A Retrospective and Future Look at Speech Recognition Applications in Assisting Children with Reading Disabilities

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Abstract— **Parents of dyslexic children dream of computer technology and applications as panacea for their children. Dyslexic children's deficits in phonological origin hinders reading skills to be developed at par with other 'normal' children. Thus this paper draws the various computer applications that have been used, and will probably be used in the future, to assist dyslexic children with reading disabilities. These applications often embed text-to-speech (TTS) technology and speech recognition (ASR) technology to aid children for both reading and writing. Given more attention to ASR, this paper reviews the previous success story of ASR, as well as future technology of it that will continue providing support for dyslexic children with diverse learning disabilities. In prospective, ASR is now advancing towards providing a reading tutor that could 'listen' to what is being read and provide correction to any incorrect reading. This paper highlights the potential of ASR in teaching the dyslexic children to read in *Bahasa Melayu* (Malaysia's national language). For that purpose, ten dyslexic children were asked to read aloud 114 *Bahasa Melayu* words in seven different sessions and each speech was recorded, resulting in a total of 6834 utterances with 6323 utterances with errors. These utterances are transcribed and the pronunciations are modeled for ASR to train on.**

Index Terms—**Assistive technology, automatic speech recognition, dyslexia, reading.**

I. Introduction

Malaysia is now progressing towards providing better, well-suited education to those with specific reading disabilities or dyslexia. Recently the government and NGOs have been active in providing knowledge and awareness to the communities to offer early assistance to those in need. Parents of dyslexic children often need teaching aids or tools to facilitate them in order to teach their children reading. Nowadays, they often turn to computer applications for solutions. An example software that could help teach the children to learn to read is 'Go Phonics' that uses phonic teaching technique. These are all teaching materials and only available in English as most of the applications. The parents are willing to purchase these educational software for the benefit of their children and spend a lot of money by sending their children to private dyslexia classes.

With increasing number of dyslexic children in Malaysia serious attention should be given to them to ensure their lifelong education not halted by their condition. It is estimated that around 5 – 10% children in primary schools throughout Malaysia are dyslexics and this number is believed to be increasing (Sariah Amirin, president of Dyslexia Association of Malaysia, personal communication, September 10, 2007).

Dyslexia is a neurological learning disability that affects the ability to accurately or fluently recognize words and have poor spelling and decoding abilities, normally causes problems in reading comprehension as well as reduced reading experience that holds back vocabulary and background knowledge expansion [1]. This learning disability is reported to affect people around the world. The International Book of Dyslexia as cited in World Dyslexia Network Foundation in [2] presents some significant percentage of dyslexia in each country as listed in Table 1. Note that however, the statistics represent not only children but also adult dyslexics collectively. According to the Dyslexia Research Institute, around 10 - 15% of the population in America is dyslexic and only five out of 100 dyslexics receive proper assistance and support [3].

Table 1. The percentage of dyslexics according to corresponding countries.

Country	%	Country	%
Belgium	5	Nigeria	11
Britain	4	Norway	3
Czech Rep.	2-3	Poland	4
Finland	10	Russia	10
Greece	5	Singapore	3.3
Italy	1.3-5	Slovakia	1-2
Japan	6	U.S.	8.3

From the table, it can be concluded that the effects of dyslexia in different countries are about the same and can be estimated to increase over time. Help should be provided early for these children to remediate their difficulties. Attention to this particular problem has long been brought forward in countries like U.S., Canada, and U.K. as many studies have been conducted involving English language from spelling to reading to cognitive processes of reading [4-8]. Also, most methods of teaching them to read, for example the Phono-Graphix, which is one of the multi-sensory methods, are also developed with regards to English language.

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The same goes with computer-based applications that serve as tools to aid these children to read and write. Most of these applications employ TTS technology to read aloud text to the users. Only some use ASR technology for dictation purposes. Hence, the focus of this paper is to highlights some of the recommended computer-based applications to help dyslexic children in education. The aim is to bring forth the current promising advancement in ASR technology that could assist these children to read on their own.

II. TECHNOLOGICAL SUPPORT

To boost the children's motivation and increase their interest towards education, various technological supports are being used. Studies have shown that children do gain significant improvements when using computers as tool to aid their reading [9-14]. Most reading software comes in CD-ROM with various methods to teach the children to read. These are the software to facilitate learning to read for dyslexic children that often use multi-sensory approach, which is an excellent way to teach the children. Examples of such include Go Phonics (www.gophonics.com) and Language Tune-up Kit (www.jwor.com).

As mentioned earlier, most of the computer-based tools read out loud to the users. This method is made available by the TTS technology. Simply, TTS is able to convert written text in digital form into voice output of that particular text using speech synthesis techniques. In a way, this technology makes the computers 'talk'. Talking computer is very much useful for dyslexic children where such application can reduce or eliminate reading process for them when they have to read for example a webpage. A number of software suitable for dyslexic children which employ TTS include TextHelp, Kurzweil 3000, Clicker 4, HelpRead, WordQ, and ReadPlease [15]. Table 2 recapitulates examples of such applications as discussed.

Table 2. Technological support software and their functions.

Software	Tech.	Function
Go Phonics	CD-ROM	Software to teach reading to dyslexic children based on Orton-Gillingham method, provides test and assessment.
Language Tune-up Kit	CD-ROM	Software to teach reading to dyslexic children based on Orton-Gillingham method, teaches grammar, punctuations, and the rules.
TextHelp	TTS	Word processing support, suggest spelling when typing, read aloud writing for checking.
Kurzweil 3000	TTS	Users can scan books/reading material and it will read out to them.
Clicker 4	TTS	Word processing support, read aloud once done typing, able to 'speak out' a word/letter upon user request.
ReadPlease	TTS	'Read' aloud text from web pages/emails.
HelpRead	TTS	Read-along software while user are reading.
WordQ	TTS	Writing tool (typing), suggest words, provide speech feedback.
Dragon Naturally Speaking	ASR	Dictation software.
ViaVoice	ASR	Dictation software.

Although useful, CD-ROM provides only one way presentation of the teaching and exercise materials. It requires the presence of a literate person (teacher or parent) should the child encounter some problems when reading. TTS-enabled software too offer one-way interaction where the computer 'talk' to the user. In most cases, TTS is used to make the computer 'read' to the user to eliminate the reading requirements for reading disabled person.

ASR technology on the other hand, provides two way interactions between user and the computer. It enables the computer to 'listen' and 'understand' what is being spoken. So far ASR technology is being used mainly in dictation software for example Dragon Naturally Speaking and IBM's ViaVoice [15]. These applications allow users to speak into a microphone attached to a computer and transform the speech into corresponding text on screen. Such applications eliminate physical writing in order to compose. This is a great tool for dyslexic children whose writing is also a challenge.

III. ASR TECHNOLOGY IN PROSPECTIVE

Recent advancement in ASR technology has brought promising notes towards providing a reading-based application that teaches children by 'listening' to and monitoring their readings. This provides an excellent platform to improve reading for dyslexic children by using such application to help the children, or perhaps develop one that is well-tuned towards the children's reading patterns for better result.

When reading, the user read certain words out loud into the computer. The spoken attributes (i.e. the read speech) get recognized by the computer so that useful feedback can be generated and output to the user. This way, the learning process is ensured to continue where immediate intervention can be provided for the children during reading in order to help them read correctly. This is done by recognizing what is being read and compare that to the actual word. If the reader

makes any mistake, the application can detect it and invoke suitable feedback to correct such mistake. ASR is also being used to enable reading tracking mechanism. By comparing the read speech with the actual word being read, current position in text could be identified. Such element is embedded in automatic reading tutor projects such as Project Listen [16] and Colorado Literacy Tutor, CoLit (www.colit.org). These ASR-based applications however are still under serious research and development and are not yet commercially available to end users. Nevertheless, studies have shown that such automatic reading tutor can bring not only motivation and encouragement but also improvement towards reading ability in children [17-21]. Unfortunately, these technology only considers reading in English.

IV. TOWARDS A *BAHASA MELAYU* READING TUTOR

To realize the vision of having such an ASR-based automatic reading tutor in *Bahasa Melayu*, certain requirements need to be fulfilled. For such an ASR application, the ASR needs to be fed with *Bahasa Melayu* words for closed vocabulary application. A total of 6834 utterances of a number of 114 words have been collected and analyzed. The speech are recorded from 10 dyslexic children, aged between 7 to 14 years old, in two public schools in Malaysia. The vocabulary selected represents all syllable patterns in *Bahasa Melayu* which comprises the combination of consonant (C)-vowel (V) pair. For example, the pair can be of V+CV for simple words such as *'aku'*(I) and *'itu'* (that) and CV+CV for words such as *'bapa'* (father) and *'baca'* (read). A total of 6323 utterances contain reading errors with respect to *Bahasa Melayu*. The most frequent error pattern obtained is of substitute vowel with slightly more than 20%. Table 3 illustrates the percentile of error type categories. The error categories are adapted from [22] of English with introduction to new categories with respect to *Bahasa Melayu*. The new categories introduced are marked by '*' symbol in the table.

Table 3. Error types of reading with respect to *Bahasa Melayu* and the percentile for each.

Error types	*n*	%
Substitutes vowel	1286	20.3
Omitted consonants	786	12.4
Nasals (*m, n*)	770	12.1
Substitutes consonants	577	9.1
Omits vowel	511	8.0
Substitutes word	384	6.0
Adds consonants	363	5.7
Substitutes with non-words	272	4.3
Reversals	268	4.2
Incorrect sequence	224	3.5
Omits syllable*	167	2.6
Liquids (*l, r*)	156	2.4
Substitutes vowel with consonant / consonant with vowel*	143	2.2
Substitutes nasals for liquid*	124	1.9
Adds vowel*	124	1.9
Syllable Division Confusion*	94	1.4
Adds syllable*	74	1.1

Noteworthy, this application targets at word recognition level of reading and thus only involves single, isolated words of simple and common vocabulary within the school syllabus. The utterances of each words are transcribed into corresponding word/non-word according to what has been read for each target word. For example, a target word '*abang'* (means older brother) is read as *'adangan'*. Hence, its transcript should spell out the uttered word whether or not it is correctly read.

Such incorrect utterances of target words together with their pronunciation model are also considered to be in the active vocabulary for the ASR to train on. This is performed in order to improve the recognition accuracy as recommended in [17]. For the utterances to serve as active vocabulary, their pronunciation are modeled in Worldbet, an ASCII representation of phonetic symbols based on the International Phonetic Alphabet (IPA). Worldbet take into consideration phones (sounds) of world's languages other than English. Fig. 1 illustrates the example of such pronunciation model.

Word	Worldbet
abang	A bc b A N
aku	A kh U
ibu	I: bc b U or I bc b U
baca	bc b A ts A
bapa	bc b A pc ph A

Fig. 1. The pronunciation model of words *'abang'* (older brother), *'aku'* (I), *'ibu'* (mother), *'baca'*, and *'bapa'* (father).

The future work involves development of a prototype for training the ASR with the active vocabulary as input using suitable ASR method. The most popular method is Hidden Markov Model (HMM) as this is the dominant technique for speech recognition. However, this prototype shall be developed using the hybrid of HMM and Artificial Neural Network (ANN) technique. The hybrid technique combines the excellent classification property of ANN with HMM for faster recognition and better recognition accuracy.

V. CONCLUSION

Dyslexic community is increasing in percentage where support is vital to ensure the continuity and quality of their education. With various technological support, it is hoped that dyslexic children are able to cope with current academic demand. As reading is important in education, advancement in the area of computer-based application to support reading especially the ones that employ ASR technology is seen as promising. Not only it could recognize words while the reader is reading, this technology also enables immediate intervention and tracking for better performance. As dyslexia could affect people of many languages, such technological support should be made available in various languages. This paper addresses the requirements needed for an ASR-based application that support single word reading (word recognition level) in *Bahasa Melayu* as the main language in schools and in the country. The requirements are the vocabulary which covers all syllable patterns in the language,

the inclusion of incorrectly read words in the active vocabulary, and modeling such pronunciation errors for ASR training.

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