SLAM based vision self-navigation robot with RTAB-MAP algorithm

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Abstract. The classic 2D SLAM are not good enough in nowadays environment. This report uses virtual machine with Ubuntu based Slam_bot package, based on the RTAB-MAP algorithm and Vision SLAM mapping to simulate the four-wheeled robot to autonomously navigate to the target point in various environments. Also, this report introduces a RGBD-SLAM based algorithm which combines the visual and depth data to process the data collect from the sensors. This robot has many sensors like, lidar sensors, RGB vision camera and odometry sensors. To see how the RTAB-MAP algorithm with RGB-D sensor replace for the 2D SALM. As results, the robot with RGB-D and RTAB-MAP algorithms have very good performance. The results show that the navigation system can complete the navigation and localization in lots of complex situations. However, some problems still exist, the speed of the robot is not fast. This may limit the application of the self-navigation robot to a certain extent, like some emergency occasion.

Keywords: RTAB-MAP, RGB-D sensor, SLAM, Self-navigation.

1. Introduction

In decades, autonomous navigation robots are a hot research topic, more and more researchers begin to do research on the mapping and self-navigation robots in unknow environments [1], and such robots can be widely used in unmanned transportation logistics. With the leading of the Tesla's research and developments, most of the car manufacturers are rushing to develop autonomous navigation vehicles, of which Simulation Localization and Mapping (SLAM) technology is widely used in autonomous navigation vehicles. The SLAM is based on the ROS, Robotics software is created using the incredibly flexible ROS software architecture [2]. Furthermore, the SLAM can be used in many areas like, construction sites, big warehouses, in the transportations and urban cites. In large-scale situations, reliable and computationally effective localization has been made possible by 2D SLAM and localization algorithms [3]. The basic 2D-SLAM can only solve some fundamental problems such as the 2D lidar-based SLAM [4]. The next wave of robotics applications will only be possible with reliable and established methods that rely on RGB-D sensors and cameras that are reasonably inexpensive [5]. This report will use virtual machine to simulate the autonomous navigation in various environments with RTAB-MAP algorithm and intelligent inspection to see the performance of this method.

2. The construction of the robot

To simulate a virtual four-wheeled robot (Figure 1-2), the chassis is the x-y plane coordinate system, the centre of the chassis is the origin of the coordinate system, and the head direction of the car is x. The coordinate system of the four wheels has the same direction as that of the chassis and the origin of the wheels are just their wheel axis. The four-wheeled car robot is equipped with a lidar and an RGB-D camera in the middle.
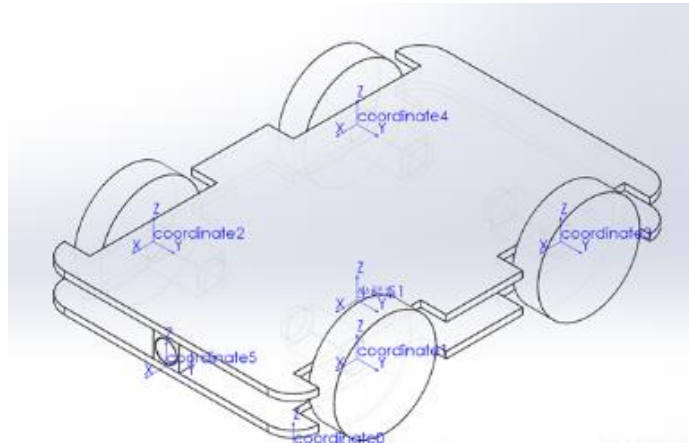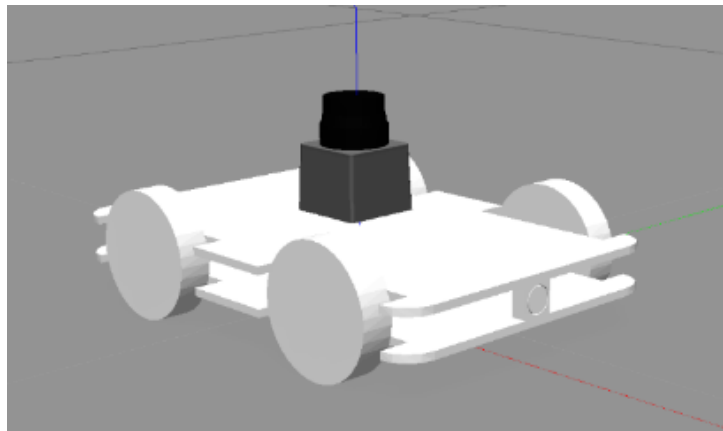

Figure 1. Robot model.

Figure 2. Robot Model in Simulation Environment.

3. Method

3.1. RTAB-MAP

The Real-time appearance-based mapping (RTAB-Map) are used in this report [6]. It was initially launched in 2013, and maintenance and support are still ongoing. [7]. It includes a broad range of input sensors, such as stereo, RGB-D, and fisheye cameras as well as odometry and 2D/3D lidar data. The Robot Operating System (ROS) has long included RTAB-Map as an alternative to 2D SLAM [3]. The RGB-D graph-based SLAM approach is used in this report, and it is also a loop closure detection, which means the in the short time the loop closure approach can help the robot to process in long-term and big scale environments. The three components of the RTAB-MAP approach are sensor measurement, the front end, and the back end. In the frontend step, geometric characteristics are taken from the subsequent picture frames once the sensor data has been processed. Odometry estimation is therefore carried out in

the frontend stage, while the backend is focused on finding a solution to the drift detection issue. Finally, RTAB-Map creates 3D maps using the g2o technique [8]. The RGB-D is built on the SLAM frame [9].

3.2. BA RGB-D algorithm

By reducing the 2D re-projection inaccuracy in the keyframes, BA improves the camera postures and the 3D points they saw. The local BA cost function is given by [10]:

$$\varepsilon_{\text{visual}}\left(\{P_j\}_{j=0}^{N_c}, \{Q_i\}_{i=0}^{N_p}\right) = \sum_{i=0}^{N_p}\sum_{j\in Ai}\left(q_{i,j} - \pi(K\,P_j\,Q_i)\right) \tag{1}$$

$\varepsilon_{\text{visual}}$: 2D error
N_c: pose of the latest cameras
N_p: 3D points Observed
P_j : pose of frame j
$q_{i,j}$: the observation of 3D point Q_i

A_i represents the collection of keyframe indices that Q_i

With the ($j \in A_i, k \neq j$), 2D projection error of each frame j in which the reconstructed 3D point Q_i occurs [10]. This is the cost function:

$$\varepsilon_{depth}\left(\{P_j\}_{j=0}^{N_c}\right) = \sum_{i=0}^{N_p}\sum_{j\in Ai}\sum_{k\in Ai}^{k\neq j}\left(q_{i,j} - \pi\left(K\,P_j\,P_k^{-1}\pi^{-1}\left(q_{i,k}, d_{i,k}\right)\right)\right) \tag{2}$$

K: camera calibration matrix
$q_{i,k}$: the observation of the frame $k's$ 3D points Q_i
$d_{i,k}$: depth

As a result, the total error reduced in RGBD-BA SLAM's may be summed up as follows: [10]:

$$\varepsilon_{visual.depth} = \varepsilon_{visual} + \varepsilon_{depth} \tag{3}$$

4. Environment for Experiments

In order to better and more comprehensively evaluate the navigation system, this paper has carried out simulation verification, such as real experimental scenarios. The simulation tool selects the terrace simulation platform of ROS to build different types of warehouse simulation. The simulation uses a turtle robot, and the laser radar is a single line laser radar. Computer CPU is Intel (R) core (TM) i5-10210u CPU@1.60ghz The Ubuntu version is 18.04, and the ROS version is medic.

The simulation environment is shown in Figure 2. The construction drawing under Scenario Figure 1 (c) is shown in Figure a, the global planning in Figures B and c is shown in the red line, and the local planning is shown in the blue line. It can well implement global and local planning. Two-point repeated accuracy test: in the real scene, the online speed of the machine is 1m/s, and the angular speed is 1.5rad/s. Set the position coordinates of the initial robot as (0, 0, 0), and the coordinates of some endpoints are shown in Table 1. A total of 50 groups are selected. The average error of X and Y is less than 2cm, and the angle is less than 0.1 radian, reaching a high level. Multipoint patrol analysis: in order to test the navigation accuracy performance under the actual application state, conduct multi-point repeated accuracy test, that is, continuous multi-point navigation and circulation. Select four lines in turn, and use six point coordinates to navigate each line. In the multi-point repeated navigation accuracy test, the distance error is less than 3cm, θ The error is less than 0.1 rad. Meet the navigation requirements of the logistics robot in the warehouse environment.
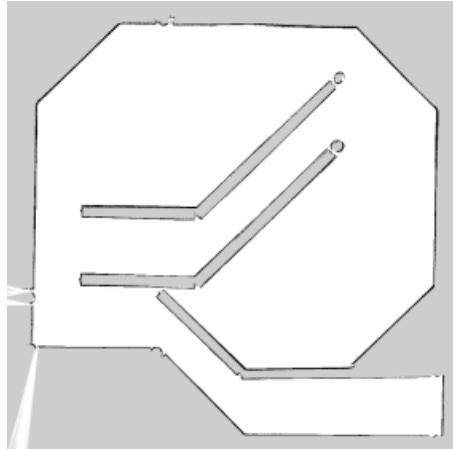
(a) scene map.
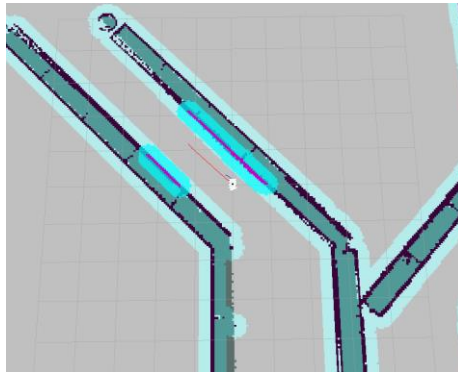
(b) navigation map.
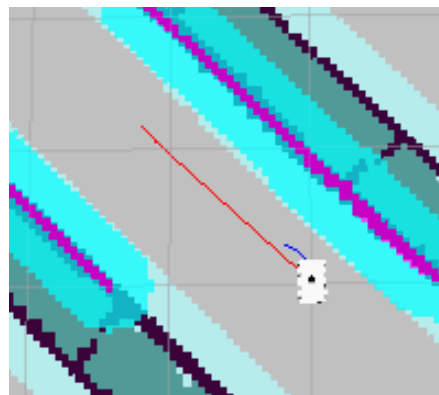
(c) navigation enlarged map.

Figure 3. Path planning diagram.

Table 1. Partial navigation coordinates.

Initial coordinates	Set end coordinates	Actual arrival coordinates	X error	Y error	Angular error
（0,0,0）	(3,3,3.14)	(2.99,3,3.13)	0.01	0	0.01
(0,0,0)	（6,6,3.14）	(5.98,5.99,3.14)	0.02	0.01	0
(0,0,0)	(9,9,3.14)	(9,8.98,3.12)	0	0.02	0.02
(3,3,0)	(0,0,3.14)	(0.01,0.01,3.13)	0.01	0.01	0.01

5. Conclusion

The application of intelligent inspection robot can improve the efficiency of production and living operations. In this paper, a high precision navigation system integrating multi-sensor information is designed for practical complex scenes. In order to better evaluate the navigation performance, simulation and real scene experiments are carried out at the same time. The results show that the navigation system can complete the navigation and positioning of complex scenes, which provides a new idea for robot navigation and has important application significance. However, it is found in the experiment that the performance of feature matching is greatly reduced with the acceleration of the speed. How to realize high-speed navigation and positioning will be the focus and difficulty of future research.

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