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Research on Prediction and Optimization of Slope Deformation in Mining Area

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Abstract: In this paper, a total of 25 periods of data from 3# monitoring points in the direction of the main slide of the slope were selected for model prediction accuracy validation. According to the volatility of the slope deformation detection data in the mining area, the slope deformation were predicted by three methods: conventional GM(1,1) model, the Autoregressive Integrated Moving Average model and BP neural network.

1. Introduction

The deformation of the slope of the mining area is a complex nonlinear dynamic system, which will be affected by various factors such as natural and artificial factors. This makes the slope monitoring data have greater volatility. If the displacement is measured from the aspects of engineering geology and mechanics, it is very difficult to accurately predict deformation. Therefore, compared with the deterministic model that needs to combine a large number of comprehensive data such as geological conditions and rock and soil materials, statistical models and nonlinear models are more widely used in the field of slope prediction.

The more classic statistical models are the gray prediction model and the Autoregressive Integrated Moving Average (ARIMA) model. Among them, GM(1,1) Models are widely used, and various improved models, fusion models, and prediction models corresponding to different sequence types have also emerged [1-4]. BP neural network is currently One of the most widely used neural network models, suitable for the study of slope prediction in mining areas.

In this paper, three methods are used to predict the slope deformation in the mining area, and the results are compared and analyzed with the actual value.

2. The algorithmic theories

2.1 GM (1,1)

$\boldsymbol{Step1}$: Set the original non-negative monitoring data sequence that has passed the quasi-exponential law test, residual error and grade ratio deviation test to $X(0)$, namely:

$$X^{(0)} = \{x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(n)\}$$

Among them, n is the number of elements in the sequence

$\boldsymbol{Step2}$: In order to weaken the randomness of the data and strengthen the regularity of the data [5] the original data is accumulated once to obtain the $1{-}AGO$ sequence $X(1)$ of $X(0)$, namely:

$$X^{(1)} = \{x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(n)\}$$

$\boldsymbol{Step3}$: To $X(1)$, construct a sequence $Z1$ that is mean generation with consecutive neighbors, namely:

$$Z^{(1)} = \{z^{(1)}(2), z^{(1)}(3), \cdots, z^{(1)}(n)\}$$

$\boldsymbol{Step4}$: Establish a gray differential equation for the cumulative sequence $X(1)$, namely:

$$x^{(0)}(k) + az^{(1)}(k) = b, k = 2,3, \cdots, n$$

$\boldsymbol{Step5}$: The estimated values $\hat{a}, \hat{b}$ of the parameters a, b can be obtained by using the least square method, and the corresponding whitening equation is:

$$\frac{dx^{(1)}(t)}{dt} = -\hat{a}x^{(1)}(t) + \hat{b}$$

$\boldsymbol{Step6}$: The prediction function of the original sequence $X(0)$ can be obtained by cumulative decrease, namely:

$$\hat{x}^{(0)}(k+1) = \hat{x}^{(1)}(k+1) - \hat{x}^{(1)}(k), k = 1,2, \cdots, n-1$$

2.2 ARIMA model

The ARIMA(p,d,q) model actually converts non-stationary data to stationary data on the time series and then regresses the time variables on the lagged values of the data as well as the random error term to predict them. The mathematical definition of the model is as follows:

$$y_t = u + \sum_{i=1}^{p} r_i y_{i-1} + \epsilon_t + \sum_{i=1}^{q} \theta_i \epsilon_{t-i}$$

Among them, y_t is the predicted value of the time series; u is a constant term; ϵ_t is assumed to be a random error value with a mean equal to zero and a constant standard deviation, r_i is the autocorrelation coefficient, and θ_i is the correlation coefficient of the MA formula.

2.3 BP neural network

The artificial neural network method has strong nonlinear mapping ability and is suitable for the analysis of multi-variable nonlinear systems. The complex nonlinear relationship between slope displacement deformation and influencing factors is consistent with this characteristic [6]. Therefore, in recent years, the method of artificial neural network to predict slope deformation has gradually been popularized and used, and BP neural network is one of the most widely used neural network models.

3. Application analysis

The conventional GM(1,1) model, ARIMA model and BP neural network were used for prediction and comparative analysis of accuracy.

Table 1 Predictive effects of the three models

phase	measured	Regular GM (1,1)		BP neural network		ARIMA（1,3,0）	
		predicted	relative	predicted	relative	predicted	relative
	value/mm	value/mm	error	value/mm	error	value/mm	error
22	7.30	7.685	5.27%	7.320	0.28%	7.332	0.44%
23	7.32	8.055	10.04%	7.363	0.86%	7.424	1.70%
24	7.34	8.443	15.02%	7.391	1.25%	7.557	3.52%
25	7.35	8.849	20.40%	7.407	1.47%	7.740	6.03%
Average relative error	-	-	12.68%	-	0.96%	-	2.92%

It can be seen from Table2 that the average relative errors of the prediction results of the conventional GM(1,1) model, ARIMA model and BP neural network are 12.68%, 2.92% and 0.96%, respectively. Among them, the conventional GM(1,1) model has the worst prediction effect, and the relative error increases gradually with the increase of the number of periods. The 25th period has reached 17.37%; the BP neural network has the best prediction effect, combined with Fig. 3 Look, the prediction result of the neural network fits the measured value curve better. It can be considered that in this example application, the prediction of the BP neural network better reflects the development trend of slope deformation in the mining area. Compared with the IGM-LSSVM model proposed by the domestic scholar Feng Tengfei [7] for this example data, the BP neural network used in this article shows better accuracy and fit.

4. Conclusion

Based on the slope deformation monitoring data of a certain mining area, this paper uses conventional GM(1,1) model, ARIMA model and BP neural network to predict the displacement of slope deformation. The results show that the BP neural network has better applicability and prediction accuracy, with an average relative error of only 0.96%, which is very consistent with the actual deformation trend of the mining slope. The prediction accuracy of the ARIMA model is average at 2.92%, while the prediction accuracy of the conventional GM(1,1) model is poor at 12.68%.

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