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A Discrete Multi-Objective Invasive Weed Optimization for Flexible Job Shop Scheduling

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Abstract: Flexible job shop scheduling problem (FJSP) is an important extension of the classical job shop scheduling problem, which provides a closer approximation to real scheduling problems. Since FJSP belongs to NP-hard problems and we cannot find an optimal solution for it, it is very important to take an appropriate meta-heuristic search algorithm for finding optimal solutions while keeping diversity of population in problem space. This paper proposes an effective Discrete Multi-Objective Invasive Weed Optimization (DMOIWO) based on NSGAII to solve the FJSP. In this study, an innovative local search for the production and distribution of children in the solution space is presented. Three minimization objectives – the maximum completion time (makespan), the total workload of machines and the workload of the critical machine are considered simultaneously. The results of experiments on some benchmark test problems are compared in terms of Pareto-based performance metrics with MOGA algorithm by Wang, Gao, Zhang, and Shao (2010) and analysis of comparisons shows the effectiveness of the proposed DMOIWO.

Keywords: Flexible Job Shop Scheduling, Multi-Objective Invasive Weed Optimization, Pareto-optimality, Non-dominated Solutions

1. Introduction

Flexible job shop scheduling problem (FJSP) is an important extension of the classical job shop scheduling problem (JSP), which is more similar to real world problems than other kinds of JSP. It assigns each operation to a machine from a set of capable machines and then sequences the assigned operations on each machine [1]. There are two methods for solving FJSP: integrated approaches and hierarchical approaches. The integrated approaches solve two sub-problems simultaneously like Simulated Annealing (SA) algorithm [1]. However, the hierarchical approaches perform two sub-problems separately to decrease the complexity [2].

Recently most studies on FJSP have focused on solving conflicting multi objective simultaneously. Xia and Wu [1] used particle swarm optimization (PSO) for machine assignment module and SA algorithm for operation sequence module. Wang et al. [3] presented a multi-objective genetic algorithm (MOGA) based on immune and entropy principle to solve the multi-objective FJSP. In their algorithm, the fitness scheme based on Pareto-optimality is applied, and the immune and entropy principle is used to maintain diversity in the population.

Multi-objective problems are more difficult than single objective problems, because these kinds of problems have a set of tradeoff solutions instead of one optimal solution.

Invasive Weed Optimization (IWO) is a population-based algorithm inspired from process of weeds colonization and distribution. Since it has shown successful results for global optimization, has attracted much attention recently [4]. Nikoofard et al. [5] presented a proposal for multi-objective IWO based on non-dominated sorting of the solutions.

Due to its capability of solving general multi-dimensional, linear and nonlinear optimization problems efficiently [5], we are attracted to propose a discrete multi-objective IWO based on non-dominated sorting solutions for FJSP. In this improved DMOIWO, an appropriate local search is proposed to preserve diversity in the population.

2. Basic concepts

A. Multi-objective flexible job shop scheduling

The FJSP is described as follows. There are a set of N jobs and a set of M machines. Each job Ji consists of a predetermined sequence of operations. For each operation, there is a set of alternative machines Mij which is sub-set of M that can process it. In addition, some restrictions must be met [3].

B. Non-dominated solutions

For minimization of objectives, a solution a is said to dominate solution b if and only if [3]:

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$$f_i(a) \le f_i(b), \forall i \in \{1,2,...,q\}$$
$$f_i(a) < f_i(b), \exists i \in \{1,2,...,q\} \quad (1)$$

C. Pareto-optimality

A feasible solution is called Pareto-optimal when it is not dominated by any other solution in the feasible space [3].

3. HANDLING MOFJSP WITH DMOIWO

The proposed algorithm in pseudo-code form is as below. Also encoding and decoding of solution according to [3] is done.

1-Generate a random population of N_0 solutions (W)
2-Evaluate objective functions for all the individuals in W
3-For each individual $w \in W$
3-1-Assign the rank based on non-dominated sorting
3-2-Assign the crowding distance (CD)
3-3-Sort the population based on rank and CD
4-For *iter =1* to $iter_{max}$ do
4-1-For each individual $w \in W$
4-2-Compute the number of seeds of *w,* according to the following formula:

$$seed_w = [S_{\min} + (\frac{nPop - rank_w}{nPop}) * (S_{\max} - S_{\min})] \quad (2)$$

4-3- Compute the standard deviation of distribution of children according to the following formula:

$$\sigma_{iter} = \frac{(iter_{\max} - iter)^n}{(iter_{\max})^n} (\sigma_{initial} - \sigma_{final}) + \sigma_{final} \quad (3)$$

4-5-Generate the seeds over the search space with the following local search:
4-5-1-Generate a random number between 0 and 1
4-5-2-If it is smaller than 0.5, the number of changes in machine assignment module will be based on the amount of deviation.
4-5-3-Else, operation sequence module will be changed based on the amount of deviation using three approaches with equal probability: Reversion, Insertion, and Swap.
4-6-Evaluate objective functions for the seeds
4-7-Add the generated seeds to the previous solution archive W
4-7-1- the rank based on non-dominated sorting
4-7-2- Assign the crowding distance (CD)
4-7-3- Sort the population based on rank and CD
4-8-If the population exceeds its maximum limi, remove weeds with lower fitness until P_{max}.

Where $iter_{max}$ is the maximum number of iterations, $rank_w$is the rank of the *w*th population member, $seeds_w$ is the number of seeds produced by it, S_{max} and S_{min} are maximum and minimum number of seeds, *nPop* is the number of population, σ_{iter} is the standard deviation (SD) in the current iteration, *n* is the nonlinear modulation index, and P_{max} is the maximum number of population.

4. EXPERIMENTAL RESULTS

To evaluate the performance of the proposed algorithm, five instances MK01-05 from Brandimarte [2] have been taken into this experiment. We set parameters as follows: N_0 =200, P_{max}=200, $iter_{max}$=200, S_{min}=1 and S_{max}=5, $\sigma_{initial}$ is between 0.03 and 0.05 depends on size of the problem, σ_{final} =1 and *n* =1. It was concluded that N_0 should be simply set to P_{max}. However, this choice is in a trade-off between the computational cost and the performance on Pareto optimality and distribution diversity [5]. Our results on MK01 are shown in Table 1. The algorithm is implemented using MATLAB 7.8.0, running on a Lap Top with 2 GHz CPU and 4 GB RAM.

Also we used some performance metrics such as number of Pareto solutions (NPS), diversity metric (DM), and mean ideal distance (MID) and comparisons with MOGA by Wang et al. [3] shows efficiency of our algorithm in all three metrics.

TABLE 1
EXPERIMENT RESULTS ON PROBLEM MK01

	MOGA			DMOIWO		
	F1	F2	F3	F1	F2	F3
MK01	42	39	158	**27**	**39**	**158**
	44	40	154	**26**	**40**	**154**
	43	40	155	**25**	**38**	**160**
	40	36	169	**26**	**36**	**165**
				31	**42**	**153**
				29	**46**	**153**
				26	**37**	**163**
DM	16.0312			16.7332		
MID	169.0676			165.2273		
NPS	4			7		

5. CONCLUSIONS

In this paper, an efficient modified discrete multi-objective IWO based on NSGAII for solving multi-objective FJSP is proposed. The numerical experiments indicate the effectiveness of the proposed approach.

6. REFERENCES

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