Optimization Techniques in Reservoir Operation

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Abstract*:* Water being a prime natural resource, its essentiality and need is getting increased constantly in industrial, agriculture and domestic purposes. It needs proper planning and efficient management of water for development of a country. For efficient use of water resources, reservoirs are to be planned and operated under proper management of water resources system. For using this water efficiently for different purposes like water supply demand, municipal and irrigation water supply, hydroelectric power generation etc, there is need of optimizing techniques of reservoir operation. Some of the optimizing techniques are harmony search algorithm, water cycle algorithm, weed optimization algorithm etc.

Keywords*:* Reservoir operation, Harmony Search algorithm, Water cycle algorithm, Weed Optimization Algorithm etc.

1. Introduction

Reservoir operation is based on a series of rules that determine the amount of water that is stored and released under different system conditions. The reservoir operation rules determine how reservoir water is allocated during periods of droughts, normal climate, or wet climate. The reservoir operation is typically to determine the operating policy, i.e. how much water is to be released in each period for various purposes such as for irrigation, water supply & to generate hydroelectric power depending on the state of the system in that period, to best attain a specified result. Hydropower is a clean energy source. Its share of electricity generation is 20% worldwide calculates the optimized reservoir release for hydropower generation based on input variables and parameters values that are found by various optimization techniques. It has been established that climate change will have impacts on the availability of water resources as well as on the operating policies for water resources systems. The consequences of climate change on water resources would be an increase in precipitation variability, amplification of extreme weather events such as droughts, changes in the frequency of floods. The impacts of climate change on water systems will include, for instance, change in the operating rules for flood control and power generation, modification of reservoir filling periods, reallocation of firm hydropower generation from the winter to summer and increase in unproductive spills. The strategies which optimize the use of water resources in the system would need to use the maximum of available resources to achieve optimum operation of the reservoir. To achieve this task, different optimization approaches such as harmony search algorithm, BAT algorithm, water cycle algorithm, weed optimization algorithm are applied to reservoir operation.

1.1 Need of optimization in reservoir operation

Water scarcity is one of the most serious problems in many parts of the world that affects on the environment, society, and economy. With increasing demand of water and limited water resource, optimization in reservoir operation is essential. To derive optimal reservoir operation policies the strategies which optimize the use of water resources in the system would need to use the maximum available resources to achieve optimum operation of the reservoir under various performance indices in the reservoir system. By utilizing the limited water resource, the purpose of irrigation demand and hydroelectric generation scheduling, is to specify the amount of water releases from a reservoir in order to maximize irrigation releases and to produce maximum power, with constraints.

2. Optimizing Techniques in Reservoir Operation:

Optimizing techniques of reservoir operation are used for different operations like water supply, flood control, hydropower generation, irrigation supply etc.

2.1 Harmony Search algorithm

The music improvisation is a process of searching for the better harmony by trying various combinations of pitches that should follow any of the following three rules:

- Playing any one pitch from the memory.
- Playing an adjacent pitch of one pitch from the memory
- Playing a random pitch from the possible range.
- This process is mimicked in each variable selection of the HS algorithm. Similarly, it should follow any of the three rules below:
- Choosing any value from the HS memory.
- Choosing an adjacent value from the HS memory.
- Choosing a random value from the possible value range.

2.2 Water cycle algorithm

The WCA is based on the water cycle of the real world. Streams and rivers flow downhill toward the sea. Water moves downhill in the form of streams and rivers, starting from high up in the mountains, and discharging to the sea and lakes. Streams and rivers collect water from rain and other streams on their way downhill. Some of the water forms rivers and lakes evaporate. Then, clouds are generated when the evaporated water is carried in the atmosphere. These clouds condense in the colder atmosphere and release the water back in the form of rain, creating new streams and rivers.

2.3 Weed Optimization Algorithm

A common phenomenon in agriculture inspired the WOA. The WOA was developed on the basis of weeds' growth characteristics. Weeds are a plant that grow spontaneously and may be harmful to pastures, farms, and gardens. They can easily adapt to almost any environment and new conditions. Despite its simplicity, the WOA emulates numerically many characteristics of plants such as seed production, growth, and competition. The following characteristics describe the growth of weed colonies:

- A limited number of seeds are spread in a search area.
- Each seed turns into a weed that produces seeds based on its quality in the colony.
- Produced seeds spread randomly in the environment and make new seeds.
- This process is repeated until the maximum number of plants in a colony is reached. Then, competition for survival starts between weeds so that in each stage weeds of lower quality are removed. This process continues to produce weeds of the highest quality.

2.4 BAT Algorithm

The BA algorithm is implemented in this study to optimize reservoir operation. Bats, the only winged mammals, can determine their locations while flying using sound emission and reception, which is called echolocation. Their population is approximately 20% of all mammal species. Bat sizes range from the tiny bumblebee bat (with mass ranging from 1.5 to 2 g) to the giant bats with wingspan of about 2 m weighing approximately 1 kg. Most micro bats are insectivores and use a type of sonar, called echolocation, to detect prey, avoid obstacles, and locate their roosting crevices in the dark. Bats emit sound pulses while flying and listen to their echoes from surrounding objects to assess their own location and those of the echoing objects. Each pulse has a constant frequency (usually in the range of 25×10^3 to 150×10^3 Hz) and lasts a few thousandths of a second (up to approximately 8 to 10 ms). About 10 to 20 sounds are emitted every second with the rate of emission up to approximately 200 pulses per second when they fly near their prey while hunting. If the interval between two successive sound bursts is less than 300 to 400 μs, bats cannot process them for path-finding purposes. As the (λ) of the ultrasonic sound bursts with a constant frequency. As the speed of sound in air is typically v ¼ 340 m/s, the wavelength (λ) of the ultrasonic sound bursts with a constant frequency λ is in the range of 2 to 14 mm for the typical frequency range from 25×10^3 to 150×10^3 Hz. Such wavelengths are of the same order of magnitude of their prey sizes. Bats emit pulses as loud as 110 dB, which are in the ultrasonic region (frequency range of human hearing is between 20 and 20, 000 Hz). The loudness also varies from the loudest when searching for prey to a quieter base when homing towards the prey. The travelling range of such short pulses is typically a few meters.

2.5 Imperialist Competitive Algorithm

This algorithm has a population-by-population approach; similar to many other evolutionary algorithms. ICA simulates political–social evolution. At the beginning of ICA process, a population of initial solutions (countries) is generated (like as chromosome in GA). More powerful countries are considered as imperialists and others as colonies. For each optimization problem with N decision variables (these variables could be culture, language etc.) each country is defined as an array. In each generation, some countries which do not have considerable progress, encounter with revolution. Revolution operator prevents trapping algorithm in local optimum. After moving colonies toward imperialists or revolution event, it is possible that one of the colonies gets better situation than its imperialist. It could exchange colony and imperialist's position. Imperialistic competition is the most important step in ICA, in which all the empires try to increase the number of their colonies. This process occurs by losing the weakest colony from the weakest empire's domain and joining to stronger empires. Joining colonies to stronger empires takes place based on probability. This probability is proportional in accordance with each imperialist strength plus percentage of arbitrary from average power of colonies.

2.6 Cuckoo Optimization Algorithm

COA is a new evolutionary optimization algorithm for solving nonlinear optimization problems. This algorithm was introduced by Rajabioun (2011) inspired from lifestyle of a bird called cuckoo. In the nature, cuckoos choose nests of other birds to lay their eggs. Cuckoos lay eggs like host birds in their nests and thereby other birds survive their own generation. Nonetheless, cuckoo's eggs may be recognized and destroyed by the host bird. In such cases cuckoos migrate to places where are more suitable for generation survival and egg-laying. Now, if living area of cuckoo is decision space, each habitat will be a solution for problem. Therefore, the algorithm begins with an initial population of cuckoos that inhabit in different places. The best habitats were known by calculating their cost. Then in the next step, when eggs are growing and maturing, cuckoos migrate to the nearest current appropriate location for egg laying. This migration is done in the nature up to a maximum certain distance. This maximum distance is called egg laying radius (ERL) that each cuckoo lays its eggs in this radius randomly.

2.7 Biogeography-Based Optimization

Biogeography is the study of the geographical distribution of living organisms. Mathematical biogeography models attempt to explain how species migrate between habitats, their appearance, adaptation, evolution, and extinction. The habitats that are more suitable places for species settlement have a relatively high habitat suitability index (HSI). The HSI depends on factors such as vegetative cover, precipitation, area, temperature, etc. Variables that determine the quality of habitat are known as suitability index variables (SIV). SIVs are independent variables and HSI is variable dependent on SIVs. Habitats with large values of HSI accommodate more species, and, conversely, a low-HSI habitat supports fewer species. As the number of species in a habitat increases there is a stronger tendency for species to emigrate from the habitat to find new ones with better life-supporting conditions and lower population density than the crowded habitats. Habitats with low population density may attract immigration provided that the habitat has adequate life-supporting characteristics.

2.8 Genetic Algorithm

Genetic algorithm (GA), invented by Holland (1975), have emerged as practical, robust optimization and search methods. Goldberg (1989) describes genetic algorithm (GA) as a stochastic numerical search method based on the natural genetics and natural selection. They combine the concept of the survival of the fittest with genetic operators extracted from nature to form a robust search mechanism. Excellent descriptions of GAs and subsequent developments can be found in Goldberg (1989) and Forrest (1993). Any nonlinear optimization problem without constraints is solved using GAs involving basically three tasks, namely, coding, fitness evaluation and genetic operation. GAs differs from conventional optimization and search procedures in four ways:

- GAs work with a coding of the parameter set, not the parameter themselves.
- GAs search from a population of solutions, not a single solution.
- GAs use payoff information (objective function), not derivatives of other auxiliary
- Knowledge.
- GAs use probabilistic transition rules, not deterministic rules

3. Scope of optimization in reservoir operation

- Hydropower generation plays an important role in reservoir operation for large multi-purpose reservoir systems.
- By utilizing the limited water resources, the purpose of hydroelectric generation scheduling is to specify the amount of water release from a reservoir in order to produce maximum power within constraints such as hydropower generation capacity, storage capacity, release capacity, and initial and ending storages.
- To satisfy demand shortages at downstream of a reservoir , optimization is needed to maximize irrigation releases with constraints such as water balance equation , storage capacity, release capacity, canal capacity and initial and end storages.
- Various optimization techniques are applied in reservoir operation serving various purposes like irrigation, hydropower and flood control.
- Recently HS algorithm is used to satisfy demand shortage and to minimize the flood damages at downstream of reservoir under various performance indices.
- GIS database is used to determine the flood damage functions.
- Impact of climate change in reservoir operation plays an important role such as to predict inflow into the reservoir to avoid future

water shortages and flood damages using SWAT model.

4. CONCLUSIONS

There are various new techniques introduced in optimization techniques based on artificial intelligence techniques, was successfully developed and applied. The new method, biogeography-based optimization, bat algorithm, particle swarm optimization etc named for representing the reservoir operational rules and is stochastically trained by an evolutionary algorithm.

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