Development of Mobile Robot SLAM Based on ROS

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***Abstract*—With the continuous development of intelligent robotics, intelligent robot can realize autonomous moving. Robot simultaneous localization and mapping technology arises at the historic moment. Adaptive monte carlo localization algorithm was used for mobile robot pose estimation. Bayesian algorithm was used to building grid map. The robot moving path was computed by the path planner algorithm. The mobile robot follows the path and realizes autonomous moving function. ROS platform was used for tracked mobile robot to realize the SLAM technology. Compared with conventional software development platform, ROS have strong focus on usability and ease of installation and have the advantages of free and open source. The experimental results demonstrated that ROS platform could greatly shorten the development cycle of the robot and the SLAM could easily realize on ROS, the robot can realize autonomous moving.**

***Index Terms*—ROS, SLAM, tracked mobile robot, path planner**

I. Introduction

With the fast development of robotic, there are more and more robots appear in field of cleaning and service. To do this, the intelligent robots required the capability location and mapping. There are lots of algorithms have been researched.

In [1], EKF is used to estimate position and motion information and FPGA is proposed to provide the matching process module with additional execution engines. In [2], a Simultaneous Localization and Mapping (SLAM) method based on Multi-Agent Particle Swarm Optimized Particle Filter (MAPSOPF) was presented by introducing the idea of multi-agent to the Particle Swarm Optimized Particle Filter (PSOPF). In [3], in this paper it presents Neuro-Evolutionary Opti-mization SLAM (NeoSLAM) a novel approach to SLAM. In [4], this paper focuses on the ability to recognize places based on image features. Successful experiments on autonomous navigation with the pro-posed map representation using an actual mobile robot are described. In [5], this paper presents a new feature initialization method for monocular EKF SLAM which utilizes a 3D measurement model in the camera frame rather than 2D pixel coordinates in the image plane. In [6], in this paper it showed that the estimated positions of the landmarks identified in the map created closely tallies with the actual positions of these landmarks in real-life. In [7], in this paper it describes the combined control and SLAM system and discuss in sights gained from its successful application in areal-world context. In [8], Measurement experiments in unknown and large indoor/outdoor environments including a large hall, a building, an urban district, and a cultural heritage have been successfully carried out using the newly developed measurement system consisting of three mobile robots named CPS-V. In [9], this paper proposes a novel approach to an RGB-D Simultaneous Localization and Mapping (SLAM) system that uses the vanishing point and door plates in a corridor environment simultaneously for navigation.

To sum up, in the navigation field of mobile robot, different researchers use different software development environment. For those reasons, it leads to the development codes can't apply more generally to other software platform or testing as well. In our work, we introduce the open source ROS. ROS (Robot Operating System) is a framework that is widely used in robotics. The philosophy is to make a piece of software that could work in other robots by making little changes in the code. What we get with this idea is to create functionalities that can be shared and used in other robots without much effort so that we do not reinvent the wheel.

II. Simultaneous Localization and Mapping

In this project the tracked mobile robot is used for the simultaneous location and mapping, the tracked robot just as the Fig. 1. The laser scan sensor is the main perception sensor of the robot. The core controller of the robot is PCM-3363, the CPU of the controller is Intel Atom D525 Dual Core 1.8 GHz, the controller for 1GB DDR3 800 MHz Memory and it is embed Ubuntu 12.04 system, ROS-fuerte is embedded on the Ubuntu system.

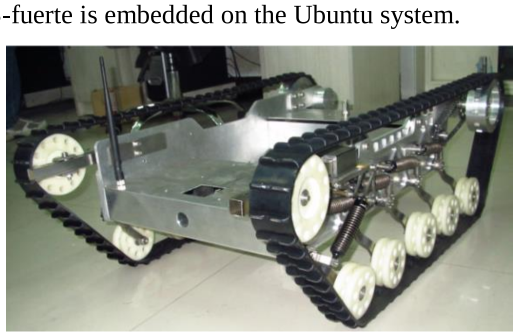

Figure 1. Tracked mobile robot

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A. *AMCL Location*

AMCL (Adaptive Monte Carlo Localization) algorithm is used for the mobile robot localization. AMCL is a probabilistic localization system for a robot moving in 2D. This system implements the adaptive Monte Carlo localization approach, which uses a particle filter to track the pose of a robot against a known map.

The AMCL node works mainly with laser scans and laser maps, but it could be extended to work with other sensor data, such as a sonar or stereo vision. The leaser scan is used in this project and URG-04LX-UG01 is a laser sensor for area scanning. The light source of the sensor is infrared laser of wavelength 785nm with laser class 1 safety. Scan area is 240 º semicircle with maximum radius 4000mm just as the Fig. 2. Pitch angle is 0.36 ºand sensor outputs the distance measured at every point (683 steps). Laser beam diameter is less than 20mm at 2000mm with maximum divergence 40mm at 4000mm.

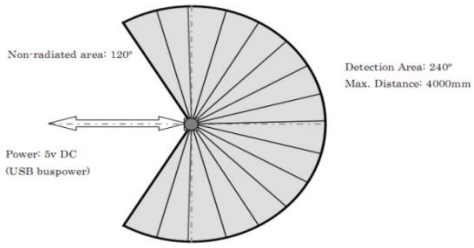


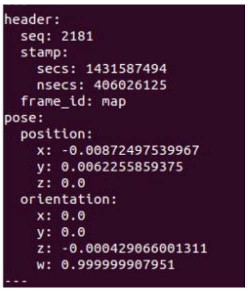
Figure 2. Model of laser scan

In this project it takes a laser-based map and laser scans, and transforms messages and generates a probabilistic pose. On startup, AMCL initializes its particle filter according to the parameters provided in the setup. If you don't set the initial position, AMCL will start in the origin of the coordinates. Anyway, you can set the initial position in rviz using the 2D Pose Estimate button.

Robot pose can be published from the topic *slam_out_pose*, if you want to check the message of the robot pose, you can using the command *rostopic show /slam_out_pose* show the robot position and the quaternion of the mobile robot just as the Fig. 3. we can compute the robot heading angle by the quaternion, the computational formula of the angle are as follow:

$$\text{Yaw} = \operatorname{atan2}\big(2\times(w\times z + x\times y),\, 1-2(z\times z)\big)\times 57.3 \quad (2.1)$$

where, Yaw is the heading angle of robot, (x,y,z,w) are the quaternion of robot.



```
header:
  seq: 2181
  stamp:
    secs: 1431587494
    nsecs: 406026125
  frame_id: map
pose:
  position:
    x: -0.00872497539967
    y: 0.0062255859375
    z: 0.0
  orientation:
    x: 0.0
    y: 0.0
    z: -0.000429066001311
    w: 0.999999907951
---
```

Figure 3. The message of the slam_out_pose

The heading angle of the mobile robot can be obtained, the message of this angle can be showed on the screen just input the command *rxgraph*, this command can draw any variable of the message. Just as the Fig. 4, the heading angle of mobile robot was drew in the figure.

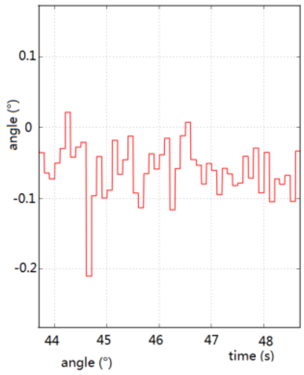


Figure 4. Heading angle of robot

B. *Mapping Algorithm Based on Bayes*

The standard occupancy grid approach breaks down the problem of estimating the map into a collection of separate problems, namely that of estimating

$$\mathrm{P(m)} = \textstyle\prod_{c\in m} p(c) \quad (2.2)$$

For all grid cell c. Each of these estimation problems is now a binary problem with static state. From [10], we obtain mapping algorithm makes occupancy decisions exclusively based on laser scan sensor measurements.

$$\mathrm{p}(c|x_{1:t}, z_{1:t}) = \left[1+\frac{1-\mathrm{p}(c|x_t,z_t)}{\mathrm{p}(c|x_t,z_t)}\cdot\frac{1-\mathrm{p}(c|x_{1:t-1},z_{1:t-1})}{\mathrm{p}(c|x_{1:t-1},z_{1:t-1})}\right]^{-1} \quad (2.3)$$

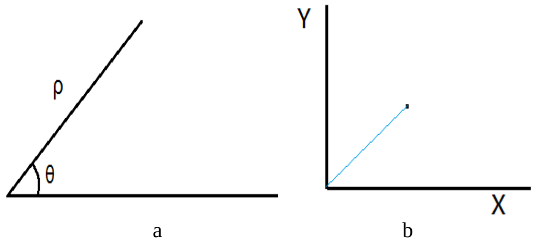


Figure 5. Transform of the laser scan coordinate

$$\begin{bmatrix} x_n \\ y_n \end{bmatrix} = \begin{bmatrix} \rho_n cos\theta_n \\ \rho_n sin\theta_n \end{bmatrix} (\mathrm{n} = 1,\ 2,\ 3\ldots) \quad (2.4)$$

Due to the distance outputs by laser scan sensor measured at every point is relations with the angle, so we should transform it to the x,y coordinates, just as formula (2.4).

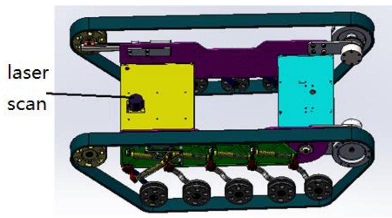


Figure. 6. Position of the laser scan

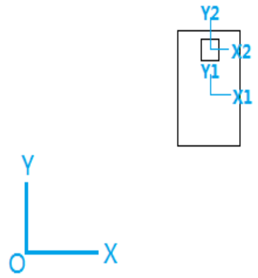


Figure 7. Coordinates relationship between grid map and robot

In the moving process of mobile robot, it is necessary to transform the measured distance from laser scan coordinates to the robot body coordinates. Finally, transform the measured distance to geodetic coordinates.

$$u_1 = T^1 \times u_2 \tag{2.5}$$

$$u = T^2 \times u_1 \tag{2.6}$$

where, u_2 is the vector, it denotes the measured distance in the laser scan x,y coordinates. u_1 is the vector, it denote the measured distance in the robot body x,y coordinates. u denote the vector which the laser scan measured distance in the geodetic coordinates. T^1 denotes the transform coordinates from laser scan coordinates to robot body coordinates. T^2 denotes the transform coordinates from robot body coordinates to geodetic coordinates. Substitute equation 2.5 into equation 2.6 we can get the formula (2.7).

$$u = T^1 \times T^2 \times u_1 \tag{2.7}$$

We can write the code by ourselves, While, ROS already contains the *GMapping* packages, from *OpenSlam*, and a ROS wrapper. The GMapping package provides laser-based SLAM (Simultaneous Localization and Mapping), as a ROS node called *slam_gmapping*. Using *slam_gmapping*, you can create a 2-D occupancy grid map (like a building floor plan) from laser and pose data collected by a mobile robot.

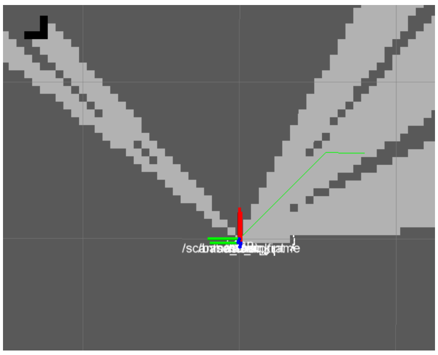


Figure 8. The message of the slam_out_pose

III. Path Planner

From ahead two chapters we can get the grid map about the environment, It shows the portion of the global plan that the local planner is currently pursuing. You can see it in green in the Fig. 8. Perhaps the robot will find obstacles during the movement and the navigation stack will recalculate a new path to avoid collisions and try to follow the global plan.

In this part, Dijkstra's algorithm is used in the path planner and this algorithm for finding the shortest paths from the start point to the goal point. In the ROS we should setup some parameters just as Fig. 9.

```
global_costmap:

  map_type: costmap
  track_unknown_space: true
  unknown_cost_value: 255
  obstacle_range: 2.5
  raytrace_range: 3.0
  footprint: [[0.25, 0.21],
              [-0.25, 0.21],
              [-0.25, -0.21],
              [0.25, -0.21]]
  inflation_radius: 0.32
  transform_tolerance: 2.0
  inscribed_radius: 0.3
  circumscribed_radius: 0.32

  global_frame: /map
  robot_base_frame: /scanmatcher_frame
  update_frequency: 0.5
  publish_frequency: 0.1
  static_map: true
  rolling_window: false

  #Investigate what this actually does
  cost_scaling_factor: 10.0
```

Figure 9. Global cost map parameters

The *obstacle_range* and *raytrace_range* attributes are used to indicate the maximum distance that the sensor will read and introduce new information in the cost maps. The first one is used for the obstacles. If the robot detects an obstacle closer than 2.5 meters in our case, it will put the obstacle in the cost map. The other one is used to clear the cost map and update the free space in it when the robot moves. The footprint attribute is used to indicate to the navigation stack the geometry of the robot. It will be used to keep the right distance between the obstacles and the robot, or to know if the robot can go through a door. The *inflation_radius* attribute is the value given to keep a minimal distance between the geometry of the robot and the obstacles.

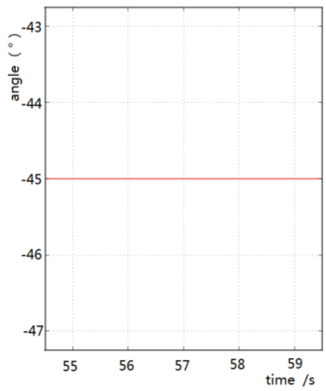


Figure 10. The angle of path planner

IV. Experiment and Conclision

In order to verify the validity of the SLAM algorithm, we use the tracked mobile robot to location and mapping indoor by laser scan, as shown in Fig. 11. This picture is the Northeastern university new mechanical fifth floor actual environment, the type of the corridor like ‘L’.

Black line in the Fig. 12 denote the obstacle edges, white areas for barrier free area, grey area as unknown location area.

Figure 11. The angle of path planner

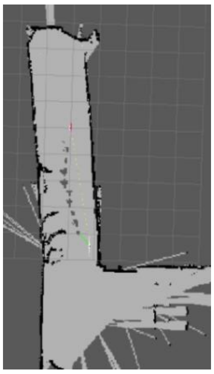


Figure 12. The angle of path planner

Now we are going to see a general image of the system. Run *rxgraph* to see whether all the nodes are running and to see the relations between them.

From Fig. 13 we can see the 1 is denote the laser scan node, 2 denote the message publish by scan, 3 denote the mapping node. Mapping node subscribe the message from leaser scan to buliding the map. In Fig. 14, the 1 denote path planner node, 2 denote the robot's pose message, 3 denote the path message for global map, 4 denote the arduino node, 5 include the parameters to setup path planner.

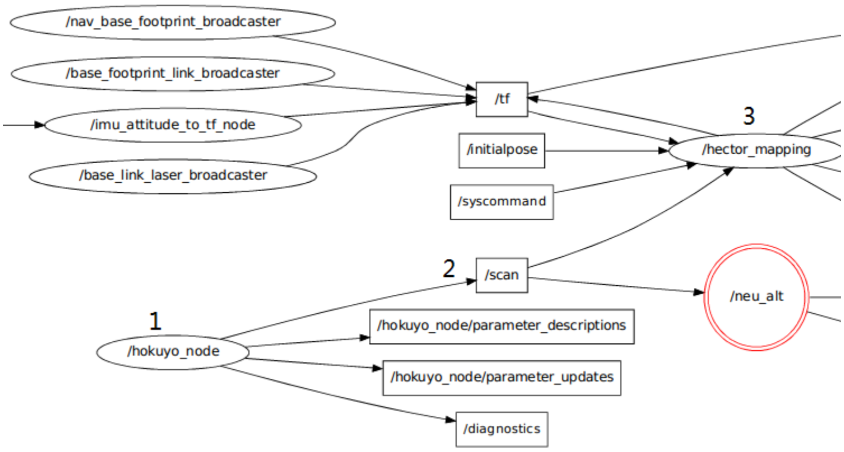


Figure 13. Mapping and laser nod

Figure 14. Path planner and Arduino node

The experimental test results demonstrated that ROS platform can greatly shorten the development cycle of the robot and the SLAM can easily realize on ROS, the robot can realize autonomous moving.

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