Exploring the State of the Art in Optimizing Intelligent Path Planning Algorithms

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Abstract. Intelligent path planning algorithms have emerged in the present time of rapid technological development, and intelligent path planning algorithms play an important role in enhancing the operational efficiency and intelligence of robots, vehicles and other moving entities. Among them, A* and Rapidly - exploring Random TreeRRT (RRT) algorithms are widely used in multiple fields such as robot navigation. Therefore, this paper focuses on intelligent path planning algorithms, an in-depth study of traditional A and RRT algorithms application, improvement and integration with other technologies, and the implementation of multi-industry and multi-domain. Intelligent path algorithms are applied in many fields and the performance improvement after improvement is significant, the efficiency is enhanced after optimization and the applications are expanded, which profoundly reflects the great development prospect of intelligent path algorithms and their high degree of compatibility with different fields. Algorithm innovation results are remarkable, the integration of a variety of technologies in a variety of fields, its development prospects are broad, the future of intelligent transportation, logistics and other industrial upgrading is of great significance.

Keywords: Intelligent Path Planning Algorithm; A* Algorithm; RRT Algorithm; Automobile Path Planning; Algorithm Improvement

1 Introduction

The application scenarios of intelligent path planning algorithms are expanding and are widely used in aerospace, intelligent warehousing, logistics and distribution industries, in addition to the traditional robotics and autonomous driving fields. For example, Qin proposed to apply intelligent path-planning algorithms to weeding robots, combining them with the field of agriculture, demonstrating the potential of the algorithm's integration in multiple fields [1]. With the continuous progress of technology, the application potential of intelligent path planning algorithms in the fields of healthcare and energy has been gradually explored, especially in medical robot surgical navigation and energy network scheduling, which demonstrates an important value.

The traditional algorithms of intelligent path planning algorithms are the A algorithm and RRT algorithm. The A algorithm improves the search efficiency and path quality by optimizing the heuristic function, search strategy and path smoothing processing,

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and the integration with other technologies is also closer. The A algorithm is combined with machine learning, deep learning, and sensor technology, and the RRT algorithm is integrated with the artificial potential field method. For example, Wei et al. conducted research around quadcopter UAV flight path planning based on the traditional A algorithm, combined with the minimum Snap algorithm, Hybrid A algorithm, VFH algorithm, IACO algorithm and other algorithms, focused on optimization and improvement and is committed to providing the optimal solution for the path of the UAV [2].

However, some algorithm improvement studies are mainly carried out in the simulation environment, such as Li's meticulous study of path planning for safe ship navigation, but it is limited to the simulation virtual scene, and the effectiveness has not yet been fully verified in the physical system, which may lead to a gap between the actual application effect and the expectation. Second, in large-scale data processing and complex environments, the computational efficiency, real-time and robustness of the algorithms still need to be further improved, such as when dealing with dynamic obstacles and high-dimensional spatial path planning, some of the algorithms may have a performance bottleneck [3].

This paper first introduces the applications and drawbacks of the traditional A-algorithm and RRT algorithm and points out that the traditional algorithms have great potential for innovation; then it summarizes the innovations of the traditional algorithms and combines them with the deep learning technology or the artificial potential field and other technologies, which results in new algorithms and greatly enhances the search efficiency and the operation efficiency; and finally, it summarizes the development of the intelligent path planning technology, which is combined with the genetic algorithm and the particle swarm algorithm, and plays a role in more fields. More fields, and points out that the data processing and numerical computation capabilities of intelligent path algorithms are greatly improved and have the prospect of being widely used in many fields such as multiple robots, aerospace and so on.

2 Application of Traditional Algorithms

2.1 On the application of the traditional A-algorithm

The A algorithm is a heuristic search algorithm that plays a key role in many fields, such as artificial intelligence and path planning. The A algorithm abstracts the problem as a state space.

The A-algorithm has been applied in many fields in recent years, especially combined with the robotics field, which plays a great role in robot path planning. Xin focuses on the intelligent path planning of mobile robots, based on the A algorithm, through software design, simulation and Hawkbot robot experimental verification, the improved algorithm effectively improves the search efficiency, the path is smoother and can avoid obstacles, which provides ideas for the improvement of the path planning algorithm for mobile robots [4].

2.2 On the application of traditional RRT algorithms

RRT, or fast extended randomized tree algorithm, is a probabilistic algorithm for path search. It is mainly applied to motion planning problems in high-dimensional spaces, especially in the field of robot motion planning. The core idea of the algorithm is to explore the space by randomly sampling points in the space and gradually constructing a tree structure to find a feasible path from the start point to the goal point. Compared with traditional grid-based path planning algorithms, the RRT algorithm can handle high-dimensional spaces and complex environments more effectively.

RRT algorithm is also one of the traditional algorithms, the developability is also very deep and can be combined with several algorithms to play a greater role. The optimal path planning of UAV routes based on RRT algorithm by Lu et al. is an application and breakthrough of RRT algorithm in the field of aviation, which also reflects the importance and superiority of RRT algorithm in path planning algorithm [5].

3 Traditional Algorithm Improvement and Application

At present, the traditional algorithms are mainly improved and optimized in various aspects such as algorithm optimization and improvement, combination with other technologies, and application field expansion, so that traditional algorithms play a vital role in the development of intelligent path planning.

In recent years, traditional algorithms have been improved and combined with other algorithms, which can be used as important algorithmic modules for path planning in different environments such as land, sea and air. Since the vehicles traveling on land, sea and air are different from each other, multiple algorithms must cooperate to realize the adaptability of the traditional algorithms to multiple environments.

3.1 Innovative development of A algorithm

The improvement of A* algorithm in recent years mainly focuses on heuristic function optimization, search efficiency improvement and combination with other techniques. Liu For the A algorithm, an improved algorithm based on two-way jump point search is proposed, which improves the search efficiency, shortens the path length, reduces the number of transitions, and makes the path smoother. For the artificial potential field method, an improved method incorporating simulated annealing algorithm is proposed to set random target points to solve the local minima problem using simulated annealing algorithm. Finally, a hybrid path planning algorithm is proposed based on the improved A-algorithm and the artificial potential field method, which achieves the path planning task by avoiding unknown and dynamic obstacles in a dynamic environment through the combination of global and local path planning [6].

Improvements for the A * algorithm have been emerging in the last five years, including optimization of the heuristic function to more accurately estimate the cost from node to target node, thus improving the algorithm's search efficiency; improvement of the search strategy, such as the use of bi-directional search, hierarchical search, etc., to reduce the search space and time complexity; and improvement of path smoothing processing, so as to make the generated paths more in line with the actual demand of movement and reduce the number of unnecessary turns. Wang takes wheeled robots as the research object and centers on their path planning algorithms. Aiming at the shortcomings of the traditional A algorithm, it improves the efficiency and path quality by optimizing node selection, improving the heuristic function and deleting redundant nodes, which provides a useful reference for the development of robot path planning technology [7].

3.2 Development of RRT algorithm

The performance of the RRT algorithm has been continuously improved in the development of several scholars, the search efficiency has been optimized, and the scene suitability and specificity have been significantly improved. Yue proposes two improved algorithms based on the traditional RRT algorithm to cope with complex environments. For multi-obstacle environments, an improved RRT algorithm based on a variable weight potential field is proposed to reduce computational redundancy, enhance obstacle avoidance capability, and make path planning more efficient and smooth. For irregular obstacle environments, an improved RRT* algorithm based on fuzzy logic is proposed, which uses fuzzy logic strategy to adjust the robot's motion state and combines with the 2-opt algorithm to select the optimal path, which improves the quality of the path and the planning efficiency. Compared with the traditional algorithms, the two new algorithms have significant advantages in terms of path planning time, obstacle avoidance effect, and path smoothing, which provide a more effective solution for the path planning of mobile robots in complex environments [8].

The RRT algorithm is more closely integrated with other technologies, expanding the application areas of the RRT algorithm and making its path planning capability climb steadily in multi-technology integration. Ruan et al. proposed improvement strategies, including target gravity bias, adaptive step size and obstacle bias, to address the problems of the RRT * algorithm's high randomness and slow convergence speed. Meanwhile, the traditional artificial potential field method is improved to solve the problems of target unreachability and local minima. Then, the improved two algorithms are fused for global dynamic scene path planning, which can effectively avoid dynamic obstacles and plan smooth and feasible paths, providing ideas for the improvement of RRT algorithms and the combination of multiple fields [9].

4 Intelligent Path Algorithm

Intelligent planned route algorithms refer to a series of computational methods capable of automatically generating effective movement paths from a start point to a goal point for moving entities (e.g., robots, vehicles, UAVs, etc.) in complex environments or under task requirements.

In today's era of rapid development of science and technology, intelligent path algorithms have become the core elements to realize efficient operation in many fields. This paper analyzes the development status and application effectiveness of intelligent path algorithm in various aspects and explores its innovation path and future direction. It mainly focuses on the intelligent path algorithm. Firstly, it elaborates the advantages and clear development direction shown by its in-depth integration with other technologies, such as the performance enhancement brought by combining machine learning and sensor technology; secondly, it explores the outstanding performance and significance in the enhancement of adaptability to the complex environment, optimization of the combination of algorithms, and expansion and deepening of the application fields such as intelligent driving, logistics management, and robot navigation.

4.1 Deep integration with other technologies

The advantages of intelligent path algorithms lie in the combination of machine learning to improve performance, the integration of sensor technology to enhance adaptability, and the combination of different algorithms to optimize the solving ability and effectively deal with complex environments. Intelligent path algorithms will deepen the integration with artificial intelligence, using deep learning to strengthen path planning; combined with big data and the Internet of Things, optimize planning based on real-time information; and at the same time, carry out cross-domain integration, such as medical and energy fields, so that the path planning is more in line with the professional needs, and comprehensively promote the process of intelligentization of various industries to improve the efficiency and accuracy of operation.

Ding mainly researches UAV path planning. For the monitoring scenario in industrial parks, he abstracts the UAV path planning problem into a multi-constraint objective planning problem and improves the path planning efficiency by improving the Gray Wolf optimization algorithm, increasing the convergence coefficient, and combining it with the simulated annealing algorithm to solve the problem. Ding also plans multi-UAV collaborative exploration based on the improved deep reinforcement learning algorithm, introduces the artificial potential field method traction mechanism, and trains the UAVs' path traveling and information exploration strategy models. In addition, Ding built an AirSim simulation platform and applied these algorithms for UAV path planning simulation, realizing the environment monitoring and adaptive path planning adjustment of UAVs, which provides effective support for the application of UAVs in real scenarios [10].

4.2 Improvement of Adaptability to Complex Environments

Improving the adaptability of intelligent path algorithms in complex environments enables robots to operate efficiently and reliably in industrial and hazardous scenarios, helps autonomous driving to improve safety and smoothness, promotes the popularization of the technology, ensures the safety of UAV flights and expands their applications, and optimizes the routes of intelligent logistics distribution and warehousing to improve the efficiency of various fields. Yin focuses on intelligent body path planning, including single intelligent body path planning in static scenarios and multi-intelligent body path planning in dynamic environments. In static scenarios, an improved ant colony potential field method is used to plan the optimal paths through adaptive volatility factor, improved pheromone update strategy and introduction of potential field function, combined with B-spline curve smoothing and validated on ROS and Gazebo platforms in dynamic environments, based on the Actor-Critic algorithm, a suitable state and action space is designed, and an experience-sharing strategy is introduced to In the dynamic environment, based on the Actor-Critic algorithm, they design the appropriate state and action space and introduce the experience sharing strategy to improve the efficiency and accuracy of multi-intelligent body path planning. This study provides effective algorithms and solutions for path planning of bits of intelligence in complex scenarios, which has important theoretical and practical significance [11].

4.3 Combination of intelligent optimization algorithms with other algorithms

Combine different types of algorithms to take advantage of their respective advantages. For example, the genetic algorithm is used to solve the vehicle path problem or the RRT algorithm is combined with the artificial potential field method, which accelerates the convergence speed of the algorithm, improves the efficiency of searching in a specific region, and strengthens the adaptability and solving ability of the algorithm in the complex environment. Jing combed the domestic and international development status of intelligent vehicles and established the kinematics and dynamics model of the vehicle. Then, the potential field ant colony algorithm is proposed, which combines the improved artificial potential field method and the ant colony algorithm, effectively solves the target unreachability problem by considering the distance between the intelligent vehicle and the target point and the relative distance adjustment factor, and then optimizes the path by using the cubic B-spline curve, which strengthens the smoothness of the path and the global search ability. Meanwhile, the MPC controller is adopted for trajectory tracking, which can enable the intelligent vehicle to track the desired trajectory accurately and stably through the prediction model, feedback correction and rolling optimization. Finally, it is verified by a joint simulation platform, which shows that the algorithm and controller can effectively plan the path and track the trajectory, providing an effective solution for the development of intelligent vehicles [12].

4.4 Expansion and deepening of application fields

Intelligent driving field: The intelligent path algorithm is a key component of automatic driving technology, and its development promotes the transformation of automatic driving from relying on high-precision maps to autonomous perception and mapless driving. Hole mainly focuses on the path planning and trajectory tracking of intelligent vehicles to carry out in-depth research. In terms of research background and current status, the importance of the development of intelligent vehicles and the current research progress of related technologies are described. He establishes the kinematics and dynamics model of the vehicle to lay the foundation for the subsequent work. In particular, the proposed potential field ant colony algorithm can efficiently plan safe and reliable paths to effectively deal with various complex environments. In addition, a joint simulation platform is built through Simulink and Carsim, which provides a solid guarantee for the practical application of intelligent vehicles and promotes the development of intelligent vehicle technology [13].

In logistics and distribution, intelligent path planning optimization can improve transportation efficiency, reduce costs, reduce traffic congestion, and achieve personalized distribution solutions to enhance the competitiveness and service quality of logistics enterprises by considering the number of goods, destination location, traffic conditions, distribution time window and other factors through technologies such as big data analysis, machine learning and intelligent algorithms. Shen focuses on multi-mobile robot picking path planning for intelligent warehouses, conducts in-depth analysis and modeling of intelligent warehouse system, including system characteristics, composition, operation flow, etc., and establishes a simplified schematic model using the raster method to select and type of picking method. In terms of path planning, the multi-robot task planning is regarded as a multi-traveler problem, and a genetic algorithm is used to solve it, the A algorithm is improved for global path planning, and by analyzing the types of path conflicts, the priority method and cooperative time-domain A algorithm are used to realize local dynamic path planning. In addition, MATLAB is utilized to establish a simulation system to conduct simulation experiments on different task planning methods and the number of robots, which verifies that the planning methods can effectively reduce the total distance and total time consumed by the tasks, and improve the efficiency of warehouse operation [14].

Intelligent path algorithms enable robots to navigate and avoid obstacles more flexibly in complex environments to accomplish a variety of tasks, such as inspection robots using improved path planning algorithms to achieve efficient inspection and industrial robots to achieve more optimized material handling and operations on production lines. Ma conducts research on path-planning algorithms for mobile robots, covering both small-scale and wide-area complex environments. In terms of modeling, the motion constraints and physical constraints of path planning for mobile robots are elaborated. Algorithmically, classical algorithms such as ant colony, RRT, artificial potential field, A-star and particle swarm are analyzed. In small-area complex environments, the raster method is used to build 30m30m maps to shorten paths and reduce inflection points. In wide-area complex environments, 100m100m maps are built by geometric method to set up safety distances using the expansion principle [15].

5 Conclusion

This paper presents the development trajectory of path algorithms in the past five years, starting from analyzing the limitations of traditional A algorithms and RRT algorithms, then exploring the innovation paths of traditional algorithms, and finally evolving to intelligent optimization algorithms, which have played a significant role and made outstanding contributions in many important fields, and comprehensively demonstrated this development process. This paper finds that intelligent path algorithms have made significant progress in the past five years. The traditional A algorithm and RRT algorithm have been improved continuously, and the A algorithm has been applied in many fields and its performance has been improved by combining with other techniques and optimizing the heuristic function, etc. The RRT algorithm has also achieved great results in the optimization of its performance and the fusion of multiple techniques. The fusion of intelligent path algorithms and machine learning improves performance, enhances adaptability and solving ability, and deepens the application in intelligent driving, logistics, robot navigation and other fields to promote the intelligence of the industry. For example, it optimizes distribution in logistics and realizes the transformation of mapless driving into automatic driving, which brings new opportunities and efficient operation modes for the development of various fields. In the future, the field of path algorithms can further study the application of intelligent path algorithms in extreme environments, such as the deep sea, space exploration and other fields, as well as the optimization of multi-intelligent body complex collaboration scenarios. This will help break through the existing technical bottlenecks, improve the automation and intelligence level of various industries, promote the development of science and technology, and enhance the ability of human beings to explore and control complex environments.

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