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Analysis of Backpropagation Algorithm in Predicting the Most Number of Internet Users in the World

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Abstract- Nowadays, the Internet has become a primary need for its users. According to a market research company, e-Marketer, there are 25 countries with the most significant internet users in the world. Indonesia is in the sixth position with 112.6 million internet users. This study aims to predict the number of internet users in Indonesia in the coming years. The method used is an Artificial Neural Network Backpropagation algorithm. The data used in this study focused on the number of internet users in 25 countries from 2013 to 2017. Data analysis was processed using Matlab R2011b (7.13). The research has found that five architectural models were utilized. The best network architecture generated was 3-50-1 with an accuracy of 92% and a Mean Squared Error (MSE) of 0.00151674. These predictions can help the government provide adequate facilities and pre-facilities to balance the growth of internet users and act as a precautionary measure in case of a decrease in internet users. Understanding these trends is crucial for planning and resource allocation.

***Keywords*- Analysis, Backpropagation, Internet, Prediction, World**

***Abstrak*- Saat ini, Internet sudah menjadi kebutuhan primer bagi penggunanya. Menurut perusahaan riset pasar, e-Marketer, terdapat 25 negara dengan pengguna internet terbanyak di dunia. Indonesia berada di posisi keenam dengan 112,6 juta pengguna internet. Penelitian ini bertujuan untuk memprediksi jumlah pengguna internet di Indonesia pada tahun-tahun mendatang. Metode yang digunakan adalah algoritma Artificial Neural Network Backpropagation. Data yang digunakan dalam penelitian ini terfokus pada jumlah pengguna internet di 25 negara pada tahun 2013 hingga 2017. Analisis data diolah menggunakan Matlab R2011b (7.13). Penelitian menemukan lima model arsitektur yang digunakan. Arsitektur jaringan terbaik yang dihasilkan adalah 3-50-1 dengan akurasi sebesar 92% dan Mean Squared Error (MSE) sebesar 0,00151674. Prediksi tersebut dapat membantu pemerintah menyediakan fasilitas dan pra fasilitas yang memadai untuk menyeimbangkan pertumbuhan pengguna internet dan sebagai tindakan pencegahan jika terjadi penurunan pengguna internet. Memahami tren ini sangat penting untuk perencanaan dan alokasi sumber daya.**

***Kata kunci*- Analisis, Backpropagation, Dunia, Internet, Prediksi**

I. INTRODUCTION

Since the discovery of internet technology in the 1990s, its use has expanded because it provides enormous benefits for the smooth process of various activities [1]. In this information era, the internet has placed itself as one of the centers of information that can be accessed from various places without being limited by space and time. The internet is called a barrier-free information center because it can connect one site to another site in a short time [2].

The Internet has become a primary need for its users nowadays [3]. The growth of Internet users is increasing along with the increasingly diverse benefits of the Internet itself. With the increasing number of internet users, the economy and education in the country concerned are expected to advance.

According to the market research institute e-Marketer, there are 25 top countries with the highest number of internet users worldwide. Until now, it is known that China has the most significant internet users, with a total of 736.2 million users in 2017. In Indonesia, internet users continue to increase yearly, with an extraordinary percentage increase [4]. Indonesia is in sixth place after Japan with 112.6 million internet users and ranked 25th by South Africa with 29.2 million internet users. The details can be seen in Table 1.

Table 1. Internet Users In The Top 25 Countries In The World

No	Country	Internet Users (millions)				
		2013	2014	2015	2016	2017
1	China	620,7	643,6	669,8	700,1	736,2
2	US	246,0	252,9	259,3	264,9	269,7
3	India	167,2	215,6	252,3	283,3	313,8
4	Brazil	99,2	107,7	113,7	119,8	123,3
5	Japan	100,0	102,1	103,6	104,5	105,0
6	Indonesia	72,8	83,7	93,4	102,8	112,6
7	Russia	77,5	82,9	87,3	91,4	94,3
8	Germany	59,5	61,6	62,2	62,5	62,7
9	Mexico	53,1	59,4	65,1	70,7	75,7

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No	Country	Internet Users (millions)				
		2013	2014	2015	2016	2017
10	Nigeria	51,8	57,7	63,2	69,1	76,2
11	UK	48,8	50,1	52,3	52,4	53,4
12	France	48,8	49,7	50,5	51,2	51,9
13	Philippines	42,3	48,0	53,7	59,1	64,5
14	Turkey	36,6	41,0	44,7	47,7	50,7
15	Vietnam	36,6	42,5	44,4	48,2	52,1
16	South Korea	40,1	40,4	40,6	40,7	40,9
17	Egypt	34,1	36,0	38,3	40,9	43,9
18	Italy	34,5	35,8	36,2	37,2	37,5
19	Spain	30,5	31,6	32,3	33,0	33,5
20	Canada	27,7	28,3	28,8	29,4	29,9
21	Argentina	25,0	27,1	29,0	29,8	30,5
22	Colombia	24,2	26,5	28,6	29,4	30,5
23	Thailand	22,7	24,3	26,0	27,6	29,1
24	Poland	22,6	22,9	23,3	23,7	24,0
25	South Africa	20,1	22,7	25,0	27,2	29,2

One of the advantages of increasing internet users is the increasing public knowledge, especially among students. Another advantage is that it can improve business opportunities for the community, both middle and upper class, for example by having online shops and online transportation. The increasing business opportunities also help open employment opportunities for the community and increase per capita income from a country, especially Indonesia. Therefore, one way we can do to increase internet users, especially in Indonesia, is to make predictions (forecasting) for the coming years. Thus, the government can provide adequate facilities and pre-facilities to offset the growth of internet users. On the other hand, the government can also take steps to anticipate a decline in internet users. However, the prediction process is not easy; it takes a basic model and time series data from these problems, which are generally complicated by estimating accuracy that is not easily achieved, requiring more advanced techniques [5]. Backpropagation is a good method for making predictions (forecasting). It was expected that with the use of this method the results would be as desired, because the backpropagation algorithm allows to avoid difficulties by using learning rules that are similar to the plasticity of time spikes that depend on synapses [6].

In previous studies, [7] conducted research to predict the value of the rupiah exchange rate against the US Dollar using Backpropagation Gradient Descent Time Series with Conjugate Gradient optimization. The results showed that the MSE value in the basic backpropagation gradient descent algorithm was 1.02159, and the conjugate gradient produced an MSE of 0.0198012. The conjugate gradient algorithm was superior from these results because it produced smaller errors. Furthermore, [8] predicted stock price movements for BRI as a government bank and BCA as a private bank which became the best bank based on its core capital above 30 trillion Rupiah in 2013 with the Backpropagation Neural Network method. This study produced the smallest RMSE of 0.0626 and MAE of 0.0456 with an architectural model of 10-5-1 for closing prices at BCA and for the closing price at BRI the smallest RMSE results and MAE were 0.084 and 0.0487 respectively with the same architectural model. Research by [9] was conducted to predict the inflation rate in Indonesia using the Backpropagation method. Data were analyzed using Cross Validation techniques. Based on the results of the study, it was found that neural networks with cross validation 80% Training and 20% validation and testing as well as learning rate 0.1 and the number of epochs 10000 were able to provide small MSE and MAE values, and the forecasting results approached actual data.

II. RESEARCH METHODS

A. Analysis

Analysis is defined as solving or separating a communication (event, understanding) into its constituent elements so that the idea (understanding, concept) is relatively clearer and/or the relationship between ideas is more explicit [10]. This systematic examination enables deeper insights into the structure, dynamics, and implications of the subject under scrutiny, empowering individuals to make informed decisions, draw meaningful conclusions, and generate novel perspectives. In essence, analysis serves as a pivotal tool for unraveling complexities, fostering comprehension, and advancing knowledge across various disciplines and domains.

B. Backpropagation

Backpropagation is one method in artificial neural networks that uses popular supervised learning and has advantages in its learning abilities [11]. The backpropagation algorithm is used for training. The backpropagation algorithm is a straightforward iterative algorithm that usually performs well, even with complex data. Unlike other learning algorithms (such as Bayesian learning), backpropagation has good computing properties, especially when large-scale data is presented [12]. Training with backpropagation is like training on other neural networks. During the training process with backpropagation, weights are arranged iteratively to minimize errors that occur [13].

C. Prediction

Prediction (forecasting) is estimating something in the future based on past data that is analyzed scientifically [14][15]. This analytical process encompasses identifying patterns, trends, and correlations within the data to make informed projections about future events or trends. By utilizing advanced statistical techniques, machine learning algorithms, or other predictive modeling approaches, prediction aims to provide valuable insights into future scenarios, enabling better decision-making and strategic

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planning in various domains ranging from finance and economics to weather forecasting and business.

D. Internet

The Internet is one part of communication that significantly delivers information the community needs [16]. At present, the use of the internet has become very global. It has even become one of the primary human needs in terms of fulfilling information and communication [17], because now almost everything can be done with the internet, starting from communicating, watching movies, and reading news, as a medium of learning and also as a business media especially in millennial times like now. With the increasing variety of benefits from the internet, the number of internet users every year around the world and in Indonesia also has increased [18].

E. The Research Framework

The research framework used in solving this research problem.

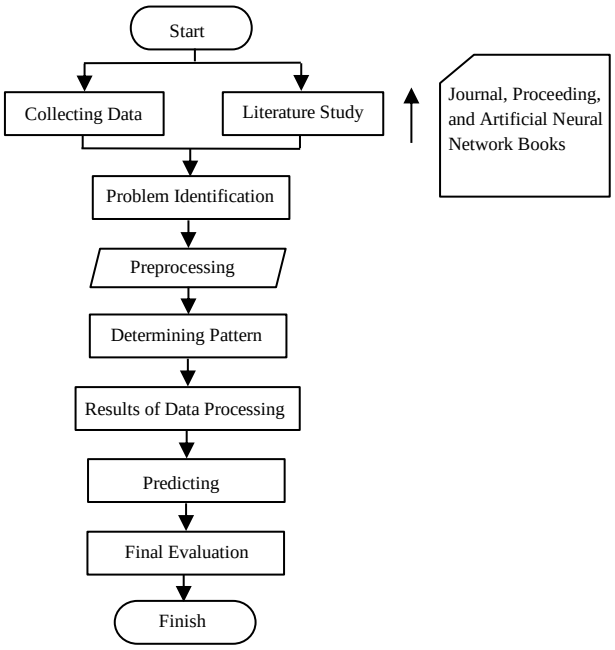

Figure 1. The research framework

Based on the framework in Figure 1, each step can be described as follows:

1. Collecting Data
   At this stage, data was obtained from the Ministry of Communication and Information, which resulted from a survey conducted by the e-Marketer, a Market Survey Institute.
2. Literature study
   The literature study was the first step in this study, and it was conducted to supplement the basic knowledge and theories used.
3. Identifying Problems
   This problem was identified after all the data had been collected. Then the appropriate dataset was obtained to be carried out at the conversion stage of the data obtained according to the specified weight.
4. Preprocessing
   The steps taken were to change several data types in the dataset attributes to facilitate understanding of the record's contents and to make selections by paying attention to the data's consistency, missing values, and redundant data.
5. Determine the Model
   The results of this stage were several models of artificial neural networks with the Backpropagation method to determine patterns.
6. Testing Data Processing Results
   After determining the complete model, the data processing results were tested using Matlab R2011b Software (7.13).
7. Predict
   Predictions were made to compare the number with the Artificial Neural Network model with the most accurate Backpropagation method.
8. Final evaluation
   A final evaluation determined whether the data processing testing results were as expected.

F. Data Used

The data used in this study was the number of Internet users in 25 major countries worldwide from 2013 to 2017 (Table 1 in the previous discussion). The training data was from 2013 to 2015, with a target for 2016. The testing data used was from 2014 to 2016, with a target for 2017.

G. Data Normalization

Before processing, the data was normalized first using the Sigmoid function (it never reaches 0 or 1), and then the data transformation was carried out at smaller intervals, namely [0.1; 0.9], indicated by equation (1).

$$x' = \frac{0.8(x-a)}{b-a} + 0.1 \quad (1)$$

Tables 2 and 3 show training data and data testing normalized using the equation (1).

Table 2. Data Training Normalization

No	Country	Input			Target
		2013	2014	2015	
1	China	0,80659	0,83353	0,86435	0,90000
2	US	0,36576	0,37388	0,38141	0,38800
3	India	0,27306	0,33000	0,37318	0,40965
4	Brazil	0,19306	0,20306	0,21012	0,21729
5	Japan	0,19400	0,19647	0,19824	0,19929
6	Indonesia	0,16200	0,17482	0,18624	0,19729
7	Russia	0,16753	0,17388	0,17906	0,18388
8	Germany	0,14635	0,14882	0,14953	0,14988
9	Mexico	0,13882	0,14624	0,15294	0,15953

No	Country	Input			Target
		2013	2014	2015	
10	Nigeria	0,13729	0,14424	0,15071	0,15765
11	UK	0,13376	0,13529	0,13788	0,13800
12	France	0,13376	0,13482	0,13576	0,13659
13	Philippines	0,12612	0,13282	0,13953	0,14588
14	Turkey	0,11941	0,12459	0,12894	0,13247
15	Vietnam	0,11941	0,12635	0,12859	0,13306
16	South Korea	0,12353	0,12388	0,12412	0,12424
17	Egypt	0,11647	0,11871	0,12141	0,12447
18	Italy	0,11694	0,11847	0,11894	0,12012
19	Spain	0,11224	0,11353	0,11435	0,11518
20	Canada	0,10894	0,10965	0,11024	0,11094
21	Argentina	0,10576	0,10824	0,11047	0,11141
22	Colombia	0,10482	0,10753	0,11000	0,11094
23	Thailand	0,10306	0,10494	0,10694	0,10882
24	Poland	0,10294	0,10329	0,10376	0,10424
25	South Africa	0,10000	0,10306	0,10576	0,10835

Table 3. Data Testing Normalization

No	Country	Input			Target
		2014	2015	2016	
1	China	0,79617	0,82555	0,85952	0,90000
2	US	0,35811	0,36528	0,37156	0,37694
3	India	0,31629	0,35744	0,39219	0,42639
4	Brazil	0,19530	0,20203	0,20887	0,21280
5	Japan	0,18903	0,19071	0,19172	0,19228
6	Indonesia	0,16840	0,17927	0,18981	0,20080
7	Russia	0,16750	0,17243	0,17703	0,18028
8	Germany	0,14362	0,14429	0,14463	0,14485
9	Mexico	0,14115	0,14754	0,15382	0,15943
10	Nigeria	0,13924	0,14541	0,15203	0,15999
11	UK	0,13072	0,13319	0,13330	0,13442
12	France	0,13027	0,13117	0,13196	0,13274
13	Philippines	0,12837	0,13476	0,14081	0,14687
14	Turkey	0,12052	0,12467	0,12803	0,13139
15	Vietnam	0,12220	0,12433	0,12859	0,13296
16	South Korea	0,11985	0,12007	0,12018	0,12041
17	Egypt	0,11491	0,11749	0,12041	0,12377
18	Italy	0,11469	0,11514	0,11626	0,11659
19	Spain	0,10998	0,11076	0,11155	0,11211
20	Canada	0,10628	0,10684	0,10751	0,10807
21	Argentina	0,10493	0,10706	0,10796	0,10875
22	Colombia	0,10426	0,10662	0,10751	0,10875
23	Thailand	0,10179	0,10370	0,10549	0,10718
24	Poland	0,10022	0,10067	0,10112	0,10146
25	South Africa	0,10000	0,10258	0,10505	0,10729

III. RESULT AND DISCUSSION

A. Analysis

Before the training was carried out, the desired parameter value was first determined to obtain optimal results. The general parameters which was later included in the Matlab 2011b application for training and testing can be seen in the following code:

```
>>net=newff(minmax(P),[Hidden,Target],{'logsig','purelin'},'traingd');
>> net.LW{1,1};
>> net.b{1};
>> net.LW{2,1};
>> net.b{2};
>> net.trainParam.epochs=10000;
>> net.trainParam.goal=0.001;
>> net.trainParam.Lr=0.01;
>> net.trainParam.show=1000;
>> net=train(net,P,T);
```

B. Result

This study used five architectures: 3-5-1, 3-7-1, 3-19-1, 3-43-1, and 3-50-1. Of these five architectures, the best architecture was 3-50-1, with an accuracy rate of 92% and epochs of as many as 4218 iterations.

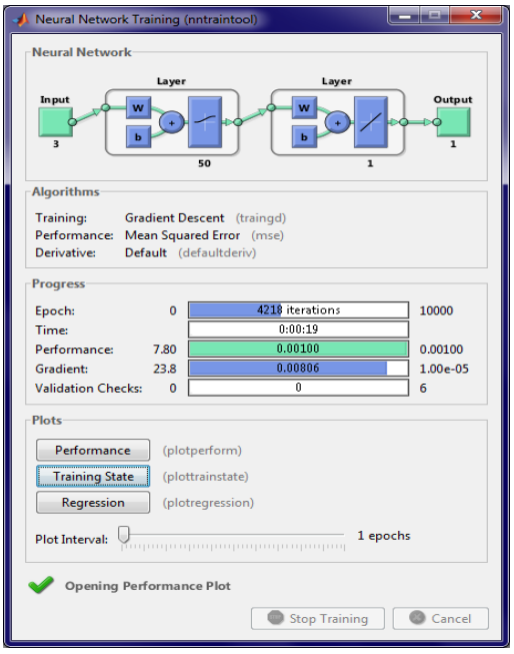

Figure 2. Best Data Training with Architecture 3-50-

Figure 2 explains that the Epoch occurred was 4218, with a duration of 19 seconds. The architectural model 3-50-1 means that 3 was the input data, 50 was a hidden layer, and 1 was the output or result.

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Table 4 shows the accuracy and MSE levels of the best architectural models, namely 3-50-1. Table 4 was created and calculated using Microsoft Excel. Based on Table 4, error was obtained from Target-Output, SSE was obtained from E3 ^ 2, Total was the Number of SSE generated from pattern No 1 to pattern No 25, and Result was obtained if the value of error in testing data <= 0.01 then the result was correct (1). If not, then the result was wrong (0). Accuracy was obtained from the correct number of results ((pattern / 25) * 100), producing 92%. Margin Error was obtained from the number of incorrect results on ((pattern / 25) * 100) or obtained from the maximum number of accuracy (100 %) minus the accuracy produced, which yields 14%. MSE was obtained from Total SSE / 25 (number of patterns). In the results column, number 1 means True while 0 means False.

Table 4. Best Architecture with Backpropagation

Data Testing					
Pola	**Target**	**Output**	**Error**	**SSE**	**Result**
1	0,90000	0,96340	-0,06340	0,00401956	1
2	0,37694	0,52770	-0,15076	0,02272718	1
3	0,42639	0,32680	0,09959	0,00991837	0
4	0,21280	0,22350	-0,01070	0,00011457	1
5	0,19228	0,21500	-0,02272	0,00051631	1
6	0,20080	0,18130	0,01950	0,00038021	0
7	0,18028	0,18280	-0,00252	0,00000635	1
8	0,14485	0,15200	-0,00715	0,00005113	1
9	0,15943	0,15460	0,00483	0,00002328	1
10	0,15999	0,15310	0,00689	0,00004742	1
11	0,13442	0,13790	-0,00348	0,00001210	1
12	0,13274	0,13710	-0,00436	0,00001901	1
13	0,14687	0,14240	0,00447	0,00001996	1
14	0,13139	0,13140	-0,00001	0,00000000	1
15	0,13296	0,13260	0,00036	0,00000013	1
16	0,12041	0,12420	-0,00379	0,00001439	1
17	0,12377	0,12410	-0,00033	0,00000011	1
18	0,11659	0,11990	-0,00331	0,00001093	1
19	0,11211	0,11480	-0,00269	0,00000724	1
20	0,10807	0,11060	-0,00253	0,00000639	1
21	0,10875	0,11140	-0,00265	0,00000705	1
22	0,10875	0,11100	-0,00225	0,00000508	1
23	0,10718	0,10890	-0,00172	0,00000297	1
24	0,10146	0,10400	-0,00254	0,00000646	1
25	0,10729	0,10880	-0,00151	0,00000229	1
			Total	0,03791849	92%
			MSE	0,00151674	

Table 5 compares the five network architecture models used. The Epoch level and time were obtained using the Matlab 2011b application, while the MSE and Accuracy of each architectural model were obtained using calculations in Microsoft Excel. Based on Table 5, the best architectural models were 3-50-1, with an accuracy rate of 92%.

Table 5. Comparison of Accuracy of All Architectural Models

No	**Architecture**	**Training**		**Testing**	
		Epoch	**Time**	**MSE**	**Accuracy**
1	3-5-1	3942	00:15	0,00093729	80%
2	3-7-1	1136	00:05	0,00071043	68%
3	3-19-1	2726	00:12	0,00113505	56%
4	3-43-1	705	00:03	0,00102460	48%
5	3-50-1	4218	00:19	0,00151674	92%

Table 6 predicts the number of internet users worldwide for 2018-2020. The results were obtained from calculations with the best architectural model (3-50-1) using the Matlab 2011b application and Microsoft Excel, just as in the previous discussion.

Table 6. Prediction of the Number of Internet Users in the World for the Next 3 Years with the Backpropagation algorithm (Year 201-2020)

No	**Country**	**Internet Users (millions)**		
		2018	**2019**	**2020**
1	China	733,0	725,9	710,5
2	US	370,5	454,7	420,9
3	India	218,2	172,0	261,4
4	Brazil	120,3	77,1	22,0
5	Japan	116,2	102,0	58,2
6	Indonesia	95,8	35,3	9,6
7	Russia	95,8	74,1	57,8
8	Germany	69,4	77,9	81,6
9	Mexico	75,6	55,0	65,1
10	Nigeria	74,5	48,8	60,1
11	UK	57,0	69,4	78,4
12	France	56,4	67,2	79,4
13	Philippines	65,0	49,6	69,3
14	Turkey	53,0	54,3	75,0
15	Vietnam	54,3	50,8	74,0
16	South Korea	43,9	60,9	76,2
17	Egypt	45,5	50,2	73,6
18	Italy	40,2	55,5	74,7
19	Spain	35,2	52,1	72,0
20	Canada	30,9	49,1	69,8
21	Argentina	32,0	48,7	70,5
22	Colombia	31,7	47,7	70,0

No	Country	Internet Users (millions)		
		2018	2019	2020
23	Thailand	30,0	43,8	68,9
24	Poland	24,2	44,5	66,2
25	South Africa	30,2	41,4	68,9

IV. CONCLUSION

From this research, several conclusions can be drawn. Firstly, employing the 3-50-1 architectural model enabled predictions with an impressive accuracy rate of 92%. Secondly, the choice of network architecture models and parameters significantly impacted the accuracy level, highlighting the importance of careful selection in model development [19][20]. Furthermore, the chosen network architecture models heavily influenced both the speed and accuracy of results, emphasizing their pivotal role in achieving desired outcomes. Lastly, one of the notable advantages of this research was the consistency between the predicted results and the initial data, indicating the reliability and effectiveness of the predictive model. For further research, exploring additional architectural models and parameter configurations is recommended to enhance prediction accuracy further. Investigating alternative approaches to network architecture selection and optimization could provide valuable insights into improving prediction performance. Additionally, conducting comparative studies with other predictive modeling techniques can offer a broader perspective on the strengths and weaknesses of different methodologies.

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