Development of ANFIS-GA Meta-Heuristic Model for Predicting Scour Depth in Vicinity of Submarine Pipelines

Ehsan Yarmohammadi[1] Ahmad Rajabi[2]
Mohammad Ali Izadbakhsh[3]

1. Introduction

Pipelines are used to transport oil, gas, and other transferable materials. These structures inevitably cross the coastal bed in coastal and marine areas. Given that there is a possibility of coastal flows and waves in these areas, the scour phenomenon occurs around pipelines. Due to the complexity of the scour process in the vicinity of these structures, many studies have been conducted by various researchers on the behavior of scouring around submerged pipelines. A review of past studies indicates that the evaluation of scouring in the vicinity of submerged pipes is of considerable importance. Also, the combination of genetic algorithm (GA) and ANFIS has not been utilized to simulate scouring around these structures so far. Therefore, the main aim of the present study is to simulate the scour depth in the vicinity of submerged pipes by the ANFIS-GA meta-heuristic model. To this end, first the parameters affecting the phenomenon are identified and then six ANFIS-GA models are introduced. Then, by analyzing the results of the mentioned models, the superior model is introduced. Also, by conducting a sensitivity analysis, the most effective input parameter is detected.

2. Physical model

In the present study, the experimental values measured by Moncada and Aguirre (1999) are used to model the scour depth around submerged pipes using the ANFIS-GA method. Their laboratory model consists of a rectangular horizontal channel in which submerged pipes are placed near the sedimentary bed. The length, width, and height of the canal are 8.3, 0.5 and 0.5 meters, respectively. In the laboratory study, they used four tubes with different diameters and sediments with two different diameters. They performed 90 experiments in different hydraulic and geometric conditions. Figure 1 shows the scour in the vicinity of the submerged pipes near the sedimentary bed.

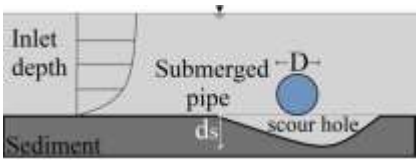

Figure 1. Layout of scour around horizontal submerged pipes

3. Numerical model

ANFIS has a wide range of applications and is divided based on the type of inferential operations on the If-Then rule into two categories including Mamdani fuzzy models, TSK fuzzy models (Takagi-Sugeno and Tsukamamoto fuzzy models). The TSK method uses simple linear or fixed functions, while the Mamdani method uses fuzzy membership functions. Due to the high accuracy and relatively small TSK model, the current study uses the fuzzy Takagi-Sugno conclusion. The Sugeno fuzzy model works to develop a fuzzy system in order to create fuzzy rules according to the input-output data set.

The Genetic Algorithm is one of the most well-known types of evolutionary algorithms starting the search with a population through random initial solutions. When the ultimate criteria are not met, it is produced with the help of genetic operators such as crossover, mutation, and selection of new populations. With each repetition of these three genetic operators, a generation is created. Primary populations are defined as strings and describe each strand as a chromosome. In the crossover operator, the genes of the two parents are combined to form two new offsprings. In the mutation operator, a sudden change in the gene occurs. In the selection operator, the populations are evaluated using the fitness function. Populations with less fitness are removed and populations are driven to optimal responses. Population selection methods for the application of genetic operators are divided into three categories: actual selection, tournament-based selection, and selection based on the roulette wheel. In the roulette wheel-based selection method, a fitness criterion is used to select each member of the population, so that in each string the value of the objective function is considered. Based on the values of the

[1]. PhD Candidate, Department of Water Engineering, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran
[2]. Corresponding Author, Assistant Professor, Department of Water Engineering, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran
Email: ahmad.rajabi1974@gmail.com
[3] Assistant Professor, Department of Water Engineering, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran.

objective function in each iteration, a specific fit is achieved for each string. The fit number is equal to the ratio of the value of the objective function of that population to the sum of objective functions of the population, which is also called the probability of survival of each population. Thus, after several generations, the genetic algorithm gradually becomes convergent towards the optimal answer. The termination criterion of the algorithm is to repeat a certain number of repetitions, which are determined by the user before the start of the algorithm.

4. Conclusion

In this study, by combining the ANFIS model and the Genetic Algorithm, a meta-heuristic model (ANFIS-GA) was developed to predict the scour depth near the submerged pipes. Then, the effective parameters on the scour depth were identified. Also, in order to examine the accuracy of the numerical models and their validation, the Monte Carlo simulation and k-fold cross validation method with k=6 were utilized, respectively. By evaluating the results of the mentioned numerical models, the superior hybrid model was introduced. This model accurately predicted scouring values. The superior model predicted scouring values in terms of all input parameters. For example, the values of RMSE and MAPE are equal to 0.079 and 9.571, respectively. Moreover, approximately 91% of the values modeled by the superior model had an error rate of less than 20%. Then, to identify the effective parameter, the effect of each of these parameters was removed separately for the next models and their accuracy was evaluated. Finally, the distance between the pipe and the sedimentary bed before scour to the pipe diameter was identified as the most influencing parameter.