ARTIFICIAL BEE COLONY (ABC) APPROACH FOR RESERVOIR OPERATION

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Abstract- Most reservoirs offer a mean of managing and regulating the downstream water flow and demands over time and space. It is a challenging task for the reservoir operator to evaluate the trade-off during drought and heavy rainfall season. This study proposes a review on the application of different computational intelligent models, especially the Artificial Bee Colony (ABC) approach in reservoir inflows and management optimization. For each model, their attempts and efficiencies along with difficulties are illustrated and well studied. The benefits derived from such comparison are used to improve the searching performance of existing models. ABC approach has gained a great potential in solving the reservoir optimization problem due to its powerful exploitation capabilities and high quality of optimal solutions. As a consequence, future works that include extend of handling a promising and viable optimization tool in an efficient and effective manner need to be further revised.

Keywords- Artificial Bee Colony, Reservoir Optimization

I. INRODUCTION

Generally, the operating rules are firstly derived by researchers from the planning of reservoir optimization. These rules are often represented the relationship between the optimal release of the reservoir with hydrological input such as reservoir storage, inflows and various reservoir variance as a function. Consider a multi-purpose reservoir operation, the operation policy must include the flood routing procedure, decreasing the over spilled water while competing water demand at the downstream and able to operate in a peak power production when it applied to a hydropower plant.

In order to analyze the performance of reservoir system, over the few decades, there is arising of different simulation algorithms that interpreted by operation rules and applied to reservoir optimization and management. There is a series of procedures in developing a model for a multi-purpose optimization system, from problem specification, hypothesis, data acquisition and pre-processing to model identification. Lastly, the validation and verification of model majority determines the performance and quality of the resultant model. Over the few decades or so, a collection of different computational intelligent models including stochastic population based algorithm, all have become a powerful modeller in dealing with data driven processes work such as reservoir operation.

By then, perplexing in the selection of the most preferable solution might happen to the reservoir operator. Some studies have shown that the youngest swarm intelligence algorithm, ABC which introduced by (Karaboga, 2005) is gaining more attention in solving optimization problem. Because of its basic ability which is very sensitive to the values of control parameters compared to the others existing stochastic algorithms such as genetic algorithm (GA). So, by this reason, it is important to review on these different computation intelligent models associated with the reservoir inflows forecasting and management optimization. The aim of this study is to compare and illustrate their attempts along with difficulties in dealing with water management planning.

II. OPTIMIZATION MODELS

Genetic Algorithm (GA) is among the most popular evolution algorithm to solve the optimization problem which imitates the natural evolution in biological processes for natural genetic and natural selection. The fundamental ideas of GA follow on the Darwinian principles of selection, mutation and the eventually recombination (crossover) in the operator (Affenzeller et al., 2009). Savic et al. (1999) took the idea of applying GA in large water distribution system expansion, which optimal the reservoir system operation. This method has been proven to be very effective and provide satisfied performance in terms of reservoir balancing. Followed by Rani and Moreira (2010), in their review of potential of simulation-optimization modelling application in reservoir system operation, suggested that evolutionary algorithms like GA is claimed barely able to deal with multi-objective analysis. Asfaw and Hashim (2011) applied the GA model to optimize the hydroelectric power generation at Temenggor Dam. They studied the water stored to get a good capacity factor for reservoir operation. As a result, GA model not only able to increase the capacity factor, but also gave a better release and reservoir level. Despite the outstanding intend of GA to find arrays of characters or numbers in the populations, GA as one of the stochastic iterative algorithms is unable to guarantee its convergence phenomena called premature

convergence. This drawback is close to the loss of genetic variation problem in the populations.

GP, an extension of the genetic algorithm concept to develop computer programs for high-level problem statements. Theoretically, GP differ from GA based on the nature of individual's population. Individual's populations in GA are linear strings of fixed length which are generated randomly or heuristically. Therefore GAs finds its difficulties to handle the tasks in computer sciences programs. Whereas individual's populations in GPs are nonlinear entities of different sizes and shapes. GP works as a learning machine in computer programs which undergoes a step by step manner from receive inputs, perform computations and produce outputs to optimize the solution for high-level problems. Lately, E. Fallah-Mehdipour et al. (2012) took the idea of applying genetic programming to operate a reservoir system in real time with inflow prediction. In their study, two operational rule curves including water release, storage volume and inflow were worked together with the prediction model, GP. GP presented its capability in the prediction of inflow and derive the rule curves. The most important characteristic of GP is that the algorithm is exactly expresses as parse trees which solution is relies on the rule of selection and the searching operator on the population of parse trees. No doubt that application of GP in optimal operation purposes capable to provide an impressive result. These somehow proved that GP models are able to explicit the mathematical formulations.

ABC algorithm is based on honey bee swarm intelligent behaviour in identifying and exploitation the infeasible region of the search area. This algorithm mimics the foraging behaviour of the honey bee swarm concepts, self-organization and division of labours. The three groups of bee swarm are the employed bees, the onlookers and the scouts. The employed bees are the bees that exploit the food sources (possible solutions) from the specified region of the search area. The onlookers are the bees that stay in the hive while waiting for the information bring by the employed bees. Information on the food sources is share between the bees using waggle dance. Good quality of food sources is preferred instead of the bad one and memorized by the onlookers to exploit. Scouts are the bees that employed to search for a new food source randomly once their food source has been fully exploited and abandoned. Formally, in ABC algorithm, population of solution is represented by the food source. The foraging route is repeated until the termination condition is fulfilled. The algorithm underlying a standard ABC is outlined in Table 1.

Table 1 Standard Algorithm of ABC

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place each employed bee on a random position in the search space
while stopping criterion not met do
    for all employed bees do
        if steps on same position == limit then
            choose random position in search space
        else
            try improve position
            if better position found then
                change position
                reset steps on same position
            end if
        end if
    end if
    for all onlooker bees do
        choose position of employed bee
        try improve position
    end for
end while
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Karaboga and Basturk (2007a) proposed that the ABC as a new powerful and efficient algorithm for numerical functional optimization. They used a modified ABC algorithm in their study for solving constrained optimization problems. Further investigation has been done (2007b) by comparing the performance of the ABC algorithm with GA. As a result, ABC algorithm provided better quality in handling optimization problem compared to the latter. Physically, the main ABC algorithm is relatively simple as there are only two control parameters in the ABC algorithm modelling: the population size (colony size) and the maximum generation number (cycle number). Therefore, application of ABC for solving optimization problems has been found to be very effective. The unique selling point of ABC algorithm is the satisfaction principles on multidimensional task allocation especially for the complex and non-linear operation like reservoir optimization system. Therefore, an effective reservoir policy for Aswan High Dam was developed by Hossain and El-shafie (2013) based on the ABC algorithm. The procedure and problem formulation of ABC application are very simple with low computation complexity. According to the results, the ABC system performance is verified applicable and as a powerful tool in the field of reservoir optimization.

As what we mentioned earlier, GP and ABC algorithm solving the optimization problems by evaluating the population solution. Considering its population solution and gather with others solution's information, better accuracy in the generation of the new solution is possible. In the views of various uncertainties in the estimated output, the possibilities of errors caused by initial vectors are fairly insignificant as both GP and ABC algorithm do not have such restriction. Both algorithms do not prescribe the situation with minimum assumption and they are representatively used to work with non-differentiable and discontinuous functions. Here we compared their collective strength and weakness with

the popular artificial intelligent algorithm, ANFIS model by little knowledge. This adaptive network provided an extensible and flexible framework which enables us to combine the advance of interpreting linguistic information ability of fuzzy system and the leaning expertise of neural networks (Jang and Sun, 1995). By using its knowledge based core-fuzzy IF-THEN rule base, ANFIS is expected to be successful assign to different global modelling. Chang et al. (2006) demonstrated that ANFIS model has the ability to deal with human knowledge by including the human decisions (reservoir outflow as input) in prediction of water level in Shihmen reservoir, Taiwan. Mousavi et al. (2007) described the application of ANFIS for reservoir operation. The use of ANFIS in optimization problem has been extensively studied in the past and proved (Chang and Chang, 2001; Chang et al., 2005) that it has superior performance with regard to the prediction of the optimal water release for a reservoir operation system. After a thorough study of the application and the performances between models, a few of these in their common strengths or weaknesses are shown in Table 2. It is particularly not a comprehensive pluralistic inter-comparison framework for the models as this study only focuses on certain structural features in common modelling approaches for some proof-of-concept problems that have been described above.

Table 2 Brief Comparison between Models

Aspects	Artificial Intelligent Algorithm	Evolution Algorithm	
	ANFIS	GP	ABC
	Bottom-up approaches for data-driven modelling		
	Self-adaptive model		
Structure	Nonlinear mapping tool by expertise learning ability	Population solution based optimization techniques (rules of selection and search operators)	
	Two-fold networks which combine fuzzy rule with neural network	Algorithm that imitates natural evolution based genetic selection, mutation and crossover	Algorithm that mimics the bees foraging (self-organization and division of labours)
Ability and Restriction	Explore information contained in the data	Explore and exploit information contained in the data	
	No	Provide global search	
	No	Multidimensional task allocation	
	Depends on initial vectors (weight/bias)	No	
	Require error function to be differentiate the algorithm	No	
	Potential work with large number or complex input	Will take longer time if large number of input yet better interpret with complex data (exploitation)	
	Advance input training scheme	No input training	
	Poor performance if out of the input training range	Outstanding intend to find the arrays of characteristic in the population	
	Overestimation due to high polynomial function or invalid data	Able to work with highly non-differentiable and discontinues function without overestimate	

	May stuck to local minima	Able to escape from local minima
	Potential to identify inherent structure of the model	Potential to find the goodness-of-fit optimization solution
	Evaluate the proportion of data from time-series	Time invariant
	Uncertainty during trial and error for the structure architecture	Unable to guarantee natural convergent
	Might have conflicts between rules	Might cause premature convergent	Might cause local optimal convergent

III. TECHNIQUES

As previously stated, the optimization criteria of the multi-purpose hydropower system should not only maximize the total power supply to make more profits, but also fully meet the requirements of the irrigation demand and the reservoir storage. Hydropower system production depends on the installed plant capacity, flow through the turbines, average effective storage head and the number of hours operated.

$$P_t = K \times Q_t \times NH_t \times \varepsilon \quad (1)$$

Where, P_t represents the output of hydropower generation in period t, whose unit is kWh; K is the constant to convert the hydropower generation to kWh; Q_t is the generation flow release in the period t; NH_t is the net head available in the period t; ε is the hydropower plant coefficient respectively.

In order to determine the solving technique for reservoir optimization model, firstly it is to analyze the constraint conditions.

A. Reservoir water balance constraints:

$$S_{(t+1)} = S_t + I_t - R_t - O_t - E_t \quad (2)$$

Where, $S_{(t+1)}$ represents the final reservoir storage during the time period t, whose unit is m^3; S_t is the initial reservoir storage in period t; I_t is the inflow into the reservoir in period t; R_t represents the release of disposable flow from the reservoir in period t; O_t is the overflow from the reservoir in period t; E_t is the evaporation, seepage water losses and so on from the reservoir in period t.

B. Reservoir water storage constraints:

$$S_{min} \leq S_t \leq (S_{max} - \theta_t) \quad (3)$$

Where, θ_t represents the required water storage in period t to be empty for flood occasion. The reservoir water storage in any time period t should not exceed the maximum storage (S_{max}) and should not less than the minimum storage (S_{min}) for which it is the dead storage. In general, the reservoir water storage will be maintained at a protection lower water level to avoid flooding in the downstream during the monsoon season (Jothiprakash and Arunkumar, 2014).

C. Reservoir overflow constraints:

$$O_t = S_{t+1} - S_{max} \quad (4)$$

Where the overflow from the reservoir in period t occurs when the final reservoir storage during the time period t exceed the maximum reservoir storage. Noted that if without overflow, $S_{(t+1)}$ will be the initial storage for the next t+1, whereas if overflow occurs, S_{max} will be initial storage for the next t+1.

D. Reservoir release constraints:

$$R_t \geq D_t \quad (5)$$

Where, D_t represents the demand for the downstream during the time period t. The release of disposable flow from the reservoir should be equal to or greater than the demand. To ensure adequate water supply to the downstream, this constraint should fully satisfy before maximizing the power production.

E. Hydropower output constraints:

$$P_t \leq P_{max} \quad (5)$$

Where, P_{max} represents the maximum generating capacity of hydropower generation in period t, whose unit is kWh. The hydropower output should be equal to or less than the maximum generating capacity. It is also essential to monitor the NH_t. It should be equal to or greater than the minimum drawdown level of the reservoir.

Since the ABC algorithm is a recent addition to the list of global search method, therefore during the course of evolving the optimal reservoir operation solution, ABC algorithm is proposed to explicit the constraint of the storage or release volumes for each of the period. Proposed algorithm is then applied to the continuity equation in order to define a new set of possible solution of the next period which satisfies the solution constraint.

IV. CASE STUDY

The proposed reservoir for this research, Chenderoh Dam, is a multi-purpose hydropower system which using storage or release volumes as the decision

variable in the operation. The probably most important goal of such research is to develop an automated and intelligent mechanism that can identify different possible events happened in the dam not only for hydropower generation, but rather whole information for the water management strategies. The particular about the reservoir is given in Table 3 and its location is shown in Fig. 1.

Table 3 Details of the Chenderoh Dam

Details	Chenderoh Dam
Catchment area (km^2)	6688
Net storage (10^6 m^3)	95
Reservoir area (km^2)	25
Maximum downstream flow (m^3/s)	14700
Water level (m)	60.4
Maximum hydropower generating capacity (MW)	38

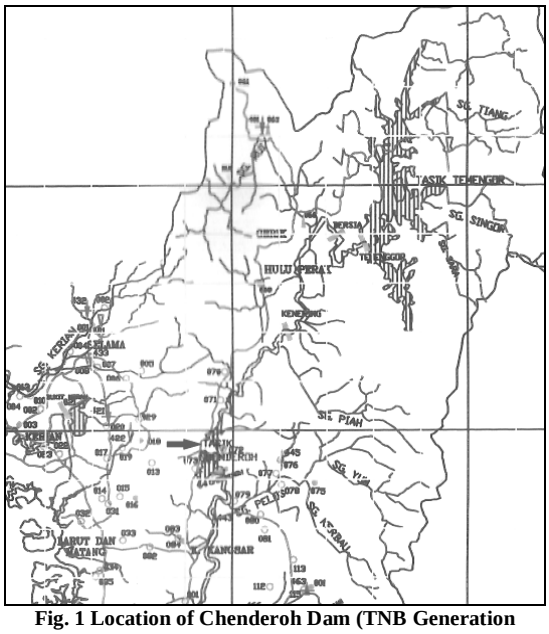


Fig. 1 Location of Chenderoh Dam (TNB Generation Department)

Real-time optimization is taking the advantage of the accurate real-time inflow forecasted value to minimize the prediction errors and hence improve the optimal reservoir operation efficiency. As a result, it is able to optimize the reservoir release to meet the storage requirement and downstream demand, minimize flood peak, and while considering the power generation management. For this reason, we take the chance in our current research that interest to combine ANFIS with ABC in dam optimization operation. We are willing to improve the efficacy of current dam optimization operation by preparing a high-quality inflow data from forecasting. The performances of the proposed algorithm will be tested and compare with the relative optimization method to verify its effectiveness and efficiency.

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