressions in their study of mathematics.

3.3 Procedure

The participants were interviewed in the schools from February to March 2009. Each student's voices were recorded during the interview for 10–15 minutes.

4 RESULTS

4.1 Students' Experiences of using a Computer

Most blind and VI students had extensive experience using the computer, while two students who are blind had slight experience and joined their partners to access the computer. All students had used Microsoft Windows. All blind students and most VI students also used a screen reader with a Thai speech synthesizer to work with the computer. Some VI students mentioned using other devices and assistive tools such as a magnifying glass, Braille display, and an enlarged visual display to work with a computer.

The majority of the blind and VI students had used the Internet for more than a year. Repeatedly, two students who joined their partners to access the computer had accessed the Internet with their partners. Most students used the Internet for retrieving information and entertaining themselves. Some students had used the Internet to obtain knowledge; exchange ideas, news and information; and communicate with other people.

For software, all blind and VI students were given a list of software that could be used on a computer. All students were quite familiar with Microsoft Word. The students also had experience using other software as shown in Figure 1. None of the students who participated had used software for writing or editing math expressions e.g., Microsoft Word Equation Editor or Math Type Editor. Most students had used PPA TATIP (Thai and English TTS system works together with Microsoft Speech and Speech Synthesizer and available for Thai blind and VI people). None of the students used VAJA (another Thai TTS system developed by NECTEC). Some sound–player software e.g., Winam and Window Media Player, were useful for providing information. Furthermore, a few of the students stated that had used TAB Player (free software player supports DAISY books for Thai and English).

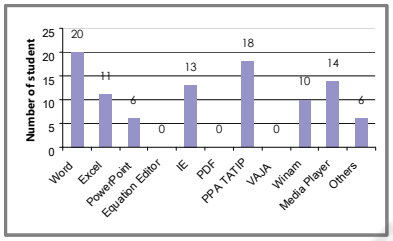

Figure 1: Students' experience of using computer software.

4.2 Students' Difficulties in using TTS to Read Math Expressions

All blind and VI students stated that they had used a Thai TTS system when they used the computer. Some students had used a TTS system to read numbers, simple math operations e.g., '+' plus sign, '–' minus sign and '%' percent sign. Some students also reported that the TTS system that they used read simple math notations with an English accent. It was difficult for the students to understand such information. Only a few VI students noted that the synthesizer did not work with simple math expressions e.g., simple fractions. Most students had never used a TTS system with the capability to read math expressions. Only one student heard synthetic sound of math expressions in Spanish.

Thirteen students attended inclusive schools (a school that encourages disabled students to transition into society). The students had problems with reading printed materials or documents from their classroom because those documents were written in a normal character system. Most students said that they needed an assistant at their side for practicing or doing homework, especially mathematics. Furthermore, a few students preferred to read such documents in Braille. However, Braille printing devices and Braille reading displays are not provided and available to individually blind and VI students. The students stated that the production of such documents in Braille took a long time because the documents were sent to another organization and then those documents were sent back to the students. They also noted that, recently, the translation from math notations into Thai Braille was practically incomplete. Moreover, it was more difficult for the students to read the math Braille system because unusual coding was used to represent numbers and special characters. The students also stated that most

math concepts composed of graphs, tables, figures and notations; so it was difficult for the blind and VI to study mathematics.

Similar to the students in the inclusive schools, the other seven students who attended a mainstream school (a school in which all students have special needs) faced problems reading the math Braille system as well. All students usually read documents and books, took short notes, and performed exercises, homework and exams in Braille. The students were required to remember unusual coding for performing mathematics.

4.3 Students' Needs for using TTS with the Capability to Read Math Expressions in Thai

The blind and VI students were asked to comment on needs for using a TTS system with the capability to read math expressions in Thai. Many students stated that if math documents could be read aloud in Thai, then they could do mathematics better than before. The students also said that they could practice exercises, do homework and perform exams by themselves anywhere and any time that they wanted. The students' comments included: "It is easy and convenient for me to do math by myself" and "It is quick to prepare and study by themselves before classroom". Some VI students reported that they had problems because their eyes were exhausted when reading the documents for a very long continuous period. The VI students also said that it was more comfortable if they had computer software read the documents aloud. Furthermore, a few students stated that they had a problem using the computer with documents. Such documents that the students had obtained from the classroom as in printed documents were not electronic files.

Most students said that they desired to use a TTS system with the capability to read math expressions in Thai. They wanted to use this TTS system help them study mathematics if it was available. They also commented that this TTS system could possibly to enhance their mathematics learning. However, one student was not interested in this TTS system because he could not catch the main idea when he listened for a very long time. He preferred to read math documents in Braille.

The students were asked for design suggestions. They recommended that when developing such a system should produce correct pronunciations and more natural speech. The system should read math expressions aloud in all levels of mathematics including scientific notations. The volume could be adjustable. The students requested that this system could be used to solve math problems, guide methods that can be used to solve the problems. In addition, the system should be available for free, could work alone, and did not need other software to work well.

[1] For each word, its pronunciation is shown in / / and its meaning is shown in { }. The numbers 0-4 are represented five tones. Each syllable is separated be hyphen e.g., "ปราการ" {wall} */pra0-kan0/*.

5 THAI TEXT AND MATH EXPRESSIONS

Math expressions differ from Thai plain text in alphabet, writing and reading listed as follows (Wongkia, Naruedomkul and Cercone, 2009):

- *Alphabet and Symbols*: The Thai alphabet system includes 44 consonants, 15 vowels and four tone markers. In math expressions, English letters in upper case and lower case, numbers, Greek letters and math notations are used.
- *Displays*: Thai text and math expressions are displayed non-linearly. Thai text is represented in a 4–level system. Each term is written in linear form from left to right without spaces between. A math expression is a multi–level system. In general, subscripts and superscripts can be writ-ten to an unlimited–level or non–linear. Special math symbols including horizontal line, summation, integral and root can be written in combination of special symbols which is complicated to read aloud.
- *Locations and Orders*: a different location and different order of appearances of characters maps onto different audios. The expression "x^3" in Figure 2 can be read "เอ็กซ์ ยกกำลัง สาม". The word "ยกกำลัง */yok3-kam0-lang0/* {the power of}[1]" is required to complete the reading.

$$3x \quad x_3 \quad x^3 \quad \sqrt[3]{x} \quad \frac{x}{3} \quad \frac{3}{x}$$

Figure 2: Different locations of "3" and "x"

- *Mapping characters into their sound*: a single character in a math notation can be mapped onto one or more sounds, e.g., "π" is mapped onto one sound */phai0/* while the notation "<" is mapped onto two sounds */noi3-kwa1/*. In Thai text, one sound corresponds to two or more alphabet symbols, e.g., a three–alphabet symbol is mapped onto one sound */mak2/* while "รถ" a two–alphabet symbol is mapped onto one sound */rot3/*.

- *Homograph*: the Thai word "สระ" can be pronounced */sa1-ra1/* {vowel} or */sa1/* {pool}. There is a kind of homograph in mathematics as well. For example, "1 – 12" means either "one to twelve" */nueng1* ***teng4*** *sip1-song4/* or "one minus twelve" */nueng1* ***lop3*** *sip1-song4/* depended on where it appears.
- *Adding words*: A word is added to indicate the expression boundary. For example, $(a+b)^2$ is read as */e0 buak1 bi0* ***tang3–mod1*** */yok3-kam0-lang0-song4/*, the word "*/tang3–mod1/*{all}" is added to indicate that the 2nd power is for $a + b$.

6 PRELIMINARY DESIGN OF MATHREADER

We present the design of MathReader–a TTS system with the capability to generate an accurate Thai speech output from Thai math problems with math expressions. The students' responses and the differences between Thai text and math expressions were carefully considered in designing the system architecture.

Figure 3: MathReader architecture.

MathReader was designed to perform speech generation in four modules: Phrase Identification, Thai Text Reader, MathEx Reader, and Math Reader shown in Figure 3. An overview of how MathReader system performs was presented in Wongkia et al. (2009). The *Phrase Identification* module segments the input string into Thai text and math expression parts since reading text is different from reading math expressions in their nature and identifies which phrase is Thai text or a math expression. The *Thai Text Reader* module generates the speech for the text part while the *MathEx Reader* module generates the speech for the math expression part. The *Math Reader* module combines all separated parts to form the corresponding speech of the original input.

MathReader generates syllable sequences for math word problems containing both plain text and math equations. MathReader should prove to be a practical educational tool for the blind and VI students to access math documents written in Thai their convenience.

7 CONCLUSIONS

Although Thai TTS systems are available for all blind and VI students, these systems are unable to generate speech from math expressions. The results of this survey suggest that the students who are blind and VI had difficulties to access mathematics. When asked about an ability to use a computer that would provide them with better access to mathematics, most students admitted having a basic skill to use a computer with standard software. Their responses suggest that the design of the MathReader system should work with that software.

Therefore, the finding from this survey confirms that the blind and VI students desire assistant technology. It is important to enables VI students to have the same opportunities as sighted students in studying, especially in mathematics and science.

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APPENDIX

This interview is used to determine the requirements for using a TTS system with the capability to automatically read math expressions for blind and visually impaired students

Part 1 students' background characteristics:

1. Personal information (sex, age, educational level and visual impairment)
2. Do you have a personal computer to use at home?
3. What platform do you use?
4. What computer software and supporting devices do you use with the computer?
5. What programs can you use? (Word, PowerPoint, Excel, Equation, PDF, IE, PPA TATIP, VAJA, Winam, Media Player, and Others)
6. Do you have experience using the Internet? If you have
   6.1 How long have you used the Internet?
   6.2 For what purposes do you use the Internet?

Part 2 students' opinions toward TTS systems with the capability to read math notations:

7. Do you ever use a screen reader or text-to-speech (TTS) system? If yes, what software do you use?
8. Do you ever use a TTS system with the capability to automatically read math expressions? If yes, what software do you use?
9. What languages of that system do you ever use to read math expressions?
10. What do you think of the contributions of the system that read math expressions in Thai?
11. What do you think of the contributions of such system for you?
12. In studying mathematics, what do you want from the instructional media?
13. How dose such system help you to study mathematics?
14. Do you need such system in your study of mathematics? If yes, why?
15. What do you think of using such system in your study of mathematics?
16. If MathReader is developed, do you want to use such system?
17. What suggestions have you to produce and pro-mote such a system?