Artificial Intelligence Based Surrogate Models for the Optimal Management of Seawater Intrusion in Coastal Aquifers

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Coastal aquifers are one of the most highly stressed sources of fresh water due to the everyday increasing demand of freshwater for drinking, agricultural and industrial purposes near the coasts. Sustainable use of coastal aquifers is crucial as they are susceptible to contamination by saltwater intrusion caused by overexploitation. Linked simulation-optimization methodology is usually used to derive optimal pumping strategies for coastal aquifer management. Surrogate models are used to replace a numerical model within an optimization algorithm to reduce the computational burden involved in the linked simulation-optimization approach. A number of studies have used artificial neural networks and its derivatives as surrogate models. Large number of input-output patterns is required to train a massive neural network model. For large networks the training time required is very large rendering the use of a surrogate model ineffective. In this work we develop two multi-objective management models with surrogate models based on Genetic Programming (GP) and Modular Neural Networks (MNN) which requires less number of training patterns, lesser training time and is parametrically less complex. Trained and tested surrogate models are linked to a multi-objective genetic algorithm, NSGA-II, to optimize the pumping from an aquifer system considering two conflicting objectives. Maximizing pumping from a set of production wells and minimizing the pumping from a set of barrier wells near the coast constitute the two conflicting objectives. The surrogate model training and the optimization search is performed in two stages. A near optimal solution is obtained after the optimization in the first stage depending on the accuracy of the initially trained surrogate models. After the first stage of optimization the search space is modified around the near optimal solutions. A search space adaptation is performed based on the relative importance of the pumping variables in model prediction. The modified search space has a bigger domain for the more significant variables. The surrogate models are retrained with training patterns from the modified search space. Performance of the surrogate model based methodology is tested for an illustrative study area. The inherent capability of GP in identifying the relative importance of the model variables makes it superior for use in this methodology.

Keywords : Coastal aquifer, pumping, surrogate model, GP, ANN