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Development of reservoir operation policies considering variable agricultural water demands

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ABSTRACT

In this paper, a genetic algorithm (GA) optimization model is developed for reservoir operation optimization considering variations in water demands. In order to incorporate the demand uncertainties in optimal operation policies, different types of linear equations with different combinations of inflow, storage at the beginning of the month, and water demands as independent variables have been considered. The coefficients of optimal operation policies are obtained using classic and fuzzy regression analysis. In the case of fuzzy regression, both symmetric and asymmetric membership functions are used. Efficiency of operation policies are evaluated based on the long-term operation simulation of Zayandeh-Rud Reservoir in central part of Iran. Estimated figures for the four criteria of reliability, resiliency, total vulnerability, and maximum monthly vulnerability and also the statistical criteria of correlation coefficient, coefficient of efficiency, and standard error indicate that the fuzzy linear regression equations with inflow, storage, and demand as independent variables, in which asymmetric membership functions are used for the coefficients of the regression equation, has the best long-term performance in meeting variable demands.

1. Introduction

More than 85% of total water consumption in Iran is related to irrigation and agricultural development. Significant variations of agricultural water demands due to the climate variations and variations in market prices have made agricultural water demands as one of the main sources of uncertainty in many water resources systems in Iran and around the world. Different simulation and optimization techniques have been developed and implemented to incorporate these uncertainties in management policies. Genetic algorithm (GAs) represents an efficient and robust search method for non-linear optimization problems and has been quite successfully applied to a number of reservoir operation optimization problems (Chang, Chen, & Chang, 2005). The literature describing the application of GAs in single and multi-reservoir systems optimization is not abundant. East and Hall (1994) suggested that GAs have potential in optimization of water resources systems and they can significantly decrease the execution time. Chang, Chen, and Chang (1998) applied a real code GA for rule-base flood control management. Wardlaw and Sharif (1999) used the GA model for short-term optimization of a four-reservoir system. They concluded that the real presentation, tournament selection, uniform crossover and mutation have satisfactory results for multi-reservoir systems. Chang et al. (2005) investigated the efficiency of real and binary coding in GA models.

Fuzzy Set Theory (FST) is one of the techniques that has been widely used for incorporating the uncertainties and vagueness in decision variables in reservoir operation optimization models and operation policies.

Many stochastic methods have been also developed for incorporating uncertainties in simulation and optimization models (Karamouz & Vasiliadis, 1992; Kelman, Stedinger, Cooper, Hsu, & Yuan, 1990). FST has been referenced as a powerful tool for dealing with different types of complexities in reservoir operation optimization problems (Chang, Hui, & Chen, 2002; Dubrovin, Jolma, & Turunen, 2002; Russel & Campbell, 1996; Tilmant, Vanclooster, Ducketein, & Persoons, 2002). For example, Mousavi, Karamouz, and Menhadj (2004) used FST for incorporating uncertainties due to discretization of continues variables in dynamic programming models for reservoir operation optimization.

Yeh (1985) presented a comprehensive state-of-the-art review of the various reservoir operation models. He pointed out, despite considerable progress; research relating to reservoir operation has been very slow in finding its way into practice, due to disregarding the reality of operation problem in some ways. Improper structure of operation policies has been one of the major problems for applying results of these models in the real-world problems.

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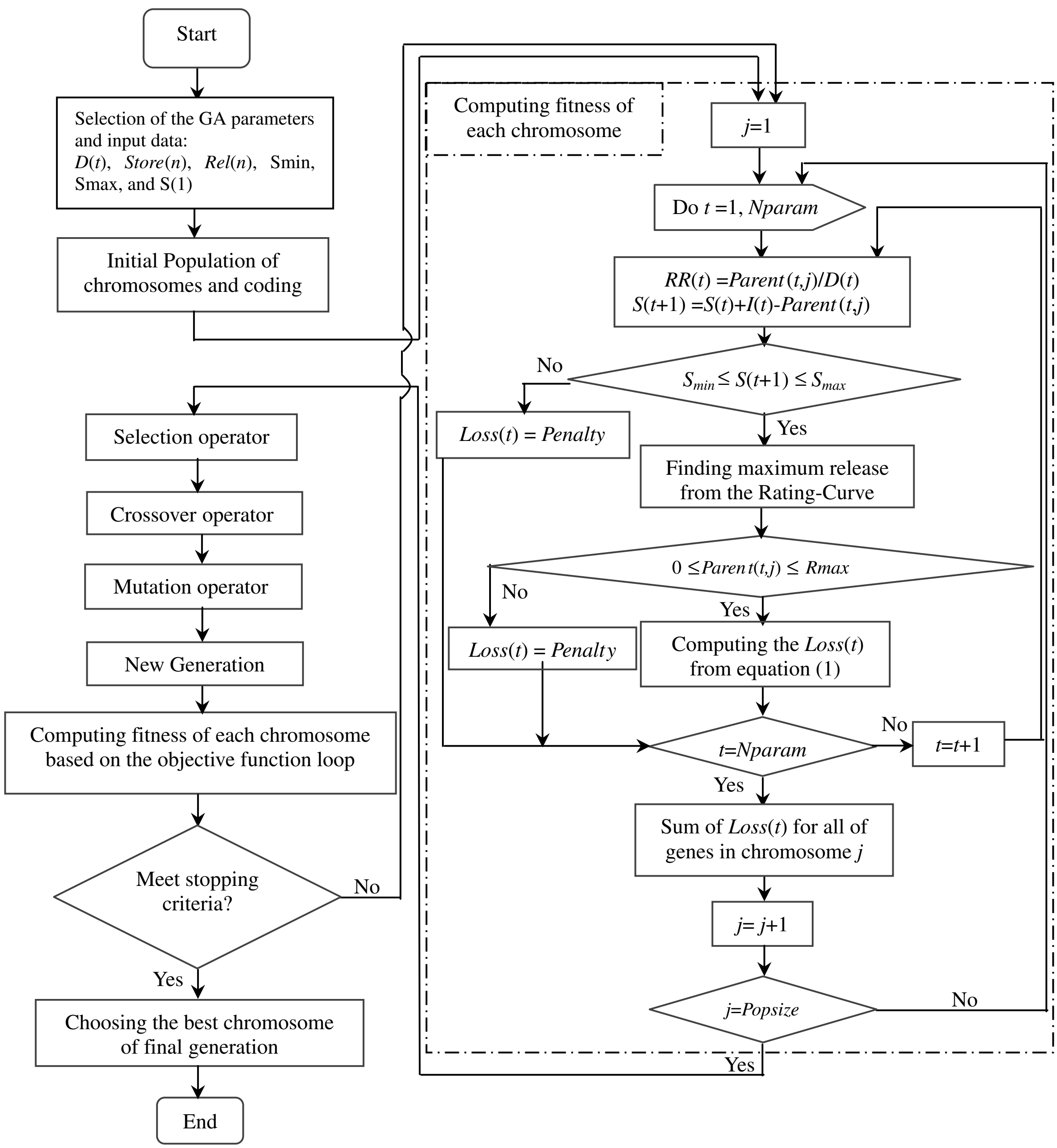
One of the main areas of FST application in water resources planning and management is called fuzzy linear regression (FLR), which is developed based on the Tanaka's approach (Tanaka, Uejima, & Asai, 1982). In fuzzy linear regression, uncertainty is due to fuzziness, not randomness and the major emphasis is on the objective function of the model for optimizing the parameters of fuzzy variables. Kacprzyk and Fedrizzi (1992) presented some of different approaches to fuzzy regression analysis. FLR determines regression models with vague relationship between dependent variable and independent variables, recommended for practical situations in which decisions often have to be made on the basis of imprecision and where human estimation is influential (Hong, Lee, & Do, 2001).

In this study, a GA model is developed for reservoir operation optimization in which the time series of variable agricultural water demand is considered as one of the inputs to the optimization loop.



j: index for chromosome number; t: index for month number; *popsize*: population size; $I(t)$: reservoir inflow at period t; $D(t)$: demand at period t; $Store(n)$: interpolated storage based on volume-area-elevation curve; $Rel(n)$: interpolated release based on rating curves of outlet gates; S_{min}: allowable minimum storage; S_{max}: allowable maximum storage; *Nparam*: number of parameters; $RR(t)$: monthly release to demand ratio; $Parent(t,j)$: t^{th} gene of chromosome j; $S(t)$: storage at the beginning of period t; $Loss(t)$: loss at period t; *Rmax*: array of allowable maximum release. *Penalty*: penalty for infeasible solutions.

Fig. 1. Flowchart of the GA model for reservoir operation optimization.