Application of Hybrid Intelligent Algorithms in Path Planning

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Abstract. Combining with the classical combinatorial optimization problem in the field of mathematics, this paper decides to take the optimal path planning problem as the research object. A new neighborhood search operator is introduced into the basic worker bee colony algorithm, and the optimization strategy of the algorithm is updated by combining the simulated annealing algorithm. Finally, the improved algorithm is applied to the optimal layout of the path planning, and the optimization results are compared with those of other algorithms. The simulation test shows that the intelligent optimization scheme proposed in this paper can get better optimization results, and has certain feasibility in the path planning. It provides valuable reference for solving the classical problems of the same type.

1. Artificial Bee Colony Algorithm

Artificial bee colony algorithm is a bionic intelligent computing algorithm proposed in 2005. Its calculation process is to imitate the process of bee harvesting. The bee colony includes three kinds: picking bees, observation bees, reconnaissance bees [1-3]. Firstly, let the dimension of solving problem be D, the quality of honey source (i) is the fitness value of solution, and NP is the total quantity of honey source. At the t-th iteration, the location of honey source (i) is expressed as $X_i^t = [x_{i1}^t, x_{i2}^t, \ldots, x_{iD}^t]$, $x_{id} \in (U_d, L_d)$, U_d and L_d represent the upper and lower bounds of search space respectively, d=1,2,…,D.

In the D-dimensional solution space, according to the number of picking bees (SN), the initial solution of the corresponding number is generated randomly according to formula (1). Then the picking bees select any component of the initial solution and search the neighborhood according to formula (2).

$$x_{id} = L_d + rand(0,1)(U_d - L_d) \tag{1}$$

In the formula, x_{id} represents the location of the initial solution of bees, U_d and L_d represent the upper and lower bounds of variables respectively, and D represents the dimension of solution space.

$$v_{id} = x_{id} + \varphi(x_{id} - x_{jd}) \tag{2}$$

In the formula, v_{id} refers to the location of the new food source, and φ is a random number with uniform distribution, its range is between [-1,1]. x_{id} refers to the location of the D dimension of the food source corresponding to the i-th picking bee. x_{jd} refers to the position of the D dimension of the food source corresponding to the j-th picking bee selected randomly, and $i \neq j$, when the fitness of the new honey source is better than that of the old honey source, the greedy selection method is used to replace the old honey source with the new honey source, otherwise keep it.

According to formula (3), the observation bees choose the better food source to follow, and search the neighborhood near the selected food source according to formula (2).

$$P_i = \frac{fit_i}{\sum_{i=1}^{SN} fit_i} \tag{3}$$

In the formula, P_i denotes the probability of the food source corresponding to the i-th bee be selected, and fit_i denotes the profitability of the i-th food source. The greater the profitability of the food source, the greater the probability of observing the bee following.

In the whole process of the algorithm, the result is prevented from falling into the local optimum by setting a limit number. When the number of neighborhood searches equals the limit number, the food source is still not updated, then this food source is discarded, and the bee corresponding to the bee source is transformed into a reconnaissance bee. According to formula (1), a new food source is generated randomly in the global scope, and the above steps are repeated until the limit conditions are met. In the whole process of artificial bee colony algorithm, the process of bee searching for the best food source is the process of function optimization [4], in which the profitability of food source is the solution of corresponding objective function.

2. Hybrid Intelligent algorithms

The basic artificial bee colony algorithm has attracted more and more researchers' attention because of its few control parameters and strong robustness. However, in the optimization process, there are some shortcomings such as easy to premature and slow convergence speed [5-7]. In this paper, the following improvements are proposed for the above shortcomings of the algorithm.

2.1. Neighborhood search strategy based on optimal solution

In the basic worker bee colony algorithm, the observer bee searches the neighborhood near the food source according to formula (2). Each iteration only randomly updates one dimension of the old honey source. The profitability of the new honey source is likely to be much lower than that of the old honey source. When the number of neighborhood searches is greater than the limit number, the honey source will be abandoned if it is not updated, thus reducing the possibility of finding the optimal solution. For this reason, this paper proposes a neighborhood search strategy based on the optimal solution, the specific idea is shown in Figure 1. Assuming that AB represents a neighborhood search area centered on x_{id}, three values x1, x2, x3 are randomly selected according to formula (2) to calculate the corresponding profitability and select the honey source with better profitability among them. If the selected honey source is x3, then three points x4, x5 and x6 are randomly selected between the global optimal solution and x3 at this time. The corresponding earnings of x4, x5 and x6 are calculated, and the profitabilities of x3, x4, x5 and x6 are compared. Choose the best honey source from them and compare it with x_{id}. This method greatly improves the probability of x_{id} being updated, which can reduce the possibility of missing the better solution in the optimization process and improve the efficiency of the algorithm.

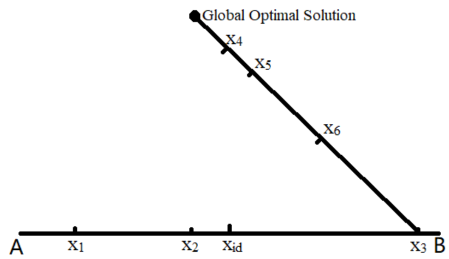


Figure 1. Neighborhood Search Diagram

2.2. Criteria for judging the benefit degree
In the hybrid intelligent algorithm, referring to the optimization strategy of simulated annealing algorithm [8-10], if the benefit of honey source generated after one iteration is better than the old one, the old one will be replaced, otherwise, according to the evaluation criteria (4):

$$\log_e(-\frac{d}{R}) \geq \text{rand} \tag{4}$$

In the formula, d denotes the absolute value of the difference between the new honey source and the old honey source, R denotes the positive number which is inverse to the number of iterations of the algorithm, and determines the specific value according to the example, rand takes the random number between 0 and 1. If the standard formula holds, it will be replaced, otherwise it will not be replaced. As the number of iterations increases, R decreases. As R decreases, the solution of the algorithm has higher diversity in the early stage and faster shrinkage ability in the later stage, which improves the operation efficiency and makes it easier to produce global optimal solution.

3. Traveling Salesman Problem
The traveling salesman problem (TSP) is a classical path planning problem [11]. Assuming that a traveling salesman needs to go through n different cities, he must plan his own path so that each city can only go through once, and finally need to return to the original city. Ant colony algorithm and genetic algorithm have been applied to solve similar path optimization problems [12-14], and they have achieved good results.

In this paper, the path planning problem of 25 cities is taken as the research object, and the shortest total distance is taken as the objective function of optimization. The proposed hybrid intelligent algorithm is applied to the path optimization. One of the paths found in each iteration is a honey source found by bees. Finally, the optimization results of the hybrid intelligent algorithm are compared with those of other algorithms to verify the effectiveness of the algorithm. The coordinates of 25 cities are shown in Table 1. Without considering the differences caused by topographic factors, the relative positions of the cities before optimization are shown in Figure 2.

Table 1. Coordinates of 25 cities (unit: 0.1km)

node	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
X	41	37	54	25	7	2	68	71	54
Y	94	84	67	62	64	99	58	44	62
node	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
X	83	64	18	22	83	91	25	24	58
Y	69	60	54	60	46	38	38	42	69
node	**19**	**20**	**21**	**22**	**23**	**24**	**25**		
X	71	74	87	18	44	82	62		
Y	71	78	76	40	35	7	32		

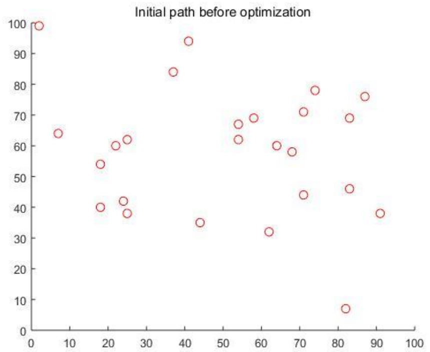
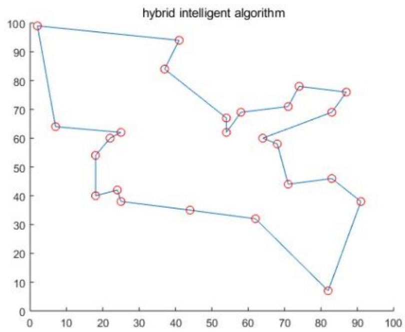
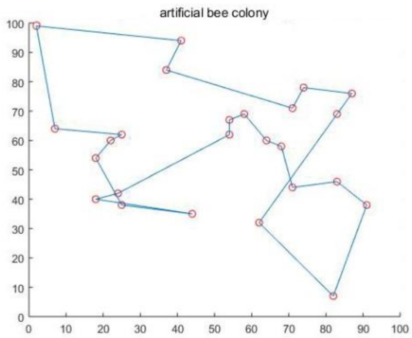


Figure 2. Relative Location of 25 Cities.

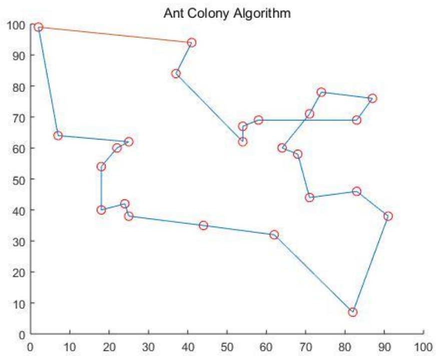
In this paper, we use matlab to compile all the algorithm programs. After several trial calculations, we determine the size of each parameter in the algorithm: the number of iterations is 300, the number of bees is 100, of which 50 are picking bees, the maximum number of searches for each honey source is 60, the value of R in the improved scheme is 50, and the objective function is the total path length between cities.The hybrid intelligent algorithm, basic artificial bee colony algorithm, ant colony algorithm and genetic algorithm are used to optimize the traveling salesman problem. The corresponding results are shown in Figure 3. Each algorithm is run 10 times, and the performance comparison is shown in Table 2.



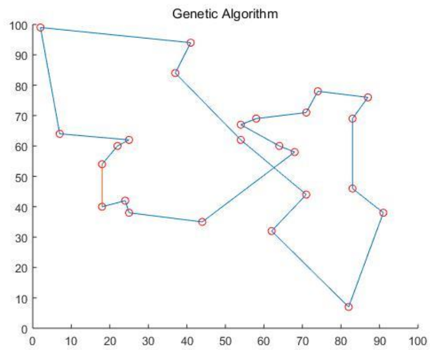
(a). hybrid intelligent algorithm



(b). Artificial Bee Colony Algorithms



(c). Ant Colony Algorithm



(d). Genetic Algorithm

Figure 3. Four Different Algorithms for Path Optimizing Result Diagrams between Cities

Table 2. PERFORMANCE COMPARISON OF FOUR ALGORITHMS

algorithms	Optimum (unit:0.1km)	Worst (unit:0.1km)	Average (unit:0.1km))	Average time (unit: s)
hybrid intelligent algorithm	382.9801	409.34	394.5317	5.69608
artificial bee colony algorithm	454.5577	493.1403	471.5921	1.72158
ant colony algorithm	387.0129	403.6092	391.8283	4.92118
genetic algorithm	420.6027	519.577	476.8048	3.00666

As can be seen from Figure 3, the four algorithms can obtain relatively ideal path planning scheme, among which the hybrid intelligent algorithm and ant colony algorithm are more reasonable. As can be seen from Table 2, the total length of the optimal layout found by the hybrid intelligent algorithm is much smaller than that of the basic artificial bee colony algorithm. Through the comparative analysis of 10 experiments, the average solution obtained by the improved algorithm is better than that of the artificial bee colony algorithm and genetic algorithm, and the search ability of the improved algorithm is basically the same as that of the ant colony algorithm. Compared with the basic artificial bee colony algorithm and genetic algorithm, the hybrid intelligent algorithm proposed in this paper has stronger optimization ability and robustness.

4. Conclusion

In this paper, some defects of the artificial bee colony algorithm are improved. In the optimization stage of the algorithm, we propose a neighborhood search strategy based on the optimal solution. And combining with simulated annealing algorithm, the judgment method of different solutions is improved. The experimental results show that compared with the basic artificial bee colony algorithm, the improved hybrid intelligent algorithm can jump out of the local optimum faster in the early stage, and improve the convergence speed in the later stage. It can get more reasonable path optimization results in solving traveling salesman problem and similar problems. However, the running time of the improved algorithm is relatively long. In order to enhance the ability of the algorithm to solve practical problems, it is necessary to optimize the time complexity of the algorithm in the future, so as to improve the flexibility of the algorithm in dealing with problems.

Acknowledgments

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