Path Planning for UAVs: A Survey

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***Abstract*—An Unmanned Aerial Vehicle (UAV) can be controlled remotely or fly autonomously by following a pre-planned flying route without an on-board pilot. UAVs have rapidly developed and been applied in many application domains, including civil security, terrain coverage, photogrammetry, and smart farming in recent decades. However, one of the major problems in such applications is path planning and view planning, which inform UAVs exactly where to go. UAV maneuver through the dynamic environments, UAV needs to avoid and pop-up threats and obstacles. Hence, one of the most critical aspects of UAVs is path planning. This paper aims to explore a recent state of the art of the algorithms for UAV path planning.**

Keywords—**UAV path planning, path planning algorithm, UAV, dijkstra algorithm, genetic algorithm.**

I. Introduction

In the real world unmanned aerial vehicles widely used in different contexts in recent years [1]– [5]. With the continuous the use of UAVs has been significantly expanded due to improvements in maneuverability, camouflage, violence, and intelligence [2,3]. The goal of UAVs is to effectively and safely conduct complex tasks autonomously, protect human lives and deliver economic benefits as UAVs collect data that can be used to enhance government and business decision making [2,4,5]. In that case, path planning is a critical component of the overall framework to ensure that UAVs complete their missions successfully. It primarily refers to determining the best UAV fighting route from a reference point to a destination that meets the UAV's performance expectations as well as the environment's requirements [5]. Different factors such as Energy consumption, maneuverability, time of arrival, flying range, and security situation must be considered for the trajectory planning to optimize the UAV's flight track between the starting point and the end point. Voronoi diagrams, A* algorithms, Generic Algorithms (GA), Virtual Potential Field (VPF), Particle Swarm Optimization (PSO), and Neural Networks have been proposed to optimize the trajectory.

II. Path Planning Algorithm

Path planning, also known as motion planning and is a computational problem that involves determining a set of valid configurations for moving an object from one location to another [5]. In the area of robotics, path planning issues have been extensively researched and using various methods and strategies, it has been discussed. Deterministic, heuristic-based algorithms and probabilistic, randomized algorithms are the most popular techniques.

A. Dijkstra algorithm

Dijkstra's algorithm is one of the earliest and most fundamental algorithms for finding the shortest route from one node in a graph to all other nodes in the same graph. The algorithm assigns a cost to all direct neighbors of the initial vertex, where the path should begin, starting at the initial vertex. It then moves from the lowest-cost vertex to all of its neighbors, labeling them with the cost of getting there alone if that cost is lower . The algorithm moves on to the vertex with the next lowest cost after checking all of a vertex's neighbors. When the algorithm hits the target vertex, the robot can then follow the edges that point to the lowest edge expense. Fig.1 illustrate method of finding the shortest distance between source vertex 'U' and remaining vertices using Dijkstra's Algorithm. The right side of the figure which represent the shortest path from the source vertex 'U' to all other vertices after the process of Dijkstra algorithm.

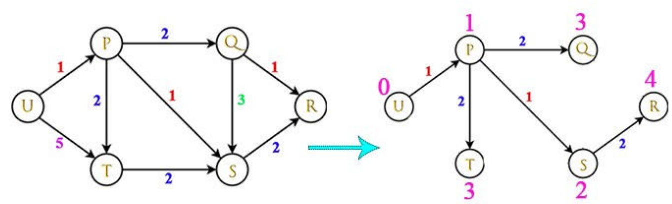

Fig. 1. Method of finding the shortest distance using Dijkstra's Algorithm

B. A* algorithm

The A-star algorithm is one of the most widely used path-finding and graph traversal techniques which is an extension of Dijkstra algorithm. Unlike other traversal methods, A* Search algorithms are equipped with "brains." This indicates that it is a clever algorithm that separates itself from others. It's also worth noting that this algorithm is used in a lot of games and web-based maps to find the shortest path (approximation). A*, on the other hand, generates sub-optimal solutions and unrealistic paths. In trajectory planning, A* with route smoothing and Linear Programming techniques is used.

$$f(n) = g(x) + h(x) \tag{1}$$

According to neighboring costs, each state's estimate $h(x)$ is usually similar to the true cost; therefore, A* has a faster rate of convergence.

C. D* algorithm

D-star, short for dynamic A*, is well-known in the DARPA unmanned ground vehicle programs for its widespread use. D* is a sensor-based algorithm that deals with dynamic obstacles by changing the weight of its edges in real time to create a temporary map, which then moves the robot from its current location to the shortest unblocked path to the target location. D *, such as A *, estimates costs by considering both post-calculations and future valuation factors. D * maintains a list of states used to distribute information about arc cost function changes. The evaluation function is,

$$f(n)' = g(x)' + h(x)' \tag{2}$$

In contrast to A*, $h(x)'$ is not always the shortest path length to the goal; additionally, $h(x)'$ computation assumes that the robot will move through obstacles. When it encounters new obstacles, it updates a minimum heuristic function and the entire graph, allowing for efficient searching in complex environments.

D. Voronoi Diagram

The Voronoi diagram was introduced into the field of computational geometry by Shamos and Hoey ; it was first used for finite points in the Euclidean plane and is now commonly used in the field of route planning with a series of improved forms. The distance between the edges and the surrounding barriers is the same in a Voronezh diagram that creates spatial relationships.

E. Genetic algorithm

J. Holland first proposed the genetic algorithm (GA) in 1975 and it is an intelligent search algorithm that simulates the process of biological evolution to find the optimal solution. GA begins with a population of genetically encoded individuals that is created at random or with a particular initial population. Collection, duplication, cross, and variation are all common operations used in GA. A genetic algorithm keeps track of a population of candidate solutions, each of which is normally encoded as a binary string known as a chromosome. Binary coding has been shown to be the safest choice of coding.

F. Particle Swarm Optimization

Particle swarm optimization (PSO) is a stochastic optimization algorithm that is based on a population. A swarm of particles is described by a PSO, which is a type of evolutionary algorithm. The study of real-life samples and social models led to the creation of particle swarm optimization. It is widely used in the field of robotic design due to its simple structure, rapid convergence, and few processing parameters. PSO is an evolutionary algorithm that involves random number generation.

III. Discussion and Future Direction

Many authors have solved the problem of route planning with UAV and discussed areas of interest in different shapes and complexities. To reduce energy consumption, some studies aim to reduce distance, flight time or maneuverability. During turning maneuvers, vehicles can decelerate, rotate, and accelerate, extending flight time and thus energy consumption. On the other hand, little research has been conducted on the subject of uncertainties and strength in general. In literature review, we found that most of the methods surveyed here do not involve much debate about their practical implementation. Thus, critical issues are likely to be overlooked by theoretical work. Many of the active implementations of UAV given in surveyed articles belonged to the hierarchical discontinued control type or in some cases focused solely on reactive readiness to overcome obstacles. In the case of digital transformation, we planned to focus on path planning for autonomous UAVs in an agricultural environment since the food demand became increasing. With the combination of automation and AI it introduces as a viable alternative for the agricultural industry. This brings agriculture towards a big leap.

IV. Conclusion

Path planning is critical in autonomous UAV navigation because it not only needs to integrate various data, such as environmental data and task objects, However, it also needs to provide accurate and stable planning to the lower layer of execution modules. The analysis of the path planning algorithm must be therefore be focused on the actual situation, and consideration should be given to the real-time and accuracy of the calculation. At the same time, the UAV efficiency constraint also poses further criteria for its algorithm for path planning, such as the restricted processing power of the UAV. The onboard computer, as well as the sensing modules' minimal precision. Although UAV motion planning research has advanced significantly, various methods still have weaknesses and vulnerabilities, and the prospect of UAV motion planning for future research remains exciting.

References

[1] Sharma, A., Vanjani, P., Paliwal, N., Basnayaka, C. M. W., Jayakody, D. N. K., Wang, H. C., Muthuchidambaranathan, P. (2020). Communication and networking technologies for UAVs: A survey. Journal of Network and Computer Applications, 102739.

[2] Hydher, H., Jayakody, D. N. K., Hemachandra, K. T., Samarasinghe, T. (2020). Intelligent UAV deployment for a disaster-resilient wireless network. Sensors, 20(21), 6140.

[3] Jayakody, D.N.K., Muthuchidambaranathan, P., Dinis, R., Panic, S. (eds) Integration of Unmanned Aerial Vehicles in Wireless Communication and Networks. Unmanned System Technologies. Springer, Cham. https://doi.org/10.1007/978-3-031-03880-8-6.

[4] H. Hydher, D. N. K. Jayakody, K. T. Hemachandra and T. Samarasinghe, "UAV Deployment for Data Collection in Energy Constrained WSN System," IEEE INFOCOM 2022 - IEEE Conference on Computer Communications Workshops (INFOCOM WKSHPS), 2022, pp. 1-6, doi: 10.1109/INFOCOMWKSHPS54753.2022.9798245.

[5] Zhou, H., Xiong, H.-L.; Liu, Y., Tan, N.-D., Chen, L. Trajectory Planning Algorithm of UAV Based on System Positioning Accuracy Constraints. Electronics 2020, 9, 250. https://doi.org/10.3390/electronics9020250.