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# Proposal of Mutation-Based Bees Algorithm (MBA) to Solve Traveling Salesman & Jobs Scheduling Problems

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**Abstract**

This paper presents an improved swarm-based algorithm which is based on Bees Algorithm and Mutation Operator. Mutation-based Bees Algorithm (MBA) is very useful to solve some NP-complete problems. This paper contains the basic version of MBA with solving two NP-complete problems as examples and experiments for testing the suggested approach. These two problems are Traveling Salesman Problem and Job Scheduling Problem. The experimental results show that the suggested approach is very suitable for solving NP-complete problems and gives good results compare with traditional Bees algorithm.

## أقتراح خوارزمية النحل المعتمدة على الطفرة لحل مشكلتي البائع المتجول وجدولة الوظائف

**الخلاصة**

هذا البحث يقدم خوارزمية مطورة ومعتمدة على التحشد وهي خوارزمية النحل ومعامل الطفرة. خوارزمية النحل المعتمدة على الطفرة هي خوارزمية مفيدة جداً لحل بعض مشاكل من نوع NP-complete. هذا البحث يحوي النسخة الاساسية من خوارزمية النحل المعتمدة على الطفرة لحل مشكلتين من نوع NP-complete كإجراء لغرض اختبار الخوارزمية المقترحة. وهاتان المشكلتان هما مشكلة البائع المتجول ومشكلة جدولة الوظائف. نتائج التجارب أثبتت أن النموذج المقترح مناسب جداً لحل مشاكل من نوع NP-complete وقد أعطت نتائج جيدة بالمقارنة مع خوارزمية النحل التقليدية.

## Introduction

The bee colony optimization-based algorithm is a stochastic population metaheuristic that belongs to the class of swarm intelligence algorithms. In the last decade, many studies based on various bee colony behaviors have been developed to solve complex combinatorial or continuous optimization problems [14]. Bee

Colony optimization-based Algorithms are inspired by the behavior of a honeybee colony that exhibits many features that can be used as models for intelligent and collective behavior. These features include nectar

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exploration, mating during flight, food foraging, waggle dance, and division of labor [18].

Bee colony-based optimization algorithms are mainly based on three different models: food foraging, nest site search, and marriage in the bee colony. Each model defines a given behavior for a specific task. Bee is social and flying insect native to Europe, the Middle East, and the whole of Africa and has been introduced by beekeepers to the rest of the world [15, 18]. There are more than 20,000 known species that inhabit the flowering regions and live in a social colony after choosing their nest called a hive. There are between 60,000 and 80,000 living elements in a hive. The bee is characterized by the production of a complex substance, the honey, and the construction of its nest using the wax. Bees feed on the nectar as energy source in their life and use the pollen as protein source in the rearing of their broods. The nectar is collected in pollen baskets situated in their legs [18].

Generally, a bee colony contains one reproductive female called queen, a few thousand males known as drones, and many thousand sterile females that are called the workers. After mating with several drones, the queen breeds many young bees called broods. Let us present the structural and functional differences between these four honeybee elements [18, 15]:

• Queen: In a bee colony, there is a unique queen that is the breeding female with life expectancy between 3 and 5 years. It is developed from special and very young larvae and eggs selected by workers, from which the colony produce a new queen to become sexually mature, after killing the old unfertilized one. It is an exclusive development that will be raised in special queen cells with rich-protein secretion. The main role of the queen is the reproduction by the egg laying. It mates with 7–20 drones in a reproductive operation called mating flight. It stores the sperms in her spermatheca and then lays up to 2000 eggs per day. The fertilized eggs become female (worker) and the unfertilized eggs become male (drones).

• Drones: Drones represent the males varying between 300 and 3000 in the hive. Drones are developed when the queen lays unfertilized eggs and they play the role of fertilizing with a receptive queen generally in the summer and exceptionally in the autumn. The drone has a life expectancy of 90 days. It dies after a successful mating.

• Workers: Workers are female bees but are not reproductive. They live from 4 to 9 months in the cold season and their number reaches up to 30,000. However, in summer, they live approximately for 6 weeks when their number attains up to 80,000. The worker is responsible for the beehive defense using its barbed stinger. Consequently, it dies after stinging. One can enumerate the worker activities by the day criterion as follows: cell cleaning (day 1–2), nurse bee (day 3–11), wax production (day 12–17), guard honeybees (day 18–21), and foraging honeybees (day 22–42). The worker ensures the habitual activities of the bee colony such as honey sealing, pollen packing, fanning honeybees, water carrying, egg moving, queen attending, drone feeding, mortuary honeybees, and honeycomb building.

• Broods: The young bees are named broods. They born following the laying of eggs by the queen in special honeycomb cells called: the brood frames. Thereafter, the workers add royal jelly on the brood heads. Few female larvae are selected to be future queens. In this case, they are flooded by royal jelly. The unfertilized eggs give birth to the broods. The young larvae are spinning by cocoon, capping the cell by the older sisters; it is the pupa stage. Then, they reach the development stage in which they receive nectar and pollen from foragers until leaving the beehive and spending its life as forager. The foraging behavior (nest site selection, food foraging) and the marriage behavior in a bee colony are the main activities in the life of a bee colony that attract researchers to design optimization algorithms.

In the other side, Evolutionary Algorithms (EA) are stochastic population metaheuristics that have been successfully applied to many real and complex problems (epistatic, multimodal, multiobjective, and highly constrained problems). They are the most studied population-based algorithms. Their success in solving difficult optimization problems in various domains (continuous or combinatorial optimization, system modeling and identification, planning and control, engineering design, data mining and machine learning, artificial life) has promoted the field known as evolutionary computation (EC) [17]. Mutation operator is one of important operators in the evolutionary algorithms. Mutation operators are unary operators acting on a single individual. Mutations represent small changes of selected individuals of the population. The probability pm defines the probability to mutate each element (gene) of the representation. It could also affect only one gene too. In general, small values are recommended for this probability (pm $\in$ [0.001, 0.01]). Some strategies initialize the mutation probability to 1/k where k is the number of decision variables, that is, in average only one variable is mutated [18].

This paper presents an improved tool to solve NP-complete problems, which is called Mutation-based Bees Algorithm (MBA). MBA is an intelligent swarm-based algorithm which depends on Bees Algorithm and Mutation Operator. The intelligent swarm-based algorithm will be described in section 2. Bees algorithm details in section 3. The proposed improved algorithm will be presented in section 4. Section 5 contains the experiments of solving Traveling Salesman Problem and Job Scheduling Problems using proposed algorithm. Section 6 consists of conclusions that are related to suggested algorithm.

The bubble column is widely used in industry as a simple and relatively inexpensive means of achieving intimate gas-liquid contact. Gas is bubble into a deep pool of liquid in cocurrent or countercurrent flow and is dispersed as a bubble swarm of high interfacial area. The absorption may be accompanied by a chemical reaction.

The output from such a reactor is obviously influenced by gas hold-up and interfacial area and by internal circulation of liquid induced by the bubbles.

**Intelligent Swarm-Based Algorithm**

Swarm-based algorithms mimic nature's methods to drive a research towards the optimal solution. A key difference between Swarm-based algorithms and direct search algorithms such as hill climbing and random walk is that Swarm-based algorithms use a population of solutions for every iteration instead of a single solution. As a population of solutions is processed in an iteration, the outcome of each iteration is also a population of solutions. If an problem has a single optimum solution, Swarm-based algorithm population members can be expected to converge to that optimum solution [13].

However, if an NP-hard problem has multiple optimal solutions, a Swarm-based algorithm can be used to capture them in its final population. Swarm-based algorithms include the Ant Colony Optimization (ACO) algorithm [7], the Genetic Algorithm (GA) [10], the Bees Algorithm (BA) [12] and the Particle Swarm Optimization (PSO) algorithm [8].

Common to all population-based search methods is a strategy that generates variation in the solution being sought. Some search methods use a greedy criterion to decide which generated solution to retain. Such a criterion would means accepting a new solution if and only if it increases the value of the objective function. A very successful non-greedy population-based algorithm is the ACO algorithm which emulates the behavior of real ants. Ants are capable of finding the shortest path from the food source to their nest using a chemical substance called pheromone to guide their search. The pheromone is deposited on the ground as the ants move and the probability that a passing stray ant will follow this trail depends on the quantity of pheromone laid [14].

The Genetic Algorithm is based on natural selection and genetic recombination. The algorithm works by choosing solutions from the current population and then applying genetic operators - such as mutation, crossover [10], controlled mutation and conjugation [1] - to create a new population. The algorithm efficiently exploits historical information to speculate on new search area with improved performance [10].

The successful applications of the Ant Systems in the complex engineering and management problems are certainly encouraging. At the same time, these successes act as a great inspiration to attempt to explore bees' behavior as a source of ideas and models for development of various artificial systems [9]. The highly organized behavior enables the colonies of insects to solve problems beyond capability of individual members by functioning collectively and interacting primitively amongst members of the group. In honey bee colonies, this behavior allows honey bees to explore the environment in search of flower patches (food sources) and then indicates the food source to the other bees of the colony when they return to the hive. Such a colony is characterized by self-organization, adaptation and robustness [6].

Particle Swarm Optimization (PSO) algorithm is an optimization procedure based on the social behavior of groups of organization, for example the flocking of birds or the schooling of fish. Individual solutions in a population are viewed as "particles" that evolve or change their positions with time. Each particle modifies its position in search space according to its own experience and also that of a neighboring particle by remembering the best position visited by itself and its neighbors, thus combine local and global search methods [8].

**The Bees Algorithm**

**- Bees in Nature**

A colony of honey bees can extend itself over long distances (more than 10 km) and in multiple directions simultaneously to exploit a large number of food sources [21,19]. A colony prospers by deploying its foragers to good fields. In principle, flower patches with plentiful amounts of nectar or pollen that can be collected with less effort should be visited by more bees, whereas patches with less nectar or pollen should receive fewer bees [3,5,12].

The foraging process begins in a colony by scout bees being sent to search for promising flower patches. Scout bees move randomly from one patch to another. During the harvesting season, a colony continues its exploration, keeping a percentage of the population as scout bees [19].

When they return to the hive, those scout bees that found a patch which is rated above a certain quality threshold (measured as a combination of some constituent, such as sugar content) deposit their nectar or pollen and go to the "dance flower" to perform a dance known as the "waggle dance" [21].

This mysterious dance is essential for colony communication, and contains three pieces of information regarding a flower patch: the direction in which it will be found, its distance from the hive and its quality rating (or fitness) [5,14,21]. This information helps the colony to send its bees to flower patches precisely, without using guides or maps. Each individual's knowledge of the outside environment is gleaned solely from the waggle dance. This dance enables the colony to evaluate the relative merit of different patches according to both the quality of the food they provide and the amount of energy needed to harvest it [5]. After waggle dancing on the dance floor, the dancer (i.e. the scout bee) goes back to the flower patch with follower bees that were waiting inside the hive. More flower bees are sent to more promising patches. This allows the colony to gather food quickly and efficiently [12].

While harvesting from a patch, the bees monitor their food level. This is necessary to decide upon the next waggle dance when they return to the hive [5]. If the patch is still good enough as a good source, then it will be advertised in the waggle dance and more bees will be recruited to the source [12].

## - The Bees Algorithm

As mentioned, the Bees Algorithm is a swarm-based algorithm inspired by the natural foraging behavior of honey bees to find the optimal solution [12,13]. Figure (1) [12,13] shows the pseudo code for the algorithm in its simplest form. The algorithm requires a number of parameters to be set, namely: number of scout bees (n), number of sites selected out of n visited sites (m), number of best sites out of m selected sites (e), number of bees recruited for the best e sites (nep), number of bees recruited for the other (m-e) selected sites (nsp), initial size of patch (ngh) which includes site and its neighborhood and stopping criterion. The algorithm starts with the n scout bees placed randomly in the search space. The fitness of the sites visited by the scout bees is evaluated in step 2.

The bees having the highest fitness values are selected as "elite bees" in step 4. The algorithm then performs several searches around the neighborhoods of the elite bees and of the other bees in steps 5-7. The fitness values may alternatively be used to calculate the probability of selecting the bees. The algorithm employs more bees to follow the elite bees than the other bees in order to perform a more detailed search around the neighborhood of the points visited by the elite bees, which represent more promising solutions. Differential recruitment within scouting is also an important operation of the bees' algorithm. Both scouting and differential recruitment are utilized in nature.

In step 7, however, only one bee with the highest fitness value will be selected for such a site to generate the next bee population while there is no such a restriction in nature. It is necessary here to reduce the number of points to be visited. In order to explore new potential solutions, the remaining bees in the population are randomly assigned around the search space in step 8. These steps are repeated until the stopping criterion is satisfied. The colony will have two parts to its new population at the end of each iteration. The first part will comprise the representatives from each selected patch and the second part will comprise other scout bees assigned to perform random searches [12,13].

## Proposed Approach : Mutation-Based Bees Algorithm

The choosing of elite and other sites for neighborhood search consider the main problem in the Bees Algorithm, because there is no perfect strategy to select the neighborhood sites (elite and other). The proposed approach mixes between Bees Algorithm and Mutation operator to solve this problem firstly and to increase the performance of Bees Algorithm secondly. The proposal uses the mutation operators of Genetic Algorithm in the Bees Algorithm as a tool to determine the neighborhood of the elite sites. Figure (2) shows the pseudo code of the Mutation-based Bees Algorithm.

The proposed algorithm requires a number of parameters to be set, namely: number of scout bees (n), number of sites selected out of n visited sites (m), number of best sites out of m selected sites (e), number of bees recruited for the best e sites (nep), number of bees recruited for the other (m-e) selected sites (nsp), initial size of patch (ngh) which includes site and its neighborhood, mutation probability (Mp) and stopping criterion.

**Mutation-based Bees Algorithm: A Tool to Solve Some NP-Hard Problems**

In this paper, two NP-hard problems have been solved using the proposed Mutation-based Bees Algorithm which are Traveling Salesman Problem and Job Scheduling Problem. As experimental results, this paper compares its approach with Bees Algorithm alone.

**Traveling Salesman Problem**

The traveling salesman problem is a classical optimization problem. Optimization problems involve finding a maximum or minimum value of a mathematical function, usually subject to some sort of constraints expressed as mathematical function [2,20]. The traveling salesman problem is easy to describe: a salesman must visit a series of cities. Each city should be visited only once. After a final city is visited, the salesman returns to the starting city. The distance between each city is known. What is the shortest possible tour the salesman can make? Several experiments have been executed on traveling salesman problem using 5, 10, 15…., and 30 nodes. Figure (3) illustrates the time execution of our experiments with different operators.

**Job Scheduling Problem**

Scheduling, in the widest sense, is concerned with the allocation of scarce resources to tasks over time. Scheduling problems are central to production and manufacturing industries, but also arise in a variety of other things [4]. This paper focuses on shop scheduling problems, where jobs have to be processed on one or several machines such that some objective function is optimized. In case jobs have to be processed on more than one machine, the task to be performed on a machine for completing a job is called an operation. All the machine-scheduling models considered in this paper holds that (1) the processing time of all jobs and operations is fixed and known beforehand, and (2) the processes of all jobs and operations can not be interrupted.

In job shop scheduling problems we are given a finite set O of operations that is partitioned into a set of subsets M = {M1,…,Mm}, where each Mi corresponds to the operations to be processed by machine i, and into a set of subsets J = {J1,…,Jn}, where each set Jj corresponds to the operations belonging to job j. Each operation is assigned a non-negative processing time, preemption is not allowed. In the job shop scheduling problems the precedence constraints among all operation of a job exist and they induce a total ordering of the operations of each job [4].

Several experiments have been executed on job shop scheduling problem using different cases. Figure (4) illustrates the time execution of our experiments with different operators.

**Conclusions**

Mutation based Bees Algorithm is an improved swarm-based algorithm that is based on important swarm-based algorithm (Bees) and mutation operator. The proposed algorithm in this paper is a good improved tool to solve NP-Complete problems. The presented algorithm uses the mutation operator as a tool to select the elite bees in the bees algorithm. In this paper two problems have been solved using proposed algorithm. In TSP and job scheduling problems MBA gives best results compare with BA.

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1. Initialize population with random solution.
2. Evaluate fitness of the population.
3. While (stopping criterion is not satisfied)
4. Choose the elite bees and the elite sites for neighborhood search.
5. Choose other sites for neighborhood search.
6. Assign bees to the selected sites and calculate their fitness.
7. Choose the fittest bee from each site.
8. Recruit remaining bees to search randomly and calculate their fitness.
9. End While

**Figure (1) Pseudo Code of the Basic Bees Algorithm**

1. Initialize population with random solution.
2. Evaluate fitness of the population.
3. While (stopping criterion is not satisfied)
4. Choose the elite bees.
5. Select neighborhood sites based on elite bee.
6. If the chosen neighborhood sites are not enough, then use Mutation Operator for choosing the elite and other sites for neighborhood search.
7. Assign bees to the selected sites and calculate their fitness.
8. Choose the fittest bee from each site.
9. Recruit remaining bees to search randomly and calculate their fitness.
10. End While

**Figure (2) Pseudo code of the Proposal of Basic Mutation-Based Bees Algorithm**

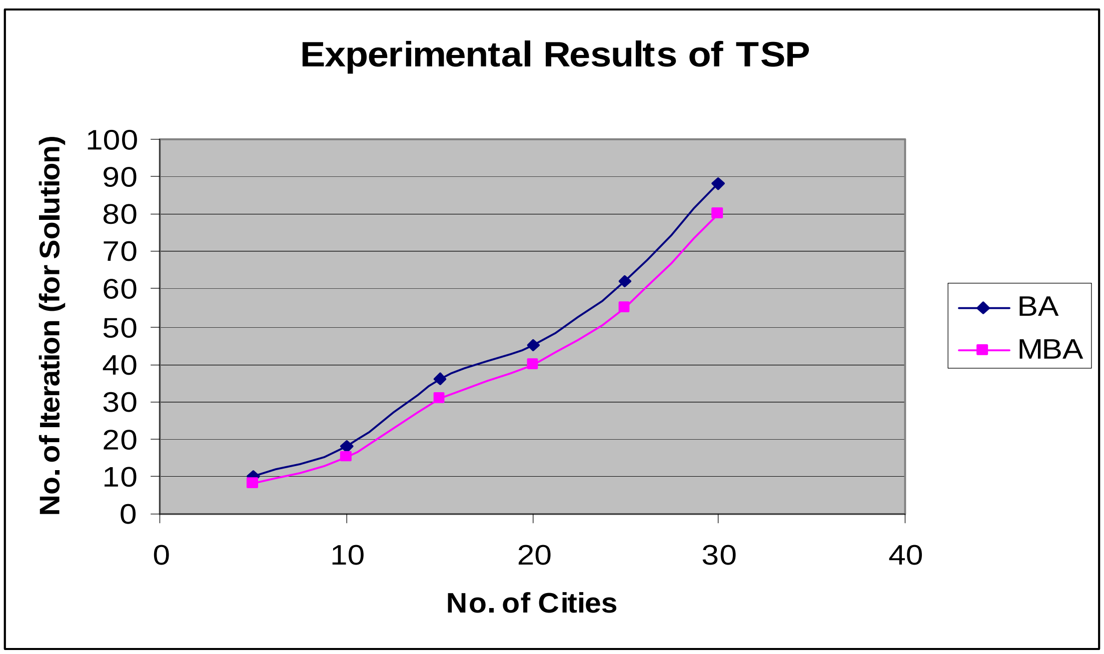


**Figure (3) Experimental Results of TSP**

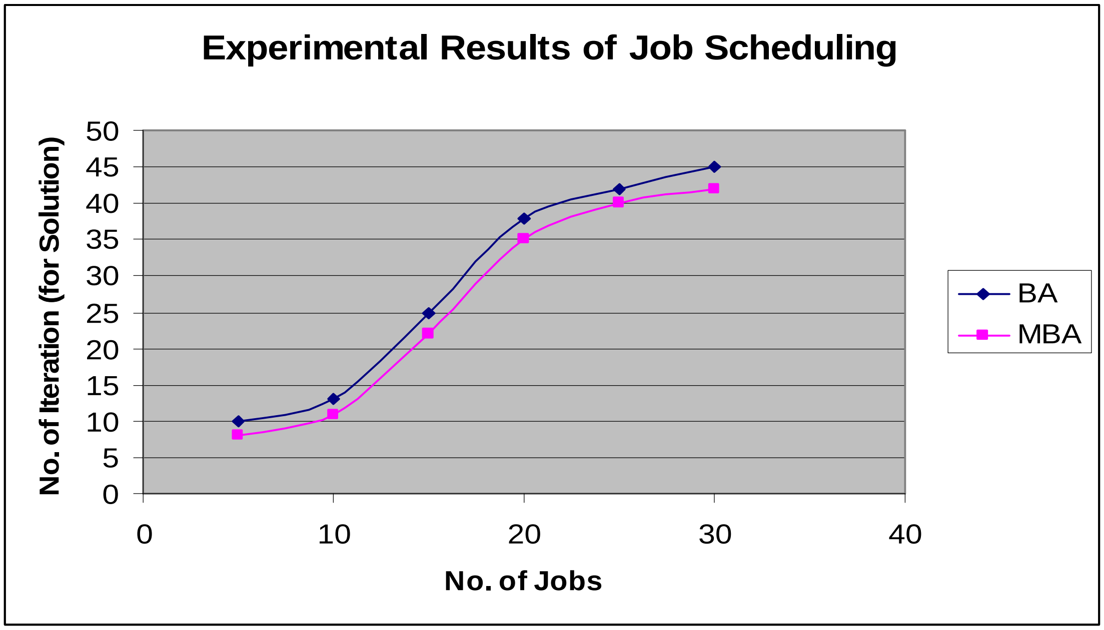


**Figure (4) Experimental Results of Job Scheduling**