Optimization of Release from Dam Reservoirs to the Agriculture Demands (Case study: Jarreh dam to Ramhormoz Irrigation and drainage network, Khuzistan)

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Abstract: This paper presents a Genetic Algorithm (GA) model for finding the optimaloperating release of reservoir, located on the river Zard, a major tributary of the basinAllah. In the presented research mathematical optimization models were used to Management and optimize the release and storage volume from Jarreh dam reservoir. For reach this objective using monthly inflow time series to the reservoir dam in the 40 years (1971-2010) and was using probability distribution the inflow to the Reservoir with different percent. For the purpose of minimization different between release and demand, a non-linear optimization was developed and excused using Matlab software and genetic algorithm tool box method. The water demand for crops in the Ramhormoz irrigation and drainage network was calculated using Penman-Montieth method and finally calculated monthly demand. The results showed that the release from dam in the different inflow was not meeting the monthly demands in Ramhormoz Irrigation and drainage network.

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1. Introduction

The average annual rainfall in Iran is less than one third of world's average annual rainfall; Iran is regarded as dry country. Then it's necessary to pay serious attention for determination of water resources in order to plan exactly through better understanding for meeting various Demands. Construction of reservoir dams over the rivers for storing water in low precipitation periods and also decreasing the consumption of river water are appropriate strategy for operation of water resources. Determining suitable program of operation of water resources systems in such a way that has desired performance in all conditions is called optimization. Then it's necessary to consider the application of optimization methods for determining reservoir operation program. It's required to enter some kinds of data to an optimization algorithm before using. Objective function of an optimization model is a relationship between decision variables or existing factors in the system that their optimized values must be determined. Decision variables are parameters that their changes will cause the change of objective function, and finding just the optimized values for these variables is considered during optimization. State Variables are quantities that their values might be needed to determine while solving and optimizing the problem,and can be calculated based on decision variables. Constraints are conditions that objective function is optimized according to them. Actually optimized objective function can be obtained in a problem when all constraints be valid, otherwise defined objective function will not be optimized. Extensive studies have been done in case of reservoir operation such as (Loucks et al, 1981). The study of GA based on Darwin's principle of evolution was first proposed in 1975 by Holland (1992). Some application of GAs to water resources problem include calibration of conceptual rainfall runoff model (Wang, 1991), reservoir system optimization (Esat and Hall, 1994), ground water management problems (McKinney and Lin, 1994; Cieniawski et al., 1995), identification of multiple reservoir operating rules (Oliveira and Loucks, 1997), reservoir system operation (Wardlaw and Sharif, 1999), waste load allocation (Burn and Yulianti,2001). (Oliveira and Loucks, 1997) used a GA to evaluate operating rules for multireservoir systems, demonstrating that GAs can be used to identify effective operating rules. (Wardlaw and Sharif, 1999) used GA to a deterministic finite horizon multi-reservoir system operation and concluded that the approach can be easily applied to non-linear and complex systems.(Yeh, 1985) have investigated some of the nonlinear programing algorithms and their applications in reservoir management. (Joubert et al., 2003) have solved a multipurpose problem in order to select appropriate policy of demands and water supply management in one of the cities of South Africa. (Chang et al., 2005) have used the genetic algorithm in order to extract optimal reservoir operation rules, in this research, intended goals were minimizing thetotal deviation of demands in each period and maximizing the total producing hydroelectric energy in each period. In this research, hydroelectric energy isproduced after meeting the irrigation demands. Actually this purpose was the last priority.The objective of this paper is to derive optimal operating release for a single reservoir using GA approach. The policies derived by GA model are basis of their performance in the reservoir simulation for 40 years of historic monthly stream flow data (1971–2010).

2. Materials and methods:

2.1 Geographical location of studying area

The reservoir considered in this study is the proposed Jarreh reservoir (Latitude 31˚ 26′ N, Longitude 49˚ 43′ E) located on the river Zard, a major north bank tributary of the Allah catchment. The reservoir requires meeting irrigation demand, which is different in different months. In recent years, major steps in the field of construction of reservoir damshave been taken in Iranespecially in the case of Karun river catchment area.

Allah catchment area is one of the most important catchment areas in this zone that has just one reservoir dam with the name of Jarreh, despite proper discharge, optimal operation of this construction can play an important role in this economy area and, due to that, in the country. The Jarreh reservoir dam has been constructed 35 km eastern north of Ramhormoz near the Jarreh village and 90 km east of Ahvaz City at southwestern slopes of Zagros over the Zard River. This is asoil dam with clay core that its executive operation has been started since March1997. The initial purpose of this dam was to provide water for Ramhormoz Plain Lands. We have investigated the purpose, meeting agriculture demands, and its optimal point has been determined that general specifications of dams is as shown in table 1.

Table 1. General specifications of Jarreh reservoir dam

1	Type of dam	Soil dam with clay core
2	Total reservoir volume in the normal level	180 million cubic meters
3	Reservoir useful volume	141.8 million cubic meters
4	Normal digits from sea level	497 meters

Table 1 shows the general specifications of Jarreh dam.

2.2 Irrigation and Drainage network of Ramhormoz

This network is located 35 km east of Ramhormoz City with the area of 22000 hectares, which its monthly water demands are as shown in table 2. The monthly irrigation demand (Table 2), monthly mean evaporation rate, monthly streamflow and other relevant data were obtained from Standards Office for Irrigation and Drainage Networks of Khuzestan, Water and Power Authority (KWPA).

Table 2: Water demands of irrigation and drainage network of Ramhormoz(MCM)

Name of	March	April	May	June	July	August	September	October	November	December	January	February
Ramhormo	43.262	46.68	42.82	35.95	27.55	23.15	16.02	8.74	12.62	2.18	6.95	31.7

Table 3: Average water inflow of Zard River to Jarreh dam in different probability (MCM)

Jarreh	Septem	Octobe	Novem	Decem	January	Februar	March	April	May	June	July	August
50 percent	9.1	14	24.1	28.5	32.7	31.1	38.6	31.6	18.7	10.4	6.6	8
60 percent	8.6	11.5	20	23.8	26.7	26.6	31.9	27.9	16.3	9.1	6.8	7.4
70 percent	8	9.3	16.3	20	21.5	22.3	26	24.4	14.2	8	6.7	6.8
80 percent	7.3	7.2	12.9	16.1	16.8	18.5	20.6	20.9	12.1	6.7	5.2	6.2
90 percent	6.6	5.2	9.3	12	11.8	14.2	14.7	16.9	9.5	5.4	4.3	5.4

The monthly streamflow data for the system considered is available for 40 years (1971–2010).

The best probability distribution is lognormal distribution about Jarreh dam time series. We used this distribution and different probability inflow to the reservoir dam. We calculated monthly.Average discharge to the reservoir dam as Table 3.

2.3 Genetic Algorithms

The simplest form of GA mechanism is proposed by (Goldberg, 1989). Flow chart of GA is shown in Fig. 1. The following steps are necessary in the application of GA.

(a) Parameters for the desired solution should be represented by binary system. Initial Random values constituting a population should be allocated where each value in its Binary form is referred to as a chromosome.

(b) The evolution from the initial population to a better subsequent solution population is achieved by probability calculations.

(c) In order to find the optimum solution, an objective function is adopted as a criterion.

(d) A serial genetic operators are used to form the previous solutions through the crossing over and mutation procedures

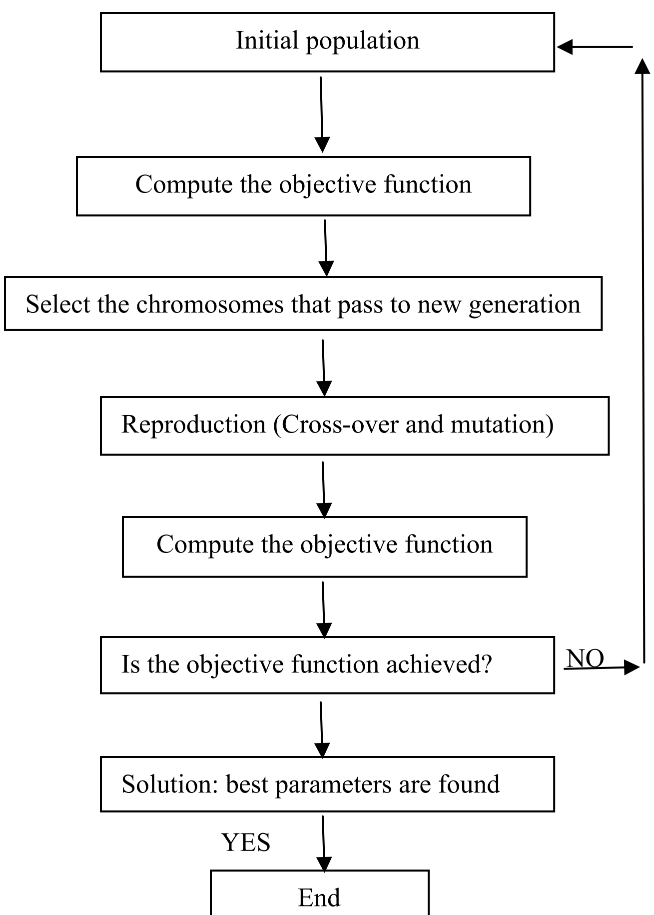

Figure 1. GA method flow chart

These steps are repeated until a certain error percentage such as 5% is achieved between the two final successive solutions. In the first step of the algorithm, initial population is constituted through the chromosomes that are selected randomly. The number of chromosomes in the population is decided by the user. This population changes by certain.rules in order to optimize the target function. Each chromosome should be evaluated by considering their objective function to find the optimum solution. During the evolution of the solution population, some chromosomes depart from the process while stronger ones remain in the updated population. In order to constitute the new generation, chromosomes that provide the most suitable conditions for objective function are selected by using roulette wheel. This wheel is partitioned into sections of which the widths are determined according to the objective function. So the chromosomes which have best objective function value have morechance to be selected as members for the next generation. The new generation is evolved from the current generation by applying some genetic operators such as cross-over and mutation. These operations are repeated until the objective function is achieved. The number of iterations required to obtain the optimal coefficient values depend on the initial population. If the initial population is close to solution point, the algorithm would reach the solution with less iteration. Advantages and differences of GAs in optimization problems compared to other methods can be listed as follows (Buckles and Petry, 1994) and (Altunkaynak, 2008).

(1) Optimization can be made through continuous or non-continuous variables.

(2) GA does not need mathematical transactions such as derivation.

(3) It is possible to start searching from many different points at solution space so that through numerous variables global optimization is possible.

(4) Even in case of target functions with extreme values optimization is possible, and

(5) GA produces a set of solution points during an adaptive and dynamic system structure evolution.

Additionally, GA approaches provide the most suitable solution in a quickest way for an optimization problem. The GA solution has different facets than classic optimization methods. They seem as indefinite methods due to the random sampling procedure and rules at their basis. Disadvantages of the classical model are that the calculations take too much time and there is no mechanism to control if achieved solution is the global optimum.

2.4 Reservoir Problem Formulation

The reservoir needs to meet different water demand for irrigation demand in different months. Release from the reservoir should be such that it does not violate the constraints of the upper limit (storage capacity at full reservoir level) and the lower limit (dead storage).The objective function used in this study is the minimization of squared deficit from demand. The expressions for constraints and objective function are given below.In the first part of this research, the objective function is minimizing the total squared difference of discharge and downstream need which is nonlinear objective function.

$$\min \sum_{t=1}^{n=12}(R_t - D_t)^2 + \sum_{t=1}^{n=12}(S_t - S_{t+1} + I_t - R_t - E_t)^2 \quad (1)$$

That in which,
R: release from dam
D:monthly demand
S:storage volume
I: inflow to the dam
E: evaporation from surface of dam

Hence decision variables in this problem include release and storage volume through 12 months of a year. Then the number of decision variables is 24.

2.5 Constraints

Through planning studies, often assume that the summation ofexisting water volume in reservoir at the beginning of a period and the amount of inflow to the reservoir through the period is equaled to the summation of existing water volume in the reservoir at the end of the period and the amount of discharge of reservoir through the period. On the other hand, if S_t represents the existing water volume in the reservoir at t^{th} month, Q_t represents water volume entrance to this reservoir during the month, R_t represents the decision variable related to the volume of water discharge of this reservoir during the month, and then E_t which is evaporation during the month, is shown by the below function which is equilibrium between above values and is called continuity equation and As below:

$$R_t = S_t - S_{t+1} + Q_t - E_t$$
t=1,2,3,4,…,12 (2)

Purposes of reservoir dams' construction are torrential flow control in the dam catchment area, saving water to deal with drought, and also production of energy. Based on the studies related to torrential flows in the catchment area and also the drought statistics in this area, several curves are determined for maximum and minimum allowable reservoir volumes which are called first command curves. Although we can calculate also optimization of these curves through optimized operation model of water production systems, but usually studies related to torrential flow control is performed separately and their results are used in optimization models in the form of command curves. Similarly parameters such as structural stability of dam and environmental limitations would affect the minimum and maximum allowable reservoir volume in each period. In this research, all above limitations are considered in the below model in the form of command curves. As a result, reservoir volume in each period **t** must be between upper and lower limits. Figure 2 shown schematics for this constraint.

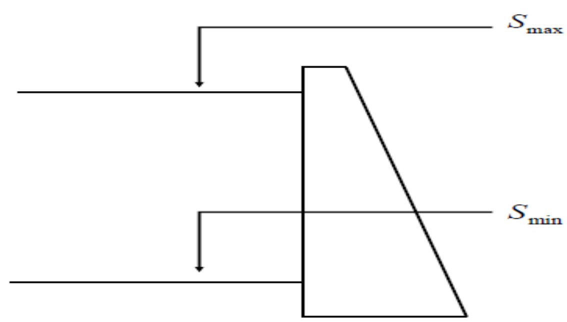

Figure 2: Diagram of Minimum and Maximum volume

On the other hand $S_{min} \le S_t \le S_{max}$ (3)

That in this research S_{min}, dead volume of the constructed dam, is equaled to 40 million cubic meters and S_{max}, reservoir volume in normal level, is equaled to 180 million cubicmeters in this research. The dam release capacity, considering its specifications, is equaled to 18 (m^3/s) or in other Words, 46 (MCM) in month.
Then:

$$R_{min} \le R_t \le R_{max} \quad (4)$$

2.6 Evaporation of surface water

Evaporation of surface water has been estimated and used, based on the meteorological studies according to table 4 at the dam site, that this amount is considered as system losses through calculations.

We must convert amounts in the table (4) at million cubic meters. Considering to existing equations for calculation of evaporation in a period, evaporation in the Jarreh reservoir dam is estimated as below that shown in Fig3.

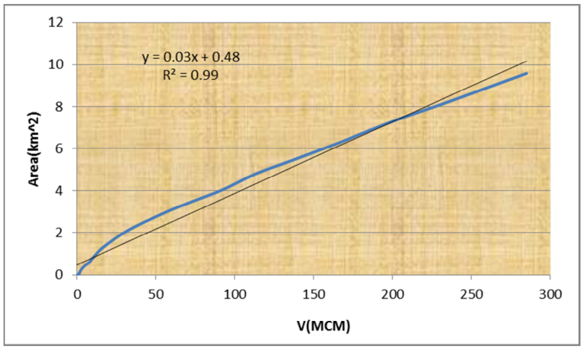

Figure 3. Area-Volume curve In this figure shawn evaporation coefficient.

$$E_t = 0.034 e_t \left(\frac{s_t + s_{t+1}}{2} \right) + 0.483 \quad (5)$$

That in above equation, e_t is the evaporation from Lake Surface during period t in the Table 4.

Table4: Evaporation from surface of lake (mm)

March	April	May	June	July	August	September	October	November	December	January	February
124.5	178.2	222	230.7	216.9	184.2	136.5	88.5	56.1	48	64.8	90.6

4. Results and Discussion

In this study we used GA tool box in the Matlab software and to fix the best parameter setting crossover probability and mutation probability for GA optimization. We changed the Crossover probability in the range 0.5–1.0 and mutation probability in the range 0.005–0.1 is tested to find the best values of crossover and mutation probability with respect to fitness function values. With mutation probability of 0.05 and crossover probability of 0.85 for 1000 generation have best answer .and set up initial population 100.In the Fig 5 We restrict the number of generation to 1000 since there is very negligible improvement of fitness function after 1000 generation**.**

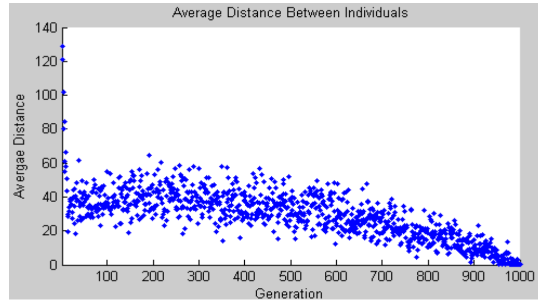

Figure 4. Average distance between generations

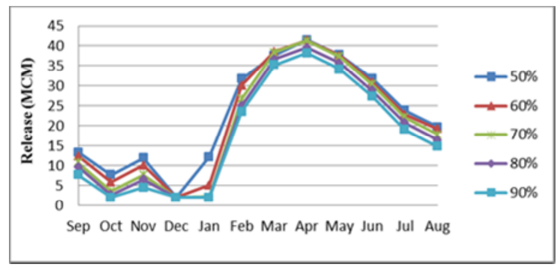

Figure5 Release from jarreh dam in different inflow percentage

The amount of monthly release, storage volume and evaporation from lake of dam for different inflow percentage has been shown in Figs 6, 7 and 8 as below based on the above constraints and defined objective function in Matlab software.

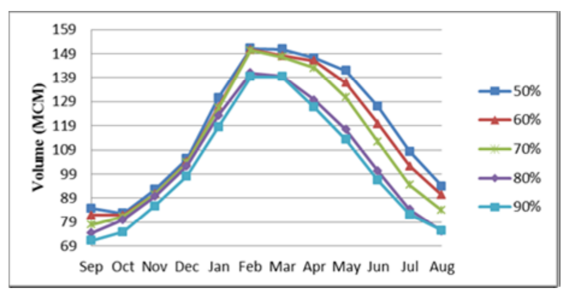

Fig6: Storage volume jarreh dam in different inflow percentage

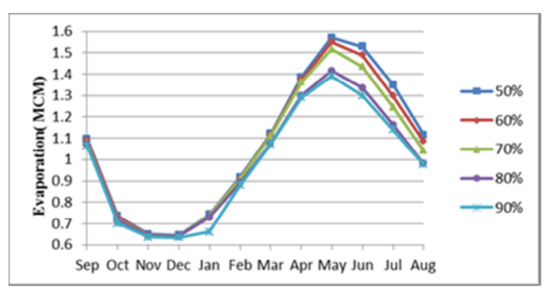

Figure7: Evaporation fromjarreh dam in different inflow percentage

5. Conclusion

In this paper, we addressed the problem of water resource release from dam reservoir in the south west of Iran; using GA optimization is introduced in this paper. The GA methodology was implemented into a software tool (MATLAB) and optimum solutions could be determined. The efficiency of release and storage volume derived by GA models is explored in this study.

With attention to the Fig5, we understand that Jarreh dam cannot available the Irrigation demand in the Ramhormoz network and in the best situation (inflow 50 percent) have 90.72 percent reliability and in the worst situation (inflow 90 percent) have 63.45 percent reliability. Aside with attention to the Fig6, we understand that storage volume have good situation in the warm month and have maximum storage volume because in the warm month have maximum demand in Ramhormoz network. In Decision-makers can, then, change some parameters of the problem in order to explore different resolution strategies**.**

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