Artificial neural networks based on principal component analysis, fuzzy systems and fuzzy neural networks for preliminary design of rubble mound breakwaters

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**ABSTRACT**

The new artificial intelligence models proposed for the preliminary design of rubble mound breakwaters consist of (1) multi layer feed forward artificial neural networks, (2) hybrid artificial neural networks with principal component analysis, (3) fuzzy systems, and (4) fuzzy neural networks. These models are applied for the stability analyses of Mersin yacht harbor main breakwater, as a case study in Turkey. A better agreement between the predicted stability numbers of hybrid artificial neural networks and measurements is obtained when compared to the stability equations. The Hybrid Artificial Neural Network model that is trained by the pre-processed database of measurements obtained from the Principal Component Analysis is considered as a robust technique in handling uncertainties inherent in the preliminary design. The fuzzy system and fuzzy neural network models have the advantages of incorporating flexible reasoning as expert systems when compared to hybrid neural networks; however, they require the development of new prediction enhancement techniques for the improvement of their forecasts.

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1. Introduction

Artificial intelligence consists of different techniques such as neural networks and fuzzy logic, utilized to solve complex problems based on human intelligence [1]. Neural networks and fuzzy systems represent methodologies that deal with uncertainty arising from system complexity and they can be effectively utilized to handle uncertainties [2–5] inherent in coastal engineering. An artificial neural network (ANN) is a non-linear computing system consisting of a large number of interconnected processing units (neurons), which simulates human brain learning. Fuzzy systems are a collection of “if-then” rules defining the fuzzy relations of fuzzy variables in systems by utilizing fuzzy logic or the fuzzy set theory [6,7]. A literature search indicates that generally they have been widely used individually for coastal engineering applications such as marine litter prediction [8], wave data assessment [9–13], time series processing [14,15], tidal level forecasting [16], reliability assessment [17,18] and structural stability analysis [19,20]. On the other hand, further improvements and investigations on the application of neural networks and fuzzy systems are also needed, since each of them have their own advantages and disadvantages.

The attractiveness of ANNs comes from their remarkable information processing characteristics pertinent mainly to non-linearity, high parallelism, fault tolerance, and learning and generalization capabilities [21]. Among different types of neural networks, the most generally used one is the multi layer feed forward neural network. This type of ANN constructs a global function approximation and, even if the direct application of a single multi layer feed forward neural network to model a complex system has been proved to be better than conventional methods, there is a need for further improvement of its performance or generalization capability [22]. The performance of a multi layer feed forward neural network depends mainly on data representation [23,24]. An important characteristic of data representation is uncorrelation, since correlated data introduce confusion to the neural network during the learning process [25]. In addition, many input variables may cause poor generalization performance [26,27]. These problems can be solved by combining a feed forward neural network with principal component analysis [28,29]. Principal component analysis [30] transforms the original data set into a set of uncorrelated variables that capture all of the variance of the original data set. On the other hand, if the database is limited and contains qualitative information, fuzzy systems can be alternatively used in modeling of complex system behaviors [31]. The advantage of fuzzy systems is that, they can handle human based information such as experience and judgment, and can consider qualitative data described...
the Fuzzy System Model were not in acceptable levels due to unrealistic aspects in safety assessment.

4. Conclusions

In this study, artificial intelligence models were developed for the stability analysis of rubble mound breakwaters. Although, ANN models (without PCA) were not adequate in capturing the non-linear characteristics of the complex hydraulic system, using PCA in the process of choosing the appropriate training data and the number of PC's enhanced the neural network prediction capabilities (HNN case). Therefore, a better agreement between the predicted stability numbers of hybrid artificial neural networks and measurements was obtained when compared to the: (a) stability equations of VdM, and (b) artificial neural networks trained by the data sets that were not pre-processed. As a result, the hybrid neural network has the advantage of robustness as an alternative for the stability assessment of coastal structures. However, hydraulic model tests for the final design are necessary to examine other failure modes; since the safety of coastal structures is highly variable and depends upon the unpredictable nature of coastal phenomena. The FS and FNN models had the advantages of capturing a complex real-world problem and incorporation of fuzzy logic as expert systems when compared to HNN models; however, they required new prediction enhancement techniques for the improvement of their forecasts. The CPU time of all of them on desktop computers was very short enabling the efficient utilization of the artificial intelligence model in the design process.

References