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A novel binary artificial bee colony algorithm based on genetic operators

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ABSTRACT

This study proposes a novel binary version of the artificial bee colony algorithm based on genetic operators (GB-ABC) such as crossover and swap to solve binary optimization problems. Integrated to the neighbourhood searching mechanism of the basic ABC algorithm, the modification comprises four stages: (1) In neighbourhood of a (current) food source, randomly select two food sources from population and generate a solution including zeros (*Zero*) outside the population; (2) apply two-point crossover operator between the current, two neighbourhood, global best and *Zero* food sources to create children food sources; (3) apply swap operator to the children food sources to generate grandchildren food sources; and (4) select the best food source as a neighbourhood food source of the current solution among the children and grandchildren food sources. In this way, the global–local search ability of the basic ABC algorithm is improved in binary domain. The effectiveness of the proposed algorithm GB-ABC is tested on two well-known binary optimization problems: dynamic image clustering and 0–1 knapsack problems. The obtained results clearly indicate that GB-ABC is the most suitable algorithm in binary optimization when compared with the other well-known existing binary optimization algorithms. In addition, the achievement of the proposed algorithm is supported by applying it to the CEC2005 benchmark numerical problems.

1. Introduction

Concentrating on local interactions of the swarm individuals (including bird flocks, fish schools, ants, bees, etc.) with each other and with their environments [5], Swarm Intelligence (SI) has become a significant research area among computer scientists, engineers, economists, bioinformaticians and several other disciplines on account of the fact that the remarkable ability of natural intelligent swarms on solving their related problems (finding food, building nests, etc.) can be simulated to deal with real world problems [32]. It is known that an intelligent swarm should have the following properties [47]: (1) the ability of proximity, (2) the ability of receiving and responding to quality factors, (3) the ability of protecting behaviours against fluctuations and (4) the ability of adapting to diverse situations. In the 1990s, two important SI based algorithms which are ant colony optimization (ACO) [18] and particle swarm optimization (PSO) [20] were developed and both of them have attracted researchers' attention.

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After realizing the above four mentioned properties of SI in honey bee swarms, researchers, especially from the beginning of the 2000s, started to concentrate on modelling various intelligent behaviours of these swarms; for instance, the behaviours of dance and communication, collective decision, task allocation, nest site selection, mating, foraging, marriage, floral and pheromone laying [29]. Some well-known bee swarm intelligence based algorithms are the virtual bees algorithm (VBA) [70], the bees algorithm (BA) [57], BeeAdHoc [64], honey bee mating optimization (HMBO) [22], the BeeHive [65], bee system (BS) [43], bee colony optimization (BCO) [61] and the artificial bee colony (ABC) algorithm [27,28]. According to [32], ABC is the most widely used algorithm among bee swarm based algorithms presented in the literature. Some successful applications of the ABC algorithm are optimization of numerical problems [31], data clustering [35], neural networks training [34], wireless sensor network deployment [54] and routing [33], and image analysis [24,25,44,52,53]. It is clearly seen that there exist various appreciated studies of the ABC algorithm on continuous space [1,6,7,13,14,30,60,66,68,72]. However, that situation is not the same for the studies of ABC on binary problems. Through this gained information, the basic aim of this study is to propose an improved binary model of the ABC algorithm to solve binary optimization problems.

1.1. Related works

It is known that the standard ABC algorithm can optimize continuous problems. In other words, the structure of the basic ABC cannot be directly adapted to the binary optimization problems. Thus, some modifications are required on the ABC algorithm for binary optimization applications. Pampara and Engelbrecht [56] considered binary solution as four dimensional real vector through angle modulation schema. Kashan et al. [37] introduced a binary version of the ABC algorithm (DisABC) which uses the dissimilarity measure of binary structures instead of the arithmetic subtraction operator. To measure the similarity of binary structures, Jaccard's coefficient of similarity is employed and to generate a new solution, two selections are applied in a probabilistic manner; random selection depending only on neighbourhood and greedy selection depending on both neighbourhood and the best solution. The performance of the algorithm was verified with the implementation of the uncapacited facility location problem (UFLP). The same methodology was also applied to the differential evolution algorithm to solve UFLP problem [36]. Kiran and Gunduz [39] proposed a binary version of the ABC algorithm based on XOR logic operator (XOR-ABC) and its performance was compared with the DisABC algorithm in terms of UFLP.

1.2. Motivations

For decades, researchers have attempted to develop algorithms in optimization satisfying superior performance with respect to the other algorithms in literature [49]. To design a suitable algorithm, it is crucial to establish a connection between the algorithm and a given optimization problem i.e. analyzing optimization problem is the starting point. There exist two mostly preferred approaches by the researchers to improve an existing algorithm, known as hybridization and modification. The former is the process of mixing of at least two heterogeneous particles through conscious manipulation or as a natural progressive manipulation [71]. The latter is the process of modifying some particles of the mechanism through internal or external forces. As observed in nature, memes, which are the basic unit of cultural transmission and imitation [17], can encounter modifications and combine with each other to generate stronger memes. Language life cycle can be given as an example to this concept. While new words are welcomed by languages on account of the needs and interests of society or community, some words lose their popularity and hence become disappeared from languages. From the algorithmic perspective, it is known that two or more properly combined distinct algorithms and modified algorithms by the operators of other algorithms can improve the ability of problem-solving mechanism. As the importance of cultural information transmission has been realized by researchers, memetic algorithms, "which are population-based metaheuristics composed of an evolutionary framework and a set of local search algorithms activated within the generation cycle of the external framework" [49], has gained popularity. That motivates us to develop a genetically modified artificial bee colony algorithm for optimizing binary search space which resembles to the memetic algorithms using genetic operators.

1.3. Contribution

In this paper, a novel binary artificial bee colony algorithm (GB-ABC) based on genetic operators is introduced. To our knowledge, this study is the first to use genetic operators in a binary model of the ABC algorithm. Furthermore, the GB-ABC algorithm is not intended to solve only a specific binary problem, it is also proposed to overcome general binary optimization problems. This is demonstrated by applying GB-ABC to well-known binary optimization problems; the dynamic image clustering problem known as the process of automatically finding the optimum number of clusters and the 0–1 knapsack problem known as maximizing the cost of a knapsack with maximum weight capacity. For the dynamic clustering problem, the performance of the GB-ABC algorithm is analyzed by comparing it with the results of the binary particle swarm optimization for dynamic clustering (known as DCPSO) [51], the quantum inspired binary particle swarm optimization (QBPSO) [10], the genetic algorithm for dynamic clustering, the discrete binary artificial bee colony (DisABC) [37], the self-organizing map (SOM), the unsupervised fuzzy clustering approach (UFA) and Snob algorithms. As for the knapsack problem, the performance of the GB-ABC is evaluated by comparing with the results of the BPSO, QBPSO, GA, and DisABC algorithms. It should be noted that the applied GA in binary problems is one of the basic type of GA in which the population is represented in bit string form, the crossover type is scattered, the mutation type is Gaussian, the reproduced population consists of 2 elitist