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Use of Binary Sigmoid Function And Linear Identity In Artificial Neural Networks For Forecasting Population Density

Anjar Wanto[1], Agus Perdana Windarto[2], Dedy Hartama[3], Iin Parlina[4]
[1,2,3]STIKOM Tunas Bangsa Pematangsiantar
[4]AMIK Tunas Bangsa Pematangsiantar
[1]anjarwanto@amiktunasbangsa.ac.id,[2]agus.perdana@amiktunasbangsa.ac.id,
[3]dedyhartama@amiktunasbangsa.ac.id,[4]iin@amiktunasbangsa.ac.id

Abstract

Artificial Neural Network (ANN) is often used to solve forecasting cases. As in this study. The artificial neural network used is with backpropagation algorithm. The study focused on cases concerning overcrowding forecasting based District in Simalungun in Indonesia in 2010-2015. The data source comes from the Central Bureau of Statistics of Simalungun Regency. The population density forecasting its future will be processed using backpropagation algorithm focused on binary sigmoid function (logsig) and a linear function of identity (purelin) with 5 network architecture model used the 3-5-1, 3-10-1, 3-5 -10-1, 3-5-15-1 and 3-10-15-1. Results from 5 to architectural models using Neural Networks Backpropagation with binary sigmoid function and identity functions vary greatly, but the best is 3-5-1 models with an accuracy of 94%, MSE, and the epoch 0.0025448 6843 iterations. Thus, the use of binary sigmoid activation function (logsig) and the identity function (purelin) on Backpropagation Neural Networks for forecasting the population density is very good, as evidenced by the high accuracy results achieved.

Keywords: *Binary Sigmoid, Identity Function, ANN, Forecasting, Population Density*

1. Introduction

Artificial Neural Network (ANN) is one of the artificial representations of the human brain that always tries to simulate the learning process in the human brain [1]. Artificial Neural Network will serve as a substitute for the nerves and brain, which at the time will relate to the outside world, the ability to learn and generalization quickly and easily in the recognition of a character pattern and easy to implement [2]. An example of using Artificial Neural Networks is in the case of forecasting. Frequently used methods for forecasting (prediction) include Backpropagation Neural Network Algorithm [3].

Forecasting is important to predict something that will happen in the future by utilizing various relevant information at previous times (historically) through a scientific method [4]. One of the important forecasts is predicting population density in a region. Because of the negative impacts of population density can hinder the progress of a region if not addressed as early as possible, such as the increasing need for water, clean air, agricultural land, education, housing, employment to poverty. Population growth in one area on the one hand is a development capital, because there is a workforce according to the development of the population, while on the other hand will become the burden of the government because every soul needs the necessities of life, such as clothing, food, provision of school facilities and infrastructure and employment [5]. This study will predict population density in each sub-district in Simalungun District Year 2010 to 2015 with prediction target to be achieved in 2016 until 2018. Population density data can be seen in table 1 below.

Table 1. Data on Population Density of Simalungun Regency

No	Districts	Population Density (Soul/Km^2)					
		2010	2011	2012	2013	2014	2015
1	Bandar	582,00	598,00	651,00	654,41	669,14	677,20
2	Bandar Huluan	251,00	254,00	242,00	242,65	244,80	245,75

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No	Districts	Population Density (Soul/Km²)					
		2010	2011	2012	2013	2014	2015
3	Bandar Masilam	249,00	250,00	269,00	270,00	271,08	271,91
4	Bosar Maligas	132,00	134,00	138,00	138,72	140,39	141,22
5	Dolok Batu Nanggar	312,00	315,00	373,00	373,29	377,01	378,73
6	Dolok Panribuan	116,00	117,00	122,00	121,89	122,82	123,20
7	Dolok Pardamean	161,00	161,00	156,00	156,06	156,80	157,03
8	Dolok Silou	48,00	48,00	46,00	46,30	46,96	47,30
9	Girsang Sipangan Bolon	116,00	118,00	112,00	112,11	113,40	114,02
10	Gunung Malela	300,00	306,00	346,00	347,03	353,13	356,35
11	Gunung Maligas	447,00	456,00	522,00	523,90	533,47	538,54
12	Haranggaol Horison	145,00	145,00	23,00	122,72	123,46	123,75
13	Hatonduhan	77,00	77,00	63,00	63,11	63,39	63,47
14	Hutabayu Raja	187,00	188,00	153,00	153,63	154,78	155,26
15	Jawa Maraja Bah Jambi	271,00	279,00	531,00	534,77	549,22	557,33
16	Jorlang Hataran	166,00	167,00	165,00	164,98	166,21	166,73
17	Kabupaten Simalungun	186,00	189,00	190,00	190,56	193,03	194,26
18	Pamatang Bandar	330,00	331,00	357,00	356,78	358,42	358,89
19	Pamatang Sidamanik	130,00	131,00	119,00	119,27	120,17	120,54
20	Pamatang Silimahuta	152,00	154,00	132,00	132,37	134,19	135,10
21	Panei	296,00	300,00	280,00	279,00	281,99	283,42
22	Panombeian Panei	233,00	235,00	262,00	262,19	263,85	264,49
23	Purba	127,00	131,00	131,00	131,86	135,33	137,27
24	Raya	92,00	93,00	95,00	94,82	96,04	96,65
25	Raya Kahean	77,00	77,00	86,00	85,78	86,46	86,75
26	Siantar	795,00	808,00	867,00	869,89	883,02	889,76
27	Sidamanik	324,00	326,00	337,00	337,62	340,16	341,21
28	Silimakuta	176,00	184,00	194,00	196,00	203,80	208,36
29	Silou Kahean	77,00	78,00	75,00	75,33	76,08	76,43
30	Tanah Jawa	218,00	219,00	269,00	269,65	271,68	272,52
31	Tapian Dolok	325,00	334,00	327,00	328,43	335,62	339,54
32	Ujung Padang	181,00	182,00	178,00	178,69	179,84	180,29

Source: Central Bureau of Statistics of Simalungun Regency

In this study, the algorithm used for population density forecasting is Artificial Neural Network backpropagation with emphasis on the use of the binary sigmoid function (logsig) and identity function (purelin). Binary sigmoid function (logsig) is an activation function used to bridge the comparison between the sum of values of all the weights that will come with the input value with a threshold value [6]. In the backpropagation of the activation function used must meet several conditions, namely: continuous, differentiated easily and is a function that does not go down. One of the functions that meet the three requirements so often used is a binary sigmoid function that has a range (0.1) [2], and linear identity function. Binary sigmoid function (logsig) is used as a hidden layer activation function, while linear (purelin) as an output layer activation function in the backpropagation later [7]. [8] Here's an explanation of linear function and binary sigmoid function :

a. Linear Function (Identity)
   The Linear function produces an output value equal to its input value. The Linear function can be formulated as follows:
   $$y = f(x) = x \qquad \text{with : } f'(x) = 1 \tag{1}$$
b. Binary Sigmoid Function
   Binary sigmoid function produces output values ranging from 0 to 1. Therefore, this function is often used for artificial neural networks that require an output value located at intervals of 0 to 1. Binary sigmoid function is formulated as follows:
   $$y = f(x)\frac{1}{1+e^{\sigma x}} \qquad \text{with : } f'(x) = \sigma f(x)\,[1 - f(x)] \tag{2}$$

In the previous study, A. Novita (2016) conducted a study to predict the movement of Share Price at the largest Bank in Indonesia with backpropagation neural network method. There are 2 ANN Backpropagation Architectures used in the study, the first using 3 hidden layers, using purelin, purelin, purelin functions. While the 2 using purelin, purelin, tansig. The first architecture produces an RMSE value of 0.0983 and MAE 0.0771. While the architecture of the two RMSE of 0.0626 and MAE 0.0456. The drawback of this research is the absence of the use of binary sigmoid activation function (logsig). Therefore, the authors are interested in doing research using binary sigmoid function (logsig) combined with linear identity function (purelin) [9].

2. Rudimentary

2.1. Artificial Intelligence

Artificial Intelligence (AI) is a general term that implies the use of a computer to model intelligent behavior with minimal human intervention. AI is generally accepted as having started with the invention of robots. The term derives from the Czech word robota, meaning biosynthetic machines used as forced labor [10]. AI is a field of study based on the premise that intelligent thought can be regarded as a form of computation - one that can be formalized and ultimately mechanized. To achieve this, however, two major issues need to be addressed. The first issue is knowledge representation, and the second is knowledge manipulation [11].

2.2. Artificial Neural Networks (ANN)

Artificial Neural Network (ANN) is one of the studies of Artificial Intelligence and is a new computing technology in the field of computer science study. Neural networks mostly used for problem-solving in pattern recognition, data analysis, control and clustering [12]. Initially ANN were developed in the field of artificial intelligence and were first introduced for image recognition. The central concept was inspired by knowledge of the nervous system, especially the human brain with its closely connected neurons [13]. Artificial neural network (ANN) is one of the methods that is suitable to deal with the internal relations of complex model because of its highly nonlinear, large amounts of data parallel processing, high robustness, and fault tolerance [14].

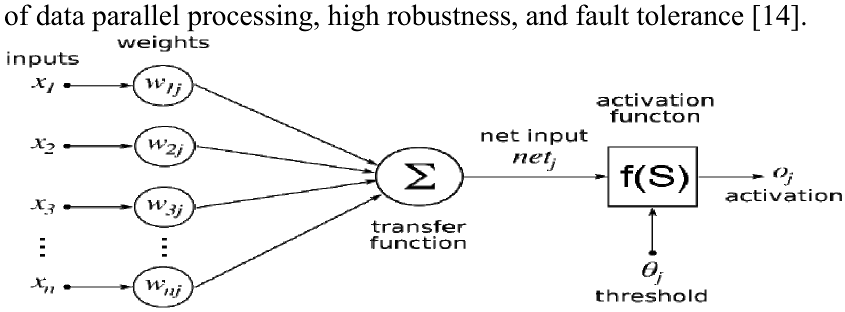

Figure 1. Artificial Neural Networks

2.3. Backpropagation

The back-propagation learning algorithm (BPLA)has become famous learning algorithms among ANNs. Backpropagation ANNs have been widely and successfully applied in diverse applications, such as patternrecognition, location selection and performance evaluations [11]. BPANN is the most extensively used ANN model. The typical topology of BPANN involves three layers : input layer, where the data are introduced to the network ; hidden layer, where the data are processed ; and output layer, where the results of the given input are produced [15]. Backpropagation training method involves feedforward of the input training pattern, calculation and backpropagation of error, and adjustment of the weights in synapses [16].

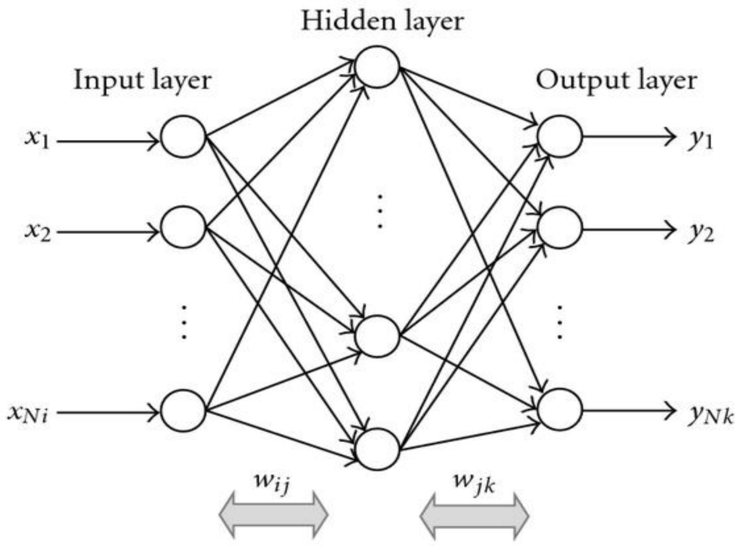

Figure 2. Schematic diagram of a general back-propagation neural network

2.4. Forecasting

Forecasting is applications-oriented. It illustrates all methods with detailed real-world applications that reect typical forecasting situations. In various places, it uses applications not simply to illustrate the methods but also to drive home an important lesson via truly realistic examples: not everything works perfectly in the real world. Forecasting is in touch with modern modeling and forecasting software [17].

3. Research Methods

The research methodology is the stages in conducting a research to collect data or information that will be used in finding a solution of the problems that have been found.

3.1. Research Framework

The research methodology can be seen in Figure 3. The study of literature used to collect data or sources related to the topic raised obtained from various sources, journals, documentation books, and internet. Then the sampling of data from Central Bureau of Statistics (BPS) of Simalungun Regency, which later will be processed by using backstop propagation by using bin sigmoid activation function (logsig) and linear identity function (purelin). System Design means designing input, file structure, program, the procedure needed to support information system. Implementation is an action or implementation plan that has been prepared based on system design. System testing is the evaluation stage of the system architecture that has been built. System Evaluation includes a review of the results of system performance.

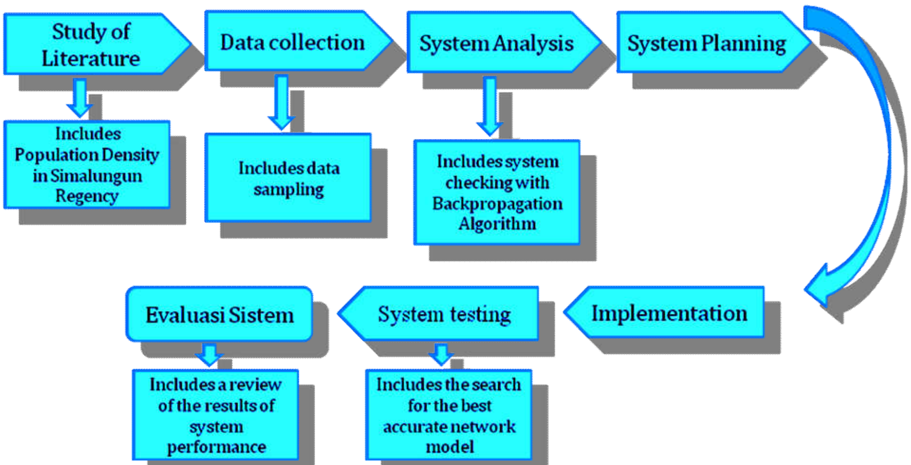

Figure 3. Research Framework

3.2. Activity Diagram

An activity diagram is essentially a flowchart, showing flow of controls from one activity to another. Unlike a traditional flowchart, it can model the dynamic functional view of a system. An activity diagram represents an operation on some classes in the system that results to changes in the state of the system. From the diagram shown in figure 4, the client is expected to provide the input dataset and the required output. The required output is used in back propagation, for the system uses it to compare its predicted value from time to time in other to get the optimal prediction. The client select a threshold constant and looking at the input value the neural network initializes the weight for the input layer and the hidden layer. Then the calculation for the activation function of both the input and the output layer is done and the system calculates the error. If the is large then the system adjust the weight and backpropagate it to the input layer for further calculation to be done. The system outputs its prediction whenever the error is small [18].

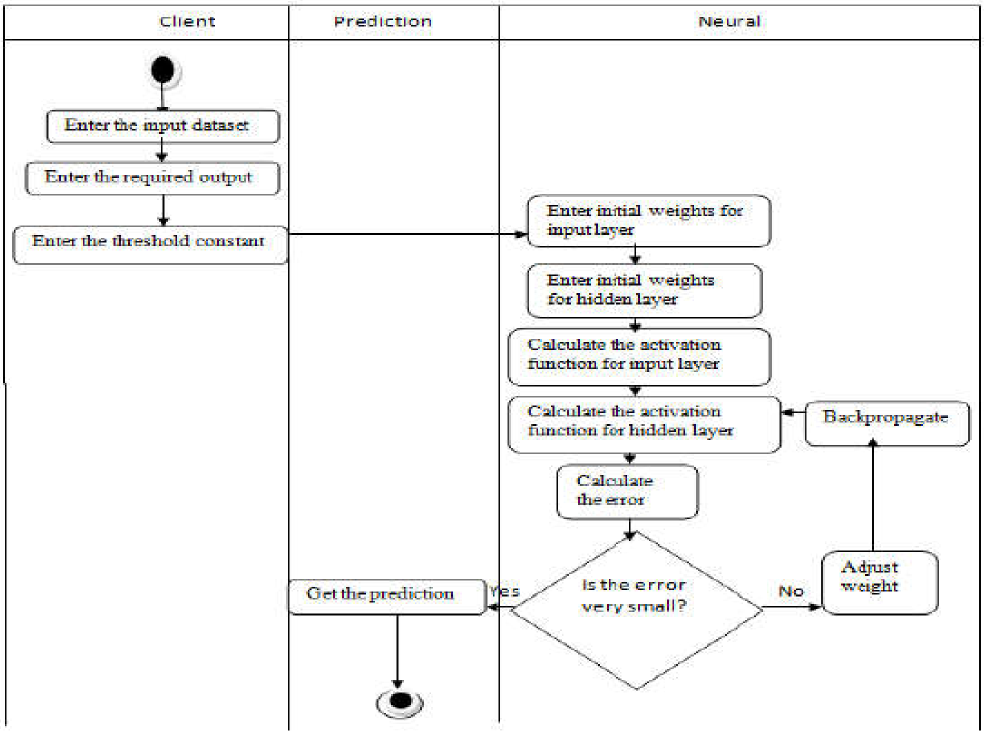

Figure 4. Activity Diagram Of The Backpropagation System

3.3. Data Retrieval

Data taken from the Central Bureau of Statistics of Simalungun Regency, namely Population density data based on sub districts 2010 to 2015 (Can be seen in table 1).

3.4. Defines Input and Target

Data on population density will then be processed using Artificial Neural Network with backpropagation method. In order for data that can be recognized by Artificial Neural Network, the data must be indicated in numerical form between 0 and 1, and the contents are data of population density data in Simalungun Regency as the introduction of pattern and output that is prediction of population density of each sub-district in simalungun district obtained from architectural model best when determining the best pattern. This is because the network uses a bin sigmoid activation function (logsig) that ranges from 0 to 1. The value used is obtained by year and also to make it easier to remember in defining it [19].

3.5. Data Normalization

Before being processed, the data is normalized first by using the Sigmoid function, represented by the equation (3).

$$x' = \frac{0.8(x-a)}{b-a} + 0.1 \quad (3)$$

Based on table 1, 2010 datasets until 2012 are used as Training data, while datasets from 2013 to 2015 are used for data testing. In training data, the maximum value (b) of the dataset is 869.89. The minimum value (a) is 23.00. By using the sigmoid function it will get the normalization data as follows:

$$x' = \frac{0.8(582{,}00 - 23{,}00)}{869{,}89 - 23{,}00} + 0.1$$

Then will be obtained results Normalization data 1 the year 2010 is 0.628050 and so on. As for the data Testing, The maximum value (b) of the dataset is 889.76. While the minimum value (a) is 28.00. By using the same formula, it will get data 1, 2012 is 0.678351, so on until the completion of normalization.

Table 2. Normalization of Training Data

Data	Input (In Years)			Target
	2010	2011	2012	
1	0,628050	0,643164	0,693229	0,696451
2	0,315376	0,318210	0,306875	0,307489
3	0,313487	0,314432	0,332380	0,333324
4	0,202965	0,204854	0,208633	0,209313
5	0,372999	0,375833	0,430621	0,430895
6	0,187851	0,188795	0,193519	0,193415
7	0,230359	0,230359	0,225636	0,225693
8	0,123616	0,123616	0,121727	0,122010
9	0,187851	0,189740	0,184072	0,184176
10	0,361663	0,367331	0,405116	0,406089
11	0,500524	0,509026	0,571372	0,573167
12	0,215245	0,215245	0,100000	0,194199
13	0,151010	0,151010	0,137785	0,137889
14	0,254920	0,255864	0,222802	0,223397
15	0,334269	0,341826	0,579873	0,583435
16	0,235082	0,236027	0,234138	0,234119

Data	Input (In Years)			Target
	2010	2011	2012	
17	0,253975	0,256809	0,257754	0,258283
18	0,390002	0,390947	0,415507	0,415300
19	0,201076	0,202020	0,190685	0,190940
20	0,221858	0,223747	0,202965	0,203314
21	0,357885	0,361663	0,104723	0,341826
22	0,298373	0,300262	0,325767	0,325947
23	0,198242	0,202020	0,202020	0,202833
24	0,165180	0,166124	0,168014	0,167844
25	0,151010	0,151010	0,159512	0,159304
26	0,829256	0,841537	0,897270	0,900000
27	0,384334	0,386224	0,396615	0,397200
28	0,244529	0,252086	0,261532	0,263421
29	0,151010	0,151955	0,149121	0,149433
30	0,284203	0,285148	0,332380	0,332994
31	0,385279	0,393781	0,387168	0,388519
32	0,249252	0,250197	0,246418	0,247070

Table 3. Normalization of Testing Data

Data	Input (In Years)			Target
	2012	2013	2014	
1	0,678351	0,681517	0,695191	0,696451
2	0,298663	0,299267	0,301263	0,307489
3	0,323728	0,324657	0,325659	0,333324
4	0,202117	0,202785	0,204335	0,209313
5	0,420275	0,420544	0,423997	0,430895
6	0,187263	0,187161	0,188025	0,193415
7	0,218827	0,218882	0,219569	0,225693
8	0,116710	0,116988	0,117601	0,122010
9	0,177980	0,178082	0,179280	0,184176
10	0,395210	0,396166	0,401829	0,406089
11	0,558596	0,560360	0,569244	0,573167
12	0,188192	0,187932	0,188619	0,194199
13	0,132492	0,132594	0,132854	0,137889
14	0,216042	0,216626	0,217694	0,223397
15	0,566951	0,570451	0,583866	0,583435
16	0,227182	0,227163	0,228305	0,234119
17	0,250390	0,250910	0,253203	0,258283
18	0,405421	0,405217	0,406740	0,415300
19	0,184478	0,184729	0,185564	0,190940
20	0,196547	0,196890	0,198580	0,203314
21	0,100000	0,333012	0,335787	0,341826
22	0,317230	0,317406	0,318947	0,325947

Data	Input (In Years)			Target
	2012	2013	2014	
23	0,195618	0,196417	0,199638	0,202833
24	0,162198	0,162031	0,163164	0,167844
25	0,153843	0,153639	0,154270	0,159304
26	0,878871	0,881554	0,893743	0,900000
27	0,386855	0,387430	0,389788	0,397200
28	0,254103	0,255960	0,263201	0,263421
29	0,143632	0,143938	0,144634	0,149433
30	0,323728	0,324332	0,326216	0,332994
31	0,377571	0,378899	0,385574	0,388519
32	0,239250	0,239890	0,240958	0,247070

4. Results and Discussion

4.1. Analysis

This study uses 5 architectural models, among others: 3-5-1, 3-10-1, 3-5-10-1, 3-5-15-1 and 3-10-15-1. Among the 5 architectural models will be training and testing with a different hidden layer. Models 3-5-1 and 3-10-1 use 1 hidden layer with 5 neurons and 10 neurons. While models 3-5-10-1, 3-5-15-1 and 3-10-15-1 each use 2 hidden layers (5 and 10 neurons, 5 and 15 neurons, 10 and 15 neurons). Network architecture model using 1 hidden layer will be trained using LP function (Logsig, Purelin), while network architecture model using 2 hidden layers will be trained using LPL function (Logsig, Purelin, Logsig). For more details on the use of functions and the determination of parameters commonly used in Backpropagation Neural Network with Matlab applications can be seen in the following description:

a. Network architecture model 3-5-1 and 3-10-1

```
>> net=newff(minmax(P),[Hidden,Target],{'logsig','purelin'},'traingd');
>> net.IW{1,1};
>> net.b{1};
>> net.LW{2,1};
>> net.b{2};
>> net.trainparam.epochs=150000;
>> net.trainparam.Lr=0.01;
>> net.trainParam.goal = 0.001;
>> net.trainParam.show = 1000;
>> net=train(net,P,T);
```

b. Network architecture model 3-5-10-1, 3-5-15-1 and 3-10-15-1

```
>> net=newff(minmax(P),[Hiden,Hidden,Target],{'logsig','purelin','logsig'},'traingd');
>> net.IW{1,1};
>> net.b{1};
>> net.LW{2,1};
>> net.b{2};
>> net.LW{3,2};
>> net.trainparam.epochs=150000;
>> net.trainparam.Lr=0.01;
>> net.trainParam.goal = 0.001;
>> net.trainParam.show = 1000;
>> net.b{3};
>> net=train(net,P,T);
```

4.2. Results

Overall, the best results from the 5 network architecture models using the binary sigmoid fusion function and the linear identity function are 3-5-1 network architecture models with an accuracy level of 94% with MSE 0.0025448 and epoch 6843 iterations.

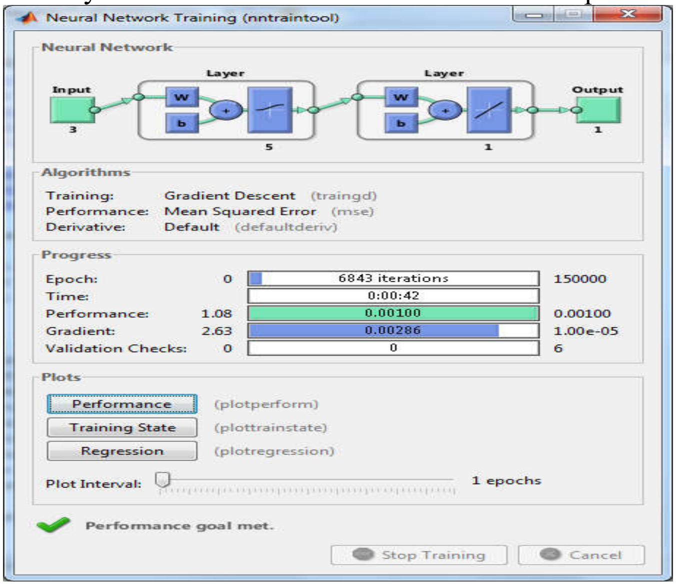

Figure 2. Training Results Model 3-5-1

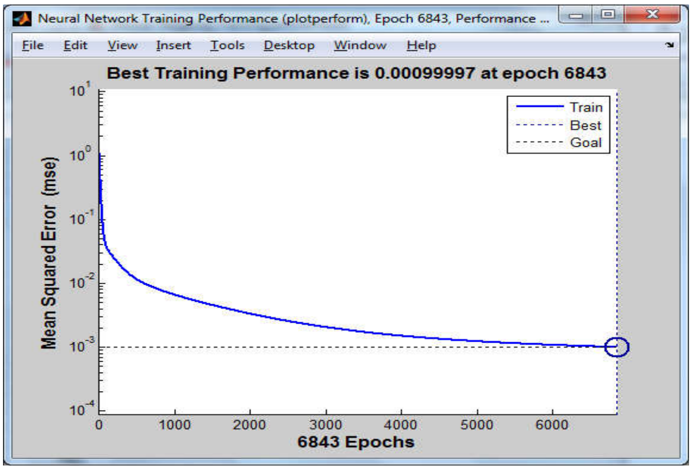

Figure 3. Results of Performance Training Model 3-5-1

Of the 5 models of network architecture used, the results of different accuracy. For more details can be seen in table 4 below.

Table 4. The overall result of the backpropagation algorithm

No	Architecture	Training				Testing	
		Epoch	Time	MSE	Activation Function	MSE	Akurasi
1	3-5-1	6843	00:42	0,0026660	Logsig, Purelin	0,0025448	94%
2	3-10-1	27280	03:01	0,0026667	Logsig, Purelin	0,0048473	63%
3	3-5-10-1	20912	02:31	0,0026672	Logsig, Purelin, Logsig	0,0022911	84%
4	3-5-15-1	12754	01:28	0,0026675	Logsig, Purelin, Logsig	0,0021657	72%
5	3-10-15-1	29646	03:33	0,0026667	Logsig, Purelin, Logsig	0,0043564	69%

Prediction results for 2016, 2017 and 2018 on the backpropagation algorithm by using the binary sigmoid activation function (logsig) and the identity linear function (purelin) can be seen in table 5 below.

No	Districts	Population Density (Soul/Km^2)						PREDICTION		
		2010	2011	2012	2013	2014	2015	2016	2017	2018
1	Bandar	582,00	598,00	651,00	654,41	669,14	677,20	678,51	660,72	669,25
2	Bandar Huluan	251,00	254,00	242,00	242,65	244,80	245,75	246,33	290,35	273,18
3	Bandar Masilam	249,00	250,00	269,00	270,00	271,08	271,91	278,03	319,63	308,67
4	Bosar Maligas	132,00	134,00	138,00	138,72	140,39	141,22	149,24	171,46	177,25
5	Dolok Batu Nanggar	312,00	315,00	373,00	373,29	377,01	378,73	413,35	438,83	464,42
6	Dolok Panribuan	116,00	117,00	122,00	121,89	122,82	123,20	133,65	150,61	162,93
7	Dolok Pardamean	161,00	161,00	156,00	156,06	156,80	157,03	162,09	187,04	188,20
8	Dolok Silou	48,00	48,00	46,00	46,30	46,96	47,30	64,68	66,36	96,27
9	Girsang Sipangan Bolon	116,00	118,00	112,00	112,11	113,40	114,02	125,96	141,44	156,29
10	Gunung Malela	300,00	306,00	346,00	347,03	353,13	356,35	384,49	420,51	433,36
11	Gunung Maligas	447,00	456,00	522,00	523,90	533,47	538,54	556,25	565,83	582,79
12	Haranggaol Horison	145,00	145,00	23,00	122,72	123,46	123,75	231,80	150,92	277,71
13	Hatonduhan	77,00	77,00	63,00	63,11	63,39	63,47	80,47	84,16	112,49
14	Hutabayu Raja	187,00	188,00	153,00	153,63	154,78	155,26	160,93	185,78	187,46
15	Jawa Maraja Bah Jambi	271,00	279,00	531,00	534,77	549,22	557,33	572,78	586,90	595,32
16	Jorlang Hataran	166,00	167,00	165,00	164,98	166,21	166,73	170,09	198,52	195,68
17	Kabupaten Simalungun	186,00	189,00	190,00	190,56	193,03	194,26	194,10	231,48	218,85
18	Pamatang Bandar	330,00	331,00	357,00	356,78	358,42	358,89	391,13	416,30	439,47
19	Pamatang Sidamanik	130,00	131,00	119,00	119,27	120,17	120,54	131,76	147,76	161,35
20	Pamatang Silimahuta	152,00	154,00	132,00	132,37	134,19	135,10	143,87	165,03	172,51
21	Panei	296,00	300,00	280,00	279,00	281,99	283,42	439,78	335,42	466,11
22	Panombeian Panei	233,00	235,00	262,00	262,19	263,85	264,49	268,55	311,52	297,83
23	Purba	127,00	131,00	131,00	131,86	135,33	137,27	145,76	170,40	175,04
24	Raya	92,00	93,00	95,00	94,82	96,04	96,65	110,59	122,49	142,18
25	Raya Kahean	77,00	77,00	86,00	85,78	86,46	86,75	101,85	110,70	133,65
26	Siantar	795,00	808,00	867,00	869,89	883,02	889,76	829,42	768,34	728,11
27	Sidamanik	324,00	326,00	337,00	337,62	340,16	341,21	368,28	399,45	413,66
28	Silimakuta	176,00	184,00	194,00	196,00	203,80	208,36	205,89	256,12	232,54
29	Silou Kahean	77,00	78,00	75,00	75,33	76,08	76,43	92,90	99,53	125,23
30	Tanah Jawa	218,00	219,00	269,00	269,65	271,68	272,52	278,45	321,42	309,20
31	Tapian Dolok	325,00	334,00	327,00	328,43	335,62	339,54	361,75	404,50	407,77
32	Ujung Padang	181,00	182,00	178,00	178,69	179,84	180,29	182,30	213,58	207,16

5. Conclusion

a. Architecture Model 3-5-1 can predict population density with 94% accuracy.
b. In addition to determining the model of network architecture, the determination of the activation function that will be used in the neural network backpropagation also greatly affect the size of the accuracy of a forecast.
c. The function of binary sigmoid activation (logsig) and linear identity function (purelin) is suitable for forecasting whose data value is quite stable.

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Authors

1st Author
Anjar Wanto
Lecturer of STIKOM Tunas Bangsa Pematangsiantar
anjarwanto@amiktunasbangsa.ac.id

2nd Author
Agus Perdana Windarto
Lecturer of STIKOM Tunas Bangsa Pematangsiantar
agus.perdana@amiktunasbangsa.ac.id

3rd Author
Dedy Hartama
Lecturer of STIKOM Tunas Bangsa Pematangsiantar
dedyhartama@amiktunasbangsa.ac.id

4th Author
Iin Parlina
Lecturer of AMIK Tunas Bangsa Pematangsiantar
iin@amiktunasbangsa.ac.id