Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(10) (2021) 645-648
DOI: 10.22060/ceej.2019.15980.6096

Using Artificial Neural Network surrogate model to reduce the calculations of leak detection in water distribution networks

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ABSTRACT: The leak detection parameters in the inverse transient analysis (ITA) are obtained in an inverse approach by solving a nonlinear programming problem using metaheuristic algorithms such as genetic algorithms (GA). Beside its high capability in deriving the leak detection parameters, the ITA method is computationally complex and costly. Applying optimization techniques like GA can reduce the complexcity of the ITA method. This study aims to increase the computational efficiency by employing surrogate models in the optimization process of the ITA method. The surrogate model is in fact a simulated sample of the main model capable of approximately calculating the objective function in a fraction of a second. The way these models are integrated into the optimization model highly affects their success or failure. To this end, two algorithms incorporating population-based surrogate models, namely (Pre-selection Strategy) PS and (Best Strategy) BS, were presented. To evaluate and compare the results, a distribution network was used to identify the leak detection parameters. The results indicated an increase in the computational efficiency compared to the ITA method integrated with the GA. The PS algorithm demonstrated the highest performance by reducing the objective function and time complexity by 58% and 78%, respectively.

Review History:

Received: 2019-03-12
Revised: 2019-09-30
Accepted: 2019-12-10
Available Online: 2019-12-15

Keywords:

Computational efficiency
Inverse Analysis
Metaheuristic Algorithm
Optimization
Transient.

1-INTRODUCTION

The Inverse Transient Analysis (ITA) method can be considered as one of the most prominent modeling methods developed in pressurized pipelines for leak detection [1]. Although this method has been successful so far, due to the application of the GA optimization algorithm, the identification of leak parameters involves high computational costs [2]. Therefore, it is limited to systems with simplified boundary conditions, and its performance is reduced in most water supply systems composed of a complex configuration. Considering the issues raised in this study, it is attempted to provide a number of specific solutions to maintain both the computational structure and to increase the accuracy and speed of access to leak parameters. In this regard, the idea of using surrogate models to solve the ITA problem arises. The most important advantage of surrogate models is to simulate the original search space at a cheaper computational cost [3]. The Artificial Neural Network (ANN) surrogate model is one of the surrogate models that has managed to achieve successful results while being simple and cost-effective [4]. The implementation approach of surrogate model within the problem-solving process is very important [5]. In this regard, this study uses two implimentiation methods of the ANN surrogate model, namely PS and BS and compare the achieved results.

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2- METHODOLOGY

The basic structure of the surrogate models of PS and BS is similar to that of the GA algorithm, except that during the optimization process in each generation, some members of the population are evaluated by the original simulator function and the rest by the ANN surrogate model. Since this study aims to determine the performance of algorithms with surrogate models of PS and BS in the leak detection process of the ITA method, a water supply network is used to find leak parameters. The configuration of the water supply network is described in Fig. 1, and other related specifications of this water supply network are provided in Haghighi and Shamloo's (2011) research [6].

3-RESULTS AND DISCUSSION

The algorithms with surrogate models of PS and BS were evaluated for the accuracy of the obtained results and the convergence rate of the objective function whose results were compared with those of the conventional ITA algorithm. Due to the random parameters in the structure of all algorithms, each method was evaluated ten times. The examination of the accuracy of the results showed that the least error rate was related to the surrogate model of PS and the BS algorithm, respectively (Fig. 2). The accuracy of the results is increased due to a smarter selection of children in the objective function minimization algorithm.

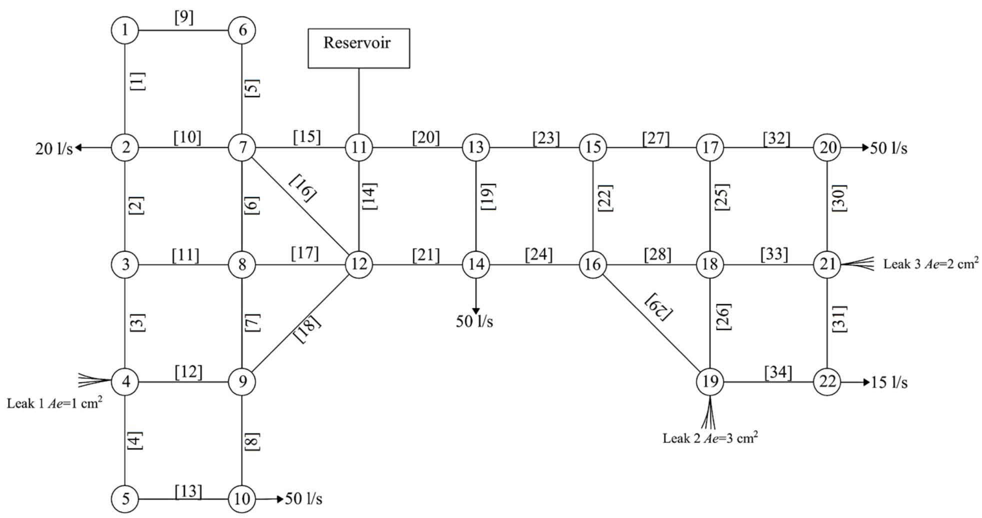

Fig. 1. Water Supply Network layout

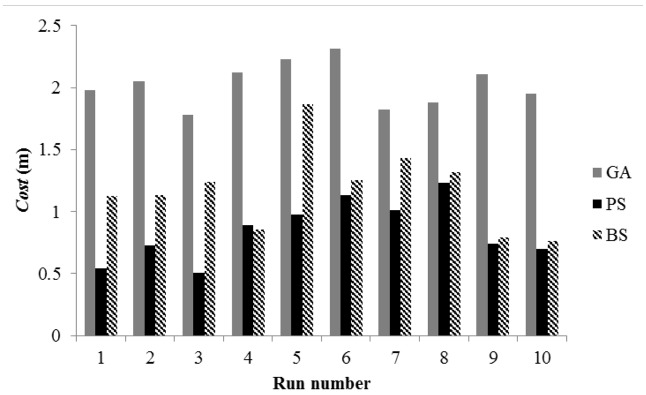

Fig. 2. Results of the evaluation of water supply network objective function 10 times using different algorithms

To compare the trend of convergence rate, the objective function minimization process is examined in each of the computational algorithms up to the stopping condition of NFE = 6,000 (Fig. 3). A careful examination of the results shows that the PS algorithm has a faster objective function minimization process than other algorithms. The PS algorithm is followed by the BS and GA algorithms, respectively. Due to the quicker detection of optimal areas in the search space, the leak detection process speeds up as a result of learning the patterns in the structure of the surrogate models.

4- CONCLUSION

The present study showed that using the ANN surrogate model along with the approach of the PS and BS algorithms would increase the computational efficiency of the ITA method. In the PS and BS methods, using the information obtained during the optimization process in the search space, the ANN surrogate model guides the optimization process pathway, which ultimately reduces the number of main simulator evaluations. Thus, using these algorithms, repetitive calculations can be avoided in solving optimization problems, especially in stochastic methods. Given the successful application of the ANN surrogate model in the optimization process of the ITA method, the application of

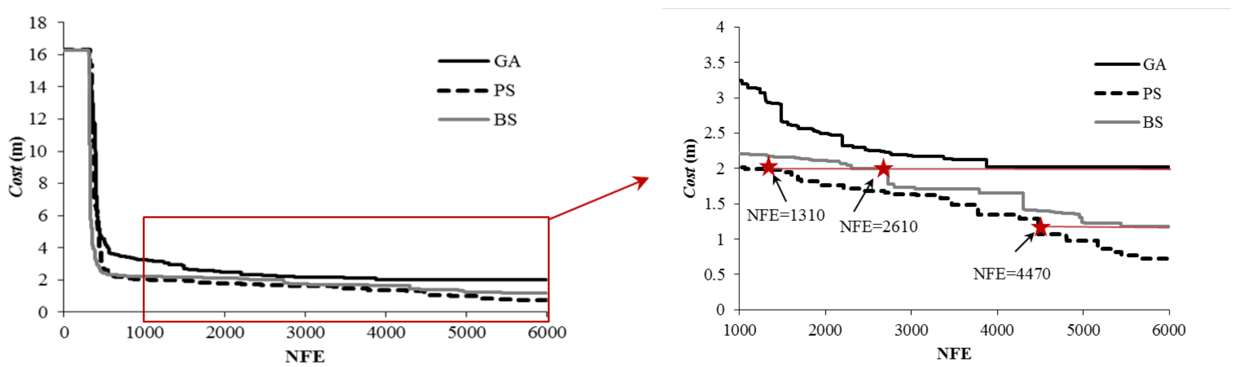

Fig. 3. Minimization of the objective function of the water supply network versus NFE

other surrogate models, as well as the design of other surrogate model management strategies in the optimization process, is suggested for future research.

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HOW TO CITE THIS ARTICLE

S. Sarkamaryan, S. M. Ashrafi, A. Haghighi, H. Mohammad Vali Samani, Using Artificial Neural Network surrogate model to reduce the calculations of leak detection in water distribution networks, Amirkabir J. Civil Eng., 52(10) (2021) 645-648.

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