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Incorporating a modified uniform crossover and 2-exchange neighborhood mechanism in a discrete bat algorithm to solve the quadratic assignment problem

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ABSTRACT

The bat algorithm is one of the recent nature-inspired algorithms, which has been emerged as a powerful search method for solving continuous as well as discrete problems. The quadratic assignment problem is a well-known NP-hard problem in combinatorial optimization. The goal of this problem is to assign n facilities to n locations in such a way as to minimize the assignment cost. For that purpose, this paper introduces a novel discrete variant of bat algorithm to deal with this combinatorial optimization problem. The proposed algorithm was evaluated on a set of benchmark instances from the QAPLIB library and the performance was compared to other algorithms. The empirical results of exhaustive experiments were promising and illustrated the efficacy of the suggested approach.

1. Introduction

Nowadays metaheuristics pose a great challenge for solving a numerous difficult combinatorial problems appearing in various industrial, economic, and scientific domains. Most of these problems are Non-deterministic Polynomial-time hard NP-hard [1,2], i.e. there is no polynomial time algorithm to solve them. Solving such combinatorial optimization problems require to involve the search for an optimal solution among a collection of solutions in finite search space. The nature has long been a rich source of inspiration for many scientists. Drawing their inspiration from the most successful process in nature, researchers develop a class of metaheuristics namely nature-inspired algorithms. The nature-inspired algorithms offer additional advantages over classical algorithms [3] and they also seek to find acceptable results within a reasonable time, rather than an ability to guarantee the optimal or sub-optimal solution. Moreover, the most metaheuristic algorithms are based on swarm intelligence, biological systems, physical and chemical systems [4]. In particular, the swarm-intelligence algorithms have shown their promising performance and they have been gaining much popularity in solving many engineering optimization problems; such as particle swarm optimization [5], spider monkey [6], cuckoo search [7], bee colony optimization [8], firefly algorithms [9] and in the last years the bat-inspired algorithm [10,11].

The Quadratic Assignment Problem (QAP) is proven to be among the hardest combinatorial optimization problems [12] and no polynomial time algorithm is expected to exactly solve the problem for large instances and sometime even small instances may require considerable computation time. In literature of combinatorial optimizations, researchers have applied different approaches ranging from heuristics or meta-heuristics until hybrid approaches, to find optimal or near optimal solutions for the QAP problem. The most widely used heuristic algorithms for QAP problem are simulated annealing [13], tabu search [14], neural network [15], ant colonies [16], memetic algorithms [17], genetic algorithms [18], iterated local search [19], hybrid heuristics [20], very large-scale neighborhood search [21], particle swarm optimization [22], bat algorithm [23], and bees algorithm [24].

The Bat-inspired Algorithm (BA) is a population-based stochastic optimization technique, which has recently been applied in many applications. This algorithm was developed to deal with continuous optimization and especially, BA has also been proven effective in solving several discrete optimization problems. Owing to the complexness of the QAP for both exact and heuristic

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approaches, this problem is a suitable testing platform for novel optimization techniques. Therefore, the design of the improved methods for the QAP still poses a challenge to many researchers. This study investigates the applicability of BA to provide a very good compromise between solution quality and execution time. To that end, this work introduces a novel discrete version of BA named Discrete Bat Algorithm (DBA) by involving some modifications of the original algorithm. Firstly, these modifications concern position representation and its update equation, and velocity representation and its update equation. Secondly, we incorporate a modified uniform crossover operator in the movement equation. This idea aims to enhance the search strategy of BA. Thirdly, we use the 2-exchange neighborhood mechanism to improve the local search of BA. Finally, we adjust some suitable parameters values to balance between intensification and diversification capabilities of BA. We compare the performance of our proposed approach to five algorithms from the current literature: Bees Algorithm (BeA) [24], Modified Bat Algorithm (MBA) [23], a genetic algorithm with Sequential Constructive Crossover (SCX) [25], Hybrid Ant colony System coupled with the QAP (HAS-QAP) [16] and Hierarchical Particle Swarm Optimization (HPSO) [22].

The rest of this paper is organized as follows: the second section presents the literature review of BA. Section 3 introduces the original BA. Section 4 describes the quadratic assignment problem. Section 5 discusses our discrete approach and details its main components. The results of computational experiments and discussions are presented in Section 6. Finally, the conclusions and some perspectives of research are given in Section 7.

2. Related work

The BA is a swarm-intelligence algorithm based on the echolocation behaviour of microbats when searching their prey. Initially, this algorithm has been developed to optimize continuous nonlinear functions [10,26]. Actually, the algorithm shows a good efficiency when it has been applied to solve various optimization problems [27]. In the current literature, many variants of BA have been introduced to enhance or to implement the original algorithm to solve different sorts of problems. Gandomi and Yang integrated chaos mechanism in BA to improve the global search mobility of the basic algorithm and to optimize effectively a set of benchmark problems [28]. Cai et al. introduced a Gaussian walk with BA to enhance the local search capability and they modified the velocity equation to assure a good exploitation of the search space [29]. Khan et al. introduced a fuzzy modification of BA for clustering of company workplaces [30]. Yılmaz and Küçüksille embedded two modifications in structure to enhance the local and global search and they also used both standard test functions and constrained real-world problems to verify the effectiveness of proposed approach [11]. Nguyen et al. hybridized BA and artificial bee colony algorithm based on communication strategies in parallel processing for swarm intelligent algorithms with the aim to

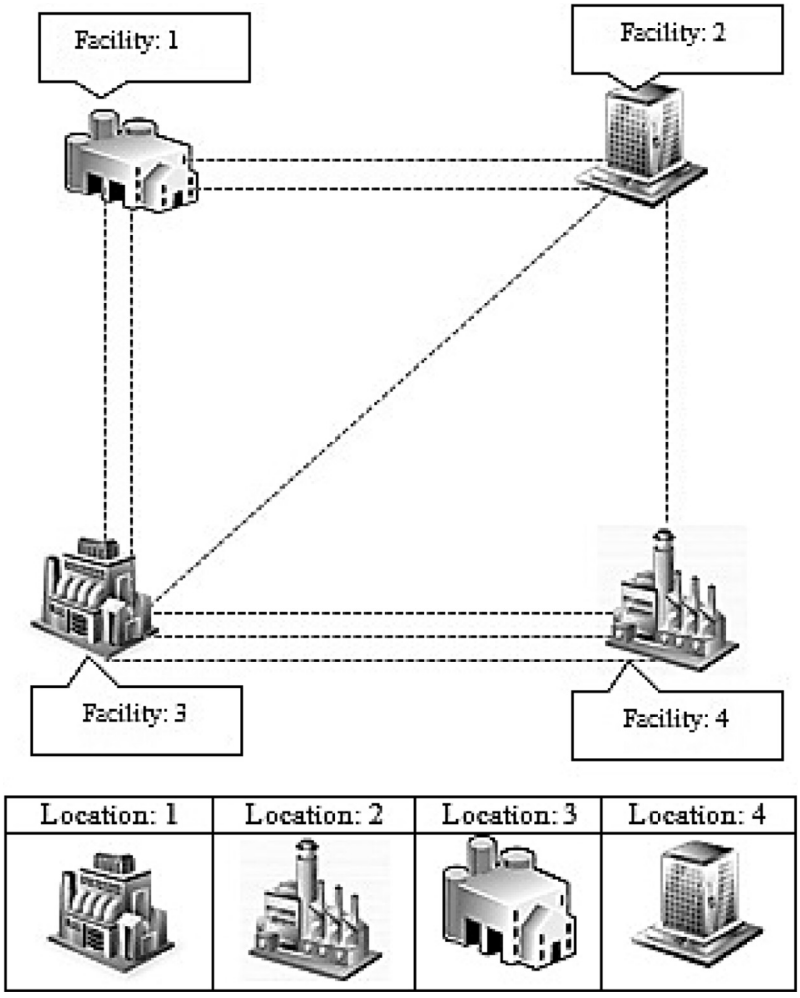

Fig. 1. Illustrative example of quadratic assignment problem with the permutation $\pi = (2, 4, 3, 1)$ corresponds to optimal solution.

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