Overview on Task Allocation Methods for Cooperative Multi-target Attack

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Abstract. The cooperative multi-target attack is a challenging mission for the military action in modern complex combat environment, and task allocation system will play a key role. Both modeling and solving are important for the task allocation problem, and they have been studied by more and more experts . This paper summarizes the task allocation methods for cooperative multi-target attack. Firstly, it introduces the development status of typical task allocation projects at home and abroad, and combs the development context of the system. The mission planning is divided into task allocation and path planning, and the task allocation modeling and solving algorithm of multi-UAV cooperative attack on multi-target are analyzed respectively, and the advantages and disadvantages of various task allocation methods are compared and summarized. Finally, the challenges in the field of task allocation are described. A comprehensive grasp of task allocation will help us to engage in innovative research in related fields.

Keywords: Task allocation · Cooperative attack · UAV · Modeling and solving · Intelligent optimization

1 Introduction

The future battlefield environment is becoming more and more complex, the battlefield space is fully multi-dimensional covered, and the new concept combat weapons are applied to modern information warfare. The "people" who face increasingly severe challenges and have decisive factors for the war need unmanned equipment to replace or assist. At the same time, with the development of modern science and technology, unmanned combat air vehicle (UCAV), as the protagonist of seizing and maintaining operational advantages in the future information war, has become the key high-tech weapons and equipment competing for development by the world's military powers [1]. The UAV dominated by ground commanders is difficult to adapt to the uncertain combat environment and attack the maneuverable multi mission targets in the future complex battlefield. Therefore, it is necessary to develop the autonomous attack technology and cooperative combat technology of UAV [2].

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Multi UCAV cooperative attack multi-target technology means that multiple UCAVs form a UCAV formation according to tactical strategies, use their own sensors or space satellites and air reconnaissance to obtain information about battlefield environment and mission target information, estimate the possible development direction of mission targets, and allocate tasks to the targets to be attacked by considering various constraints, Determine the specific tasks to be performed for each UCAV, and plan the flight path that meets the constraints for each UCAV according to the attack mission, battlefield environment and enemy friend confrontation situation of each UCAV, so as to ensure that there is no conflict with other UCAVs at the space, time and mission levels, so as to guide the UCAV to reach the specified mission area at the specified time [3].

The multi-target task allocation problem of multi UCAV cooperative attack is a complex combinatorial optimization problem, which belongs to the category of task assignment and resource allocation [4]. Task allocation problem refers to assigning appropriate tasks to each member of UCAV formation at appropriate time according to certain allocation principles under the constraints of resources, platform and time, so as to optimize the overall task efficiency of UCAV formation [5]. For the combinatorial optimization problem of task allocation, the general methods are [6]: 1) the method based on exhaustive thought; 2) Heuristic search algorithm; 3) Intelligent computing method.

Aiming at the problem of multi-target cooperative task allocation of multi UAV formation attack in complex air combat environment, firstly, the development status of typical mission planning projects at home and abroad is introduced, and the development context of the system is combed. The mission planning is divided into task allocation and path planning. The task allocation modeling and algorithm of multi UAV cooperative attack on multi-target are analyzed, and the advantages and disadvantages of various task allocation methods are compared and summarized. Finally, the challenges in the field of task allocation are described.

2 Task Allocation Project for Cooperative Attack

The activities carried out by aircraft in the air, such as reconnaissance, air shielding, electronic countermeasures, air transportation, ground target attack, air support, etc., are collectively referred to as tasks. UAV mission planning refers to formulating an implementation plan for UAV that meets mission requirements, flight constraints and optimal mission efficiency on the basis of target, terrain, meteorology and other environmental information [7]. This concept and requirement can be traced back to the U.S. military in the 1970s. Initially, it was to realize the functions of cruise missile threat avoidance and mobile penetration, and has successively developed two generations of mission planning systems. The development of this technology has greatly reduced the track planning time. To the third generation mission planning system, the off-line planning time of U.S. UAV is 19 min compared with the previous system. It has been shortened to less than 10 min [8].

Figure 1 shows the development of some mission planning systems of the U.S. military from 1975 to 2010 [9]. As can be seen from Fig. 1, with the rapid development of aviation science, information science and control science, task planning technology has gradually changed from the initial special system to a general-purpose multi-functional

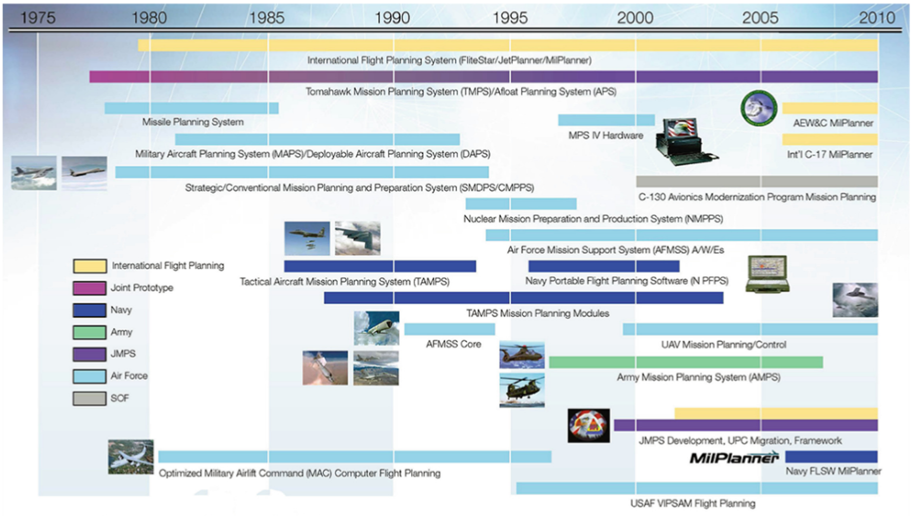

Fig. 1. Development of US military mission planning system.

software planning system. As shown in Fig. 1, amps (Army mission planning system) system is mainly equipped in the U.S. Army for use by battalion and company forces. The system can automatically realize flight mission decision and planning and has good portability. Tamps (tactical aircraft mission planning system) system is mainly equipped in the aircraft carrier or land base of the U.S. Navy. It can formulate planning schemes for enemy targets, and has the function of flight route optimization and evaluation. AFMSS (air force mission support system) system is mainly equipped in the U.S. air force. The system is mainly used for special operations, tactical decision assistance, threat encapsulation and other combat tasks. It has the functions of target area planning, threat analysis, flight path and airdrop planning.

3 Multi-UAV Cooperative Task Allocation

When a single UCAV attacks multiple targets, it faces some problems, such as limited sensing range and limited attack ability. If multiple UCAVs are used to perform attack tasks together, the attack efficiency will be greatly improved. The multi-target task allocation process of multi UCAV cooperative attack mainly refers to the design of a certain algorithm to maximize the combat effectiveness of the whole UCAV formation based on a certain battlefield environment and task requirements, considering the constraints of task execution, and according to the index value of task allocation. The current research on task allocation should not only consider the task allocation model, but also consider the task allocation algorithm.

3.1 Task Allocation Modeling

At present, the research on UCAV collaborative task allocation in various countries mainly considers the threat of combat environment, the dynamics of combat process, the diversity of combat tasks and the vastness of their distribution. According to these complex factors, the focus of current research is to establish a multi UCAV collaborative task allocation model, give full play to the maximum role of each UCAV and improve the overall combat effectiveness [10, 11].

For the dynamic task allocation problem in complex battlefield environment, literature [12] adopts a variety of negotiation mechanisms to establish a distributed multi UCAV control system, which overcomes the limitation of local optimization caused by a single sales contract. Aiming at the complexity of task allocation problem, literature [13] proposed a hierarchical multi UCAV negotiation model, which uses the extended contract network of multi contract types to solve the task allocation problem with time sequence, and adopts the negotiation mechanism based on efficiency compensation to appropriately reduce local efficiency to improve the overall efficiency. In reference [14], aiming at the task allocation problem of air defense fire suppression, considering the initial position, speed and combat effectiveness of UCAV, as well as the value and firmness of enemy targets, a method based on multi-agent distributed collaborative auction is proposed to obtain a solution close to the ideal optimal value.

Aiming at the task allocation problem, MIT proposes a mixed integer linear programming method, which unifies the discrete decision variables and continuous decision variables into the same optimization problem, and transforms the constraints into equations or inequalities. Considering multiple indexes and complex constraints of collaborative task allocation problem, document [15] decomposes it to different levels for processing. On this basis, a multi UCAV collaborative task allocation model based on multi-objective integer programming is established. According to the defined time constraints and task timing constraints, document [16] established an integer linear programming model for multiple UCAV different attack tasks.

For the multi UCAV single task allocation problem, the US Air Force Research Laboratory has studied the reconnaissance mission planning of “Global Hawk” and “Predator” UAVs based on the vehicle routing problem model [17]. Literature [18] regards UCAV as a supplier, takes tasks as logistics on the commercial supply and demand network, and establishes multi UCAV collaborative task allocation based on the supply and demand network model. Reference [19] established a UCAV formation cooperative task allocation model based on decision graph Bayesian optimization algorithm, introduced the distance discount factor, and considered the task allocation in case of electronic interference. Literature [20] considers three kinds of burst tasks respectively, and proposes a multi-target planning method for multi UCAV cooperative attack and a target allocation scheme at the same time, by considering the target coverage, according to the damage threshold constraints and task allocation balance constraints. Literature [21] established a cooperative target allocation model with the maximum attack efficiency cost ratio as the index.

3.2 Task Allocation Solution

After establishing the mathematical model of multi-target task allocation problem of multi UCAV cooperative attack, various optimization methods can be used to solve the problem. The commonly used methods for solving task allocation problems are mainly divided into optimization methods and heuristic methods (see Fig. 2).

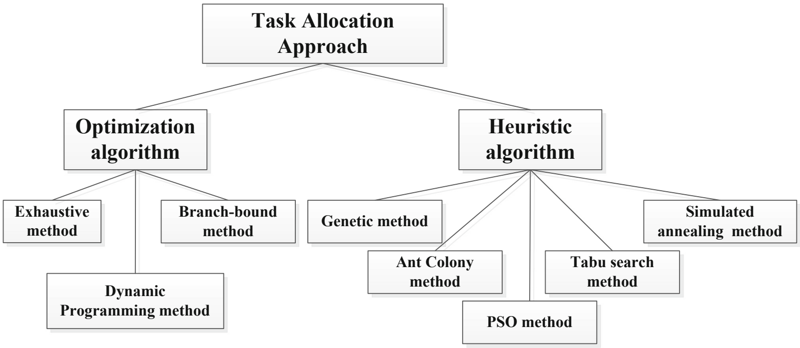

Fig. 2. Task allocation algorithm classification.

Optimization methods include exhaustive method, dynamic programming, branch and bound and so on. However, with the increase of the scale of the problem, the solution time and difficulty are also increasing, and cannot fully reflect the dynamics of the battlefield environment. In reference [22], aiming at the uncertainty of combat environment, the multi-attribute scheme ranking method of random probability is used to solve the task allocation model based on interval information environment, according to the characteristics of over the horizon air combat. Literature [23] designed a target allocation model based on enumeration method on the basis of considering azimuth, velocity and distance advantage functions. In reference [24], aiming at the uncertain factors of air to ground multi-target attack model, in order to improve the accuracy of attack, rich method is used to solve the multi-target model of cooperative attack based on multi-layer tree.

According to the NP characteristics of multi UCAV task allocation problem, the heuristic algorithm compromises the calculation time and allocation effect to obtain the near optimal solution or satisfactory solution. Heuristic algorithms can be divided into traditional heuristic algorithms and modern intelligent optimization algorithms. Among them, intelligent optimization algorithms are easy to implement, low computational complexity and superior performance. Reference [25] uses the nonparametric method to construct the comprehensive advantage function between the missile and the target, and uses the multi round random auction strategy to modify the allocation result based on ant colony optimization algorithm to ensure that the solution result of the target allocation model is optimal. In reference [26], considering task priority constraints, time constraints and trajectory constraints, a multi UCAV collaborative multi task allocation model is established, which is solved by genetic algorithm. The effectiveness of multi UCAV task allocation based on genetic algorithm is verified by simulation. Literature [27] takes the damage target income, UCAV consumption and range as the indicators of multi-objective UCAV collaborative multi-objective allocation model, and uses the multi-agent group optimization method combining firefly optimization algorithm and frog leaping algorithm to solve it. The allocation results can be obtained quickly and stably through simulation. Considering the relationship between task execution time and task revenue, document [28] established a multi UCAV task allocation problem based on time window constraints, and proposed a solution method combining particle swarm optimization algorithm. The effectiveness of this method is verified by simulation.

4 Challenges and Prospects

(1) Coupling problem between task allocation and track planning

In the task planning system, there is a certain coupling relationship between the task allocation problem and the track planning problem. At present, most of the literature studies the above two problems separately, that is, after the task allocation, the track planning is carried out for the assigned attack target, and in the subsequent research, Further research can be carried out on the problem that the planning results meeting the requirements of task allocation and track planning can be obtained through one-time planning.

(2) Research on the integrity of mission planning system

Mission planning system is a complex system composed of multiple functional modules. Most scholars have only studied task allocation and track planning. In the future, further systematic research can be carried out on UAV formation control, tactical decision-making, track tracking, attack track planning, threat assessment and so on. On the other hand, based on the research of typical intelligent optimization algorithms, while improving the optimization efficiency and accuracy of the algorithm itself, we can further study the combination methods and solution methods according to the characteristics of the above problems, so as to broaden the application research field of intelligent optimization computing in task planning system.

5 Conclusions

This paper summarizes the task allocation of multi UAV formation cooperative attack in complex game confrontation environment. This paper generally introduces the development status of typical mission planning projects at home and abroad, and combs the development context of the system. The task planning is divided into task allocation and track planning. The task allocation modeling and algorithm of multi UAV cooperative attack on multi-target are analyzed, and the advantages and disadvantages of various task allocation methods are compared and summarized. On this basis, the cooperative track planning method of multi UAV formation is analyzed, and the difficulties of cooperative track planning are explored. Finally, the challenges in the field of task allocation are described.

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