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ScienceDirect

Procedia Computer Science 115 (2017) 30–38

Procedia Computer Science

www.elsevier.com/locate/procedia

7th International Conference on Advances in Computing & Communications, ICACC-2017, 22-24 August 2017, Cochin, India

An improved biogeography-based optimization for achieving optimal job shop scheduling solutions

Hamed Piroozfard[a], Kuan Yew Wong[a] *, Ali Derakhshan Asl[a]

[a]*Department of Manufacturing and Industrial Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia*

Abstract

In job shop scheduling, we attempt to optimally assign a set of machines to a set of operations. The purpose of this research is to develop an improved biogeography-based optimization approach in order to minimize makespan in the job shop scheduling problems. Stepwise delineation of the proposed approach is provided and twenty-two well-studied problem instances of job shop scheduling are solved by the proposed improved biogeography-based optimization in order to prove its efficiency and effectiveness. The numerical results indicate that the proposed algorithm is able to provide optimal or near-optimal schedules for all of the problem instances.

Peer-review under responsibility of the scientific committee of the 7th International Conference on Advances in Computing & Communications.

Keywords: Job shop scheduling problem; Makespan minimization; Combinatorial optimization; Biogeography-based optimization

1. Introduction

Scheduling attempts to optimally assign a set of resources to a set of tasks that must be performed during a specified time period while satisfying multiple constraints. Job shop scheduling is a form of classical scheduling problems, in which it has been extensively investigated in different fields of science and engineering. The main aim in the job shop scheduling problem is to find an optimal sequence of all operations on all production equipment while achieving an optimized objective function, such as makespan, tardiness, and total late work criterion (e.g., [1-

* Corresponding author. Tel.: +607 5534691.
E-mail address: wongky@mail.fkm.utm.my; phamed2@live.utm.my

1877-0509 © 2017 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the scientific committee of the 7th International Conference on Advances in Computing & Communications
10.1016/j.procs.2017.09.073

3]). In job shop or flexible job shop scheduling, machines are structured and grouped together based on their similar functionalities, where a variety of jobs can be carried out by these general-purpose machines.

Job shop scheduling is considered as a typical *NP*-hard combinatorial optimization problem which is numerically intractable with stubborn behavior [4]. The complexity of the job shop instances is exceedingly increasing as the problem scale (jobs × machines) gets bigger. Through the literature, three different approaches have been applied for solving the job shop scheduling problems. They are exact methods, heuristic approaches, and metaheuristic approaches. Exact methods, like dynamic programming and mathematical methods, could achieve the global optimum solutions for the small scale problems; however, they can be insufficient for the bigger scale problems in terms of higher computational execution time. Heuristic approaches, however, are able to provide near-optimal solutions within an acceptable computational execution time.

Metaheuristic approaches, which are also called high-level heuristics, are typically used to obtain optimal or near-optimal solutions for difficult problem instances. Metaheuristics such as genetic algorithm [5-7], particle swarm optimization [8-10], tabu search [11-13], simulated annealing [2, 14, 15], ant colony optimization [16, 17], imperialist competitive algorithm [18], immune system [3, 19], harmony search [20], and water drops algorithm [21, 22] have been proven to be efficient and powerful approaches for solving the job shop scheduling problems. A survey of the state of the art has been carried out on job shop scheduling techniques that interested readers can refer to for more details [23].

Biogeography-based optimization is a population-based and nature-inspired metaheuristic approach which has been first introduced by Simon [24]. This optimization algorithm has been successfully adopted for solving different engineering problems, specifically different problems in the scheduling arena, such as distributed assembly permutation flow shop scheduling [25], permutation flow shop scheduling [26], hybrid flexible flow shop scheduling [27], automated warehouse scheduling [28], flexible job shop scheduling [29-31], economic load dispatch problems [32], and benchmark functions [33]. Based on the promising computational outcomes of the biogeography-based optimization approach from these studies, it can be concluded that this metaheuristic can be an efficient and powerful method for solving different optimization problems. However, further research should be carried out to adopt this algorithm in other optimization problems, while improving its efficiency and effectiveness with problem-specific or knowledge-based operators.

In this research, an improved biogeography-based optimization approach is customized and adopted for solving the job shop scheduling problems with the objective of minimizing makespan. The original biogeography-based optimization algorithm is customized and improved by adopting the following schemes: (1) Random key and operation-based encoding and decoding are utilized for solution representation of the algorithm and job shop scheduling, (2) Migration process, which includes the immigration and emigration phases, is used as an adoptive process in order to modify the existing habitats, (3) Information sharing is adopted between habitats by applying crossover operators, (4) Problem-specific mutation operators, namely, swap, insert, and inverse are utilized to prevent solutions from getting trapped in local optima and increase the local exploitation ability of the algorithm, (5) A local search operator is also designed to further improve the solution quality of schedules, and (6) To increase diversity in the ecosystem, habitats with higher similarities are removed from the ecosystem. Finally, a set of well-studied job shop scheduling benchmarked instances is collected from the Operations Research Library [34] in order to test and evaluate the performance of the proposed algorithm as compared to other numerical results from the literature.

The remaining contents of this research are organized as follows. In section 2, the job shop scheduling problem is defined and the related assumptions are provided. In section 3, the improved biogeography-based optimization algorithm is presented. In section 4, computational experiments of the proposed algorithm and related discussion of the results are provided. Finally, conclusions and future research opportunities are given in section 5.

2. The job shop scheduling problem

This research studies one of the real-world encountered manufacturing scheduling problems, specifically a non-preemptive job shop scheduling problem, where minimization of maximum completion time (makespan) is considered in order to improve the schedule efficiency and machine utilization. In job shop scheduling, unlike flow shop scheduling, jobs are independent where each of them follows a unique route based on defined technological