Evaluation of compaction quality of earth-rock dam based on bacterial foraging-support vector regression algorithm

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Abstract. Compaction quality is an important part of quality assessment of earth-rock dam. Current evaluation methods tend to use the graphical reports of compaction parameters based on real-time compaction monitoring system, or built compaction quality prediction model, such as the multiple linear regression model and the neural network model, to evaluate compaction quality of storehouse surface. However, the precision of these models is not enough. In this study the bacterial foraging -support vector regression algorithm is proposed and employed to establish a high prediction model between multiple attributes and compactness to evaluate compaction quality of storehouse surface. This compaction quality evaluation method gets rid of the one-sided shortcomings of the compaction graphical reports, and greatly improve the prediction accuracy compared with current models, which provides reasonable compaction quality evaluations for quality management works.

Keywords: evaluation of compaction quality, earth-rock dam, support vector regression, bacterial foraging algorithm.

1 Introduction

The compactness is an important indicator of compaction quality assessment of earth-rock dam. Currently, Researchers evaluate compaction quality mainly through two different ways, namely post-evaluation such as sampling tests [1] and nucleon methods [2], and real-time evaluation which is based on the real-time monitoring system of earth-rock dam [3] [4]. However, given that post-evaluation may incur compactness in dam filling process or affect the construction schedule. While the real-time monitoring system fails to evaluate compaction of storehouse surface directly. Therefore, some researchers have investigated the method of compaction quality assessment. Liu Donghai etc. establish the multiple linear regression model and neural network prediction model on the basis of the intrinsic relationship between rolling parameters and the compactness [5-7]. Furthermore, he adopted CVs to evaluate compaction quality, which is maturely used in the road construction [8]. However, during construction works, unsatisfactory grain composition of gravelly soil may produce strong noises to the vibration signal of rolling machine and therefore, there are inevitably deviations when the method is employed in the monitoring of the compaction. Liu Yvxi etc. [9], taking the climatic conditions of construction and integrating climatic data and compaction data, establish multiple linear regression model for compaction quality evaluation. The above researchers applied traditional method

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to establish the compaction quality prediction model, although they can guide the constructors to a certain extent, the reliability of their assessment outcomes is not enough due to the poor accuracy. In order to overcome the deficiencies of the above research, this study combining the bacteria foraging algorithm and the support vector regression algorithm, proposes bacterial foraging-support vector regression algorithm, and use this algorithm to reconstruct the compaction quality prediction model to evaluate the compaction quality of storehouse surface. The precision degree of this prediction model is improved by a large extend compared with multiple linear regression model and neutral network model.

2 Bacterial foraging -support vector regression algorithm

Support Vector Regression (SVR) is the employment of Support Vector Machine (SVM) in the domain of functions [10], which is mainly used in the approximation of functions. The concrete form of SVR can be determined only if proper penalty parameter C , insensitive loss coefficient ε and kernel function are chosen. It is unreasonable to carry out optimal choice for each parameter separately. Rather, the optimal parameter pairs (γ, ε, C) shall be chosen simultaneously. Bacterial foraging algorithm[11], which simulate foraging behavior of Escherichia coli bacteria present in the human intestine, is adopt to optimize the hyper-parameters of the support vector regression algorithm in this work. The central idea of bacteria foraging -support vector regression algorithm runs as follows: take parameter pairs (γ, ε, C) as the search space of bacteria and take the mean square error, which directly reflects the regression performance of SVR, as the fitness of bacteria. Then let bacteria move towards the optimal value by foraging behavior so as to find out the optimal positions of bacteria population and take them as the input parameter of SVR algorithm. Object-oriented thinking is adopted to write this algorithm and it is convenient to manage the dynamic changes of bacteria. The flowchart of the algorithm runs as Fig.1.

```

→ BF-SVR Start()
// Initialize position and fitness of each bacteria
for i=1: PopSize
    BFi.Position=Random(C,  $\gamma$ ,  $\varepsilon$ )
    SVRModeli=SVR.Train(BFi.Position, TrainingData)
    BFi.Fitness= -SVRModel.Accuracy=SVR.Predict(SVRModeli, TestData)
end for
// Adjust the position of each Bacteria according to the Fitness.
for j=1: NumofMigrate
    for k=1: NumofCopy
        for l=1: NumofChemotaxis
            for m=1: PopSize
                for n=1: Ns
                    BFm.Position=BFm.Position+BFm.OrientationofChemotaxis* StepSize
                    SVRModelm=SVR.Train(BFm.Position, TrainingData)
                    BFm.Fitness= SVRModel.Accuracy=SVR.Predict(SVRModelm, TestData)
                    if (BFm.OldFitness<BFm.Fitness)           Continue;
                    else if (BFm.OldFitness>BFm.Fitness)   BFm.OrientationofChemotaxis=RandOrientation
                end for
            end for
        end for
        Replication
    end for
    Elimination-Dispersal
end for
// Output the location of the optimal bacteria.
OutPut: BF.BestPosition→ (C,  $\gamma$ ,  $\varepsilon$ )opt
→ BF-SVR End()

```

Figure 1. Pseudo code of BF-SVR algorithm process.

3 Evaluation of compaction quality of earth-rock dam based on bacterial foraging -support vector regression algorithm

In order to establish high precision compaction quality prediction model, this study integrate the compaction data and material sources data as the basis of modeling data. This research takes the quality inspection data of gravel soil core wall from Aug. 2nd 2013 to Sept.10th 2015 as integration object, and 620 data are integrated in total. These data consist of so many attribute, in which some attributes are useful while the others may be redundant. Therefore, effective data reduction is essential. Finally, seven attributes of material source are chosen to evaluate the compactness of all materials, as is shown in the table 1. Some of the data samples are presented in table 2.

Table 1. The Component of selected attributes.

Category	Attribute	abbreviation
Material sources parameters	P5 content	P5C
	Maximum particle size	MPS
	All material moisture content	AMMC
	High vibration passes	HVP
Compaction parameters	Static rolling passes	SRP
	Rolling thickness	RT
	Rolling velocity	RV
Quality test parameter	All material compactness	AMC

Table 2. A few samples of dataset used for constructing the model.

No.	Input							Output
	MPS[mm]	P5C[%]	AMMC[%]	RT[m]	HVP[1]	SRP[1]	RV[km/h]	AMC[%]
1	115	37.5	10	0.29	13	5	2.36	99.2
2	75	30.1	10.4	0.28	12	3	2.85	97.7
3	126	43	10.5	0.35	10	3	2.23	100.2
4	100	41.1	10.7	0.31	14	2	2.54	99.5
5	170	47.6	8.8	0.25	13	3	2.63	98.2
...	...	...	...	...	...	...	...	...

3.1 Establishment of compaction quality prediction model based on bacterial foraging -support vector regression algorithm

Based on the algorithm flowcharts in 1.3, we randomly allocate the 620 data we have integrated, partly used for training and partly for test in order to elevate the generalization of SVR algorithm and to eliminate over-fitting. Based on the research introduced by Üstün B etc. [12], parameters of SVR algorithm $C = [1, 108]$, $\varepsilon = [0, 0.2]$, $\lambda = [0.01, 2.0]$. And the size of the bacteria populations is set as 50, while other parameters are set conventionally.

At the beginning of the algorithm, the bacteria are randomly distributed in the search space. Subsequently, with the iterations of the algorithm, bacteria move towards the optimal position. When the algorithm reaches its maximum number of iterations, the algorithm terminates and the position of optimal bacteria is the input parameter of the SVR algorithm. Fig.2 shows the initial positions of bacteria and Fig.3 displays the movement of bacteria.

Figure 2. Initial position of bacteria.

Figure 3. Position upgrading of bacteria.

Table 3. Error Statistic of Different Models.

	linear regression model	Neural network model	BF-SVR model
MSE	2.855	2.122	0.685
RAE	2.083	1.9632	0.650
MAE	1.846	1.7452	0.576
MA	12.736	9.926	2.819
X			
MIN	0.004	0.015	0.004

3.2 Evaluation of storehouse surface compaction quality

The monitoring data of ChangHe Dam, a large scale high core rock-fill dam in the southwest of China is taken for the evaluation of compaction quality. Firstly whole storehouse surface is partitioned with a 4m×4m lattice, and the average value of the data in each lattice is used to represent the input parameters, as is shown in Fig.4-5. Finally we taking the compaction quality prediction model constructed by the BF-SVR algorithm on the surface compaction quality prediction, the conclusions are shown in Fig.6.

Figure 4. The distribution of material sources parameters.

Figure 5. The distribution of rolling parameters.

Figure 6. The distribution of compactness predicted by BF-SVR algorithm.

It can be seen from the Fig. 6. that the percentage of the compaction quality of the surface above 98% is 100%. That is to say, it conforms to construction design requirements and the surface quality reaches standards.

4 Conclusion and prospect

This research proposes bacteria foraging-support vector regression algorithm, and use it to build prediction model. The achievements of this research includes:

1. Bacteria foraging -support vector regression algorithm is proposed in this research, and compaction prediction model is reconstructed by this algorithm. Compared with multiple linear

regression model and neural network model, this new model has made much improvement in prediction precision.

2. When employed on the storehouse surface compaction quality prediction, this algorithm reveals the surface compaction quality more comprehensively, in comparison with traditional test of test pits and graphical reports of compaction parameters.

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