A Design of Intelligent House Inspection Robot

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Abstract

Aiming at the current tedious housing quality inspection procedures resulting in a lot of manpower consumption, an intelligent housing quality inspection robot is designed. Robots can independently test the quality of indoor walls and other structures. Robots consist of embedded devices combined with other devices. Independent navigation, remote control. It can obtain a variety of environmental information for mapping and can quickly and accurately measure the defects of the building, realizing the unmanned intelligent detection.

Keywords: intelligent robot, independent navigation, remote control, intelligent detection

1. Introduction

Building quality inspection robot is a research result of artificial intelligence in the field of robotics, and it is the frontier and hot spot in the field of robotics. House inspection robot is a member of the inspection robot family. It is a platform with inspection function and intelligence. The house inspection robot can detect the information of the external environment and make corresponding judgments, and transmit feedback to the client through wireless Bluetooth. House inspection robot has high performance requirements. The robot has a mechanical caterpillar chassis. This allows the robot to better maintain stability and adapt to the complex ground environment, which is the bottom rough frame of the robot. The SLAM lidar is mounted on top of the robot to create a radar scan by scanning the environment. The robot has a vision system, which can always observe the surrounding environment and feedback the observed influence to the client, so that the client can manually identify the visual image. The robot has a laser ranging module and maintain the stability of the head, the use of gyroscope to determine the robot's position and posture so as to control the head to stabilize the position and posture of the laser ranging module, can better measure the information of the surrounding buildings. The wireless Bluetooth module of the robot
can be used as a mobile phone to control the robot at any time.

2. The Main Text

In this design, STM32 is used as the main controller for image acquisition and processing, THE SLAM laser radar is controlled by raspberry PI microcomputer alone, L298N is used as the driving module to control the operation of the motor, and the steering gear of the head part is directly controlled by STM32.The six-axis gyroscope controls the pose of the head and then the pose of the laser ranging module.

3. Design of robot hardware system

3.1. *Robot structure design*

This design uses caterpillar chassis, its size is 175.9mm long, 178.6mm wide, 57.3mm high, caterpillar length is 160.5mm, 40mm wide, 44.5mm high. While using MG513 motor, chassis load 4kg, maximum speed up to 1.1m/s, except the track part are aluminum alloy material. The tracks are designed with one driving wheel on each side and five slave wheels on each side, and are equipped with a suspension shock absorption system. The 3-DOF head is composed of two steering gear, which can meet the pose stability requirements of laser ranging module.(as shown in Fig.1 and Fig.2) Its hardware design is mainly as follows:
1. The raspberries pie do PC 4 b, STM32F407 MCU do lower machine, raspberry pie than 4 raspberry pie 3 generation, plate type, part of the interface change, change, small circuit are not familiar with raspberry pie 3 May be the first time cannot distinguish the two

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generation of friends, but the configuration upgrade of the sea are used to describe too much, the main are:

A. Made a comprehensive upgrade on CPU, from 64-bit A53 to 64-bit A72, and the main frequency was upgraded from 1.2ghz to 1.5ghz;

B. GPU core remains unchanged, but the main frequency is increased from 400MHz to 500MHz;

C. WiFi upgrade 5.0/BLE to facilitate the development of intelligent products;

D. The power supply circuit is upgraded to 5V-3A, increasing the possibility of expanding more modules.

2.The raspberry PI 4 is the most exciting upgrade for developers:

1) Upgrade the processor to 1.5GB

2) Multiple memory options are 1GB, 2GB and 4GB respectively

3) Bluetooth upgrade to 5.0

4) More power output 5V.3A

5)USB port is upgraded to 3.0

6)4K dual display

Caterpillar structure is adopted, self-made PCB, 6 GPIO are reserved for user-defined development.

3.Adopt 24V7A160W dual-channel H bridge L298N logic 4-channel DC motor drive board, the drive motor is suitable for all kinds of terrain, to ensure that the vehicle has strong enough power under various conditions.

4.Using SBUS to 16 channel PWM receiver with remote control of the car's movement, can transmit a variety of signals so that the vehicle can make a variety of set actions, can transmit long distance, strong signal, can be used in bad environment.

5.MPU9250 nine-axis accelerator is used to monitor and control the stability of the vehicle, combined with PID algorithm, to ensure the vehicle can maintain stability in various sections to the greatest extent.

6.The vehicle adopts the front axle, rear axle, transmission shaft, shock absorption and other mechanical structures, which can adapt to various terrains to ensure that the vehicle will not overturn in dangerous terrains, protect the safety of the vehicle and ensure the speed of the vehicle.

7.Adopt high-power power supply, output strong power at any time, to ensure the endurance of two hours.

8.Laser SLAM is adopted for faster mapping and navigation.

9.Built-in A* algorithm and Dijkstar algorithm, convenient for users to do development.

Fig.1.Robot diagram

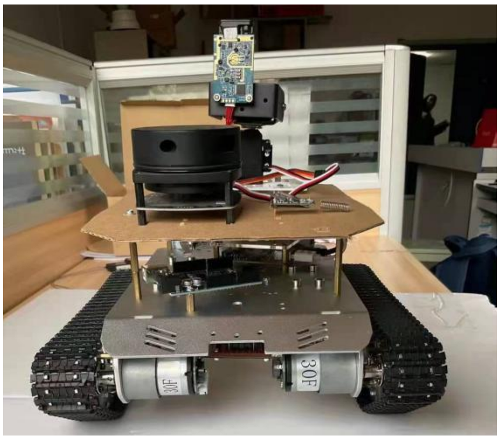

Fig.2. Main view of house inspection robot

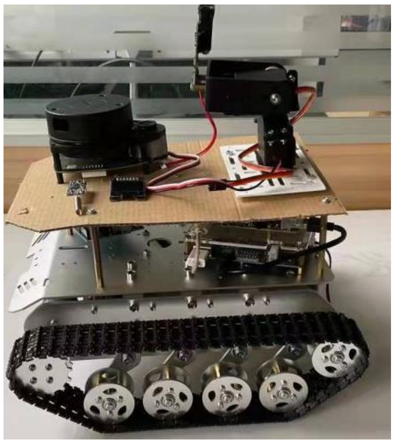

Fig.3. Side view of house inspection robot

3.2. *Introduction of controllers and peripheral modules*

The main controller adopted in this design is STM32F407, 32-bit single chip microcomputer (see Fig.4), based on ARM® The STM32F4 series of high performance microcontrollers with the Cortex™-M4 kernel use 90 nm NVM technology and ARTART technology to achieve zero wait for execution of programs, improve the efficiency of program execution, and maximize the performance of CorTEXT-M4. The STM32 F4 series can reach 210DMIPS@168MHz.The adaptive Real-time accelerator can fully unlock the performance of the Cortex-M4 kernel; When the CPU is operating at all permissible frequencies (≤168MHz), programs running in flash can achieve performance equivalent to zero wait periods. It can be used as the main controller of this kind of robot.

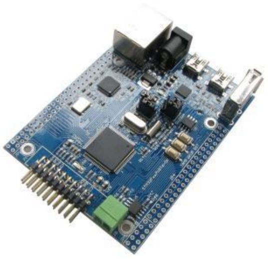

Fig. 4. STM32F407 microcontroller

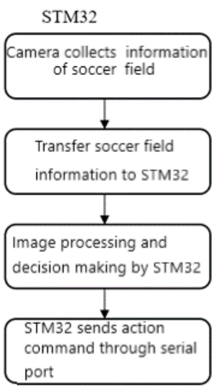

Fig.5.The flow chart of STM32

In this design, a Raspberry PI microcomputer (as shown in Fig.6) is selected to control SLAM lidar. It is an ARM-based microcomputer motherboard with SD/MicroSD card as memory hard disk and has all the basic functions of PC.

Fig.6.Raspberry PI 4B

This design adopts RPLIDAR A1 lidar (as shown in Fig.7), based on SLAM algorithm, adopts laser triangle ranging technology, in conjunction with the self-developed high-speed visual acquisition and processing mechanism, which can carry out ranging action more than 8000 times per second. Traditional non-solid state lidar mostly uses slip ring to transmit energy and data information, which is easy to be damaged due to mechanical wear. The lidar integrates wireless power supply and optical communication technology, and uniquely designs the optical magnetic fusion technology to enhance the life and stability of the radar. The radar is implemented at a scanning frequency of 5.5 Hz with a ranging resolution of 0.2% of the current range value. It can scan and detect the surrounding environment accurately and effectively.

Fig.7. Lidar

Tw10s-uart laser ranging module (as shown in Fig.8) is used to measure the distance of walls, etc., and calculate whether the walls are vertical according to the measured data. The sensor can sense the distance of the target by detecting the phase difference of laser. With high resolution. Temperature adaptability, small drift, high signal to noise ratio, small volume and other advantages. Use 3.3V TTL serial interface.

Fig.8. Single point laser ranging module

Hc-12 wireless serial communication module is a new generation of multi-channel embedded
Incoming wireless data transmission module. The wireless working frequency band is 433.4 -- 473.0MHz, and multiple channels can be set. The stepping frequency is 400KHz, and there are 100 in total. The maximum

transmitting power of the module is 100mW (20dBm), the receiving sensitivity is -116dbm at 5000Bps air baud rate, and the communication distance is 1000 meters in the open ground. We can choose one of the antennas according to the requirements. There is MCU in the module, so users do not need to program the module in addition. All kinds of transparent transmission modes just send and receive serial port data, which is easy to use. The module adopts a variety of serial port transparent transmission mode, users can choose according to the use of AT instruction. The module is controlled by STM32 master controller and can communicate with the robot remotely to control the robot.

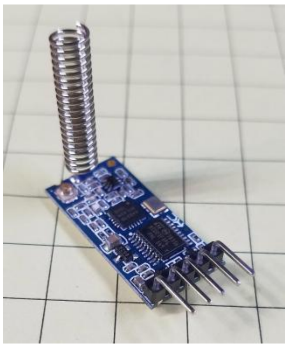

Fig.9. HC-12 wireless serial port communication module

4. The algorithm used in this paper

Maj mainly used SLAM algorithm and A* algorithm in this design.SLAM algorithm helps the radar to construct the map effectively, while A* algorithm and Dijkstra algorithm provide the autonomous navigation function of the robot.

4.1. Laser SLAM algorithm

SLAM algorithm uses structured light principle. Depth camera based on structured light usually has three core components: laser projector, optical diffraction element (DOE) and infrared camera. The fitting degree of this algorithm is better (as shown in Fig.10). SLAM system is generally divided into five modules: sensor data, visual odometer, back-end, mapping and loopback detection.
Sensor data: It is mainly used to collect various types of original data in the actual environment. Including laser scanning data, video image data, point cloud data, etc.
Visual odometer: mainly used to estimate the relative position of moving targets at different times. Including feature matching, direct registration and other algorithms.
Back end: mainly used to optimize the visual odometer cumulative error. Including filter, graph optimization and other algorithm applications.
Drawing: used for 3d map construction.
Loopback detection: mainly used for spatial cumulative error elimination. [4]

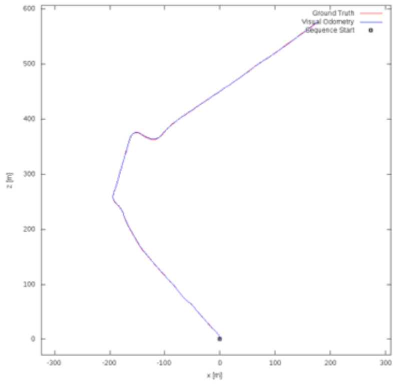

Fig.10. Fitting diagram of laser SLAM

4.2. A * algorithm

A* (pronounced: A Star) algorithm is A very common path search and graph traversal algorithm. It has better performance and accuracy. In this paper, the algorithm will be explained at the same time will also provide Python language code implementation, and will use the Matplotlib library to dynamically show the algorithm operation process. There are many similar algorithms, such as breadth-first search, Dijkstra algorithm.
A* algorithm is actually integrated with the characteristics of the above algorithms.
The A* algorithm calculates the priority of each node by using the following function.

$$f(n) = g(n) + h(n) \qquad (1)$$

Among them:
F (n) is the comprehensive priority of node N.When we choose the next node to traverse, we always select the node with the highest overall priority (lowest value).
G (n) is the cost of the distance between node n and the starting point.
H (n) is the estimated cost of node N from the end point, which is also the heuristic function of A* algorithm. Heuristic functions are discussed in detail below.
A* algorithm selects the node with the lowest f(n) value (highest priority) from the priority queue as the next node to be traversed.
In addition, the A* algorithm uses two sets to represent the nodes to be traversed, and the nodes that have been traversed, which are usually called open set and close set [5].
The flow of the algorithm is shown in the figure11.

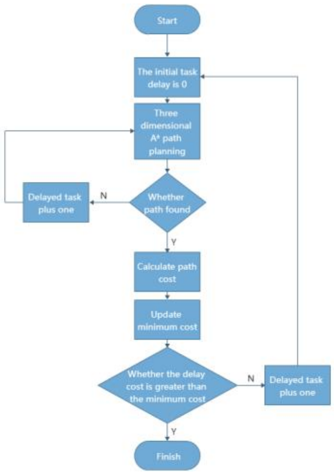

Fig.11.A* Algorithm flow chart

4.3.Dijkstra algorithm

The Dijkstra algorithm was proposed by computer scientist Edsger W. Dijkstra in 1956.
Dijkstra algorithm is used to find the shortest path between nodes in a graph.
Consider a scenario in which the costs of moving between adjacent nodes in a graph are not equal. For example, if a picture in the game has both flat ground and mountains, the game character will usually move at different speeds between flat ground and mountains.
In Dijkstra algorithm, it is necessary to calculate the total movement cost of each node from the starting point. You also need a priority queue structure. For all nodes to be traversed, the priority queue will be sorted by cost [3].
In the running process of the algorithm, the node with the lowest cost is selected from the priority queue as the next traversal node. Until we reach the finish line.
The calculation results of breadth-first search without considering the difference of node movement cost and Dijkstra algorithm considering the movement cost are compared as follows (from Fig.12 to Fig.15) :

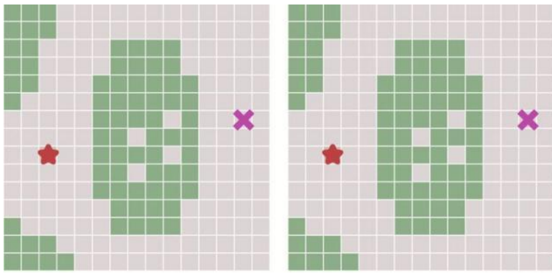

Fig.12.Result 1

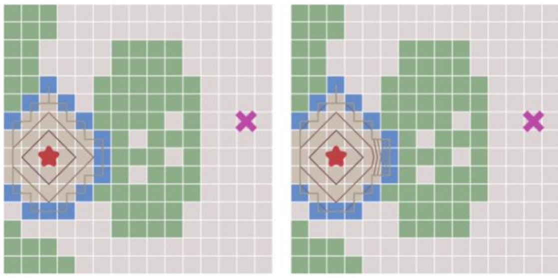

Fig.13.Result 2

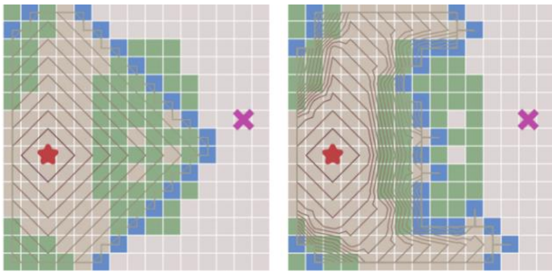

Fig.14.Result 3

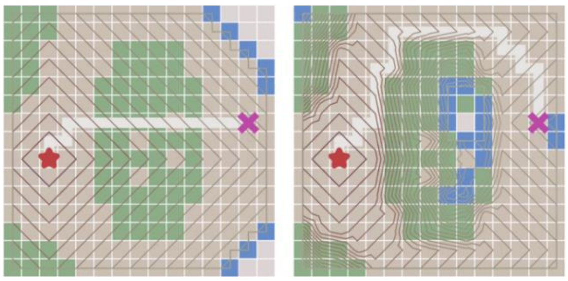

Fig.15.Result 4

When the graph is a grid graph and the cost of moving between nodes is equal, Dijkstra's algorithm becomes the same as the breadth-first algorithm.

5. Conclusion

This project mainly studies a remote-controlled intelligent house inspection robot, which can work instead of human resources under the background of aging population, labor shortage and cumbersome and inefficient use of various tools in house inspection, greatly saving human, material and financial resources.
The product has an advanced operating system and is combined with STM series of embedded devices, cameras, SLAM lidar and other sensors for quality inspection of the house. The robot can navigate automatically through SLAM laser radar mapping, and the related sensors added can detect the wall, including wall, ceiling, floor flatness, cracks, cleanliness, etc.
In addition to its autonomous navigation and positioning function as the basic platform function, it can also add a variety of replaceable sensors for different environments, greatly improving the compatibility of the device.

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References

1. SLAM for Dummies
2.CAI Zixing. Robotics. Beijing: Tsinghua University Press,2000.9.1.
3. Yongqi Chen, Shengxin Lin, Wenxiang Peng, Mingtao Guo, Xinghuan Li, Shuye Chen. Research on indoor mobile robot based on ROS. Journal of dongguan institute of technology, 2021, 28 (3) : 33-39. DOI: 10.16002 / j.carol carroll nki 10090312.2021.03.007.
4. Gong Wenting, Sun Zuolei, Pan Pan. Based on two-dimensional laser robot indoor composition . Micro computer and application, 2017, 4 (18) : 58 + 55-62. The DOI: 10.19358 / j.i SSN. 1674-7720.2017.18.017.
5. Liu Xiaofan, Zhao Bin. Mobile robot platform based on the ROS system design. Micro computer and applications, 2017, 4 (11) : 54-56 + 59. DOI: 10.19358 / j.i SSN. 1674-7720.2017.11.016.
6.HUANG Bing. Principle and application of microcomputer. Chongqing: Chongqing University Press,2001.
7.Zhou Yuanqing, Zhang Zixing, Xu Wanyong, Jia Peifa, et al. Intelligent robot system. Beijing: Tsinghua University Press,1988.
8.He Limin.Single-chip microcomputer application technology selected 1/2/3.Beijing: Beihang Press, 1992.

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