University of Tabriz

Journal of Civil and Environmental Engineering
Volume 52 (2023), Issue 4 (Winter), 163-171

EXTENDED ABSTRACT

Efficiency of Particle Swarm Optimization and Multiobjective Genetic Algorithm in Optimal Operation of Agricultural Water Resources

Mohammad Amin Zarei [a,*], Reza Lalehzari [b]

[a] *Department of Civil Engineering, Bushehr Branch, Islamic Azad University, Bushehr, Iran*
[b] *Department of Civil Engineering, University of Tehran, Tehran, Iran*

Received: 23 July 2015; **Accepted:** 17 August 2021

Keywords:
Water Resource Management, Pareto Front, Non-Dominated Sorting, Multiobjective Optimization, Water Allocation.

1. Introduction

The main problem of water resources planning is the inappropriate allocation between different consumers. Water allocation planning is a complex, multi-variable, and multi-constraint problem, which requires advanced optimization methods to be solved. Classical optimization methods are facing some limitations such as being trapped in local optimum points, and difficulties in handling different variables. In this paper two of these methods including particle swarm optimization, PSO and multiobjective non-dominated sorting genetic algorithms, NGGAII were explored and their efficiency in optimization water reservoir operation problems is compared. Dealing with the necessary of multiobjective programing accuracy, two single objective models was developed separately using PSO to verify the NSGAII results.

1.1. Non-dominated Sorting Genetic Algorithm-NSGAII

The Non-dominated Sorting Genetic Algorithm abbreviated as NSGA was one of the first evolutionary algorithms that utilized the principle of Pareto optimality in solving multiobjective problems. Deb et al., (2002) raised some criticisms to the NSGA and developed a powerful approach known as NSGAII. In comparison with the previous version, the NSGAII has a less computational complexity, considers elitism, systematically preserves the diversity of Pareto-optimal solutions and adaptively handles the problem constraints.

1.2. Particle Swarm Optimization-PSO

Particle Swarm Optimization (PSO) is another computing technique that the several recent researchers have summarized the essentials of its modelling. PSO is a biologically inspired computational search and intelligent optimization method developed in 1995 by Eberhart and Kennedy based on the social behaviors of birds flocking or fish schooling. Particle swarm optimization consists of a swarm of particles, where particle represent a potential solution (Shi and Eberhart, 1999).

2. Methodology

The structure of the optimal allocation of water is summarized in the two objective functions. Thereby, the first objective function (OF1) is minimization of water allocation and the second objective function (OF2) is maximizing the total benefits of cropping pattern relative to its costs. Irrigation water requirement for each

---

* Corresponding Author

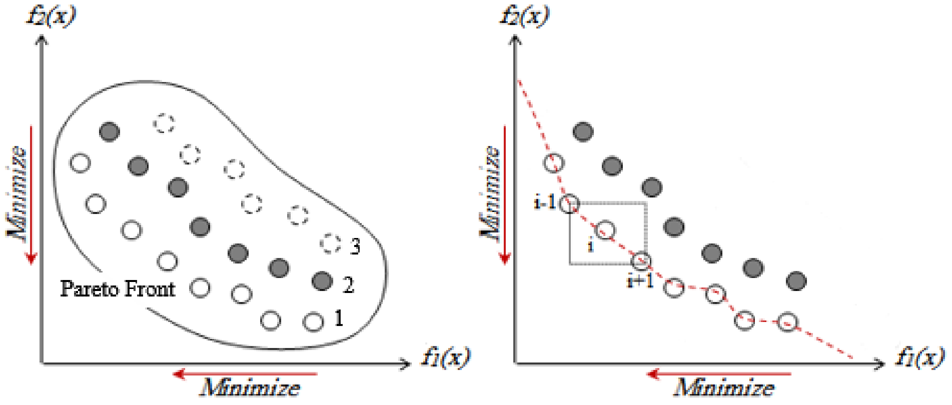
E-mail addresses: mohammadaminzarei@gmail.com (Mohammad Amin Zarei), reza.lalehzari@ut.ac.ir (Reza Lalehzari).

growing stage and cultivated area have been considered as decision-making variables. Field data for the model, covering the period 2013-2014, were obtained from Baghmalek plain in Iran.

The first step of NSGAII algorithm is generation of initial population randomly and evaluate by two objective functions. Then, the population is sorted based on the non-domination principle and is classified in different fronts that the best level of non-dominated fronts is called Pareto front. Every chromosome in each fronts ranked by crowding distance criterion for preserving diversity among the population members. As shown in Fig. 1 and follow equation, crowding distance is obtained:

$$CD_i = \sum_{m=1}^{2} \frac{OF_m\left(i+1\right) - OF_m\left(i-1\right)}{OF_i^{\max} - OF_i^{\min}} \tag{1}$$

Where, *CD*= crowding distance, *OF*= objective function, *i*= chromosome rank in front.



(a) (b)

Fig. 1. Schematic illustration of the non-dominated sorting: a) and crowding distance, b) concepts

In the next step, the usual binary tournament selection, crossover and mutation are used to create offsprings with participation of non-dominated solutions. After that, in the main loop, parents and offsprings population are combined. So a population with the size of 2N is created (N is number of solutions). In the next step, the population is sorted according to non-domination and the new population will be created with the selection procedure based on the ranking and crowding distance parameter of a solution. This process continues until the number of generation is at the end (Goldberg, 1989).

3. Results and Discussion

The comparison between NSGAII and PSO algorithms was carried out in endpoints of objective functions. The intersection of two axes of NSGAII is the ideal point of endpoint Pareto front. The results show that the ideal solution value of NSGAII was better than PSO in benefit per cost ratio (first objective function). The more details of the comparison between two models showed in Tables 1 and 2.

Tabel 1. The results of single and multiobjective models

Technique	OF	Barley	Barley	Colza	Lentil	Tomato	Onion	Cucumber
NSGAII	Min RE	0.34	0.27	0.41	0.33	0.18	0.21	0.26
	Min B/C	1.3	1.3	1.6	2.6	1.4	1.7	1.4
	Max RE	1	1	1	1	0.97	0.91	0.99
	Max B/C	2.2	2.3	6.4	7.1	5.4	6.3	4.9
Optimal Solution	RE	0.98	0.98	1	1	0.86	0.79	0.93
	B/C	2	2	6.4	7.1	4.5	5.8	4.5
PSO	Min RE	0.37	0.28	0.48	0.33	0.24	0.26	0.24
	Min B/C	1.3	1.3	1.8	2.6	1.4	1.7	1.4
	Max RE	1	1	0.96	0.98	0.91	0.94	1
	Max B/C	2.2	2.2	5.8	6.6	5.4	6.1	4.8

Table2. Comparison between PSO and NSGAII

Parameters	PSO		NSGAII	
	Value	Unit	Value	Unit
Population	300	Particle	200	Chromosomes
Iteration	10000	-	10000	-
Run time	25	Min	39	Hours

4. Conclusions

This study was conducted to evaluate the NSGAII model using PSO for water allocation problem. For this subject, non-dominated sorting principle and crowding distance criterion were applied to find the best solution of two objective functions simultaneously. The results showed that in the developed multiobjective scheduling, there is the set of solution in Pareto front with the great potential to maximize the net income and water saving in the water shortages problem. Therefore, the optimum strategies of water allocation should be designed in a predetermined economic framework.

5. References

Deb K, Pratap A, Agarwal S, Meyarivan T, “A fast and elitist multi-objective genetic algorithm: NSGA-II”, IEEE Transaction on Evolutionary Computation, 2002, 6,181-197.

Shi Y, Eberhart R, “Empirical study of particle swarm optimization”, Proceeding IEEE International Congers Evolutionary Compution, Washington, DC., USA, 1999, 1945-1950.

Goldberg DE, “Genetic algorithms in search, optimization and machine learning”, Addison-Wesley, Reading, Mass, 1989, 399.