Mission planning of multi base UAV Based on improved artificial bee colony algorithm

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Abstract. Aiming at the constraint that the take-off and landing position of Unmanned Aerial Vehicle (UAV) varies from time in maritime operations, a cooperative attack model of multi-base UAV is established. An improved artificial bee colony algorithm based on coding operation pool is proposed, which retains the basic idea of standard artificial bee colony algorithm, It draws lessons from RNA coding operation and introduces coding operation pool to ensure that the algorithm has better global search ability. The simulation results show that the cooperative attack model of multi-base and multi-UAV complies with the characteristics of modern maritime unmanned combat missions, and the proposed algorithm has strong optimization efficiency and optimization ability.

1. Introduction
In this paper, according to the combat characteristics of shipborne UAV, a cooperative attack model of multi-base UAV is established. The model selects the number of UAV, configures the mission load, determines the target and plans the flight path, compared with the traditional single-machine mode, it improves the efficiency. In actual situation, in order to attack the important targets in time, several ships are usually sent with a combat mission, and several UAVs on each ship can cooperate to attack several targets at the same time. Shipborne multi-UAV cooperative attack mission planning has become an important application of UAV combat, and has gradually become a research focus in related research fields at home and abroad.

At present, the multi-UAV cooperative attack have several models, including multi-traveling Salesman problem model\textsuperscript{[1]}, vehicle routing problem model\textsuperscript{[2]}, mixed integer linear programming model\textsuperscript{[3]} and so on. The algorithms for solving the mission planning model of multi-UAV include genetic algorithm\textsuperscript{[4]}, particle swarm optimization algorithm\textsuperscript{[5]}, ant colony algorithm\textsuperscript{[6]} and some compound intelligent algorithms\textsuperscript{[7]}. These models and corresponding algorithms solve the mission planning problem of multi-UAV to a certain extent, but in the actual combat environment, we still need to consider the following problems: first, the cooperation of multi-UAV to attack multi-target; second, the limitation of the carrying capacity of UAV; third, the change of UAV take-off and landing position caused by the movement of warship.

In view of the above problems, this paper comprehensively considers the constraints of UAV missile carrying capacity and the change of UAV take-off and landing position with time in the mission planning model. In this paper, a multi-base and multi-UAV cooperative attack model which keeps up with UAV
combat application is established. An improved artificial bee colony algorithm based on coded operation pool is proposed. The algorithm can not only effectively solve the problem of multi-base and multi-UAV cooperative attack, but also has strong optimization efficiency and optimization ability, which compiles with the mission characteristics of modern unmanned combat at sea well.

2. Mission planning model of multi base UAV

2.1. Problem description

The application of shipborne UAV has its own characteristics, which is different from land-based UAV. The shipborne UAV can only take off and land on the shipborne platform. With the movement of the shipborne platform in the process of mission, the take-off and landing site of the UAV is not fixed. On the contrary, it moves with the movement of the warship.

According to the mission characteristics of shipborne UAV, the mission planning problem of multi-base UAV is simplified as follows:

(1) Multiple ships move at a fixed speed along a fixed route, and the number of drones on each ship is limited.

(2) Each target point is executed only once, and each target point is sure to be attacked.

(3) The UAVs carrying out the mission and the payload belong to the same type. That they pass over the target means they complete the mission.

Based on the above assumptions, the UAV mission planning problem can be simplified to a multi-traveling salesman problem based on a two-dimensional plane. That is, multiple UAV reconnaissance needs to start from the platform, traverse each target node, and return to the same platform with different coordinates.

2.2. Model building

The set of targets to be scouted target is defined as \{T_1, T_2, \ldots, T_{N_T}\}. The number of UAV is \(N_u\), UAV_k, \((k=1,2,\ldots,N_u)\) ship are expressed as base1, base2,\ldots.

If multiple UAVs carrying out the mission cooperate to attack all targets while avoiding being attacked by air defense fire during the mission. That is to say, multiple UAV reconnaissance needs to start from the platform, traverse each target node, and return to the same platform with different coordinates.

The objective function of the model is:

\[
 f = \min \left( \sum_{k=1}^{N_u} \sum_{j=0}^{N_T} X^k_{ij} d^k_{ij} / v_k \right)
\]

Where \(X^k_{ij}\) is the decision variable, indicating whether the UAV_k has a path from the \(i\) node to the \(j\) node. \(d^k_{ij}\) represents the length of the path from the \(i\) node to the \(j\) node of the UAV_k, which \(v_k\) is the cruising speed of the UAV_k.

The constraints are:

\[
 \sum_{k=1}^{N_u} \sum_{(i,j) \in N_T} X^k_{ij} = 1
\]

\[
 0 \leq n_k \leq N_T, k = 1,2,\ldots,K
\]

\[
 t^k_0 + t^k_{ij} + t^k_{ij} \leq L_i / v_k
\]
3. Improved artificial bee colony algorithm

3.1. Standard ABC algorithm

Artificial Bee Colony (ABC) algorithm is a novel high-performance random search algorithm based on swarm intelligence. In 2005, the professor of Turkish university put forward the artificial bee colony algorithm model for the first time in the reference [8], The algorithm flow is shown in Tab.1. The ABC algorithm divides all honeybees in the population into three categories: Employed bees to record their honey source locations, Onlooker bees to select possible food source locations according to probability and constantly improve the optimal solution, and Scout bees to find other potential optimal positions to ensure that they will not fall into the local minimum position. In the algorithm, the three phases iterate over and over again, and finally approach and optimize the global optimal value.

| Tab.1 Standard ABC algorithm flow |
|----------------------------------|
| Initialize: the food source positions, Population size; |
| Repeat |
| Employed Bees’ Phase |
| Improved location, greedy selection; |
| Calculate the probability values $p_i$ for the solution. |
| Onlooker Bees’ Phase |
| Improved location, greedy selection; |
| Scout Bees’ Phase |
| replace with a new random source positions |
| Memorize the best solution achieved so far |
| Until cycle = Maximum Cycle Number |

3.2. Integer coding operation

According to the sequence information of UAV and target, an integer sequence $m = (N_t + N_u-1)$ bit is randomly generated by referring to the coding form of genetic algorithm, which represents a honey source location. That the coding value is less than or equal to $N_t$ is defined as the target coding sequence, and that the coding value which is greater than $N_t$ is defined as UAV coding. The real number of the UAV serial is $(UAV$ coding-$N_t + 1)$. The coding sequence from the left to the first UAV coding is the UAV1 attack sequence, and then the corresponding target coding sequence between the two adjacent UAV codes is the target attack sequence corresponding to the real sequence of the left neighbor UAV. The odd UAV sequence takes off and lands at base1 and the even UAV sequence takes off and lands at base2.

Figure 1: Assuming that the number of targets to be attacked is $N_t = 10$, the number of UAVs is $N_u = 3$, the attack sequence of UAV1 is T2-T3-T9-T3, the attack sequence of UAV2 is T10-T8, and the attack sequence of UAV3 is T7-T8-T1-T6. UAV1 and UAV3 take off and land at base1 and UAV2 take off and land at base2.

With reference to RNA coding operation, three kinds of operator operators are introduced, which are transposition operator, conversion operator and permutation operator. It is described in detail as follows:

Transposition operator: Randomly select a subsequence in the current coding sequence and transfer it as a whole to a new random position in the current individual. The transposition operator operation is
shown in figure 2, where the blue part is the selected subsequence, and the sequence length and position are randomly selected. The position of the insertion point is also randomly selected, and the whole subsequence is moved to this position and inserted into a new coding sequence equal to the length of the original sequence.

Conversion operator: In the same coding sequence, two subsequences of equal length are randomly selected and their positions are completely changed. The operation diagram is shown in figure 3. Two blue parts are suborders and their lengths are also randomly selected, but the length must be the same. The two subsequences in the graph are separated from each other, and they are allowed to cross each other. Two subsequences are not allowed to be exactly the same.

Replacement operator: As shown in figure 4, different from the former two operators, the replacement operator shows that a subsequence in one coded sequence is replaced by a subsequence of equal length in another sequence. This is similar to the common crossover operation commonly used in genetic algorithms, which is the exchange of equal-length fragments of two different sequences. The difference is that in the ordinary crossover operation, the positions of the two exchanged subsequence fragments are the same, while in the replacement operator, the two fragments can be located in different positions.

The above three operators are introduced into the ABC algorithm to form an improved ABC algorithm. When the algorithm enters the coding operation pool, except for the first 10% of the individuals retained as elites, all the remaining individuals are sorted according to the fitness function and divided into two parts. Because the first half of the "neutral individual" retains more excellent genes, the replacement operation is carried out between the "neutral individual", and the new individual replaces the parent individual to keep the population size unchanged. Transposition operation and conversion operation were carried out in the latter part of the "bad individuals" in order to maintain the diversity of the population. In the algorithm, the three operations are performed sequentially, the probability of the replacement operation is 1. The probability of the transposition operation is 0.5. The conversion operation is performed on the individuals which do not perform the transposition operation.

3.3. flow chart of the improved algorithm
The flow chart of the algorithm is shown in figure 5:
Start

Satisfy the probability of executing the transposition operator

Initialization Parameter: the food source positions, Population size ect;

Assess individual fitness values

Employ bees to search the neighborhood

Greedy choice to improve honey source location

Onlooker bees roulette and choose the honey source location

Keep the elites, and the rest constitute the coding operation pool

Performing replacement operators on “neutral individuals”

Satisfy the probability of executing the transposition operator

Transposition operators for “bad individuals”

Conversion operator to “bad individual”

Reset limit value

Check if limit value is exceeded

Replace with a new random source positions

Meet termination conditions

Output results, end

4. simulation experiment

4.1. Parameter setting.
Suppose there are two ships carrying combat drones from a certain base, and the $v_b=6\text{km/h}$ moves in two directions perpendicular to each other at the same speed. As shown in figure 6, along the X-axis and Y-axis, each ship can support two UAVs to take off and land at the same time. The maximum carrying capacity of each UAV is 5. There are 15 enemy targets to be attacked. The UAV parameters are shown in Table 2, and the target position parameters are shown in Table 3.

| Tab.2 UAV parameters | v/ (km/h) | D/km | B (x,y)/m |
|----------------------|-----------|------|-----------|
| UAV                  | 18        | 20   | 5         |

| Tab.3 Target position parameters | Tj (x,y)/m | Tj (x,y)/m | Tj (x,y)/m | Tj (x,y)/m | Tj (x,y)/m |
|----------------------------------|------------|------------|------------|------------|------------|
| 1                                | (100,2100) | (250,1450) | (410,1800) | (590,1950) | (200,950)  |
| 2                                | (120,1550) | (260,2000) | (500,1550) | (540,300)  | (1200,300) |
| 3                                | (160,600)  | (400,1200) | (600,1400) | (750,500)  | (1050,700) |
4.2. Experimental results and analysis.
A comparative experiment is carried out between the improved ABC algorithm and the standard ABC algorithm. Suppose the number of experiments is 100, the population size is 100, the maximum number of iterations is 500, and the maximum number of honey source search in the algorithm limit is 10. The simulation results are shown in figure 6 and figure 7.

![Figure 6. UAV attack path](image)

![Figure 7. Comparison of two algorithms](image)

The analysis of the results is as follows:

1. From figure 6, it can be seen that the starting point of each UAV is the same, but the landing point is different. UAV2 landed on the ship moving in the X-axis direction. UAV1 and UAV3 landed on the ship moving along the Y-axis. The landing time was different, indicating the accuracy of the model.

2. From figure 6 and figure 7, the two algorithms can effectively attack all important targets, which verifies the feasibility of the algorithm.

3. From the comparison of the convergence of the finite iterations of the two algorithms in figure 7, the improved ABC algorithm achieves the global optimal solution in an average of 13 iterations, and the standard ABC algorithm achieves the global optimal solution after 355 iterations, indicating that the optimization efficiency of the improved ABC algorithm is better than that of the standard ABC algorithm.

5. Conclusion
The main contributions of this paper are as follows: (1) the model of cooperative attack of multi-base UAV is established for the first time, which fully considers the take-off and landing position of UAV and the distribution of multiple targets. It aims to minimize the time cost of UAV mission, which meets the requirements of the actual combat situation at present and for a period of time in the future. (2) The paper proposes the improved ABC algorithm to solve the model, which retains the idea of the standard ABC algorithm, and draws lessons from the RNA coding operation. It introduces the coding operation pool, transposition, conversion and replacement operators for "elite individuals", "neutral individuals" and "bad individuals", so that the algorithm has a good global search ability, and it is easier to obtain the optimal solution.

In the process of carrying out the attack mission, the UAV is affected by the dynamic, complex and changeable battlefield environment. The position and time constraints of some targets and the state of the UAV may change. Therefore, in the follow-up work, the problem of dynamic multi-UAV cooperative attack needs to be further studied.

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