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Implementation of ANN with the Cyclical Order Method For Forecasting the Life Span of the World's Population

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Abstract

This study aims to predict the age (life expectancy) of the world's population. This research is the development of research that has been done before. But in this study only to get the best architectural model to predict the age (life expectancy) of the world's population, using the Cyclical Order method. Whereas in this follow-up research, it will produce forecasting in the form of age (life expectancy) of the population in the world based on a model that has been obtained from previous research. The research data is the age data (life expectancy) of the world's population from the United Nations: "World Population Prospect: The 2010 Revision Population Database". This study uses 5 architectural models including: 3-5-1, 3-8-1, 3-10-1, 3-5-8-1 and 3-5-10-1. Of the 5 models used, architectural models 3-5-10-1 are the best with an accuracy of 97%, the value of MSE training is 0,0009979400 and MSE testing is 0,0008358919. Forecasting results from this study are expected to be a reference for governments in the world, especially Indonesia to pay more attention to the level of health and well-being of its population so that the level of life of the population is getting better and higher.

Keywords: *ANN, Cyclical Order, Life Span, Forecasting, World Population*

1. Introduction

The life span of a population is the number of years of life in general that are still and are being lived by a person so that they reach a certain age. The benefits of knowing this include evaluating the performance of the government in improving welfare and decent life, specifically improving the health status of its population. The low life span of a population in an area/country should be directly proportional to the health development program, as well as other social programs, be it a healthy environment, adequate nutrition and calories as well as including poverty eradication programs [1]. Based on the life span of the world's population whose information was obtained from the United Nations: "World Population Prospect: The 2010 Revision Population Database" and the Indonesian Statistics Agency in 1995-2015, which is calculated every 5 years, it is noted that the country that has the lowest life span of the population in 2010-2015 Nigeria was 52,3 years, followed by Myanmar with 65,1 years. While Indonesia ranks 8th out of 38 countries with the lowest life expectancy of 70,1 years [2].

Forecasting the life span of the world's population, especially Indonesia, is important, so that each country, especially the Indonesian government, has clear references and references to make policies and strategic steps that are appropriate so that the lifespan of the world's population, especially in Indonesia, does not decrease, even increasing each year. One good method used for forecasting is the Cyclical Order method. This method is one of the methods of ANN. ANN itself is part of the Artificial Intelligence family. There are many previous studies that use the science of artificial intelligence, including Decision Support Systems [3]–[9], Data Mining [10]–[16], Search Method [17], Artificial Neural Networks [18]–[30], etc. Artificial Neural Networks are widely used for problem solving related to forecasting (prediction), pattern recognition, data analysis, control and grouping [31]. Simple Artificial Neural Networks were first introduced by McCulloch and Pitts in

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1943. McCulloch and Pitts concluded that the combination of several simple neurons into a neural system would increase their computational ability. Weights in the network proposed by McCulloch and Pitts are set to perform simple logic functions. The activation function used is the threshold function [32].

The Cyclical Order method is an artificial neural network method that trains networks with heavy and biased learning rules with additional updates after the data are presented in the input. The input data is presented in a circular order [33]. With this method, the World Life Expectancy Data will later be divided into 2 parts, namely training data and testing data, each of which has a different target. Just like other ANN methods, this method also uses parameters with hidden layer neurons to obtain the best network architecture model. This best network architecture model will be used to estimate the World Life Expectancy in the years to come [34]. In general, the method works by updating the weights and bias values according to the data presented [35].

This research is a development from previous research that discusses the prediction of Life Expectancy of the world population, but the research is still limited to getting the best architectural model, it has not yet obtained the results of its prediction. The best architectural model is the architectural model 3-5-10-1 with an accuracy of 97%, the value of MSE training is 0,0009979400 and MSE testing is 0,0008358919 [36]. Based on this background, the authors are interested in predicting the results of the life span of the World Population by using the same method that is the Cyclical Order method based on the best architectural model chosen. The results of this study are expected to contribute to the Indonesian government as a reference and reference in determining policies to improve the life expectancy of people in the Indonesian state.

2. Research Methodology

2.1. Data Source

The research data used are data on the age of the world's population in 38 countries, which began in 1995 until 2015. This data is calculated once every 5 years. Research data sourced from the Indonesian Central Statistics Agency and the United Nations: "World Population Prospect: The 2010 Revision Population Database".

Table 1. Life Age of World Population (Age / Year), 1995-2015

No	Country's	Age/Years			
		1995-2000	2000-2005	2005-2010	2010-2015
1	United States	76.4	77.1	78.1	78.9
2	Saudi Arabia	71.6	73.1	74.3	75.4
3	Australia	78.9	80.4	81.7	82.4
4	Bangladesh	64.1	66.4	68.4	70.5
5	Netherlands	77.8	78.7	80.2	80.9
6	Belgium	77.3	78.3	79.5	80.4
7	Brazil	69.4	71.0	72.4	73.8
8	China	70.9	73.4	74.4	75.2
9	Denmark	76.0	77.3	78.6	79.3
10	Russian Federation	65.7	65.0	67.2	67.9
11	The Philippines	66.4	67.1	67.8	68.6
12	Finland	77.0	78.3	79.5	80.5
13	Hong Kong SAR	79.4	81.3	82.4	83.3
14	India	61.2	63.1	64.9	66.3
15	Indonesia	66.0	67.8	69.1	70.1
16	English	77.1	78.4	79.6	80.4
17	Italy	78.7	80.2	81.5	82.3
18	Japan	80.5	81.8	82.7	83.5

No	Country's	Age/Years			
		1995-2000	2000-2005	2005-2010	2010-2015
19	German	77.2	78.6	79.8	80.7
20	Cambodia	59.8	64.5	69.5	71.6
21	Canada	78.5	79.7	80.5	81.4
22	Kazakhstan	63.0	64.6	65.7	66.4
23	South Korea	74.9	77.4	80.0	81.4
24	Kuwait	72.9	73.4	73.8	74.2
25	Malaysia	72.3	73.3	74.0	74.9
26	Mexico	68.0	69.0	69.9	71.1
27	Egypt	73.7	75.0	76.3	77.4
28	Myanmar	61.3	62.8	64.2	65.1
29	Nigeria	46.3	47.3	50.2	52.3
30	Norway	78.2	79.2	80.6	81.4
31	Pakistan	63.1	64.5	65.7	66.5
32	France	78.3	79.5	80.9	81.7
33	Singapore	77.7	79.2	81.2	82.2
34	Sri Lanka	69.1	73.2	73.4	74.2
35	Sweden	79.2	80.1	81.1	81.7
36	Thailand	70.6	71.5	73.3	74.3
37	Venezuela	72.1	72.8	73.7	74.5
38	Vietnamese	73.0	74.4	75.1	75.9

Source: United Nations: "World Population Prospect: The 2010 Revision Population Database

2.2. Research Flow

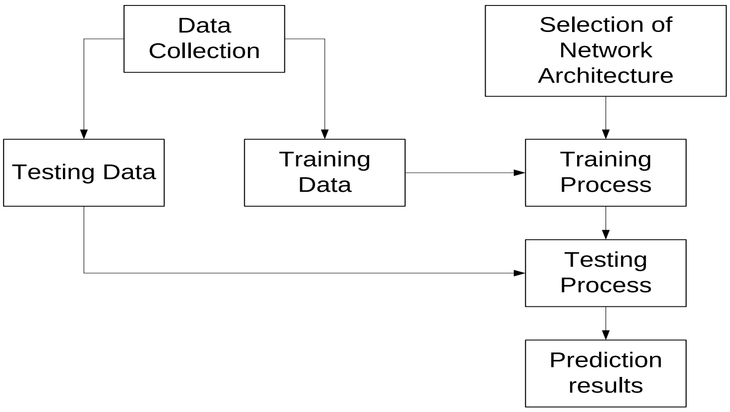

Figure 1. Research Flow

In Figure 2 it can be explained that the first thing to do is collect the research dataset. The research dataset used was data on the age of life of the world's population in 38 countries. Then the preprocessing and dividing the data is done into several parts, namely the data used for training and the data used for testing, after which the data is normalized first. After that determine the network architecture model that will be used for the training process and the testing process. After everything is done, an architectural model will be used. Furthermore, several architectural models that are used, the best is chosen. After that, a prediction will be made using the best architectural model that has been selected.

2.3. Normalization Formula

The data in table 1 will be normalized using the following formula [40]–[47]:

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

Explanation : *x*' is the result of normalization. *x* is data that will be normalized. *a* is the lowest data and *b* is the highest data from the dataset.

3. Results and Discussion

3.1. Normalized Result Data

Life data for the world's population is divided into two parts, the first data for 1995-2010 is used as training data, while the data for 2005-2010 is used as training targets. The second data from 2000-2015 is used as test data, while the data for 2010-2015 is used as test target data.

Table 2. Normalization of Training Data

Data	Input (In Years)			Target
	1995-2000	2000-2005	2005-2010	
1	0,761538	0,776923	0,798901	0,798901
2	0,656044	0,689011	0,715385	0,715385
3	0,816484	0,849451	0,878022	0,878022
4	0,491209	0,541758	0,585714	0,585714
5	0,792308	0,812088	0,845055	0,845055
6	0,781319	0,803297	0,829670	0,829670
7	0,607692	0,642857	0,673626	0,673626
8	0,640659	0,695604	0,717582	0,717582
9	0,752747	0,781319	0,809890	0,809890
10	0,526374	0,510989	0,559341	0,559341
11	0,541758	0,557143	0,572527	0,572527
12	0,774725	0,803297	0,829670	0,829670
13	0,827473	0,869231	0,893407	0,893407
14	0,427473	0,469231	0,508791	0,508791
15	0,532967	0,572527	0,601099	0,601099
16	0,776923	0,805495	0,831868	0,831868
17	0,812088	0,845055	0,873626	0,873626
18	0,851648	0,880220	0,900000	0,900000
19	0,779121	0,809890	0,836264	0,836264
20	0,396703	0,500000	0,609890	0,609890
21	0,807692	0,834066	0,851648	0,851648
22	0,467033	0,502198	0,526374	0,526374
23	0,728571	0,783516	0,840659	0,840659
24	0,684615	0,695604	0,704396	0,704396
25	0,671429	0,693407	0,708791	0,708791
26	0,576923	0,598901	0,618681	0,618681
27	0,702198	0,730769	0,759341	0,759341
28	0,429670	0,462637	0,493407	0,493407
29	0,100000	0,121978	0,185714	0,185714
30	0,801099	0,823077	0,853846	0,853846
31	0,469231	0,500000	0,526374	0,526374
32	0,803297	0,829670	0,860440	0,860440
33	0,790110	0,823077	0,867033	0,867033
34	0,601099	0,691209	0,695604	0,695604
35	0,823077	0,842857	0,864835	0,864835
36	0,634066	0,653846	0,693407	0,693407
37	0,667033	0,682418	0,702198	0,702198
38	0,686813	0,717582	0,732967	0,732967

As for the results of Normalization of test data can be seen in table 3 below.

Table 3. Normalization of Testing Data

Data	Input (In Years)			Target
	2000-2005	2005-2010	2010-2015	
1	0,758564	0,780663	0,798343	0,798343
2	0,670166	0,696685	0,720994	0,720994
3	0,831492	0,860221	0,875691	0,875691
4	0,522099	0,566298	0,612707	0,612707
5	0,793923	0,827072	0,842541	0,842541
6	0,785083	0,811602	0,831492	0,831492
7	0,623757	0,654696	0,685635	0,685635
8	0,676796	0,698895	0,716575	0,716575
9	0,762983	0,791713	0,807182	0,807182
10	0,491160	0,539779	0,555249	0,555249
11	0,537569	0,553039	0,570718	0,570718
12	0,785083	0,811602	0,833702	0,833702
13	0,851381	0,875691	0,895580	0,895580
14	0,449171	0,488950	0,519890	0,519890
15	0,553039	0,581768	0,603867	0,603867
16	0,787293	0,813812	0,831492	0,831492
17	0,827072	0,855801	0,873481	0,873481
18	0,862431	0,882320	0,900000	0,900000
19	0,791713	0,818232	0,838122	0,838122
20	0,480110	0,590608	0,637017	0,637017
21	0,816022	0,833702	0,853591	0,853591
22	0,482320	0,506630	0,522099	0,522099
23	0,765193	0,822652	0,853591	0,853591
24	0,676796	0,685635	0,694475	0,694475
25	0,674586	0,690055	0,709945	0,709945
26	0,579558	0,599448	0,625967	0,625967
27	0,712155	0,740884	0,765193	0,765193
28	0,442541	0,473481	0,493370	0,493370
29	0,100000	0,164088	0,210497	0,210497
30	0,804972	0,835912	0,853591	0,853591
31	0,480110	0,506630	0,524309	0,524309
32	0,811602	0,842541	0,860221	0,860221
33	0,804972	0,849171	0,871271	0,871271
34	0,672376	0,676796	0,694475	0,694475
35	0,824862	0,846961	0,860221	0,860221
36	0,634807	0,674586	0,696685	0,696685
37	0,663536	0,683425	0,701105	0,701105
38	0,698895	0,714365	0,732044	0,732044

3.2. Training and Testing

This study uses 5 architectural models, including: 3-5-1, 3-8-1, 3-10-1, 3-5-8-1 and 3-5-10-1. Training and test parameters using Target Minimum Error = 0.001 – 0.03, Epoch = 1000, and max_fail = 5. The method used is Cyclical order weight/bias (trainc). Of the 5 architectural models, the best architecture is 3-5-10-1 with an accuracy of 97%.

For the results of training using architectural models 3-5-10-1 can be seen in the following figure.

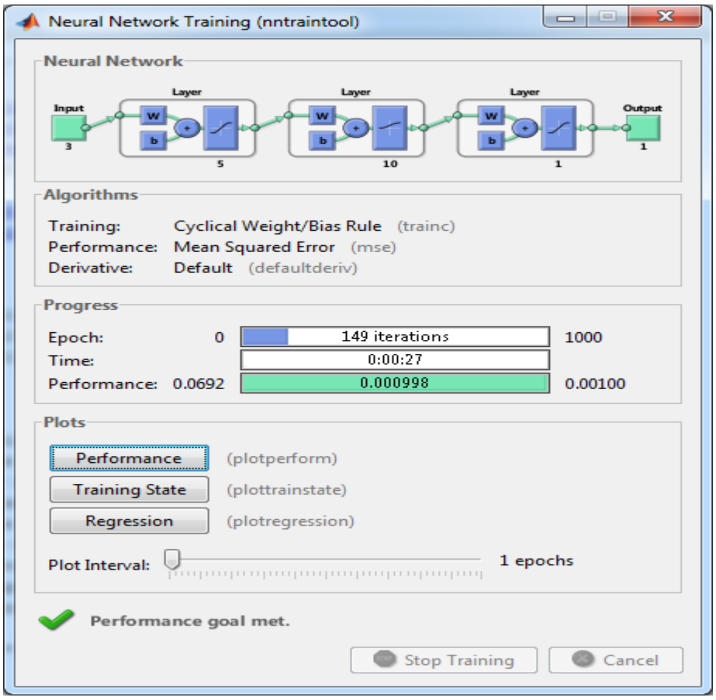

Figure 2. Training Results with Architectural Models 3-5-10-1

From figure 2 it can be explained that Epoch 149 iterations with a duration of 27 seconds, and this model is the best architecture compared to the other 4 models. For training and testing tables can be seen in table 4 and table 5 below.

Table 4. Training with Models 3-5-10-1

Data	Target	Output	Error	SSE
1	0,79890	0,85820	-0,05930	0,0035163597
2	0,71538	0,69940	0,01598	0,0002555079
3	0,87802	0,86660	0,01142	0,0001304616
4	0,58571	0,58800	-0,00229	0,0000052245
5	0,84505	0,87140	-0,02635	0,0006940619
6	0,82967	0,86800	-0,03833	0,0014691636
7	0,67363	0,64370	0,02993	0,0008955878
8	0,71758	0,66920	0,04838	0,0023408583
9	0,80989	0,84180	-0,03191	0,0010182411
10	0,55934	0,55280	0,00654	0,0000427802
11	0,57253	0,55670	0,01583	0,0002505089
12	0,82967	0,85930	-0,02963	0,0008779174
13	0,89341	0,86130	0,03211	0,0010308333
14	0,50879	0,57320	-0,06441	0,0041484924
15	0,60110	0,58910	0,01200	0,0001439736
16	0,83187	0,86060	-0,02873	0,0008255202
17	0,87363	0,86630	0,00733	0,0000536758
18	0,90000	0,87660	0,02340	0,0005475600
19	0,83626	0,86010	-0,02384	0,0005681675
20	0,60989	0,57740	0,03249	0,0010556072
21	0,85165	0,87880	-0,02715	0,0007372120

Data	Target	Output	Error	SSE
22	0,52637	0,55080	-0,02443	0,0005966477
23	0,84066	0,78680	0,05386	0,0029008286
24	0,70440	0,73130	-0,02690	0,0007238465
25	0,70879	0,71740	-0,00861	0,0000741113
26	0,61868	0,60150	0,01718	0,0002951977
27	0,75934	0,77430	-0,01496	0,0002237819
28	0,49341	0,55120	-0,05779	0,0033400778
29	0,18571	0,16000	0,02571	0,0006612245
30	0,85385	0,87320	-0,01935	0,0003745714
31	0,52637	0,54920	-0,02283	0,0005210433
32	0,86044	0,86980	-0,00936	0,0000876178
33	0,86703	0,85160	0,01543	0,0002381765
34	0,69560	0,61520	0,08040	0,0064648668
35	0,86484	0,88410	-0,01926	0,0003711339
36	0,69341	0,67800	0,01541	0,0002373631
37	0,70220	0,71290	-0,01070	0,0001145370
38	0,73297	0,74240	-0,00943	0,0000889809
			Total SSE	0,0379217218
			MSE	**0,0009979400**

Table 5. Testing with Models 3-5-10-1

Data	Target	Output	Error	SSE	Results
1	0,79834	0,85190	-0,05356	0,0028684014	1
2	0,72099	0,72110	-0,00011	0,0000000111	1
3	0,87569	0,88110	-0,00541	0,0000292615	1
4	0,61271	0,59600	0,01671	0,0002791299	1
5	0,84254	0,87000	-0,02746	0,0007539727	1
6	0,83149	0,86910	-0,03761	0,0014143833	1
7	0,68564	0,66070	0,02494	0,0006217721	1
8	0,71657	0,72800	-0,01143	0,0001305401	1
9	0,80718	0,85280	-0,04562	0,0020809727	1
10	0,55525	0,56350	-0,00825	0,0000680853	1
11	0,57072	0,55670	0,01402	0,0001965108	1
12	0,83370	0,86820	-0,03450	0,0011901356	1
13	0,89558	0,88080	0,01478	0,0002184517	1
14	0,51989	0,56110	-0,04121	0,0016983051	1
15	0,60387	0,58900	0,01487	0,0002210397	1
16	0,83149	0,87100	-0,03951	0,0015609048	1
17	0,87348	0,87940	-0,00592	0,0000350386	1
18	0,90000	0,88550	0,01450	0,0002102500	1
19	0,83812	0,87220	-0,03408	0,0011613410	1
20	0,63702	0,55990	0,07712	0,0059469661	0
21	0,85359	0,88620	-0,03261	0,0010633364	1
22	0,52210	0,52920	-0,00710	0,0000504178	1
23	0,85359	0,82570	0,02789	0,0007779168	1
24	0,69448	0,71640	-0,02192	0,0004806996	1
25	0,70994	0,72550	-0,01556	0,0002419658	1
26	0,62597	0,60950	0,01647	0,0002711572	1
27	0,76519	0,78870	-0,02351	0,0005525616	1
28	0,49337	0,53240	-0,03903	0,0015233280	1

Data	Target	Output	Error	SSE	Results
29	0,21050	0,25520	-0,04470	0,0019983370	1
30	0,85359	0,87420	-0,02061	0,0004247243	1
31	0,52431	0,53490	-0,01059	0,0001121610	1
32	0,86022	0,87570	-0,01548	0,0002395996	1
33	0,87127	0,85910	0,01217	0,0001481264	1
34	0,69448	0,71650	-0,02202	0,0004850945	1
35	0,86022	0,88790	-0,02768	0,0007661273	1
36	0,69669	0,66870	0,02799	0,0007831649	1
37	0,70110	0,70630	-0,00520	0,0000269883	1
38	0,73204	0,76570	-0,03366	0,0011327129	1
			Total SSE	0,0317638928	**97 %**
			MSE	**0,0008358919**	

3.3. Determination of the Best Architectural Model

After training and testing data on models 3-5-1, 3-8-1, 3-10-1, 3-5-8-1 and 3-5-10-1 using the help of Matlab and Microsoft Excel tools, the best architectural model is obtained 3-5-10-1 with an accuracy level of 97% or the highest accuracy compared to the other 4 models. So it is known that a margin error of 3% obtained from the maximum amount of accuracy (100%) is reduced by the resulting accuracy. The overall results of the 5 architectural models used can be seen in table 6 below.

Table 6. Comparison of Overall Results of the Architectural Model Used

No	Model	Training			Testing	
		Epoch	Time	MSE	MSE	Accuracy
1	3-5-1	703	01.58	0,0009998079	0,0011031685	92%
2	3-8-1	279	00.42	0,0010000729	0,0012539833	89%
3	3-10-1	414	01.01	0,0009996201	0,0013519990	76%
4	3-5-8-1	52	00.10	0,0009975211	0,0013937552	87%
5	3-5-10-1	149	00.27	0,0009979400	0,0008358919	97%

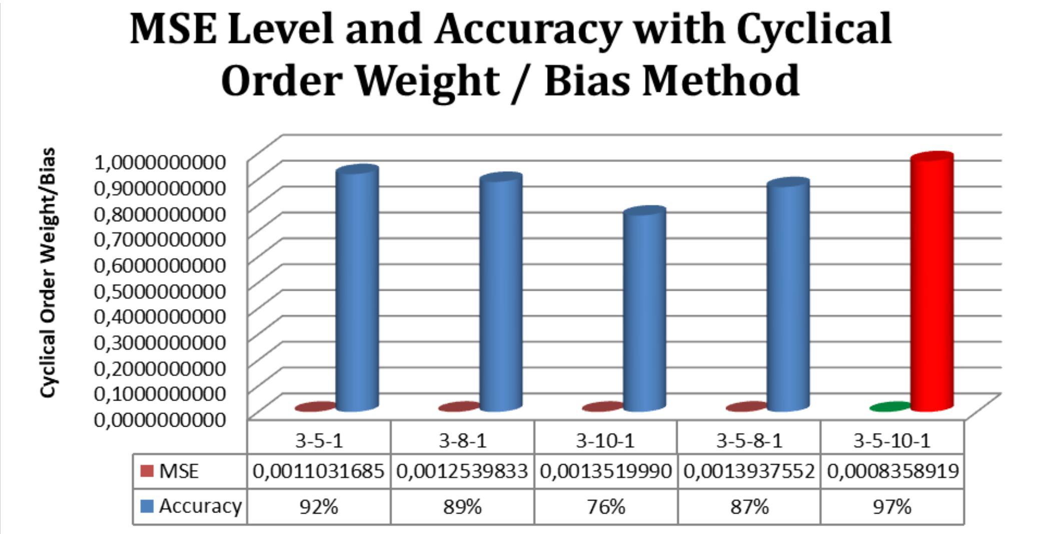

Figure 3. Tingkat MSE dan Akurasi Dengan Metode Cylical Order

Figure 3 is the level of MSE and the accuracy of the forecast life span of the world's population using the Cyclical order method. Of the 5 models used, the MSE level and accuracy have quite high scores, but the 3-5-10-1 architectural model is the best because of the higher level of accuracy and too long training time.

3.4. Prediction Results

Furthermore. predictions will be made with models 3-5-10-1 using the formula returns the value:

$$x_n = \frac{(x - 0,1) * (b - a)}{0,8} + a \quad (2)$$

The formula description can be seen in equation (1).

The prediction results of the life span of the world population in 2015-2020, 2020-2025 and 2025-2030 can be seen in the following table.

Table 7. Life Forecasting Results for World Populations

No	Country's	Forecasting Results		
		2015-2020	2020-2025	2025-2030
1	United States	81,0	79,6	77,8
2	Saudi Arabia	76,0	76,1	74,8
3	Australia	82,2	80,9	79,3
4	Bangladesh	71,8	71,2	72,1
5	Netherlands	81,7	80,2	78,9
6	Belgium	81,7	80,4	78,6
7	Brazil	73,9	80,1	77,5
8	China	76,4	73,8	73,3
9	Denmark	81,0	76,5	76,6
10	Russian Federation	71,0	79,9	76,2
11	The Philippines	70,8	72,1	71,4
12	Finland	81,6	72,4	73,6
13	Hong Kong SAR	82,2	80,1	79,8
14	India	71,1	81,2	76,9
15	Indonesia	71,8	71,5	71,8
16	English	81,8	72,2	73,1
17	Italy	82,1	80,1	79,4
18	Japan	82,3	80,8	79,7
19	German	81,8	81,2	78,7
20	Cambodia	69,7	80,2	78,5
21	Canada	82,4	73,3	75,0
22	Kazakhstan	69,9	73,0	71,6
23	South Korea	79,8	81,2	79,2
24	Kuwait	76,4	76,0	73,0
25	Malaysia	76,4	75,8	73,7
26	Mexico	72,5	72,1	71,9
27	Egypt	78,4	78,7	77,4
28	Myanmar	70,0	73,3	71,6
29	Nigeria	53,9	54,2	55,1
30	Norway	81,9	80,5	79,0
31	Pakistan	70,1	72,7	71,4
32	France	81,9	80,6	79,1
33	Singapore	81,2	81,2	79,3
34	Sri Lanka	76,4	75,0	72,5
35	Sweden	82,5	80,4	79,1

No	Country's	Forecasting Results		
		2015-2020	2020-2025	2025-2030
36	Thailand	74,0	75,2	74,2
37	Venezuela	75,7	75,5	73,4
38	Vietnamese	77,9	77,6	75,4

4. Conclusion

a. Architecture Model 3-5-10-1 can predict lifespan of the world's population with an accuracy rate of 97%.
b. Based on a comparison between preliminary research data and forecasting results, the life span of the world's population is relatively stable, the increase or decrease is not too significant.

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