

The Application of Improved Genetic Algorithm in the Reverse Calculation of Mechanical Parameters of Sluice Foundation

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Abstract

The global optimization algorithm is the ideal approach to solve the typical complex nonlinear function optimization problem such as engineering inversion analysis. With the efficient ABAQUS kernel solver, the finite element inversion model is established based on quantum genetic algorithm, then use MATLAB programming to realize ABAQUS interface command and establish fitness function with inversion calculation value and measured value of the typical measuring point, thus realizing inversion analysis of physical and mechanical engineering parameters through the intelligent optimization function, which solves the phenomenon of the poor iterations number or convergence speed and being prone to local extremum caused by the improper selection, crossover or mutation operation of traditional genetic algorithm. A sluice foundation mechanical parameters inversion calculation is taken as an example and the inversion results are compared with the traditional GA method, thus illustrating accuracy of this method.

Keywords : Improved genetic algorithm; Sluice; Finite element method; Reversion analysis

Introduction

The design of hydraulic structure and the mechanism analysis of stress, strain,

and crack characteristics of engineering structures are mainly determined by physical and mechanical parameters in geotechnical engineering (soil, rock, dam etc.). The selection of the parameters can be used as a feedback and testing of the design and construction of hydraulic structure. Inversion of the main physical and mechanical parameters of rock and soil engineering medium analysis is very important. For example, the inversion analysis of the physical and mechanical parameters of the sluice foundation is of great importance for the safety evaluation of the sluice.

With the efficient ABAQUS kernel solver, the finite element inversion model is established based on quantum genetic algorithm, then MATLAB programming is used to realize ABAQUS interface command and establish fitness function with FEM calculated value and measured value of the typical measuring point which realizes the inversion analysis of physical and mechanical engineering parameters through the intelligent optimization function, which solves the phenomenon of the poor iterations number or convergence speed and being prone to local extremum caused by improper selection, crossover or mutation operation of traditional genetic algorithm.

Inversion model combining quantum genetic algorithm and finite element method

Quantum genetic algorithm method. Quantum genetic algorithm (Quantum genetic algorithm, QGA) is a combination of quantum computation and genetic algorithm, which is a newly developed probability evolutionary algorithm. Quantum genetic, based on quantum theory, adopts qubit probability coding to represent chromosomes by quantum rotation gates. QGA has achieved remarkable effect in solving combinatorial optimization problems. The procedure of quantum genetic algorithm is shown in Fig.1.

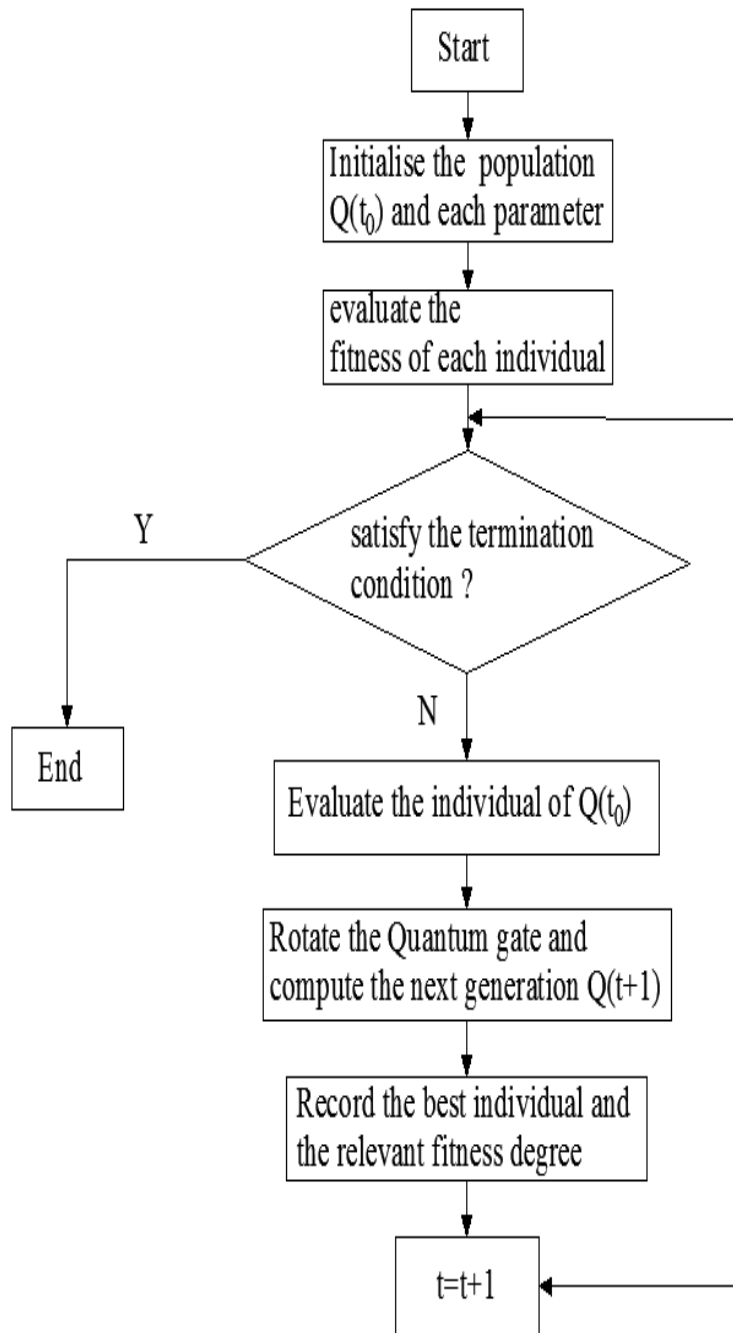


Fig. 1 The procedure of quantum genetic algorithm

The inversion model combining quantum genetic algorithm and finite element method. The commercial finite element software ABAQUS with high kernel solver, can greatly accelerate the process of inversion analysis. Based on this, quantum genetic algorithm and finite element method with the characteristics of joint inversion of rock and soil medium parameter calculation was proposed. The measured and calculated values are utilized to establish the error function point measured value by MATLAB inversion. And the inversion procedure is as follows:

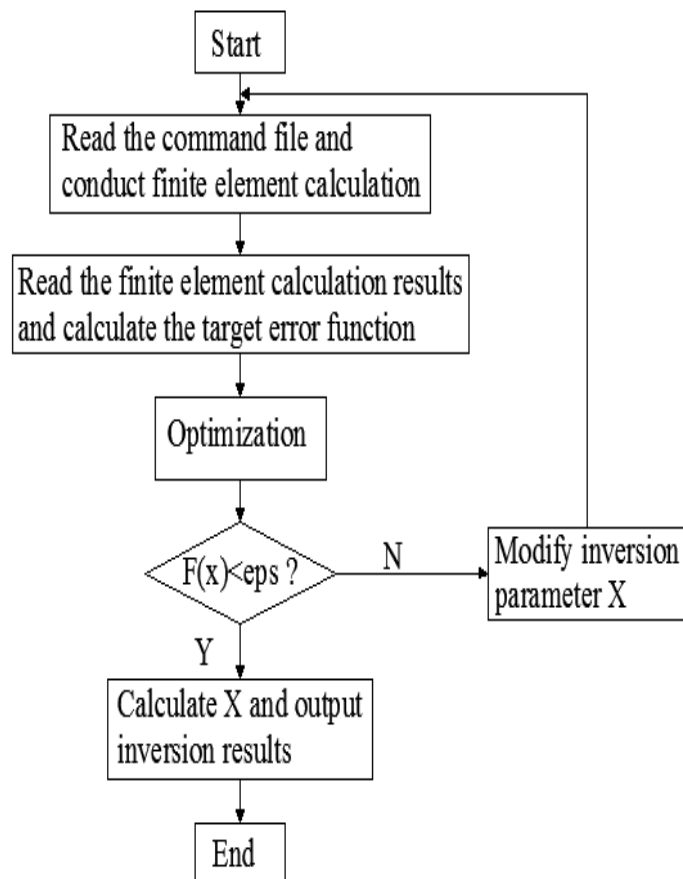


Fig. 2 Flowchart of QGA and FEM inversion calculation

Engineering project

The basic information of a certain sluice. The combination of a sluice and dam layout is used as the sluice structure. -- hole layout scheme in the hole, hole is arranged on both sides of the weir gate. The finite element model is shown in Fig. 3.

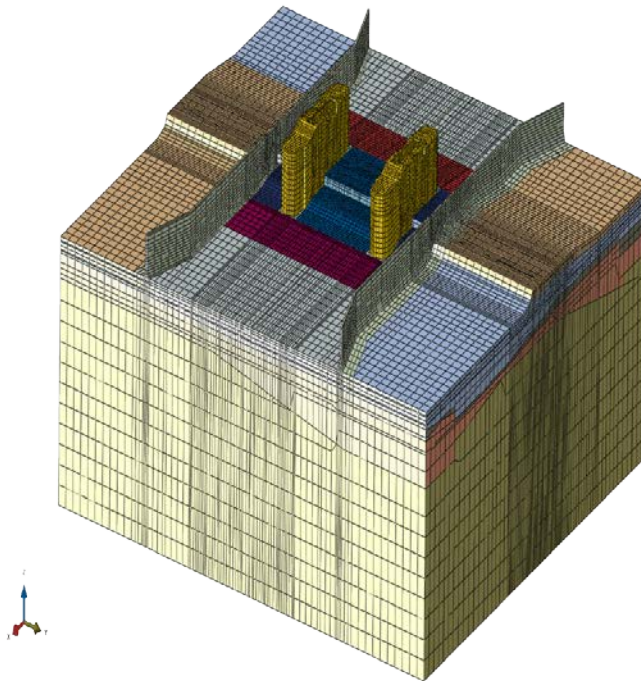


Fig. 3 3-D finite element model of a sluice

The analysis of parametric inversion results. The sluice finite element calculation model soil using the Duncan-Chang nonlinear elastic model was established and 3D models of the sluice is calculated by the finite element software ABAQUS.

The control parameters of quantum genetic algorithm for parameter inversion are as follows: The initial population is set as 0.1-10 times of the parameters inversion and the population size is 30. In order to guarantee the results, calculation of the two methods is defined as 20 and the calculated results are as follows:

Table.1 Comparison of calculation results of two optimization algorithm

Model	Method	Parameter		Best value	Mean value	Shortest time	Mean time	Mean fitness	Best fitness
Three layers	GA	2-K	1176	1168.5	1159.7				
		3-K	1224	1219.8	1218.6	12563.7	31875.4	0.0085	3.767e-4
		4-K	1314	1310.7	1300.5				
	QGA	2-K	1176	1175.5	1138.5				
		3-K	1224	1221.6	1233.4	10575.5	19505.8	0.0057	1.425e-4
		4-K	1314	1312.4	1302.9				

From table 1 we know that QGA has better approximation than GA and the optimal values of foundation soil initial modulus is more accurate; the QGA search average is slightly worse than the GA average since the QGA quantum probability coding enhances the diversity of the population. But the defects easy to fall into local minima of GA are avoided and the fitting parameters of good value can be obtained through the QGA; the average fitting results of the two methods are similar, the best fitting values of QGA are better than GA. Two methods of optimal calculation have similar computing efficiency. But the average search time of QGA is shorter than GA, about 2/3 of GA, improving the efficiency of calculation significantly. The structure analysis is conducted by using initial modulus of inversion. Testing stress measured value calculation and two kinds of algorithm inversion value comparison are as shown in table 2.

Table.2 Comparison of measuring stress and calculated stress of feature points

Stress	Measured value (pa)	Computed value (pa)		Relative error (%)	
		QGA	GA	QGA	GA
σ_{11}	-13982.8	-13794.7	-13654.5	1.35	2.35
σ_{22}	-21822.7	-21782.8	-21692.7	0.18	0.60
σ_{33}	-60263.8	-60278.4	-60183.9	-0.02	0.13
σ_{12}	87.9	81.6	70.9	7.17	19.34
σ_{13}	2623.6	2696.4	2757.8	-2.77	-5.12
σ_{23}	2484.9	2406.3	2394.7	3.16	3.63

Conclusion

(1) The error function is established by use of the reordered and calculated values measures and thus the initial modulus of soil material in a sluice foundation is obtained. The results are more accurate than the traditional genetic algorithm.

(2) Quantum genetic algorithm (Quantum genetic algorithm, QGA) is a combination of quantum computation and genetic algorithm, which is a newly developed probability evolutionary algorithm. Quantum genetic, based on quantum theory, adopts qubit probability coding to represent chromosomes by quantum rotation gates.

(3) The finite element calculation module is the key factor to solve the complex inversion analysis. ABAQUS finite element software is a powerful engineering simulation kernel, which can greatly accelerate the inversion analysis process and reduce the amount of calculation.

Reference

- [1] Zhong Ru Wu. The Safety Monitoring Theory of Hydraulic Structure and its Application [M]. Beijing: Higher Education Press, 2003
- [2] FRISWELL M I.A combined genetic and eigensensitivity algorithm for the location of damage in structures. Computers and Structures . 1998
- [3] SANKAR K N.Velocity inversion in cross-hole seismic tomography by counter -propagation neural network, genetic algorithm and evolutionary programming techniques. Geophysical Journal International . 1999
- [4] Li Shouju, Liu Yingxi, Wang Denggang. The aquifer parameters of the simulated annealing algorithm based on nonlinear inversion [J]. Journal of Xi'an Jiao Tong University. 2001 (05)
- [5] Li Shouju, Liu Yingxi, Wang Denggang. Genetic algorithm initial rock stress field inversion [J]. Journal of China coal society based on 2001 (01)
- [6] Moore M P, Narayanan A. Quantum Inspired Computing [Technical Report].Exeter: Department of ComPuterSeienee, UniversityofExeter, ExterEX44PT, UK. 1995