Bipolar function in backpropagation algorithm in predicting Indonesia’s coal exports by major destination countries

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Abstract. Coal is one of the most widely used energy sources in the world, and Indonesia is one of the coal exporting countries. Therefore, Indonesia’s long-term availability of coal must be maintained, to support various industrial projects and the world economy. One way to maintain coal reserves is to predict the timing data of coal exports, to make it easier for the government to issue a coal export policy. In this study, the prediction method used is backpropagation algorithm. The algorithm is able to solve many problems by building a well-trained model that shows good performance in some non-linear problems. The function used is bipolar, because this function is able to calculate data whose value is not stable. The data used in this study is the data of Coal Exports in Indonesia based on the main destination countries processed from customs documents of the Directorate General of Customs and Excise and Statistics Indonesia. This study uses 3 architectural models, namely: 4-5-1, 4-10-1 and 4-15-1. The best architectural model is 4-5-1, yielding 93% accuracy, Margin error 7%, MSE 0.0117017098 with error rate 0.001-0.04. It is expected that these results can predict well.

1. Introduction

Coal is one of the fossil fuels composed of burning sedimentary rocks, formed from organic sediments, primarily the remains of plants. The main elements consist of carbon, hydrogen, nitrogen, and sulfur. Coal is also an organic rock that has complex physical and chemical properties that can be encountered in various forms. In the process of formation, coal inserted rocks containing minerals. Together with moisture, this mineral is a coal impurity so that in its utilization, the content of these two materials is very influential [1]. Coal is the primary energy source used for power generation, and currently supplies ± 41% of global electricity demand [2][3]. In Indonesia, coal is often used in the industrial world, among others as one of the energies that can produce gas, fuel supporting aluminum industrial products, helping cement products industry, helping steel products industry, assisting in the paper industry, chemical industry, pharmaceutical industry and others -other. Even the world's economy is one of them highly dependent on coal, which is driving some of the biggest advances in technology and energy efficiency in the world today [4][5][6].

Indonesia is well known as one of the largest coal producers and exporters in the world. Since 2005, when it exceeded Australian production, Indonesia has become a leading exporter of thermal coal [7]. While in 2006 to 2015 Indonesia is still exporting coal, but in the year 2014 and 2015 the number is decreasing. Based on information submitted by the Ministry of Energy and Mineral Resources of Indonesia, Indonesia's coal reserves are estimated to be depleted approximately in the next 83 years if current production levels are continued [8]. Therefore, it is necessary to predict[9], [10] the export of coal for the following years.
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[9], [11], so that the government has a reference in determining the right policies to avoid the crisis of coal inventories and so that Indonesia can still export coal even though the amount is not too large for the next years.

In this study, the technique used to predict the artificial neural network backpropagation by using the bipolar function[12]. It is expected that using this method will get predicted results as desired because backpropagation algorithm will calculate the gradient of loss inverted inference layer to convolutional layer. Thus, it will create a new type of convolution neural network [9][14][15]. Moreover, Backpropagation has been widely and successfully applied in various applications, such as pattern recognition, site selection, and performance evaluation[12][13][18]. In this research, back propagation algorithm will use the bipolar function. The bipolar sigmoid function is almost the same as the binary sigmoid function, only the output of this function has a range between 1 to -1. The bipolar sigmoid function is often used to predict time series data whose value is up and down (unstable), therefore we could readily analyze the situation of using bipolar function [15][16][21]. This study uses 3 architectural models, namely: 4-5-1, 4-10-1 and 4-15-1. The best architectural model is 4-5-1, yielding 93% accuracy, Margin error 7%, MSE 0.011701710 with error rate 0.001 - 0.04. Expected with this result, will be able to predict coal exports in Indonesia for the next 5 years (2016, 2017, 2018, 2019, 2020) well. So that can be used as a reference by the government in determining the policy of coal exports for subsequent years.

2. Methodology
2.1. Data Used
The data used in this study is the data of Coal Exports In Indonesia by the main destination countries in 2006-2015 (can be seen in Table 1). Data Processed from customs documents of the Directorate General of Customs and Excise quoted from the Publication of Statistics Indonesia.

Table 1. Export of coal in Indonesia by country of destination

| Country Of Destination | 2006         | 2007         | 2008         | 2009         | 2010         | 2011         | 2012         | 2013         | 2014         | 2015         |
|------------------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Japan                  | 35.295,7     | 35.198,5     | 36.259,8     | 32.217,7     | 35.266,7     | 35.364,0     | 35.518,3     | 37.711,5     | 35.584,6     | 32.509,0     |
| Hongkong               | 10.985,2     | 11.235,5     | 10.497,1     | 10.714,2     | 9.706,2      | 11.868,2     | 11.984,8     | 12.964,3     | 12.581,6     | 9.833,2      |
| South Korea            | 21.314,1     | 27.371,5     | 26.286,8     | 33.418,4     | 43.275,6     | 39.598,2     | 37.899,1     | 36.273,3     | 35.631,5     | 34.015,7     |
| Taiwan                 | 26.723,8     | 24.863,1     | 24.669,4     | 24.723,4     | 25.002,2     | 27.131,8     | 29.105,2     | 28.323,3     | 27.271,8     | 24.393,4     |
| China                  | 6.656,5      | 14.122,3     | 15.673,7     | 39.330,8     | 74.805,0     | 104.143,4    | 115.702,1    | 130.393,4    | 99.280,3     | 72.740,8     |
| Thailand               | 8.475,1      | 11.963,2     | 12.822,8     | 11.229,7     | 13.081,8     | 13.293,9     | 14.676,0     | 14.365,0     | 16.241,5     | 17.865,1     |
| Philippines            | 5.818,2      | 6.023,5      | 6.338,0      | 7.518,1      | 11.110,9     | 10.989,7     | 11.636,2     | 14.508,8     | 15.021,3     | 15.823,2     |
| Malaysia               | 8.782,6      | 9.376,5      | 11.104,3     | 12.483,3     | 15.535,7     | 17.337,5     | 16.138,0     | 17.128,9     | 14.949,0     | 16.567,5     |
| India                  | 20.742,4     | 25.179,1     | 26.327,5     | 39.108,9     | 51.254,3     | 74.723,2     | 96.076,0     | 118.285,5    | 136.352,1    | 124.481,5    |
| USA                    | 3.740,8      | 4.557,7      | 3.993,8      | 2.081,6      | 1.936,5      | 805,4        | 215,6        | 1.177,4      | 1.311,8      | 731,7        |
| Netherlands            | 5.690,9      | 1.266,9      | 3.740,7      | 3.384,8      | 2.719,1      | 2.848,4      | 154,3        | 172,2        | 0,0          | 82,5         |
| Italy                  | 7.637,8      | 6.193,8      | 5.592,8      | 5.797,0      | 6.306,3      | 5.080,8      | 4.082,8      | 3.016,6      | 3.516,3      | 3.106,0      |
Spain & 4.444.9 & 4.308.6 & 4.387.4 & 4.808.4 & 1.564.3 & 3.559.3 & 5.704.8 & 4.078.0 & 4.071.5 & 4.826.5 \\ Others & 17.701.0 & 14.125.7 & 13.327.6 & 7.976.8 & 7.279.8 & 6.654.3 & 5.414.0 & 5.924.0 & 6.880.1 & 9.994.3 \\ Amount & 184.009.0 & 195.785.9 & 201.021.7 & 234.793.1 & 298.844.4 & 353.398.1 & 384.307.2 & 424.325.2 & 408.238.4 & 366.970.4 \\ 

**Figure 1.** Graph export of coal in Indonesia by country of destination

Based on table 1 and figure 1 it can be explained that coal exports in Indonesia by destination country from 2006 to 2014 experienced a considerable increase, but in 2015 coal exports decreased. In table 1 and figure 1 there is no mention of the number of coal exports in 2016 and 2017, whereas the year 2016 and 2017 have passed. This is because the Directorate General of Customs and Excise quoted from the Publication of Statistics Indonesia update the data within 4 years.

2.2. Flowchart Research

Broadly speaking, the flowchart of the study in this study can be described as follows:

![Flowchart](image)

**Figure 2.** Flowchart Research

Based on the picture 2 can be explained that the data training/testing is the first data must be there and stored in the computer[17], [22], [23]. Then the training/testing data must first be normalized using the formula contained in equation (1). The normalized data will then be processed using backpropagation algorithm parameter using the bipolar sigmoid activation function. The next stage of the network will train the data training/testing based on the parameters that have been determined. After all the steps are done, it will get the best testing results that will be used to predict.
2.3. Normalization Data

The data listed in table 1 will be normalized by using the formula:

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

(1)

Explanation:

\( x' \): Transformed data  
\( x \): The data will be normalized  
\( a \): Minimum data  
\( b \): Maximum data

Coal export data will be divided into 2 parts, 2006-2009 data used as input training data, while 2010 data used as target data training. 2011-2014 data is used as training data input, while 2015 data is used as a target of test data. Based on data table 1 will get the results of normalization as follows:

**Table 2. Normalization of training data**

| Pattern | 2006      | 2007      | 2008      | 2009      | Target  |
|---------|-----------|-----------|-----------|-----------|---------|
| Pattern 1 | 0.47019   | 0.46913   | 0.48068   | 0.43670   | 0.46987 |
| Pattern 2 | 0.20572   | 0.20845   | 0.20041   | 0.20277   | 0.19181 |
| Pattern 3 | 0.31809   | 0.38398   | 0.37218   | 0.44977   | 0.55700 |
| Pattern 4 | 0.37694   | 0.35670   | 0.35459   | 0.35518   | 0.35821 |
| Pattern 5 | 0.15863   | 0.23985   | 0.25673   | 0.51409   | 0.90000 |
| Pattern 6 | 0.17842   | 0.21636   | 0.22571   | 0.20838   | 0.22853 |
| Pattern 7 | 0.14951   | 0.15175   | 0.15517   | 0.16801   | 0.20709 |
| Pattern 8 | 0.18176   | 0.18822   | 0.20702   | 0.22202   | 0.25523 |
| Pattern 9 | 0.31187   | 0.36013   | 0.37263   | 0.51167   | 0.64380 |
| Pattern 10 | 0.12691  | 0.13580   | 0.12967   | 0.10886   | 0.10728 |
| Pattern 11 | 0.14813  | 0.10000   | 0.12691   | 0.12304   | 0.11580 |
| Pattern 12 | 0.16931  | 0.15360   | 0.14706   | 0.14928   | 0.15482 |
| Pattern 13 | 0.13457  | 0.13309   | 0.13395   | 0.13853   | 0.10324 |
| Pattern 14 | 0.27878  | 0.23989   | 0.23120   | 0.17300   | 0.16541 |

**Table 3. Normalization of Testing Data**

| Pattern | 2011      | 2012      | 2013      | 2014      | Target  |
|---------|-----------|-----------|-----------|-----------|---------|
| Pattern 1 | 0.30713   | 0.30803   | 0.32091   | 0.30842   | 0.29037 |
| Pattern 2 | 0.16919   | 0.16988   | 0.17563   | 0.17338   | 0.15724 |
| Pattern 3 | 0.33199   | 0.32201   | 0.31247   | 0.30870   | 0.29921 |
| Pattern 4 | 0.25880   | 0.27038   | 0.26579   | 0.25962   | 0.24272 |
| Pattern 5 | 0.71091   | 0.77877   | 0.86502   | 0.68236   | 0.52656 |
| Pattern 6 | 0.17756   | 0.18567   | 0.18385   | 0.19486   | 0.20440 |
| Pattern 7 | 0.16403   | 0.16783   | 0.18469   | 0.18770   | 0.19241 |
| Pattern 8 | 0.20130   | 0.19426   | 0.20007   | 0.18461   | 0.19678 |
| Pattern 9 | 0.53819   | 0.66355   | 0.79395   | 0.90000   | 0.83031 |
| Pattern 10 | 0.10424  | 0.10078   | 0.10643   | 0.10722   | 0.10381 |
| Pattern 11 | 0.11624  | 0.10042   | 0.10053   | 0.09952   | 0.10000 |
### Data

| Pattern 12 | 2011     | 2012     | 2013     | 2014     | Target  |
|------------|----------|----------|----------|----------|---------|
| Pattern 13 | 0.12041  | 0.13301  | 0.12346  | 0.12342  | 0.12785 |
| Pattern 14 | 0.13858  | 0.13130  | 0.13429  | 0.13991  | 0.15819 |

#### 3. Results And Discussion

This research uses 3 architectural models with 2 hidden and 2 outputs, among others: 4-5-1, 4-5-10, and 4-5-15. Training and test parameters using Target Minimum Error = 0.001 - 0.05, Maximum Epoch = 100000, and Learning Rate = 0.01. The Backpropagation algorithm will be combined with the bipolar sigmoid activation function (tansig). Broadly speaking, the analysis of this combination will be applied using Matlab 2011. The program listing can be seen as follows:

```matlab
>> net=newff(minmax(P),[Hiden,Target],{'tansig','tansig'},'traingd');
>> net.LW{1,1};
>> net.b{1};
>> net.LW{2,1};
>> net.b{2};
>> net.trainParam.epochs=100000;
>> net.trainParam.goal = 0.001;
>> net.trainParam.Lr = 0.01;
>> net.trainParam.show = 1000;
>> net=train(net,P,T)
```

Note: ‘tansig’ is a bipolar sigmoid activation function that will be incorporated into the matlab application.

This research uses 3 architectural models. Among others are 4-5-1, 4-10-1, and 4-15-1. Of the 3 models of this architecture, the best architecture is 4-5-1 with an accuracy of 93%.

![Figure 3. Training with architecture 4-5-1](image-url)
From the picture above, a 4-5-1 architectural model can be explained that the epoch that occurred for 39814 with a duration of 4 minutes 43 seconds.

**Table 4. Best architecture results with Model 4-5-1**

| Pattern | Target | Output | Error | SSE   | Target | Output | Error | SSE   | Results |
|---------|--------|--------|-------|-------|--------|--------|-------|-------|---------|
| Pattern 1 | 0.46987 | 0.46020 | 0.00967 | 0.0000935886 | 0.29037 | 0.42170 | -0.13133 | 0.0172484242 | 1 |
| Pattern 2 | 0.19181 | 0.22330 | -0.03149 | 0.0009916997 | 0.15724 | 0.16010 | -0.00286 | 0.0000081591 | 1 |
| Pattern 3 | 0.55700 | 0.61390 | -0.05690 | 0.0032375353 | 0.29921 | 0.35760 | -0.05839 | 0.0034091410 | 1 |
| Pattern 4 | 0.35821 | 0.34550 | 0.01271 | 0.0001615328 | 0.24272 | 0.43730 | -0.19458 | 0.0378604549 | 1 |
| Pattern 5 | 0.90000 | 0.84420 | 0.05580 | 0.0031136400 | 0.52656 | 0.51080 | 0.01576 | 0.0002482572 | 1 |
| Pattern 6 | 0.22853 | 0.25870 | -0.03017 | 0.0009910173 | 0.20440 | 0.19370 | -0.00286 | 0.0000081591 | 1 |
| Pattern 7 | 0.64380 | 0.63380 | 0.01000 | 0.0000999731 | 0.83031 | 0.51090 | 0.31941 | 0.1020234439 | 0 |
| Pattern 8 | 0.10728 | 0.13080 | -0.02352 | 0.0005529840 | 0.10381 | 0.12780 | -0.01005 | 0.0001010003 | 1 |
| Pattern 9 | 0.11580 | 0.10450 | 0.01130 | 0.0001276464 | 0.10000 | 0.11530 | -0.01530 | 0.0002349090 | 1 |
| Pattern 10 | 0.15482 | 0.13470 | 0.02012 | 0.0004049027 | 0.11775 | 0.12780 | -0.01005 | 0.0001010003 | 1 |
| Pattern 11 | 0.10324 | 0.14080 | -0.03756 | 0.0014111045 | 0.12785 | 0.14030 | -0.01245 | 0.0001549858 | 1 |
| Pattern 12 | 0.16541 | 0.15260 | 0.01281 | 0.0001641633 | 0.15819 | 0.13770 | 0.02049 | 0.0004198136 | 1 |

**Table 5. Architectural Results Bipolar Function In Backpropagation**

| Architecture | Epoch | Time | MSE | Accuracy |
|--------------|-------|------|-----|----------|
| 4-5-1        | 39814 | 04:43| 0.0117017098 | 93%      |
| 4-10-1       | 15516 | 01:36| 0.0366863418 | 86%      |
| 4-15-1       | 5851  | 00:36| 0.0070593182 | 86%      |
Figure 4. Graph of Bipolar Function In Backpropagation

Based on table 5 and figure 4 it can be explained that the best architectural model of 3 architectural model used is 4-5-1 with 93% accuracy level, 4:43 pm, Epoch 39814 iteration and MSE 0.0117017098. From Figure 4 it is also known that a 7% margin error is obtained from the maximum amount of accuracy (100%) reduced by the resulting accuracy.

Table 6. Prediction Results 5 Years Ahead With Bipolar Function (the Year 2016-2020)

| Country Of Destination | 2016     | 2017     | 2018     | 2019     | 2020     |
|------------------------|----------|----------|----------|----------|----------|
| Japan                  | 33.732,4 | 38.794,4 | 42.471,5 | 34.743,2 | 25.837,9 |
| Hongkong               | 8.292,8  | 9.165,4  | 4.731,9  | 10.469,8 | 15.942,6 |
| South Korea            | 36.500,3 | 40.645,3 | 49.437,8 | 42.455,9 | 48.575,8 |
| Taiwan                 | 17.094,1 | 17.537,2 | 13.642,0 | 6.504,6  | 7.969,4  |
| China                  | 64.645,6 | 64.308,6 | 49.717,7 | 57.601,5 | 62.984,5 |
| Thailand               | 9.365,8  | 9.151,1  | 8.510,5  | 8.075,1  | 15.330,4 |
| Philippines            | 10.065,5 | 8.268,4  | 10.205,5 | 8.463,9  | 14.689,7 |
| Malaysia               | 7.841,9  | 8.909,1  | 6.862,2  | 8.619,4  | 16.198,9 |
| India                  | 120.049,8| 97.767,5 | 86.757,5 | 70.476,8 | 59.282,6 |
| USA                    | 7.002,2  | 15.529,7 | 13.346,5 | 11.309,5 | 338.207,9 |
| Netherlands            | 6.147,0  | 16.526,3 | 12.911,1 | 11.465,0 | 14.120,1 |
| Italy                  | 6.411,3  | 14.632,7 | 9.785,6  | 10.765,3 | 14.091,7 |
| Spain                  | 6.986,6  | 14.063,2 | 12.055,9 | 10.081,1 | 13.564,9 |
| Others                 | 7.157,7  | 11.429,2 | 12.195,9 | 8.883,7  | 13.963,5 |
| Amount                 | 343.309,0| 368.745,1| 334.649,7| 301.933,7| 338.207,9 |

4. Conclusion
The conclusions that can be drawn from this research are:
a. The 4-5-1 architecture model using the bipolar function in Backpropagation can predict with 93% Accuracy and margin error 7%.
b. The activation function, network model, and parameters used greatly affect the level of accuracy and quality of prediction.
c. It is hoped that this result will help the government in determining the right policies in the future related to the export of coal in Indonesia to the main destination countries.

References

[1] S. D. Killops and V. J. Killops, *Introduction to Organic Geochemistry*. 2013.

[2] S. Dai and R. B. Finkelman, “Coal as a promising source of critical elements: Progress and future prospects,” *Int. J. Coal Geol.*, 2017.

[3] J. Yuan, C. Na, Q. Lei, M. Xiong, J. Guo, and Z. Hu, “Coal use for power generation in China,” *Resour. Conserv. Recycl.*, pp. 1–11, 2016.

[4] S. Massari and M. Ruberti, “Rare Earth Elements as Critical Raw Materials: Focus on International Markets and Future Strategies,” *Resour. Policy*, vol. 38, no. 1, pp. 36–43, 2012.

[5] J. Hower, E. Granite, D. Mayfield, A. Lewis, and R. B. Finkelman, “Notes on Contributions to the Science of Rare Earth Element Enrichment in Coal and Coal Combustion Byproducts,” *Minerals*, vol. 6, no. 32, pp. 1–9, 2016.

[6] A. S. Ahmar *et al.*, “Modeling Data Containing Outliers using ARIMA Additive Outlier (ARIMA-AO),” *J. Phys. Conf. Ser.*, vol. 954, no. 1, 2018.

[7] B. Lucarelli, “The History and Future of Indonesia’s Coal Industry: Impact of Politics and Regulatory Framework on Industry Structure and Performance,” 2010.

[8] Indonesia Coal Mining Association, “Indonesia Coal Industry Update 2016,” in *JOGMEC Coal Investment Seminar*, 2016, no. January, p. 24.

[9] U. Khair, H. Fahmi, S. Al Hakim, and R. Rahim, “Forecasting Error Calculation with Mean Absolute Deviation and Mean Absolute Percentage Error,” *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 012002, Dec. 2017.

[10] P. Harliana and R. Rahim, “Comparative Analysis of Membership Function on Mamdani Fuzzy Inference System for Decision Making,” *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 012029, Dec. 2017.

[11] K. M. Kitani, B. D. Ziebart, J. A. Bagnell, and M. Hebert, “Activity forecasting,” in Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 2012, vol. 7575 LNCS, no. PART 4, pp. 201–214.

[12] R. Rahim, T. Afriliansyah, H. Winata, D. Nofriansyah, Ratnadewi, and S. Aryza, “Research of Face Recognition with Fisher Linear Discriminant,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 300, p. 012037, 2018.

[13] P. Witoonchart and P. Hongstitvatana, “Structured SVM Backpropagation To Convolutional Neural Network Applying To Human Pose Estimation,” *J. LATEX*, vol. 92, pp. 39–46, 2017.

[14] S. Putra Siregar and A. Wanto, “Analysis Accuracy of Artificial Neural Network Using Backpropagation Algorithm In Predicting Process (Forecasting),” *Int. J. Inf. Syst. Technol.*, vol. 1, no. 1, pp. 34–42, 2017.

[15] M. Fauzan *et al.*, “Epoch Analysis and Accuracy 3 ANN Algorithm Using Consumer Price Index Data in Indonesia,” 2018.

[16] A. Wanto, M. Zarlis, Sawaluddin, and D. Hartama, “Analysis of Artificial Neural Network Backpropagation Using Conjugate Gradient Fletcher Reeves in the Predicting Process,” *J. Phys. Conf. Ser.*, vol. 930, no. 1, pp. 1–7, 2017.

[17] R. Rahim, S. Nurarif, M. Ramadhan, S. Aisyah, and W. Purba, “Comparison Searching
Process of Linear, Binary and Interpolation Algorithm,” *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 012007, Dec. 2017.

[18] A. Wanto *et al.*, “Analysis of Standard Gradient Descent with GD Momentum And Adaptive LR for SPR Prediction,” 2018.

[19] Yunong Zhang and Ke Chen, “Comparison on Zhang Neural Network and Gradient Neural Network for Time-Varying Linear Matrix Equation $AXB = C$ Solving,” *2008 IEEE Int. Conf. Ind. Technol.*, pp. 1–6, 2008.

[20] Q. Zhang, X. ku Zhang, and N. kyun Im, “Ship Nonlinear-Feedback Course Keeping Algorithm Based on MMG Model Driven by Bipolar Sigmoid Function for Berthing,” *Int. J. Nav. Archit. Ocean Eng.*, vol. 9, no. 5, pp. 525–536, 2017.

[21] A. Wanto *et al.*, “Levenberg-Marquardt Algorithm Combined with Bipolar Sigmoid Function to Measure Open Unemployment Rate in Indonesia,” 2018.

[22] R. Rahim, A. S. Ahmar, A. P. Ardyanti, and D. Nofriansyah, “Visual Approach of Searching Process using Boyer-Moore Algorithm,” *J. Phys. Conf. Ser.*, vol. 930, no. 1, p. 012001, Dec. 2017.

[23] R. Rahim, I. Zulkarnain, and H. Jaya, “A review: search visualization with Knuth Morris Pratt algorithm,” in *IOP Conference Series: Materials Science and Engineering*, 2017, vol. 237, no. 1, p. 012026.