Gravitational Search Algorithm (GSA) for Optimal Reservoir Operation of Timah Tasoh Dam

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A R T I C L E   I N F O

A B S T R A C T

Reservoir or dam is an expensive structure to build and the impact to the environment during the dam construction as well as operational phase had been debated by the scientist. Therefore it is essential to improve the operation effectiveness and efficiency of the existing reservoir to cope the current and future demand. In this study a new Evolutionary Computation algorithm called Gravitational Search Algorithm (GSA) will be applied to optimize the reservoir operation of Timah Tasoh in Perlis, Malaysia. The GSA method is based on Newton Law of gravity and mass interaction. The result from this research will improve the release operation of the reservoir and prove the workability of GSA application in water resources study.

INTRODUCTION

Reservoir Optimization is among the classic problem been study by scientist in water resources. Beginning with the birth of linear Programming in 1939 the optimization technique continues to develop to nonlinear, dynamic programming and current trend Evolutionary Computation which contribute by the advancement of computer hardware and software today. Rani and Moreira (2009), state that the evolutionary algorithm such as Genetic Algorithm, Simulated Annealing, Tabu Search, Particle Swarm Optimization and Honey Bees Mating Optimization are good prospective tools when dealing with nonlinear and multiobjective analysis plus most of them can be linked to the simulation model. Singh (2012) have list many water resources studies using optimization technique to solved reservoir system operation problem.

Climate change, growing number of human population and increasing water demand force the reservoir capacity to its limit of current Standard Operating Procedure. Therefore, it is necessary to the reservoir to improve the efficiency of it operational procedure by using optimization method. Hence, the objective of this study is to optimize the release policy of the TimahTasoh Reservoir by analyzing the water deficit between proposed release and water demand within the limit or constraint of the reservoir feature.

Experimental procedure:
Gravitational Search Algorithm (GSA):

Gravitational Search Algorithm (GSA) is a recent optimizing method in operation research and was introduced by Rashedi *et al*. (2009). GSA was developed based on the Newton Law of gravity and mass interaction. In GSA, every mass has four specifications which are position, inertial mass, active gravitational mass and passive gravitational. The locations of the mass match up to the solution of the problem, with the gravitational and inertial masses are determined using a fitness function. See Figure 1.

The GSA has been compared to other optimization algorithm like modified particle swarm optimization by Chatterjee *et al*. (2010) and GSA proves to be better than MPSO in term of computational time and final fitness value. Sarafrazi *et al*. (2011) have introduced a new operator called Disruptor to improve the capability of GSA to explore and exploit the search space. The modified GSA proved to be faster and more accurate when compare to the standard GSA. The GSA have successfully apply for optimal power flow (Duman *et al*, 2012), electromagnetic study (Chatterjee, 2010) and filter modeling (Sarafrazi, 2011). However there are no application of GSA in water resources analysis have been found in the literature. Therefore in this study we like to examine

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the performance of GSA in optimization problem for TimahTasoh reservoir which located at the northern part of Peninsular Malaysia.
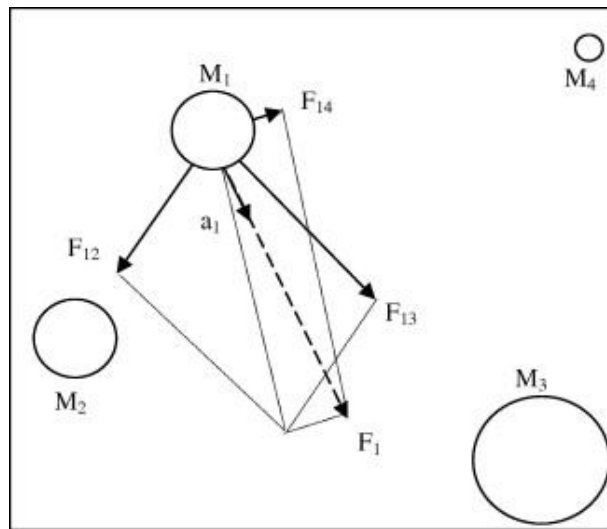

Fig. 1: Gravitational Search Algorithm Illustrated (Rashedi, 2009)

Study Area:

Timah Tasoh Reservoir is located in Perlis, Malaysia. The catchment area is about 191 km^2 and it storage capacity is about 40million cubic meter. It is built forIrrigation, Water Supply and Flood Mitigation.The reservoir system is In Figure 2.
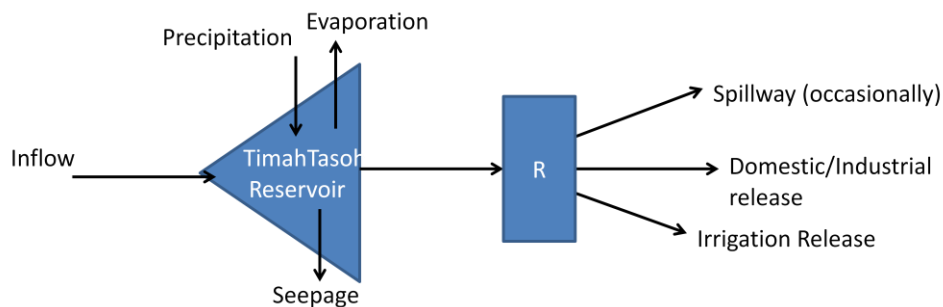

Fig. 2: Reservoir system.

Objective Function:

The objective of this study is to minimize the water deficit as given in the following expression.

$$Min\ Z = \sum_{t=1}^{12}(D_t - R_t)^2 \tag{1}$$

Where, the month in a year represent by *t*, while D_t and R_t are monthly demand and release of the month subsequently.

Continuity Constraint:

The continuity constraint;

$$S_{t+1} = S_t + I_t - R_t - L_t \tag{2}$$

Where, S_{t+1} and $S_t$is the final and initial storage of time period *t* (monthly). The inflow to the reservoir is indicated by I_t .R_t is the release information from the reservoir and Losses (L_t) in this study were from the evaporation of the water body and seepage from the reservoir.

Hydrological data from 1995 to 2012 have been obtained from Department and Irrigation and Drainage.

Constraint of the Reservoir Capacity:

At any time the storage capacity must be with the limit below ;

Storage capacity = 6.7 x 10^6 m^3 ≤S$_t$ ≤ 40 x 10^6 m^3

ReleaseConstraint:

Release for Domestic and Industry (R_{DI}) = 0.421 m^3/s ≤ R_{DI}≤ 0.737m^3/s

Annual Release for Irrigation (R_{irr}) $\geq$ 46.49 x 10^6 m^3
Outlet Capacity 8.2 m^3/s $\leq$ R_{Cap} $\leq$ 24.8 m^3/s
Spillway capacity for Flood release $\leq$ 436 m^3/s

Analysis Procedure:
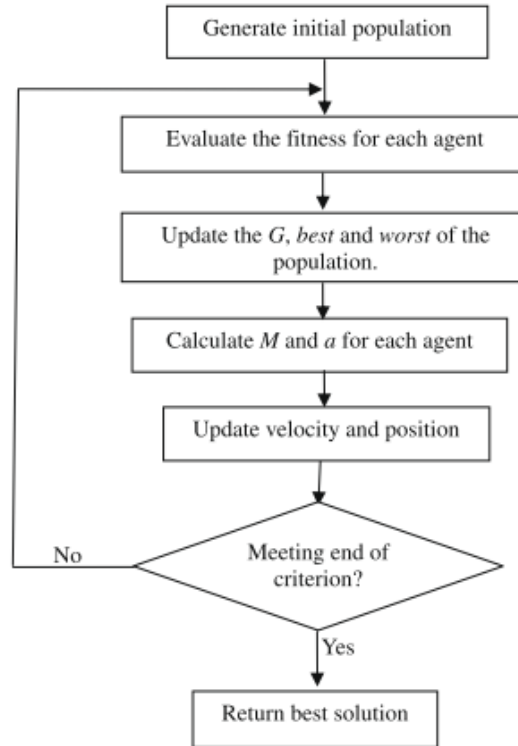The typical steps of GSA are as follows. See Figure 3.

Fig. 3: Flowchart of gravitational search algorithm (Rashedi, 2009)

In the reservoir optimization the monthly release will become decision variable. The analysis will be done using programming code in the MATLAB environment. A m-file code for GSA will be use to run the objective function, constraint, final storage calculation and losses.

Expected result:
The performance of GSA will be analysis by using the Mean Best Fitness Value with given Iteration. The result from optimization and the current release policies will be compared and will evaluate itsreliability, resiliency and vulnerability (Hashimoto, 1982). The optimum release for each month is the release which give the lowest release value but at the same time fulfill the demand and constraint. This release will be proposed to replaces the standard operating procedure currently be applied by the dam operator.

Conclusion:
The application of GSA in water resources study is still new. If the algorithm proves to be better in the efficiency and reliability, it can be a good alternative for optimization technique in water resources study. Furthermore, the result from this study can improve the efficiency of release policies and the procedure can be apply to other reservoir in that region.

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