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Research on Permutation Flow-shop Scheduling Problem based on Improved Genetic Immune Algorithm with vaccinated offspring

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Abstract

This work proposes a hybrid of GA and immune algorithm for permutation flowshop scheduling problems to overcome the problem of GAs early convergence during the evolutionary processes. The proposed algorithm, called VacGA, introduces vaccination into the field of GAs based on the theory of immunity in biology. VacGA employs a GA to perform global search and an artificial immune system to perform local search. VacGA has been tested on Taillard's benchmarks, and compared with standard GA and the best existing hybrid GAs. The obtained results shed light on the efficiency of our new hybrid method. Furthermore, the effects of some parameters are discussed.

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Keywords: Permutation flowshop; Genetic algorithms; Artificial immune system; common subsequence; Vaccination.

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1. Introduction

The permutation flowshop problem (PFSP) is a classic scheduling problem where *n* jobs must be processed on a set of *m* machines disposed in series and where each job must visit all machines in the same order. Many production scheduling problems resemble flowshops and hence it has generated much interest and had a big impact in industrial field as it is based on ideas gleaned from engineering [1].

The PFSP is one of the most studied problems in the OR literature. Since [2] showed the problem to be *NP-complete* for more than two machines; most researchers have focused on implementing approximate methods to find high quality solutions for problems of medium or large size without excessive computation times. The reader may refer to the most recent review in [3], which covered heuristics and metaheuristics published in the literature from [4] compared with other non-efficient algorithms and/or under incomparable conditions.

In the last decades, approaches based on genetic algorithms (GA) have received increased attention from the academic and industrial communities for dealing with optimization problems that have been shown to be intractable using conventional problem solving techniques. GA is different from most conventional calculus-based search algorithms in the following characteristics: no limitation on the continuity or discreteness of the search space, parallel computation of a population of solutions, using natural selection criteria, and no gradient information [5].

Nevertheless, one major drawback of GA is its premature convergence to local minima resulting in low accuracy. Also, since GA lacks hill-climbing capacity, it may easily fall in a trap and find a local minimum not the true solution. To avoid the premature convergence, one way is to use large population, but its computation time is a burden and the convergence speed to obtain results with reasonable precision is slow. Under the restriction of small population, GAs merged with other nature-inspired metaheuristics were developed resulting in more robust combinatorial optimization tools for solving complex problems. Hybridization, when properly applied, may further enhance effectiveness of the solution space search, and may overcome any inherent limitations of single metaheuristic algorithms [6].

In the literature, much research has gone into the hybridization of conventional GAs for PFSPs. In general, GA acting as a global search scheme is hybridized with a local search scheme to enhance both diversification and intensification [7-8]. The most recent hybrid GAs for PFSPs are surveyed in the following. Nearchou [9] proposed a metaheuristic that integrates a simulated annealing (SA) algorithm together with features borrowed from the fields of GAs and local search heuristics. Ruiz *et al.* [10] proposed a GA hybridized with a local search based in an insertion neighborhood for the flowshop scheduling problem (FSSP). Tseng and Lin [11] hybridized a GA and a novel local search scheme. It employs GA to do the global search and two local search methods to do the local. Zhang and Wang [12] addressed a hybrid GA named HGA. Their algorithm obtained 115 best results and 92 of which were newly discovered. Tseng and Lin [13] proposed the GLS algorithm which hybridizes GA and tabu search (TS). It used GA to do global search and the TS to do the local. Chang *et al.* [14] proposed ACGA (artificial chromosomes embedded in GA), which is a hybrid framework of EDAs and GAs, to tackle the PFSP to minimize makespan. The probabilistic model and genetic operators are used to generate new solutions. Their results show that ACGA performs better than GAs. Newly, Xu *et al.* [15] presented AGA, a hybrid GA where an enhanced variable neighborhood search (E-VNS) as well as a simple crossover operator is used on all pairs of individuals. For 120 benchmark instances, AGA obtains 118 best solutions reported in the literature and 83 of which are newly improved. Chen *et al.* [16] propose a self-guided GA for PFSP, which is based on a novel method to combine global statistical information with location information about individual solutions to deal with intractable combinatorial optimization problems. In 2012, Chen *et al.* [17] extend their previous study in ACGA and propose an extended ACGA (eACGA) to deal with the intractable combinatorial optimization problems by using both the univariate and the bivariate statistic information.

Among the modern metaheuristic-based algorithms, the artificial immune systems (AIS) algorithm emerged as highly effective and efficient algorithmic approaches to *NP-hard* combinatorial optimization problems. Studies [18] have shown that it possesses several attractive immune properties, such as strong self-learning, long lasting memory, self-identity, fault tolerance and strong adaptability to the surroundings, that allow evolutionary algorithms to avoid premature convergence and improve local search due to global search and quick convergence ability.

Many researchers have concluded that hybrid approaches for scheduling problems could end up with high quality results. In earlier researches, [19-22] proposed improved approaches hybridizing GA and AIS. The effects for hybrid