A kinectV2-based 2D Indoor SLAM Method

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ABSTRACT

SLAM is the key to realize the autonomous movement of the robot. 2D laser scanner performs well in indoor SLAM. However, with high resolution, wide viewing angle and low cost, kinectV2 has become a new platform for SLAM research. In this paper, we propose a 2D indoor SLAM method to replace 2D laser scanner. The real-time kinectV2 depth image information is obtained and converted into 2D laser data, effectively replacing the 2D laser scanner. The whole experiment is based on the robot operating system (ROS), using Hector SLAM algorithm for 2D SLAM. The results show that the proposed method is a reliable and effective 2D SLAM method, which achieves the expected results.

CCS Concepts

• Hardware→Communication hardware, interfaces and storage • Hardware→Sensor devices and platforms.

Keywords

KinectV2; 2D SLAM; Robot Operating System

1. INTRODUCTION

SLAM(simultaneous localization and mapping) is the foundation and key of the mobile robot to solve the problems about exploration, detection, navigation and rescue in the unknown environment. The robot creates the environment map according to the sensor information acquired by the sensor, and estimates the position of the robot according to the partially created map.

Numerous SLAM techniques have been developed by previous researchers utilizing different devices, including sonar sensors [1,2], cameras [3-5] and laser scanners[6-10].However, these methods use sensors that are often expensive and limited to specific functions. Microsoft for its game products developed supporting human-computer interaction sensor--kinect sensor, in 2014, Microsoft presented the second-generation product kinectV2.,it is based on a time-of-flight(TOF) technology instead of triangulation-based former scanner. According the technical specifications,KinectV2 improves KinectV1 with higher camera resolution, depth resolution and frame rate[11]. It is equipped with RGB camera and depth sensor provides a good platform for SLAM research, many researchers use it for 3D or RGB-D map experiment. A drawback is the higher performance requirements of their respective devices, such as higher CPU frequency, otherwise there will be data loss of frame situation. The 2D laser scanner, only in the two-dimensional plane scan, but it is simple, fast scanning and data points dense and accurate, it is widely used in the construction of indoor autonomous mobile robot map. At the same time, 2D laser scanner is often used in robot self-localization, obstacle avoidance, trajectory tracking and navigation.

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AIACT '17, April 07-09, 2017, Wuhan, China

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ACM ISBN 978-1-4503-5231-4/17/04…$15.00
http://dx.doi.org/10.1145/3080845.3080877

In this paper, we discuss the use of kincetV2 instead of 2D laser scanner for a specific indoor environment for 2D SLAM. Section2 reviews related work .Section3 presents the experimental materials and methods. The experimental process is presented in Section4.Section5 concludes this paper and gives an outlook on future work.

2. RELATED WORK

The Kinect V2 depth sensor obtains the depth information from the time reflected back through the projected infrared pulse, namely Time of Flight (TOF),its schematic diagram as shown in Figure 1.

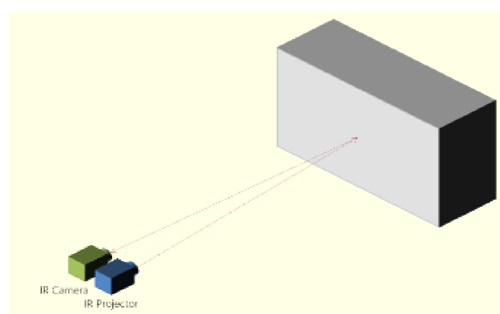


Figure 1. TOF schematic diagram

Kinect as a game sensor, now more and more widely used areas, including medicine, art, business and sports. In 2011, Kinect Fusion algorithm was introduced, and 3D reconstruction was realized in real-time to obtain the depth image, which made the SLAM research based on kinect get very fast development[12].

Oliver A et al.[13]compare the performance of Kinect based 2D and 3D SLAM algorithm, indicates that the Kinect is a viable option as a sensor for mobile robotic SLAM. Ghani M F A et al.[14]present an improved approach to get laser scan data from

Kinect depth image, by projecting 3D point clouds to 2D horizontal plane, the validity of the method is verified by gazebo simulation.

Kamarudin K, Mamduh S M et al. join a team in the field have high contributions. In 2013[15], they present a method converting the 3D depth data from the device's depth sensor into 2D map, suggest that the Kinect is suitable for indoor SLAM application.In2014[16],they present a performance analysis of two open-source, laser scanner-based SLAM techniques using a Microsoft Kinect to replace the laser sensor, shows the disadvantages of kinect for 2D SLAM.In2015[17], team merge the data from both sensors (i.e the KinectV1 and a laser scanner), the inaccurate due to the limited field of view of the individual sensor.

3. MATERIALS AND METHODS

3.1 ROS

The whole experimental environment is based on the robot operating system (ROS), a distributed operating system developed for robots, and communicates and controls through node, topic, service and so on.

NODEA:node is an executable program that uses ROS to communicate with other nodes.

TOPIC:Nodes can publish messages on a topic, or subscribe to a topic to receive messages.

MESSAGE:The type of data used when publishing or subscribing a topic.

The working mechanism of ROS as shown in Figure 2.

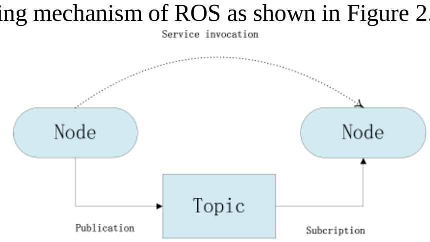


Figure 2. Working mechanism

3.2 KinectV2

KinectV2 laser scanner((its front view as shown in Figure 3)with a RGB camera, a IR sensor and a IR illuminator,its dismantling diagram as shown in Figure 4.

Figure 3. KinectV2 front view

Figure 4. KinectV2 dismantling diagram

Kinect's camera is 1920 × 1080 pixels (VGA size). The sensor has a field of view of 70 °horizontal and 60 °vertical. The optimum operating range of the sensor is between 0.5 and 4.5 meters(its depth viewing Angle as shown in Figure 5). Kinect's depth sensor is capable of providing a depth resolution of 1 cm and a spatial x/y resolution of 3 mm at a distance of 2 meters from the sensor. The maximum stable transfer rate of the frame is up to 30 Hz depending on the drive and computer performance.

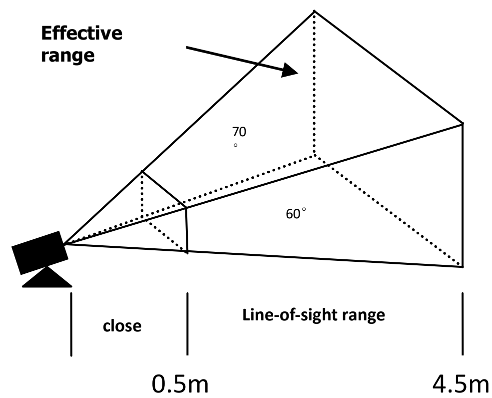


Figure 5. KinectV2 depth viewing Angle

3.2.1 KinectV2 Installation

Experimental environment is Ubuntu14.04, support for the driver libfreenect2, installation instructions through git clone, use OpenGL to achieve image rendering, image processing rely on OpenCV library[18].

Open a terminal, use the roslaunch command to start kinectV2(start interface as shown in Figure 6):

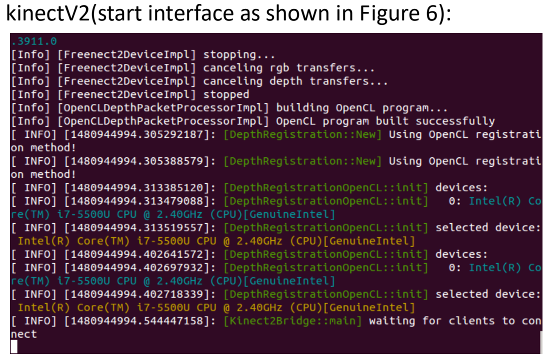


Figure 6. KinectV2 start interface

Reopen a terminal and view the screen using the kinect2_viewer node, this experiment uses qhd format(as shown in Figure 7 and 8):

Figure 7. Color image（qhd）

Figure 8. Depth image（qhd）

3.2.2 KinectV2 Calibration

Before experiment, the first calibration[19] to ensure that the depth map and color map between the one-to-one correspondence, making the SLAM results more accurate.

We use kinect2_calibration module, the choice of $5 \times 7 \times 0.03$ checkerboard calibration, each image acquisition of more than 50.

3.3 KinectV2 VS. 2D laser scanner

KinectV2 and laser scanner have many differences, their contrast as shown in Table 1.

Table 1. Compare KinectV2 and 2D laser scanners.

	KinectV2	**2D Laser Scanner**
Maximum depth range	4.5m	250m
Minimum depth range	0.5m	0.06m
Horizontal angle	70(°)	180 ~ 360(°)
Vertical angle	60(°)	_
Frequency	30Hz	10Hz
Camera resolution	1920×1080	Up to 6000
Depth resolution	512×424	_
Approx. costs	150USD	1000 ~ 15,000USD

3.4 Hector SLAM

Hector SLAM is an open source 2D SLAM algorithm. It uses a least squares method to match the scanning points and relies on high-precision laser radar data to create a grid map of the surrounding environment. The Hector SLAM does not require odometer information as compared to most grid map SLAM[20,21] techniques.

The scan matching algorithm used in Hector SLAM is based on the Gauss-Newton method[22]. The algorithm optimally aligns the endpoints of the laser scan with the constructed map by finding information on the rigid transformation $\xi = (p_x, p_y, \psi)^T$ that minimizes:

$$\xi^* = \arg\min_{\xi} \sum_{i=1}^{n} [1 - M(S_i(\xi))]^2 \tag{1}$$

Where the map value returned by the function is the world coordinate of the scanned endpoint. The initial estimation of a given step transformation can be achieved by optimizing the measurement error such that:

$$\sum_{i=1}^{n} [1 - M(S_i(\xi + \Delta\xi))]^2 \to 0 \tag{2}$$

The first-order Taylor expansion is applied to and set the Gauss-Newton equation to minimize the partial derivatives relative to zero:

$$\Delta\xi = H^{-1} \sum_{i=1}^{n} [\nabla M(S_i(\xi)) \frac{\partial S_i(\xi)}{\partial \xi}]^T [1 - M(S_i(\xi))] \tag{3}$$

where:

$$H = [\nabla M(S_i(\xi)) \frac{\partial S_i(\xi)}{\partial \xi}]^T [\nabla M(S_i(\xi)) \frac{\partial S_i(\xi)}{\partial \xi}] \tag{4}$$

4. EXPERIMENT PROCESS

4.1 Generate laser data

Gathers the depth information of surrounding environment, converts 3D depth information into laser data through depthimage_to_laserscan node, and publish a scan topic. Hector SLAM algorithm subscribes this topic to complete the experiment.The experimental flow chart as shown in Figure 9.

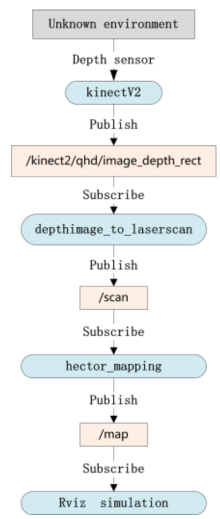


Figure 9. Experimental flow chart

After starting kinectV2, use the rqt_image_view function to view information about the depth topic/kinect2/qhd/image_depth_rect(depth information as shown in Figure 10).

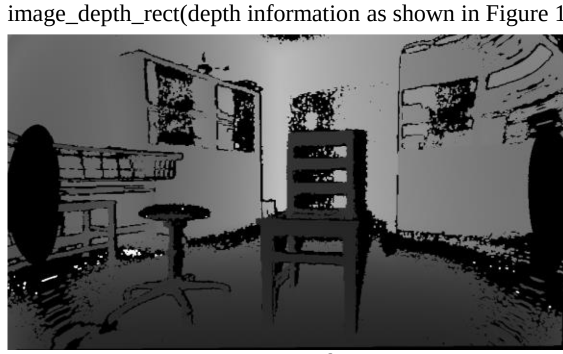
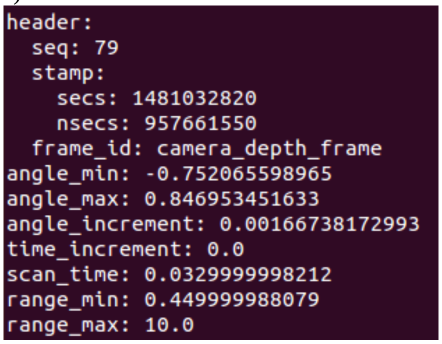


Figure 10. Depth information

ROS uses .launch files to start multiple nodes. Add the important parameters to the .launch file:
<remapfrom="image"to="/kinect2/qhd/image_depth_rect"/>
<remap from="camera_info" to="/kinect2/qhd/camera_info"/>
Start the depthimage_to_laserscan node, subscribe to the topic /kinect2/qhd/image_depth_rect, and publish a new topic /scan with the message type sensor_msgs :: LaserScan.
Use rostopic info command to view/scan information(as shown in Figure 11):



```
header:
  seq: 79
  stamp:
    secs: 1481032820
    nsecs: 957661550
  frame_id: camera_depth_frame
angle_min: -0.752065598965
angle_max: 0.846953451633
angle_increment: 0.00166738172993
time_increment: 0.0
scan_time: 0.0329999998212
range_min: 0.449999988079
range_max: 10.0
```

Figure 11. Topic /scan information

scan_time(default:1/30Hz) represent time between scans.
range_min(default:0.45m) represent the minimum ranges to return in meters.
range_max(default:10.0m)represent the maximum ranges to return in meters.
output_frame_id(default:camera_depth_frame) represent the frame id of the laser scan.
Start rviz(as shown in Figure 12), add image and laserscan: (Red is close to camera, purple is far from camera):

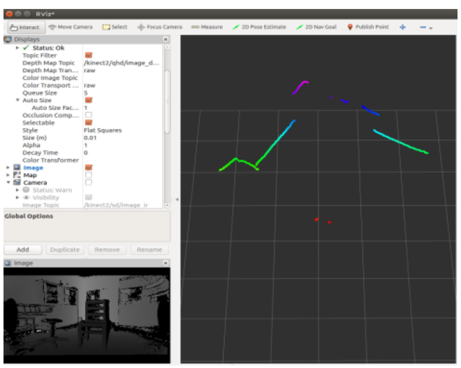


Figure 12. Rviz Effect diagram

Experimental environment(as shown in Figure 13) and it's laser display(as shown in Figure 14):

Figure 13. Experimental environment

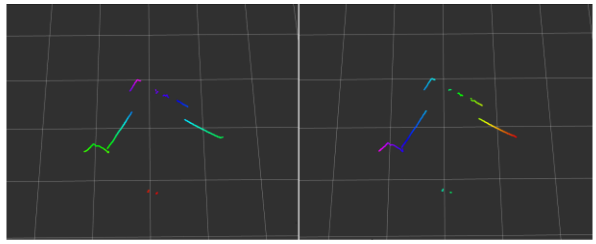


Figure 14. laser effect:X direction(left) Y direction(right)

Every two rays, the angle θ between the: vectors $\vec{\alpha}$ and $\vec{\beta}$:

$$\theta = \arccos\left(\frac{\vec{\alpha}\vec{\beta}}{|\vec{\alpha}||\vec{\beta}|}\right) \tag{5}$$

The real distance r between the two points a and b on the Cartesian coordinate axis:

$$r = \sqrt{a^2 + b^2} \tag{6}$$

4.2 Hector SLAM algorithm

First set the Hector SLAM parameters, build a slam. launch file to start Hector SLAM, hector_mapping node subscribe to the topic /scan data, publish topic / map, display a local map as shown in Figure 15:

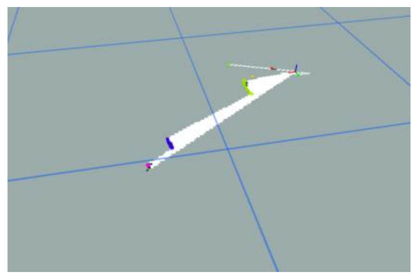


Figure 15. Local map

View the changes from the laser coordinate system to the map coordinate system by the position change tf node,use the command rosrun tf view_frames(as shown in Figure 16):

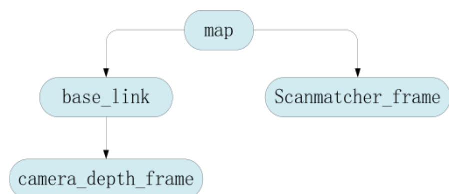


Figure 16. Tf conversion diagram

At the same time, we carried out the experiment in the real corridor environment, the 2D grid map is constructed as shown in Figure 17:

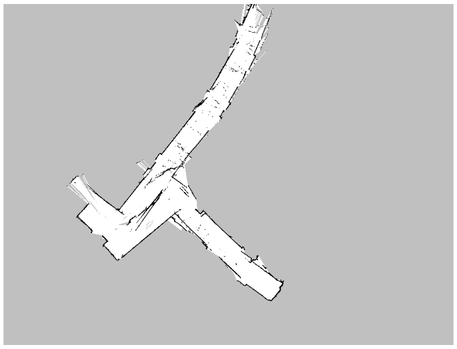


Figure 17. 2D grid map

5. CONCLUSIONS

In this paper, KinectV2 instead of 2D laser scanner for indoor 2D SLAM has a good performance, with its higher resolution, a wider range of viewing angle, can effectively detect obstacles and improve the accuracy of SLAM. The depth information of KinectV2 is converted into 2D laser data, and the 2D grid map is constructed with high accuracy. The experimental results are in accordance with the expected results.

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