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Research Article

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Prediction of gas emission quantity using artificial neural networks

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ABSTRACT

Gas emission quantity is a crucial factor in the productive process of coal mine. However, because of the complexity of determination, the measuring process is time consuming with a series of norms and manipulations. In our study, we aimed at using the Artificial Neural Networks (ANN) with known experimental data to predict the gas emission quantity. We took seam gas content, embedding depth of coal seam, coal bed thickness, coal bed pitch, working thickness, the length of working face, advancing speed, recovery ratio, gas emission quantity in adjacent layer, the thickness in adjacent layer, the interlayer distance, lithology of interlayer, mining intensity as the independent variables while the gas emission quantity as the dependent variables. By analyzing 18 data groups using General Regression Neural Network (GRNN) and Multilayer Feedfoward Neural Network (MLFN) methods, we found that GRNN model is the best model for predicting the gas emission quantity, with the RMS error 0.50. Results proved that GRNN model is accurate and robust.

Keywords: gas emission quantity, Artificial Neural Network, General Regression Neural Network, Multilayer Feedfoward Neural Network.

INTRODUCTION

Background

Gas is one of the insecurity factors in the productive process of mine. It is the main cause of the mine accident. Gas emission quantity is a crucial factor in security technology of aeration and management [1], hence the accuracy of prediction will directly impacts the economic technological indexes of mine, especially for the large mine. When the prediction is on the low side, ventilation needs modify soon after production, otherwise the production may reduce. In contrast, when the prediction is on the high side, it may cause a great waste of resources to some extent. Therefore, establishing a correct approach to predict this property is a great prerequisite to ensure the safety of production.

The factors that make great influence on the gas emission quantity are complex, and we must clearly realize that only by choosing the correct factors as the independent variables can we ensure a precise and robust model in predicting such property.

Principle of Artificial Neural Networks

Artificial neural networks (ANNs) are computational models inspired by animals' central nervous systems that are capable of machine learning and pattern recognition [2-3]. They are usually presented as systems of interconnected "neurons" that can calculate different values from inputs by feeding information through the network. As the development of the algorithm, this method is mature and has been packed into a module of the software. Represented by nonlinear functions, Artificial Neural network analysis is an artificial intelligence (AI) approach to modeling.

In natural conditions, elements form groups and connect each other as neurons within the discrete layer. Each connection of them has its identified weight coefficient. The multiple layer consisted of the structure of such network. Usually, there are one or more than one layers of the elements followed by an output layer. Multiple layers of elements can drive the network to learn nonlinear and linear relationships between input and output vectors.

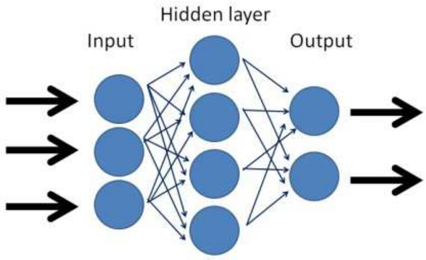

Figure 1.A schematic view of artificial neural network structure

Figure 1 shows the main structure of the ANN [4]. It is mainly made up of input layer and output layer. The input layer introduces the input variables to the network. The output of the nodes in this layer represents the predictions made by the network for the response variables. In addition, it contains hidden layers. The optimal number of neurons in the hidden layers depends on the type and complexity of the process or experimentation and it's usually iteratively determined.

EXPERIMENTAL SECTION

Training process of ANN models

The ANN prediction models were constructed by the NeuralTools® Software (Trial Version, Palisade Corporation, NY, USA). We chose the General Regression Neural Networks (GRNN) [5] module and Multilayer Feedfoward Neural Networks (MLFN) [6] module as the training modules. All the measured data of predictive index were provided by the researches of Cai and his co-workers [7]. According to the previous studies, we considered that the seam gas content, embedding depth of coal seam, coal bed thickness, coal bed pitch, working thickness, the length of working face, advancing speed, recovery ratio, gas emission quantity in adjacent layer, the thickness in adjacent layer, the interlayer distance, lithology of interlayer, mining intensity should be seem as the independent variables, which play important roles in gas emission quantity. There are 18 sample groups, from which we chose 11 groups as the training set, the rest of which are the testing set.

Two groups of models were established, in order to find out the best model, experiments of each property were done repeatedly, with GRNN model, and MLFN model with different nodes (nodes were set from 2 to 16), ensuring the model we found are the most robust one. The training processes are shown as table 1:

Table 1. Results of different models in predicting gas emission quantity

ANN Model	Trained Samples	Tested Samples	RMS Error	Training Time	Finishing Reason
GRNN	11	7	0.50	0:00:00	Auto-Stopped
MLFN 2 Nodes	11	7	1.90	0:40:25	Auto-Stopped
MLFN 3 Nodes	11	7	0.74	0:40:56	Auto-Stopped
MLFN 4 Nodes	11	7	1.82	0:44:30	Auto-Stopped
MLFN 5 Nodes	11	7	1.11	0:47:25	Auto-Stopped
MLFN 6 Nodes	11	7	1.26	0:51:41	Auto-Stopped
MLFN 7 Nodes	11	7	1.47	0:51:16	Auto-Stopped
MLFN 8 Nodes	11	7	4.39	0:52:39	Auto-Stopped
MLFN 9 Nodes	11	7	1.35	0:56:31	Auto-Stopped
MLFN 10 Nodes	11	7	1.31	0:57:41	Auto-Stopped
MLFN 11 Nodes	11	7	10.69	1:04:38	Auto-Stopped
MLFN 12 Nodes	11	7	12.10	1:07:20	Auto-Stopped
MLFN 13 Nodes	11	7	7.86	1:09:22	Auto-Stopped
MLFN 14 Nodes	11	7	15.25	1:11:21	Auto-Stopped
MLFN 15 Nodes	11	7	17.40	1:13:42	Auto-Stopped

Table 1 shows that the GRNN model can generate the lowest RMS error (0.50), indicating that the GRNN model is the best model to predict the gas emission quantity during the training experiments.

RESULTS AND DISCUSSION

Training and testing results of GRNN model

For more intuitionistic, the training results of GRNN model are presented in the form of figures, which are shown as figure 2 to 4:

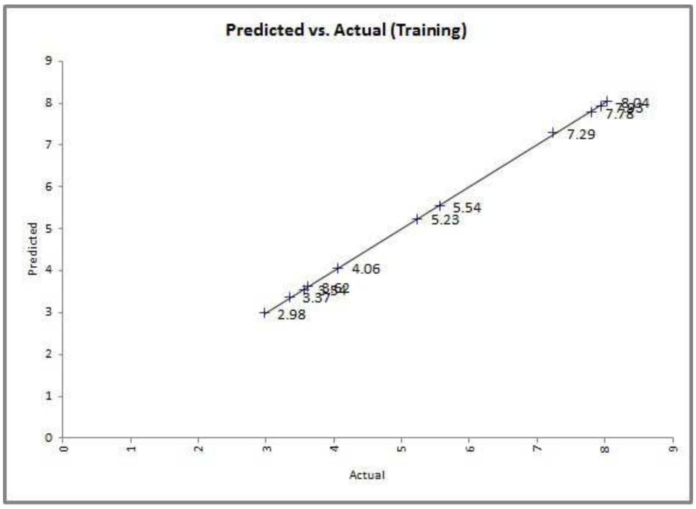

Figure 2.Comparison between predicted values and actual values in training process

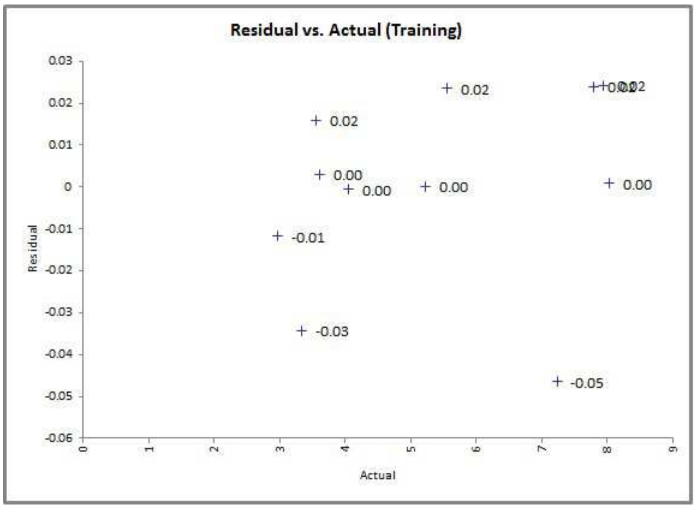

Figure 3.Comparison between residual values and actual values in training process

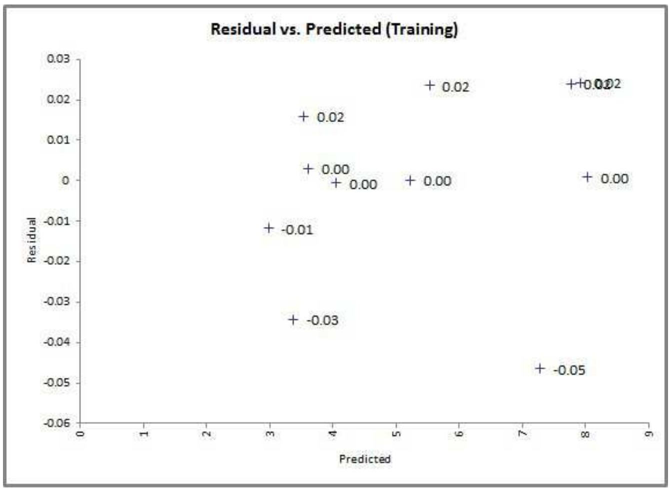

Figure 4.Comparison between residual values and predicted values in training process

Figures 2 to 4 depict that the training process of GRNN model is correct and robust since the predicted values and actual values are very close and, residual values are concentrate on the zero area with the permission error.

In addition, the testing results of GRNN model are presented in the form of figures, which are shown as figure 5 to 7:

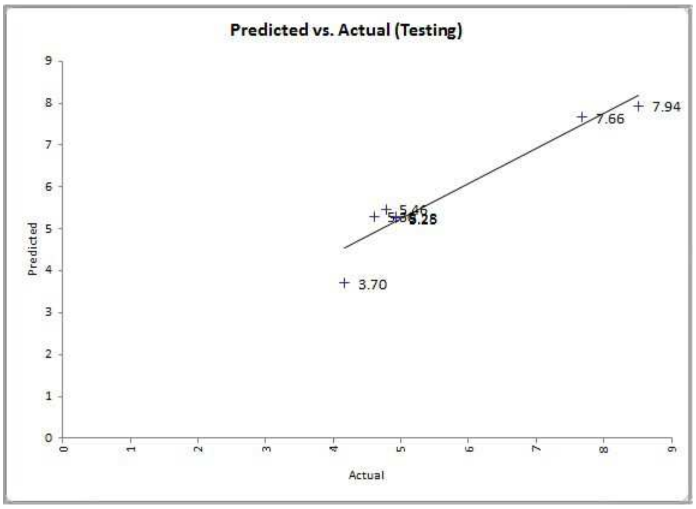

Figure 5.Comparison between predicted values and actual values in testing process

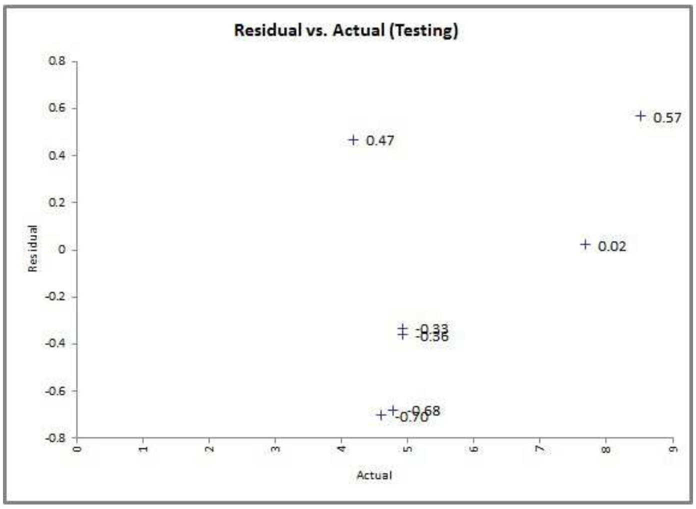

Figure 6.Comparison between residual values and actual values in testing process

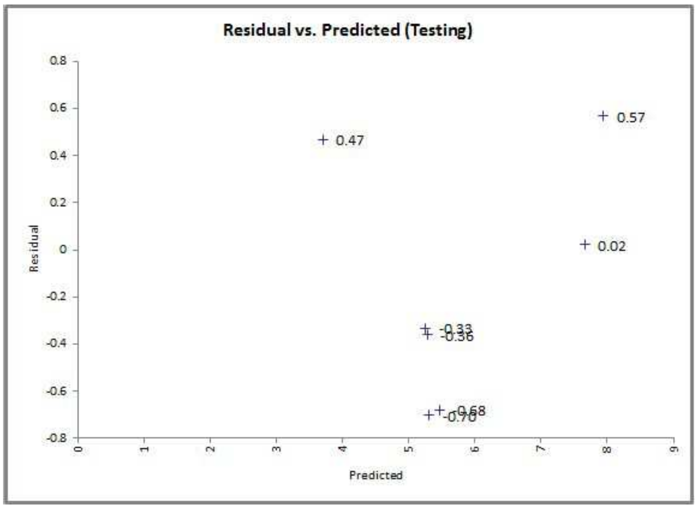

Figure 7.Comparison between residual values and predicted values in testing process

Figures 5 to 7 depict that the testing process of GRNN model is correct and robust since the predicted values and actual values are very close and, residual values are concentrate on the zero area with the permission error.

According to the training and testing results shown on Figures 2 to 7, GRNN model is proved to be robust and precise in predicting the gas emission quantity, with different respects of independent variables.

CONCLUSION

Gas emission quantity is a crucial factor in the productive process of coal mine. Because of the difficulty of determination, it is difficult to obtain the precise value of gas emission quantity. In our study, instead of calculating the values by partial regression square sum, it is possible to use the artificial neural networks with known experimental data to make a prediction. By analyzing 18 data groups using General Regression Neural Network (GRNN) and Multilayer Feedfoward Neural Network (MLFN) methods, we developed a GRNN model to predict the Gas emission quantity. Results have proved that this model is accurate and robust.

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