Contents

			Page
Αt	stract		(3)
Ac	knowledge	ement	(4)
Co	ntents		(5)
Lis	st of Tables	s	(7)
Lis	st of Figure	es	(8)
Gl	ossary of A	Abbreviations	(9)
Ch	apter	•	
1.	Introduction		1
	1.1 Motivations		2
	1.2 Goals	and Expected Outcome	3
	1.3 Outlin	ne	3
2.	Pitch Det	ection Algorithm	5
	2.1 Backs	grounds	5
	2.1.1	Pre-processing of Pitch Tracking	5
	2.1.2	Pitch Tracking Algorithm	6
	2.1.3	Smoothing	9
	2.1.4	Feature Extraction	10
	2.2 Implementations		11
	2.2.1	AMDF	11
	2.2.2	Auto-correlation	12
	2.2.3	Classification Framework	13
	2.3 Experiments and Discussions		14
	2.3.1	Experiments Setting	14
	2.3.2	Experiments Results and Discussions	15
	2.3.2.1 Voiced/Unvoiced Decision and Smoothing		15
	2.3.2.2 Effects of Pre-processing		16
	2.3.2.3 Feature Extraction		17
	2.3.2.4 Classification		18
	2.4 Sumn	nary	19
3.	Configuration of Tone Feature		20
	3.1 Backgrounds		20
	3.1.1	Scaling	20
	3.1.2	Normalization	22
	3.2 Implementations		23

	3.2.1	Framework	23
	3.2.2	Feature Adaptation	23
	3.3 Exper	iments and Discussions	24
	3.3.1	Experiments Subject	24
	3.3.2	Experiments Setting	24
	3.3.3	Experiments Results and Discussions	25
	3.3	3.3.1 Tone-critical Segment	25
	3.3.3.2 Feature Setting		26
	3.3.3.3 Frequency Scaling		27
	3	3.3.4 Normalization	28
	3	3.3.5 Confusion Analysis	30
	3.4 Summ	nary	30
4.	Final Con	asonants and Tone Classification	31
	4.1 Final	Consonant of Thai Language	31
	4.2 Final	consonants and Tone Classification	32
	4.3 Exper	riments and Discussions	33
	4.4 Summ	nary	35
5.	2-stage N	N Approaches for Tone Classification	36
	5.1 The o	bservation of biased and unbiased NN	36
	5.2 Propo	sed Method	38
	5.3 Exper	riments and Discussions	38
	5.4 Sumn	nary	44
6.	Conclusio	ons and Future Works	45
	6.1 Sumn	nary	45
	6.2 Future	e works	48
Bil	bliography		49
Αp	Appendix		53
Vi	Vitae		5.6

List of Tables

Table		Page
2-1.	Confusion-matrix of Tone Classification for Thai Digit	18
3-1.	Tone-critical segment classification results	25
3-2.	Feature Setting Classification Results	26
3-3.	Classification Results of Scaling	28
3-4.	Classification Results of Normalization	30
3-5.	Confusion-matrix	30
4-1.	Distribution of final consonants in speech database	32
4-2.	Tone Classification with Two sub-classifier based on voiced and	
	voiceless of final consonants	34
4-3.	Tone Classification with Three sub-classifier based on distributions	
	of final consonants	35
4-4.	Tone Classification with four-sub-classifier based on final consona	ints
		35
5-1.	Tone classification using same number of training data for each tone	37
5-2.	Confusion-matrix for biased NN	38
5-3.	Distribution of NN Training Data	38
5-1.	Classification confusion-matrix of tone0-tone1,4-tone2,3	41
5-2.	Classification results for NN2	41
5-3.	Classification results for NN3	42
5-4.	Final Classification Results and Original Results	42
5-5.	Confusion-matrix for NN0,1,3-2-4	43
5-6.	Classification Results for tone0-1-3	43
5-7.	Comparison of Final Classification Results	43
5-8.	Classification Results of Tone0 output	44
5-9.	Classification Results of Tonel Output	44
5-10.	Classification Results of Tone3 Output	45
5-11.	Comparison of Final Classification Results	45
A1-1	. Tone Classification Results of HTK Experiments	54
A3-1	. Distribution of Tone Data	55

List of Figures

Figure		Page
2-1.	x(n), $clc[x(n)]$, $sgn[x(n)]$ and the auto-correlation	6
2-2.	Block Diagram of the Coarse Pitch Detection using AMDF	12
2-3.	Block Diagram of Pitch Detection Algorithm using Modified	
	autocorrelation	13
2-4.	Classification Framework for Pitch Detection Algorithms	13
2-5.	Waveform of Thai Digit("07229")	14
2-6.	Waveform of Mandarin Speech "hao" with 3 rd tone	14
2-7.	Pitch Track Using Autocorrelation Method and AMDF	15
2-8.	the Voice/Unvoiced Detection in Autocorrelation Method	16
2-9.	Smoothing of "hao(3)" Pitch Contour	16
2-10.	Effects of LPF in Auto-correlation method	17
2-11.	The pitch pattern extracted	17
2-12.	Four Discrete Legendre bases(Point: base 1 *: base 2 Δ: base 3	
	o: base 4)	18
2-13.	Average F0 contours of the five Thai tones produced in isolation	19
3-1.	Experiment's Framework	23
3-2 .	Feature Adaptation Framework	24
3-3 .	Pitch contour with final consonant and the vowel only	25
3-4.	Pitch Contour and Tone Feature	26
3-5.	Histogram of Scaling	27
3-6.	Histogram of Two Speaker's Pitch	28
3-7.	Histogram after Normalization	29
4-1.	Framework of Tone classification using alphabet information	33
5-1.	Framework of 2-layer NN	39
5-2.	NN framework based on confusion information	40
5-3.	Grouping of tone according the initial level	41
5-4	Tone Groups based on the shape of them	42

Glossary of Abbreviations

PDA Pitch Detection Algorithm

AMDF Average Magnitude Difference Function

ACF Auto-correlation Function

V/UV Voiced/Unvoiced

CL Clipping Threshold
clc Center Clipping

NN Neural Network

LPF Low Pass Filter

LMS Least Mean Square

JND Just Noticeable Difference

HTK Hidden Markov Model Toolkit

F0 Fundamental Frequency

CB Critical Band

ERB Equivalent Rectangle Bandwidth

MFCC Mel-frequency Cepstrum Coefficients

Tone 0 Middle Tone in Thai Language
Tone 1 Low Tone in Thai Language
Tone 2 Falling Tone in Thai Language
Tone 3 High Tone in Thai Language
Tone 4 Rising Tone in Thai Language