Hybrid Algorithm for Solving Traveling Salesman Problem

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Abstract. The basic genetic algorithm has the disadvantages of falling into local optimum and slow convergence. To solve this problem, a hybrid algorithm combining simulated annealing strategy is proposed. The cooling process in simulated annealing is used to complete the iterative process in the hybrid algorithm. The algorithm is used to solve the traveling salesman problem. The results show that the convergence speed and accuracy of the hybrid algorithm is significantly better than the basic genetic algorithm.

1. Introduction
The Genetic Algorithm (GA) are global optimization methods a which founded by Holland[1], University of Michigan, and GA is a random search algorithm by simulating the natural selection and natural genetic mechanisms of the biological world. However, genetic algorithm has the disadvantages of premature convergence and local extremum [2]. There are many problems in solving the Traveling Salesman Problem (TSP). Therefore, many scholars have proposed various improved algorithms to solve the TSP problem. Sun et al [3] proposed an indefinite period traveling salesman problem, and used exact as well as heuristic procedures for solving TSP. The computational experiments showed that the proposed method produced high quality solutions for given problems. Zhang X L[4] uses heuristic information to reduce the cross-edges in the travel route, which has great advantages in solving such problems with the mutation operator in the genetic algorithm. Venkatesh et al [5] proposed an artificial bee colony algorithm for the generalized covering TSP. The computational experiments showed the effectiveness of the approach over all the other state-of-the-art approaches in terms of solution quality. Liu F[6] uses multiple non-enhanced mutation operators to adjust the individual's mutation strategy according to the individual's evolutionary characteristics, which can not only maintain individual diversity., while increasing the speed of convergence. The ant colony algorithm and particle swarm optimization algorithm are combined[7] to solve the problem. The experimental results show that the algorithm has good convergence performance. T Srinivas Rao [8] uses ant colony optimization algorithm to design the visit route. The results show that the algorithm performs well in selecting the shortest route.

In this paper, the basic genetic algorithm solves the TSP problem with slow convergence speed. The satisfactory travel route is not obtained. The paper proposed a hybrid algorithm, that is the combination of genetic algorithm and simulated annealing strategy [9], and the effectiveness of the hybrid algorithm is verified.
2. Traveling Salesman Problem
The TSP is one of the most widely studied NP-hard combinatorial optimization problem which cannot be solved exactly in polynomial time. This problem is, for a given set of n cities, to determine a minimum distance circuit (Hamiltonian circuit or cycle) passing through each vertex one and only once. In a classical two-dimensional TSP, TSP can be represented as graph \( G = \{V, E\} \), where \( V = 1, 2, \ldots, n \) is the set of nodes and \( E \) is the set of edges. A salesman has to travel \( n \) cities at minimum cost. In this tour, a salesman starts from a city, visits all the cities exactly once and comes back to the starting city using minimum cost. Let \( d_{ij} \) be the distance for traveling from \( i \)-th city to \( j \)-th city. Then the model is mathematically formulated as

Minimize

\[
Z = \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij}
\]  

(1)

Determine

\[
d_{ij} \neq 1, 2, \ldots, n \neq 1, 2, \ldots, n
\]  

(2)

Subject to

\[
\sum_{j=1}^{n} d_{ij} = 1, \quad j = 1, 2, \ldots, n
\]  

(3)

\[
\sum_{i=1}^{n} d_{ij} = 1, \quad i = 1, 2, \ldots, n
\]  

(4)

where \( d_{ij} = 1 \) if the salesman travels from city \( i \) to city \( j \), otherwise \( d_{ij} = 0 \).

![Figure 1. Hybrid algorithm flow chart](image)

3. Steps of the hybrid algorithm
The algorithm of fusion simulated annealing is based on the basic genetic algorithm. The annealing process of the simulated annealing algorithm is integrated into the genetic algorithm. The mixture of the two algorithms is used to optimize the algorithm and improve the search ability of the GA. The execution process of this algorithm is shown in Figure 1.

3.1. Implementation of genetic algorithm
Genetic algorithm is a randomized search method that draws on the natural selection of the biological world and the natural selection mechanism [10]. The main advantage of the algorithm is the random selection mechanism. There is no special requirement for the search space in the process of solving the
problem. It has the advantages of simple operation and fast convergence, and has strong competitiveness in solving the path problem.

The main feature of genetic algorithm is the group search strategy and the information exchange between individuals in the group. It is actually simulating the overall learning process from the individual to group. Each individual corresponds to the research problem' solution when simulating the algorithm. The genetic algorithm can eliminate the individuals with low fitness by selecting operator, cross operator and mutation operators, so that the group evolves to the best region in the search space, and finally generates chromosomes that correspond to the optimization goals.

In the process of solving the problem, the main workflow of the standard genetic algorithm is as follows:

1. Chromosome coding
   There are many ways to encode chromosomes. In this paper, each city is coded by natural number coding. The city point is used as the gene, and the chromosome formed according to the order of traveler's visit is the solution to the problem.

2. Population initialization
   When chromosome coding is completed, the number of populations needs to be set according to the size of the city, and then an individual is randomly selected from the population as the initial solution to the problem.

3. fitness function
   In the process of the salesman access to the city route, the main cost is the distance, and the fitness function is the reciprocal of the total distance after visiting \( n \) cities.

\[
f = \frac{1}{Z}
\]

(5)

The goal of TSP optimization is to select chromosomes with the largest fitness function, which correspond to shorter route distance, that is the better chromosome quality.

4. Select operation
   The selection operation is to select a certain number of individuals from the old population to the new group according to a certain probability, with the fitness value of the individual. which can make the individuals with large fitness values remain as much as possible, thereby improving the performance of the algorithm.

   a: Calculate the probability that each individual will occupy the entire population:

   \[
f_i = \frac{f_i}{\sum_{i=1}^{n} f_i}
\]

   (6)

   b: For the \( i \)-th individual, calculate the cumulative fitness from the first individual to the \( i \)-th individual:

   \[
p_i = \sum_{i=1}^{n} f_i
\]

   (7)

c: Generate a random number between \([0, 1]\) and select the individual according to a certain ratio.

5. Cross operation
   The purpose of the crossover operation is to combine new individuals so that a more efficient search can be performed. There are many types of crossover operators, such as single-point crossover, double-point crossover, multi-point crossover for binary coding, partial mapping crossover, sequential crossover, etc. for natural number coding. In this paper, the cross operation is partial mapping intersection. Firstly, the parent samples are grouped in pairs, and each group is crossed according to the same process. Take the number of cities as 10 as an example:

6. Mutation operation
   The mutation operation is based on randomly generating two random integer \( \text{rand}1 \) and \( \text{rand}2 \) between \([1,n]\) in the selected individuals, and the two points are changed to make them mutate.
(7) Evolutionary reverse operation
In order to further improve the local search ability of the genetic algorithm, after the traditional
collection, crossover and mutation, the evolutionary reverse operation is introduced into the algorithm
optimization. It is necessary to judge whether the fitness value is improved according to the reversal. If
fitness value better than before, the reverse result is valid.

3.2. Implementation of simulated annealing algorithm
The simulated annealing algorithm is a general optimization algorithm. It's annealing process is mainly
composed of heating process, isothermal process and cooling process. The implementation process is

a: Control parameters
The main control parameters of the simulated annealing algorithm are initial temperature $T_0$,
cooling rate $q$, ending temperature $T_{end}$, and chain length $L$.

b: Generation of initial solution
For TSP problem with n cities, the solution to the problem is a sort in 1–n full sorting, where each
number corresponds to the city number according to the encoding rules. Using a random selection
method, select an individual from the population as the initial solution to the problem.

c: Solution transformation to generate a new solution
A new route is generated using the two-neighbor transform method for the currently obtained
solution. The location to be transformed

d: state acceptance function
Using the Metropolis criterion as a state acceptance function, the probability of accepting a new
solution is

$$ P = \begin{cases} 
1, & df < 0 \\
\exp\left(-\frac{df}{T}\right), & df \geq 0 
\end{cases} $$

If $df < 0$, the new path is accepted with probability 1; otherwise the new path is accepted with the
probability $\exp\left(-\frac{df}{T}\right)$.

The advantage of the Metropolis acceptance criterion is that it can accept the optimization solution
with a certain probability, avoiding the local optimization as much as possible, and finally obtained the
global or approximate global optimal solution of the system.

e: Stop rule
After several successive cooling, the iteration is stopped when the initial temperature is less than
the termination temperature.

The simulated annealing algorithm has certain advantages in solving the TSP problem and is very
competitive in solving the optimization problem. Aiming at the shortcomings of genetic algorithm in
local search ability, the paper combines genetic algorithm and simulated annealing algorithm to
enhance the local search ability of the algorithm. The algorithm only needs to integrate the simulated
annealing algorithm based on genetic algorithm. In this paper, the degenerative process of the
simulated annealing algorithm is mainly used as the iteration number of the hybrid algorithm, and the
optimal solution is obtained.

4. Simulation results analysis
According to the actual problem, the traveling salesman problem contains 31 cities to visit, and the
visit route is reasonably arranged to minimize the total access distance. In this paper, the mixed
algorithm computer program of this problem is compiled and experimentally calculated using
MATLAB language.
According to the characteristics of such problems, the main parameters used by the author in solving the problem are: population size 100, evolutionary algebra 270, generation gap 0.9, crossover probability 0.9, mutation probability 0.05, initial temperature 1000. The termination temperature was 1e-3 and the cooling rate was 0.95. In order to facilitate the comparison, the author also solved the problem 30 times with genetic algorithm and simulated annealing algorithm respectively. Under the premise that the number of searches for each solution is 270 times, the comparison of the calculation results of the three algorithms is shown in Table 1 and Table 2.
It can be seen from Table 1 and Table 2 that the solution to the problem is solved by the hybrid algorithm. The average value of the access route is 15562.42km, and the shortest access route distance is 15385.4258km, which is better than genetic algorithm and simulated annealing algorithm. The algorithm and simulated annealing algorithm have higher computational efficiency.

It can be seen from the above experimental calculation that by combining the genetic algorithm and the simulated annealing algorithm to construct a hybrid algorithm for solving the traveling salesman problem, the convergence speed and the optimization speed of the genetic algorithm can be overcome to some extent, so that it can be better. Calculation results of genetic algorithm and simulated annealing algorithm. At the same time, the hybrid algorithm also has the characteristics of high computational efficiency and stable calculation results.

5. Conclusion
This paper discusses the mathematical model of traveling salesman problem and the detailed implementation process of genetic algorithm and simulated annealing algorithm. It points out that genetic algorithm has the disadvantages of poor local search ability and easy to produce premature phenomenon, and incorporates simulated annealing in the process of genetic algorithm search process. The new algorithm takes into account both local and global aspects, overcoming the shortcomings of genetic algorithm. The experimental results show that the hybrid genetic algorithm for TSP can overcome the shortcomings of the local search ability of the genetic algorithm to solve the problem and the shortcomings of the simulated annealing algorithm in the global search ability to a certain extent, which is better than the simulated annealing algorithm. And the calculation results are better than genetic algorithm and simulated annealing algorithm. At the same time, the hybrid algorithm also has the characteristics of high computational efficiency and stable calculation results, which shows its good optimization performance. The hybrid algorithm to solving multi-objective optimization problems is a further research direction.

References
[1] Holland J H .1992. Adaptation in natural and artificial system[M].Ann Arbor: The University of Michigan Press
[2] Dong G , Guo W W and Tickle K .2012. Solving the traveling salesman problem using cooperative genetic ant systems[J]. Expert Systems with Applications, 39(5):5006-5011.
[3] Lei Sun, Mark H. Karwan, Moustapha Diaby. 2019. The indefinite period traveling salesman problem[J]. European Journal of Operational Research, 270(3):1171-1181.
[4] Zhang X L, Zuo G C and Yang J.2010. Solving Travelling Salesman Problem by Genetic Algorithms with Heuristic Mutation Stratgey[J]. Computer Applications and Software, 27(3):237-240.
[5] Venkatesh Pandiri, Alok Singh.2019. An artificial bee colony algorithm with variable degree of perturbation for the generalized covering traveling salesman problem[J]. Applied Soft Computing, 78:481-495.
[6] Liu F, Lv S H and Zhao Z H.2011. Study of hybrid genetic algorithm based on multi-step reinforcement mutation operator[J]. Computer Engineering and Applications, 47(29):46-48.
[7] Aditi Khanra , Manas Kumar Maiti and Manoranjan Maiti .2015. Profit maximization of TSP through a hybrid algorithm[J]. Computers & Industrial Engineering, 88:229-236.
[8] T Srinivas Rao.2018. An Ant Colony TSP to Evaluate the Performance of Supply Chain Network[J]. Materials Today: Proceedings, 5:13177-13180.
[9] Bertsimas D , Tsitsiklis J .1993. Simulated Annealing[J]. Statistical Science, 8(1):10-15.
[10] Chen G L, Wang X F, Zhuang Z Q, et al. Genetic Algorithms and Its Application[M]. POSTS & TELECOM PRESS, 1999.