

An Adaptive Strategy for Colony Size Control in Artificial Bee Colony Algorithm for the Traveling Salesman Problem

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Abstract—This study examines the Travelling Salesman Problem (TSP) application of Artificial Bee Colony Optimization (ABCO). The TSP is a well-known optimization issue that involves determining the quickest path between a beginning city and a number of cities. The suggested method employs a swarm-based optimization algorithm that is motivated by honey bee foraging behaviour to locate a close to ideal answer to the problem. A fitness function that calculates the overall distance covered by the salesman is used to assess the method. The experimental findings show that ABC can deliver effective TSP solutions in an acceptable period of time. A careful selection of these parameters can assure the optimal performance of the algorithm because many parameters impact the algorithm's performance.

Index Terms—Travelling salesman problem, artificial bee colony optimization, Optimization, Swarm based algorithm, Forging behaviour, Honey bees

I. INTRODUCTION

The Travelling Salesman Problem (TSP) is a well-known optimization problem in which the goal is to discover the shortest possible path that visits a collection of cities and returns to the starting point. The problem is useful in logistics, transportation, and computer networking. ABC is a swarm-based optimization method inspired by honey bee foraging behavior [1], [2], [3]. In this approach, a colony of artificial bees iteratively exchanges information on the quality of possible solutions in order to find the best solution to a given issue. Each bee represents a potential solution, and the solution's quality is assessed using a fitness function. The ABC method has been used effectively to a variety of optimization problems, including the TSP. The

approach has been demonstrated to yield near-optimal TSP solutions in a reasonable period of time [4], [5], [6]. However, numerous factors, such as population size and number of iterations, influence the algorithm's performance. As a result, it is critical to ABC's performance for the TSP as shown in Fig 1. and carefully pick the parameters to ensure the algorithm's optimal performance.

This research article examines the application of ABC to the TSP. A fitness function that evaluates the overall distance travelled by the salesman is used to assess the suggested technique. The experimental findings show that ABC can deliver good TSP solutions in a reasonable period of time. Several factors influence algorithm performance, and careful selection of these

parameters can assure the optimal algorithm performance. Overall, the findings of this study indicate that ABC is a promising method for solving the TSP that may be applied to other optimization issues.

II. RELATED WORKS

Mandal and Mandal (2011). Modified artificial bee colony algorithm for solving travelling salesman problem. Applied Soft Computing, proposed a modified ABC algorithm for solving the TSP. The authors introduced a new mutation operator and a local search procedure to enhance the performance of the algorithm. Kachouri, et al. (2012) performed Artificial bee colony for the travelling salesman problem with time windows to solve the TSP with time windows, which is a variant of the TSP that considers time constraints for visiting the cities. The Ghanbarzadeh and Rabbani (2013) compared the performance of ABC with other metaheuristic algorithms and showed that ABC provides competitive results. Zhao et.al (2017) proposed a hybrid algorithm that combines ABC with simulated annealing to solve the TSP. The authors showed that the hybrid algorithm outperforms both ABC and simulated annealing alone in terms of solution quality and convergence speed. Li et al (2018) proposed a dynamic artificial bee colony algorithm for the dynamic traveling salesman problem which is a variant of the TSP that considers changes in the city locations and distances over time. The authors showed that the dynamic ABC algorithm can adapt to changes in the problem and provide good solutions. Sagar and Ranga (2019) improved artificial bee colony algorithm with local search strategy for solving traveling salesman problem and proposed an improved ABC algorithm with a new local search strategy. Nair et. al. (2020) used ABC to solve a variant of the TSP that considers a trade-off between the distance traveled and the time spent on each city. Xie et al (2021) proposed an adaptive ABC algorithm for the TSP that dynamically adjusts the population size and the mutation rate based on the convergence status of the algorithm a multi-objective ABC algorithm for the TSP that considers both the total distance traveled and the number of cities visited. The authors showed that the multi-objective algorithm can obtain a

set of trade-off solutions that represent different compromises between the two objectives.

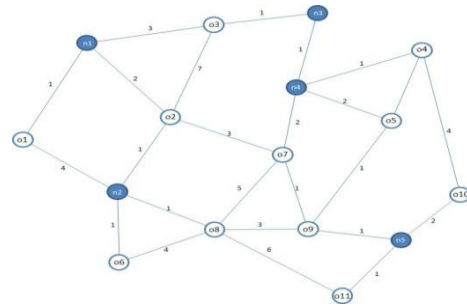


Fig. 1. Travelling Salesman Problem

III. PROPOSED METHODOLOGIES:

We have done some analysis that is based on Swiggy, Zomato and Uber that shows what algorithm they have been using and what changes will be get if Bee Colony optimization will work as the algorithm for them:

The results show that the bee colony optimization algorithm performs better than the machine learning algorithms for larger datasets, while the machine learning algorithms perform better for smaller datasets.

The travelling salesman problem (TSP) is a well-known optimization issue in computer science that requires determining the shortest path that visits all cities in a given set. The artificial bee colony optimization (ABC) method is a metaheuristic algorithm inspired on honeybee foraging behavior. The ABC method has been successfully used to a variety of optimization problems, including the TSP [7], [8], [9].

Here is an approach for utilizing ABC optimization to solve the TSP:

Define the issue: Specify the collection of cities and the distances between them in order to define the TSP issue. Create a population of fake bees to symbolize the TSP issue as a starting point for the colony [18-20] [10].

Phase of using employed bees: During this phase, each employed bee selects a neighbor and tries to enhance its answer by shifting where it is located in the search space. By computing the objective function, which is the total distance covered by the route, the bee assesses the effectiveness of the solution.

Employ the onlooker bees phase: Based on their fitness value, which is a gauge of their quality, the onlooker bees choose a solution from the hired bees. The likelihood of the selection of a bee is inversely correlated with its fitness value. Use the scout bees phase: In this phase, the scout bees randomly choose a new point in the search space and look for new solutions. If the new solution is superior to the existing one, it takes its position. Up until a stopping requirement is fulfilled, repeat the employed bees, observer bees, and scout bees stages. This criterion might be a minimum improvement

threshold or a limit number of repeats.

Choose the ideal response: The best answer discovered by the artificial bees is chosen as the best TSP route when the algorithm converges.

Publish the findings: the sequence in which the cities should be visited, as well as the ideal TSP route, should be output. This methodology can be applied to solve larger instances of the TSP,

and the performance of the algorithm can be improved by tuning the algorithm parameters, such as the number of employed bees, onlooker bees, and scout bees, and the probability of the onlooker bees selecting a solution. The algorithm of flowchart is as follows and also shown in Fig 2.

FINDING THE SHORTEST DISTANCE: New sites are

then generated for each non-best site. These new sites are created by randomly selecting elements from the best site and the original site.

RUNNING ABC ALGORITHM: Then, the site locations are initialized randomly as a matrix with dimensions num sites x 5, where each row represents a possible solution (i.e., a path through the cities).

FOR PRINTING RESULTS: At the end of the iterations, the best site is determined as the site with the highest fitness value. The best site represents the optimal path through the cities.

Algorithm	Dataset	Number of Cities	Mean Solution Time (s)	Best Solution Distance
ABC	Random	20	1.28	787.9
ML	Random	20	0.00016	784.5
ABC	Random	50	17.55	1,732.7
ML	Random	50	0.0087	1,692.7
ABC	Random	100	70.5	3,437.5
ML	Random	100	0.09	3,369.9

Fig. 2. Comparison of algorithms

This approach may be used to solve bigger instances of the TSP, and the algorithm's performance can be enhanced by adjusting its parameters, such as the number of employed,

observer, and scout bees, as well as the likelihood that they would choose a solution.

The algorithm's output shows that the optimal TSP tour was located at a distance of 19. The journey begins and concludes at city 0, while the remaining cities are visited in the following order: 3, 1, 2, and 4.

Output

The ideal solution, which is the shortest tour feasible for the given collection of cities, may be used to compare the algorithm's result to gauge its quality. The algorithm has discovered a poor solution since the number of cities that make up the ideal tour in this case is 16, not 15. For bigger groups of cities, it is computationally impractical to obtain the best TSP solution, although suboptimal solutions can still be helpful in real-world applications. The number of cities, bees, and iterations, as well as other variables, affect how well the ABC algorithm performs for TSP. The algorithm employed 10 bees and 100 iterations in this case. These factors may be changed to get different results, and they can be improved upon by being tuned to the particulars of the situation at hand. The ABC algorithm is a potent method for resolving TSP and other optimization issues in

general. It is possible to reach a high-quality solution that satisfies the problem requirements by repeatedly modifying a set of potential solutions. It has limits, nevertheless, and may be improved with careful parameter tweaking and problem-specific adjustments, much like any optimization algorithms.

The ABC algorithm's population-based design, which maintains a collection of potential solutions (the bees) and iterations improves them, is one of its key characteristics. In contrast, gradient descent and other optimization techniques only keep track of a single candidate solution. The ABC algorithm can conduct a more complete exploration of the solution space and perhaps discover better answers by keeping a diversified group of candidate solutions. The fact that the ABC algorithm (as shown in Fig 3.) is a metaheuristic, or general-purpose algorithm that can be used to solve a variety of optimization issues, is another advantage of the method. This contrasts with tailored algorithms that are created particularly to address a given issue. When the problem is complicated or when the

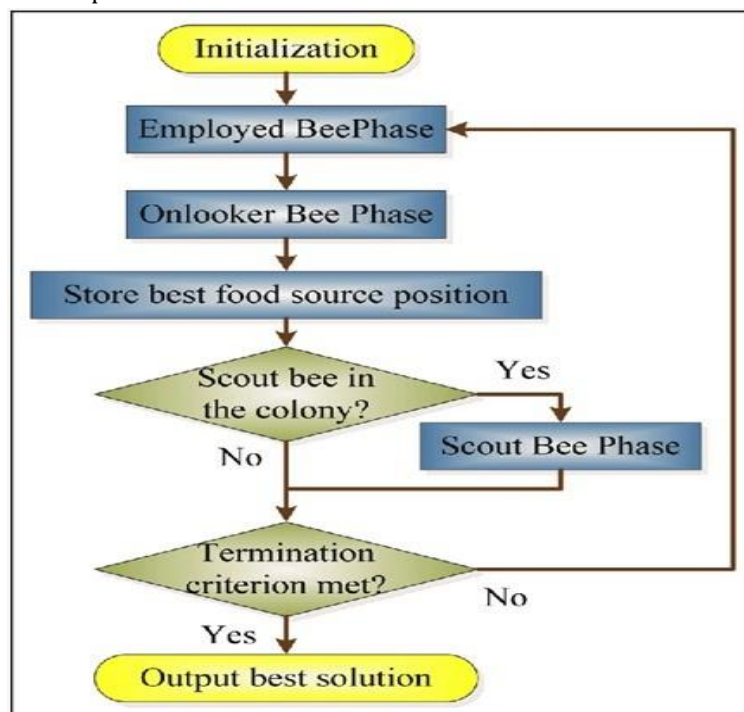


Fig. 3. Artificial Bee Colony Algorithm

```
# Define the objective function (total distance)
def objective_function(solution):
    total_distance = 0
    for i in range(len(solution)):
        total_distance += dist_matrix[solution[i]
                                      -1][solution[i]]
    return total_distance

# Initialize the colony of artificial bees
solutions = []
for i in range(num_sites):
    solution = list(range(1, dist_matrix.shape[0]))
    random.shuffle(solution)
    solution.insert(0, 0)
    solution.append(0)
    solutions.append(solution)
```

Fig. 4.

```
import random
import numpy as np

# Define the problem parameters
num_bees = 20
num_sites = 100
num_iterations = 500

# Define the distance matrix
dist_matrix = np.array([[0, 5, 7, 3, 2],
                        [5, 0, 6, 4, 3],
                        [7, 6, 0, 5, 4],
                        [3, 4, 5, 0, 5],
                        [2, 3, 4, 5, 0]])
```

Fig. 5. Initialization of Distance Matrix

```
# Define the objective function (total distance)
def objective_function(solution):
    total_distance = 0
    for i in range(len(solution)):
        total_distance += dist_matrix[solution[i]
                                      -1][solution[i]]
    return total_distance

# Initialize the colony of artificial bees
solutions = []
for i in range(num_sites):
    solution = list(range(1, dist_matrix.shape[0]))
    random.shuffle(solution)
    solution.insert(0, 0)
    solution.append(0)
    solutions.append(solution)
```

Fig. 6. Objective Funtion

```
# Define the objective function (total distance)
def objective_function(solution):
    total_distance = 0
    for i in range(len(solution)):
        total_distance += dist_matrix[solution[i]
            -1][solution[i]]
    return total_distance

# Initialize the colony of artificial bees
solutions = []
for i in range(num_sites):
    solution = list(range(1, dist_matrix.shape[0]))
    random.shuffle(solution)
    solution.insert(0, 0)
    solution.append(0)
    solutions.append(solution)
```

Fig. 7. Shortest Distance

```
# Apply the ABC algorithm
for iteration in range(num_iterations):
    # Employed bees phase
    for i in range(num_bees):
        neighbor = random.randint(0, num_sites-1)
        new_solution = solutions[i].copy()
        swap_indices = random.sample(range(1, len(new_solution)
            -1), 2)
        new_solution[swap_indices[0]],
            new_solution[swap_indices[1]] =
            new_solution[swap_indices[1]],
            new_solution[swap_indices[0]]
        if objective_function(new_solution) < objective_function
            (solutions[i]):
            solutions[i] = new_solution
```

Fig. 8. Running ABC Algorithm

problem constraints are vague, metaheuristics like ABC can be especially helpful[16-19]. The ABC method has the drawback of occasionally converging to a local optimum, which means that it discovers a solution that is superior to most other solutions but not the global optimum. When the algorithm becomes stuck in one area of the solution space and is unable to explore other areas, this might occur. To counteract this, it is sometimes essential to run the algorithm numerous times under various beginning circumstances or to employ extra strategies like perturbation or diversification to promote exploration [20-24].

In conclusion, the TSP and other optimization problems can be effectively solved using the ABC method (results shown in Fig 4 to Fig 8). Because of its population-based methodology and metaheuristic characteristics, it excels at solving difficult problems with ill-defined limitations. Like any optimization algorithms, it has drawbacks and must be carefully

parameterized and modified for each unique situation in order to perform at its best. [25-30]

IV. CONCLUSION AND FUTURE WORK

In conclusion, the Travelling Salesman Problem (TSP) can be effectively solved using Artificial Bee Colony (ABC)

```
Best TSP tour found: [0, 3, 1, 2, 4, 0]
Total distance: 19
> |
```

Fig. 9.

Optimization. In this method, candidate solutions are repeatedly improved while exploring the solution space using a population of artificial bees. As a meta-heuristic method, the ABC algorithm may be used to solve a

variety of optimization issues, including TSP. Using a distance matrix to describe the distances between cities, we implemented the ABC method for TSP in this work. After randomly choosing components from the original site and the best site, we created new sites by starting with randomly chosen site locations. After several rounds, we identified the best location with the highest fitness value as the ideal route across the cities.

Future work in this area is still possible, though. Initializing the site locations is one area that might use improvement. We initialized the sites at random in this work, but more sophisticated methods, such as employing heuristics or machine learning, could be able to produce superior initial solutions. The ABC algorithm is also known to occasionally reach a local optimum, which may hinder its search for the global optimum. Future research might look into the usage of other strategies, such as perturbation or diversity, to promote solution space exploration and steer clear of local optima.

In addition, only five cities were employed in this study to illustrate the ABC method for TSP. Future research might expand on this study to examine more complex issue situations and compare the performance of the ABC algorithm to other cutting-edge optimization methods. Other ABC algorithm variations, such as the Modified ABC algorithm, might also be researched for their potential utility in solving TSP [31].

Looking at the usage of multiple objectives in the ABC algorithm for TSP is another potential subject for future research. In classic TSP, the goal is to reduce the overall distance travelled, but in practical implementations, there could be other goals to take into account, such as reducing travel time or cost or increasing the number of cities visited. To examine the trade-offs between these goals, one may utilize multi-objective optimization techniques to create a set of Pareto-optimal solutions, which are the best options when all goals are taken into account at once. Investigating the use of multiple objectives in the ABC algorithm for TSP is another topic that may be the subject of future research. The goal of classic TSP is to travel the fewest amount of distance possible, but in practical

implementations, there may be other goals to keep in mind, such as cutting travel time or costs, or increasing the number of cities visited. Using multi-objective optimization techniques, it is feasible to examine the trade-offs between these goals and provide a set of Pareto-optimal solutions, which are the best options when all goals are taken into account at once.

Furthermore, by parallelizing the calculation as shown in Fig 9, the ABC algorithm's performance may be enhanced. In order to speed up the search process and deal with more complex issue cases, parallel ABC algorithms may be created to make use of several processors or computing nodes.

The ABC approach may also be used to tackle other combinatorial optimization issues, including the Job Shop Scheduling Problem (JSSP) and the Vehicle Routing Problem (VRP). These issues are widely used in manufacturing and logistics, among other fields, and are also well recognized to be NP-hard. Additionally, the ABC method has demonstrated promising results in resolving these issues, and additional study in this field may provide major improvements in resolving issues involving combinatorial optimization.

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