Architecture Model Optimization of Cyclical Order Algorithm with Binary Sigmoid and Linear Function for Prediction

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Abstract. This research is a development of previous research to predict the life expectancy of people in Aceh province. The purpose of this study is to determine a model that is better and more optimal than previous studies that have been conducted with the 8-9-1 model, with a prediction accuracy rate of 91% using the ANN Cyclical Order Algorithm. Meanwhile, the current research will use the same algorithm, the same data, but the analysis process will use the activation process and different models. The results of this study are in the form of a better model that can be used to predict the life expectancy of people in Aceh province with an accuracy rate of 100%. The architectural model is 8-3-1. Also, this model produces a lower MSE level, namely 0.0008332545 compared to the previous 8-9-1 model of 0.0010800577. As is well known, the smaller the MSE value, the better.

1. Introducing

The ANN Cyclical Order algorithm is a development of the Backpropagation algorithm which is often used to predict. This algorithm is able to speed up the training process on the standard backpropagation algorithm, as well as the Conjugate gradient [1][2], Bayesian regularization [3], Resilient [4][5], Levenberg-Marquardt [6], Batch training [7], etc. Just like the ANN algorithm in general, this algorithm also uses 3 layers for analysis to find the best architectural model results which will later be used for reference data predictions, namely the input layer, hidden layer, and output layer. In addition, each Neural Network algorithm must use an activation function to activate or deactivate neurons.

In this study, an analysis will be carried out to obtain the best architectural model which is the development of previous research to predict the life expectancy of people in Aceh province using the ANN Cyclical Order Algorithm [8]. This study uses six architectural models, the best model is 8-9-1, with an accuracy of 91% and an MSE value of 0.0010800577. This development will later use other architectural models as well as the activation function of the Binary Sigmoid (Logsig) and the linear function (Purelin), which are expected to increase accuracy so that it can be used as a reference so that the prediction results are better than before.

Related studies that contributed to the background of this research include: Research to predict fresh milk production on the island of Sumatra using the Cyclical order method. The best model in this study which is used to predict is the 4-5-10-1 model with an accuracy rate of 90% [9]. Furthermore, research conducted to predict the life expectancy of the world's population also uses the Cyclical order
method. This study produces an accuracy of 97% with the best architectural models 3-5-10-1 [10]. The results of this study will be in the form of the best model which is expected to be better than previous studies, which can be used as a reference for predicting life expectancy in 23 districts/cities in Aceh province.

2. Methodology

2.1. Method of collecting data

The data collection method used in this study is a quantitative method, which is taking data on the Life Expectancy Rate of the community in Aceh province in 23 districts/cities through the Aceh Central Statistics Agency (BPS) website [11]. The research method used is the Cyclical Order Algorithm with the Binary Sigmoid (Logsig) activation function and the linear (Purelin) function.

2.2. Research Stages

The research stages can be seen in Figure 1.

![Figure 1. Research Stages](image)

3. Results and Discussion

3.1. Results of Normalization Data

Data on the life expectancy of the people in Aceh province can be seen in table 1.

| No | Region     | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 |
|----|------------|------|------|------|------|------|------|------|------|------|------|
| 1  | SIMEULUE   | 64.05| 64.15| 64.22| 64.23| 64.24| 64.66| 64.78| 64.90| 65.00| 65.22|
| 2  | ACEH SINGKIL | 66.71| 66.76| 66.85| 66.91| 66.94| 66.97| 67.02| 67.07| 67.16| 67.36|
| 3  | ACEH SELATAN | 62.92| 63.03| 63.12| 63.16| 63.18| 63.64| 63.75| 63.89| 64.02| 64.27|
| 4  | ACEH TENGGARA | 66.85| 66.93| 66.96| 67.03| 67.07| 67.40| 67.51| 67.62| 67.77| 68.04|
| 5  | ACEH TIMUR  | 67.92| 67.97| 68.02| 68.05| 68.06| 68.20| 68.26| 68.33| 68.44| 68.67|
| 6  | ACEH TENGAH | 68.22| 68.27| 68.30| 68.35| 68.38| 68.44| 68.48| 68.53| 68.62| 68.82|
| 7  | ACEH BARAT  | 67.16| 67.21| 67.25| 67.30| 67.33| 67.49| 67.56| 67.62| 67.72| 67.93|
| 8  | ACEH BESAR  | 69.34| 69.38| 69.41| 69.44| 69.46| 69.49| 69.52| 69.59| 69.77| 69.77|
| 9  | PIDIE       | 66.14| 66.20| 66.25| 66.27| 66.28| 66.46| 66.52| 66.58| 66.68| 66.89|
| 10 | BIREUEN     | 70.27| 70.30| 70.32| 70.34| 70.35| 70.64| 70.72| 70.80| 70.92| 71.16|
| 11 | ACEH UTARA  | 68.32| 68.36| 68.40| 68.41| 68.42| 68.48| 68.51| 68.54| 68.61| 68.79|
| 12 | ACEH BARAT DAYA | 63.44| 63.55| 63.63| 63.69| 63.72| 64.20| 64.35| 64.51| 64.65| 64.91|
Furthermore, Table 1 data will be normalized using equation (1).

\[ x' = \frac{0.8(x - a)}{b - a} + 0.1 \]  

(1)

Data that has been normalized using equation (1) can be seen in Table 2.

| No | Region          | 2010     | 2011     | 2012     | 2013     | 2014     | 2015     | 2016     | 2017     | 2018     | 2019    |
|----|----------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|---------|
| 13 | GAYO LUES      | 64.24    | 64.31    | 64.38    | 64.42    | 64.44    | 64.77    | 64.88    | 64.98    | 65.12    | 65.38   |
| 14 | ACEH TAMIAH    | 68.57    | 68.61    | 68.65    | 68.66    | 68.67    | 68.69    | 69.08    | 69.16    | 69.28    | 69.52   |
| 15 | NAGAN RAYA     | 68.17    | 68.24    | 68.26    | 68.28    | 68.29    | 68.59    | 69.09    | 68.76    | 68.99    | 69.14   |
| 16 | ACEH JAYA      | 66.29    | 66.35    | 66.39    | 66.45    | 66.48    | 66.63    | 66.70    | 66.77    | 66.88    | 67.11   |
| 17 | BENER MERAH    | 68.51    | 69.56    | 68.58    | 68.62    | 68.64    | 68.79    | 68.85    | 68.90    | 69.28    | 69.19   |
| 18 | PIDIE JAYA     | 69.01    | 69.05    | 69.07    | 69.11    | 69.13    | 69.49    | 69.59    | 69.68    | 69.81    | 70.06   |
| 19 | BANDA ACEH     | 70.71    | 70.74    | 70.76    | 70.79    | 70.80    | 70.89    | 70.92    | 70.96    | 71.00    | 71.36   |
| 20 | SABANG         | 69.52    | 69.54    | 69.54    | 69.54    | 69.54    | 69.93    | 70.01    | 70.09    | 70.21    | 70.45   |
| 21 | LANGSA         | 68.65    | 68.70    | 68.75    | 68.78    | 68.79    | 68.94    | 69.00    | 69.06    | 69.16    | 69.37   |
| 22 | LHOKSEUMAWE    | 70.53    | 70.57    | 70.56    | 70.61    | 70.62    | 70.96    | 71.05    | 71.14    | 71.27    | 71.52   |
| 23 | SUBULUSSALAM   | 62.59    | 62.83    | 62.83    | 62.86    | 62.87    | 63.27    | 63.42    | 63.56    | 63.69    | 63.94   |

The results of normalization in Table 2 will be divided into 2 parts, namely training data and testing data. The training data uses data from 2010 to 2017 with a target of 2018. As for the testing data, it uses data from 2011 to 2018 with a target of 2019.
3.2. Comparison of Preliminary Research Results with current research

In previous research [8], it is explained that there are 6 architectural models used, including: 8-5-1, 8-6-1, 8-7-1, 8-8-1, 8-9-1 and 8-10-1. Based on these 6 models, model 8-9-1 is the best model chosen because of its higher accuracy (91%) and the Mean Square Error (MSE) value of 0.0010800577. Parameters used: Epoch = 1000, Goal = 0, max_fail = 5, show = 25, showCommandLine = false, showWindow = true and time = inf. The method used is cyclical order weight / bias (trainc). The analysis process uses Matlab and Microsoft Excel tools.

In the current research, using 3 architectural models: 8-2-1, 8-3-1, and 8-4-1 and the same parameters, the best model 8-3-1 is obtained with an accuracy rate of 100%.

| Table 3. Model 8-9-1 | Table 4. Model 8-3-1 |
|----------------------|----------------------|
| **Data** | **Target** | **Output** | **Error** | **SSE** | **Res** | **Target** | **Output** | **Error** | **SSE** | **Res** |
| 1 | 0.3356 | 0.3064 | 0.0292 | 0.0008532418 | 1 | 0.3356 | 0.3080 | 0.0276 | 0.0007623288 | 1 |
| 2 | 0.5273 | 0.5591 | -0.0318 | 0.0010097378 | 1 | 0.5273 | 0.4929 | 0.0344 | 0.0011849862 | 1 |
| 3 | 0.2505 | 0.2810 | -0.0305 | 0.0009300109 | 1 | 0.2505 | 0.2810 | -0.0305 | 0.0009300109 | 1 |
| 4 | 0.5882 | 0.6327 | -0.0445 | 0.0019765243 | 1 | 0.5882 | 0.5458 | 0.0424 | 0.0018013133 | 1 |
| 5 | 0.6447 | 0.6480 | -0.0033 | -0.0000110167 | 1 | 0.6447 | 0.6297 | 0.0150 | 0.0002244259 | 1 |
| 6 | 0.6581 | 0.6579 | 0.0002 | 0.0000000478 | 1 | 0.6581 | 0.6514 | 0.0067 | 0.0000451409 | 1 |
| 7 | 0.5784 | 0.6116 | -0.0332 | 0.0011030729 | 1 | 0.5784 | 0.5554 | 0.0250 | 0.0006243731 | 1 |
| 8 | 0.7432 | 0.7424 | 0.0008 | 0.0000006808 | 1 | 0.7432 | 0.7459 | -0.0027 | 0.0000071552 | 1 |
| 9 | 0.4852 | 0.5087 | -0.0235 | 0.0005513872 | 1 | 0.4852 | 0.4383 | 0.0469 | 0.0022013330 | 1 |
| 10 | 0.8677 | 0.8420 | 0.0257 | 0.0006630192 | 1 | 0.8677 | 0.8436 | 0.0241 | 0.0005831819 | 1 |
| 11 | 0.6554 | 0.6580 | -0.0026 | 0.0000065991 | 1 | 0.6554 | 0.6548 | 0.0006 | 0.0000039831 | 1 |
| 12 | 0.3078 | 0.3080 | -0.0002 | 0.0000000260 | 1 | 0.3078 | 0.2933 | 0.0145 | 0.0002113751 | 1 |
| 13 | 0.3499 | 0.3070 | 0.0429 | 0.0018441879 | 1 | 0.3499 | 0.3122 | 0.0377 | 0.0014246102 | 1 |
| 14 | 0.7208 | 0.6934 | 0.0274 | 0.0007523318 | 1 | 0.7208 | 0.6990 | 0.0218 | 0.0004764907 | 1 |
| 15 | 0.6868 | 0.6720 | 0.0148 | 0.0002186292 | 1 | 0.6868 | 0.6647 | 0.0221 | 0.0004877964 | 1 |
| 16 | 0.5049 | 0.5362 | -0.0313 | 0.0009779873 | 1 | 0.5049 | 0.4568 | 0.0481 | 0.0002316228 | 1 |
| 17 | 0.6913 | 0.6312 | 0.0601 | 0.0036078520 | 0 | 0.6913 | 0.6963 | -0.0050 | 0.0000025347 | 1 |
| 18 | 0.7692 | 0.7257 | 0.0435 | 0.0018926787 | 1 | 0.7692 | 0.7421 | 0.0271 | 0.0007346771 | 1 |
| 19 | 0.8857 | 0.8279 | 0.0578 | 0.0033369447 | 0 | 0.8857 | 0.8733 | 0.0124 | 0.0005192525 | 1 |
| 20 | 0.8041 | 0.7661 | 0.0380 | 0.0014472955 | 1 | 0.8041 | 0.7789 | 0.0252 | 0.0006372261 | 1 |
| 21 | 0.7074 | 0.6914 | 0.0160 | 0.0002557062 | 1 | 0.7074 | 0.6968 | 0.0106 | 0.0001121654 | 1 |
| 22 | 0.9000 | 0.8646 | 0.0354 | 0.0012531600 | 1 | 0.9000 | 0.8675 | 0.0325 | 0.0001056250 | 1 |
| 23 | 0.2209 | 0.2673 | -0.0464 | 0.0021491894 | 1 | 0.2209 | 0.2772 | -0.0563 | 0.0031651145 | 1 |

Sum SSE 0.0248413272
MSE 0.0010800577 91%

Sum SSE 0.0191648540
MSE 0.0008332545 100%

Explanation:
Data = The number of areas (districts and cities) in Aceh Province
Target = obtained from data of training years and normalized testing data.
Output = obtained from Matlab with the formula [a,Pf,AF,e,Perf]=sim(net,P,[],[],T),
Error = obtained from the value Target-Output
SSE = obtained from the value error ^ 2
Sum SSE = overall value SSE
Results = If the error value <= 0.05 then the result is true (1), otherwise it is false (0).
91% = obtained from the number of correct results / 23 x 100
MSE = obtained from total (SSE) / 23 (amount of data)
Margin error = obtained from the number of false results (0) / 12 x 100 or obtained from the maximum amount of accuracy of 100% minus the resulting accuracy.
The comparison of the level of accuracy and MSE between the Initial Research and the current research can be seen in Table 5 and Table 6. From the two tables, it can be concluded that the 8-3-1 model produces 100% accuracy compared to the 8-9-1 model which only 91%. In addition, the MSE value for the 8-3-1 model is smaller than the 8-9-1 model.

| Models | MSE Training | MSE Testing | Accuracy |
|--------|--------------|-------------|----------|
| 8-5-1  | 0.0016524361 | 0.0032518144 | 74%      |
| 8-6-1  | 0.0022644298 | 0.0050925141 | 70%      |
| 8-7-1  | 0.0016498479 | 0.0021446460 | 74%      |
| 8-8-1  | 0.0022282395 | 0.0044749101 | 48%      |
| 8-9-1  | 0.0009907466 | 0.0010800577 | 91%      |
| 8-10-1 | 0.0011626474 | 0.0022476613 | 70%      |

| Models | MSE Training | MSE Testing | Accuracy |
|--------|--------------|-------------|----------|
| 8-2-1  | 0.0059914976 | 0.0078334870 | 70%      |
| 8-3-1  | 0.0010558666 | 0.0008332545 | 100%     |
| 8-4-1  | 0.0030969561 | 0.0045541474 | 61%      |

In Figure 2 it can be seen that the 8-3-1 model is the best model of the other 8 models, especially the 8-9-1 model which is the best model from previous studies.

4. Conclusion

The 8-3-1 architectural model with the Cyclical Order Method, the Binary Sigmoid function, and the linear function is better if later used to predict Life Expectancy in Aceh because the accuracy rate reaches 100%. The architectural model, parameters and activation functions used in fact affect the results of a prediction, and the smaller the MSE value the better.
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