An Improved Monkey Search Algorithm to Solve the Flexible Job Shop Scheduling Problems With Makespan Objective

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INTRODUCTION

Scheduling is a vital decision making processes in both manufacturing and service industries. The main objective of scheduling is to allocate the available limited resources to perform a group of tasks over a period of time to optimize some performance measures. The most important performance measures are minimization of makespan, flow time, tardiness, and lateness. A wide variety of scheduling problems were addressed by the researchers. Among them flexible job shop scheduling problem (FJSP) is considered in this paper due to its theoretical and practical significance. The FJSP is an extension of the classical job-shop scheduling problem (JSP). In the classical JSP, *n* jobs are to be processed on *m* machines and it is assumed that the *n* jobs have pre-determined sequences of operations and also each operation is performed on a predefined machine. In the FJSP, the operations are processed on the multiple capable machines. The FJSP is formed by assigning each operation to a machine out of a set of capable machines and sequencing the assigned operations on each machine to obtain a feasible schedule by considering a predefined objective function. The FJSP were proved to be non-deterministic polynomial-time hard (NP-hard) type combinatorial optimization problems (Garey et al., 1976). Hence, with the increase in problem size, the computational time would also increase. Therefore, the exact algorithms such as branch and bound, branch and cut, Lagrangian relaxation and dynamic programming cannot be used to solve the large size problem instances. To overcome this difficulty, researchers have developed many heuristics. However, heuristics are based on a specified thumb rule for a particular problem. Hence, many meta-heuristic algorithms are addressed in the literature. Monkey search algorithm (MSA) is one of the recently developed meta-heuristic algorithms. In this paper, an improved MSA (IMSA) is considered to solve the FJSP with makespan objective function. The main objective of the work is to develop an improved monkey search algorithm (IMSA) for solving the flexible job shop scheduling problems for minimizing makespan and validate the performance of the proposed IMSA using the benchmark problems addressed in the literature. The background of the proposed research work is presented in the next section.

BACKGROUND

In this section the literature review on the FJSP, monkey search algorithm and variable neighbourhood search algorithm are present.

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FLEXIBLE JOB SHOP SCHEDULING

The FJSP was first addressed by Brucker and Schile, 1990. They developed a polynomial algorithm to solve the FJSP with two jobs. They also proposed hierarchical approaches and integrated approaches to solve the FJSP with many jobs. However, the exact algorithms could be used to solve only smaller problem instances. The real problems are larger in nature and hence they cannot be solved by the exact algorithms. A new neighbourhood structure was proposed by Dauzère-Pérès and Paulli (1997) to solve the FJSP. The TS algorithm was suggested by them for re-sequencing and rearranging the operation. Zhang and Gen (2005) proposed a multistage operation based GA to deal with the FJSP. Gao et al. (2006) presented a General Particle Swarm Optimization (GPSO) algorithm for solving FJSP. In the proposed GPSO, crossover and mutation operations in the Genetic Algorithm were incorporated to exchange the information and search randomly. In addition, the Tabu Search (TS) was also used for the local search. The performance of the proposed algorithm was demonstrated with the benchmark problems.

Fattahi et al. (2007) developed a mathematical model and heuristic procedures to solve the FJSP. Tabu search (TS) and simulated annealing (SA) are the heuristics proposed by them. They also addressed six different algorithms to solve the FJSP. They considered both integrated and hierarchical approaches in their research. Gao et al. (2008) proposed a hybrid GA and variable neighbourhood descent (HGVND) algorithm to solve the FJSP. Two local search procedures were introduced by them. The proposed algorithm was tested on 181 benchmark problems and the effectiveness of the algorithm was proved. Pezzella et al. (2008) presented a GA to solve the FJSP by developing different strategies to generate the initial population, selection and reproduction. They compared the results, with other GAs and TS algorithms.

Bagheri et al. (2010) introduced an artificial immune system (AIS) algorithm to solve the FJSP to minimize the makespan. In the AIS, Different strategies were developed to produce the initial population and selecting the individuals for reproduction. Different mutation operators were utilized for reproducing new individuals. Xing et al. (2010) addressed a knowledge-based ant colony optimization (KBACO) algorithm to solve the FJSP. In the KBACO, the knowledge model learned some available knowledge from the optimization of ACO. The existing knowledge is then applied to guide the current heuristic searching. Yazdani et al. (2010) solved the FJSP by a parallel variable neighbourhood search (PVNS) algorithm to solve the FJSP. The proposed method increased the diversification and the exploration in the search space. Al-Hinai and ElMekkawy (2011) introduced a hybrid GA (HGA) to solve the FJSP. The initial population generation algorithm and a local search method were combined in the HGA and hence the performance of the GA was improved. The proposed HGA outperformed other versions of GA.

Yuan and Xu (2013) presented two algorithms for solving the FJSP with makespan criterion. Hybrid harmony search (HHS) and large neighborhood search (LNS) are the two algorithms. In the HHS, a local search procedure was carried out to improve the solution quality. The proposed algorithms were used to obtain the new upper bounds for the benchmark instances. A teaching–learning based optimization (TLBO) algorithm was proposed by Baykasoğlu et al. (2014) to solve the job shop scheduling problems. González et al. (2015) addressed the scatter search (SS) algorithm combined with path re-linking and TS for solving the FJSP with makespan objective. They compared the performance of the proposed algorithm with several other algorithms addressed in this literature for standard benchmark problems. A biogeography based optimization (BBO) algorithm with some heuristics was proposed by Lin (2015) for solving the FJSP. He also introduced a path re-linking technique, an insertion-based local search heuristic and an efficient machine assignment rule. Cinar et al. (2016) developed a priority-based genetic algorithm (PBGA) for solving the FJSP. In the proposed algorithm, the priority of each operation was represented by a gene on the chromosome. Iterated local search (ILS) was applied to the chromosomes at