Differential Evolution Algorithm for Parameter Identification in Groundwater Modeling

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Abstract

Based on the experimental data obtained, the parameters of the groundwater models have to be determined, which is usually called the parameter identification and represents a basic problem routinely solved in groundwater modeling. The parameter identification may usually be formulated as a nonlinear optimization problem, and traditionally, solved by the gradient-based method, which can trap in the local minimum easily. In the recent years, evolutionary algorithms like genetic algorithm (GA) have been used for solving such problems without the requirement of gradient information about the response surface. However, the coding of real parameters into binary chromosomes used in GA is not intuitive and the convergence of finding global optimum is very slow. In this study, a new global optimizer, differential evolution (DE) algorithm, is demonstrated for solving parameter identification in groundwater models. DE is a population-based optimizer and the crucial idea behind DE is a new mutation scheme for generating trial parameter vectors, by adding the weighted difference vector between two population members to a third member. A synthetic unconfined groundwater model has been developed to represent the complex non-linear physical system and the DE is used to solve the parameter identification problem. A comparison of the results obtained by the traditional approach, GA, and DE is presented. A sensitivity analysis of variables used in DE is employed to examine the influence on optimal solution. The results demonstrate that the DE is to be one of the most promising novel algorithms, in terms of efficiency, effectiveness and robustness.

Introduction

Groundwater is the main water resources in many regions, including Taiwan, and water demand, especially in summer months, can be very high. The uses of the groundwater resources wisely and the necessity of maintain them in good quality require rational design and management. However, before finding an optimal strategy to management groundwater resources, a well performed numerical model is essential. Groundwater models used in applied research are often defined by a system of partial
differential equations and should be noted that in general the solutions of such a system need not be an elementary function. The accurate estimation of parameters in the groundwater model, also called the parameter identification, affects the performance of models and the capability of finding the optimal policy for the management. The parameter identification, which frequently arises, while developing the mathematical models, may be formulated as a nonlinear optimization problem, and a sophisticated algorithm to determine the best set of parameters is essential.

Plenty of varied procedures were reported in literature for parameter identification of groundwater models, and these procedures can be categorized into two groups, gradient-based methods and evolutionary algorithms (EAs). The gradient-based methods, also called local search like quasi-linearization method, can find the optimal solution efficiently, but, in the meantime, can trap in a local optimum easily because of the nonlinearity of groundwater model. EAs, also called global search, such as the genetic algorithm (GA), can identify the global optimum without the requirement of gradient information. However, its convergence is very slow, and the implementation, like classical GAs, using binary coding for the representation of the genotype results in that floating point coding moves EAs close to the problem space, allowing the operators to be more problem specific (Michalewicz, 1999). Differential evolution (Price et al., 2005; Karterakis et al., 2007; Bayer et al., 2010; Beck et al., 2010) is an evolutionary optimization technique, which is simple, significantly faster and robust at numerical optimization and likely chances of finding true global optimum.

References