Research on Application Evaluation of Support Vector Machine Prediction Model in Slope Engineering

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Abstract: Support vector machine is a two-class classification model based on hyperplane segmentation algorithm, because of its good supervised learning effect, it is widely used in engineering prediction. This paper in connection with many uncertainties in slope engineering, proposes support vector machine prediction method based on slope sample collection. At the same time, based on the slope samples in the reference, the model is used to predict the slope stability, and then based on the stability analysis results in the reference, the prediction results of the support vector machine model are evaluated, it fully verifies the reliability of the model prediction results. The results show that the established support vector machine model has a high degree consistency with the reference in slope stability analysis, support vector machine model predicts good results, and it provides a new idea for highway slope stability prediction.

1. Introduction

Slope stability analysis is one of the key topics in the field of geotechnical engineering. It is widely used in many fields such as highways, water conservancy and hydropower, mining, and construction. Slope stability is directly related to the overall economic benefits of the enterprise and the safety of people's lives and property. However, due to the complexity, variability and uncertainty of geological conditions in slope engineering, and the diversity of external factors, there are still many difficulties in slope stability analysis at present. Although frequent slope engineering accidents have seriously affected enterprises and people, they have provided valuable slope cases to scholars. Therefore, how to explore the internal relationship between slope stability and various parameters from the perspective of the slope case is called the research trend of the slope field [1].

At present, the research methods of slope stability mainly include quantitative research methods and qualitative research methods. The qualitative research method explores the slope stability law from the perspective of mechanics, and mainly forms the limit equilibrium method and the limit analysis method. In 1927, the Swedish scholar W. Fellenius proposed Swedish Arc Method in his writings [2], which laid the foundation for limit equilibrium method. On this basis, the limit equilibrium methods such as simplified Bishop method [3], Morgenstern-Price method [4], and Spencer method [5] are successively proposed. On the other hand, limit analysis method explore slope stability from the perspective of plastic mechanics. In 1975, W.F.Chen [6] applied limit analysis method to geotechnical engineering, afterwards, K.Karal, Michalowski [7] and other scholars used flow rule to further explore the application of limit analysis method in slope engineering. In recent years, with the rapid development of modern mathematical theory and the practice of slope engineering as references, the slope stability analysis method based on modern mathematical theory is called the inevitable trend of slope engineering development. Among them, many mathematical methods such as grey relational analysis, BP neural network and catastrophe theory have been widely used in slope engineering, and have achieved good prediction results in engineering [8]. However, due to the complexity of geological conditions in slope engineering and the uncertainty of influencing factors, various mathematical methods at present have certain limitations. In order to solve such problems, this paper uses the hyperplane separation function of support vector machine, and uses its good supervised learning effect to propose a slope stability prediction method based on support vector machine model, and evaluate accuracy of predictive model of support vector machine. The accuracy of the evaluation is sufficient to verify the accuracy of the calculation results and provide a new idea for slope stability analysis.

2. Support vector machine calculation method

2.1 Support vector machine classification

The support vector machine classification should consider the pattern classifier, assuming that the sample set to be trained is T, the sample set to be trained can be expressed as:

$$T=\{(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)\} \in (X\times Y)^n \tag{1}$$

In the formula (1), x_i is the classification factor, $x_i \in \mathrm{R}^n$, $y_i \in \{-1, +1\}$, if for arbitrary $\omega \in \mathrm{R}^n$ and arbitrary $b \in \mathrm{R}$, it exists (x_i, y_i):

$$b+(x_i\times\omega)\geq 1,\ y_i=1 \text{ or } b+(x_i\times\omega)\leq -1,\ y_i=-1 \tag{2}$$

In other words, if it exists $y_i\times(b+x_i\times\omega)\geq 1$, then ω is normal vector of hyperplane and b is offset of hyperplane, we call the training set T is linearly separable. If the training set T is separated by a hyperplane without errors, the distance between the vector closest to the hyperplane and the hyperplane is the largest, the training set T is separated by the maximum interval hyperplane, its principle is shown in figure 1.

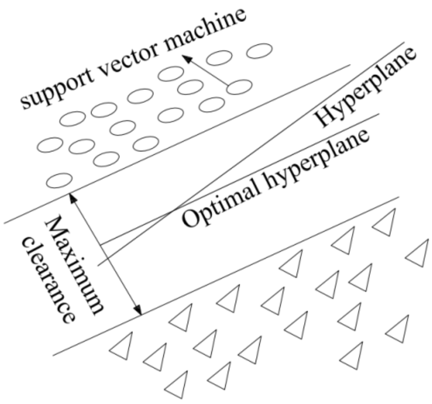

Figure 1. Schematic figure of support vector machine

The key problem is how to find the support vector machine to construct the optimal classification hyperplane, the essence of optimal classification hyperplane construction problem is to solve quadratic optimization problem, and then get the optimal decision function. Its optimal hyperplane can be expressed as:

$$f=\min_{w}\frac{1}{2}\|\omega\|^2 \qquad y_i\cdot(b+x_i\cdot w)\geq 1 \tag{3}$$

Due to the incompleteness of the data, this paper introduce a slack variable $\lambda_i(\lambda_i\geq 0)$ and a penalty parameter C to balance the hyperplane. Penalty parameter C is a variable parameter to indicate the degree of misjudgment sample. Thus the optimal hyperplane construction can be expressed as:

$$f=\min\frac{1}{2}\|w\|^2+C(\sum_{i=1}^{n}\lambda_i) \qquad y_i\cdot(b+x_i\cdot w)\geq 1-\lambda_i \tag{4}$$

Using the optimization method and the dual theory, the above support vector machine classification problem can be transformed into the following dual problem:

$$y_i\cdot\left(b+x_i\cdot w^{*T}\right)\geq 1-\lambda_i \qquad 0\leq\alpha_i\leq C \tag{5}$$

In the formula (5), α_i is auxiliary variable, and it is called Lagrange operator.

2.2 Support vector machine calculation theory

Assumed sample $T=\{(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n) \mid x_i \in R^n, y_i \in R\}$, and for arbitrary $\varepsilon > 0$, if exist hyperplane in R^n flat, $f(x)\leq\omega$, $x > b$, $\omega\in R^n$, $b\in R$, and satisfy $|f(x)-y_i|\leq\varepsilon$, then we called $f(x)\leq\omega$,

$x > b$ is the linear regression ε of the sample set T. For linear regression problems, it is desirable to adjust the slope to increase the distance from any point in the range as much as possible, then the linear regression problem of the sample set is transformed into the optimal solution problem. Introduce slack variables and Lagrange operators, the optimized duality obtained is:

$$f = \min\left[-\frac{1}{2}\sum_{i,j=1}^{l}\left(\alpha_i - \alpha_i^*\right)\left(\alpha_j - \alpha_j^*\right) < x_i, \sum_{i=1}^{l}\left(\alpha_i - \alpha_i^*\right)y_i - \sum_{i=1}^{l}\left(\alpha_i + \alpha_i^*\right)\varepsilon < x_j\right]$$
$$s.t. \quad \sum_{i=1}^{l}\left(\alpha_i - \alpha_i^*\right) = 0 \quad 0 \le \alpha_i \quad \alpha_i^* \le C \tag{6}$$

3. Slope application practice

The factors affecting the stability of the slope are diverse, in order to build a support vector machine model for the slope, this paper explores slope stability from the aspects of slope geometry, soil strength and water pressure. In the slope geometry parameters, the slope height and slope angle are selected as evaluation parameters, in the slope soil strength, the bulk density, cohesion force and internal friction angle of the slope rock mass are selected as evaluation parameters, in the slope water pressure, the pore water pressure coefficient is selected as the evaluation parameter. Among the factors of slope stability evaluation, slope stability coefficient and slope stability state are selected as stability evaluation factors. The slope stability coefficient is the ratio of the slope anti-sliding force to the slope sliding force, while the slope stability state is the relationship between the slope stability coefficient and the design stability coefficient. When the slope stability coefficient is greater than the slope design stability factor, the steady state is represented by 1, and when the slope stability coefficient is smaller than the slope design stability factor, the steady state is represented by 0. Select the slope sample set in Reference 1 as the support vector machine sample, the first 15 slope samples are used as learning samples, and the last 5 slope samples are used as prediction samples, based on this, the slope support vector machine model is established. Selection of slope sample sets in reference 1 are shown in table 1.

Table.1. Slope samples

number	H/m	β/°	γ/kN·m^{-3}	c/kPa	φ/°	r_u	S	Fs
1	10. 67	16	20.41	33.52	11	0.35	1	1.4
2	12.19	22	19.63	11.97	20	0.405	0	1.35
3	12.8	28	21.82	8.62	32	0.49	0	1.03
4	40	30	20.6	16.28	26.5	0	0	1.25
5	10.67	25	18.84	15.32	30	0.38	1	1.63
6	21	35	19.06	11.71	28	0.11	0	1.09
7	30.5	20	18.84	14.36	25	0.45	0	1.11
8	8	33	22	0	40	0.35	1	1.45
9	88	30	14	11.97	26	0.45	0	0.625
10	20	45	18	24	30.15	0.12	0	1.12
11	100	20	23	0	20	0.3	0	1.2
12	15	45	22.4	100	45	0.25	1	1.8
13	10	45	22.4	10	35	0.4	0	0.9
14	50	45	20	20	36	0.25	0	0.96
15	50	45	20	20	36	0.5	0	0.83
16	50	45	20	0	36	0.5	0	0.79
17	8	20	18	5	30	0.3	1	2.05
18	45.72	16	20.41	33.52	11	0.2	0	1.28
19	76.81	31	21.51	6.94	30	0.38	0	1.01
20	30.5	20	18.84	14.36	25	0	1	1.875

In table 1, H is slope height, m, β is slope angle, °, γ is bulk density, kN·m^{-3}, c is cohesion force, kPa, φ is internal friction angle, °, r_u is pore water pressure coefficient, S is slope stability state, Fs is slope stability coefficient. Based on MATLAB and Libsvm software platform, the support vector machine model for regression analysis is used to realize slope stability analysis. Among them, 20 samples will be obtained, 15 will be used as training samples for support vector machine prediction model, and the other 5 will be used as prediction samples of support vector machine model. In the vector regression problem, the penalty factor C determines the pros and cons of the function, and the insensitive parameter g is the accuracy of the regression curve. The results of the forecast sample analysis are shown in Table 2.

Table.2. Slope samples

number	reference analysis results *Fs*		forecast result	
	S	*Fs*	*S*	*Fs*
16	0	0.79	0	0.81
17	1	2.05	1	2.04
18	0	1.28	0	1.31
19	0	1.01	0	0.97
20	1	1.875	1	1.86

Table 2 shows that from the perspective of slope stability, the prediction results are highly consistent with the analysis results in the reference documents, and the accuracy rate reaches 100%. From the perspective of stability coefficient, the prediction results are slightly different from the analysis results in the reference literature. The difference, but the error rate is less than 5%, can fully meet the needs of engineering practice, so the model has high accuracy, simple calculation method, strong engineering applicability, and has important promotion significance.

4. Conclusion

(1)This paper introduces a slope stability support vector machine prediction method, and evaluates the accuracy of the prediction method by using the slope samples in the reference.

(2)Evaluate the accuracy of the predictive model from the perspectives of slope stability and stability coefficient, from the perspective of slope stability the accuracy rate reaches 100%, and from the perspective of stability coefficient the error rate is less than 5%, the support vector machine prediction method can fully meet the needs of engineering practice, so it has important promotion significance.

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