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Design of Patrol Robot in Petrochemical Plant Area Based on ROS

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Abstract: In order to solve the problems of inspection safety and inspection efficiency in oil factory area, this paper introduced an inspection robot based on Robot Operating System (ROS), which has the functions of synchronous positioning and drawing, autonomous navigation and obstacle avoidance. Firstly, the inspection robot of the oil factory area uses lidar to perceive the depth information of the surrounding environment, and integrates the depth camera to collect the surrounding image information. Secondly, Gmapping with SLAM algorithm is used to draw the 2D raster map. At the same time, the Move_base function package realizes the global and local optimal route planning, as well as the obstacle avoidance function, and then completes the navigation inspection task.

1. Introduction

As we all know, the oil factory area belongs to the inflammable and explosive field area, which may cause fire, explosion and other safety accidents at any time due to a small fault not discovered in time or handled improperly, resulting in huge economic losses and social negative impact[1]. In addition, complex processing equipment and high-risk operating environment not only make the inspection situation of the oil factory more severe, but also require the inspection personnel to have skilled inspection technology. At the same time, the oil factory in order to strengthen the safety management, require inspection personnel to carry on the inspection regularly, this kind of repetitive work requires a lot of manpower material resources, and inspection quality are greatly influenced by subjective factors, there are such as inspection personnel careless, check is not careful, judgment and other adverse factors, lead to some potential risk could not be found in time and processing, It's inefficient and dangerous. Therefore, in order to ensure the safety of the oil plant and reduce the workload of the inspection personnel in the oil plant, robot-assisted inspection or manual inspection can be adopted. The intelligent robot uses the technology of drawing and navigation to realize the autonomous inspection, which can go deep into the area that inspection personnel are not allowed to enter, and monitor the environmental conditions of the oil plant from an all-round, all-weather and multi-angle, effectively reducing or even preventing the occurrence of such safety accidents as explosions, so that petrochemical enterprises can develop in a long-term and stable way[2,3].

The ROS-based inspection robot for oil plant uses the hardware framework of robot motion control combined with Raspberry Pi 4B and STM32 to draw 2D raster map through lidar. The constructed map can provide a blueprint for the subsequent path planning and obstacle avoidance function, finally realizes the independent inspection functions of the robot[4,5]. At the same time, the robot also integrates the depth camera, which can collect the image data of the area in real time, and then complete the more complex inspection task, and comprehensively improve the inspection safety management of the oil factory.

2. Hardware System Design

2.1. Hardware Composition of Inspection Robot in Petroleum Factory Area

ROS is a popular open-source robot operating system, which contains various functional packages for operating robots. When writing robot programs, you can modify parameters or directly quote them[6]. The factory inspection robot uses Raspberry Pi 4B as each module function of the upper computer control robot, and STM32 as the lower computer control motor to realize the trolley movement. In addition, the Gmapping function package with SLAM algorithm is selected to complete the construction of 2D raster map, and on this basis, the global and local optimal path planning and autonomous obstacle avoidance function are completed[7,8]. The hardware system of the patrol robot in the petroleum factory area is shown in Figure 1.

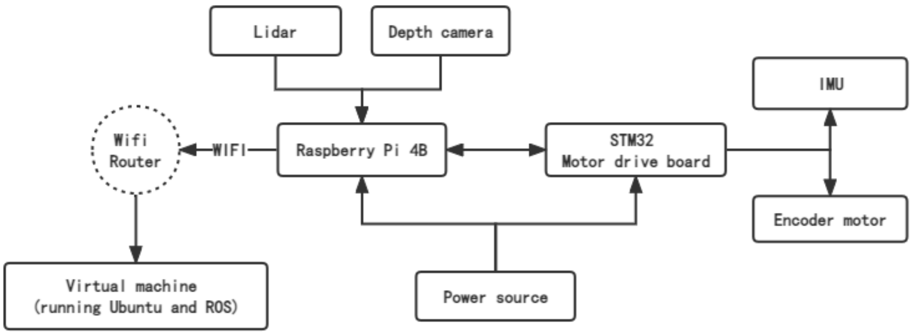

Figure 1: Hardware system of patrol robot in oil factory area

The petroleum inspection robot in the factory adopts the development and debugging method composed of robot end and remote workbench end. The robot is equipped with Raspberry Pi with built-in ROS system, which can run various sensor drivers, mapping and navigation programs, etc. The remote workstation uses notebook computers, runs Ubuntu and ROS systems on virtual machines, and uses SSH remote login software, Rviz graphics tools and other tools to control and debug the algorithm programs of the robot. The remote workbench and the robot are connected through WIFI, and the distributed network communication characteristics of ROS system are used to transmit data, so as to realize the remote control of the robot. Laser radar has SLAM function, which can build a two-dimensional map of its area in real time when it is running. Depth camera can transmit video images to application layer in real time. Motor drive board can drive the robot to move by receiving control instructions from Raspberry Pi. Similarly, IMU, motor encoder and other data signals can be fed back to Raspberry Pi[9,10].

2.2. Lidar

Laser radar uses infrared laser signal to obtain information, and it can automatically and quickly complete mapping without too much manual participation, so it has a high mapping cost performance. The RPLIDAR A1 used in this paper can scan the surrounding environment in 360 degrees, with an effective ranging radius of 12 meters and a scanning frequency of more than 8,000 times per second. Laser radar collects the depth information of the map and fits the data with SLAM algorithm, thus completing the map construction of the robot's area[11].

2.3. Depth camera

Depth camera can be regarded as "the eyes of the terminal and the robot". It can measure the distance between the camera and the position of each point in the plane image corresponding to the actual scene, and combine its plane coordinates to obtain the three-dimensional coordinates of each point in the image corresponding to the actual scene. ORBBEC Astra Pro depth camera is selected in this system, and high-resolution RGB camera is adopted, which can assist the robot in visual simultaneous positioning and mapping.

2.4. Motor drive board

The motor drive board is a low-cost, highly integrated and fully functional motor control solution, which can be applied to ROS robot differential chassis motor control, intelligent remote control vehicle motor control, coded motor control system, etc. It supports the default GM37 coded deceleration motor, onboard IO expansion pin, and high-power coded motor. The supporting ROS host computer driver is provided to help users control the motor and obtain the coded odometer in ROS more easily. The motor drive board of this paper is equipped with STM32 single chip microcomputer and TB6612 motor drive chip, which can run PID algorithm to realize the closed-loop control of the speed of DC coded deceleration motor, and can also receive the motion control instruction from the upper computer through serial communication, and feed back the coded mileage information of the motor. In addition, the motor drive board is connected with the host computer through USB cable and adopts serial communication mode. Its driver program includes chassis motor control, odometer calculation, PID parameter setting, odometer linear velocity and angular velocity calibration, etc.

3. Software Design

Master, as the dispatching center of ROS, can be regarded as a server, and other nodes are publishers or subscribers, communicating through topics or services[6,7]. Therefore, the software of this system can be divided into three layers: application control layer, navigation control layer and perception execution layer. The software system framework is shown in Figure 2.

(1) Application control layer: the upper computer application program running on Ubuntu system connects to the inspection robot through SSH remote login, and the visual application interface can obtain the relevant information of the inspection robot in real time, and control the robot's mapping and navigation functions.

(2) Navigation control layer: realize the communication and control between the upper layer and the lower layer.

(3) Perception execution layer: the motor is driven by the motion control node, so that the inspection robot can move; Acquiring the information and data of the surrounding environment through an environment-aware node; The video image transmission node can collect the image information of the robot's environment; The real-time map of the robot's area is constructed by lidar, which provides data for the autonomous navigation and obstacle avoidance of the patrol robot.

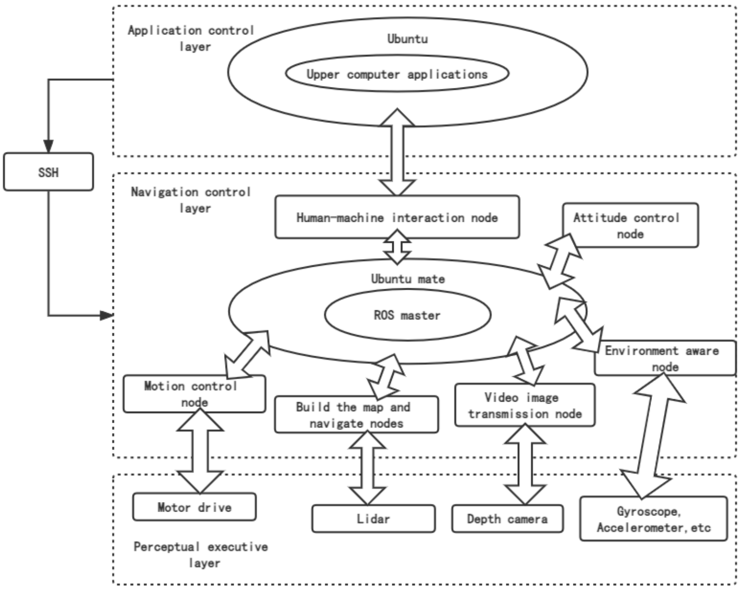

Figure 2: Software system framework of inspection robot in petroleum factory area

In Figure 2, the inspection robot obtains the data of the surrounding environment through the perception and execution layer, and uses the navigation control layer to realize the communication between the application layer and the bottom layer, so as to complete the transmission of data and commands. Users can monitor the inspection robot only through the application control layer.

4. Experimental Test

Figure 3 shows the navigation inspection test results of the inspection robot in the petroleum factory area in the indoor environment. Among them, the lower right corner of Figure 3 shows the image of the experimental site taken by a depth camera. In the process of testing, firstly, the remote workstation SSH logs in to the robot to realize the network communication between PC and car. Then, remotely start the drivers of all sensors on the robot, run the Gmapping function package at the same time, and remotely control the robot in the application control layer to complete the indoor map. After the indoor map is built, the robot navigation can be set in the Rviz interface of the car control software, and finally the car can complete the functions of autonomous navigation and obstacle avoidance. The experimental results show that the robot used in this experiment can basically complete tasks such as synchronous positioning, mapping and automatic navigation.

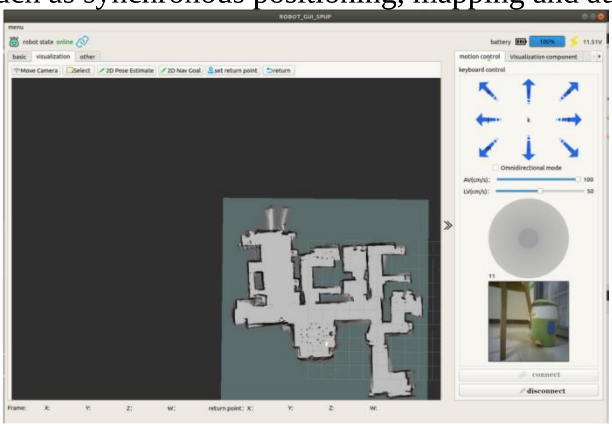

Figure 3: Inspection Robot Test

5. Conclusion

In this paper, a low-cost scheme of building inspection robot in petroleum factory area based on ROS system is designed and implemented. The car takes Raspberry Pi 4B as the core controller, STM32 as the motion controller, uses laser radar and depth camera to collect the information of the surrounding environment, and completes the map construction by Gmapping algorithm. At the same time, the Move_base function package realizes the path planning on the 2D raster map, and finally realizes the automatic navigation and inspection. Based on the principles of low cost, short cycle and strong expansibility, this design scheme can provide more reference schemes for service robots used in supermarkets, hospitals and banks.

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