Assignment 2 Executive Summary

This executive summary highlights the key points in Assignment 2's work. The flat exploration robot, designed for the first mission, carefully constructed a world of pavilions that represented the interior space, complete with appropriate sensors. Then, through Gazebo and Rviz, the flat exploration robot autonomously navigated complex indoor environments, mapped the world, and successfully recognized and photographed human avatars. Figure 1 shows the car running in the world I created, with a camera shot in the small window next to it. Rviz shows what the robot thinks is happening, while Gazebo shows what is actually happening.

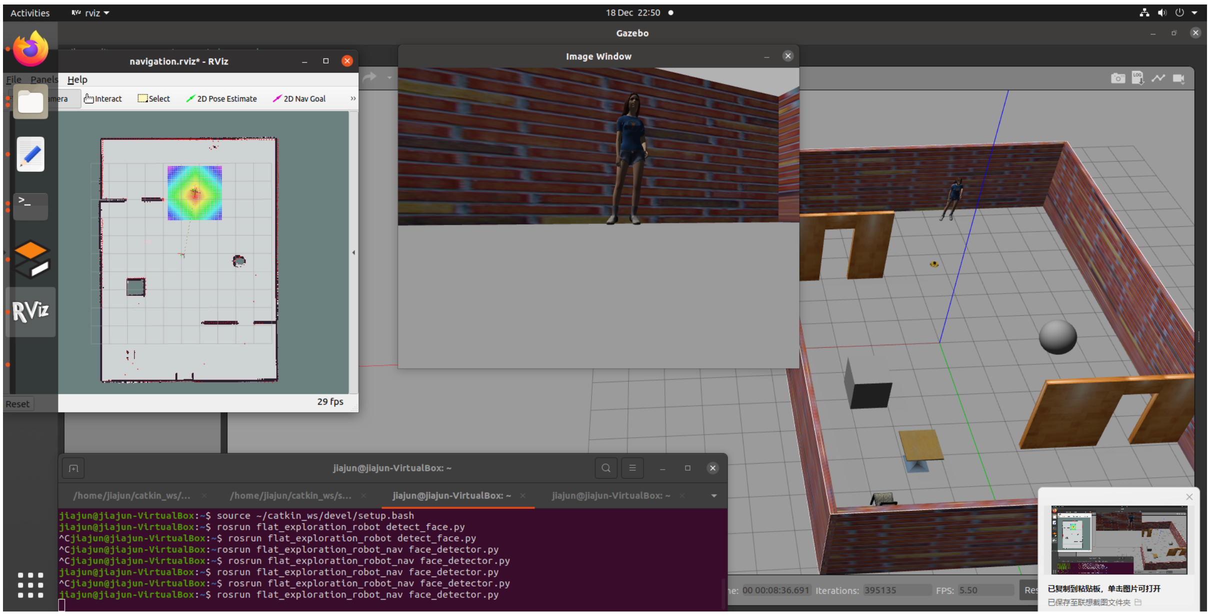

Figure 1

1. World Design

It is clear from Figure 1 that the world created is an enclosed interior space consisting of six walls, two doors and two Windows with a chair, a coffee table, a bookshelf, a sphere and a cube. It is also noteworthy that there is a female human model, make sure to select Low-poly eyes when creating, and select scale units as meters when exporting. The first part of the appendix on the creation of human models is further explained. The starting position of the robot is in the middle of the whole world so that the robot can navigate to the target.

2. Sensor selection and robot modification

The flat exploration robot designed for the first assignment included a camera and an ultrasonic sensor, considering that for complex environments, LiDAR can better detect and map the surrounding space, providing higher performance and reliability. Compared to the original URDF file, a virtual "base_footprint" Link has been added to meet some of the conventions of ROS, which represents the projection of the robot body coordinate "base_link" to the ground. At the same time, a new xacro and gazebo.xacro file were created to simplify the code. While the original urdf file defined a static model of the robot without any dynamic behavior or physical properties, the xacro file added the link and joint of Laser to the contents of the urdf file. The code associated with the simulation is placed in the gazebo.xacro file, which adds simulation properties to the robot model, such as material properties, sensor configurations, and differential drive controllers to control the behavior of the robot in the simulation. When processed, the Xacro file generates an URDF file, which is then used by ROS or Gazebo.

3. Autonomous navigation

The Laser sensor facilitates SLAM and map generation. By using gmapping to transcribe the indoor environment into .map files for accurate robot positioning and motion planning within Rviz. Using the gmapping package, the robot begins a preliminary exploration mission to scan the entire interior space, create a preliminary map through SLAM, and refine it each time the robot moves through the environment. After obtaining the map, ROS navigation stack is used to give a target point in Rviz, and you can see the path planned by the robot and reach the target position by avoiding obstacles through autonomous navigation. Multiple launch files are used in this section, which are further described in the appendix.

4. Face detection

The face detection system utilizes camera sensors mounted on the robot, as well as OpenCV-based algorithms to recognize and capture the face of a human avatar. Write a ROS node to subscribe to camera topics and use OpenCV for face detection. The ROS package creates a Python script that uses a Haar features-based classifier provided by OpenCV that can be used to detect faces in images. Run the script after the script is executable through the command, and the script will display the image in an OpenCV window when the face is detected and draw a rectangular box in the corresponding position.

5. Discussion and reflection

Firstly, launch SLAM by using gmapping algorithm. In the simulation environment, the mapping area in Rviz changes with the movement of the robot. After the car scans the whole world and saves the map, the fidelity of the generated map is crucial. To this end, a large number of test runs were conducted to ensure the accuracy of the robot's positioning and the robustness of the map. Before the navigation stack test, the starting position of the car may occasionally be biased, and the initial Pose of the car is adjusted by 2D Pose Estimate to be consistent with the map. Although the robot's performance in map generation and autonomous navigation was satisfactory, several limitations and room for improvement were revealed during the experiment. For the mapping of indoor Spaces, the choice of LIDAR sensors proves the importance of their accuracy in creating high-fidelity maps, especially for detailed scenes in indoor environments. However, in the face of reflective surfaces and sparse feature areas, we recognize that a single sensor may not be sufficient to fully capture environmental detail, and in the future it may be necessary to consider integrating multiple sensing technologies to optimize the map generation process.

Regarding the autonomous navigation of the robot, in the scenario of testing the robot navigation, it showed the ability to reach the specified target point, and the navigation stack performed well in path planning, obstacle avoidance and adaptive re-planning, and the ability of the robot to re-plan to reach the target in time when it encountered obstacles. However, robots sometimes exhibit problems of over-rotation and inaccurate positioning in complex environments, indicating that TF transformation and further optimization of navigation parameters are necessary, especially considering how the initial positioning of robots affects subsequent navigation accuracy.

In terms of face detection, our system can only successfully recognize faces in a few cases, considering that the camera position may be too low, or the face light of the character is too dark, especially in some conditions and the environment of large robot mobility, the performance of the system will be limited, resulting in false detection or missing detection, we need to further optimize our computer vision system. The navigation stack proved adept at path planning and replanning in response to obstacles, although some limitations were observed in small Spaces. When the robot kept a moderate distance from the virtual character, the face detection was always successful, and the accuracy of the detection was inversely proportional to the distance of the virtual character.

6. Conclusion

To sum up, with a properly designed indoor environment and a powerful sensor suite, robots can navigate autonomously and perform complex tasks such as face detection. The key to success is a well-defined SLAM process, a powerful test scenario, and a multifunctional face detection algorithm. And through further research and experiments, it is expected to improve the robot's navigation performance in the indoor environment, and enhance its perception and interaction ability in the complex world.