Model Of Difficulty Coal Seam Water Injection Based on Bayes Discriminant Analysis

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Abstract. Based on the basic idea of Bayes discriminant analysis method, the Bayes discriminant analysis model for the difficulty of coal seam water injection was established. This model selects seven indicators, namely burial depth, crack development degree, porosity, wetting edge angle, solidity coefficient, saturated water increment, and gas pressure, as discriminant factors. The difficulty of coal seam water injection is divided into three levels as three normal populations for Bayes discriminant analysis. Taking 23 groups of actual data of coal seam water injection project as training samples, Bayes discriminative model is established. Perform cross validation on 23 sets of measured data to obtain the accuracy of the model. Finally, Bayes discriminative model is applied to the actual coal seam water injection project. The research results show that the Bayes discriminant analysis model has a lower misjudgment rate and can be better applied in practical engineering.

1. INTRODUCTION

With the deepening of coal seam water injection technology, the evaluation of the difficulty of coal seam water injection is becoming more and more important. The effect of coal seam water injection is closely related to the physical structure of macroscopic water injection and the chemical characteristics of microscopic wetting[1,2]. Coal seam water injection is to inject high-pressure water into coal seam bedding, joints, pores and cracks before coal mining, so as to expand the original cracks in the coal rock body and increase the moisture in the coal body. The factors affecting the difficulty of coal seam water injection have not yet been uniformly regulated, and the influencing factors can be simply divided into geological and coal body factors and technological factors, of which the former plays a major role in the difficulty of coal seam water injection.

Scholars have conducted research on the physical and chemical water injection effect of coal seams. Zhen Liu et al.[3] pointed out that the structure and seepage characteristics of coal samples around the borehole determine the effect of water injection. Yijie Shi et al. [4] used Fluent to discuss the influence of water injection process parameters such as water injection time, water injection pressure, wellbore diameter and characteristic parameters of coalbed methane on the wetting radius. Jianlong Li et al.[5] believed that wetting agents are usually used to improve the efficiency of mine dust water injection. Based on the Bayes discriminant analysis method, Liu Nianping [6] selected six indicators such as the degree of fracture development as discriminant factors and established a discriminant analysis model for the difficulty of coal seam water injection. Qin Shuyu et al.[7] used the BP neural network evaluation method to establish a neural network model for coal seam water injection by selecting six indicators such as coal seam porosity. However, the prediction results are closely related to the model structure and parameter selection, and there is still a lack of mature theory in parameter selection. Yuan Zhigang et al.[8] established a corresponding Fisher discriminant function to determine the effectiveness of coal seam water injection based on 15 sets of measured data of coal seam water injection, using the Fisher discriminant method. However, they had high requirements for sample size and representativeness. Luo Genhua et al.[9] used the AHP fuzzy comprehensive evaluation method to establish a comprehensive evaluation model for coal seam wetting, which includes factors such as coal chemical composition and structural parameters. However, the subjective weighting of the indicators is single. Chen Shaojie et al.[10] extended extension theory to the evaluation of coal seam water injection effectiveness and established a method for evaluating coal seam water injection effectiveness based on matter elements and correlation functions. The evaluation results are in line with reality. Qiu Jinwei et al.[11] used the kernel grayscale method to evaluate the difficulty of coal seam water injection. This method first uses distance projection to determine the kernel gray level weights of various indicator factors, and then sorts the size of interval gray levels, which is the ranking of the difficulty of coal seam water injection.

Although these methods have high accuracy in discrimination, with the increase of mining depth, the increase of ground pressure, ground temperature and the accumulation of gas content, new and higher requirements

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are put forward for the discriminative model of the difficulty of coal seam water injection. This article is based on the basic idea of Bayes discriminant analysis method and establishes a Bayes discriminant analysis model for the difficulty of coal seam water injection. And apply the model to actual coal seam water injection engineering. The research results show that the Bayes discriminant analysis model has a lower misjudgment rate and can be better applied in practical engineering.

2. Bayes discriminant method

2.1 The basic idea of Bayes discriminant method

Before classifying, the Bayes classification method first makes sure that the sample attributes are independent of each other and do not affect each other before. Then, based on Bayes theory, the training samples are learned to obtain a Bayes discriminant function, which is used to distinguish the data to be determined. The group with the highest value obtained is the discriminant group.

2.2 Bayes discriminant function

Set two p-dimensional normal populations G1, G2, and their probability density function$f_i(x)$:

$$f_i(x)=(2\pi)^{\frac{p}{2}}|\Sigma_i|^{\frac{1}{2}}\exp\left[-\frac{1}{2}\left(x-\mu_i\right)^T\Sigma_i^{-1}\left(x-\mu_i\right)\right] \quad (1)$$

In the equation: u_i, Σ_i is the average vector of two normal general overall, and the coordinated differential matrix, i=1,2

When $\Sigma_1=\Sigma_2=\Sigma$, from the relevant theory in the discrimination, the Bayes judgment function can be reached W(x):

$$\frac{f_1(x)}{f_2(x)}=\exp\left\{\frac{1}{2}\left[\left(x-\mu_2\right)^T\sum^{-1}\left(x-\mu_2\right)-\left(x-\mu_1\right)^T\sum^{-1}\left(x-\mu_1\right)\right]\right\}=\exp\{W(x)\}$$

$$W(x)=\left[x-\frac{1}{2}\left(\mu_1+\mu_2\right)\right]^T\Sigma^{-1}\left(\mu_1-\mu_2\right) \quad (2)$$

2.3 The multi -positive Bayes judgment method

Let G1,G2,⋯,Gg be normal populations of g p-dimensions, and assume that the covariance matrices of each population are equal, that is, $\Sigma_1=\Sigma_2=\ldots=\Sigma_g=\Sigma$, and the Bayes discriminant function is calculated as

$$W_i(x)=\mu_i^T\Sigma^{-1}x-\frac{1}{2}\mu_i^T\Sigma^{-1}\mu_i+\ln q_i \quad (3)$$

In the equation: $q_i$is the general priority probability of each overall, $q_i=\frac{n_i}{n}$, $n=\sum_{i=1}^{k}n_i$, n_i is the number of samples contained in the overall G_i, where of which, i=1,2,⋯⋯,g.

In actual engineering applications, if μ_i and Σ_i are unknown, you can use training samples to estimate, that is, using the sample average value $\overline{X}^{(i)}$ and sample variance S_i of the sample samples as an estimate of μ_i and Σ_i, then:

$$\hat{\mu}_k=\frac{1}{n_k}\sum_{i=1}^{n_k}x_i^k=\overline{X}^{(k)} \quad (4)$$

$$\Sigma=\frac{(n_1-1)s_1+(n_2-1)s_2+\ldots+(n_g-1)s_g}{n_1+n_2+\ldots+n_g-g} \quad (5)$$

$$S_k=\frac{1}{n_k}\sum_{i=1}^{n_k}\left(x_i^k-\overline{X}^{(k)}\right)\left(x_i^k-\overline{X}^{(k)}\right)^T \quad (6)$$

In the equation: x_i^k is the i-th sample in the k-th population, k=1,2,...,g; $\hat{\mu}_k$and $\hat{\Sigma}$ are estimates of the k-th population mean $\hat{\mu}_k$and the population covariance matrix Σ, respectively; s_k is the within-group covariance matrix for the k-th population.

2.4 Criterion

In actual engineering applications, due to the loss of mistakes C (1) is not easily determined, it is usually assumed that the loss of various misunderstandings is equal, then the guidelines for Bayes judgment are:

$$\text{If } \max\left\{\underset{i\ll k\ll g}{W_k(x)}\right\}=W_i(x),\text{then } x\in G_i$$

2.5 Judgment effect evaluation

It is used to train samples as evaluation data, and by using cross -verification methods to obtain the accuracy of the discriminator model.

The total number of training samples used is G, and the misjudgment sample number generated during the cross -verification process is G, then the error rate can be defined as η, that is,

$$\eta=\frac{g}{G} \quad (7)$$

3. Bayes discriminatory analysis model with a difficult degree of water injection of coal seams

3.1 Different judgment factor in the degree of water injection of coal seams

The factors that affect the difficulty of coal layer water injection have not yet been unified. It can simply divide the influencing factor into the geological and coal body's own factors and process factors. The former has a main impact on the difficulty of water injection of coal seams.

In terms of geological and coal body's own factors, this article will be buried depth x_1, crack growth degree x_2, porosity x_3, wet edges x_4, saturated water increment x_5, consistent coefficient x_6 and gas pressure x_7 as coal seam water injection The difficulty of judging factor, and divide the coal seams into three levels: easy water injection coal seam (grade I), more easy injection coal seams (grade II), and difficult water injection coal seams (grade III).

3.2 Bayes to judge the establishment of a function

The actual data of 23 coal seam water injection projects in [6] and [11] are used as training samples. The actual data of the coal layer water injection project and the results of the Bayes discrimination are shown in Table 1. The Bayes judgment function is as follows:

$$W_1(x)=0.148x_1+2.0711x_2+0.267x_3+0.202x_4+7.269x_5+6.908x_6-8.506x_7-87.819$$

$$W_2(x)=0.172x_1+2.366x_2+0.285x_3+0.338x_4+7.525x_5-0.899x_6-5.388x_7-112.804$$

$$W_3(x)=0.177x_1+1.356x_2+0.341x_3+0.156x_4+5.681x_5+11.521x_6-13.506x_7-69.801$$

3.3 Bayes to determine the test of the model

In order to verify the correctness of the model established, according to the above -mentioned Bayes judgment functions, the actual project data of the 23 coal seams in Table 1 was interrogated and verified in the judgment function, respectively, and the discrimination results were obtained according to the Bayes judgment criteria.

It can be seen from the results of the discrimination in Table 1 that the number of misjudgment samples is only one, and the misjudgment rate of the model can be obtained through the formula (7). The correct rate is as high as 95.7%. Compared to the discrimination results, the same is good. The misjudgment sample is sample 8. Although the discrimination result is one level higher than the actual results, it also guarantees that the effect of coal seam water injection can achieve the expected effect.

In summary, the establishment of coal seams of water is difficult to easily and easy to judge the analysis model of Bayes.

4. Engineering verification

Based on the three coal seam water injection project data of different regions, different coal mines, and different coal seams provided based on citations [6] provided data (Table 2), use consideration of gas pressure factors, and the trained Bayes judgment analysis model pair of engineering examples. The degree of difficulty in water injection coal seams is difficult to discriminate. At the same time, the above -mentioned engineering instance data uses the Bayes discrimination, fuzzy cluster analysis, BP neural network, and Fisher's discrimination using the above -mentioned data. The actual results are compared, and the discrimination results are shown in Table 2.

According to the above table, the discriminant results of Bayes discriminant method considering gas pressure are consistent with the actual results, indicating that the Bayes discriminant analysis model considering gas pressure has a lower false positive rate and can be better applied to practical engineering.

Table 1. The actual data and discrimination results of the coal layer water injection project.

Number	Judgment factor							Differential functional value			Judgment results	
	x_1 /m	x_2 /(strip·(5cm)-1)	x_3 /%	x_4 /(°)	x_5 /%	x_6	x_7 /Mpa	$W_1(x)$	$W_2(x)$	$W_3(x)$	Bayes	Reality
1	420	21	9.5	88	3.7	1.8	1.2	67.246	61.332	75.533	III	III
2	265	35	23.3	38	5.4	0.9	1.1	73.861	68.970	64.627	I	I
3	385	24	38.2	30	1.7	0.8	1.2	42.777	36.835	51.262	III	III
4	625	18	7.5	66	1.9	1.9	2.6	62.096	60.310	75.654	III	III
5	470	44	8.8	53	5.3	1.1	2.2	113.288	119.602	97.391	II	II
6	360	38	16.1	73	4.7	1	1.3	93.180	95.751	82.989	II	II
7	480	23	4.8	60	1.1	2.3	2.4	47.703	39.101	57.677	III	III
8	340	55	10.3	55	3.6	1.2	0.8	117.864	119.032	100.52	II	I
9	437	45	11.73	60.3	4.53	1.1	1.6	112.445	117.006	99.119	II	II
10	380	22	9.9	71.5	3.65	1.5	1	59.435	52.326	66.332	III	III
11	455	21	6.15	58	1.5	2.1	1.8	46.449	36.200	58.760	III	III
12	385	24	38.2	30	1.7	0.8	1.2	42.777	36.835	51.262	III	III
13	230	33	16.5	60	5.1	1.0	0.7	69.359	63.487	62.144	I	I
14	285	24	131	49	2.8	1.4	1.2	68.733	60.243	81.332	III	III
15	412	18	8.3	85	3.3	1.7	1	57.028	49.660	68.448	III	III
16	430	20	10	89	4.1	1.9	1.8	65.486	60.854	71.594	III	III
17	334	27	11	20	6.1	1.1	0.7	70.466	59.563	70.673	III	III
18	360	32	12.7	30	7	1.3	1.3	89.958	83.089	83.508	I	I
19	233	36	24.6	45	5.9	1	1.1	77.282	72.241	65.847	I	I
20	465	18	1.2	56	0.6	2	1	39.565	26.363	59.002	III	III
21	488	25	5.8	64	1.7	2.5	2.4	59.845	51.181	68.483	III	III
22	615	16	5.5	62	1.4	1.8	1.9	56.763	52.035	75.327	III	III
23	631	19	8.2	70	2.5	2.2	2.6	72.483	69.505	85.799	III	III

Table 2. Assessment of coal layer water injection project data and multiple judgment methods

Number	Judgment factor							Classification result					
	x_1 /m	x_2 /(strip·(5cm)$^{-1}$)	x_3 /%	x_4 /(°)	x_5 /%	x_6	x_7 /Mpa	Bayes (New)	Bayes	FC AM	NNM	FDA	Reality
1	286	39	27.2	48.3	5.92	1.05	2	II	II	II	II	II	II
2	300	51	15.7	40	8.5	1	0.5	I	II	I	II	II	I
3	370	22	12.1	70	2.7	2.1	1.3	III	III	III	III	III	III

5. Conclusions

This chapter is mainly based on the theory of Bayes discrimination analysis. It has established an analysis model that considers the difficulty of water injection of coal seams that consider gas pressure, and applies this model to the actual project.

(1) This model uses 7 indicators of buried depth, crack growth degree, porosity, wet edges, saturated water increment, consistent coefficient and gas pressure as a judgment factor. The difficulty of coal seam water injection is divided into three grades : easy water injection coal seam (grade I), more easy water injection coal seam (grade II) and difficult water injection coal seam (grade III) as three normal populations of Bayesian discriminant analysis. Based on the actual data of 23 sets of coal seam water injection projects as training samples, the Bayes discrimination model was established. Cross verification of 23 groups of actual testing data to obtain the accuracy of the model. In the end, the difficulty of water injection of coal seams was applied to the actual coal seam water injection project, and the discrimination effect was ideal.

(2) In the application of engineering examples, use the learning Bayes to judge the analysis model to determine the difficulty of water injection of each coal seam. In addition, the prediction results and the Bayes discrimination and blur cluster analysis of the prediction results and the Bayes pressure of the stress of gas pressure The prediction results of the prediction of the law, the BP neural network method, and the Fisher's discrimination method were compared. The results show that the Bayes discriminant analysis model considering gas pressure has a lower false positive rate and can be better applied to practical engineering.

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