

**AUTOMATIC SPEECH RECOGNITION MODEL FOR
DYSLEXIC CHILDREN READING IN BAHASA MELAYU**

HUSNIZA HUSNI

**DOCTOR OF PHILOSOPHY (Ph.D.)
UNIVERSITI UTARA MALAYSIA
2010**



Kolej Sastera dan Sains
(UUM College of Arts and Sciences)
Universiti Utara Malaysia

PERAKUAN KERJA TESIS / DISERTASI
(Certification of thesis / dissertation)

Kami, yang bertandatangan, memperakukan bahawa
(We, the undersigned, certify that)

HUSNIZA HUSNI

calon untuk Ijazah
(candidate for the degree of)

PhD

telah mengemukakan tesis / disertasi yang bertajuk:
(has presented his/her thesis / dissertation of the following title):

**"AUTOMATIC SPEECH RECOGNITION MODEL FOR DYSLEXIC CHILDREN READING
IN BAHASA MELAYU"**

seperti yang tercatat di muka surat tajuk dan kulit tesis / disertasi.
(as it appears on the title page and front cover of the thesis / dissertation).

Bahawa tesis/disertasi tersebut boleh diterima dari segi bentuk serta kandungan dan meliputi bidang ilmu dengan memuaskan, sebagaimana yang ditunjukkan oleh calon dalam ujian lisan yang diadakan pada : **26 April 2010.**

That the said thesis/dissertation is acceptable in form and content and displays a satisfactory knowledge of the field of study as demonstrated by the candidate through an oral examination held on:

April 26, 2010.

Pengerusi Viva:
(Chairman for Viva)

Prof. Dr. Zulkhairi Md Dahalin

Tandatangan
(Signature)

Pemeriksa Luar:
(External Examiner)

**Assoc. Prof. Dr. Sharifah Mastura Syed
Mohamad**

Tandatangan
(Signature)

Pemeriksa Luar:
(External Examiner)

Assoc. Prof. Dr. Manjit Singh Sidhu

Tandatangan
(Signature)

Nama Penyelia/Penyelia-penyelia:
(Name of Supervisor/Supervisors)

Assoc. Prof. Dr. Zulikha Jamaludin

Tandatangan
(Signature)

Tarikh:

(Date) **April 26, 2010**

**AUTOMATIC SPEECH RECOGNITION MODEL FOR
DYSLEXIC CHILDREN READING IN BAHASA MELAYU**

A Thesis submitted to the UUM College of Arts and Sciences in
full fulfillment of the requirements for the degree of Doctor of
Philosophy
Universiti Utara Malaysia

by
Husniza Husni

© 2010, Husniza

PERMISSION TO USE

In presenting this thesis in fulfilment of the requirements for a postgraduate degree from Universiti Utara Malaysia, I agree that the University Library may make it freely available for inspection. I further agree that permission for the copying of this thesis in any manner, in whole or in part, for scholarly purpose may be granted by my supervisor(s) or, in their absence, by the Dean of Postgraduate Studies and Research. It is understood that any copying or publication or use of this thesis or parts thereof for financial gain shall not be allowed without my written permission. It is also understood that due recognition shall be given to me and to Universiti Utara Malaysia for any scholarly use which may be made of any material from my thesis.

Requests for permission to copy or to make other use of materials in this thesis, in whole or in part, should be addressed to:

Dean of Postgraduate Studies and Research

UUM College of Arts and Sciences

Universiti Utara Malaysia

06010 UUM Sintok

Kedah Darul Aman

IKHTISAR

Kanak-kanak disleksia mengalami masalah pembelajaran yang berkait rapat dengan sistem fonologi yang mengganggu perkembangan mereka dalam kemahiran membaca dan mengeja. Bagi mereka, membaca dan mengeja merupakan proses yang sukar, melelahkan dan kurang menarik perhatian. Konsentrasi yang lemah juga mengakibatkan mereka sebolehnya mengelak untuk belajar membaca dan mengeja. Masalah disleksia ini menyebabkan mereka melakukan kesalahan pembacaan walaupun ketika membaca dan mengeja perkataan-perkataan mudah. Walau bagaimanapun, keadaan ini tidak bermakna mereka memiliki tahap IQ yg rendah berbanding kanak-kanak normal. Selalunya, kanak-kanak disleksia memiliki tahap IQ yang setara dengan rakan-rakan mereka yang lain dan mungkin juga lebih tinggi. Fakta ini merumuskan bahawa kanak-kanak disleksia mempunyai potensi jika diberikan bantuan dan sokongan padu seperti motivasi dan kaedah pengajaran yang sesuai. Dengan kemajuan teknologi dalam bidang pendidikan, aplikasi berasaskan komputer dilihat dapat membantu proses pengajaran dan pembelajaran khususnya bagi membaca dan mengeja. Justeru itu, kajian ini merupakan inisiatif yang mencadangkan sebuah model *automatic speech recognition* (ASR) yang berupaya 'mendengar' dan seterusnya mengenalpasti kesalahan bacaan bagi kanak-kanak ini. Skop kajian menghadkan kepada pemodelan dan pengecaman perkataan terpilih dalam Bahasa Melayu (BM) yang terkandung di dalam silibus pengajaran tahap satu di sekolah rendah. Untuk mengesyorkan pemodelan ASR dalam BM, sebuah model pembacaan khusus bagi kanak-kanak disleksia terlebih dahulu dicadangkan. Teknik kajian etnografi, iaitu pemerhatian dan temubual secara tidak formal, telah diguna untuk mendapatkan kesalahan-kesalahan bacaan yang juga melibatkan kesalahan ejaan. Sepuluh orang murid berusia 7 hingga 14 tahun yang mempunyai tahap kebolehan membaca yang hampir sama telah dipilih menyertai kajian. Mereka terdiri daripada murid di dua buah sekolah rendah yang menawarkan kelas khas disleksia. Sebanyak 6112 bacaan telah direkod dalam bentuk audio dan daripada itu, sejumlah 6051 kesalahan bacaan telah berjaya dikenal pasti. Antara kesalahan yang paling menonjol adalah kesalahan berkaitan penggantian huruf vokal, penyingkiran huruf konsonan, kesalahan berkaitan dengan huruf nasal dan penggantian konsonan. Justeru itu, model ASR tersebut telah mengambilkira aspek kesalahan bacaan yang paling kerap tersebut dan menjadikan ia sebagai elemen penting bagi tujuan

pengesanan. Model ASR tersebut mengambilkira kesalahan bacaan bagi sesuatu perkataan sebagai alternatif kepada sebutan yang betul di mana kesalahan-kesalahan itu telah dimodelkan ke dalam model leksikalnya. Strategi penambahbaikan fonem juga digunakan bagi tujuan meningkatkan ketepatan pengesanan, iaitu menurunkan kadar kesalahan perkataan (*word error rate*, WER). Untuk itu, sebuah prototaip pengesam (*recognizer*) telah dihasilkan bagi membolehkan proses penilaian dilakukan terhadap ketepatan pengesam yang berasaskan model cadangan. Penilaian ketepatan ini diukur menggunakan WER dan kadar pengesanan kesalahan bacaan (*miscue detection rate*, MDR) yang berkait rapat dengan *false alarm rate* (FAR). Pengesam berasaskan model cadangan tersebut berjaya mencapai tahap kepuasan WER serendah 25% dan 80.77% untuk MDR dengan kadar FAR 16.67%.

Katakunci: *Pengesanan suara automatik, model leksikal, kanak-kanak disleksia, Bahasa Melayu.*

ABSTRACT

Dyslexic children suffer from dyslexia, a condition that profoundly impedes reading and spelling ability due to its phonological origin. Often, these children find reading and spelling difficult, exhaustive, and less interesting, and thus they are self-withdrawn from the learning process. When reading and spelling, they make many mistakes even for simple, common words that they themselves find embarrassing. However, this does not mean that they have lower IQ level than normal children. In fact, dyslexic children have average or high level of IQ and thus have a lot of potential when given the right help and support such as motivational support and suitable teaching techniques. With advancement in technology in education, computer-based applications are used to stimulate the learning process of reading and spelling. Hence, this study is an initiative towards proposing an automatic speech recognition (ASR) model to enable computer to 'listen' should incorrect reading occurs. The scope of this study focuses on modeling and recognizing single Bahasa Melayu (BM) words within the school syllabus for level one (*tahap satu*) dyslexic pupils of primary schools. To propose the ASR model, a reading and spelling model of dyslexic children reading in BM is first proposed, which models reading at word recognition level. To propose such model, ethnographic techniques are employed namely informal interviews and observation, in order to obtain the reading and spelling error patterns of dyslexic children. A number of ten dyslexic children, aged between 7 to 14 years old whose reading level is similar, participated in the study. These children are recruited from two public schools that offer special dyslexia classes for the children. A total of 6112 utterances are recorded in audio form resulting in a total of 6051 errors of various types. Among these, the patterns that are most frequently made by these children are of 'Substitutes vowel', 'omits consonant', 'nasals', and 'substitutes consonant'. The ASR model is proposed taking into consideration the error patterns that make lexical model a fundamental element for speech recognition. The lexical model is modeled to treat mispronunciations as alternative pronunciations or variants of target words. To that, a phoneme refinement strategy is applied aiming to increase recognition accuracy. A prototype recognizer is developed based on the proposed model for further evaluation. The evaluation is performed to evaluate the recognizer's performance in terms of accuracy, measured in word error rate (WER) and miscue detection rate (MDR) that is closely related to false

alarm rate (FAR). The recognizer scores a satisfying 25% of WER and a relatively high MDR of 80.77% with 16.67% FAR.

Keywords: *Automatic speech recognition, lexical model, dyslexic children, Bahasa Melayu.*

ACKNOWLEDGEMENTS

‘Alhamdulillah’, praise be to Allah, The Most Beneficent, The Most Merciful.

First and foremost, my deepest thank you goes to my supervisor, Assoc. Prof. Dr Zulikha Jamaludin for without her support, guidance, and help this thesis would not have been successfully materialized. I cannot fully express my gratitude to the exceptional advice every time I seek enlightenment, be it regarding PhD or about life itself. So, thank you.

My sincere appreciation to the important people who have contributed, in various ways, by providing the help and support needed during the research: Dr. Abd. Razif b. Abd. Razak, consultant paediatrician of Kedah Medical Center; Dr. Tan of Bureau of Learning Difficulties (BOLD), Penang; Pn. Sariah Amirin, presiden of Dyslexia Association Malaysia, Kuala Lumpur; Kim Wilson-Rymer of Davis Dyslexia Program, Ontario, Canada for continuous information on dyslexia; headmasters and dyslexia teachers of Sekolah Kebangsaan Taman Tun Dr. Ismail 2 (SKTTDI 2), Kuala Lumpur, especially Datin Zahrah Abdullah, Dyslexia programme coordinator of SKTTDI 2 and Madam Ratana and Madam Bibi of Sekolah Kebangsaan Jalan Datuk Kumbar, Alor Setar.

A special thank you goes to Assistant Professor John-Paul Hosom of Center of Spoken Language Understanding (CSLU), Department of Science and Engineering, School of Medicine, Oregon Health and Science University, N.W. USA for his generous assistance especially in modelling the ASR lexical, developing, and testing the ASR recognizer.

Last but not least, a heartiest thank you to my husband, Suhairizam Omar, and my son, Humayl Suhair for everything. Thank you also to my parents, Husni and Norain, and to my friends for their love and continuous pray, support, and understanding. Without them, the PhD journey would not have been wonderful. Thank you.

TABLE OF CONTENTS

PERMISSION TO USE	i
<i>IKHTISAR</i>	ii
ABSTRACT.....	iv
ACKNOWLEDGEMENTS	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	x
LIST OF FIGURES	xii
LIST OF ACRONYMS	xv
NAMING CONVENTION	xiv

CHAPTER 1: INTRODUCTION

1.0	Introduction.....	1
1.1	Research Taxonomy	5
1.2	Motivation.....	6
1.3	Problem Statement – Challenges at Hand.....	7
1.4	Research Objective	10
1.5	The Scope	12
1.6	Contribution of Research	15
1.7	Overall Thesis Summary	17
	1.7.1 Research Recapitulated	17
	1.7.2 Thesis Organization.....	19

CHAPTER 2: LITERATURE REVIEW

2.0	Introduction.....	21
2.1	Using ASR Technology to Facilitate Reading: Theory-based Perspective	23
2.2	The Vocabulary and Age-Matched Dyslexic Children.....	26
2.3	Reading and Spelling Error Patterns.....	28
2.4	Dyslexic Children’s Reading Model.....	31
2.5	ASR 1, 2, 3.....	37
	2.5.1 ASR for BM	37
	2.5.2 Discrete vs. Continuous ASR System for Dyslexic	38
	2.5.3 ASR Methods	42
	2.5.3.1 Template Matching	42
	2.5.3.2 Acoustic-Phonetic Approach	43
	2.5.3.3 Hidden Markov Model.....	44
	2.5.3.4 Artificial Neural Network Approach	45
	2.5.3.5 Hybrid Method of HMM/ANN.....	46
	2.5.4 ASR Models	48
	2.5.5 Lexical Model and Context-dependent Modeling.....	52

2.6	Evaluation: The Recognition Accuracy	54
2.7	Chapter Summary	58

CHAPTER 3: METHODOLOGY

3.0	Introduction.....	60
3.1	Task 1: Data Collection	62
3.1.1	The vocabulary	64
3.1.2	The participants – Dyslexic children.....	68
3.1.3	Primary data collection.....	71
3.2	Task 2: Model Creation	74
3.2.1	Data analysis	75
3.2.2	Pronunciation model	79
3.2.3	Improvement of the reading model	81
3.2.4	Improvement of the ASR model	84
3.3	Task 3: ASR Recognizer Development	89
3.4	Task 4: Evaluation	92
3.4.1	The WER evaluation	92
3.4.2	MDR and alignment technique	93
3.5	Summary.....	95

CHAPTER 4: THE DEVELOPMENT OF THE ASR RECOGNIZER

4.0	Introduction.....	97
4.1	Setting the ‘Stage’	98
4.1.1	The speech files (.wav).....	99
4.1.2	The transcription files (.txt).....	100
4.1.3	The phoneme files (.phn)	101
4.2	Creating Descriptions Files.....	103
4.2.1	The lexical model as the key component in ASR	103
4.2.2	The corpora	109
4.2.3	The grammar and parts specifications.....	110
4.2.4	The .info files.....	112
4.3	The Training Process	114
4.4	Phoneme Refinement Strategy.....	125
4.5	Summary	128

CHAPTER 5: EVALUATION: WORD ERROR & MISCUE DETECTION

5.0	Introduction.....	129
5.1	Evaluation and Results: WER.....	130
5.2	Evaluation: MDR.....	135
5.3	Results: MDR	137
5.4	Analysis and Discussion	138
5.4.1	The Effects of Phoneme Refinement on WER, MDR, and FAR.....	139
5.4.2	The Overall Performance	142
5.4.3	The Shortcoming	144
5.5	Summary	145

CHAPTER 6: CONCLUSION & FUTURE DIRECTIONS

6.0	Introduction.....	147
6.1	Research Recapitulation	148
6.2	The Objectives Achieved.....	150
6.2.1	To collect vocabulary in BM.....	152
6.2.2	To recognize reading and spelling patterns.....	153
6.2.3	To model dyslexic children’s reading in BM.....	154
6.2.4	To model an ASR for the reading model	155
6.2.5	To develop an ASR recognizer based on the ASR model.....	156
6.2.6	To evaluate in WER and MDR	157
6.3	Upshot – The reading model and the ASR model	157
6.4	Future works	160
6.5	Summary.....	162

REFERENCES	163
------------------	-----

APPENDICES

Appendix A: Consonant–Vowel (CV) pairs in syllable patterns of BM words	178
Appendix B: The Readings of Dyslexic Children According to Word Syllable Patterns.....	180
Appendix C: Percentage of Occurrences of Modeled Pronunciations	204
Appendix D: Algorithm for transcription and miscue detection in tcl	219
Appendix E: CSLU Toolkit’s Training Instructions.....	223
Appendix F: Target words and hypotheses (incorrect recognition).	238
Appendix G: Place and Manner of Articulation for BM	240
Appendix H: The Alignment Technique (<i>wordsfa2net.28</i>).....	241
Appendix I: The Alignment Technique (<i>worsfanet.10</i>).....	246
Appendix J: The Alignment Technique.....	251

LIST OF RELATED PUBLICATION TO THESIS	261
---	-----

LIST OF TABLES

<i>Table 1.1.</i>	Research problem and research questions addressed in this study together with summary of methods and expected deliverables.	18
<i>Table 2.1</i>	Phonological error types and their definitions and example words adapted from Sawyer et al. (1999).	30
<i>Table 2.2.</i>	The different effects of discrete ASR and continuous ASR adapted from Higgins and Raskind (2000).	40
<i>Table 2.3.</i>	Discrete vs. continuous ASR effects on various skills adapted from Higgins and Raskind (2000).	41
<i>Table 2.4.</i>	The WER percentage of recognition tasks using HMM and HMM/ANN performed in various domains.	48
<i>Table 2.5.</i>	MDR and FAR of various ASR.	58
<i>Table 3.1.</i>	Example of clusters of common words within level 1 syllabus, tabled accordingly in random cluster sampling technique.	66
<i>Table 3.2.</i>	Examples of words for each of the syllable patterns of consonant-vowel categories and used as stimuli for data collection.	67
<i>Table 3.3.</i>	The readings of <i>sunyi</i> , which have been transcribed into correspondence spellings according to how they were pronounced.	75
<i>Table 3.4.</i>	Classification of errors for read words, which have been transcribed into corresponding spellings.	78
<i>Table 3.5.</i>	Categories of error types for analysis of read words error classification and the corresponding definitions.	79
<i>Table 3.6.</i>	Reading and spelling errors, in descending percentile, of dyslexic children reading aloud controlled vocabulary in BM.	80
<i>Table 3.7.</i>	Pronunciation models for word <i>ibu</i> , <i>aku</i> , <i>dan</i> , <i>rumah</i> , and <i>kereta</i> in Worldbet.	82
<i>Table 3.8.</i>	Alignment of target, transcript, and hypothesis tokens for miscue detection.	96
<i>Table 4.1.</i>	The relationship of speech file, transcription file, and phoneme file.	101
<i>Table 4.2.</i>	The mispronunciations of <i>wad</i> and their frequencies that later	108

suggest future potential feedback.

<i>Table 4.3.</i>	The commands used in training the recognizer and their functions.	123
<i>Table 4.4.</i>	Target words and recognized words (hypotheses) comparison.	129
<i>Table 4.5.</i>	The letters and their pronunciation variations allowed in the lexical model to enhance accuracy.	130
<i>Table 5.1.</i>	The output of <code>select_best.tcl</code> on development dataset, extracted from the summary file showing word level accuracy.	135
<i>Table 5.2.</i>	The output of <code>select_best.tcl</code> on development dataset after force-alignment, extracted from the summary file showing word level accuracy.	136
<i>Table 5.3.</i>	The output of <code>select_best.tcl</code> on development dataset after second force-alignment, extracted from the summary file showing word level accuracy.	136
<i>Table 5.4.</i>	The output of <code>select_best.tcl</code> on development dataset after third force-alignment, extracted from the summary file showing word level accuracy.	137
<i>Table 5.5.</i>	The best network for the development dataset fed into cycles of force- alignment.	138
<i>Table 5.6.</i>	The final output evaluated on test dataset.	138
<i>Table 5.7.</i>	The alignment of transcripts, targets, and hypotheses.	141
<i>Table 5.8.</i>	The output of <code>select_best.tcl</code> on development dataset.	143
<i>Table 5.9.</i>	The output of <code>select_best.tcl</code> on test dataset.	144
<i>Table 5.10.</i>	The performance of the proposed lexical model and its counter model measured in WER, MDR, and FAR.	145
<i>Table 5.11.</i>	The performance of the proposed recognizer among the recognizers built for similar purposes.	147
<i>Table 6.1.</i>	The results and deliverables and their contributions outlined for the specific objective achieved.	156

LIST OF FIGURES

<i>Figure 2.1.</i>	Basic architecture of the dual-route model adopted from Coltheart et al. (2001).	33
<i>Figure 2.2.</i>	The structure of the Seidenberg-McClelland's computer simulated model of reading, adopted from Seidenberg and McClelland (1989).	34
<i>Figure 2.3.</i>	A simple model of cognitive processes involved in word recognition of a single word, adopted from Ellis (1993).	36
<i>Figure 2.4.</i>	HMM structure consists of five nodes with their transitions and recursive transitions adopted from Rabiner and Juang, 1993.	45
<i>Figure 2.5.</i>	A multilayer neural network, illustrating an input layer, a hidden layer, and an output layer.	47
<i>Figure 2.6.</i>	The general components involved in speech recognition.	50
<i>Figure 2.7.</i>	HMM architecture for isolated word recognition (source: Rabiner and Huang (1993).	51
<i>Figure 2.8.</i>	The illustration of the hybrid HMM/ANN architecture adopted from Shobaki et al. (2000).	52
<i>Figure 3.1.</i>	The methods and deliverables encapsulated in the research framework.	63
<i>Figure 3.2.</i>	The process of selecting the words to serve as vocabulary and stimuli.	69
<i>Figure 3.3.</i>	DAS's causal model of dyslexia, illustrating the various environmental factors in a bilingual or multilingual community, adopted from DAS (2003).	71
<i>Figure 3.4.</i>	A reading model that models the most frequent reading and spelling errors as a result of dyslexic children reading aloud controlled vocabulary in BM.	84
<i>Figure 3.5.</i>	The reading model and how it supports the ASR model.	87
<i>Figure 3.6.</i>	The proposed ASR model with inclusion of reading errors as active lexicon and phoneme refinement.	89
<i>Figure 3.7.</i>	The process flow of ASR recognizer development.	93

<i>Figure 3.8.</i>	Running <code>select_best.tcl</code> to obtain WER on test dataset.	94
<i>Figure 4.1.</i>	Example of speech files recorded displayed in SpeechView.	102
<i>Figure 4.2.</i>	The phonetic labels (in Worldbet) of every phoneme of the word <i>kelapa</i> and their positions given in millisecond (ms).	104
<i>Figure 4.3.</i>	The view of speech window (top), 2-D spectrogram window (middle), and the label window (bottom).	105
<i>Figure 4.4.</i>	A snippet of the lexicon file containing target words' pronunciations as well as mispronunciations represented in Worldbet, separated by the OR () operator.	107
<i>Figure 4.5.</i>	Alternative pronunciations of target words modeled into the lexical model.	111
<i>Figure 4.6.</i>	The context-dependent phoneme model of the word <i>aku</i> .	114
<i>Figure 4.7.</i>	2-D Spectrogram of phoneme A in the word <i>bawang</i> .	115
<i>Figure 4.8.</i>	Speech files divided into three datasets according to the 3:1:1 ratio.	116
<i>Figure 4.9.</i>	The overview of the training process for developing a prototype speech recognizer using CSLU Toolkit.	118
<i>Figure 4.10.</i>	Automatic generations of training, development, and testing datasets using <code>find_files.tcl</code> command.	119
<i>Figure 4.11.</i>	An illustration of the 3 layer feed-forward network architecture.	120
<i>Figure 4.12.</i>	A snippet of the output of the vector file created showing the maximum number of categories on the left column, which gives 77.	120
<i>Figure 4.13.</i>	The results for learn rate and total errors while training the hybrid network using <code>nntrain.exe</code> of CSLU Toolkit.	122
<i>Figure 4.14.</i>	The flow of training process in detail.	124
<i>Figure 4.14 (cont.).</i>	The flow of training process in detail (continues).	125
<i>Figure 4.15.</i>	The force-alignment process.	127
<i>Figure 4.15 (cont.).</i>	The force-alignment process (continues).	128
<i>Figure 4.16.</i>	The illustration of phoneme refinement rule applied to modeling the lexicon.	130

<i>Figure 5.1.</i>	The final performance comparison between different lexical models of the same data, measured in WER and MDR-FAR.	145
<i>Figure 6.1.</i>	The theoretical foundation constitutes to dyslexia and phonetically similar vocabulary and how it benefits the ASR.	154

LIST OF ACRONYMS

3M	<i>Membaca, Menulis, Mengira</i> (Reading, Writing, and Calculating)
ADD	Attention Deficit Disorder
ADHD	Attention Deficit Hyperactivity Disorder
ANN	Artificial Neural Network
ASCII	American Standard Code for Information Interchange
ASR	Automatic Speech Recognition
BM	Bahasa Melayu
CoLiT	Colorado Literacy Tutor
CSLU	Center for Spoken Language Understanding
C-V	Consonant-Vowel
DAS	Dyslexia Association Singapore
DC	Dyslexic Children
FAR	False Alarm Rate
HMM	Hidden Markov Model
HMM/ANN	Hybrid of Hidden Markov Model and Artificial Neural Network
ICT	Information and Communication Technology
IPA	International Phonetic Alphabet
LD	Learning Disability
LISTEN	Literacy Innovation that Speech Technology ENables
LLP	Liberated Learning Project
MDR	Miscue Detection Rate
MoE	Ministry of Education
NICHCY	National Dissemination Center for Children with Disabilities
OGI KIDS	Oregon Health & Science Univeristy (OGI) Children's Corpus (called KIDS Corpus)
PDP	Parallel Distribute Processing
PIPP	<i>Pelan Induk Pembangunan Pendidikan</i>
R&D	Research and Development
RAD	Rapid Application Development
TTS	Text-to-Speech
UTMK	<i>Unit Terjemahan Melalui Komputer</i>
WER	Word Error Rate

NAMING CONVENTION

Words	Naming Convention
<i>Bahasa Melayu</i> words	In italics e.g. <i>ibu, abang</i>
English words	In quotes e.g. “tyrannosaurus”
Non-words	In quotes e.g. “idu”
Error types	In inverted commas e.g. ‘Reversals’, ‘substitutes vowel’
Alphabet or value or digit or syllable	In inverted commas e.g. ‘b’, ‘1’, ‘bu’
Emphasized word(s)	In bold face e.g. dual-route model
New terms	In italics e.g. <i>backpropagation</i>
Programming code or phonetic symbols (Worldbet) or file names or mathematical equation	In Courier New face e.g. <code>aku = A kh U,</code> <code>words.lexicon</code>

CHAPTER 1

INTRODUCTION

1.0 Introduction

Learning disabilities (LD) have gained serious attention from research communities in various fields – clinical, psychological, education, as well as computer science. LD is a condition where people have problems in acquiring skills essential in learning. Skills that are mostly affected are reading, writing, spelling, speaking, reasoning, and doing mathematics. The National Dissemination Center for Children with Disabilities, NICHCY (2004) revealed that 1:5 people are learning disabled. LD is a term generally used to refer to more specific types of learning problems such as Attention Deficit Disorder (ADD), Attention Deficit Hyperactivity Disorder (AHDD), and dyslexia.

Dyslexia is a type of LD that affects the individual's ability to learn basic literacy skills. The International Dyslexia Association (2006) defines it as a learning disability which is neurological in origin. Its characteristics are problems in accurate or fluent word recognition and also poor spelling and decoding abilities. These problems are strongly related to phonological deficits which are not clearly apparent in other cognitive abilities and from general classroom instructions. Other consequences include problems in reading comprehension and reduced reading experience that holds back the growth of vocabulary and background knowledge.

People who are dyslexics normally have average or high intelligence but found reading, spelling, and writing such overwhelmed tasks. Phonological deficit is

The contents of
the thesis is for
internal user
only

References

- Aist, G., Chan, P., Huang, X. D., Jiang, L., Kennedy, R., Latimer, D., et al. (1998). How effective is unsupervised data collection for children's speech recognition? *Proceedings of the International Conference on Speech and Language Processing (ICSLP98)*, Sydney, Australia, 3171-3174.
- Association for Computing Machinery. (1998). *The ACM Computing Classification System 1998*. Retrieved Feb 14, 2008, from <http://www.acm.org/class/1998/ccs98.html>.
- Audiblox. (2000). *Phonological awareness and phonemic awareness*. Retrieved Mar 30, 2007, from http://www.audiblox2000.com/learning_disabilities/phonological.htm.
- Bain, K., Basson, S. H., & Wald, M. (2002). Speech recognition in university classrooms: Liberated Learning Project. *Proceedings of the 5th International ACM Conference on Assistive Technologies*, Edinburgh, Scotland, 192 -196.
- Banerjee, S., Beck, J., & Mostow, J. (2003a). Evaluating the effect of predicting oral reading miscues. *Proceedings of the 8th International European Conference on Speech Communication and Technology (Eurospeech-03)*, Geneva, Switzerland, 3165-3168.
- Banerjee, S., Mostow, J., Beck, J., & Tam, W. (2003b). Improving language models by learning from speech recognition errors in a reading tutor that listens. *Second International Conference on Applied Artificial Intelligence*, Fort Panhala, Kolhapur, India.

- Baumer, B. H. (1998). *How to teach your dyslexic child to read: A proven methods for parents*. New York: Kensington Publishing Corp.
- Bourlard, H., & Morgan, N. (1998). Hybrid HMM/ANN systems for speech recognition: Overview and new research directions. In C.L. Giles & M. Gori (Eds.), *Adaptive Processing of Sequences and Data Structures, Lecture Notes in Artificial Intelligence (1387)*, (pp. 389-417). USA: Springer Verlag.
- Bradley, L., & Bryant, P. E. (1983). Categorizing sounds and learning to read: A causal connection. *Nature*, *301*, 419-421.
- Castles, A. (2006). The dual-route model and the developmental dyslexia. *London Review of Education*, *4*(1), 49-61.
- Coltheart, M., Curtis, B., Atkins, P., & Haller, M. (1993). Models of reading aloud: Dual-route and parallel distributed processing approaches. *Psychological Review*, *100*(4), 589-608.
- Coltheart, M., Rastle, K., Perry, C., Langdon, R., & Ziegler, J. (2001). DRC: A dual-route cascaded model of visual word recognition and reading aloud. *Psychological Review*, *108*(1), 204-256.
- Conn, N., & McTear, M. (2000). Speech technology: A solution for people with disabilities. *IEEE Seminar on Speech and Language Processing for Disabled and Elderly People*, *7*, London, UK, 1-6.
- Cosi, P. (2000). Hybrid HMM-NN architectures for connected digit recognition. *IEEE Transactions on ASSP*, *5*, 85-90.

- Das, S., Nix, D., & Picheny, M. (1998). Improvements in children's speech recognition performance. *Proceedings of the 1998 IEEE International Conference on Acoustics, Speech and Signal Processing 1998*, Seattle, WA, USA, 1, 433-436.
- Duchateau, J., Wigham, M., Demuynck, K., & Van hamme, H. (2006). A flexible recognizer architecture in a reading tutor for children. *Proceedings of ITRW on Speech Recognition and Intrinsic Variation*, Toulouse, France, 59-64.
- Dupont, S., Ris, C., Couvreur, L., & Boite, J.-M. (2005). A study of implicit and explicit modeling of coarticulation and pronunciation variation. *Proceedings of Interspeech 2005*, Lisbon, Portugal.
- Dwyer, B. (2000). *The uses of computer technology in the remediation of children with specific learning difficulties (Dyslexia)*. Retrieved Mar 28, 2007, from <http://webpages.dcu.ie/~farrenm/spec.pdf>
- Dyslexia Association Singapore, DAS. (2003). *DAS hypothesis on the cause of dyslexia*. Retrieved August 14, 2007, from <http://www.das.org.sg/news/dashyp.htm>
- D'Arcy, S. M., Wong, L. P., & Russell, M. J. (2004). Recognition of read and spontaneous children's speech using two new corpora. *Proceedings of International Conference on Spoken Language Processing (ICSLP'04)*, Jeju Island, Korea.
- Ellis, A. W. (1993). *Reading, writing and dyslexia: A cognitive analysis* (2nd ed.). UK: Lawrence Erlbaum Associates Ltd.
- Fairweather, P., Nix, D., Oblinger, D., Adams, B., & Carla, L. (n.d.). *Overcoming technical barriers to a speech-enabled children's reading tutor*. Retrieved Mar

13, 2007, from <http://www.research.ibm.com/AppliedLearningSciWeb/Fairweather/techbar.pdf>

Fausett, L. V. (1994). *Fundamentals of neural networks: Architectures, algorithms, and applications*. New Jersey: Prentice-Hall.

Fawcett, A. J., & Nicolson, R. I. (2002). Children with dyslexia are slow to articulate a single speech gesture. *Dyslexia*, 8, 189-203.

Franco, H., Cohen, M., Moran, N., Rumelheart, D., & Abrash, V. (1994). Context-dependent connectionist probability estimation in a hybrid hidden Markov model-neural net speech recognition. *Computer Speech and Language*, 8, 211-222.

Frost, J. (2001). Phonemic awareness, spontaneous writing, and reading and spelling development from a preventive perspective. *Reading and Writing: An Interdisciplinary Journal*, 14, 487 - 513.

Goswami, U. (2002). Phonology, reading development and dyslexia: A cross-linguistic perspective. *Annals of Dyslexia*, 52, 1-23.

Hagen, A. (2006). *Advances in children's speech recognition with application to interactive literacy tutor*. Unpublished doctoral dissertation, University of Colorado, Colorado.

Hagen, A., Pellom, B., & Cole, R. (2003). Children's speech recognition with application to interactive books and tutors. *Proceedings of the IEEE Workshop on Automatic Speech Recognition and Understanding 2003*, St. Thomas, USA, 186-191.

- Hagen, A., Pellom, B., Van Vuuren, S., & Cole, R. (2004). Advances in children's speech recognition within an interactive literacy tutor. *Proceedings of HLT-NAACL*, Boston Massachusetts, USA.
- Hain, T. (2002). Implicit pronunciation modelling in ASR. *ISCA Tutorial and Research Workshop on Pronunciation Modeling and Lexicon Adaptation for Spoken Language Technology (PMLA)*, Colorado, USA, 129-134.
- Hieronymus, J. L. (1993). *ASCII phonetic symbols for world's languages: Worldbet* (Tech. Rep.). NJ, USA: AT&T Bell Labs.
- Higgins, E. L. (2004). Speech recognition-based and automaticity programs to help students with severe reading and spelling problems. *Annals of Dyslexia*, 54, 365 - 392.
- Higgins, E. L., & Raskind, M. H. (2000). Speaking to read: The effects of continuous vs. discrete speech recognition systems on the reading and spelling of children with learning disabilities. *Journal of Special Education Technology*, 15, 19 - 30.
- Hosom, J.P., Cole, R.A., & Cosi, P. (1999). Improvements in neural-network training and search techniques for continuous digit recognition, *Australian Journal of Intelligent Information Processing Systems (AJIIPS)*, 5(4), 277-284.
- Hosom, J. P., de Villiers, J., Cole, R., Fanty, M., Schalkwyk, J., Yan, Y. et al. (2006). Training Hidden Markov Model/Artificial Neural Network (HMM/ANN) hybrids for automatic speech recognition (ASR) [Computer software and manual]. Retrieved July 7, 2007, from <http://www.cslu.cse.ogi.edu/tutordemos/>

- Husniza, H., & Zulikha, J. (2010). Improving ASR performance using context-dependent phoneme models. *Journal of Systems and Information Technology (JSIT)*, 12(1).
- Husniza, H. & Zulikha, J. (2009a). Pronunciation variations and context-dependent model to improve ASR performance for dyslexic children's read speech. *Proceedings of International Conference on Computing and Informatics (ICOICI 2009)*, Kuala Lumpur, Malaysia.
- Husniza, H. & Zulikha, J. (2009b). Dyslexic Children's Reading Pattern as Input for ASR: Data, Analysis, and Pronunciation Model. *Journal of Information and Communication Technology (JICT)*, 8, 1-13.
- Indirawati, Z. & Mardian, S. O. (2006). *Fonetik dan Fonologi Bahasa Melayu*. Kuala Lumpur, Malaysia: PTS Professional Publishing.
- International Dyslexia Association. (2006). *What is Dyslexia?* Retrieved Mar 30, 2007, from http://www.interdys.org/servlet/compose?section_id=5&page_id=95
- Jabatan Pendidikan Khas. (1999). *Buku Panduan Pelaksanaan Program Pemulihan Khas: Masalah Penguasaan 3M*. Kuala Lumpur, Malaysia: Jabatan Pendidikan Khas, Kementerian Pelajaran Malaysia.
- Jelinek, F. (2001). *Statistical methods for speech recognition*. Cambridge, Massachusetts: The MIT Press.
- Kasselimis, D., Margarity, M., & Vlachos, F. (2006). The relation of dyslexia to cerebellar function and articulation speed. *Annals of General Psychiatry*, 5(1), 160.

- Kementerian Pelajaran Malaysia. (2006). *Pelan Induk Pembangunan Pendidikan (PIPP) – Edisi Pelancaran PIPP 2006*. Kuala Lumpur, Malaysia: Kementerian Pelajaran Malaysia (KPM).
- Lee, K. A., Hagen, A., Romanyshyn, N., Martin, S., & Pellom, B. (2004). Analysis and detection of reading miscues for interactive literacy tutors. *Proceedings of the 20th International Conference on Computational Linguistics (Coling) 2004*, Geneva, Switzerland.
- Lerner, J. (1997). *Learning disabilities: Theories, diagnosis, and teaching strategies* (7th ed.). Boston: Houghton Mifflin Company.
- Li, X., Ju, Y., Deng, L., & Acero, A. (2007). Efficient and robust language modeling in an automatic children's reading tutor systems. *Proceedings of IEEE International Conference on Acoustics, Speech and Signal Processing (ICASSP'07)*, Honolulu, Hawaii, IV-193-IV-196.
- Li, X., Deng, L., Ju, Y., & Acero, A. (2008). Automatic reading tutor on hand held devices. *Proceedings of the Interspeech 2008*, Brisbane, Australia, 1733-1736.
- Liu, C., Pan, F., Ge, F., Dong, B., Zhao, Q., & Yan, Y. (2008). Application of LVCSR to the detection of Chinese Mandarin reading miscues, *Proceedings of International Conference on Natural Computation*, 5, 447-451.
- Liu, M., Xu, B., Huang, T., Deng, Y., & Li, C. (2000). Mandarin accent adaptation based on context-independent/context-dependent pronunciation modeling. *Proceedings of the IEEE International Conference on Acoustic, Speech, and Signal Processing*, 2, II1025 - II1028.

- Livescu, K. & Glass, J. (2000). Lexical modeling of non-native speech for automatic speech recognition. *Proceedings of the IEEE International Conference on Acoustic, Speech, and Signal Processing*, Istanbul, Turkey, 3, 1683-1686.
- Lundberg, I. (1995). The computer as a tool of remediation in the education of students with reading disabilities: A theory-based approach. *Learning Disability Quarterly*, 18(2), 88-99.
- Lundberg, I. & Olofsson, A. (1993). Can computer speech support reading comprehension? *Computers in Human Behavior*, 9, 283-293.
- Manis, F. R., Custodio, R., & Szeszulski, P. A. (1993). Development of phonological and orthographic skill: A 2-year longitudinal study of dyslexic children. *Journal of Experimental Child Psychology*, 56, 64-86.
- Markowitz, J. A. (1996). *Using speech recognition*. New Jersey: Prentice Hall PTR.
- Md Sah, S., Dzulkipli, Y., & Sheikh Hussein, S. S. (2001). Neural network speaker dependent isolated Malay speech recognition system: Handcrafted vs. genetic algorithm. *Proceedings of International Symposium on Signal Processing and Its Applications (ISSPA)*, Kuala Lumpur, 731-734.
- Mioduser, D., Tur-Kaspa, H., & Leitner, I. (2000). The learning-value of computer based instruction of early reading skills. *Journal of Computer Assisted Learning*, 16, 54-63.
- Mostow, J. (2006). Is ASR accurate enough for automated reading tutors, and how can we tell? *Proceedings of the 9th International Conference on Spoken Language Processing (Interspeech 2006 — ICSLP)*. Pittsburgh, 837-840.

- Mostow, J., Roth, S., Hauptmann, A. G., & Kane, M. (1994). A prototype reading coach that listens. *Proceedings of the 12th National Conference on Artificial Intelligence (AAAI-94)*, Seattle, WA, 785-792.
- Mostow, J., Beck, J., Winter, S. V., Wang, S., & Tobin, B. (2002). Predicting oral reading miscues. *Proceedings of the 7th International Conference on Spoken Language Processing (ICSLP-02)*, Denver, CO, 1221-1224.
- Mostow, J., & Beck, J. (2003). When the rubber meets the road: Lessons from the in-school adventures of an Automated Reading Tutor that listens. *Proceedings of the Conceptualizing Scale-Up: Multidisciplinary Perspectives*, Park Hyatt Hotel, Washington, D.C.
- National Dissemination Center for Children with Disability. (2004). *Learning Disabilities*. Retrieved Mar 7, 2007, from <http://www.nichcy.org/pubs/factshe/fs7.pdf>
- Nix, D., Fairweather, P., & Adams, B. (1998). Speech recognition, children, and reading. *Proceedings of the ACM Conference on Human Factors in Computing Systems*, Los Angeles, USA, 245-246.
- Noraini, S., & Kamaruzaman, J. (2008). Acoustic pronunciation variations modeling for standard Malay speech recognition. *Journal of Computer and Information Science*, 1(4), 112-120.
- Nor Hasbiah, U. (2007). *Perisian Kursus Multimedia dalam Literasi Matematik (D-Matematika) untuk Pelajar Disleksia*. Unpublished doctoral dissertation, Universiti Kebangsaan Malaysia, Bangi.

- Olofsson, A. (1992). Synthetic speech and computer aided reading for reading disabled children. *Reading and Writing: An Interdisciplinary Journal*, 4, 165-178.
- Olson, R. K. & Wise, B. W. (1992). Reading on the computer with orthographic and speech feedback: An overview of the Colorado remediation project. *Reading and Writing: An Interdisciplinary Journal*, 4, 107-144.
- Rabiner, L. & Juang, B-H. (1993). *Fundamentals of Speech Recognition*. New Jersey: PTR Prentice-Hall, Inc.
- Rainger, P. (2003). *A dyslexic perspective on e-content accessibility*. Retrieved Mar 9, 2007, from <http://www.techdis.ac.uk/resources/files/dyslexia.doc>
- Ranaivo-Malacon, B. (2005). Malay lexical analysis through corpus-based approach. *Persidangan Antarabangsa Leksikologi dan Leksikografi Melayu (PAMA 2005)*, Kuala Lumpur, Malaysia.
- Raskind, M. H., & Higgins, E. L. (1999). Speaking to read: The effects of speech recognition technology on the reading and spelling performance of children with learning disabilities. *Annals of Dyslexia*, 49, 251 - 281.
- Raskind, M. H., & Shaw, T. (1999). Assistive technology for individuals with learning disabilities. *Proceedings of Technology and Persons with Disabilities Conference 1999*. Retrieved Mar 9, 2007, from <http://www.csun.edu/cod/conf/1999/proceedings/session1002.htm>
- Reid, G. (2003). *Dyslexia: A practitioner's handbook* (3rd ed.). West Sussex: John Wiley & Sons Ltd.

- Renals, S., Morgan, N., Boulard, H., Cohen, M., & Franco, H. (1994). Connectionist probability estimators in HMM speech recognition. *IEEE Transaction on Speech Audio Processing*, 2, 1, 161-174.
- Rigoll, G., & Willett, D. (1998). A NN/HMM hybrid for continuous speech recognition with a discriminant nonlinear feature extraction. *Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing (ICASSP)*, Seattle, USA, 9-12.
- Russell, M., Brown, C., Skilling, A., Series, R., Wallace, J., Bonham, B., et al. (1996). Applications of automatic speech recognition to speech and language development in young children. *Proceedings of the 4th International Conference on Spoken Language ICSLP'96*, Philadelphia, USA, 1, 176-179.
- Sawyer, D. J., Wade, S., & Kim, J. K. (1999). Spelling errors as a window on variations in phonological deficits among students with dyslexia. *Annals of Dyslexia*, 49, 137-159.
- Seidenberg, M. S., & McClelland, J. M. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, 96(4), 523-568.
- Shaywitz, S. E. (1996, November). Dyslexia. *Scientific American*, 98-104.
- Sheikh Hussain, S. S., Ahmad, Z., Zulkarnain, Y., Rahman, S., & Lim, S. C. (2000). Implementation of speaker identification systems by means of personal computer. *Proceedings of TENCON 2000*, Kuala Lumpur, Malaysia, 1, 43-48.
- Shobaki, K., Hosom, J. P., & Cole, R. A. (2000). The OGI KIDS' Speech corpus and recognizers. *Proceedings of the 6th International Conference on Spoken Language Processing (ICSLP)*, Beijing, China.

- Smith, L., Pham, T., Bower, J., Pilgrim, B., Schwarz, P., & Stevens, D. (2002). Toward voice applications for children. *International Journal of Speech Technology*, 5, 321-329.
- Snowling, M. J. (2000). *Dyslexia* (2nd ed.). UK: Blackwell Publishers.
- Stanovich, K. E., & Seigel, L. S. (1994). Phenotypic performance profile of children with reading disability: A regression-based test of the phonological-core variable-difference model. *Journal of Educational Psychology*, 86, 24-53.
- Syed Abdul Rahman, A-H., Salina, A. S., Aini, H., Khairul, A. I., & Mirvaziri, H. (2007). Decision fusion for isolated malay digit recognition using dynamic time warping (DTW) and Hidden Markov Model (HMM). *Proceedings of the 5th Student Conference on Research and Development (SCOReD 2007)*.
- Sutton, S., Cole, R. A., de Villiers, J., Schalkwyk, J., Vermeulen, P., Macon, M. et al. (1998). Universal speech tools: The CSLU toolkit. *Proceedings of the 5th International Conference on Spoken Language Processing*, Sydney, Australia, 7, 3221-3224.
- Tam, Y.-C., Mostow, J., Beck, J., & Banerjee, S. (2003). Training a confidence measure for a reading tutor that listens. *Proceedings of the 8th European Conference on Speech Communication and Technology*, Geneva, Switzerland, 3161-3164.
- Ting, H. N., Jasmy, Y., Sheikh Hussain, S. S., & Cheah, E. L. (2001). Malay syllable recognition based on Multilayer Perceptron and Dynamic Time Warping. *Proceedings of International Symposium on Signal Processing and Its Applications (ISSPA)*, Kuala Lumpur, Malaysia, 743-744.

- Ting, H. N., Jasmy, Y. & Sheikh Hussein, S. S. (2001). Speaker-independent Malay syllable recognition using singular and modular neural networks. *Jurnal Teknologi*, 35, 65-76.
- Trentin, E., & Gori, M. (2001). A survey of hybrid ANN/HMM models for automatic speech recognition. *Neurocomputing*, 37, 91-126.
- Trentin, E., & Gori, M. (2003). Robust combination of neural network and hidden Markov models for speech recognition. *IEEE Transactions on Neural Networks*, 14, 6, 1519-1531.
- Tsakalidis, S., Prasad, R., & Natarajan, P. (2009). Context-dependent pronunciation modeling for Iraqi ASR. *Proceedings of the IEEE International Conference on Acoustics, Speech and Signal Processing, ICASSP 2009*, 4457-4460.
- University of Washington. (2002). *DO-IT - Working together: Computers and people with learning disabilities*. Retrieved Mar 18, 2007, from <http://www.washington.edu/doi/Brochures/PDF/atpwld.pdf>
- Vellutino, F. R., Scanlon, D. M., & Spearing, D. (1995). Semantic and phonological coding in poor and normal readers. *Journal of Experimental Child Psychology*, 59, 76-123.
- Vellutino, F. R., Scanlon, D. M., Sipay, E. R., Small, S. G., Pratt, A., Chen, R. S. et al. (1996). Cognitive profiles of difficult-to-remediate and readily remediate poor readers: Early intervention as a vehicle for distinguishing between cognitive and experiential deficits as basic causes of specific reading disability. *Journal of Educational Psychology*, 88(4), 601-638.

- Vellutino, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific Reading Disability (dyslexia): What we have learned in the past four decades?, *Journal of Child Psychology and Psychiatry*, 45(1), 2-40.
- Wald, M. (2004). Using automatic speech recognition to enhance education for all students: Turning a vision into reality. *Proceedings of the 34th ASEE/IEEE Frontiers in Education Conference*, Indianapolis, Indiana, USA, 22-25.
- Wald, M. (2005). SpeechText: Enhancing learning and teaching by using automatic speech recognition to create accessible synchronised multimedia. *Proceedings of ED-MEDIA 2005 World Conference on Educational Multimedia, Hypermedia, and Telecommunications*, Montreal, 4765-4769.
- Wald, M. (2006). An exploration of the potential of automatic speech recognition to assist and enabled receptive communication. *ALT – J: Research in Learning*, 14(1), 9 - 20.
- Williams, S. M., Nix, D., & Fairweather, P. (2000). Using speech recognition technology to enhance literacy instruction for emerging readers. In B. Fishman & O'Connor-Divelbiss (Eds.). *Fourth International Conference of the Learning Sciences*, 115-120, Mahwah, NJ: Erlbaum.
- Wolf, M. (1999). What time may tell: Towards a new conceptualization of developmental dyslexia. *Annals of Dyslexia*, 49, 3-28.
- Wolf, M., Bowers, P. G., & Biddle, K. (2000). Naming speed processes, timing, and reading: A conceptual review. *Journal of Learning Disabilities*, 33(4), 387-407.
- Yan, Y., Fandy, M., & Cole, R. (1997). Speech recognition using neural networks with forward-backward probability generated targets. *IEEE International Conference*

on Acoustics, Speech, and Signal Processing, ICASSP-97, Munich, Germany, 4,
3241-3244.

Zaharin, Y. (2000). Computational linguistic in Malaysia. *Proceedings of the 38th Annual Meeting on Association of Computational Linguistics*, Hong Kong, 1-2.

Ziegler, J. (2006). Do differences in brain activation challenge the universal theories of dyslexia? *Brain and Language*, 98, 341-343.

Zulikha, J., & Abdullah, E. (2007). *A Malay speech recognition prototype for telephony-related vocabulary* (Tech. Rep.), UUM Sintok, Kedah, Malaysia: Universiti Utara Malaysia.