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Research on UAV Task Assignment Based on Fireworks Algorithm

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Abstract: *From military, industry, agriculture to artificial intelligence and other fields, unmanned aerial vehicles (UAVs) have been widely used. Task allocation and path planning are the two most basic technologies in all the application research of UAV. As the core of multi-aircraft tactical deployment and cooperative control, the task allocation scheme largely determines the operational efficiency and execution effect of multi-UAVs. Due to the influence of the task environment and its own resources, the multi-machine cooperative task allocation problem is a multi-objective optimization and decision-making problem limited by many constraints. In recent years, many methods of task assignment and path planning have been put forward, and some progress has been made. According to the overall control of the application scenario, the task planning makes a reasonable task allocation scheme for the UAV to help it complete the task better. Multi-UAV task assignment is a complex multi-constraint multi-objective nonlinear optimization problem. Aiming at the respective defects of common intelligent algorithms, this paper proposes to use fireworks algorithm to deal with this problem.*

Keywords: *Fireworks algorithm; Drone; task allocation*

1. Introduction

Since the 21st century, the rapid development of science and technology, especially high-tech, has led to great changes in the world's military field. As a result, future wars are no longer determined by the number of manpower and equipment, but rely more on the advantages of high-tech, information, network and personnel quality, etc. The military equipment presented in high-tech wars is becoming more and more automatic, intelligent and unmanned [1]. As a new type of aircraft, UAV has the advantages of low cost, convenient operation and high safety, and has been widely used in military and civil fields [2]. Unmanned aerial vehicles (UAVs) need relevant control strategies to control them when they perform tasks. How to formulate relevant control strategies according to the types of tasks performed by UAVs is a research hotspot in the field of UAVs. Multi-UAV cooperative mission planning is the key to give full play to the advantages of multi-UAV cooperative operations and keep good coordination between mission complexity and UAV capability. It is a multi-parameter nonlinear multi-objective optimization problem with numerous and complex constraints [3]. Under the background of the hot development of UAV system, UAV system has made great breakthroughs in all aspects of research. However, with people's constant demand for unmanned aerial vehicles (UAVs) and the increasingly complex application environment, a single UAV still shows shortcomings in many aspects due to its own constraints [4]. In recent years, with the maturity of UAV technology, the development of UAV has gradually changed from single machine to multi-machine system. Compared with single UAV, multi-UAV system has advantages in the ability to perform tasks, the resources it owns and the distributed space characteristics, and can accomplish tasks that single UAV can't. In many application fields in the future, UAV will present a multi-machine cooperative working mode to accomplish tasks together. Unmanned aerial vehicle (UAV) group refers to a mixed group composed of several different types of UAVs. Of course, it can also refer to a heterogeneous group composed of UAVs and other manned or unmanned combat machines and equipment, such as armored vehicles and submarines, etc. Such a combat mode will inevitably play a leading role in the future complex battlefield [5].

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2. Research status

2.1. Multi-UAV Task Assignment Algorithm

Multi-UAV task assignment problem is a kind of task assignment problem. When solving the task assignment problem, it is usually regarded as a combination optimization problem. The best task assignment scheme is determined by looking for the optimal solution of the combination optimization problem [6]. The task assignment of UAV is divided into multi-UAV task pre-assignment and dynamic re-assignment. Multi-UAV task pre-assignment refers to determining the task set and sequence of each UAV according to the UAV state and task information before the task is executed. The classical algorithms to solve task assignment problems mainly include linear programming, heuristic algorithm, market mechanism algorithm and swarm intelligence algorithm [7]. Let's explain various methods of multi-UAV task assignment.

The linear programming method can get the global optimal solution of the problem by solving the matrix, which can achieve good results for small-scale problems [8]. However, the multi-UAV task assignment problem belongs to NP-hard problem. When the number of UAVs and tasks increases, the calculation amount of linear programming method increases exponentially, which not only can't meet the real-time requirement, but also can't necessarily find the optimal solution. Fast branch and bound algorithm is used to solve the multiprocessor scheduling problem with non-negligible communication time, and can output the optimal solution for many instances in a short computing time. In recent years, the intelligent optimization algorithm has been more and more used in the task pre-assignment of multi-UAVs because of its self-adaptation and low computational complexity [9]. For large-scale combinatorial optimization problems, the heuristic search method can give a feasible solution within an acceptable time range, which is an approximate optimal solution of the problem to be solved. Compared with the precise algorithms such as linear programming, the heuristic search method is a feasible scheme in many practical problems, in which the accuracy of the solution decreases for the improvement of time efficiency.

2.2. Multi-UAV Path Planning Algorithm

As a military weapon, the development and application of unmanned aerial vehicle (UAV) are constantly interfering with fighters [10]. Unmanned Aerial Vehicle (UAV) is a kind of unmanned flying device, which has the characteristics of strong concealment, high maneuverability, and can participate in large-scale wars in all time and space. It can improve the completion rate of combat missions, reduce equipment losses, and reduce casualties, so UAV is widely used in modern information warfare [11]. In multi-UAV cooperation, task assignment is to complete the assignment of sub-tasks at the lowest cost, and it is one of the keys to solve multi-aircraft multi-task problems. At the same time, as a new type of military weapon with high cost performance and both offensive and defensive capabilities, UAV can carry high-power reconnaissance cameras or guidance weapons, transmit battlefield information data to the control center in real time, and quickly form a threat to the enemy, which is an important development direction of new-type operations in the information age [12].

Path planning refers to the unmanned aerial vehicle (UAV) seeking the optimal or suboptimal path from the starting point to the end point in the working environment with obstacles/threats, which is one of the keys to realize the autonomous flight of UAV. The path planning of UAV usually considers the path length, security and other aspects at the same time, so it is essentially a multi-objective optimization problem. Generally, the best flight path scheme of UAV is determined by finding the optimal solution of the multi-objective problem. In the aspect of path planning, artificial potential field method is mostly used to solve path planning problems [13]. However, the conventional artificial potential field method can't adapt to the complex environment, and it is easy to fall into a local stagnation state, and the planned path is not smooth enough. Aiming at the multi-UAV combat mission, mission planning is to rationally allocate its combat targets for each UAV based on comprehensive consideration of mission parameters, time constraints, cluster coordination and other factors, and plan a number of safe and feasible UAV tracks to meet mission requirements, improve mission completion efficiency and success rate, and reduce UAV damage probability.

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3. Task assignment of UAV based on fireworks algorithm

3.1. Fireworks algorithm

In recent years, researchers have invested a lot of energy in the research of swarm intelligence algorithms, and put forward many new algorithms and effective improvements, which make this field show a thriving scene [14]. As a new swarm intelligence optimization algorithm, the optimization process of Fireworks Algorithm (FWA) is inspired by the process of fireworks explosion. In the process of fireworks algorithm optimization, every spark produced by fireworks and explosion is regarded as a feasible solution [15]. Good quality fireworks explode a lot of sparks, and the sparks are distributed densely; On the contrary, fireworks with poor quality explode fewer sparks, and the spark distribution is scattered. After a firework explodes, the firework with the best fitness value is selected as the firework for the next explosion (fireworks are regarded as fireworks after explosion), which is simple and easy to operate, and has few parameters; Multiple fireworks explode at the same time, and each firework searches its neighborhood independently in parallel, so the algorithm has distributed characteristics. The algorithm is robust, and the process of one fireworks explosion search is independent of other fireworks, which will not have too much impact. The flow chart of fireworks algorithm is shown in Figure 1.

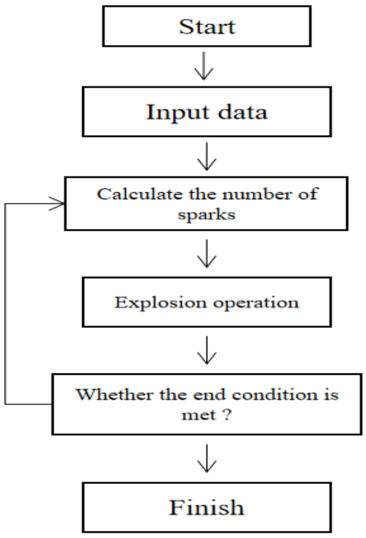

Figure 1: Flow chart of fireworks algorithm

In the original fireworks algorithm, it is stipulated that fireworks explosion produces two kinds of sparks-explosion spark and Gaussian spark. The function of explosion spark is to search the neighborhood, and the function of Gaussian spark is to ensure the diversity of solutions by using Gaussian random numbers. Then, fireworks and sparks with good quality and scattered distribution are selected to enter the next generation. The comparison of the optimal solution between this algorithm and the traditional algorithm is shown in Figure 2.

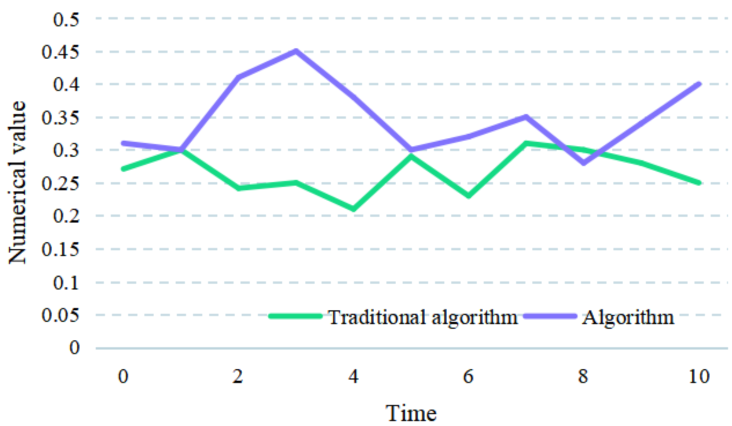

Figure 2: Comparison of the optimal solution between this algorithm and the traditional algorithm

The algorithm searches the surrounding space evenly, which will waste some searching fireworks. In the actual process of fireworks explosion, high-quality fireworks produce more sparks with dense distribution, while low-quality fireworks produce fewer sparks with scattered distribution. Compared with other early intelligent algorithms, Fireworks algorithm is not mature enough, and its application field has not been completely excavated, so it needs further research. Optimization is one of the classical optimization problems, which is discrete in most cases, so it is necessary to discretize the fireworks algorithm to solve this kind of problems.

3.2. Multi-UAV task allocation model

The optimization process of the algorithm is inspired by the process of fireworks explosion and has been widely used in recent years. At present, scholars' modeling of multi-aircraft cooperative task assignment mainly focuses on single task or multi-task of UAV. Because there are constraints in the optimization problem, when the intelligent optimization algorithm is used to solve the problem, it is often impossible to strictly control the search area of the algorithm, so the search area of the algorithm is not necessarily a feasible area. In this case, the efficiency of the algorithm will be greatly reduced. In the intelligent optimization algorithm, the general idea is to pull the search population into the feasible area, and then search for the optimal solution in the feasible area. In the multi-objective optimization problem, there are many optimized target components, and if the penalty term is added after these target components, the comparison of each target component will be affected. At present, constraints in multi-objective optimization problems are mostly treated as an optimization target component. "One-piece" task assignment originates from a situation widely studied by scholars at present.

In this task assignment, the factors among formations are not considered, but all UAVs that arrive in the designated mission area are regarded as the executing subjects. That is to say, in the "integrated" mission, after all formation UAVs arrive at the designated area, their formation attributes are ignored, that is, they are assigned to the target as a whole. The key to transforming a constrained multi-objective optimization problem into an unconstrained multi-objective optimization problem is to measure the degree of constraint violation that will be the optimization target, that is, how to use a value to measure the degree of constraint violation as an attribute. The advantage of "one-piece" allocation is that this allocation strategy makes it easier to establish a matching mathematical model and solve it. The essence of violation degree is how far an individual is from a feasible solution, and the farther the distance is, the greater the constraint degree is. When an individual is a feasible solution, the value of violation degree is 0. When the violation degree is taken as an optimization goal, the optimization direction is also minimized.

4. Conclusions

Since the 21st century, the rapid development of science and technology, especially new and high technology, has led to great changes in the world military field. The military unmanned aerial vehicle (UAV), which integrates new and high technologies such as aerospace technology, intelligent information processing technology, communication technology, precision locking technology and strike technology, has begun to emerge in the modern battlefield. Multi-aircraft cooperative task assignment is the key point in the field of multi-UAV task planning, which provides technical support for tactical planning and battlefield situation analysis in modern warfare. First of all, for multi-UAV task allocation, the objectives of task allocation are various, such as time, path length, security, task consumption and task completion, etc. How to further improve the modeling of multi-UAV task allocation is one of the next problems to be further solved. In addition, for the task assignment problem with high complexity, how to further improve the algorithm speed and reduce the complexity of the algorithm is also the work to be further explored.

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