ISSN: 2414-1895 DOI: 10.6919/ICJE.202405_10(5).0029

Simulation Study on Mobile Robot Obstacle Avoidance and Path Planning based on Unity3D

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Abstract

This study used Unity3D to develop a simulation system for obstacle avoidance and path planning in mobile robots, based on an improved RRT algorithm, combined with the artificial potential field method. Modeling the environment through Maya, Blender, Unity TerrainTools, and other tools, including obstacles, starts, and ends. The improved RRT algorithm introduces the artificial potential field to make the robot have the autonomous obstacle avoidance ability, and improves the path planning speed, efficiency and path smoothness. Compared with the traditional RRT algorithm shows that the improved algorithm is superior in path planning. The research innovation lies in the improvement of the RRT algorithm, combined with the artificial potential field method to make up for the shortcomings of the traditional method, and has a wide application potential of autonomous obstacle avoidance and path planning.

Keywords

Mobile Robot; Unity3D; RRT; Obstacle Avoidance; Path Planning.

1. Introduction

With the rapid development of robotics technology, mobile robot has become a key application in industrial manufacturing, logistics, agriculture, medical assistance, service and other fields. In these scenarios, the ability to avoid obstacles and path planning is crucial in order to ensure that mobile robots can complete the task safely and efficiently. Therefore, the study of obstacle avoidance and path planning of mobile robots not only has important theoretical value, but also plays an important role in practical application.

This paper aims to explore the simulation of obstacle avoidance and path planning in mobile robots based on Unity3D[1]. Based on the traditional fast random search tree (RRT) algorithm, we analyze the advantages and disadvantages of the existing RRT path planning algorithm. Subsequently, visual simulation using Unity3D simulation engine to verify the effectiveness of the proposed method. This research not only helps to promote the development of the theory, but also provides a strong support for the obstacle avoidance and path planning of mobile robots in the practical application.

2. Overall System Design

2.1 Design Principle

This design uses Unity3D as the simulation engine and uses C # to control the movement of the robot in the movement and algorithm execution in the Unity scenario. Unity is a cross-platform 3D simulation engine, widely used in games, virtual reality, architectural design and other fields. It is easy to use, powerful to use and easy to expand. In terms of robot simulation, Unity provides powerful functions and plug-in support, including physical engine simulation of robot motion, collision and friction effects, as well as plug-in support of robot mechanical arm motion and sensor simulation.

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Based on the traditional Rapidly Exploring Random Trees (RRT) algorithm, this paper is improved. The RRT algorithm performs path search through random sampling and tree structure, but may produce local optimal solutions and cannot search for the best path globally. To solve this problem, an artificial potential field is introduced to increase the target attraction while avoiding obstacles and achieve a more global search.

The core idea of the algorithm is to influence the sampling point by introducing the artificial potential field force, increase the probability of the tree structure growing towards the target point, and at the same time, generate repulsion force when encountering obstacles to avoid collision. During execution, a point is randomly generated, and the nearest tree node is found, and the tree is extended in the direction of the line between that node and the sampling point, until the target point is generated. According to the introduced artificial potential field force, the distance and direction of the tree node to the sampling point are calculated to update the node state, and finally get the optimal path from the starting point to the target point on the tree structure.

2.2 Overall Framework Design

First, the robot scene is designed in Unity, including the starting point, end point and possible obstacles, and the scene is constructed using the simple geometry provided by Unity. At the same time, design a model for the robot to display the movement trajectory in the scene. As shown in Figure Figure 1.

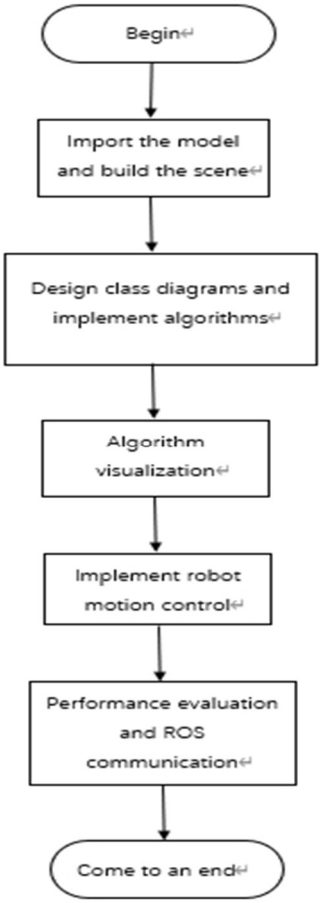

Figure 1. Design principle

C # and collision avoidance and trajectory visualization with the Unity physics engine. The robot control needs to realize the path motion generated according to the algorithm, and update the robot status information.

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The RRT algorithm is used to implement path planning, and the tree is constructed by randomly generating points in the scene to search the path from the starting point to the end point. Based on the RRT algorithm, the artificial potential field method is introduced to reduce the useless nodes and improve the search efficiency. Improve the system ease of use and performance by adding interactive interface, adding debugging information and conducting performance optimization, such as adding control buttons, displaying path planning results, and improving operation efficiency.

Finally, communicate with the ROS system through the interface supported by Unity, or export the C # source code as a dynamic library available in the C / C + + environment, connect the algorithm with the mature mobile robot technology, and provide path planning technical support for the mobile robots.

3. Principles of the Algorithm Design

3.1 RRT Algorithm Basis

The traditional Rapidly Exploring Random Trees (RRT) algorithm performs path search through random sampling and tree structure. In our system, it is used to build the tree structure, starting from the starting point and continuously expanding the nodes of the tree until the target point is reached. However, due to the characteristics of the RRT algorithm [3], it may lead to local optimal solutions, and it is difficult to search for the optimal path globally.[3]

3.2 Introduction of the Artificial Potential Field Method

To compensate for the shortcomings of the traditional RRT algorithms, we introduce the artificial potential field method. The artificial potential field method transforms the distance between the robot and the obstacle into potential [2] by simulating the interaction between the robot and obstacles. In this way, the robot has the ability to avoid obstacles, and the algorithm can search for paths more globally.[2]

3.3 Algorithm Execution Process

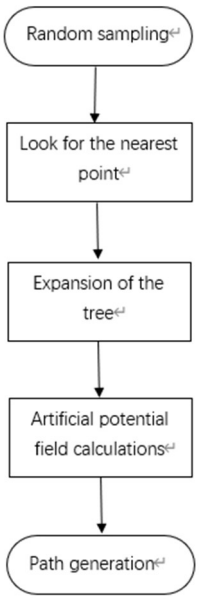

Figure 2. Algorithm execution flowchart

Our algorithm design studies the problem of obstacle avoidance and path planning in mobile robot, and realizes intelligent navigation in complex environment by innovatively integrating the traditional Rapidly Exploring Random Trees (RRT) algorithm and artificial potential field method. First, sampling points are randomly generated in a random space, and subsequently the node in the tree nearest to that sampling point is found as the extended starting point of the current tree. During the

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tree extension, we consider the influence of introducing artificial potential field forces to improve obstacle avoidance. The node state is updated according to the introduced artificial potential field force by calculating the distance and direction of the tree node to the sampling point. Finally, we obtain the optimal path from the starting point to the target point on the tree structure. This algorithm design principle provides a comprehensive and efficient autonomous obstacle avoidance and path planning solution for mobile robots, and provides important support for the intelligent navigation of robots in practical application. As shown in Figure Figure 2.

4. Unity3D Simulation Implementation

In the Unity3D simulation implementation, the primary task is to build the simulation environment of the robot through the scene design and modeling, including the starting point, the end point, and the possible obstacles. With Unity's simple geometry and model creation tool [4], we can easily build a simulation scenario that truly reflects the background of the robot task.[4]

Second, we wrote the robot motion control script through C # to realize the motion of the robot in the Unity scenario. By integrating Unity's physics engine, we simulate the motion trajectory of the robot while implementing the RRT algorithm in the script, including random sampling, finding the nearest nodes, tree extension, artificial potential field calculation, and path generation. This allows us to test and optimize our path planning algorithm in a simulation environment.

[5]Finally, we visualize the simulation effects through Unity's rendering engine, and show the robot's motion trajectory, path planning results, and environmental obstacles and information [5]. To improve the ease of use of the system, we can also add the function of interactive interface and debugging information, as well as ensure the smooth operation of the system through performance optimization. Finally, through the interface supported by Unity, we are able to communicate with ROS systems and provide path planning technical support for mobile robots.

5. Conclusion

This study is deeply explored in the field of mobile robot path planning, which provides a useful reference for the future development of mobile robots. We focus on RRT algorithm path planning fusing artificial potential field in Unity to improve the search efficiency, obtain better path solutions, and realize the robot autonomous motion control in the simulation environment. The study work included the following aspects:

First, we introduce the principle of the traditional RRT algorithm, point out its shortcomings, and discuss the improvement scheme, especially the improvement based on the artificial potential field algorithm.

Secondly, the basic concepts of Unity3D and C # language are introduced in detail, the overall structure of the algorithm simulation system is designed, the execution process of the algorithm is shown through the visualization tool, and the linear interpolation and spherical interpolation methods are adopted to realize the movement control of the robot. At the same time, the communication with the ROS system is realized through the ROS-TCP-Connector, providing support for the mature mobile robot technology.

Finally, Unity3D is used as the simulation engine to improve the traditional RRT algorithm and solve the artificial potential field method. Implement visualization of the algorithm, movement control of the robot and data communication with the ROS system. The performance evaluation shows that the improved algorithm avoids the problem of blindness and randomness of traditional RRT, effectively reduces useless nodes and improves the practicability of the algorithm.

Overall, the implementation of RRT algorithm path planning integrated with artificial potential field in Unity3D is useful for robot motion control research. With the continuous evolution of mobile robotics technology, this study provides a path planning simulation framework based on Unity3D,

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laying a foundation for future research on mobile robotics technology under more complex environments and dynamic obstacles.

Acknowledgments

Fund Project: 2024 Liaoning Institute of Science and Technology College Students Innovation and Entrepreneurship Project :Big innovation project of LiaoNing Institute of Science And Technology and Technology Simulation of RRT path planning for artificial potential fields, project number: 20241143007.

Fund Project: 2023 Liaoning Institute of Science and Technology College Students Innovation and Entrepreneurship Project: Design of intelligent disinfection robot in public places based on automatic navigation technology project number : 202311430018.

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