

Research on Unmanned Aerial Vehicle Path Planning

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Abstract: This paper reviews and analyses the research progress in the field of UAV path planning. Firstly, the importance of UAV path planning and the current research work related to UAV path planning are introduced. Then how UAV path planning is modelled is analysed and key issues to be considered are given. Finally, classical search algorithms, evolutionary algorithms, heuristic search-based algorithms and deep learning methods are analysed in UAV path planning. For each method, its principle, characteristics, advantages and disadvantages, and applicable scenarios are analysed. The aim of this paper is to provide a comprehensive overview for researchers and scholars in the field of UAV path planning in order to promote the development and application of related technologies.

Keywords: Unmanned Aerial Vehicle; Path Planning; Intelligent Optimization Algorithms.

1. Introduction

With the continuous evolution of unmanned aerial technology, unmanned aerial vehicles (UAVs) have captured considerable attention for their capacity to navigate through intricate and perilous environments. Path planning and design represent pivotal elements within UAV mission systems, demanding the derivation of a secure, feasible, and seamless flight trajectory from an initial point to a designated destination, all while adhering to specified constraints. Consequently, the UAV path planning conundrum can be perceived as a multifaceted optimization challenge, necessitating the deployment of efficient intelligent optimisation algorithms for resolution. How UAV path planning solves this problem has triggered a large number of scholars to carry out in-depth research, this paper will provide a review and analysis of path planning research.

2. Overview of Relevant Work

A number of researchers and teams have studied the path planning algorithms and some results have been obtained, the following is a brief analysis of recent related research work.

Researchers have proposed various methods to address UAV path planning challenges, encompassing traditional approaches like artificial potential field algorithms[1], Rapidly-exploring Random Trees[2](RRT), and neural network algorithms[3], alongside emerging reinforcement learning techniques such as Q-learning algorithms[4]. However, these methods often entail significant computational overhead.

Swarm optimization algorithms, inspired by biological intelligence or natural phenomena, represent a category of stochastic search algorithms. They mimic collective behaviors observed in nature—such as foraging and reproduction—by abstracting these behaviors into quantifiable metrics, forming mathematical models applicable to diverse problem sets. The advent of intelligent optimization algorithms has notably enriched optimization techniques, offering pragmatic solutions to combinatorial optimization problems that conventional methods struggle to

address. Furthermore, they furnish a novel means to explore biological concepts and mechanisms from alternative perspectives. Swarm intelligence optimization algorithms are highly effective in overcoming the drawbacks of conventional optimization methods, efficiently handling complex real-world challenges[5,6,7]. As a result, a growing number of researchers are turning to a range of biological phenomena for inspiration in devising distinctive swarm intelligence optimization algorithms[8]. These algorithms, drawing from natural physical phenomena or collective behaviors, are applied to address function optimization problems and are celebrated for their simplicity and effectiveness across a variety of practical applications[9]. They offer fresh perspectives for tackling intricate path planning issues in unmanned aerial systems. This type of algorithm[10-12] is also the direction of current scholars actively conducting in-depth research.

3. UAV Path Planning Model

The establishment of the UAV path planning model is one of the key steps in solving the UAV path planning problem, and the following aspects need to be considered.

Firstly, problem definition. Before modelling, the specific problem of UAV path planning needs to be clearly defined. This includes identifying the inputs, outputs, and possible constraints of the problem. The inputs usually include start points, target points, obstacle information, etc., while the outputs are the optimal path or set of paths.

The second is mathematical modelling. Once a problem has been clearly defined, it can begin to be translated into a mathematical model. This usually involves abstracting aspects of the problem into mathematical expressions or equations. For example, a graph from graph theory can be used to represent the possible paths and obstacles for a UAV, and then an optimisation algorithm can be used to find the optimal path.

The third is constraints consideration, the UAV path planning model must also take into account various constraints, such as the maximum flight speed of the UAV, the minimum turning radius, and obstacle avoidance

requirements. These constraints will affect the selection and optimisation of the final path.

The fourth is the path assessment metrics. In building the model, metrics need to be identified to assess the merits of the path. These metrics can include path length, flight time, energy consumption, safety, and so on. Depending on different application scenarios and needs, the importance of these indicators may vary.

4. UAV Path Planning Algorithms

UAV path planning algorithms in general can be classified into classical search algorithms, evolutionary algorithms, heuristic search based algorithms and deep learning methods. It can also be summarised as categorised as in Figure 1.

Classical search algorithms try to find the optimal path from the starting point to the goal point in space based on the principle of graph search. Among them, Dijkstra's algorithm and A-star algorithm are the most common representatives; Dijkstra's algorithm finds the optimal path by calculating the shortest paths from the starting point to each node, but it may have the problem of high computation; while A-algorithm combines the idea of heuristic search, and guides the direction of the search by a heuristic function (e.g., estimation of the distance to the goal point), which enhances the efficiency of the search. Evolutionary algorithms include genetic algorithms, particle swarm algorithms, etc. These algorithms search for optimal solutions in the solution space by

simulating the process of natural evolution. Genetic algorithms optimize paths step by step by simulating operations such as natural selection, crossover and mutation, and are suitable for complex path planning problems; particle swarm algorithms simulate the behaviour of flocks of birds or schools of fish, search for optimal solutions in the solution space, and have better global search capability and convergence. Algorithms based on heuristic search improve search efficiency by introducing heuristic information to guide the search direction. They include ant colony algorithm, artificial bee colony algorithm, etc. Ant colony algorithms simulate the behaviour of ants searching for food, searching for the optimal path in the solution space; artificial bee colony algorithms simulate the behaviour of bees searching for nectar, searching for the optimal path through the process of 'recruitment' and 'observation'. Deep learning methods use either neural network models or reinforcement learning methods to learn path planning strategies. Neural network models can learn complex path planning strategies through training, which is suitable for path planning problems with large-scale data and complex environments; while reinforcement learning methods learn optimal path planning strategies through the interaction between intelligences and environments, which is suitable for path planning problems requiring real-time adjustment of strategies.

Here is an example of the Gold Rush algorithm. Fig. 2 demonstrates the application of the Gold Rush algorithm for UAV path planning in mountainous terrain.

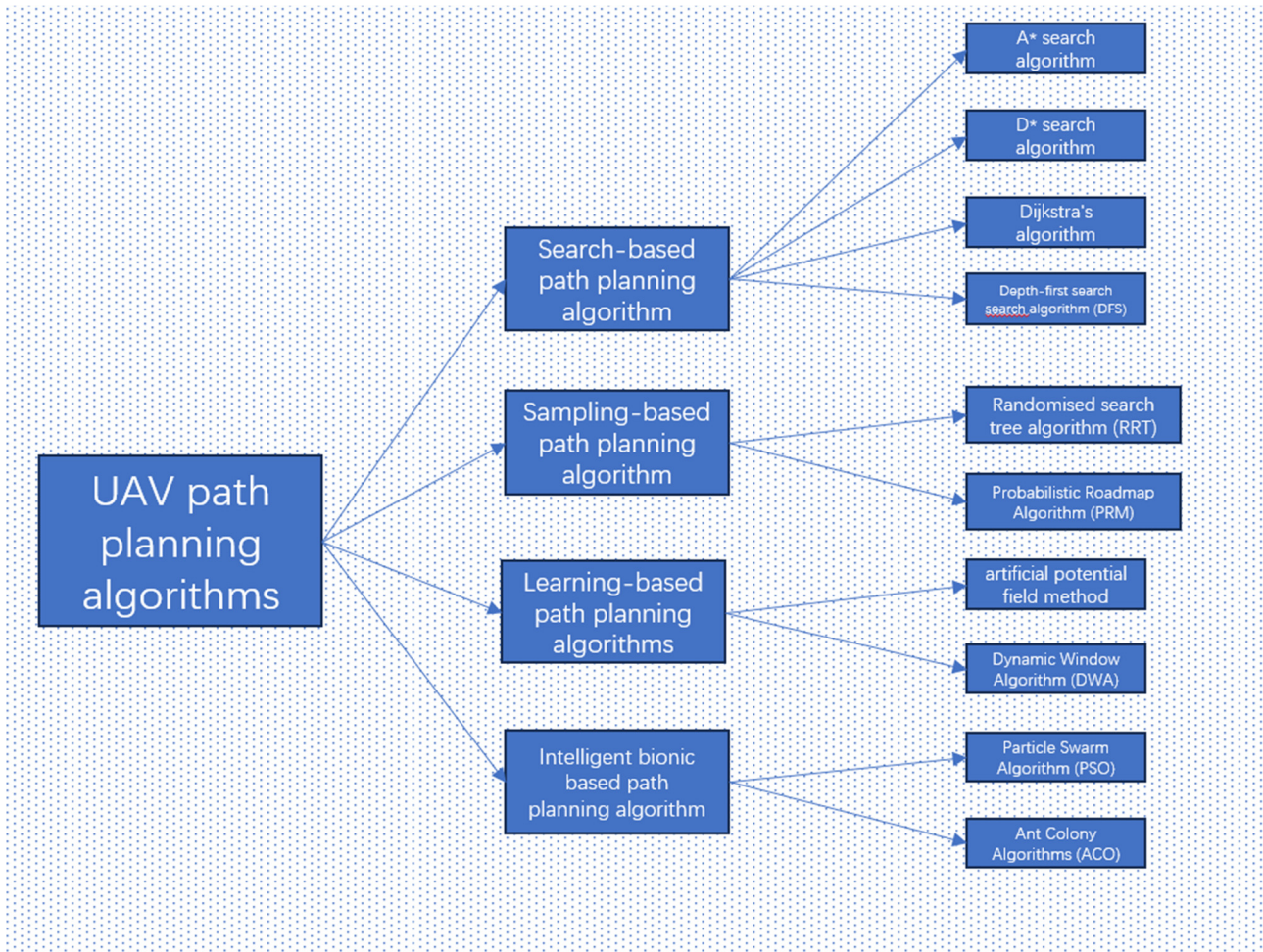


Fig 1. Path planning algorithm

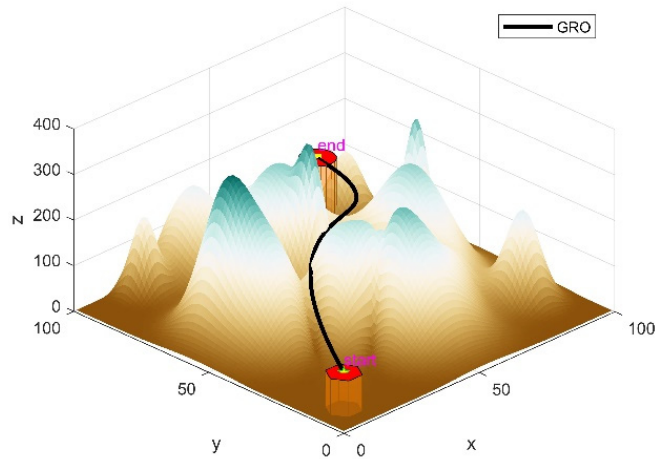


Fig 2. Effectiveness of gold rush algorithm in UAV path planning

5. Conclusion

UAV path planning is a complex and critical problem, which is of great significance in UAV applications. For the UAV path planning problem, there exist a variety of algorithms and methods, including classical search algorithms, evolutionary algorithms, heuristic search-based algorithms, and deep learning methods. Each method has its unique advantages and applicable scenarios, and the appropriate algorithm can be selected according to the specific problem characteristics and needs. Combining the characteristics of various algorithms, classical search algorithms are suitable for path planning in static environments; evolutionary algorithms are suitable for complex path planning problems and have better global search capabilities; heuristic-based search algorithms combine heuristic information to guide the search direction, and are suitable for path planning problems that require efficient search; and deep learning methods are suitable for path planning problems in large-scale data and complex environments. Based on the above analysis, when choosing an algorithm to solve a specific UAV path planning problem, the characteristics of the problem and specific constraints need to be considered comprehensively in order to improve the efficiency and performance of path planning.

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