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MOBILE ROBOT MISSION PLANNING TEACHING PROJECT DESIGN

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Abstract— **Comprehensive design teaching projects are an important part of cultivating applied innovative talents. This paper studies the simulation of mobile robot mission planning algorithms, designs an experimental system in the actual environment through the ROS platform, and develops a new comprehensive design teaching project by combining algorithm research, robot control, SLAM mapping, etc. This teaching project provides a new way and platform for students to carry out independent learning, independent experiments, innovative practice and other activities, and can be applied to the simulation and verification of mobile robot mission planning algorithms in multiple scenarios, thereby training students to solve complex engineering problems ability.**

Keywords— **MATLAB, Mission Planning, Simulation, ROS Platform**

I. INTRODUCTION

With the development of science and technology, mobile robots have been widely used in many fields, such as driver-less driving, smart cities, aerospace, etc. Path planning is one of the key technologies for mobile robots to achieve autonomous movement. It directly affects the robot's movement efficiency, safety and autonomy, and has high research and teaching value.

Path planning algorithms [1] have the characteristics of various types, strong theoretical basis, and fast knowledge updating. How to enable students to understand the algorithm more intuitively and apply it to actual robots is a focus and difficulty in teaching project design. This paper designs a mobile robot task planning teaching innovation project based on the ROS robot platform [2] to allow students to carry out teaching activities such as independent learning, independent experiments, innovative practice, and professional design.

II. TEACHING PROJECT DESIGN

2.1 Main content of the study

This experiment constructed a grid map of the robot's cleaning area and monitored the movement of the sweeping robot in real time. Convert the grid model into an obstacle matrix. The different values in the matrix represent whether the grid is an obstacle. In the grid map, the black grid represents obstacles and the white grid represents the passable area. Starting from any grid on the border of the grid map, full coverage cleaning is performed and the cleaning position is recorded. The area cleaned for the first time is colored blue. Grid recording, the area cleaned twice is recorded with red grid.

When the full-coverage cleaning is completed, the robot plans a feasible path (indicated in light green) from the cleaning end position (indicated in light green) and returns to the charging location (indicated in dark green). In order to facilitate simulation, assumptions are made for the model in the system: (1) the sweeping robot moves forward at a constant speed; (2) the sweeping robot can only turn 90°; (3) the sweeping robot's own position and cleaning environment are known; (4) the sweeping robot can Clean the area of your own area.

2.2 Design core algorithms

In order for the sweeping robot to avoid all obstacles in the cleaning environment and travel through all feasible areas, the design uses a depth-first search algorithm to plan a full-coverage sweeping path for the sweeping robot and record the position where the cleaning ends. Finally, the ant colony algorithm is used to plan the shortest path for the sweeping robot from the cleaning end position back to the charging position.

2.2.1 Ant Colony Algorithm

Ant colony algorithm[3][4] is a large-scale, random heuristic search algorithm[5].

This algorithm simulates the process of an ant colony foraging for food and returning to its nest. Taking the ant colony's nest as the starting point and the food location as the end point,each ant explores different routes by avoiding obstacles, and gives these paths a certain concentration of pheromones, finally plan an optimal obstacle avoidance path.

In the early stage of the algorithm, ants will aimlessly explore the next node and leave a certain concentration of pheromones on the path they have traveled to attract other ants to walk along this path. The random selection probability of ant k from the current position i to the next candidate node j at time t is shown in formula (1):

$$p_{ij}^{k}(t)=\begin{cases}\dfrac{[\tau_{ij}(t)]^{\alpha} * [\eta_{ij}(t)]^{\beta}}{\sum\limits_{s\in allowed_k}[\tau_{ij}(t)]^{\alpha} * [\eta_{ij}(t)]^{\beta}}, & j\in allowed_k \\ 0, & j\notin allowed_k\end{cases} \quad (1)$$

In the formula: $\tau_{ij}(t)$ is time t.

Pheromone concentration on path i to j:$\eta_{ij}(t)=1/d_{ij}$, d_{ij} is the Euclidean distance from path i to j;$\alpha$and β are the pheromone elicitation factor and the expectation elicitation factor respectively; $j\in allowed_k$ is the set of grids to be selected.

During the continuous iteration of the algorithm, ants will continue to traverse the grid and accumulate pheromones. In order to ensure the overall operating efficiency, the pheromone concentration on the path needs to be updated for the ants that have completed the path planning. As shown in formulas (2) and (3):

$$\tau_{ij}(t+1)=(1-\rho)\tau_{ij}(t)+\sum_{k=1}^{m}\Delta\tau_{ij}^{k} \quad (2)$$

$$\Delta\tau_{ij}^{k}(t)=\begin{cases}\dfrac{Q}{l_k}, \text{ant k passes by}(i,j) \\ 0, \text{not passed}\end{cases} \quad (3)$$

In the formula: ρ ($0<\rho<1$)is the pheromone volatilization factor; τ_{ij} is the pheromone concentration between nodes i and j; m is the number of ants; Q is the pheromone intensity; I_k is the path length.

The depth-first search algorithm and the ant colony algorithm are integrated to realize the function of full coverage cleaning and returning to the charging position of the sweeping robot. The program flow chart is shown in Figure 1.

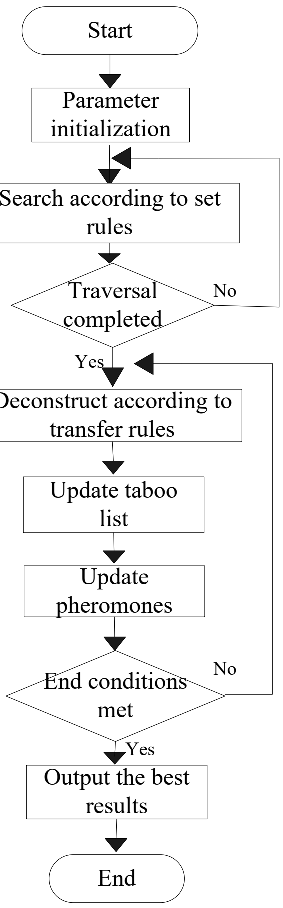


Fig. 1. Program flow chart

2.2.2 Ant Colony Algorithm

Depth-First Search (DFS) is one of the graph search methods[6][7]. The idea of depth-first search: assuming that the initial state is that all vertices in the graph have not been visited, starting from a certain point, visit that point first, and then start a depth-first search to traverse all points in the graph starting from each of its unvisited adjacent points, until all vertices in the graph that have paths connected to the starting point have been visited. If there are other points that have not been visited at this time, select another unvisited point as the starting point, and repeat the above process until all points in the graph have been visited. The essence of deep search first search is continuous search. After traversing all possible situations, the solution will definitely be obtained. The process of the DFS algorithm is in the form of a tree. Each time a path reaches black, the steps of the DFS algorithm are as follows:

(1) All nodes in the initialization graph have not been visited.
(2) Starting from a certain node v in the graph, visit v and mark it as visited.
(3) Check all adjacent points w of v in turn. If w has not been visited, perform a depth-first traversal starting from w (recursive call, repeat steps (2) and (3) until all nodes are traversed).

The DFS algorithm flow is shown in Figure 2.

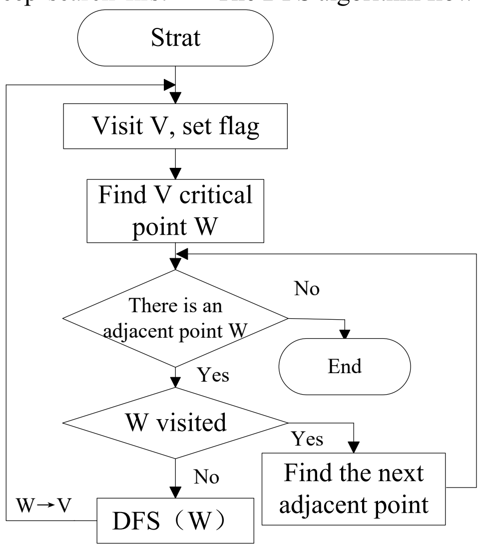
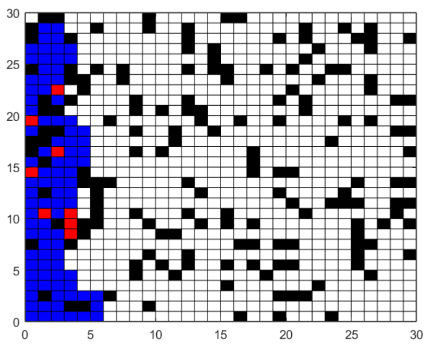


Fig. 2. DFS algorithm flow chart

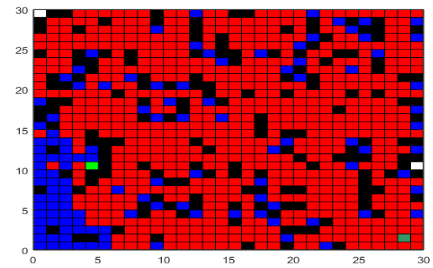
III.EXPERIMENTAL SYSTEM IMPLEMENTATION

3.1 2D Plane Simulation

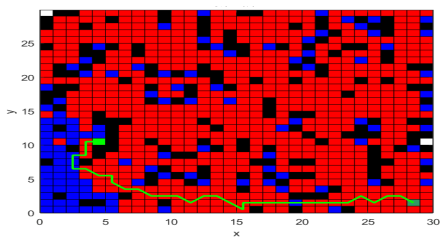
Set a 30×30 grid area as the cleaning environment of the sweeping robot. Set the side length of the grid to 1 and the area of the sweeping robot to 1. The sweeping robot plans a collision-free full coverage path in this grid area and an optimal path back to the charging position. The simulation results are shown in Figure 3:



(a)



(b)



(c)

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Fig. 3. (a) The early days of robot sweeping （b） The robot completes the overall sweeping （c） The robot successfully planned the return path

3.2 3D space simulation

Set up a 30×30 cleaning area and conduct a three-dimensional simulation model of the laboratory layout. The taller black combination is regarded as a desk, the lower black combination is regarded as a seat, and the x-y plane they cover is regarded as an obstacle. The uncovered area is considered a passable cleaning area, as shown in Figure 4. Set the cleaning area of the sweeping robot to 1, the grid side length to 1, and set the starting point to (1, 1, 0). The grids cleaned once are represented by yellow, and the grids cleaned twice are represented by blue. The light green grid is the end position of the robot after cleaning, and the dark green grid is the final target point that the robot needs to reach, as shown in Figure 5. MATLAB R2021b software was used to conduct experimental simulations on the two-dimensional plane and the three-dimensional simulation space respectively, making the experimental results clear and proving the feasibility of the design scheme to a certain extent.

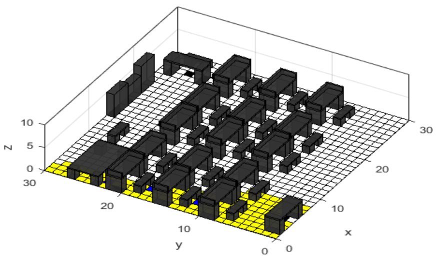
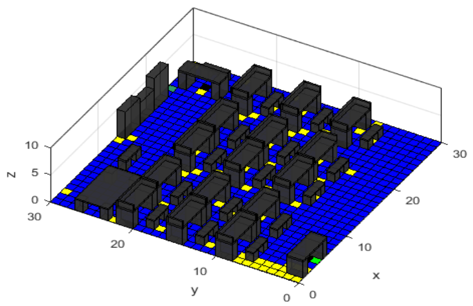
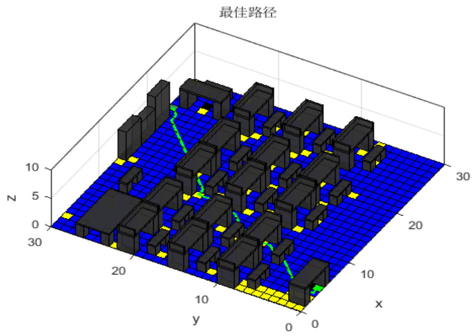


Fig.4. 3D space simulation modeling



（a）



（b）

Fig. 5. （a） The robot completes the overall sweeping （b） The robot successfully planned the return path

3.3 ROS robot platform experiment

In order to further verify the feasibility of system design and experimental simulation, application experiments in actual environments were conducted through the ROS platform. The selected mobile robot platform is shown in Figure 6, which includes core hardware such as OpenCR controller, Raspberry Pi 3 development board, LDS (HLS-LFCD2) laser radar. Among them, the Raspberry Pi is installed with the Ubuntu mate system and the ROS (kinetic) environment is installed based on this system. The Ubuntu16.04 system is installed on the remote computer, and the running environment is ROS (kinetic).

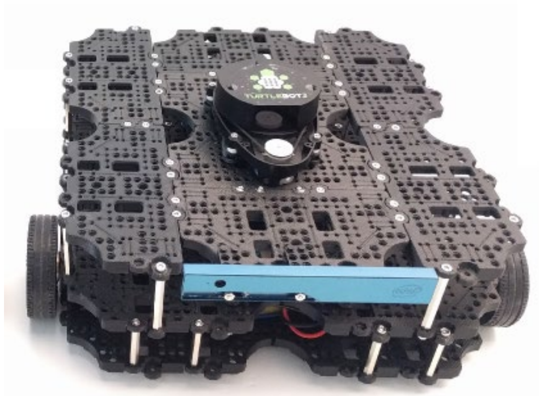


Fig. 6. move robot

After the mobile robot and the remote computer are connected through network configuration, map modeling is performed by controlling the robot to move repeatedly and using the Gmapping algorithm and Rviz visualization tool for real-time monitoring. The actual application scenario is shown in Figure 7, and the map modeling is shown in Figure 8.

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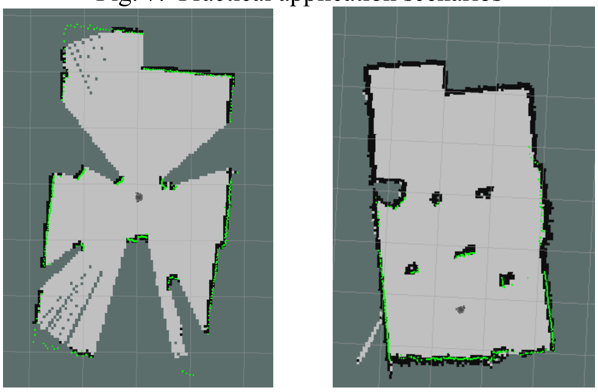
Fig. 7. Practical application scenarios



(a) (b)

Fig. 8. (a) Early stage of mapping (b) End of mapping

Add map information, robot model and path planning information through the Rviz visualization tool, and use the 2D Nav Goal function to set the robot's final end point and posture.The robot's planned path can be obtained as shown in Figure 9.

Through experiments on the ROS robot platform, further support is provided for the practical applicability of the design scheme. In the overall design, students comprehensively applied the knowledge they learned and designed system solutions by reading a large amount of literature and collaborating with others. They also used Matlab software simulation and ROS platform physical experiments for theoretical verification, and finally successfully realized the design requirements, It perfectly embodies the teaching idea of combining theory and practice and improves students' ability to solve complex engineering problems.

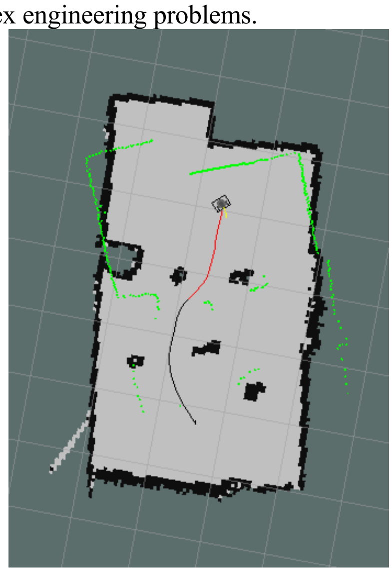


Fig. 9. Path planning results

IV. TEACHING PROJECTS AND ABILITY DEVELOPMENT

Through the above teaching project design, the following teaching projects can be carried out in sequence, so that students can carry out independent learning, independent experimentation and innovative practice through thematic design and comprehensive design. The mobile robot path planning and design project improves students' independent learning ability, cultivates students' rigorous scientific research attitude and their ability to solve practical complex engineering problems.

Table -1 Mobile robot path planning and design teaching project

Project	Teaching projects	Content and ability development
1	ROS introductory experiment	Learn the communication mechanism of ROS, master the ROS file system and related programming
2	Mobile robot motion control	Learn mobile robot control models, robot motion control methods and related programming
3	Mobile robot	Master the mobile robot

	SLAM mapping	SLAM mapping method and the use of related software tools
4	Mobile robot mission planning	Carry out simulation research on mobile robot task planning algorithms, construct SLAM maps, and implement ROS robot task planning.

V. CONCLUSION

The mobile robot mission planning teaching project has designed multiple links, from ROS introduction to robot control, to sensor use, SLAM mapping, and finally formed a comprehensive design project for robot mission planning research. Through practical training in teaching projects, we stimulate students' innovative thinking and help them apply what they learn in the classroom to solve practical problems. At the same time, we cultivate students' ability to integrate multiple disciplines and encourage them to work together with their peers to continuously raise and solve problems, thereby strengthening their ability to deal with complex engineering problems such as algorithm programming. Through this series of training, students can not only meet the teaching requirements, but also form a rigorous scientific research attitude, improve their ability to learn independently, and also achieve the improvement of students' innovation ability and comprehensive quality, laying a solid foundation for their future development.

VI. ACKNOWLEDGEMENT

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