

Contents

	Page
Abstract (Thai)	(3)
Abstract (English)	(4)
Acknowledgments	(5)
Contents	(6)
List of Figures	(7)
List of Tables	(13)
Chapter 1 Introduction	1
1.1 Seismic refraction method	1
1.2 Artificial neural networks	6
1.3 Literature Review	14
1.4 Objective	16
1.5 Scope of research	16
Chapter 2 Methodology	18
2.1 Materials	18
2.2 Equipment	19
2.3 Network design for two-layer structure with horizontal interface	19
2.4 Network design for two-layer structure with dipping interface	22
2.5 Network design for two-layer structure with irregular interface	30
Chapter 3 Results and Discussion	35
3.1 Network for two-layered dipping interface structure	35
3.2 The results of network for two-layer dipping interface structure	40
3.3 Network for two-layer irregular interface structure	56
Chapter 4 Conclusions	74
Bibliography	77
Appendix A Testing results of horizontal interface	79
Appendix B Testing results of dipping interface	87
Vitae	131

List of Figures

Figure	Page
Chapter 1	
1.1 Raypath and traveltime curve	3
1.2 Raypath diagram and travel time curves of two dipping layers for a forward (S_1) and reversed shotpoint (S_2).	5
1.3 Schematic Drawing of Biological Neurons	7
1.4 Single-Input Neuron	7
1.5 Linear Transfer Function	8
1.6 Hyperbolic Tangent Sigmoid Transfer Function	9
1.7 Multiple-Input Neuron	10
1.8 Layer of S Neurons	11
1.9 Three-Layer Network	12
1.10 Three different types of interested structures	17
Chapter 2	
2.1 Two horizontal layered model	20
2.2 Non-separated networks for horizontal interface	21
2.3 Travel time curve and Dipping interface structure model	24
2.4 $t_{\text{minus}}-t_{\text{plus}}$ inputs and travel time inputs	24
2.5 Non-separated networks of $t_{\text{minus}}-t_{\text{plus}}$ inputs	25
2.6 Non-separated networks of travel time inputs	26
2.7 Depth networks of $t_{\text{minus}}-t_{\text{plus}}$ inputs	27
2.8 Depth networks of travel time inputs	28
2.9 Velocity networks of $t_{\text{minus}}-t_{\text{plus}}$ inputs	30
2.10 Velocity networks of travel time inputs	30
2.11 Irregular Interface depth network	32
2.12 Irregular Interface velocity network	33

List of Figures (Continued)

Figure	Page
Chapter 3	
3.1 Training time, MSE of training data, and MSE of testing data of two-layer architecture network trained by non-normalization data	36
3.2 Training time, MSE of training data, and MSE of testing data of two-layer architecture network trained by normalization data	36
3.3 Training time, MSE of training data, and MSE of testing data of three-layer architecture network trained by non-normalization data	37
3.4 Training time, MSE of training data, and MSE of testing data of three-layer architecture network trained by normalization data	37
3.5 Mean and standard deviation of error for each dipping angle of $t_{\text{minus}}-t_{\text{plus}}$ inputs	41
3.6 Mean and standard deviation of error for each dipping angle of travel time inputs	44
3.7 Mean and standard deviation of the trained depth network predicting error for each dipping angle of $t_{\text{minus}}-t_{\text{plus}}$ inputs	48
3.8 Mean and standard deviation of the trained depth network predicting error for each dipping angle of travel time inputs	50
3.9 Error distributions for all predicted depths of training data sets	56
3.10 Predicted depth of an average 2-m interface depth testing data set	59
3.11 Predicted depth of an average 6-m interface depth testing data set	61
3.12 Predicted depth of an average 10-m interface depth testing data set	63
3.13 Error distributions for all predicted depths of testing data sets	65
3.14 Error distributions for predicted depths of intermediate and deep interface testing data sets	66
3.15 Predicted V_1 of training and testing data sets by each velocity network	69
3.16 Predicted V_2 of training and testing data sets by each velocity network	70
3.17 Predicted V_1 and V_2 of testing data sets by each velocity network	72

List of Figures (Continued)

Figure	Page
Appendix A	
A1 Predicted h_1 by two-layer architecture network trained by non-normalization data	79
A2 Predicted V_1 by two-layer architecture network trained by non-normalization data	80
A3 Predicted V_2 by two-layer architecture network trained by non-normalization data	80
A4 Predicted h_1 by three-layer architecture network trained by non-normalization data	81
A5 Predicted V_1 by three-layer architecture network trained by non-normalization data	82
A6 Predicted V_2 by three-layer architecture network trained by non-normalization data	82
A7 Predicted h_1 by two-layer architecture network trained by normalization data	83
A8 Predicted V_1 by two-layer architecture network trained by normalization data	84
A9 Predicted V_2 by two-layer architecture network trained by normalization data	84
A10 Predicted h_1 by three-layer architecture network trained by normalization data	85
A11 Predicted V_1 by three-layer architecture network trained by normalization data	86
A12 Predicted V_2 by three-layer architecture network trained by normalization data	86

List of Figures (Continued)

Figure	Page
Appendix B	
B1 Predicted depth of 2.5 degree of dipping angle for $t_{\text{minus}}-t_{\text{plus}}$ inputs	87
B2 Predicted depth of 8.5 degree of dipping angle for $t_{\text{minus}}-t_{\text{plus}}$ inputs	88
B3 Predicted depth of 14.5 degree of dipping angle for $t_{\text{minus}}-t_{\text{plus}}$ inputs	89
B4 Predicted V_1 of Testing data 1 normalized by testing data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	90
B5 Predicted V_2 of Testing data 1 normalized by testing data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	91
B6 Predicted V_1 of Testing data 1 normalized by training data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	92
B7 Predicted V_2 of Testing data 1 normalized by training data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	93
B8 Predicted V_1 of Testing data 2 normalized by testing data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	94
B9 Predicted V_2 of Testing data 2 normalized by testing data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	95
B10 Predicted V_1 of Testing data 2 normalized by training data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	96
B11 Predicted V_2 of Testing data 2 normalized by training data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	97
B12 Predicted depth of 2.5 degree of dipping angle for travel time inputs	98
B13 Predicted depth of 8.5 degree of dipping angle for travel time inputs	99
B14 Predicted depth of 14.5 degree of dipping angle for travel time inputs	100
B15 Predicted V_1 of Testing data 1 normalized by testing data sets for travel time velocity networks	101
B16 Predicted V_2 of Testing data 1 normalized by testing data sets for travel time velocity networks	102
B17 Predicted V_1 of Testing data 1 normalized by training data sets for travel time velocity networks	103

List of Figures (Continued)

Figure	Page
B18 Predicted V_2 of Testing data 1 normalized by training data sets for travel time velocity networks	104
B19 Predicted V_1 of Testing data 2 normalized by testing data sets for travel time velocity networks	105
B20 Predicted V_2 of Testing data 2 normalized by testing data sets for travel time velocity networks	106
B21 Predicted V_1 of Testing data 2 normalized by training data sets for travel time velocity networks	107
B22 Predicted V_2 of Testing data 2 normalized by training data sets for travel time velocity networks	108
B23 Predicted depth of 2.5 degree of dipping angle of trained depth networks for $t_{\text{minus}}-t_{\text{plus}}$ inputs	109
B24 Predicted depth of 8.5 degree of dipping angle of trained depth networks for $t_{\text{minus}}-t_{\text{plus}}$ inputs	110
B25 Predicted depth of 14.5 degree of dipping angle of trained depth networks for $t_{\text{minus}}-t_{\text{plus}}$ inputs	111
B26 Predicted depth of 2.5 degree of dipping angle of trained depth networks for travel time inputs	112
B27 Predicted depth of 8.5 degree of dipping angle of trained depth networks for travel time inputs	113
B28 Predicted depth of 14.5 degree of dipping angle of trained depth networks for travel time inputs	114
B29 Predicted V_1 of Testing data 1 normalized by testing data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	115
B30 Predicted V_2 of Testing data 1 normalized by testing data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	116
B31 Predicted V_1 of Testing data 1 normalized by training data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	117

List of Figures (Continued)

Figure	Page
B32 Predicted V_2 of Testing data 1 normalized by training data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	118
B33 Predicted V_1 of Testing data 2 normalized by testing data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	119
B34 Predicted V_2 of Testing data 2 normalized by testing data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	120
B35 Predicted V_1 of Testing data 2 normalized by training data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	121
B36 Predicted V_2 of Testing data 2 normalized by training data sets for $t_{\text{minus}}-t_{\text{plus}}$ velocity networks	122
B37 Predicted V_1 of Testing data 1 normalized by testing data sets for travel time velocity networks	123
B38 Predicted V_2 of Testing data 1 normalized by testing data sets for travel time velocity networks	124
B39 Predicted V_1 of Testing data 1 normalized by training data sets for travel time velocity networks	125
B40 Predicted V_2 of Testing data 1 normalized by training data sets for travel time velocity networks	126
B41 Predicted V_1 of Testing data 2 normalized by testing data sets for travel time velocity networks	127
B42 Predicted V_2 of Testing data 2 normalized by testing data sets for travel time velocity networks	128
B43 Predicted V_1 of Testing data 2 normalized by training data sets for travel time velocity networks	129
B44 Predicted V_2 of Testing data 2 normalized by training data sets for travel time velocity networks	130

List of Tables

Table	Page
Chapter 2	
2.1 The model details of synthesizing training data	19
Chapter 3	
3.1 Mean error and standard deviation of error of estimated ground parameters	38
3.2 Mean error and standard deviation of error of estimated depth with non-separated networks of $t_{\text{minus}}-t_{\text{plus}}$ inputs	40
3.3 Mean error and standard deviation of error of estimated velocities of Testing data 1 with non-separated networks of $t_{\text{minus}}-t_{\text{plus}}$ inputs	42
3.4 Mean error and standard deviation of error of estimated velocities of Testing data 2 with non-separated networks of $t_{\text{minus}}-t_{\text{plus}}$ inputs	43
3.5 Mean error and standard deviation of error of estimated depth with non-separated networks of travel time inputs	44
3.6 Mean error and standard deviation of error of estimated velocities of Testing data 1 with non-separated networks of travel time inputs	46
3.7 Mean error and standard deviation of error of estimated velocities of Testing data 2 with non-separated networks of travel time inputs	46
3.8 Mean error and standard deviation of error of estimated depth with depth networks of $t_{\text{minus}}-t_{\text{plus}}$ inputs	48
3.9 Mean error and standard deviation of error of estimated depth with depth networks of travel time inputs	49
3.10 Mean error and standard deviation of error of estimated velocities of Testing data 1 with non-separated networks of $t_{\text{minus}}-t_{\text{plus}}$ inputs	51

List of Tables (Continued)

Table	Page
3.11 Mean error and standard deviation of error of estimated velocities of Testing data 2 with non-separated networks of $t_{\text{minus}}-t_{\text{plus}}$ inputs	52
3.12 Mean error and standard deviation of error of estimated velocities of Testing data 1 with non-separated networks of travel time inputs	53
3.13 Mean error and standard deviation of error of estimated velocities of Testing data 2 with non-separated networks of travel time inputs	54
3.14 The overall mean error without data set of average 2 m interface depth	73