HCTL Open Int. J. of Technology Innovations and Research
HCTL Open IJTIR, Volume 2, March 2013
e-ISSN: 2321-1814
ISBN (Print): 978-1-62776-111-6

Enhanced Artificial Bee Colony Algorithm and It's Application to Travelling Salesman Problem

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Abstract

Artificial bee Colony algorithm (ABC) is a population based heuristic search technique used for optimization problems. ABC is a very effective optimization technique for continuous optimization problem. Crossover operators have a better exploration property so crossover operators are added to the ABC. This paper presents ABC with different types of real coded crossover operator and its application to Travelling Salesman Problem (TSP). Each crossover operator is applied to two randomly selected parents from current swarm. Two off-springs generated from crossover and worst parent is replaced by best offspring, other parent remains same. ABC with real coded crossover operator applied to travelling salesman problem. The experimental result shows that our proposed algorithm performs better than the ABC without crossover in terms of efficiency and accuracy.

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Keywords

Artificial Bee Colony algorithm, Genetic Algorithm, Real Coded Crossover Operators.

Introduction

The problem of optimization is the most crucial problem in today's era and a great many work have been done to solve it. Previously a lot of work has been done on GA, ABC and hybridization of various evolutionary algorithms. There are few literatures available which compares their performance evaluation and suggests the best technique to be opted for specific problems.

Artificial Bee Colony (ABC) is one of the most recently defined algorithms by Dervis Karaboga in 2005 [1], motivated by the intelligent behaviour of honey bees. It is as simple as Particle Swarm Optimization (PSO) [13] and Differential Evolution (DE) algorithms, and uses only common control parameters such as colony size and maximum cycle number. ABC as an optimization tool provides a population-based search procedure in which individuals called foods positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar.

In this paper, we have extended the classical Artificial Bee Colony algorithm to the area of optimization problem. Proposed method basically adds an additional step of crossover operator in the Artificial Bee Colony for finding out the optimality. To validate the performance of proposed method, TSP is used in our experiment.

The organization of the paper is as follows: section 1 gives brief introduction on optimization algorithms. Artificial bee colony algorithm is explained in section 2, section 3 explain genetic algorithm, Section 4 explain Travelling Salesman Problem and Section 5 explain Proposed Methodology. Section 6 describes the Experimental Results on TSP and the Section 7 gives Conclusion.

Artificial Bee Colony Algorithm

The Artificial Bee Colonies (ABC) [3] is a novel optimization algorithm. The ABC uses the natural bees and tries to imitate the same behaviour. The

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concept of Artificial Bee Colony was introduced by Dervis Karaboga in the year 2005 [1, 2]. The natural bees are excellent in searching their food sources and whenever a bee finds a food source it signals the following bees by dancing. This dance signals the other bees about the quantity and the location of the food source. In their food search, this helps in guiding and attracting a large number of other bees towards good sources of food and to carry forward the task. The ABC algorithm applies the similar concepts and methodology used by bees in the food search.

In ABC algorithm [4, 5, 6, 7], a possible solution of the optimization problem is represented by a food source and corresponding fitness of the solution is represented by the nectar amount. There are three main groups of bees, namely, employed bees, onlookers and scouts. Both the numbers of employed bees and onlookers are equal to that of food sources. Where, SN denote the food source number, and the position of the ith food source is denoted by xi (i=1,2,,SN). So SN food sources are randomly produced and assigned to SN employed bees correspondingly at the beginning of the approach. And then employed bee associated to the i^{th} food source searches for new solution according to equation 1.

$$v_{ij} = x_{ij} + \phi_{ij}(x_{ij} - x_{kj}) \tag{1}$$

where j=1,2,...,D, and D is the dimension of the optimized problem, ϕ_{ij} is a random generalized real number within the range [-1, 1], k is a randomly selected index number in the colony. Then v_i is compared with its original position x_i, and the better one should be remained. As a next step, each onlooker selects a food source with the probability (equation 2) and creates a new source in selected food source site by equation 1.

$$P_i = \frac{fit_i}{\sum_{i=1}^{SN} fit_j} \tag{2}$$

where, the fitness of the solution x_i is defined as fit_i,
After onlookers are all allocated a food source, if in a food source it is found that its fitness hasn't been improved for a given number (this number is called limit) steps, it should be ignored, and the involved employed bee becomes a scout and makes another random search by following the equation 3.

$$X_{ij} = x_{jmin} + r(x_{jmax} - x_{jmin}) \tag{3}$$

where r is a random real number within the range [0,1], and x_{jmin} and x_{jmax} are the lower and upper borders in the j^{th} dimension of the problem space.

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In the ABC, there are four control parameters used, these are: The number of food sources [FS] which is equal to the number of employed or onlooker bees (SN), the value of the limit, and the maximum cycle number (MCN). ABC algorithm is given below in detail:

1. Initialize the population of solutions $X_{i,j}$, i =1, ...SN, j = 1, ...D.
2. Evaluate the population.
3. Cycle = 1.
4. Repeat.
5. Produce new solutions $V_{i,j}$ for the employed bees by using(step 1) and evaluate them.
6. Apply the greedy selection process.
7. Calculate the probability values $P_{i,j}$ for the solutions $X_{i,j}$ by(step 2).
8. Produce the new solutions $V_{i,j}$ for the onlookers from the solutions $X_{i,j}$ selected depending on $P_{i,j}$ and evaluate them.
9. Apply the greedy selection process.
10. Determine the abandoned solution for the scout, if exists, and replace it with a new randomly produced solution $X_{i,j}$ by(step 3).
11. Memorize the best solution achieved so far.
12. Cycle = Cycle + 1.
13. Until Cycle = Maximum Cycle Number (MCN).

Genetic Algorithms

Holland [10, 11] developed a family of computational models known as Genetic algorithms (GAs), which are based on the natural biological evolution principles. For a specific problem, GA codes a solution candidate as an individual chromosome. The approach begins with an initial chromosome population which represents the set of initial search points in the solution space of the problem. Then the genetic operators such as selection, crossover and mutation are applied to obtain a new generation of chromosomes. Since the operators are under the principle of `survival of the fittest, extinction of the unfitness`, it is expected that over all the quality the chromosomes will be improved with the generation increasing. This process runs repeatedly till its reach the termination criterion and as a final solution the best chromosome of the last generation is achieved.

The GAs [12] have been applied successfully to resolve issues in many application areas including optimization design, fuzzy logic control, AI, neural networks and expert systems, and many others. The GA defines a solution as an individual chromosome for a specific individual problem. Then the initial population these individuals representing parts of the possible solutions are defined by it. A solution space in which each possible solution is represented by an individual chromosome is termed as search space. To form the initial population, a set of random chromosomes are selected from the search space before the search starts. Based on the fitness calculated by a specific objective function, the next individuals are selected through computations in a competitive manner. In order to get the better quality of new generation chromosomes than that of the previous generations, genetic search operators (such as selection, mutation and crossover in a sequence) are applied. This process is continues until the final termination criterion is met, and as a final solution, the best chromosome of the last generation is reported.

Travelling Salesman Problem

The Travelling Salesman Problem (TSP) is one of the important topic which have been widely and extensively studied, reviewed and documented by mathematicians and computer scientists and is an example of combinatorial optimization issues known to be NP-complete. Also is also a sub-topic of research in various application areas such as network communications, transportation systems, manufacturing and resource planning, logistics, etc. [8]. Formally, the TSP may be defined as follows [9] It is a permutation problem with the objective of finding the path of the shortest length (or the minimum cost) on an undirected graph that represents cities or node to be visited. The travelling salesman starts at one node, visits all other nodes successively only one time each, and finally returns to the starting node. i.e., given n cities, named c1, c2,..., cn, and permutations, $\sigma 1$,...,$\sigma n!$, the objective is to choose σi such that the sum of all Euclidean distances between each node and its successor is minimized. The successor of the last node in the permutation is the first one. The Euclidean distance d, between any two cities with coordinate (x1, y1) and (x2, y2) is

e-ISSN: 2321-1814
ISBN (Print): 978-1-62776-111-6

calculated by equation 4.

$$d = \sqrt{(|x_1 - x_2|)^2 + (|y_1 - y_2|)^2} \tag{4}$$

In General, the TSP states that for a salesman who wants to visit n different cities, his objective would be to find a tour plan that minimizes the cost and travel efforts by visiting each city exactly once and finally returning back to the starting point. TSP have an easy definition but is a difficult one to solve.

Proposed Methodology

The Artificial Bee Colony (ABC) Algorithm is inspired by the natural behaviour of food search by honey bees. ABC algorithm belongs to a category of intelligent optimization technique based on the intelligent and natural behaviour of honey bee swarm. It is a method for optimization on metaphor of the foraging behaviour of bee colony. Artificial Bee Colony algorithm with crossover operator applied to the TSP problem for testing the efficiency of our algorithm. ABC with crossover works in five phases: first is initialization second is employed bee phase, third is crossover phase, fourth is onlooker bee phase and at last scout bee phase. The first step consists of the generation of the population using the Artificial Bee Colony. Initial populations generated by ABC are used by employed bees. After this crossover operators are applied. If crossover criteria or probability satisfies than two random parents are selected to perform crossover operation on them. After crossover operation new off springs are generated. Replacement of worst parent is done with best generated offspring if it is better than the worst parent in terms of fitness. crossover operator is applied to two randomly selected parents from current population. Two offspring generated from crossover and worst parent is replaced by best offspring, other parent remains same. The whole process repeats itself until the maximum numbers of cycles are completed.

Proposed algorithm is defined in the algorithm 1.

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Algorithm 1 Enhanced Artificial Bee Colony Algorithm and It's Application to Travelling Salesman Problem

```
[Initialsation Phase]
for i=0 to max number of Food source size do
for d=0 to dimension size do
Randomly initialize food source
positions X_ij
end for d
Compute fitness of each food source
end for i
[Employed Bee Phase]
for i=0 to max no of employed bee do
for d=0 to dimension do
Produce new candidate solution
end for d
Compute fitness of individual
if fitness of new candidate solution is better than the existing solution
   replace the older solution.
[Crossover phase]
If crossover criteria satisfies
For i = 0 to the the maximum no. of food source
Select two random individuals from the current population for crossover
   operation.
Apply crossover operation.
New off springs generated from parents as a result of crossover. Replace
   the worst parent with the best new offspring if it is better.
End for i
[Onlooker Bee Phase]
for i=0 to max no of onlooker bee do choose food source on the basis of
   probability Pi
for d=0 to dimension do
Produce new candidate solution for food source position X_ij
end for d
Compute fitness of individual food source
if fitness of new candidate solution is better than the existing solution
   replace the older solution.
end for i
[Scout Bee Phase]
If any food source exhausted than
replace it by new random position generated by scout bee
Memorize the best food source so far
Until (Stopping criteria met).
```

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Experimental Results

For solving Travelling salesman problem by using ABC with crossover algorithm, we have taken the result for 500,1000,1500 and 2000 MCN value respectively and the colony size equals to the population size, i.e. 20. Nodes Sequence for

Table 1: *Comparison Results For Dimension D = 10.*

	MaxCycle 500	MaxCycle 1000	MaxCycle 1500	MaxCycle 2000
ABC	88.8333	83.4000	81.3333	79.9333
ABCX	86.1666	80.1000	78.6000	78.3666

ABCX at MaxCycle = 1500 : - 0 2 3 1 8 6 4 5 9 7

Table 2: *Comparison Results For Dimension D = 20.*

	MaxCycle 500	MaxCycle 1000	MaxCycle 1500	MaxCycle 2000
ABC	88.8333	83.4000	81.3333	79.9333
ABCX	86.1666	80.1000	78.6000	78.3666

Nodes Sequence for ABCX at MaxCycle = 2000 : - 0 18 16 14 9 15 10 13 3 4 12 17 6 8 1 11 7 19 5 2

Table 3: *Comparison Results For Dimension D = 30.*

	MaxCycle 500	MaxCycle 1000	MaxCycle 1500	MaxCycle 2000
ABC	88.8333	83.4000	81.3333	79.9333
ABCX	86.1666	80.1000	78.6000	78.3666

Nodes Sequence for ABCX at MaxCycle = 1000 : - 2 0 15 4 2 23 17 5 9 26 14 18 29 28 25 3 20 16 11 7 6 21 13 10 24 22 19 12 27 1

Conclusion

For solving Travelling salesman problem by using ABC with crossover algorithm, we have taken the result for 500, 1000, 1500 and 2000 MCN value respectively and the colony size equals to the population size, i.e. 20. The percentage of onlooker bees was 50% of the colony, the employed bees were 50% of the colony and the number of scout bees was selected as one. The dimension of each individual is taken as 10, 20, 30 respectively. Each of the experiments was repeated 30 times with different random seeds. The best function values of the best solutions found in 30 runs by the algorithm for different dimensions have been recorded. Crossover probability is taken as 0.3. For both ABC and ABCX algorithm mean cost function value of TSP were calculated and compared. Linear crossover is used as a crossover operator.

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