Improved RRT*-Connect Based on MATLAB

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Abstract

The article analyzes an improved RRT*-Connect path planning algorithm based on MATLAB software. First, the sampling domain of the algorithm is changed to an elliptical sampling domain. Second, adaptive compensation expansion is introduced to accelerate the search speed of the path planning algorithm. Finally, the algorithm is combined with a greedy algorithm to optimize the path. Simulation results show that this algorithm significantly improves both the path length and planning time compared to the traditional RRT*-connect algorithm.

Keywords: RRT*-Connect, Path planning, Greedy Algorithm

1. Introduction

Path planning is one of the key issues in robot navigation. The RRT*-Connect [1] (Rapidly-exploring Random Tree Star Connect) algorithm, as an effective random sampling algorithm, has been widely applied in the field of path planning. However, the traditional RRT*-Connect algorithm has problems such as low search efficiency and longer path lengths in certain scenarios, which limits its effectiveness in practical applications.

To address the above issues, this paper proposes an improved RRT*-Connect path planning algorithm. First, the sampling domain of the algorithm is changed to an elliptical sampling domain to better adapt to the distribution of environmental obstacles. The elliptical sampling domain can more effectively explore the space around obstacles, improving the search efficiency of the algorithm. Secondly, an adaptive compensation expansion strategy is introduced, which dynamically adjusts the expansion step size to further accelerate the search speed of the algorithm. Finally, a greedy algorithm [2] is combined with the improved RRT*-Connect algorithm to optimize the generated path, making it smoother and shorter.

Through MATLAB simulation experiments, the superiority of the proposed algorithm in terms of path length and planning time has been verified. Compared with the traditional RRT*-Connect algorithm, the improved algorithm not only generates shorter paths but also significantly reduces planning time. This provides an efficient path-planning method for robot navigation, with broad application prospects in practical applications.

The main contributions of this paper include: 1) proposing an improved RRT*-Connect algorithm based on an elliptical sampling domain, which improves the search efficiency of the algorithm; 2) introducing an adaptive compensation expansion strategy to further accelerate the search speed of the algorithm; 3) combining a greedy algorithm with the improved RRT*-Connect algorithm to optimize the generated path. Simulation results show that the proposed algorithm has significant improvements in both path length and planning time.

The structure of this paper is arranged as follows: Section 2 introduces the specific implementation of the improved RRT*-Connect algorithm; Section 3 presents the setup and results analysis of the simulation experiments; Section 4 summarizes the work of this paper and looks forward to future research directions.

2. Algorithm Principles

2.1. Elliptical sampling domain

The traditional RRT*-Connect algorithm uses a rectangular sampling domain, which may not adapt well to the distribution of environmental obstacles in certain scenarios. Therefore, this paper changes the sampling domain to an elliptical shape to better cover the space around obstacles. The mathematical expression for the elliptical sampling domain is Eq. (1):

$$\frac{(x-x_c)^2}{a^2}+\frac{(y-y_c)^2}{b^2}\leq 1 \tag{1}$$

where (x_c, y_c) are the coordinates of the center of the ellipse, and a and b are the lengths of the semi-major and semi-minor axes, respectively.

2.2. Adaptive compensation expansion

The traditional RRT*-Connect algorithm uses a fixed expansion step size, which may lead to low search efficiency in certain areas. To address this, this paper introduces an adaptive compensation expansion strategy. Specifically, when the tree node is close to the target point, a smaller expansion step size is used; when the tree node is far from the target point, a larger expansion step size is employed. This can accelerate the search speed of the algorithm.

2.3. Greedy algorithm optimization

To further optimize the path generated by the algorithm, this paper combines a greedy algorithm with the improved RRT*-Connect algorithm. During each tree node expansion, in addition to the random sampling point, the nearest sampling point is also selected for expansion. This helps to make the generated path smoother and shorter.

2.4. Algorithm process

To further optimize the path generated by the algorithm, this paper combines a greedy algorithm with the improved RRT*-Connect algorithm. During each tree node expansion, in addition to the random sampling point, the nearest sampling point is also selected for expansion. This helps to make the generated path smoother and shorter.

The specific process of the improved RRT*-Connect algorithm is as follows:

1. Initialization: Set the starting point x_s and the goal point x_g, and establish two trees T_s and T_g, with x_s and x_g as the root nodes, respectively.

2. Sampling: Randomly sample a point x_{rand} within the elliptical sampling domain.

3. Expansion: For each tree $T_i(i = s, g)$, find the nearest node x_{nearest} to x_{rand}, and use x_{nearest} as the starting point to calculate the expansion step size Δx based on the adaptive compensation expansion strategy, resulting in a new node x_{new}. If x_{new} does not intersect with any obstacles, it is added to the tree T_i.

4. Connection: Check if the two trees meet; if they do, use the greedy algorithm to optimize and obtain the final path.

5. Iteration: Repeat steps 2-4 until a feasible path is found or the maximum number of iterations is reached.

6. Combine the generated path with the greedy algorithm to prune and optimize the original path, resulting in a new path.

Through the above steps, the improved RRT*-Connect algorithm can generate shorter and smoother paths, with a significant reduction in planning time.

3. Simulation Analysis

3.1. Experimental setup

To verify the performance of the proposed algorithm, this paper conducts experiments in a MATLAB simulation environment. The simulation scenario is shown in Figure 1, which includes multiple irregularly shaped obstacles. The starting point and the goal point are set at (0, 0) and (1000, 1000), respectively. In the experiment, we compare the improved RRT*-Connect algorithm with the traditional RRT*-Connect algorithm.

3.2. Result analysis

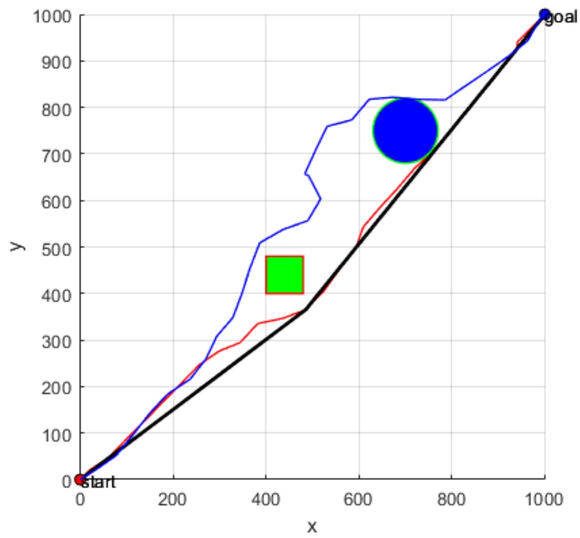

Fig.1. Algorithm simulation in simple environment

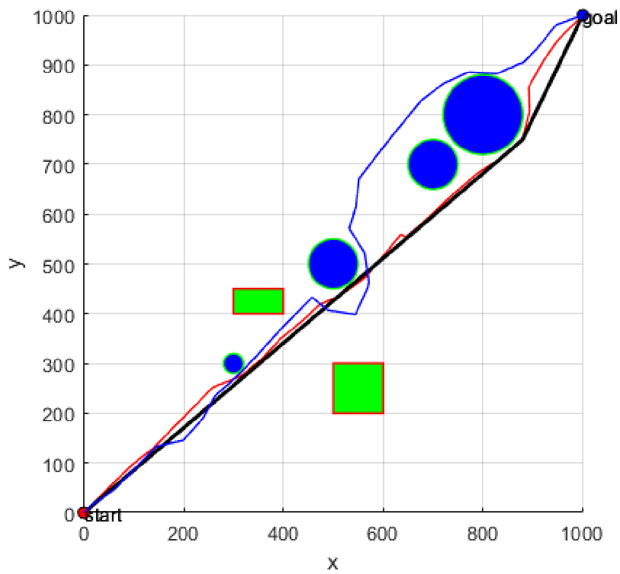

Fig.2. Algorithm simulation in medium environment

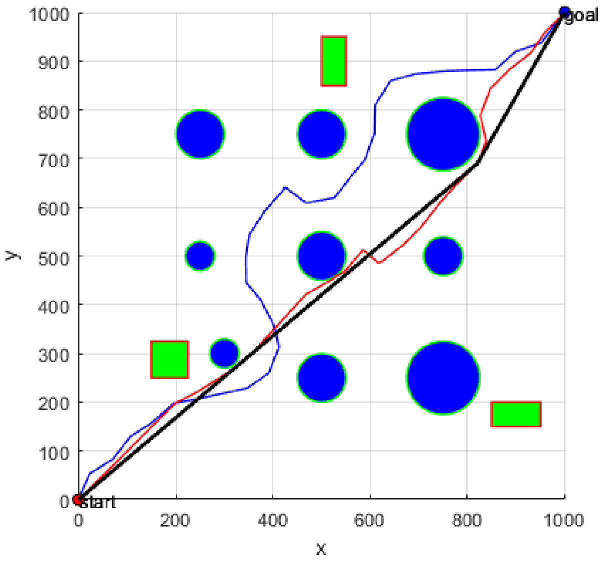

Fig.3. Algorithm simulation in complex environment

Fig.1, Fig.2, and Fig.3 show the paths generated by the traditional RRT*-Connect algorithm and the improved RRT*-Connect algorithm (RRT*-connect algorithm generates a blue path, the Improved RRT*-connect algorithm does not combine with the greedy algorithm generates a red path, and the Improved RRT*-connect algorithm combines with the greedy algorithm generates a black path), respectively. It can be observed that the paths generated by the improved algorithm are smoother and shorter.

Table 1. Algorithm comparison

Environ-ment	Algorithm	Time/s	Path length / pixel
Simple	RRT*-connect	6.04	1573.64
	Improved RRT*-connect	2.70	1424.61
Medium	RRT*-connect	6.67	1612.05
	Improved RRT*-connect	4.72	1434.96
Complex	RRT*-connect	7.25	1721.87
	Improved RRT*-connect	5.12	1498.27

Table 1 lists the comparative results of the two algorithms in terms of path length and planning time. It can be seen that the improved algorithm reduces the average path length by 11.19% and the average planning time by 37.09%, showing significant improvements compared to the traditional RRT*-connect algorithm. This result indicates that the improved algorithm has a clear advantage in optimizing path planning and can more effectively address path planning issues in complex environments.

Further analysis of the advantages of the improved algorithm reveals that it performs particularly well in handling obstacles and dynamic environments. The traditional RRT*-connect algorithm often requires a long time to search for paths when faced with complex obstacles, while the improved algorithm, by introducing a more efficient heuristic search strategy, can quickly find feasible paths, significantly reducing planning time. Additionally, the improved algorithm has also enhanced path smoothness, generating paths that are not only shorter but also more natural, reducing sharp turns and unnecessary path backtracking.

In practical applications, this performance improvement is of great significance in fields such as robot navigation and autonomous driving. Shorter paths and faster planning times mean that robots can respond more quickly to environmental changes, thereby improving the overall efficiency and safety of the system. Therefore, the application prospects of the improved algorithm are broad and worthy of further exploration and promotion in future research.

4. Conclusion

In this study, we compared the performance of the traditional RRT*-connect algorithm with the improved algorithm in terms of path length and planning time. The results indicate that the improved algorithm shows significant enhancements in both key metrics, with an average path length reduction of 11.19% and an average planning time reduction of 37.09%. These results not only validate the effectiveness of the improved algorithm but also demonstrate its potential for application in complex environments. This is primarily attributed to the following improvements:

1. The use of an elliptical sampling domain, which better adapts to the distribution of environmental obstacles and enhances the search efficiency of the algorithm.
2. The introduction of an adaptive compensation expansion strategy that dynamically adjusts the expansion step size, accelerating the search speed of the algorithm.
3. The combination of a greedy algorithm with the improved RRT*-Connect algorithm, which further optimizes the generated paths.

In summary, the improved algorithm exhibits good performance in the field of path planning and has broad application prospects. Future research can further explore the adaptability and optimization potential of this algorithm in different scenarios to promote its implementation in practical applications such as robot navigation and autonomous driving.

Based on the above simulation analysis, the air provided by the air conditioner can cover the whole room, and the air supply by the air conditioner can meet the comfort of indoor personnel.

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Authors Introduction

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