

Bank Indonesia Interest Rate Prediction and Forecast With Backpropagation Neural Network

Rini Sovia, Musli Yanto,
Rima Liana Gema, Rizki Fernando
Universitas Putra Indonesia YPTK padang
Padang
rini_sovia@upiypk.ac.id
musli_yanto@upiypk.ac.id
rimalianagema@upiypk.ac.id

Authors Name/s per 2nd Affiliation (*Author*)
line 1 (of *Affiliation*): dept. name of organization
line 2-name of organization, acronyms acceptable
line 3-City, Country
line 4-e-mail address if desired

Abstract —The BI Rate is a policy interest rate that plays a role in directing the movement of the national economy. The problem that arises in the study is to determine a forecast for the movement of the BI Rate. Predictions of bank interest rates can be done with various techniques and methods, one of which uses backpropagation artificial neural networks. This method is a branch of artificial intelligence that has the same process carried out by human brain tissue. The method of working method starts from analyzing the data to be used. The process starts from determining the variables namely: Dollar Exchange Rate, Amount of Money Supply, Inflation, and JCI. The process of backpropagation artificial neural network calculation is continued until the final stage of the process is to find the network output which is used as a forecasting number. The author uses Matlab Software that can determine the weight and bias values. The network architecture used is 4 input layers, 2 hidden layers, and 1 output layer and the desired target is the interest rate number

Keywords — Artificial Neural Network, Backpropagation, BI Rate

I. INTRODUCTION

The more rapid development of computer technology, computer experts try to replace computers into a tool that can mimic the intelligence of the human brain that can make their own decisions like humans. One computational technique grouped in artificial intelligence technology is artificial neural networks. Artificial Neural Network is one of the processing systems that are designed and trained to have the ability as possessed by humans in solving complex problems by carrying out the learning process. Artificial Neural Network Research on forecasting and prediction usually applies backpropagation algorithm methods. Bank Indonesia interest rate (BI Rate) is a policy interest rate that reflects the monetary policy stance or stance set by Bank Indonesia and announced to the public. Estimates of the BI Rate increase or decrease are based on the inflation rate. Inflation has a positive influence on market returns. When inflation rises, production output prices also increase, so the level of loans at banks will increase. This caused the amount of money circulating in Indonesia to increase so that the Rupiah exchange rate weakened. In addition, the high price of production output has resulted in investors preferring to invest their capital in the

capital market so that the stock price falls and the Composite Stock Price Index (JCI) will generally decline. Thus, BI will raise the BI Rate as a monetary policy response. Vice versa, when inflation has decreased, the Rupiah will strengthen, the amount of money in circulation has decreased, and the JCI has strengthened, so the monetary policy response adopted by BI is to raise the BI Rate. In other words, factors that are very influential in the BI Rate Determination are the rate of inflation and the money supply in Indonesia, the exchange rate of the Rupiah against the US Dollar, and the JCI. Therefore, through the design and construction of applications that can implement and predict the BI Rate, it is expected that it can help both the government and certain agencies in making policies related to the BI Rate.

The problem discussed in this study is forecasting the BI Rate by using Backpropagation Artificial Neural Networks. Backpropagation is an algorithm that trains data that is used to find a specified target or output form. In previous studies, predictions of bank interest rates can be done with various techniques and methods, one of which is using backpropagation artificial neural network algorithms. In this study seven input variables were used, namely the development of economic liquidity, inflation rate, economic growth rate, CAR, LDR, US interest rates and BI interest rates which were taken from the Bank Indonesia Annual Report, SEKI (Indonesian Economic and Financial Statistics) and Banking Data Indonesia [1]. The results of the prediction system implementation and evaluation use the Artificial Neural Network and compare the prediction results with the Exponential Smoothing method. The conclusions can be drawn as follows: 1. Parameter configuration for predictive system training using the best artificial neural network obtained from the experiment results in the configuration of the number of hidden nodes 50, the learning rate is 0.95, the training year limit is 1998, the momentum value is 0.95 and the MAPE tolerance is 3.97% [6]. From previous studies that have been produced, the author will conduct research with the same case in forecasting using Backpropagation Neural Networks.

II. THEORETICAL FRAMEWORK

A. Artificial Intelligence

Artificial Intelligence or Artificial Intelligence is one part of Computer Science that makes the machine (computer) can do work like and as good as humans do [9]. Artificial Intelligence meant here refers to machines that are capable of thinking, weighing the actions to be taken, and being able to make decisions like those done by humans. When compared with natural intelligence (intelligence possessed by humans), artificial intelligence has advantages, including [9]:

- Artificial Intelligence is more permanent
- Artificial Intelligence is more easily duplicated and distributed.
- Artificial Intelligence is cheaper than Natural Intelligence
- Artificial Intelligence is consistent.
- Artificial Intelligence can be documented
- Artificial Intelligence can do the job faster than Natural Intelligence
- Artificial intelligence can do a better job than natural intelligence.

B. Artificial Neural Network

Artificial Neural Network (ANN) / Simulated Neural Network (SNN) / Neural Network (NN) is a network consisting of a group of small processing units that are modeled based on human neural networks [9]. A key element of this paradigm is the structure of an information processing system that consists of a large number of interconnected processing elements (neurons), working simultaneously to solve certain problems [9]. There are three important basic components when we create a functional model of biological neurons. First, neuronal synapses are modeled as weights. The strength of the relationship between input and neurons is determined by the weight value. The negative weight value reflects the inhibitory connection, while positive values indicate the connection of the cell family. The second component is the sum of all entries modified by each weight. This activity is called a linear combination. The third component acts as a control function for the activation of the amplitude output of neurons [9]. Based on the mathematical model, whether or not an ANN model is determined by the following [5]:

- The pattern of relationships between neurons (called network architecture)
- The method for determining connecting weights (called training / learning methods / algorithms).
- Activation function.

C. Backpropagation

Backpropagation is one of the supervised learning methods that is widely used by researchers in building systems. This method is generally used in multi-layer networks with the aim of minimizing errors in output generated by the network during training. The backpropagation architecture can be seen in Figure 1 below:

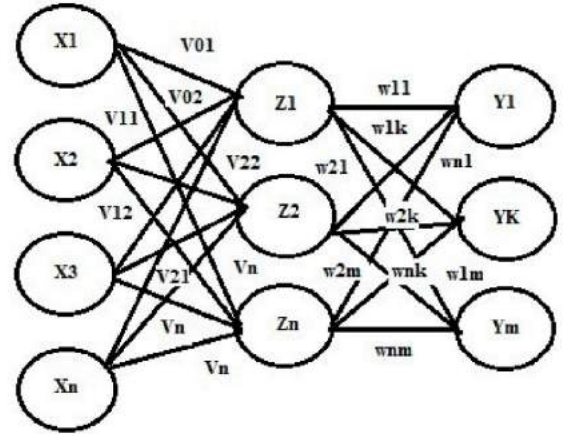


Figure 1. Backpropagation Architecture

Backpropagation algorithm training consists of 3 phases, where all three phases are repeated until the termination condition is fulfilled. Generally the termination condition that is often used is the number of iterations or errors. The iteration will be stopped if the number of iterations done has exceeded the maximum number of iterations specified or if the error is smaller than the allowable tolerance limit. Following are the training steps in the Backpropagation algorithm with one hidden screen (with binary sigmoid activation function) [4].

- Step 0 : initialization weights with small random numbers.
 Step 1 : if the termination condition has not been met, do steps 2-9
 Step 2 : for each pair of training data, take steps 3-8
 Step 3: each input unit receives a signal and passes it to the hidden unit above it
 Step 4 : calculate all outputs in hidden units
 Step 5 : In each unit in the hidden layer z_j (from the 1st unit to the nth to nth unit, $i = 1, \dots, n; j = 1, \dots, p$) the output signal of the hidden layer is calculated by applying the activation function to the sum of x_i input signals weighs x_i :

$$Z_j = f(V_{0j} + \sum_{i=1}^n X_i V_{ij}) \quad (1)$$

- Step 6 : unit in the output layer y_k (from the 1st unit to the mth unit $i = 1, \dots, k = 1, \dots, m$) calculated its output signal by applying the activation function to the sum of the weighted input signals Z_j for this layer:

$$Y_k = f(W_{0k} + \sum_{j=1}^p Z_j W_{jk}) \quad (2)$$

- Step 7 : Each unit of output Y_k (from 1st unit to mth unit $j = 1, \dots, p; k = 1, \dots, m$) receives target t_k pattern then output layer error information (δ_k) is calculated δ_k sent to the layer below and used to calculate the weight and bias weight (Δw_{jk} and Δw_{0k}) between the hidden layer and the output layer:

$$\delta_k = (t_k - y_k) f'(W_{0k} + \sum_{j=1}^p Z_j W_{jk}) \quad (3)$$

$$\Delta W_{jk} = \alpha \delta_k Z_j \quad (4)$$

$$\Delta W_{0k} = \alpha \delta_k \quad (5)$$

- Step 8 : In each unit in the hidden layer (from unit 1 to unit $p; i = 1, \dots, N; j = 1 \dots p; k = 1 \dots m$) the calculation of the hidden layer error information (δ_j). (δ_j) is then used to calculate the weight and bias correction (ΔV_{ij} and ΔV_{0j}) between the input layer and the hidden layer.

$$\delta_j = (\sum \delta_k W_{jk})_{k=1}^m f'(V_{oj} + \sum X_i V_{ij})_{i=1}^n \quad (6)$$

$$\Delta V_{ij} = \alpha \delta_j X_i \quad (7)$$

$$\Delta V_{oj} = \alpha \delta_j \quad (8)$$

Phase Change of weight and bias

Step 9 : In each unit of output Yk (from unit 1 to unit m) changes are biased and weighted ($j=0, \dots, p; k=1, \dots, m$) so the new bias and weights become:

$$W_{jk}(\text{baru}) = W_{jk}(\text{lama}) + \Delta V_{ij} \quad (9)$$

from the 1st unit to the p unit in the hidden layer also changes the bias and its weight ($i=0, \dots, n; j=1, \dots, p$):

$$V_{jk}(\text{baru}) = W_{jk}(\text{lama}) + \Delta V_{ij} \quad (10)$$

Step 10 : The stop condition test

III. METHODOLOGY

In conducting the research in order to obtain the expected results, a research framework is required. Where the research framework is done as illustrated as Figure 2 :

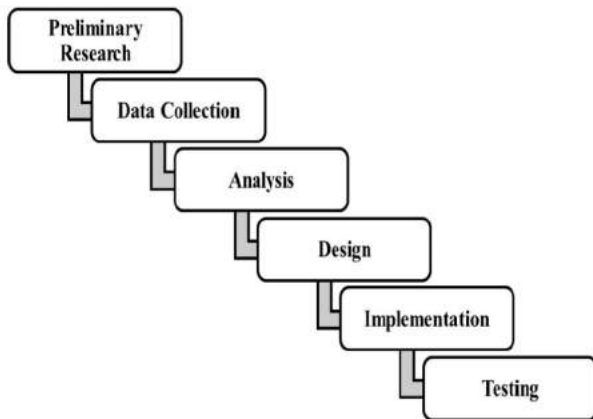


Figure 2 : Research Framework

A. Preliminary Research

In the preliminary study the authors do an understanding of the research with one form describes the research framework. The framework of this study has a function to regulate the activities undertaken in the study from the beginning until the completion of this study

B. Method of Collecting Data

The data used is the Dollar Exchange Rate Index, the money supply, inflation. Data needed in this study is 2016 data.

C. Data Training Method

Training data retrieved first March 2016 and test data retrieved first September 2017.

D. Data Analysis

The Data analysis phase is the most important stage in the development of a system, because it is at this stage that performance evaluation will be carried out later, identification of existing problems, system design and steps required for the design of the desired system to the expected analysis.

E. System Analysis

System analysis is a decomposition of a complete information system into its component parts with a view to identifying and evaluating problems, opportunities, obstacles that occur and the expected needs so that improvements can be proposed.

IV. RESULTS

A. Data Analysis Process

System analysis is a description of a complete information system into a part that is formed from a useful component to identify and evaluate the BI Rate forecast.

Table 1. Artificial Neural Network Data

Year	Month	Kurs	JUB (M2)	Inflation	IHSG	BI Rate
		(IDR/USD)	(Billion) IDR	(%)	(Million) IDR	(%)
2016	Mar	13.276k	4.562k	3,61	4.845k	5,5
2016	Apr	13.204k	4.582k	3,83	4.839k	5,5
2016	May	13.615k	4.614k	3,49	4.797k	5,5
2016	Jun	13.180k	4.738k	3,02	5.017k	5,25
2016	Jul	13.094k	4.730k	3,58	5.216k	5,25
2016	Aug	13.615k	4.746k	3,31	5.386k	5,25
2016	Sep	12.998k	4.738k	3,07	5.365k	4,75
2016	Oct	13.051k	4.779k	2,79	5.423k	4,75
2016	Nov	13.563k	4.869k	3,21	5.149k	4,75
2016	Dec	13.436k	5.005k	3,45	5.103k	4,75
2017	Jan	13.343k	4.937k	3,33	5.303k	4,75
2017	Feb	13.343k	4.938k	3,6	5.383k	4,75

B. Transformation Process

The activation function used to process the data above is sigmoid (binary) function. Then the data must be transformed first because the output range of the sigmoid activation function is [0,1]. The data is transformed into smaller intervals, eg at [(0.1), (0.9)] intervals.

Table 2. Data Input Transformation Training Results

X1	X2	X3	X4	T
0,1006	0,2179	0,7116	0,2373	0,1001
0,8689	0,2203	0,1354	0,2341	0,1001
0,9	0,2297	0,1	0,2507	0,1001
0,8671	0,2291	0,1422	0,2658	0,1001
0,8606	0,2303	0,1218	0,2786	0,1001
0,9	0,2297	0,1037	0,277	0,1001

Table 3. Results of Test Data Input Transformation

X1	X2	X3	X4	T
0,858	0,2476	0,1	0,2954	0,2455
0,8619	0,2543	0,1311	0,2751	0,2455
0,9	0,2644	0,149	0,2716	0,2455
0,9805	0,2593	0,1401	0,2865	0,2455
0,8836	0,2595	0,1601	0,2924	0,2455
0,8836	0,1003	0,2232	0,308	0,2455

C. Network Architecture

The pattern of this training process, the author will try to do the training using some appropriate and accurate patterns so that it can determine the right qualification of the supply request. These patterns are the number of neurons in the input layer as many as 4 neurons, the number of neurons in the hidden layer are 2 neurons, the error tolerance is 0.01, the Learning Rate is 0.95, the momentum is 0.5 and Max epoch is 100000.

D. Backpropagation Algorithm Design

At this design stage the results of the analysis that has been obtained will be applied to the steps of the backpropagation algorithm using the sigmoid activation function. The steps for using the backpropagation algorithm are [5]:

1. Initialization Phase
It is a step to define initial values for the required variables
2. Stage Activation
At this stage, there are two activities, namely calculating actual output on the hidden layer and actual output on the output layer
3. Stage Weight Training
At this stage there are two activities: calculating gradient errors in the output layer and calculating gradient errors in the hidden layer
4. Phase Iteration
At this last stage is the stage for testing where if the expected error has not been found, it will return to the second stage, the activation stage

E. Calculation Process of Artificial Neural Network BackPropagation Algorithm

To form the Artificial Neural Network, first initialization of the initial weights, the initial weights that connect the knots in the input layer and the hidden layer for the above architecture are $v = (v11, v12, v21, v22, v31, v32, v41, v42)$ and the bias weights are randomly selected, as well as the initial weights that connect the nodes in the hidden layer and the output layer ($w1, w2$) are also randomly selected

Table 4. Initial weight and input bias to hidden from matlab

	Z1	Z2
X1	96.3588	97.0264
X2	-362.88	314.055
X3	24.1552	-57.359
X4	-60.045	9.9249
Bias	5.3452	-147.38

Table 5. Initial and hidden weights to the output from matlab

Y	Z1	Z2	BIAS
	0.7061	0.2441	0.0265

X1 = 0.8744
X2 = 0.2179
X3 = 0.1445
X4 = 2373

V11 = 96.3588 V12 = 97.0264
V21 = -362.878 V22 = 314.0554
V31 = 24.1552 V32 = -57.3593
V41 = -60.0448 V42 = 9.9249

$$W11 = 5.3452$$

$$W12 = -147.375$$

$$\Theta1 = 0.915$$

$$\Theta2 = 0.9298$$

$$\Theta3 = -0.6848$$

Step 0 : Initialize all weights with small random numbers.

Step 1 : If the calculation condition has not been met, do the steps 2-9

Step 2 : For each pair of training data, do 3-8

Step 3 : Each input unit receives the signal and continues it to the hidden unit above it.

Step 4 : Calculate all outputs in the hidden unit Z_j ($j= 1,2,\dots,p$).

$$Z_{netj} = \left[v_{jo} \sum_{i=1}^n x_i v_{ji} \right]$$

$$Z_{net 1} = 0.9150 + (0.8744*96.3588) + (0.2178*-362.878) + (0.7116*24.1552) + (0.2373-60.0448) = -0.2279$$

$$Z_{net 2} = 0.9298 (0.8744*97.0264) + (0.2178314.0554) + (0.7116-57.3593) + (0.2373*9.9249) = -0.03568$$

$$Z_j = \frac{f(z_{netj})}{1 + e^{-z_{netj}}}$$

$$Z1 = 0.04432$$

$$Z2 = 0.4910$$

Step 5 : Calculate unit output Y_k

Because the network only has an output unit y then $y_{net k}$

$$Y_{netk} = w_{ko} + \sum_{j=1}^p z_j w_{kj}$$

$$Y_{net} = -0.6848 + (5.3452 * 0.04432) + (-147.375 * 0.4910) = 0.1773 = 0.544229$$

Checking for errors, the iteration will stop when | error | < 0.01.

$$Error = (0.2872 - 0.544229) = -0.2570$$

Step 6: calculate the factor in the output unit y_k

$$\delta k = \delta = (t - y)y(1 - y) = (0.2872 - 0.544229) * (0.544229 (1 - 0.544229)) = -0.1171$$

Change rate of W_{kj} weight:

$$\Delta w_{kj} = \alpha \cdot \delta k \cdot Z_j$$

$$\alpha = 0.95$$

$$\Delta w_{10} = 0.95 * (-0.1171) * 1 = -0.1112$$

$$\Delta w_{11} = 0.95 * (-0.1171) * 0.0525 = -0.0058$$

$$\Delta w_{12} = 0.95 * (-0.1171) * 0.0026 = -0.0002$$

Step 7: Calculate the summation of errors from hidden units

$$\delta_{netj} = \sum_{k=1}^m \delta_k W_{kj}$$

$$\begin{aligned} _net1 &= -0.1171 * 0.915 = -0.1071 \\ _net2 &= -0.1171 * -147.375 = 17.2576 \end{aligned}$$

Error factor in the hidden unit

$$\begin{aligned} 1 &= 0.1071 * 0.04432 * (1 - 0.04432) = 0.0045 \\ 2 &= 17.2576 * 0.4910 * (1 - 0.4910) = 4.3130 \end{aligned}$$

Table 6. Change the input weight to hidden

	Z1	Z2
X1	$(0.95) * (0.0045) * (0.8744) = 0.00374$	$(0.95) * (4.3130) * (0.8744) = 3.5827$
X2	$(0.95) * (0.0045) * (0.2179) = 0.0009$	$(0.95) * (4.3130) * (0.2179) = 0.8928$
X3	$(0.95) * (0.0045) * (0.1445) = 0.0006$	$(0.95) * (4.3130) * (0.1445) = 0.5920$
X4	$(0.95) * (0.0045) * (0.2373) = 0.0010$	$(0.95) * (4.3130) * (0.2373) = 0.9723$

Step 8: Calculate all changes in weight Change in unit weight:

$$\begin{aligned} \Delta W_{kj}(\text{baru}) &= \Delta W_{kj}(\text{lama}) + \Delta W_{kj} \\ \Delta W_{11}(\text{baru}) &= (-0.1112) + 5.234 \\ &= -147.375 + (-0.0058) = -143.3808 \\ &+ (-0.0002) = -0.685 \end{aligned}$$

Table 7. Changes in bias and new bias in hidden neurons

Bias Changes in New Hidden		Bias Neurons in Hidden Layer Neurons	
$\Delta V[0,1]$	$0.95 * 0.0045 = 0.004275$	$V[0,1]$	$0.004275 + 0.04432 = 0.4859$
$\Delta V[0,2]$	$0.95 * 4.3130 = 4.0973$	$V[0,2]$	$4.0973 + 0.4910 = 4.5883$

Table 8. Changes in new input weights

new	Z1	Z2
X1	$96.3588 + 0.00374 = 96.3625$	$97.0264 + (3.5827) = 100.6091$
X2	$-362.878 + (0.0009) = -363.8771$	$314.0554 + (0.8928) = 314.9482$
X3	$24.1552 + (0.0006) = 24.1558$	$-57.3593 + (0.5920) = -56.7673$
X4	$-60.0448 + (0.0010) = -60.0438$	$9.9249 + (0.9723) = 10.8972$

From the results of processing and design using artificial neural networks with backpropagation method, it can be seen the relationship that Artificial Neural Networks can be used to predict the movement of the BI Rate based on the Dollar Rate,

Amount of Money in circulation, Inflation, and Ihsq as input and the BI rate for tomorrow as output his

$$\begin{aligned} X &= y * (x_{max} - x_{min}) + x_{min} \\ &= 0.1773 * (13.615 - 3.02) + 3.02 = 4.89 \end{aligned}$$

This manual data processing will then be processed using MATLAB for some network architecture patterns. The results obtained from the data processing using MATLAB will then be compared with the results of manual data processing to see the difference in results. In using the backpropagation method, the architectural pattern used greatly influences the process of determining results. Each result obtained by an architectural pattern allows different results obtained using other architectural patterns.

F. Verification Process with Matlab

Matlab is a supporting application to help get Hidden values and Bias values from data with the backpropagation method. The following are the test steps with matlab:

Enter the Input and Target values on the CommandWindow page in Matlab with the formula for input `>> p = [;];` and Target `>> t = [;];`

Like the picture below:

```
p=[0.8744 0.8689 0.9 0.8671 0.8606 0.9;
0.2179 0.2203 0.2297 0.2291 0.2303 0.2257;
0.1445 0.1461 0.1334 0.1 0.1422 0.1218;
0.2373 0.2341 0.2507 0.2458 0.2786 0.277;];
t=[0.2871 0.2872 0.2872 0.2483 0.2633 0.2463];
net = newff(minmax(p), [2,1], {'logsig','purelin'}, 'tra
```

Figure 3. Display Input Input and Target

After getting the bias value then do the testing by entering coding with the net value. `Trainparam.epochs = 100,000;` `net.trainparam.goal = 0.01;` and after entering, do the testing with coding `input net = train (net, p, t);` After getting the maximum value of the Epoch, which is the Epoch number 13/100000, MSE 0.0098496, Gradient 0.014593. as shown below:

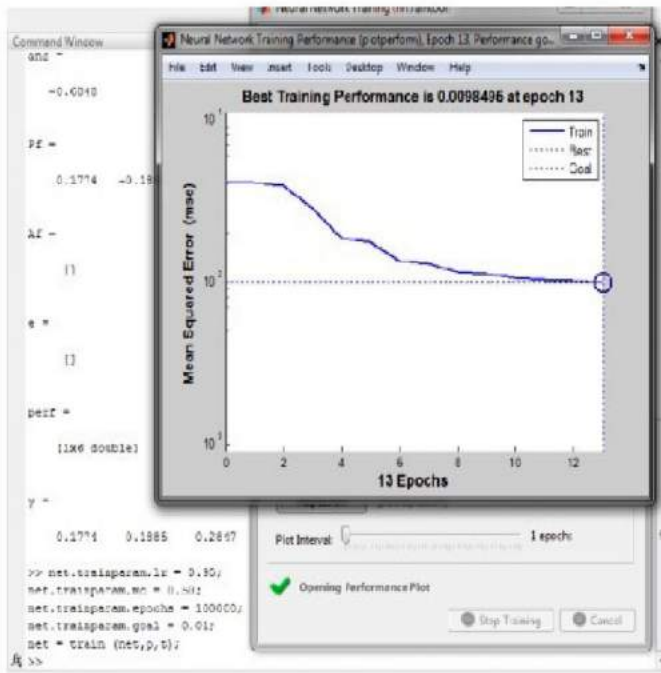


Figure 4. Epoch Testing Display

After using the tools with Matlab Software, the author tries to compare the network architectural patterns from several patterns used. Comparison of patterns aims to find the best patterns of several network patterns that are built. The following are the results of a comparison of several patterns:

Table 9. Comparison of network patterns

Training		Testing	
Pattern 4-2-1		Pattern 4-2-1	
mape	0,00246025	mape	0,00277374
%mape	0,2460246	%mape	0,27737368
accuracy	99,7539754	accuracy	99,7226263
Pattern 4-3-1		Pattern 4-3-1	
mape	0,010758219	mape	0,004703714
%mape	1,075821868	%mape	0,470371448
accuracy	98,92417813	accuracy	99,52962855
Pattern 4-4-1		Pattern 4-4-1	
mape	0,00761219	mape	0,002317913
%mape	0,761218979	%mape	0,231791291
accuracy	99,23878102	accuracy	99,76820871
Pattern 4-5-1		Pattern 4-5-1	
mape	0,00761219	mape	0,002899816
%mape	0,761218979	%mape	0,289981573
accuracy	99,23878102	accuracy	99,71001843

Based on the comparison comparison seen, the author concludes that the best pattern can be seen from the results of the highest accuracy values are in the 4-2-1 pattern with an average accuracy value of 99.73%

Next, it is proven by manual search and compared with the value that can be obtained from the Y value and the error using 1 epoch. Like figure 7 below.

G. Manual Testing

In this manual testing process using Microsoft Exel-2007 software. This process is the process of searching the value of manual design of Backpropagation algorithm. At this design stage the results of the analysis that has been obtained will be applied to the web that has been designed. The search process is:

- Calculate all hidden the unit outputs Z_j
- Calculate the unit output Y_k
- Calculate the diunit output factor y_k
- Calculate the sum of errors from hidden units

After the calculation process has been carried out, the author tries to do a second comparison, namely the comparison of the results of the network output value with a predetermined target. following the results of the comparison that has been done:

Table 10. Comparison of Network Outputs with Targets

Comparison of Network Output with Target	
Yink	0,177379
Target	0,2455

H. Web Based View

Website based display is an offline application which will open it by running Mowes Potrteble and will show automatically Localhost on Mozilla Firefox. That way the admin can access this system. Website-based apps can be used by admins, where admins can run all their respective functions such as accessing certain menus in accordance with the provisions.

- Data Display

In this view all the data in the system and the admin can add data to the system.

Figure 5. Data Display

- Add Data View

Display new data input is a page for admin to add data for predicting needs.

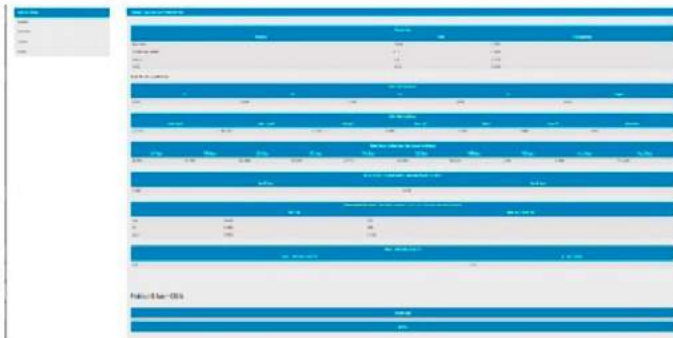


Figure 6. Display Manage Data Form

- **Predicted Results Data View**
Predictive data view is an existing data page predicted by BI Rate.

No	Kurs/Pe	Asli (Miliar)	Salah (%)	HRG	Prediksi BI Kurs (%)	Aksi
1	17.776	8.751	381	4.515	5.15	Detail
2	18.282	8.699	383	4.658	5.12	Detail
3	17.786	8.718	380	4.708	5.17	Detail
4	18.018	8.681	378	4.708	5.08	Detail
5	18.18	8.727	382	4.744	5.76	Detail
6	17.947	8.71	376	4.711	5.38	Detail
7	18.3	8.788	383	4.788	5.76	Detail
8	17.923	8.758	371	4.642	5.6	Detail
9	18.888	8.823	375	4.882	4.8	Detail
10	17.923	8.816	373	4.787	5.88	Detail
11	18.218	8.888	38	4.882	5.8	Detail

Figure 7. Display Prediction Result Data Form

V. CONCLUSION

- Forecasting or prediction process with Backpropagation algorithm is able to provide solutions to problems in determining the BI Rate, the resulting forecasting results

are presented in the form of predictive numbers more quickly, accurately and have a fairly small error rate.

- The accuracy of the results of forecasting depends on how much tolerance the error is obtained from the calculation process based on the network architecture.
- This prediction or forecasting process is implemented in the form of an application that can be used easily in an effort to forecast the BI Rate.

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