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Indirect Estimation of Uniaxial Compressive Strength of Rock Using New Meta-Heuristic Algorithms

Hadi Fattahi[1] Farshad Malekmahmoudi[2]
Hossein Ghaedi [2]

1. Introduction

The uniaxial compressive strength (UCS) of rock is very important parameter for rock classification and the design of structures either upon or inside rocks. In addition, this parameter is essential for judgment about their suitability for various construction purposes. However, determining UCS of a rock material is time consuming and expensive and involves destructive tests. Therefore, indirect test is often used to predict the UCS. Many researchers have attempted to find alternative and indirect methods for estimating UCS using different methods.

Although previous efforts are valuable, in many cases, the aforementioned empirical models are not capable of distinguishing the sophisticated structures involved in dataset. These reasons have been the main causes of the interest to better find out the interaction between UCS and input parameters and to propose a more precise and sure models for the estimation of the UCS. For doing the purpose, using developed methods such as meta-heuristic algorithms, which can successfully model the behavior of linear and nonlinear involved in data, is useful. In this study, the application of meta-heuristic algorithms for data analysis named gray wolf (GWO) and fruit fly algorithm (FFOA) to estimate UCS of rocks is demonstrated. In these models, point load index (Is (50)), Schmidt hammer return values (Rn), wave velocity p (Vp) are utilized as the input parameters, while UCS of rocks is the output parameter. The estimation abilities offered using meta-heuristic algorithms are presented by using experimental data given in open source literatures.

2. Analysis and results

2.1. Gray wolf algorithm. The GWO is a new bio-inspired heuristic optimization algorithm that imitates the way wolves search for food and survive by avoiding their enemies. This algorithm divides the population into four groups: delta, omega, beta, and alpha. In addition, the three hunting stages are simulated: attacking prey, looking for prey, and encircling prey. The GWO algorithm needs a parameter number to be set, which includes initialize alpha, the stopping criteria, the sites selected number for neighborhood search, the search agents number, delta, the maximum iterations number, and beta. Figure 1 depicts the GWO's pseudo code.

Initialize the grey wolf population X_i (i = 1, 2, ..., n)
Initialize a, A, and C
Calculate the fitness of each search agent
X_α=the best search agent
X_β=the second best search agent
X_δ=the third best search agent
while *(t < Max number of iterations)*
    for *each search agent*
        Update the position of the current search agent
    end for
    Update a, A, and C
    Calculate the fitness of all search agents
    Update X_α, X_β, and X_δ
    t=t+1
end while
return X_α

Figure 1. Pseudo code of the GWO algorithm

2.2. Fruit fly algorithm. An approach to solve the FFOA is an intelligent search algorithms based on foraging behaviors of the Fruit-Fly, Drosophila. The FFOA has immense potential to deal with the variety of complex optimization problems. These processes are Smell and Sensitive Vision. Through Smell process, Fruit-Fly smells the food source available in the surrounding by osphresis organ, which is a function of stochastic in nature, and flies towards the corresponding location. The perception of fruit flies is better than other species, and fruit flies can smell food sources 40km away. They also possess extremely strong perception and search ability for various smells in the air, and they can find food and companies with keen vision near the food, so as to fly to the destination smoothly. With favorable group intelligence, FFOA is widely applied to various fields, especially on function optimization, neural network, support vector regression parameter optimization, financial management, and early warning of enterprise risks. Of course, as FFOA is a newly proposed algorithm, theories about it are still in exploration, and its application fields need to be further promoted. Figure 2 shows the procedure of a Fruit-Fly group's food finding behavior.

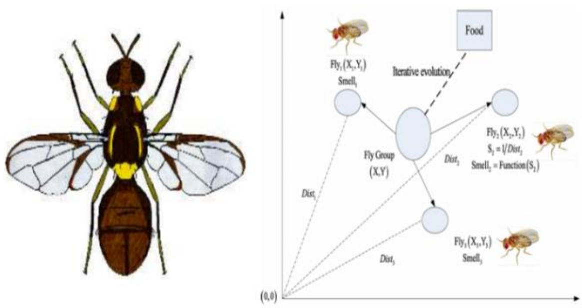

Figure 2. Group iterative foraging process of Fruit-Fly
The procedure of the original FFOA is given below.

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[1]. Corresponding author. Associate Professor in Rock Mechanics Engineering, Faculty of Earth Sciences Engineering, Arak University of Technology, Iran. Email: H.fattahi@arakut.ac.ir

[2]. MSc. Student, Faculty of Earth Sciences Engineering, Arak University of Technology, Iran

Step 1: Randomly initialize the location of the Fruit-Fly swarm.

Step 2: Each individual searches for food in a random direction and distance around the swarm location using osphresis to generate a new population.

Step 3: Evaluate all the new individuals.

Step 4: Identify the best Fruit-Fly with the maximum smell concentration value (i.e., the best objective), and then the Fruit-Fly group flies towards the best location utilizing vision.

Step 5: End the algorithm if the maximum number of iterations is reached; otherwise, go back to Step 2.

2.3. Analysis. The aim of this study was to use the new meta-heuristic algorithms of GWO and FFOA to indirectly estimate uniaxial compressive strength. To achieve this goal, data from 124 granite rock samples from the Selangor freshwater transfer tunnel project in Malaysia, including the results of point load index (Is (50)), Schmidt hammer return values (Rn), wave velocity p (Vp) (As input parameters) and uniaxial compressive strength (as output parameter) were used. To evaluate and validate the models obtained by intelligent algorithms, the indices of square correlation coefficient (R^2), variance inclusion (VAF), mean absolute error percentage (MAPE), root mean square error (RMSE), and mean square error (MSE) were used. According to the results obtained in this paper as well as the validation of the models, the predicted values of uniaxial compressive strength by the new metamorphosis algorithms of GWO and FFOA are very close to the real values of the region, indicating the low error of the models in indirect estimation of the uniaxial compressive strength.

3. Conclusion

After creating the models (prediction relationships) using coding in MATLAB software, in order to validate this model, the indices of R^2, VAF, MAPE, RMSE, and MSE were used for each of the algorithms, training, and test data. The validation results showed that the prediction relationships made by the meta-heuristic algorithms of GWO and FFOA with the actual values obtained are very close and have high accuracy. After validating the model, @Risk software was used to evaluate the sensitivity analysis. The results showed that the Rn parameter will have the greatest effect on uniaxial compressive strength compared to other parameters. Finally, it can be reliability method, with a linear approximation of the limit state surface, does not make accurate predictions. As the Monte Carlo simulation requires a large amount of random data (n=280000) and replication of the simulation to reduce the changes in the probability of failure and to achieve a high-precision answer, for the present problem the second order method at a much lower computational cost is an alternative.