Design of an Indoor Surveying and Mapping Robot Based on SLAM Technology

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***Abstract*—Simultaneous localization and mapping (SLAM) are a key technology for indoor mapping and navigation of mobile robots. As traditional surveying and mapping work depends on the general simple tools or Artificial completed exist inaccuracies, insecurity and high repeatability errors. To solve the problems mentioned above, an experimental system of mobile robot mapping based on SLAM technology is designed and implemented. The mobile robot is equipped with lidar and odometer sensor. Through the cartographer algorithm [1], lidar data and odometer data are integrated to realize indoor map construction and navigation. The open-source robot operating system (ROS) based on Linux was used for realizing information communication, data processing, real-time display between the upper machine and lower machine. The system simulation and real scene test are carried out. The mobile robot can build reliable and efficient map. Compared with the traditional technology of surveying and mapping, simulation and real experiment results show that the system has high practicability and reliability.**

Keywords—Mobile robot, SLAM algorithm, Raspberry Pi, Laser radar, Interior of surveying and mapping

I. Introduction

The indoor surveying and mapping problem has been one of the hotspots in the field of mapping over the past decade. In the field of mapping, outdoor mapping scheme has been relatively mature, whose cost is too high, complex and big. So, it generally does not apply to indoor mapping. With the rapid development of the new generation of information technology, intelligent machine technology has achieved great progress. The application technology of the intelligent machines is also showed a trend of all-round progress. The various types of intelligent products and services are used for all areas, which plays an irreplaceable role. The research of indoor service robot has attracted more and more attention. In the research of this problem, the accurate localization of the robot, map reconstruction and real-time path planning of robot are important problems [2-4]. In recent years, many effective solutions have been put forward, such as hector SLAM algorithms, gmapping algorithms and cartographer algorithms used for indoor mapping[5], fang algorithms, taylor algorithms and chan algorithms used for indoor localization[6],Dijkstra, A*,D*,LPA*,D*lite algorithms used for path planning[7]. However, these methods have some cost is too high, some not too accurate, which hinder their widespread application.

Now more and more service robots using multi-core processors and multi-sensor system. The robot performance has been improved to a great extent. Hardware the hardware costs are rising and the soft system has no portability and usability, Which is bad for universal mobile platform development. In order to solve this problem, the raspberry pi is widely applied to the core of robot control part and ROS system is developed in 2010, which effectively solved the problem that the hardware is not compatible, and provided a robot software common platform [8-12].

The main work of this paper is to design a mobile robot based on SLAM technology and ROS, and design an indoor mapping solution based on raspberry pi 3B+. Simulation and real environment experiments verify the feasibility and effectiveness of the scheme from two aspects of theory and technology.

II. Platform structure of mobile robot platform

The mobile robot platform designed in this paper includes four parts: acquisition layer, control layer, execution control layer and client layer. As shown in Figure 1, the lidar data is collected from its surroundings for 360° uninterrupted scanning. The camera and lidar data of the acquisition layer are transferred to the Raspberry Pi 3B+ based core board via USB port, and the IMU (Inertial Measurement Unit) data and odometer data are transferred to the driver board via STM32L475. The control layer mainly builds maps and generates navigation paths based on the collected data. The executive control layer is mainly responsible for driving two DC motors. The client layer mainly controls mobile robots or video surveillance remotely. The client layer is mainly responsible for remote control of robots and video surveillance based on OpenCV camera through Android mobile phone software. Mobile terminals can also complete the construction of map APP and autonomous navigation. In the unknown environment, real-time automatic mapping and path planning based on data and laser sensor data is the most critical problem. ROS - based mapping algorithm is used to solve the problem of accurate positioning and composition.

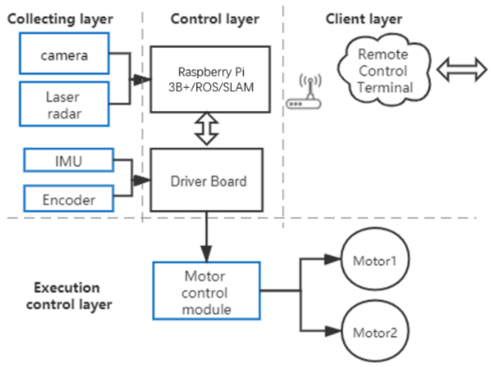


Figure 1. The overall architecture of mobile robot.

III. Hardware design of mobile robot

A. Core control module

The Raspberry Pi 3 Model B+ board performance is strong. It has a Broadcom BCM2837B0 CPU running at 1.4 GHz. The CPU based on ARM A53 architecture has four core processor, which is a part of the 64 V8 architecture. Moreover, Raspberry Pi 3 Model B+ also has 1GB LPDDR2 SDRAM. In terms of interfaces, it fully compatible with the market mainstream interface, respectively HDMI, USB 2.0 ports, gigabit Ethernet, CSI cameras, DSI display connector and extended 40-pin GPIO header. Raspberry Pi 3 Model B+ support 2.4 GHz and 5GHz IEEE 802.11 b/g/n/ac wireless LAN, Bluetooth 4.2, BLE wireless connections, which can provide a compact for the connection of equipment, integration of the intelligent solution.

B. Driver Board module

The driver board module is mainly composed of STM32L475, step-down controller module, power batteries, dc motor and motor driver module of hardware unit. At the same time, the IMU sensor, odometer and TFT touch screen is installed. STM32L475 is ultra-low power high performance MCU of STMicroelectronics (ST) Company, it uses 32-bit DSP and floating-point unit (FPU). The kernel architecture is ARM M4, which is working at frequency 80MHZ.It has 512 KB of flash memory,128 KB SRAM and variety of common peripheral interface, such as USB 2.0, CAN, SDIO, IIC interface and so on. The highest frequency of performance can reach 100 DMIPS. STM32L475 chip performance is strong, low power consumption and high performance. It can satisfy the industrial, medical and consumer markets of various application requirements. It is particularly well suited for the application of Internet of ultra-low power consumption scenarios. The control system of drive board has integrated into the upper machine ROS, which is a Node of ROS. It is convenient to call STM32 the underlying protocol and realize the mobile robot control actuator. At the same time, in order to increase the stability of the platform, four universal wheels are installed based on the two driving wheels. Damping spring mechanism is added to strengthen the platform in uneven impact resistant and shock resistant performance.

C. Camera and laser radar

In this paper, RPLIDAR A1 laser radar from SLAMTEC is adopted. Laser radar's advantage is that it is not affected by light and almost all-round high precision data acquisition environment. RPLIDAR A1 uses laser triangulation ranging technology and high-speed visual collection processing agency which is the independent research and development. Distance measurement can be carried out more than 8000 times per second. RPLIDAR A1 ranging core clockwise rotation, can be realized on the surrounding environment of 360 degrees * scanning range detection. Thus, the rough outline of the surrounding environment is obtained and the point cloud of the surroundings is formed. USB ports are used to connect lidar and mobile robots. The laser data is read for ROS by subscribing to SCAN the them. SLAM is used to match the point cloud which is formed by collecting e a series of scattered angle and distance of the environment and calculate the distance and the posture change, so as to realize the robot perception and its positioning in the environment. The mobile robot platform uses Raspberry Pi CSI camera. The Open CV3 is used to analysis and processing images, in order to providing powerful target identification and patrol robot.

IV. Software design of mobile robot platform

A. ROS system overview

In this paper, the software part of the mobile robot platform based on Linux operating system ROS, which is used to realize the upper machine and lower machine information communication, data processing, the experimental results of real-time display, etc. ROS (robot operating system) was founded in 2007 by Stanford University's artificial intelligence laboratory and willow garage robot project cooperation launched an open-source robot operating system. It is applied to the field of robot research in robot system [13]. ROS for robot researchers and enthusiasts to provide a free open-source platform, which is a kind of distributed operating system. It encapsulates the packet to the heap and stack, in order to facilitating the sharing of data and distribution. Point-to-point design was adopted to realize multithreading and multi-master synchronous operation. It supports Java/c + + / Python/Lisp languages and realize the mixing and coordination of the various language freely use. It also includes a large number of small tools to compile, run and visualization, and so on. And eventually the whole robot control system is decomposed into more loosely coupled processes, which is one Node (the Node) ROS.ROS controller is called ROS Master, which guarantee working in an orderly way, not to find other nodes, and ensure the message exchange and service invocation through the registration and registration on each Node. This design can adapt to changes in the demand structure through adding or deleting the corresponding function module directly. So, the design method is very flexible.

B. SLAM algorithms

In this paper, cartographer algorithm is used to draw maps and generate navigation paths in 2D-SLAM. Cartographer is a real-time simultaneous Location and Mapping (SLAM) library launched by Google in October 2006[14]. Google has designed a backpack that is fitted with sensors to draw a two-dimensional grid of the interior in real time as operators walk around. Each frame obtained by laser radar laser scan data. The best estimate location is inserted into the graph (the submap) by using scanning matching (scan matching) and scan matching associated only with the current the submap. Cartographer did not adopt the method of particle filter, through regular optimization to solve the problem of accumulated error. When generating a new scan, the submap and no insert, it will conduct a local loopback. After completion of the submap, the loop back will automatically be closed. If the laser scanning and the current estimate of the position is very close, it will find a consistent scan in the submap. If the optimal matching result is found at the current position, it is added to the optimization problem as a closed-loop constraint. Branch and bound and predictive grid are used to solve the global loopback problem. It optimizes every few seconds. When the robot moves to a repeated position, the scan matching will generate a new scan in advance to realize the closed-loop test. In this paper, the cartographer algorithm was applied to mobile robot platform. The system overview of cartographer is shown in figure 2:

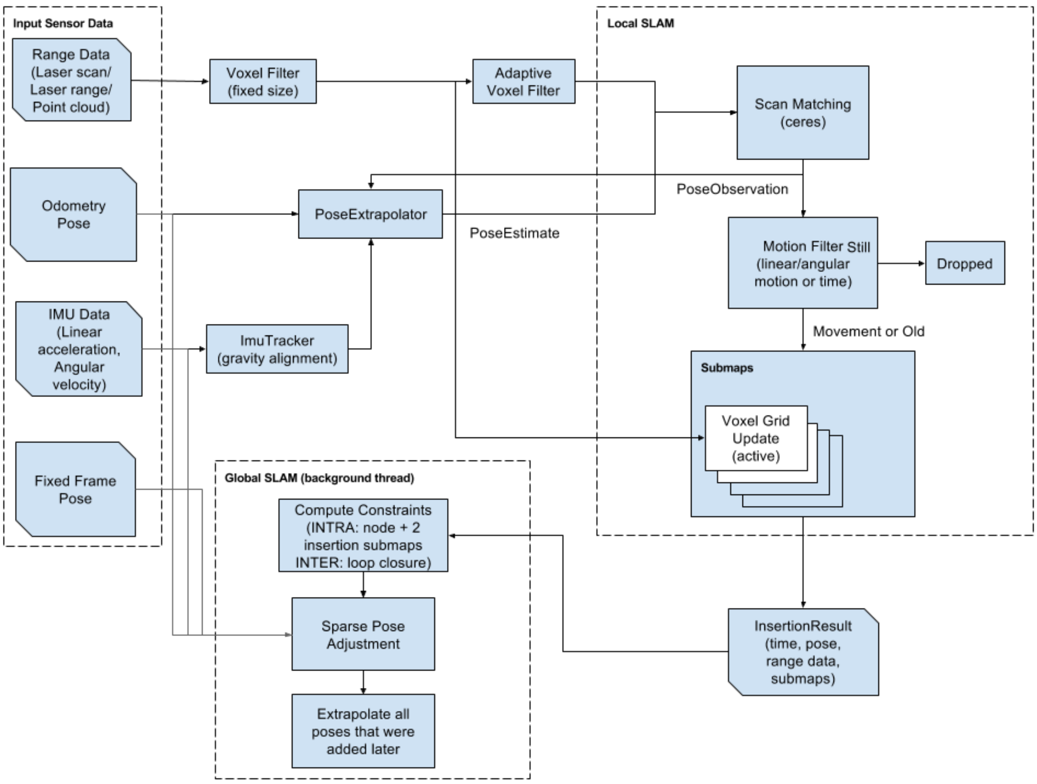


Figure 2. The system overview of cartographer.

C. Indoor mapping software framework

The mobile robot software architecture designed in this paper is shown in Figure 3. The motor encoder and MPU9250 sensor data are fused to generate IMU data. Data from the lidar and camera are transmitted to the control layer through the USB port. The control layer is composed of Raspberry Pi 3 Model B+ core board, and the driver board mainly uses STM32L475 controller. Raspberry Pi 3 Model B+ comes with ROS software, which integrates mapping and navigation path building.

The overall framework of mobile robot mapping and navigation path is shown in Figure 4.

The cartographer_ros overall code structure as shown in figure 5. The top layer is cartographer_ros, which is called rosj interface layer. It can subscribe to the multisensor data (/ scan, / imu, odom, etc.) and publish the map, the robot location information (/ map, tf, etc.) by calling the cartographer core algorithm. Next, the cartographer is the core of SLAM algorithm. Feature extraction, graph building, a closed-loop detection and global optimization are realized. The optimization process needs to call Ceres - solver nonlinear optimization library. Finally, the Ceres - solver is nonlinear optimization library, which is used for solving the optimization problem of SLAM.

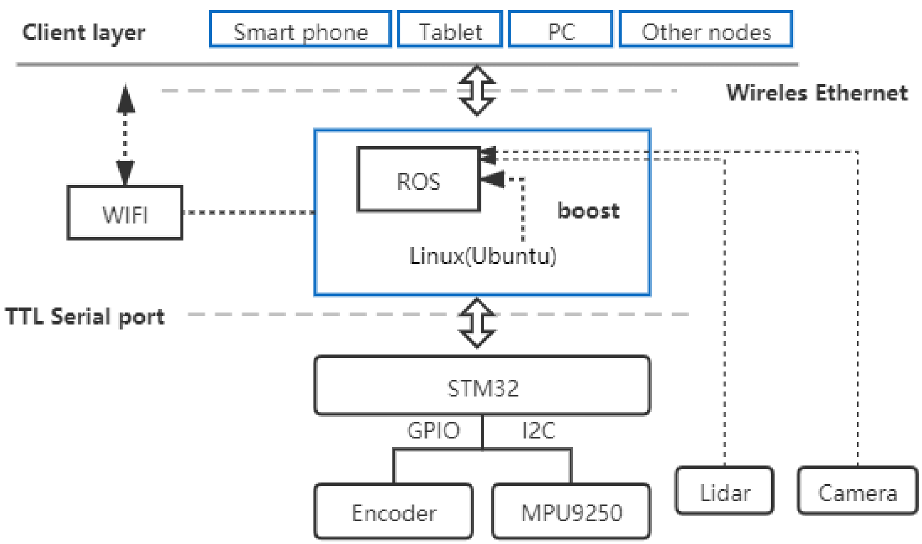


Figure 3. The software structure diagram.

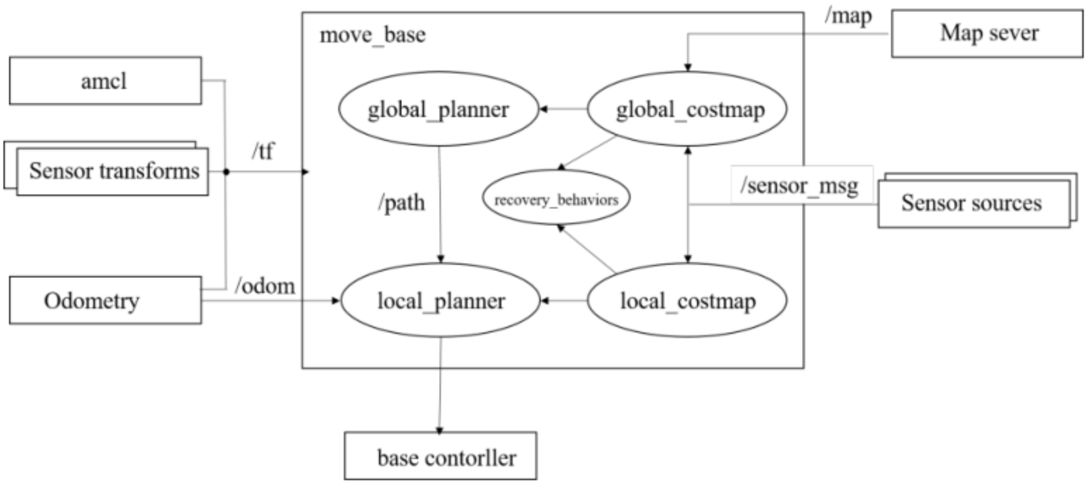


Figure 4. The overall framework of mobile robot mapping and navigation path.

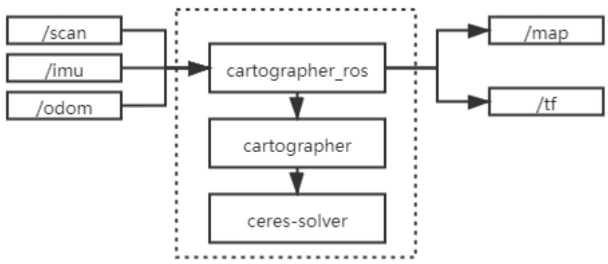


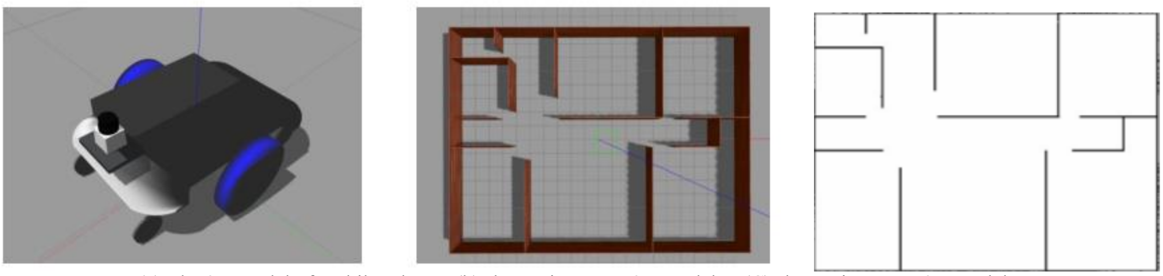
Figure 5. The cartographer_ros overall code structure

V. Indoor mapping simulation and testing

The mobile robot designed in this paper based on SLAM algorithm can realize the mapping and path planning function of the map in the indoor environment, and complete the simulation test and real environment test process of the robot.

A. Simulation

In this paper, Gazebo simulation tool is adopted to improve the simulation experiment[15]. According to the shape of the size of the mobile robot, a simulated robot 3D model is created by writing Unified Robot Description Format (URDF) file in the ROS, which is an XML file used to describe the robot parts, joint, freedom, and so on. At the same time, we add some sensor components, such as laser radar and IMU to accurate estimate the pose of the robot. Figure 6 (a) shows the 3D model of robot. The simulation environment maps are built by using the Gazebo in another powerful. Figure 6 (b) shows the environment 3D model created in the Gazebo. The simulation environment will be used for the next SLAM simulation experiment.



(a) The 3D model of mobile robot. (b)The environment 3D model. (C)The environment 3D model.

Figure 6. The simulation experiment platform

In order to simplify the experiment steps, the laser data acquisition node, map load node, robot motion control node, build graph of cartographer node and map visualization node are written to the same launch file. It is easy to start the SLAM experiment through a start command for avoiding mistakes and saving time. Control commands are sent by computer keys to control the robot to walk in the unknown indoor environment. The system realizes the calculation of SLAM algorithm through move_base node, so as to draw the map and plan the path, and show the results in a visual way. Figure 6(c) shows the simulation results of Carographer. The map is saved by map saver node in the ROS. Two files are generated: The PGM file is an environment map and the YAML file is used for map configuration.

B. Physical verification experiment

Through simulation experiments, we verify the correctness of SLAM algorithm. Next, we need to test the mobile robot in a real environment. First of all, we asked everyone to test the real environment, set appropriate parameters, control the robot to walk in the unknown environment through the mobile terminal, and update the map synchronously during the walking process. As shown in Figure 7, the map constructed by mobile robot is quite consistent with the real environment actually built. White areas represent areas where robots can travel, and gray areas represent unknown areas. The black area is occupied by obstacle. The effect of map is good with no obvious structure error. The wall and doorcase is clearly visible. Specially, in the process of drawing, the robot's movement speed should not be too fast. If the laser matching is too late to update, the map will produce serious deviation. The experimental results show that the mobile robot hardware and software systems development is successful.

Figure 7. Mobile robot physical verification experiment scene

VI. CONCLUSIONS

In this paper, a low-cost, high-reliability indoor mapping mobile robot platform is designed and implemented, and we verify the effectiveness of the system through software simulation and real environment test. This system uses 2D_SLAM algorithm to realize robot localization and map drawing in unknown environment. Compared with traditional surveying and mapping methods, the surveying and mapping platform designed in this paper has the advantage of low cost and can quickly build a map consistent with the real environment in an unknown environment. At the same time, it can also control the movement of the robot in a remote way and provide the function of remote video monitoring. There are still some defects in this platform, and further optimization of SLAM algorithm is needed to make indoor mobile robot more intelligent, autonomous and practical.

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