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SPV and Mutation based Artificial Bee Colony Algorithm for Travelling Salesman Problem

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ABSTRACT
Artificial Bee Colony (ABC) Algorithm is an optimization algorithm used to find out the global optima. In ABC, each bee stores the information of feasible solution or candidate solution and stochastically modifies this over time, based on the information provided by neighboring bees, it speculative modifies over time and based on the best solution found by the bee itself.. In this proposed work, enhanced ABC algorithm with SPV for travelling salesman problem is used. In this modified bee colony algorithm, additional phase in the form of mutation is used after the scout bee phase and the SPV rule is used in this work for improving local search. After modification, proposed algorithm is implemented on standard travelling salesman problem for checking the efficiency of proposed work. The experimental results are compared with ABC algorithm and ABC with SPV algorithm.

Keywords
Artificial Bee Colony, ABC, Genetic Algorithm, Mutation, SPV, Swarm Intelligence.

1. INTRODUCTION
The problem of optimization is one of the most crucial problems now a day and lots of work have been done previously to solve these problems. There are many types of optimization algorithm like GA, ABC, PSO, ACO[4], etc. and lots of works in these algorithms are available in the literature. In paper [1], Dervis Karaboga defined an algorithm, called Artificial Bee Colony (ABC) for solving numerical optimization problem. This algorithm is based on the foraging behavior of honey bees. Different versions of ABC algorithm have been proposed like artificial bee colony algorithm with mutation [9], ABC with crossover, ABC with SPV [10], ABC with crossover and mutation [11] and many different versions have been proposed. In paper [2], dynamically division of bees into subgroup and the searching process is performed on these generated subgroups. In paper [3], Karaboga defines the modified algorithm for solving real parameter optimization problems and comparative study on different evolutionary algorithms like particle swarm optimization (PSO), ABC algorithm, Differential evolution (DE), Ant colony algorithm (ACO) etc and performance derived on different benchmark functions, are discussed on paper [5,7]. For improving the exploitation, karaboga proposed a modified ABC algorithm based on global best solution in paper [6]. D. Haijun and F. Qingxian proposed a enhanced artificial bee colony algorithm for function optimization in paper [8].

In paper [10, 11], travelling salesman problem using bee colony with SPV rule is used. In this paper, SPV rule is used in standard ABC algorithm for improving local search. Here proposed work is the extended version of this paper. In this work, SPV rule and mutation operator is used in standard ABC algorithm.

The remainder of this paper is organized as follows. Section 2 explained the artificial bee colony algorithm with mutation. In section 3, proposed algorithm is explained. Travelling salesman problem is discussed in section 4. Experimental results and parameter setup for result comparison are shown in section 5. Finally, section 6 concludes the paper.

2. ARTIFICIAL BEE COLONY ALGORITHM WITH MUTATION
In paper [9], one more phase in the form of mutation operator is added to original Artificial Bee Colony algorithm. In standard ABC algorithm, there are only 4 phases that described the overall working of this algorithm, but here one additional phase after the scout bee phase of ABC algorithm is added in the form of Mutation operator. Now modified artificial bee colony algorithm has five phases: first initialization phase then employed bee phase, onlooker bee phase, scout bee phase and finally mutation phase. For the local search, employed bee phase is used and the mutation phase is used to find out the new search area of the solution space. With the help of mutation operator, there may be a possibility to change the local best position and the algorithm may not be trapped into local optima. In this work, the mutation phase is implemented on the probabilistic way in each iteration for searching food source during the life process of ABC optimization technique. Food sources are selected randomly from the food size to perform mutation operation. In mutation phase, if generated offspring's fitness is greater than the older one then replaces the older offspring's from the new one. Uniform mutation is used in this work.

The overall algorithm is described in following steps:

• Initialization phase.

• REPEAT

(a) In the Memory, Employed bees are placed on the food sources;

(b) Generate new offspring from older offspring after Applying mutation operator.

(c) In the memory, onlooker bees are placed on the food sources;

(d) For finding new food sources, Send the scout bee to the search space.

• UNTIL (requirements are not met).

3. PROPOSED WORK
In this proposed work, modified artificial bee colony algorithm with SPV rule is used. In the modified artificial bee

colony algorithm, one additional phase in the form of mutation operator is used. In the standard ABC algorithm, after the employed bee phase, uniform mutation operator is used. Now modified ABC algorithm has five phases: Initialization phase, employed bee phase, mutation phase, onlooker bee phase and scout bee phase. When applying uniform mutation, randomly select one of the food sources and replace it with the value generated in between the lower bound and the upper bound of the food source value. Also SPV rule is used in this proposed work. This SPV rule is used in the initialization phase of modified ABC algorithm. The smallest position value named as SPV is basically used for finding the permutations among continuous positions X_j^k. considers the travelling salesman problem where there are n cities and m food sources. Here continuous set of position vector is represented by X_j^k and on the basis of continuous position vector, a new sequence vector is generated and represented by S_j^k. now the operation vector is represented by following formula-

$$R_j^k = S_j^k \bmod m$$

Here for every individual generated from ABC algorithm, a sequence vector is generated using SPV rule. After getting initial population and associated sequence vector, fitness value is calculated. Now these individual visits employed, mutation and onlooker bee phase. Finally scout bee phase is used, if all the food sources are exhausted and to generate new food source.

Proposed enhanced algorithm is described below-

1. **Initialsation Phase**
   REPEAT
   - REPEAT

     Initialize food source position randomly

     Sequence vector is generated using SPV rule
   - UNTIL (Dimension Size)

     Calculate each food source fitness value
   - UNTIL (Maximum number of Food Sources)

REPEAT

2. **Employed Bee Phase**
   - REPEAT
   - REPEAT

     Produce new feasible solution

     On the basis of candidate solution, produce candidate sequence using SPV rule
   - UNTIL(Dimension)

     Calculate fitness of generated individual
   - If new candidate solution fitness is better than the existing feasible solution fitness, then replace the new solution with existing feasible solution and its sequence vector.
   - UNTIL (Max number of employed bee)
   - REPEAT

     Compute each food source probability.
   - UNTIL (Max Number of Food Sources)
3. **Onlooker Bee Phase**
   - REPEAT

     choose food source on the basis of probability
   - REPEAT

     For food source position, produce new candidate solution

     Using SPV rule, produce new candidate sequence.
   - UNTIL (Dimension)

     Compute the fitness of each individual food source
   - If new candidate solution fitness is better than the existing solution fitness then replaces the older solution with existing solution and its sequence vector.
   - UNTIL (Max number of Onlooker Bee)
4. **Scout Bee Phase**
   - If any of the food source exhausted then

     (a) By scout bee phase, new random position is generated to replace that food source.

     (b) Best food source and sequence vector memorized so far.
5. **MUTATION PHASE**
   - If mutation criteria is met then

     (a) From current population, select random particle for mutation operator.

     (b) After applying mutation operation, new individuals and new sequence vector using SPV rule generated.

     (c) New feasible solution generated as a result of mutation operation.

     (d) New set of sequence is generated for the feasible solution

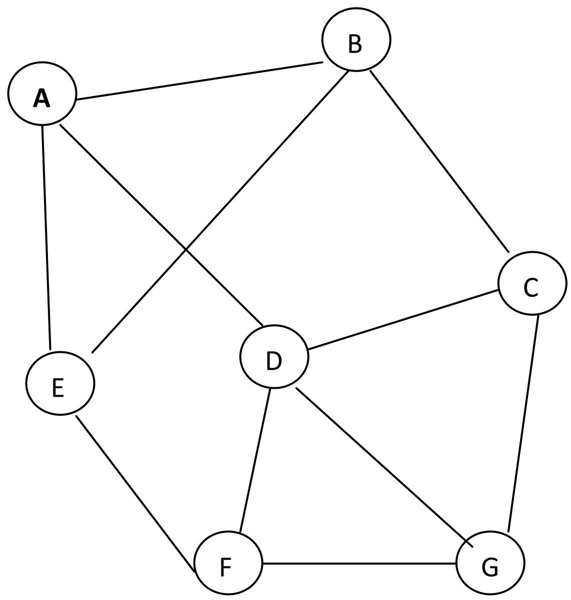
     (e) Calculate the cost for that individual.

     (f) Calculate updated individual fitness.

Until (Stopping criteria not met).

4. TRAVELLING SALESMAN PROBLEM

The travelling salesman (TSP) problem is described as follows: Given a list of cities and a travelling cost between each pair of cities. Here the TSP problem is that to find the shortest route with minimum cost between all the cities and returning to starting position.



Source node

Figure 1: Graph representation of TSP Problem

In figure 1, there are 7 cities which are connected and A is the source node or starting position. Here from the starting node, visit all the cities with minimum cost. Cost between two cities is not mentioned here. It may vary from problem to problem.

To calculate the minimum cost between all the cities from initial node, following formula is used.

$$\text{Cost} = \sum_{1}^{n} C_{ij}$$

.5. EXPERIMENTAL RESULTS & PARAMETER SETUP

For solving TSP problem by using proposed algorithm described in this work, some of the control parameters are used to solve this. The first control parameter is MCN (Maximum cycle number), second control parameter is the colony size which is equal to the population size. Third control parameter is the problem dimension of each individual and the last control parameter is the number of repetitions for executing the algorithm. The best function values of the best solutions found in 30 runs by the algorithm for different dimensions have been recorded. For GA, ABC, ABC with SPV and proposed work, mean cost function value of travelling salesman problem were calculated and compared. Experimental results for the dimensions 10, 20 and 30 are shown in table 1, table 2 and table 3 respectively. The following parameters are used for performing experiments using proposed work -

MCN = 500, 1000, 1500 and 2000
Colony Size = 20
Problem Dimension = 10, 20 and 30
Repetitions = 30

6. CONCLUSION

Artificial bee colony algorithm is well known optimization problems used to find out the global optima. In this work, Modified algorithm is used which uses one additional step in the form of mutation operator after the scout bee phase and SPV rule is used. With this mutation operator and SPV rule, local search improves and the proposed work is compared with previously proposed algorithms like ABC algorithm and ABC with SPV algorithm and implemented on travelling salesman problem. Future work is to used the proposed work on different types of optimization problem and compare them with older one.

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Table 1: Comparative Results for Dimension = 10

Algorithm	MCN = 500	MCN = 1000	MCN = 1500	MCN = 2000
ABC	88.73	83.21	81.19	79.88
ABC with SPV rule	87.20	82.66	80.49	78.65
Proposed Algorithm	86.82	81.47	79.94	77.80

Node sequences for proposed algorithm at MCN (1000): 0, 2, 3, 1, 8, 7, 5, 4, 9, 6

Table 2: Comparative Results for Dimension = 20

Algorithm	MCN = 500	MCN = 1000	MCN = 1500	MCN = 2000
ABC	175.56	172.25	169.36	167.65
ABC with SPV rule	174.66	170.38	168.02	166.56
Proposed Algorithm	174.44	169.60	167.82	165.25

Node sequences for proposed algorithm at MCN (1500): 0, 13, 14, 12, 10, 15, 11, 17, 2, 1, 16, 19, 6, 8, 9, 3, 7, 18, 5, 4

Table 3: Comparative Results for Dimension = 30

Algorithm	MCN = 500	MCN = 1000	MCN = 1500	MCN = 2000
ABC	268.31	265.90	263.29	261.94
ABC with SPV rule	266.45	264.55	261.74	259.63
Proposed Algorithm	266.13	263.58	260.16	258.67

Node sequences for proposed algorithm at MCN (2000): 1, 0, 11, 3, 2, 23, 14, 5, 21, 24, 13, 19, 29, 9, 25, 4, 27, 16, 15, 7, 6, 28, 17, 10, 26, 20, 18, 12, 22, 8