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Geotechnical Slope Protection Model Based on Genetic Algorithm

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ABSTRACT

In order to study the rock slope protection model based on a genetic algorithm, the theory of slope stability and evaluation theory were introduced. Slope engineering geological model framework, slope safety and stability mathematical mechanics model and slope evolution bifurcation model were studied. The application of artificial intelligence in slope stability was analyzed. Based on the theoretical results at home and abroad, an FCM clustering analysis based on genetic algorithm was obtained. Soft set theory and fuzzy soft set theory were introduced. An algorithm model for evaluating decision-making in slope management was proposed. An example analysis was carried out in combination with the developed system. The results showed that the evaluation system had obvious advantages. The model provides an effective reference for engineering decision-making.

INTRODUCTION

The evaluation of slope stability plays an important role in the construction of the project. With the development of mathematics, more and more new mathematical methods are widely used in slope stability research. The evaluation method is a discrete, random, nonlinear and complex problem (Cao et al. 2017; Roslee et al. 2018; Kushwah et al. 2017). In 1916, Peterson first proposed the stability analysis of soil slope with sliding surface as arc. In 1955, Bishop proposed a Bishop method that takes into account the force between strands. Domestic scholars have done a lot of research on slope stability evaluation. A study used fuzzy clustering method to analyze slope stability problems (Thong & Le 2016, Oyedotun 2019, Nawaz et al. 2018). Based on the fuzziness of slope stability problems, Xue Xinhua (2007) presented a fuzzy neural network model for slope stability prediction. Combining the fuzzy method and the limit equilibrium theory, Wang (2008) analyzed the stability of the slope. Zhang (2011) gave the logistic regression model of slope stability. Some scholars gave a homotopy FCM clustering algorithm for slope stability classification evaluation (Pei et al. 2017, Ismail et al. 2018, Zainal Abidin 2018).

At present, many scholars have proposed a lot of slope management programs. For different slopes, different measures should be taken. However, there will be a variety of suitable treatment schemes for a slope. The economics and safety of the programs to be evaluated. It should be conducive to environmental protection and construction. After a comprehensive evaluation of the advantages and disadvantages of each program, the best plan is selected. The evaluation and design of large slope engineering is a challenge. The existing theory of slope is needed to develop into the new technology theory of information and intelligence (Alameda-Hernández 2017, Khan et al. 2018, Herayani et al. 2018, Siew Len et al. 2018). Therefore, in order to study slope engineering, some other disciplines, such as mathematics, mechanics and other basic disciplines, as well as simulation, neural network and other cutting-edge theories, need to be combined.

MATERIALS AND METHODS

Slope engineering theory: The slope engineering has achieved great achievements in the analysis of failure law, the study of failure mechanism and the study of stability. It has preliminarily formed an independent subject system of slope engineering (Li et al. 2017, Md Atikuzzaman et al. 2018, Zahan et al. 2018, Yang et al. 2018). The theory of rock mass structure control mainly focuses on the study of the control of rock mass structure and various geological structures in the face of deformation and failure. Fractal theory is mainly used in the study of self-similar graphics. Under the condition of obtaining the fractal dimension of the graph, the nature and the law of the graph are described. The theory is applied to the study of slope engineering. The 3S system contains GIS, RS, and GPS. Based on this system, the 3S theory gives a new observation, description and thought for the prediction and prevention of slope engineering. The theory of reliability is to combine the specific conditions of the slope with the theory of structural reliability under the condition that the

cognition of rock mass properties and loads is not completely determined. The failure probability or reliability index is used to characterize the quality of the slope. Compared with deterministic theory, it is closer to the actual state of slope engineering, which can reasonably explain many problems that cannot be correctly explained in deterministic theory. More importantly, this model is conducive to creating a new sense of risk and reliability.

Influence factors of slope stability: The structure surface plays an important role in the slope failure. Especially in the transition or intersection of structural planes, it will appear tensile stress concentration and very large compressive stress area. The destruction and deformation of this area are often intense. The shape of a river and other bank slopes will be changed by the scour of the waves. When the weak structural surface at the bottom of the slope is eroded, the experience of the slope is in the state of being in the air. When the top surface of the weak layer of the slope is eroded, the instability of the slope is produced, which causes the slope to be damaged.

In addition, the strength of rock and soil will gradually become smaller because of the effect of weathering, and the stability will become worse, which increases the possibility of slope deformation. The blasting, earthquake and other factors will also lead to the direct force of the slope, which has a rapid and direct impact on the stability of the slope. The seismic action can cause the vibration of the slope body, which is equivalent to the slope body bearing some additional load. The slope body is subjected to a large amount of impact, which makes the bite force and shear strength between the weak layers smaller. Finally, the slope stability decreases and even loses stability. Therefore, the structure, environment and geomorphology of rock and soil are very important. On the basis of the development history of the region, the utility and sensitivity of all factors are discussed to demonstrate the stability of the slope (Cheng et al. 2017, Ogunyele et al. 2018, Xu 2018, Hazmi & Hanafiah 2018, Chinakwe et al. 2019).

Analysis method of slope stability: There are various methods for the analysis of slope stability. In the process of slope stability evaluation, fuzzy mathematics enables researchers to have a more reasonable and accurate understanding of the engineering studied, which provides a more effective reference for decision-making of engineering. It can objectively control the cost and risk. The principle of maximum membership degree and the principle of fuzzy transformation are applied. Some related factors of things or their attributes are considered synthetically, and category or grade evaluation is carried out. The evaluation subsets of m factors constitute the total evaluation matrix R.

$$\underset{\sim}{R} = \begin{Bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{Bmatrix} \quad \ldots(1)$$

According to the comprehensive evaluation model, the final evaluation results can be obtained by the fuzzy transformation after the experts give the evaluation information.

RESULTS AND DISCUSSION

Study on slope protection model: Genetic algorithms (GA) originate from computer simulation of biological systems. In fact, it is a universal framework, and this framework can be applied to the solution of complex systems that do not rely on the specific areas of the problem. Therefore, it is widely used in the optimization of various disciplines.

Genetic algorithm is a method of computing which includes the principle of randomness. However, in the process of computing, it is not a complete random search. Through the information carried by the parent, it can accurately calculate the point set of the performance improvement of the sub generation. After many iterations and evolution, an individual with the maximum value of fitness function is obtained on the premise of satisfying the convergence precision, and the optimal solution is decoded. The five main factors in genetic algorithms are coding, group initialization, adaptive function, genetic manipulation and control parameters. The basic flow chart of the standard genetic algorithm (SGA) is shown in Fig. 1.

As can be seen from Fig. 1, the genetic algorithm is actually a very conventional iterative solution.

Fuzzy set theory: Fuzzy set theory is a mathematical theory that uses a clear mathematical method to describe and study fuzzy things. The description of the fuzzy subset is as follow:

For any given domain U, any mapping from U to the closed interval [0,1] is:

$$\begin{aligned} \mu_A : U &\to [0,1] \\ u &\to \mu_A(u) \end{aligned} \quad \ldots(2)$$

To determine the fuzzy subset A of U, μ_A is called the membership function. $\mu_A(u)$ is called the membership of u for A, and it can also be recorded as $A(u)$. Usually, a fuzzy subset is also called a fuzzy set.

FCM cluster analysis: Fuzzy C mean clustering algorithm (FCM) is a kind of fuzzy clustering method. The FCM clustering analysis based on genetic algorithm first

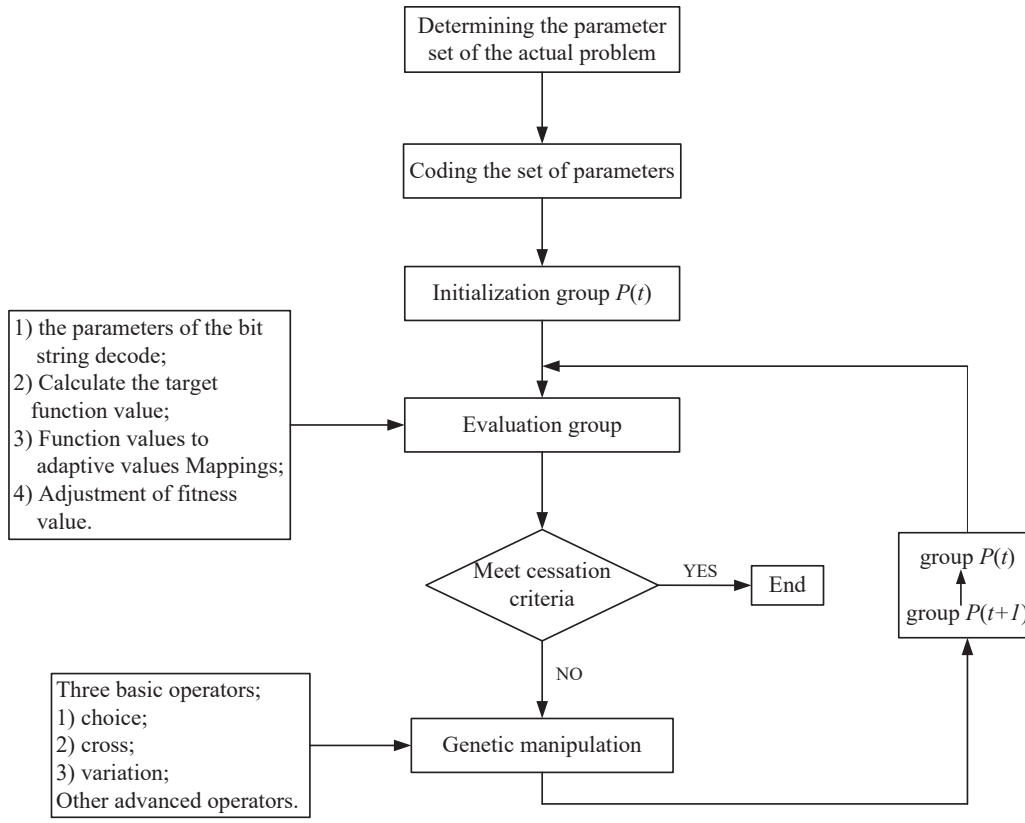

Fig. 1: The basic flow chart of the standard genetic algorithm.

optimizes the initial cluster centre by genetic algorithm and then executes the FCM algorithm. The basic steps of the genetic algorithm are:

Encoding: the cluster centre V is encoded,

$$b = Ec\{v_1, v_2, \cdots v_c\} = \left\{ \underbrace{\beta_1\beta_2\cdots\beta_k}_{Ec(v_1)} \cdots \beta_l \cdots \beta_{ck} \right\} \quad \ldots(3)$$

In the formula, $Ec\{\cdot\}$ is the encoding operator.

The construction and calculation of fitness function are:

$$ff(U,V) = \frac{1}{J_m(U,V) + \xi} \quad \ldots(4)$$

In the formula, ξ is a small positive number. It is mainly to avoid the case of $J_m(U, V)$ is 0.

The steps of genetic manipulation are as follows:

Choice: The method of Roulette is used. According to the probability of individual fitness value, the individual in the current group is selected.

Cross: Single point cross is used.

Variation: Based on the above selection operation, chromosome $b_i = \beta_1\beta_2 L\, \beta_{ck}$ is obtained. First, a $Rand\,(1)$ is produced. If $Rand\,(1) \le P_m$, a $l = Rand(ck), T_m : b_i = \beta_1 \cdots \beta_l \cdots \beta_{ck} \rightarrow b_i' = \beta_1 \cdots (1-\beta_l) \cdots \beta_{ck}$ is produced; otherwise, it does not change.

An initial cluster centre $V^{\{0\}}$ is obtained by the above genetic algorithm. Then, the optimal classification matrix U and cluster centre V are obtained by using the FCM algorithm.

Intelligent analysis system of slope stability: From the relevant literature, 10 sets of data are selected as shown in Table 1. FN is the slope status. 0 represents destruction, and 1 represents stability. The first 7 groups are taken as sample data, and the latter 3 groups are used to identify the accuracy of the system as the samples to be identified.

The neural network toolbox of MATLAB is used to establish the network of the above structure. The first 7 sets of data are used as input samples, and the next 3 sets of data are used as test samples. Using the network model designed above, the training and simulation can be carried out. After the simulation iteration, the precision of the network reaches the requirement, which shows that the fitting of the nonlinear mapping relation between the input and output is very accurate.

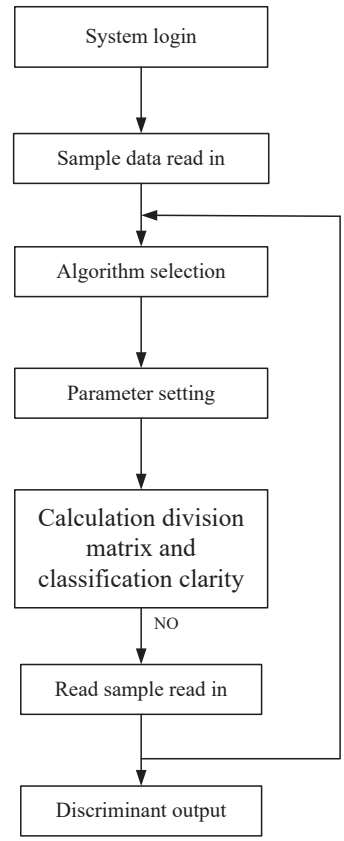

Fig. 2: Flow chart of the system.

Table 1: Cointegration test results.

Number	$\gamma\left(KN\bullet m^{-3}\right)$	$c(KPa)$	$\phi\left(^{\circ}\right)$	$\psi_f\left(^{\circ}\right)$	H(m)	μ	F_N
1	22.4	10	35	45	10	0.4	0
2	20	20	36	45	50	0.5	0
3	20	0.1	36	45	50	0.25	0
4	20	0.1	36	45	50	0.5	0
5	27	50	40	42	407	0.25	1
6	27	35	35	42	359	0.25	1
7	27	37	35	37.8	320	0.25	1
8	27	32	33	47.2	289	0.25	1
9	27.3	10	39	41	511	0.25	1
10	27.3	10	39	40	470	0.25	1

On the basis of the sample data, two kinds of intelligent algorithms are set up in the system by using MATLAB. The parameters of each algorithm need to be set up independently. The sample data can be stored in the excel file in advance. The data are read by selecting the path of the file, which facilitates the management and update of the sample data. Flow chart of the system is shown in Fig. 2.

The method of cluster analysis is adopted to evaluate the stability of the slope. The principle of the system is based on FCM clustering and genetic algorithm. A relatively perfect

database is set up through the arrangement of the existing engineering data. By analysing the sample data of the database, the degree of proximity between the identified samples and the known samples is calculated. Then, the stability of the identified samples is judged by the approach of proximity.

CONCLUSION

Slope engineering is an important problem in the process of engineering construction. Landslide and collapse caused by slope instability often bring great loss of life and property. On the basis of previous research and combined with artificial intelligence method, the slope stability is analysed. The slope protection model is emphatically studied. An FCM clustering analysis method based on genetic algorithm is obtained. On the basis of this algorithm, MATLAB is used to develop the software system. The system establishes a relatively perfect database through the arrangement of the existing engineering data. Finally, an intelligent analysis system for evaluating the stability of the slope is obtained. The results show that the system is reasonable.

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