CHAPTER VI

FORECASTING OF NEW ISSUED BANKNOTES USING BACKPROPAGATION

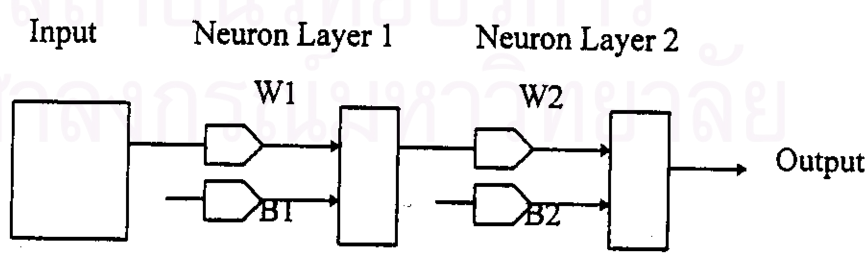
6.1 Introduction

This chapter includes the experimentation of forecasting the new issued banknotes using backpropagation. The experimentation here concerns adjusting parameters such as learning rate, number of neurons, rate of increasing learning rate, and rate of decreasing learning rate of the network in order to obtain minimum SSE of testing data. Both training data and testing data are the ones used in Chapter 5.

6.2 Experimental Conditions

6.2.1 Architecture

Network with two layers and one layer are included here as shown in Figure 6.1. For one-layer network, there is no neuron layer 2 and others are the same.



W1: Weight for neuron layer 1 W2: Weight for neuron layer 2

B1: Bias for neuron layer 1 B2: Bias for neuron layer 2

Figure 6.1 - Two Layer Network

6.2.2 Normalization

1) Type A

Each element of input vectors (GDP growth rates and saving deposit rates) is divided by 100. Each element of output vectors is divided by 10,000. All elements are between 0 and 1.

2) Type B

All inputs are put through the function "normr" which normalizes the row of a matrix. Each row of the new matrix has the property that the sum of its squared elements is equal to 1.0., while the ratios between its elements are preserved. Each element of output vectors is divided by 10,000. All elements are between 0 and 1.

6.2.3 Training Data

Training data contains 48 input vectors having GDP growth rates and saving deposit rates and 48 output vectors which are issued banknotes from 1989 to 1992. The input data which are GDP growth rates and saving deposit rates are shown in Table 5.1 and 5.2 respectively. The outputs, the values of monthly issued banknotes are shown in Table 5.3.

1. <u>GDP Growth Rates</u> (%)† January 1989 - December 1992

2. <u>Saving Deposit Rates</u> (%)† January 1989 - December 1992

3. <u>Values of Monthly Issued Bank Notes</u> (millions of baht) :

January 1989 - December 1992

6.2.4 Testing Data

Testing data contains 48 input data having GDP growth rates and saving deposit rates and 48 output data which are issued banknotes from 1993 to 1996. The inputs, monthly GDP growth rates and saving deposit rates are shown in Table 5.4 and 5.5 respectively. The outputs, the values of issued banknotes are shown in Table 5.6.

1. GDP Growth Rates (%)† January 1993 - December 1996

2. Saving Deposit Rates (%)† January 1993 - December 1996

3. Value of Monthly Issued Banknotes (millions of baht)† :

January 1993 - December 1996

6.2.5 Initial Parameters

The parameters increasing rate of increased learning rate, rate of decreased learning rate, momentum and error ratio are initialized at 1.05, 0.7, 0.95, and 1.04 [4].

6.2.6 Experimental Objectives

The experimental objectives are as follows:

1. Investigate and compare the result of using normalization type A, different learning rates (0.99, 0.1, 0.01, and 0.001), and different numbers of neuron varying from 1 to 48.

2. Investigate and compare the result of using normalization type B and different learning rates (0.99, 0.1, 0.01, and 0.001), and different numbers of neuron varying from 1 to 48.

3. Confirm the number of neuron that provides the minimum sum-squared error of testing data.

4. Confirm the parameters that gives the minimum sum-squared error of testing data.

5. Investigate whether one-layer network performs better than two-layer network or not.

6.3 Training and Results

6.3.1 Investigation and comparison of the result of using normalization type A, different learning rates, and different numbers of neuron.

This section covers test set 1-4 where introducing normalization type A described earlier in section 6.2.2, different learning rates (0.99, 0.1, 0.01, and 0.001), and differnent number of neuron varying from 1 to 48. The parameters rate of increased learning rate, and rate of decrease learning rate are initialized at 1.05 and 0.7. Epoch is set at 2,000. The network architecture is two layers backpropagation.

Each test set trains data for 48 times varying from one neuron to 48 neurons. Test set 1, 2, 3, and 4 use initial learning rates at 0.99, 0.1, 0.01, and 0.001 respectively.

The results are shown in Table 6.1-6.4.

1. <u>Test Set 1</u>: initial learning rate = 0.99

Table 6.1 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.110197	24.7623
2	0.110109	22.0566
3	0.110446	22.0495
4	0.111312	22.6211
5	0.110349	23.4948
6	0.110121	27.3943
7	0.111119	25.5137
8	0.110066	24.8098
9	0.110575	24.8301
10	0.110205	29.1743
11	0.111766	18.5523
12	0.110201	31.8880
13	0.110354	27.0340
14	0.109951	29.2458
15	0.110498	23.2747
16	0.110493	26.1941
17	0.110523	24.7634
18	0.110351	27.0740
19	0.110297	28.7701
20	0.110631	25.0818
21	0.109988	28.0401
22	0.110219	21.7054
23	0.109962	27.8759
24	0.111803	26.6091
25	0.112863	5.42770
26	0.110087	23.7140
27	0.109851	29.5932
28	0.110057	25.1700
29	0.115908	26.7718
30	0.110366	27.8996
31	0.110160	23.5076
32	0.118674	28.7417
33	0.111060	11.0603
34	0.109887	24.4172
35	0.112888	24.8723
36	0.110427	26.2935

Table 6.1 Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
37	0.115160	23.3860
38	0.110178	24.4420
39	**0.106822**	**1.55720**
40	0.110005	30.3036
41	0.110151	25.0251
42	0.111895	25.5716
43	0.115050	28.0862
44	0.110099	26.6895
45	0.110636	26.8850
46	0.110078	27.1811
47	0.110359	28.9399
48	0.109986	28.0996

From Table 6.1, the best number of neuron that generates the minimum sum-squared error of testing data, 1.5572, is 39. There is no sign of convergence while the number of training neurons is increasing. The minimum sum-squared error of training data is also generated at 39.

2. Test Set 2: initial learning rate = 0.1

Table 6.2 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.110230	24.8107
2	0.110101	22.0714
3	0.110338	22.1167
4	0.113032	22.1133
5	0.110278	23.5251
6	0.110207	27.2715
7	0.115591	25.9685
8	0.112779	24.5211
9	0.110205	24.9533

Table 6.2 - Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
10	0.110239	29.1336
11	0.110025	24.7271
12	0.110242	31.8961
13	0.110380	27.0022
14	0.10997	29.1532
15	0.110502	23.3161
16	0.110529	26.1341
17	0.110493	24.7421
18	0.110350	26.9886
19	0.110299	28.7617
20	0.110351	24.8560
21	0.110056	28.1890
22	0.112982	**21.7123**
23	0.109961	27.8867
24	0.110256	26.3281
25	0.110303	27.0333
26	0.110176	23.7977
27	0.109776	29.6596
28	0.111359	25.4922
29	0.110256	27.3315
30	0.113283	27.5114
31	0.110174	23.4719
32	0.110385	28.1020
33	0.110103	26.8985
34	0.109895	24.3981
35	0.109903	25.1838
36	0.110437	26.2835
37	0.115413	23.4408
38	0.110160	24.5217
39	0.110272	25.5377
40	0.109986	30.3049
41	0.110248	25.1413
42	0.115194	25.0016
43	0.113470	27.2897
44	0.109899	26.8159
45	0.110635	26.8868

Table 6.2 - Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
46	0.111353	27.4390
47	0.110395	28.9307
48	0.117451	27.5243

From Table 6.2, the number of neuron that gives the minimum sum-squared error is 22 where the sum-squared error of testing data is 21.7123. Similar to Table 6.1, there is no sign of convergence. The reason for higher sum-squared error of testing data is that lower learning rate slows down the training.

3. Test Set 3: intial learning rate = 0.01

Table 6.3 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.110194	24.8009
2	0.110103	22.0612
3	0.110906	21.9703
4	0.130342	23.2724
5	0.110858	23.6097
6	0.110100	27.3737
7	0.116965	25.0747
8	0.110064	24.8200
9	0.113793	24.5786
10	0.110230	29.1480
11	0.109971	24.7771
12	0.110264	31.8375
13	0.110500	27.0929
14	0.109973	29.2758
15	0.110472	23.2406
16	0.110501	26.1853
17	0.110477	24.8232
18	0.110333	27.0465

Table 6.3 - Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
19	0.110266	28.8890
20	0.116030	25.3261
21	0.110375	28.2203
22	0.110165	**21.9226**
23	0.112607	28.2191
24	0.110312	26.3183
25	0.110283	27.1275
26	0.110071	23.7694
27	0.109768	29.6625
28	0.113542	25.6133
29	0.110069	27.2410
30	0.110810	27.6671
31	0.113446	23.2844
32	0.113981	28.7183
33	0.117085	27.7625
34	0.112361	24.3093
35	0.110004	25.1110
36	0.110431	26.3010
37	0.111210	22.9652
38	0.110167	24.4865
39	0.109943	25.5842
40	0.109952	30.2445
41	0.110109	25.2082
42	0.110023	25.3593
43	0.110323	27.6486
44	0.109898	26.7972
45	0.110661	26.8760
46	0.110982	26.9637
47	0.110347	28.9812
48	0.110011	28.0538

From Table 6.3, the minimum sum-squared error of testing data is 21.9226 where the number of neuron is 22. Again there is no sign of convergence while the number of neuron is increased.

4. Test Set 4: initial learning rate = 0.001

Table 6.4 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.110246	24.7590
2	0.110131	22.0620
3	0.111973	21.8739
4	0.113223	22.7446
5	0.110403	23.3968
6	0.110148	27.4752
7	0.111329	25.4109
8	0.110063	24.7933
9	0.115762	25.3946
10	0.110245	29.1585
11	0.109982	24.7321
12	0.110934	31.9146
13	0.110358	27.1245
14	0.109960	29.2285
15	0.110581	23.2702
16	0.110486	26.2490
17	0.110514	24.6438
18	0.110345	27.0041
19	0.110306	28.7432
20	0.110279	25.2548
21	0.109988	28.0259
22	0.112577	**22.2216**
23	0.109962	27.8898
24	0.110253	26.3522
25	0.110290	27.0107
26	0.110117	23.7710
27	0.109825	29.7070
28	0.110167	25.3161
29	0.110070	27.2457
30	0.110175	27.8267
31	0.110166	23.4962
32	0.110401	28.0363
33	0.110147	26.4443
34	0.109867	24.5571

Table 6.4 - Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
35	0.109914	25.0863
36	0.110863	26.2668
37	0.111432	22.9637
38	0.110179	24.4298
39	0.110286	25.4878
40	0.110317	30.4245
41	0.110145	25.0447
42	0.110013	25.3746
43	0.111011	27.8332
44	0.109898	26.7830
45	0.111023	26.9775
46	0.110121	27.2424
47	0.110343	28.9724
48	0.110189	28.1721

From Table 6.4, 22.2216 is the minimum sum-squared error of testing data that is obtained from having 22 neurons in the training network. Once again there is no sign of convergence while the number of neuron is rising.

From Table 6.1 to 6.4, both the minimum sum squared error of testing data and that of training data are 1.5572 and 0.106822 which are from test set 1 and number of neuron and learning rate are 39 and 0.99 respectively. Generally the sum squared errors of training sets are not obviously different. They range from 0.106822 to 0.130342 while the sum squared errors of testing sets range from 1.5572 to 31.9146. It is interesting to see that the minimum sum squared errors of testing data from most test sets, except test set 1, have the same number of neuron which is 22.

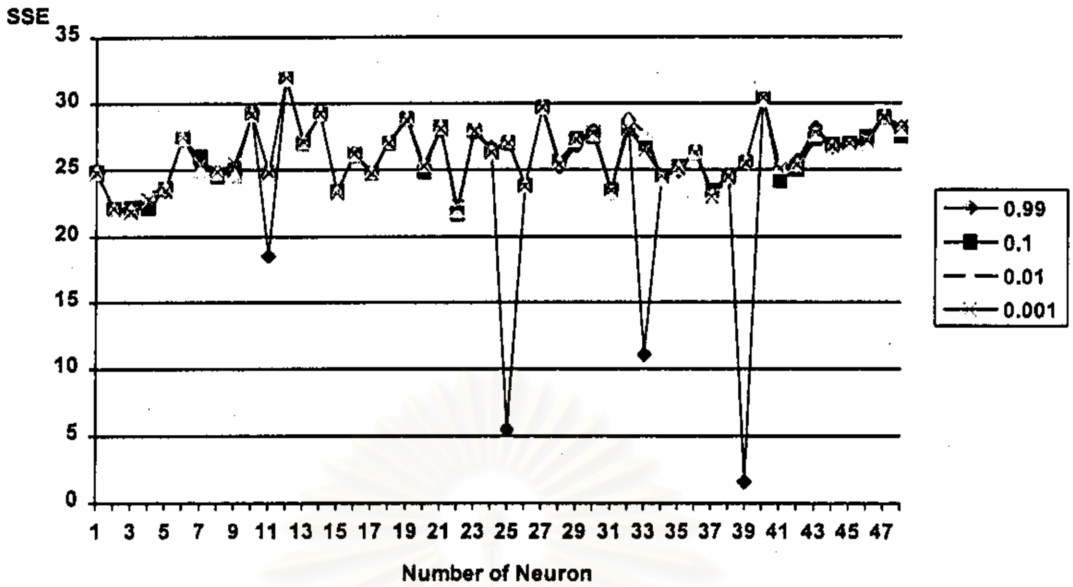


Figure 6.2 - SSE of Testing Data

Different learning rates and different number of neurons give different sum-squared error of training data and testing data. From Figure 6.2, there are four outstanding numbers of neurons that give obvious different sum-squared errors of from others. They are 11, 25, 33, and 39 where sum-squared errors of testing data are 18.5523, 5.4277, 11.0603, and 1.5572. The minimum one is 1.5572.

Comparing to minimum sum-squared error of testing data from previous chapter which is 2.4423, it can be concluded that backpropagation performs better than Widrow-Hoff learning rule.

6.3.2 Investigatation and comparison of the result of using normalization type B, different learning rates, and different numbers of neuron.

This section covers test set 5-8 where introducing normalization type B described earlier in section 6.2.2, different learning rates (0.99, 0.1, 0.01, and 0.001), and differnent number of neuron varying from 1 to 48. The parameters rate of increased learning rate, and rate of decrease learning rate are initialized at 1.05 and 0.7. Epoch is set at 2,000. The network architecture is two layers backpropagation.

Each test set trains data for 48 times varying from one neuron to 48 neurons. Test set 5, 6, 7, and 8 use initial learning rates at 0.99, 0.1, 0.01, and 0.001 respectively. The results are shown in Table 6.5-6.8.

1. <u>Test Set 5</u>: initial learning rate = 0.99

Table 6.5 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.1078400	1.9379
2	0.1302910	4.2652
3	0.0962733	3.2108
4	0.1006020	2.4058
5	0.1137110	2.3176
6	0.1080930	2.0043
7	0.0971032	2.6585
8	0.0975727	2.1322
9	0.1948470	3.3240
10	0.0871117	2.8795
11	0.0850317	1.7470
12	0.1132580	5.0929
13	0.0969694	1.9264
14	0.0937469	2.6675
15	0.0960511	2.9703
16	0.1124720	4.5385
17	0.1005920	2.1378
18	0.0910575	3.0692
19	0.0961418	3.0474
20	0.0958787	1.8338
21	0.0860025	2.9903
22	0.1465560	3.8792
23	0.0846333	2.4752
24	0.0928872	3.7879

Table 6.5 - Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
25	0.0850295	2.3057
26	0.0955691	3.2007
27	0.0883512	2.8069
28	0.0781416	2.2148
29	0.0860872	5.1493
30	0.0892071	4.2371
31	0.0864595	3.2123
32	0.0879011	4.4794
33	0.0940491	2.2566
34	0.0847535	1.6670
35	0.0937190	2.6546
36	0.0818780	3.3077
37	0.0792335	**1.0650**
38	0.0729121	1.9201
39	0.0838569	2.7911
40	0.1028400	2.7749
41	0.0802178	1.7113
42	0.0815704	3.5647
43	0.0869156	1.5201
44	0.0914180	2.3649
45	0.0817698	2.7216
46	0.0778991	2.8817
47	0.0815066	3.6547
48	0.0741739	2.1409

From Table 6.5, 1.0650 is the minimum sum-squared error of testing data where the number of neuron is 37. Overall sum-squared error of both training and testing data are better than those in test set no.1-4. There is no convergence whereas the number of neuron is increasing.

2. Test Set 6: initial learning rate = 0.1

Table 6.6 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.1078860	1.9517
2	0.1303600	4.2566
3	0.0970512	2.0788
4	0.1029510	2.2227
5	0.1085590	2.1167
6	0.1081150	1.9955
7	0.0970470	2.6690
8	0.0973438	2.1876
9	0.1874560	3.6702
10	0.0893781	2.8872
11	0.0858206	1.7858
12	0.1160990	4.6360
13	0.0963127	2.0243
14	0.0937326	2.6268
15	0.0960277	3.0083
16	0.1162340	4.7558
17	0.1005090	2.1124
18	0.0910261	3.0688
19	0.0966742	3.0492
20	0.0985972	1.9755
21	0.0859959	2.9962
22	0.1466290	3.9035
23	0.0834005	2.5264
24	0.0913905	4.0822
25	0.0816540	2.3963
26	0.0957261	3.2105
27	0.0880094	2.8402
28	0.0781314	2.1766
29	0.0860744	5.1242
30	0.0882594	4.3841
31	0.0860235	3.3812
32	0.0910332	4.3524
33	0.0942257	2.2674
34	0.0842687	1.6354

Table 6.6 - Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
35	0.0934677	2.6696
36	0.0821404	3.2486
37	0.0793219	**1.0885**
38	0.0733559	1.9096
39	0.0849634	2.8264
40	0.1042570	3.2152
41	0.0804303	1.7107
42	0.0815736	3.5563
43	0.0869383	1.5571
44	0.0883520	2.4687
45	0.0811843	2.6985
46	0.0773281	2.7862
47	0.0818958	3.5396
48	0.0744350	2.1193

From Table 6.6, the number of neuron is 37 produces the minimum sum-squared error which is 1.0885. It is noticed that the number of neuron is the same as test set 5.

3. Test Set 7: initial learning rate = 0.01

Table 6.7 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.1078490	1.9439
2	0.1302860	4.2860
3	0.0961802	3.2222
4	0.1009550	2.5164
5	0.1087770	2.1593
6	0.1081740	2.0278
7	0.0971128	2.6629
8	0.0975486	2.1124
9	0.1871580	3.6144

Table 6.7 - Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
10	0.0864142	2.5718
11	0.0853479	1.7517
12	0.1131270	4.8868
13	0.0962227	2.0089
14	0.0936920	2.6747
15	0.0959912	3.0594
16	0.1140850	4.3580
17	0.1010120	2.1633
18	0.0910041	3.0808
19	0.0961877	2.9781
20	0.0981464	1.9563
21	0.0864781	3.0636
22	0.1044320	2.5421
23	0.0834665	2.7510
24	0.0934692	3.8392
25	0.0848538	2.3559
26	0.0948934	3.2142
27	0.0878199	2.9214
28	0.0776426	2.8915
29	0.0860588	5.1108
30	0.0903585	4.1133
31	0.0862014	3.2450
32	0.0882152	4.4673
33	0.0939799	2.2485
34	0.0872813	1.7299
35	0.0934418	2.6901
36	0.0819016	3.3248
37	0.0793327	**1.0442**
38	0.0772698	1.4419
39	0.0843945	2.8531
40	0.1017590	2.8464
41	0.0801942	1.7006
42	0.0816422	3.5827
43	0.0867939	1.5363
44	0.0939152	2.2927
45	0.0828031	2.7654

Table 6.7 - Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
46	0.0781031	2.9640
47	0.0819482	3.5731
48	0.0738311	2.1223

From Table 6.7, the number of neuron that generates 1.0442 as the minimum sum-squared error is 37 which is the same as test set 5 and 6.

4. Test Set 8: initial learning rate = 0.001

Table 6.8 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.1098780	2.0822
2	0.1303360	4.2727
3	0.0962630	3.2598
4	0.0858446	3.0486
5	0.1085670	2.1231
6	0.1081900	2.0289
7	0.0971621	2.6462
8	0.0976901	2.0900
9	0.1871240	3.6064
10	0.0859292	2.3637
11	0.0841215	1.7501
12	0.1142170	4.7272
13	0.0961905	1.9866
14	0.0936674	2.5156
15	0.0973704	2.9513
16	0.1124440	4.6112
17	0.1003510	2.0973
18	0.0912237	3.1163
19	0.0982896	3.2683
20	0.0962775	1.8712
21	0.0860163	3.0041

Table 6.8 - Training Result (cont.)

No.of Neuron	SSE of Training Data	SSE of Testing Data
22	0.1386030	4.2078
23	0.0960656	3.0224
24	0.0913409	3.8151
25	0.0848365	2.3890
26	0.0948739	3.1891
27	0.0876664	2.8781
28	0.0774114	2.2205
29	0.0860579	5.1013
30	0.0881804	4.3706
31	0.0935707	2.9677
32	0.0927269	4.1821
33	0.0941573	2.3127
34	0.0852810	1.6859
35	0.0937448	2.6474
36	0.0819628	3.3302
37	0.0810876	**1.0098**
38	0.0732830	1.9676
39	0.0837797	2.8680
40	0.1023040	3.2013
41	0.0804141	1.7286
42	0.0815916	3.5607
43	0.0869279	1.5268
44	0.0941407	2.2299
45	0.0815344	2.6057
46	0.0779424	2.6423
47	0.0822880	3.5173
48	0.0742888	2.1155

From Table 6.8, the minimum sum-squared error is 1.0098 which is gained at neuron number at 37. The number of neuron is the same as other test set using normalization type B.

From Table 6.11 to 6.14, using normalization type B, the minimum sum squared error of testing data is 1.0098 from test set 8 and the minimum sum sqaured error of training data is 0.0729121 test set 5, no. of neuron = 38. Sum-squared errors of training data and testing data vary from 0.0729121 to 0.187456, and from 1.0098 to 5.1493 each test set, the minimum sum squared error of testing data appears at the same number of neuron, 37.

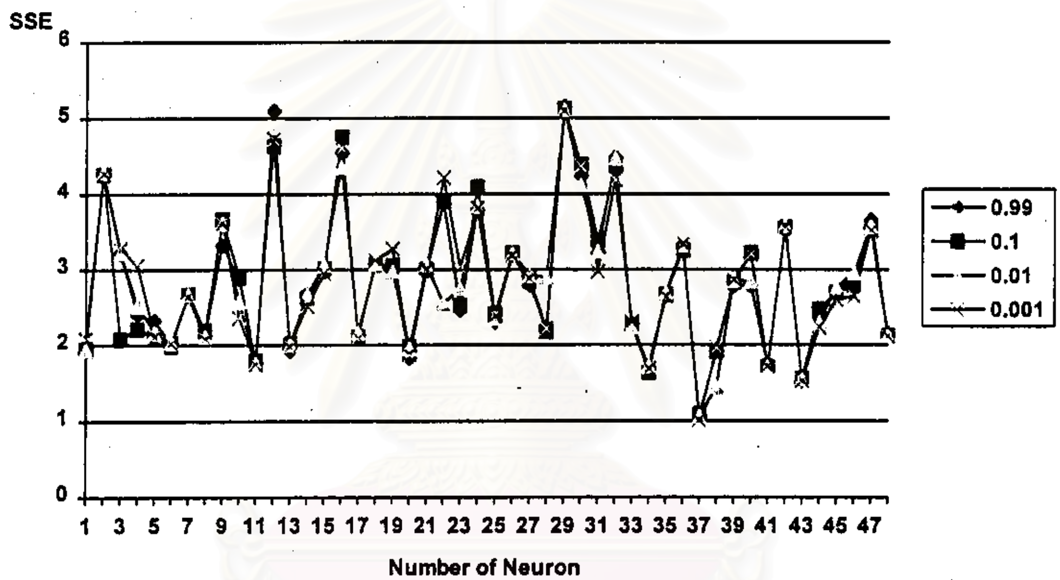


Figure 6.3 - SSE of Testing Data

From Figure 6.3, sum-squared errors of all learning rates flow in the same direction. The minimum sum-squared errors of testing data for all learning rates are all at 37 neurons. The minimum one is equal to 1.0098. Comparing to minimum sum-squared error (1.5572) where normalization type A is applied, normalization type B gives more accurate result. Hence normalization type B is chosen for further training.

6.3.3 Confirmation of the number of neuron that provides the minimum sum-squared error of testing data.

This section covers test set 9 and 10. Since different number of neurons generate different sum-squared errors, some numbers of neurons which provide small sum-squared errors from test set 8 are chosen and the results are compared with that of 37 neurons in order to confirm the number of neurons that gives the minimum sum-squared error of testing data. The results are shown in Table 6.9-6.10.

For test set 9, the learning rate is changed to 0.01 to see whether there is any difference of the result. the selective number of neurons are 1, 11, 20, 34, 38, 41, and 43. Epoch is set at 10,000 while other parameters remain the same.

For test set 10, the learning rate is changed to 1.5 to see whether there is any difference of the result. The selective number of neurons are 1, 11, 20, 34, 38, 41, and 43. Epoch is set at 10,000 while other parameters remain the same.

1. Test Set 9: initial learning rate = 0.01

Table 6.9 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.1072400	1.7074
11	0.0803366	1.6396
20	0.0837732	1.9741
34	0.0858364	1.2232
37	0.0746450	**1.1376**
38	0.0711755	1.3571
41	0.0754783	1.3409
43	0.0815476	2.1789

The learning rate that generates the minimum sum-squared error of testing data is 0.01. Some other potential learning rates are chosen for training and comparing the result. From Table 6.9, after training for 10,000 epochs, the best number of neurons that gives minimum sum-squared error is still 37. But the minimum sum-squared error here is not better than test set 8.

2. Test Set 10: initial learning rate = 1.5

Table 6.10 - Training Result

No.of Neuron	SSE of Training Data	SSE of Testing Data
1	0.1091480	1.9965
11	0.0838564	1.8197
20	0.0921599	2.1402
34	0.0838882	1.5961
37	0.0790534	**1.0936**
38	0.0773293	1.4536
41	0.0793910	1.5017
43	0.0884732	1.7898

From Table 6.10, only sum-squared error of testing data at 37 neurons is improved while those of others are higher than ones in Table 6.9 which the learning rates are lower. Also the minimum sum-squared error of testing data is still at 37 even learning rate is changed.

Even the training is continued for more epoch and higher learning rate is used, the minimum sum-squared error is still at the same number of neurons. It can be concluded from Table 6.9 and 6.10 that 37 is the number of neurons that gives the minimum sum-squared error.

6.3.4 Confirmation of the parameters that gives the minimum sum-squared error of testing data.

A number of parameters are used in each training. In order to confirm the proper parameters that give the minimum sum-squared error, various parameters are tested through training.

Learning rate, rate of increased learning rate, rate of decreased learning rate are adjusted to deliver the minimum sum-squared error of testing data. Number of neurons and epoch are set at 37 and 2000 while other parameters remain the same.

Learning rate is varying from 0.0001 to 5.1. Rate of increased learning rate and rate of decreased learning rate range from 1.01 to 1.1, and from 0.6 to 1.07 respectively. The results are shown in Table 6.11.

Test Set 11:

Table 6.11 - Training Result

lr	lr_inc	lr_dec	SSE of Training Data	SSE of Testing Data
0.0001	1.01	0.70	0.0788311	1.0738
0.0010	1.01	0.70	0.0786706	1.0878
0.0010	1.04	0.70	0.0792426	1.0813
0.0010	1.05	0.60	0.079054	1.0982
0.0010	**1.05**	**0.70**	0.0810876	**1.0098**
0.0010	1.05	0.80	0.0796494	1.0099
0.0010	1.05	0.90	0.0795266	1.0108
0.0010	1.06	0.70	0.0793086	1.0653
0.0010	1.10	0.70	0.0790178	1.0793
2.1000	1.05	0.70	0.0819176	1.1452
3.1000	1.05	0.70	0.0823446	1.1461
3.5000	1.05	0.70	0.0792176	1.0567
4.1000	1.05	0.70	0.0793524	1.0483
4.5000	1.05	0.70	0.0792542	1.0554
5.1000	1.05	0.70	0.0793101	1.0793

From Table 6.11, learning rate, rate of increased learning rate, and rate of decreased learning rate are adjusted to deliver the minimum sum-squared error of testing data. Those that provide the minimum sum-squared error are 0.001, 1.05, and 1.07 respectively.

6.3.5 Investigatation of whether one-layer network performs better than two-layer network or not.

This section covers test set 12 to 14. The network is changed to one layer where three transfer functions are tested. They are linear , log-sigmoid , and tan-sigmoid functions. Learning rates range from 0.0001 to 1.9. Other parameters remain the same otherwise compulsory changed due to the architecture. The results are shown in Table 6.12-6.14.

1. Test Set 12: transfer function is linear function.

Table 6.12 - Training Result

No.	Learning Rate	SSE of Training Data	SSE of Testing Data
1	0.0001	0.119015	1.1679
2	0.0005	0.117842	1.1588
3	0.0009	0.123217	**1.1404**
4	0.0010	0.121249	1.1454
5	0.0050	0.119205	1.1646
6	0.0090	0.121125	1.1733
7	0.0100	0.118639	1.1619
8	0.0500	0.118036	1.1595
9	0.0900	0.118361	1.1606
10	0.1000	0.119141	1.1683
11	0.5000	0.117910	1.1626
12	0.9000	0.118919	1.1626

Table 6.12 - Training Result (cont.)

No.	Learning Rate	SSE of Training Data	SSE of Testing Data
13	1.1000	0.119179	1.1633
14	1.5000	0.122343	1.1764
15	1.9000	0.118256	1.1604

From Table 6.12, the minimum sum-squared error of testing data obtained from learning rate = 0.0009 is 1.1404.

2. <u>Test Set 13</u>: transfer function is log-sigmoid function.

Table 6.13 - Training Result

No.	Learning Rate	SSE of Training Data	SSE of Testing Data
1	0.0001	0.111842	2.1034
2	0.0005	0.115381	**2.0435**
3	0.0009	0.110239	2.1820
4	0.0010	0.110200	2.1780
5	0.0050	0.110239	2.2074
6	0.0090	0.110218	2.2153
7	0.0100	0.115184	2.3466
8	0.0500	0.110330	2.2091
9	0.0900	0.110193	2.1795
10	0.1000	0.110298	2.1620
11	0.5000	0.110341	2.1590
12	0.9000	0.110124	2.1959
13	1.1000	0.110250	2.1720
14	1.5000	0.110773	2.2336
15	1.9000	0.110395	2.1549

From Table 6.19, the minimum sum-squared error of testing data obtained from learning rate = 0.0005 is 2.0435.

3. Test Set 14: transfer function is tan-sigmoid function.

Table 6.14 - Training Result

No.	Learning Rate	SSE of Training Data	SSE of Testing Data
1	**0.0001**	0.118631	**1.8945**
2	0.0005	0.117280	1.9427
3	0.0009	0.118002	1.9206
4	0.0010	0.117688	1.9255
5	0.0050	0.118249	1.9081
6	0.0090	0.117472	1.9323
7	0.0100	27.62080	13.4054
8	0.0500	27.62080	13.4054
9	0.0900	27.62080	13.4054
10	0.1000	27.62080	13.4054
11	0.5000	27.62080	13.4054
12	0.9000	27.62080	13.4054
13	1.1000	27.62080	13.4054
14	1.5000	27.62080	13.4054
15	1.9000	27.62080	13.4054

From Table 6.14, the minimum sum-squared error of testing data obtained from learning rate = 0.0001 is 1.8945.

The test sets from 12 to 14, the number of network layer is reduced to one. The results are not better than those of two layers network. The transfer function that produces the lowest sum-squared error is linear function.

6.4 Discussion of the Result

The parameters that provide the minimum sum squared errors are number of neurons = 37, learning rate = 0.001, rate of increasing learning rate = 1.05, rate of decreasing learning rate = 1.07, momentum = 0.95, error ratio = 1.04 and epoch =

2000. The minimum sum-squared error of testing data is 1.0098. Its outputs or forecasted figures are compared with the actual data in Table 6.15 and together with errors.

Table 6.15 - Comparison between Actual and Forecasting Issued Banknotes

Month/Year	Actual (millions of baht)	Forecast (millions of baht)	Error (millions of baht)
Jan 1993	43,600	31,740	11,860
Feb 1993	27,070	31,740	-4,670
Mar 1993	33,260	31,740	1,520
April 1993	36,470	31,740	4,730
May 1993	30,300	31,740	-1,440
June 1993	32,660	31,740	920
July 1993	35,680	31,740	3,940
Aug 1993	33,300	31,740	1,560
Sep 1993	34,800	31,740	3,060
Oct 1993	36,060	34,280	1,780
Nov 1993	37,680	34,280	3,400
Dec 1993	55,200	37,420	17,780
Total for 1993	**436,080**	**391,640**	**44,440**
error = 10.2%			
Jan 1994	38,840	39,330	-490
Feb 1994	48,900	39,330	9,570
Mar 1994	40,230	39,330	910
April 1994	40,100	38,070	2,030
May 1994	35,850	36,820	-960
June 1994	41,870	36,820	5,050
July 1994	38,580	36,820	1,760
Aug 1994	41,700	36,820	4,880
Sep 1994	44,200	36,820	7,380
Oct 1994	41,050	36,820	4,230
Nov 1994	44,720	36,820	7,900
Dec 1994	66,990	36,820	30,170

Table 6.15 Comparison between Actual and Forecasting Issued Banknotes(cont.)

Month/Year	Actual (millions of baht)	Forecast (millions of baht)	Error (millions of baht)
Total for 1994	**523,030**	**450,620**	**72,410**
error = 13.8%			
Jan 1995	66,890	36,940	29,950
Feb 1995	36,350	36,940	-600
Mar 1995	54,340	36,940	17,400
April 1995	47,390	36,940	10,450
May 1995	49,520	36,940	12,580
June 1995	60,170	36,940	23,230
July 1995	43,740	36,940	6,790
Aug 1995	50,760	36,940	13,820
Sep 1995	48,970	36,940	12,030
Oct 1995	51,040	36,940	14,100
Nov 1995	55,640	36,940	18,700
Dec 1995	72,970	36,940	36,020
Total for 1995	**637,780**	**443,280**	**194,500**
error = 30.5%			
Jan 1996	52,250	45,770	6,480
Feb 1996	81,850	45,770	36,080
Mar 1996	55,350	45,770	9,580
April 1996	63,580	45,770	17,810
May 1996	59,180	45,770	13,410
June 1996	55,450	45,770	9,680
July 1996	57,430	45,770	11,660
Aug 1996	56,520	45,770	10,750
Sep 1996	54,440	45,770	8,670
Oct 1996	63,870	45,770	18,100
Nov 1996	61,800	45,770	16,030
Dec 1996	80,140	45,770	34,370
Total for 1996	**741,860**	**549,240**	**192,620**
error = 25.964467%			
Overall Error = 21.54%	**2,338,750**	**1,834,780**	**503,970**

Comparison between forcasting and actual issued banknotes are made as in Table 6.15. The error of forecasting issued banknotes in 1993, 1994, 1995, and 1996 are 10.19, 13.84, 30.49, and 25.96. The overall error is 21.54. It is noticed that the values of forecasting issued banknotes are groups of numbers over the period.

The values of new issued banknotes are obtained by deducting the values of old issued banknotes from the values of issued banknotes. All figures are in Table 6.16 and as well as the results in Table 6.17, comparing to those of regression method.

Table 6.16 - Figures of Old and New Issued Banknotes

Year	Issued Banknotes (Millions of Baht)	New Issued Banknotes (Millions of Baht)	Old Issued Banknotes (Millions of Baht)
1993	436,086.2	235,221	200,865.2
1994	523,031.9	279,240	243,791.9
1995	637,777.9	323,148	314,630.4
1996	741,846.0	371,620	370,226.0

Table 6.17 - Comparison the Results from Neural Network and Regression

Year	Neural Network (Millions of Baht)	Actual (Millions of Baht)	Regression (Millions of Baht)
1993	190,290.8	235,221	240,990.35
1994	206,328.1	279,240	275,134.97
1995	128,124.1	323,148	317,050.22
1996	188,925.0	371,620	354,069.77

Table 6.18 - Comparison the errors from Neural Network and Regression

Year	Neural Network (%)	Regression (%)
1993	19.10	**-2.45**
1994	26.12	**1.47**
1995	60.35	**1.89**
1996	49.16	**4.92**

From Table 6.18, neural network does not perform better than regression in any year. Hence the selected input variables may not be appropriate or are not adequate.

6.5 Conclusion

The conclusion is made based on experimental objectives as follows:

1. Different number of neurons, learning rates, and normalization method result in different sum-sqaured error. For normalization type A, 0.99 and 39 are learning rate and number of neuron that produce the minimum sum-squared error of testing data which is 1.5572. For normalization type B, 0.001 and 37 are those that generate 1.0098 as the minimum one.

2. Comparing to the minimum sum-sqaured error of testing data from the previous chapter which is 2.4423, one-layer and two-layer backpropagation perform better than that of Widrow-Hoff learning rule.

3. One-layer backpropagation does not perform better than two-layer backpropagation. Using linear function in one-layer network outperforms other transfer functions.

4. In this case, neural network does not outperform regression analysis at all. Therefore the methodology should be improved by adding more input variables in order to obtain accuracy improvement.