NN-BASED BUILDING SITE CONTINUOUS CLASSIFICATION

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ABSTRACT :

Firstly, the spatial distribution graphic of two-dimensional membership function for 4 types of standard site was presented. It can be used in fuzzying the site classification directly. The site classifications and their fuzzy characteristics are given much consideration. Then, a continuity method of site classification methods based on the two-dimensional membership function was provided. Nextly, by using spatial distribution graphic of continuous classification above, the method of site continuous classification based on neural network (NN) is established. Finally, the applications are given. The practical results show that this method realized site intelligent continuous classification. This method gets rid of the illogicality of discontinuity and appreciable distinction displayed on the code chart between the site edges, as well as overcomes disadvantage of intelligence level and lower efficiency, those exit in traditional classification. This method causes the spatial distribution of site classification to be more smoothly, and is more corresponding to the practical engineering.

KEYWORDS: site, continuous classification, neural network (NN)

1 INTRODUCTION

Large amounts of investigation of the earthquake damage, seismic records and theoretical analysis in our country and abroad indicate that the site soil have an important impact on the seismic spectrum characteristics(Hu Y.X, Sun P.Sh., Zhang Z.Y. and Tian Q.W..(1980)). One often characterizes the effect of different site on earthquake by classifying the site in engineering practice. The rationality of the site classification will effect directly on characteristic period of seismic response spectra and the rationality of determining earthquake action. Meanwhile it will influence indirectly on the adequacy and the construction cost of the factors: engineering structural form selection, earthquake action analysis and structural measures treatment. Objective and scientific classification for sites is the key issue in the earthquake resistant design of engineering structure.

Since Wood began to classify sites according to terrene lithology in 1908(Wood H O(1908)), almost a hundred classification methods have been established. But some problems still exist: (1) Subjectivity characterizes is represented in decision the weights that express the relative importance of each classification index. (2)When they consider the synthetic influence of the indexes, they did not consider the complex influence between indexes. (3)The continuous functions of site classification and characteristic period were not formed. Therefore, a method of site continuous classification based on back-propagation (BP) neural network is presented in this paper. Practice and theory analysis shows that the continuous classification method is more conform to the characteristics of randomness; fuzziness and transition existed in the engineering sites. And this method makes the site classification more precise and reasonable. It also gets rid of some disadvantages exited in traditional classification, such as the appreciable distinction displayed on the code chart between the site edges, subjectivity in determining the weights and low in intelligent automation.

2.SITE CONTINUOUS CLASSIFICATION BASED ON TWO-DIMENSIONAL MEMBERSHIP FUNCTION

2. 1 Fuzziness of Site

First, there are many complicated facts influencing site classification. But for a certain practical project, there are usually only limited indexes available to classify the site. In this case, therefore, even a definite classification index or method tends to make the classification fuzzy. Secondly, the site soil consists of three

phases: solid, liquid and gas, its manifests extremely complicated and ambiguous characteristics due to variation in proportion of three phases, the shapes of solid granules, the mineral element and sizes of granules. Thirdly, the concept of site class lacks precision in intension and clearness in extension. All of the above indicates that site classification inevitably contains fuzzy characteristics.

2.2 the Two-Dimensional Membership Function of Site Fuzzy Classification

In combination with four standard site classes and their characteristics period isoclines diagrams classified by current earthquake resistance code (GB50011-2001.(2001).),the two-dimensional membership function about the four classes of site classification are established in paper (Zhang et al.(2005).) based on v_{se} (cut wave speed) and d_{ov} (covering layer thickness). The spatial distribution diagrams about four two-dimensional membership functions are given in Fig. 1.In which, $\mu_i(d_{ov},v_{se})$ is the membership function of the i th (i∈[1,4]) class standard site, v_{se} and d_{ov} can be ascertained with the method prescribed in Code (GB50011-2001. (2001).) and Code (GB/T50269-97.(1998)).

The site classification method based on two-dimensional membership function has the following characteristics:1) It realizes the fuzziness of the site classification boundary. 2) It takes into consideration the fuzzy characteristics of site soil and its classification. 3)It expresses the complex non-linear relationships between the classification indexes and the site classes. It makes full use of current classification result and conception in anti-seism code (GB50191-93.(1994)) and code(GB50011-2001. (2001).). To do the site classification on this basis, we can expect more objective and ideal results. However, the method above is rather complicated in calculation. In addition, its intelligence level and efficiency are comparatively low.

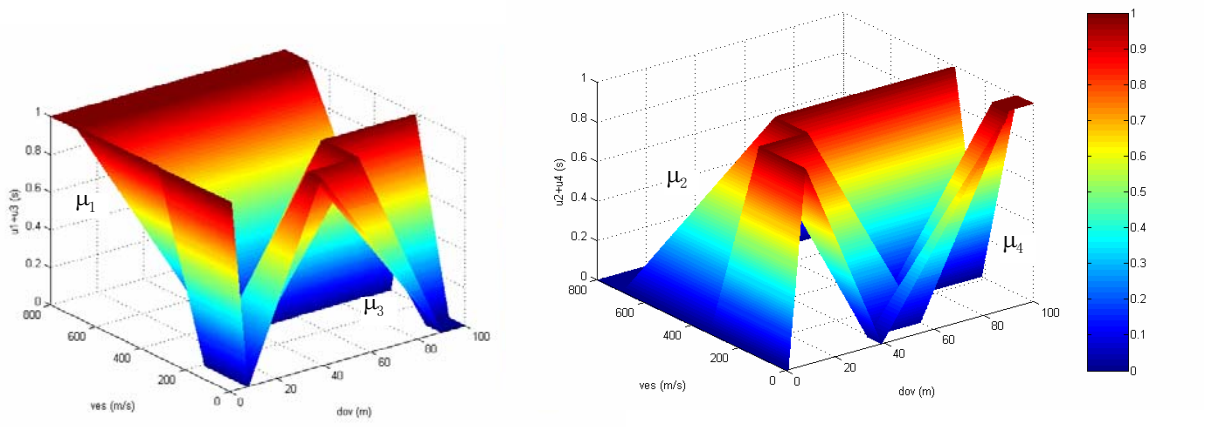

Fig.1 The two-Dimensional Membership Function of Four Classes of Standard Site

2.3 Site Continuous Classification Based on Two-Dimensional Membership Function of the Site Fuzzy Classification

The two-dimensional membership function μ_i of the standard site expresses the membership degree of this site to the i th (i∈[1,4]) class standard site. The unified μ_i is used to characterize such information as how much the weight of the i^{th} class site is to a specific site classification. If we use the c_i（$c_i \in C=\{c_i\}_4=[1, 2, 3, 4]$）to express the classification representative value of four standard site provided in the code (GB50011-2001. (2001)), the continuous classification method of site can be given in express (2.1). In which f ($f \in [1, 4]$) takes advantage of all the information of the membership function μ_i of site fuzzy classification. The fuzziness of site is given much consideration and the continuous classification for sites are realized. Thus lays the foundation for more comprehensive and reasonable consideration the effect of the site on earthquake motion. The spatial distribution diagrams of site continuous classification are shown in Fig. 2.

This method can obtain the spatial distribution, but its calculation is complicated and with a lower intelligence level. So, below we will establish an intelligence site classification method based on NN.

$$f = \sum_{i=1}^{4} (\mu_i c_i) \Big/ \sum_{i=1}^{4} \mu_i \qquad (2.1)$$

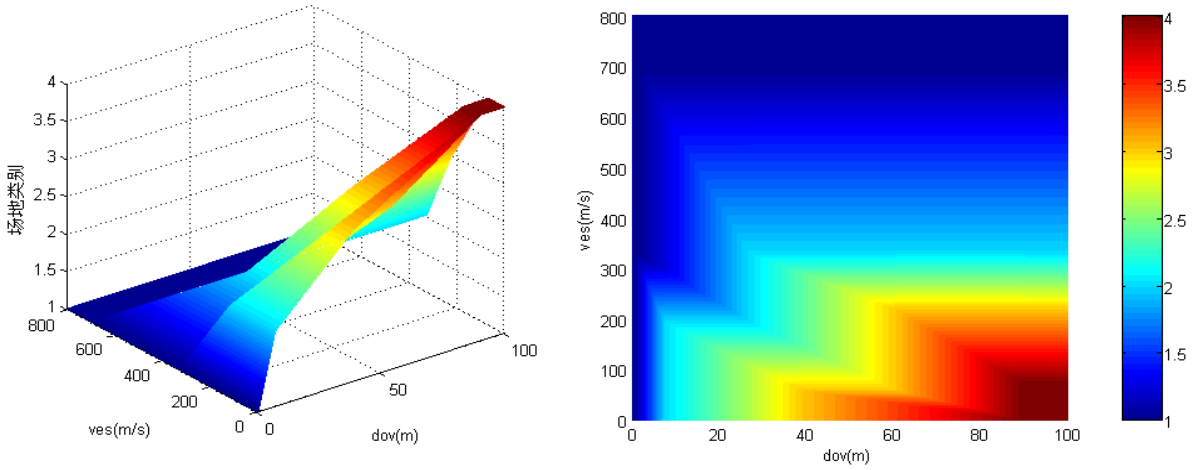

Fig.2 Site Continuous Classification based on Two-Dimensional Membership Function

3. BP-BASED SITE CONTINUOUS CLASSIFICATION METHOD

3.1 The Topology of Neural Network for Sites Continuous Classification

NN is a nonlinear forecasting model studying by training. It is composed of an input layer, some implicit layers and an output layer. One can receive site information through input layer, and receive, solve, transport and save the relevant information hidden in the site conditions and classification though the connections between neurons, the connection strength and the neuronal effort function. At last it outputs or predicts the types of construction sites related to input site conditions through the output layer.

There are many kinds of NN, and its structure and performance are also different. The back-propagation (BP) algorithm is one of the most frequently used methods in NN algorithm(Mills P M, Zomaya A Y, Tade M O.(1994)). This paper is intended to use the BP network in site fuzzy classification. Considering the spatial distribution characteristics of the two-dimensional function, we adopt the 6-layer multi-input-single-output network shown in Fig.3. In this structure, the 1st layer is the transition layer of input, which transforms the plane coordinate point $p(d_{ovp},v_{esp})$ of the site classification into an input vector $\{d_{ovp}, v_{esp1}, \dots, v_{espi},\dots,v_{espm}\}$ (where d_{ovp} is the p^{th} covering layer thickness and v_{espi} is the i^{th} cut wave speed) in the NN input layer(the 2nd layer). There are altogether m+2 nodes (in this paper m=800, including a bias node). The 3rd and 4th layers are implicit ones, adopting 20 nodes. The 5th layer is output layer containing m nodes. It is the vertical coordinate value vector$\{f_{pi}\}_m$ of site continuous classification corresponding to the input and output vectors. The 6th layer is also a transition layer. Its function is to identify site classification value $f(d_{ovp},v_{esp})$ corresponding to the input point $p(d_{ovp},v_{esp})$ from the output vectors.

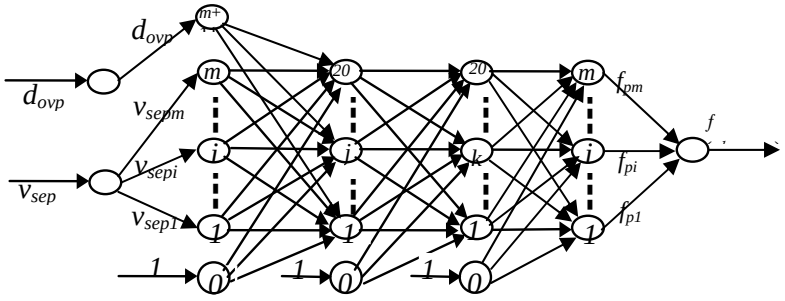

Fig.3 BP topologic structure of site fuzzy classification

3.2 the Activation Function and Learning Algorithms of Sites Fuzzy Classification Neural-Network

The continuous differentiable S-shape function is adopted as the activation function. The improved arithmetic of BP provided in Paper (Hecht-Nielsen R.(1989)) is adopted as the learning arithmetic.

3.3 Site Continuous Classification based on BP neural network

Based on the neural network structure ascertained in Fig. 3, taking the spatial distribution of site continuous classification given in Fig. 2 as the training samples and 1 as step, traversing the value interval between d_{ov} and $v_{es,}$ we train the NN of site continuous classification. The training result is shown in Fig. 4. It proves that the training result match well with the training samples. Meanwhile, it realizes the moderation or evenness and indistinctness on the turning borders of the training samples. This method removes the disadvantage of break on the turning borders of the samples functions and tallies with demands of actual engineering situation. The trained networks, as a whole, express the mapping relationships between any input point $p(d_{ovp},v_{esp})$ and the site classes. According to this, the continuous classification of any site $p(d_{ovp},v_{esp})$ can be obtained intelligently and automatically.

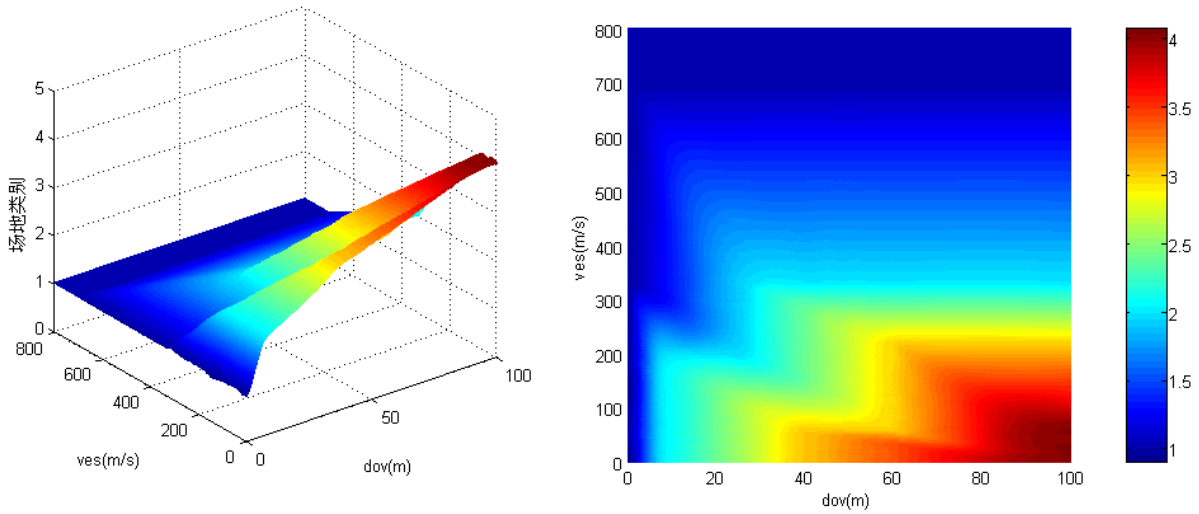

Fig.4 Distribution Graphs of the Site Continuous Classification based on NN

3.4 Example of Site Continuous Classification Based on BP Neural-Network

One project belongs to 1st seismic group, d_{ov}=30m and v_{se}=320 m/s.
Using the four two-dimensional membership functions given in Fig.1 we can ascertain the membership vector as $u=\{u_i\}_4=\{0.00, 0.8485, 0.1485,0.00\}$. As such, we work out the classification result of this site (see Table 1).In it, Method 1 is a classification method based on the maximum membership function. Method 2 is a method by using express (1). Method 3 and Method 4 are established in the Reference(Zhang Shi-hai, Liu Shu-jun, Ou Jing-ping, Wang Guan-yuan.(2006)).Method 5 is the one provided in reference (GB50011-2001.(2001)). Method 6 is established in this paper using the NN-based site continuous classification method.

Table 1 Results of the site classification

	Method 1	Method 2	Method 3	Method 4	Method 5	Method 6
Site classification	Ⅱ	2.1425	Ⅱ	2.1551	Ⅱ	2.1503

Theoretical analysis and the classification results above show that the results of Method 1 and Method 3 are same with Method 5, the results of Method 2, Method 4 and Method 6 are more precise. Compared to Method 2 and Method 4, the classification result of Method 6 is gentler on the turning borders, and it is more corresponding with the practical condition.

4 CONCLUSIONS

Based on the analysis of site fuzzy characteristics, the spatial distribution of two-dimensional membership function is proposed for four standard site fuzzy classifications according to current seismic code. The spatial distribution diagrams present directly the fuzzy method on the classification boundary. The fuzzy characteristics of site soil and its classification are taking full consideration. Based on the two-dimensional membership functions of four types of standard site, the site continuous classification method is established. In which, the classification results and ideas according to current seismic Code(GB50011-2001. (2001).) and Code(GB50191-93.(1994)) are utilized. To do the site continuous classification on this basis, we can expect more objective and ideal results. Thus lays the foundation for comprehensive and reasonable consideration the influence of the sites upon earthquake motion.

Moreover, the site continuous classification method based on two-dimensional membership function has the following disadvantages:1) It is rather complicated in calculation.2)The intelligence level and efficiency are comparatively low. 3) Local boundary of classification spatial curve is not gradual or gentle. So, taking the spatial distribution diagrams of site continuous classification above as the training samples, a continuous classification method based on BP neural network is established. The training results, the topologic structure about BP and its applications are also presented. Practice proves that the training results of this method match well with training samples and remove the disadvantage above. This continuous classification method based on BP neural network possesses the advantage of higher in intelligent automation level and efficiency of classification. Its results are more tallies with practical engineering.

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