Design of mobile garbage collection robot based on visual recognition

Zhoulin Chang
College of Electrical and Mechanical Engineering
Guangdong University of science and technology
Dongguan, China
czl_ll@163.com

Linzhao Hao
College of Electrical and Mechanical Engineering
Guangdong University of science and technology
Dongguan, China
897464969@qq.com

Hanhong Tan
College of Electrical and Mechanical Engineering
Guangdong University of science and technology
Dongguan, China

Wenjing Li
College of Electrical and Mechanical Engineering
Guangdong University of science and technology
Dongguan, China

2020 IEEE 3rd International Conference on Automation, Electronics and Electrical Engineering (AUTEEE) | 978-1-7281-9827-9/20/$31.00 ©2020 IEEE | DOI: 10.1109/AUTEEE50969.2020.9315545

***Abstract*—This design mainly studies the intelligent mobile garbage collection robot based on visual recognition technology, which can carry out path planning, traverse the given area, scan and identify and pick up recyclable garbage. The system is composed of navigation unit, target identification unit and sorting control unit. The navigation unit is based on ROS distributed framework, uses lidar to collect the environment information of given area, realizes SLAM function based on scanning matching algorithm, and carries out path planning through optimal path algorithm and traverses the selected area. In the process of robot traversal, the target recognition unit passes through MobileNetv3-SSD deep learning algorithm detects and classifies the target from the image acquired by the camera, obtains the coordinate position and angle information of the target, and controls the manipulator to carry out the garbage grabbing task.**

***Keywords*—visual recognition, deep learning, garbage sorting**

I. Introduction

Today, the human cost is higher and higher. Applying robots to various fields instead of manual operation can reduce production costs, improve work efficiency and improve the market competitiveness of enterprises. Garbage sorting robot is a kind of mechanical equipment instead of manual garbage sorting. This kind of robot combines artificial intelligence technology, machine vision technology, intelligent control technology and vision and sorting. Through these technologies, the objects on the workbench can be accurately identified and sorted, and the sundries in the work area can be cleaned up, and even can be used for garbage classification in daily life [1]. This paper studies the intelligent mobile garbage sorting robot based on visual recognition technology, which can carry out path planning, traverse the cleaning area, scan and identify garbage and grab garbage. The corresponding products are suitable for cleaning plastic bottles, glass bottles, paper, metal and other public places in family gardens, parks, stations and other public places. It has the characteristics of high degree of automation, low cost and high efficiency. It can greatly save the manual of garbage cleaning and has a good application prospect.

II. System framework

The design of the robot is divided into two parts: the mechanical part and the control part. The main function of the mechanical part is to ensure the robot's free walking, picking and sorting actions. This part is mainly composed of wheels, frame, robot and other parts. The robot wheels mainly play the role of walking. There are 4 wheels in total. The wheels are selected considering the stability of the system structure and better motion performance. The frame is mainly used for supporting and fixing. The entire frame is made of multiple aluminum alloy base plates. The base plate mainly supports the components of the entire system and needs to meet the mechanical performance requirements. The robot is responsible for picking up the garbage. Considering the production cost of the system, the robot is assembled into a robot with digital steering gear, metal steering wheel, mechanical gripper, and 3D printed robot arm. The system power supply adopts 12000mAh high-power lithium battery pack, and the 12V power supply is convenient to provide reliable power supply for each part of the functional modules. The walking control part of the robot adopts wheels controlled by 4 DC geared motors. The motor is mainly used to drive the robot to walk. It is driven by a 4-way drive board module. The drive module integrates push-pull power amplifier ASIC devices, and integrates discrete circuits in a single Chip IC reduce the cost of peripheral devices and improve the reliability of the whole machine [2].

The system control framework is shown in Figure 1. The upper computer completes the work site monitoring function through wireless communication, and the main controller is responsible for the coordination and distribution of specific tasks of the robot. Based on the ROS distributed framework, the laser radar is used to collect the environmental information of the cleaning area, and realize the scanning-based The SLAM function of the matching algorithm, and path planning through the optimal path algorithm to traverse the cleaning area. During the robot traversal process, the target recognition unit uses the MobileNetv3-SSD deep learning algorithm to perform target detection and target classification on the images obtained by the camera, obtain the coordinates of the target and its angle information as the input information of the sorting control unit, and control the sorting control unit to execute garbage Grab task [4].

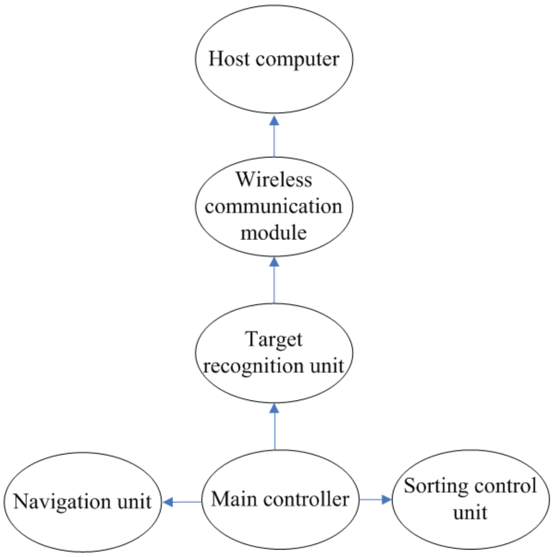

Fig. 1. System control structure block diagram

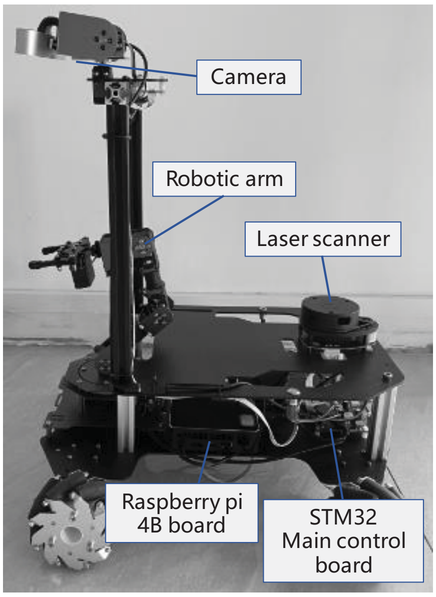

Fig. 2. The intelligent mobile robot prototype

III. System Design

A. System working principle

The working principle of the intelligent mobile garbage sorting robot is as follows. First, put the garbage sorting robot in the working environment to be cleaned, turn on the main power switch of the robot, and power on the system. The robot automatically creates a 2D plane image of a certain area through the navigation unit, and the recognition unit automatically scans and recognizes the area. If the garbage that needs to be recycled is not found in the work area, continue to scan the new area. If the recyclable garbage is found in the working area, the robot navigates to the nearby garbage through the guidance of the navigation unit, and adjusts the garbage sorting manipulator arm according to the position of the identified garbage, and then completes the garbage collection task. When the robot is navigating, once it detects a garbage-like image, the target recognition unit will obtain the image data result after processing according to the target detection algorithm MobileNetv3-SSD, and compare it with the garbage characteristic value stored in the system library. If the similarity exceeds 90%, the system will identify it as the garbage that can be recognized in the learning library, and the control unit will control the manipulator to grab and recycle it.

B. Hardware structure design

The physical prototype of this design is shown in Fig.2, including STM32 control board, Raspberry Pi 4B board, lidar detector, robotic arm, camera, 12V power supply, etc. The main body of the robot uses a metal plate as the main frame of the car. In order to increase the space, the robot is divided into upper and lower layers. The upper layer is placed with lidar detectors, robotic arms, trash cans, etc.; the lower layer is placed STM32 control board, Raspberry Pi 4B board, Power supply, etc. The lidar detector uses SLAMTEC RPLIDAR A2 with a sampling frequency of 8000 times per second to ensure the quality of map construction when the robot moves quickly. When the lidar rotates clockwise, it can realize the 360-degree scanning range detection of the environment, and then obtain the contour map of the surrounding environment, and construct the 2D plane image.

The robot uses the latest raspberry Pi 4B module to deal with the navigation task. Through the navigation algorithm, the safe and reliable robot action and speed control instructions are calculated. The STM32f407 main control board is mainly responsible for controlling the deceleration DC motor and controlling the steering gear on the manipulator. Four Wheels mainly used for walking. Rubber tires are used in the two power wheels to effectively increase the friction force and improve the environmental adaptability of the robot. The mechanical arm is used to complete the action of picking up garbage. The 4-DOF manipulator is used to meet the general garbage sorting operation. The steering gear is mainly used to complete the movement of the manipulator. Considering the speed and strength, the metal gear steering gear MG996R is finally selected, which can complete the rotation in the range of $0^{o} \sim 180^{o}$. The system uses Intel depth camera d435i, equipped with global image shutter and wide field of view, and is attached with inertial measurement unit (IMU) BMI 055. It can synchronize data and depth information in real time, facilitate the position perception of ROS system, and effectively capture the depth data of moving objects, to provide help for robot to accurately perceive moving objects.

C. System software design

The software flow of the system is shown in Fig. 3. After the system is initialized, the robot will navigate the established route, collect images through the camera, and perform algorithmic processing on the images to determine whether there is garbage. If not, the robot will continue to navigate and scan for garbage. If so, the raspberry Pi 4B module will send a signal to STM32F407 main control board and navigate around the garbage by the adaptive Monte Carlo positioning algorithm. After reaching the location of garbage, the robot will control the robotic arm calibrated by hand and eye to perform the grabbing action, and then continues the navigation scan after grabbing the garbage.

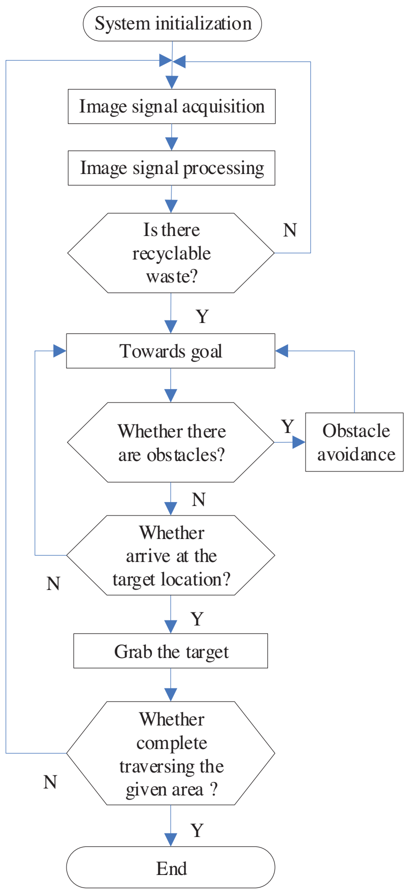

Fig. 3. System sotfware flow block diagram

D. Selection of target detection algorithm

There are many algorithms for target detection, such as RCNN series, YOLO series and SSD, and front-end networks such as VGG, AlexNet and SqueezeNet. A common method is to set the front-end network as MobileNet and the back-end algorithm as SSD for target detection [6,8].

The MobileNetv3 is a new generation of MobileNet that combines search technology with architecture design. Mobilenetv3 is a lightweight attention model which combines the depth wise separable convolutions of MobileNetv1, the inverse residual with linear bottleneck structure of MobileNetv2 and the lightweight attention model based on squeeze and extraction structure. Compared with MobileNetv2, MobileNetv3-large improves the accuracy of ImageNet classification by 3.2% and reduces the latency by 15%. Compared with MobileNetv2, the accuracy of MobileNetv3-small is 4.6% higher and the delay is reduced by 5%. The detection speed of MobileNetv3-large is 25% faster than that of MobileNetv2[7].

The SSD (Single Shot multibox Detector) belongs to one stage detection method. It mainly adopts the method of direct regression of target category and location, and through prediction of feature layers of different scales, it can also detect targets well at low resolution of image, and ensure its accuracy [16]. In the process of training, the end-to-end method is used for training. Compared with the two steps of Fast R-CNN that get candidate frames through CNN first, then classify and regress, SSD can complete detection in one step. Compared with Yolo, SSD uses CNN to detect directly. SSD extracts feature maps of different scales for detection. Large scale feature map can be used to detect small objects, while small feature map is used to detect large objects [5,12,13].

The network model of MobileNet-SSD can realize the function of target detection, and is suitable for the computer vision neural network in mobile devices, such as vehicle license plate detection, pedestrian detection and other functions, with the advantages of fast speed, small model and high efficiency [14,16].

IV. PERFORMANCE INDEX ANALYSIS

In order to verify the correctness of the design and implementation of the system, the experiment verification is designed for the main functions of the system, which mainly includes two aspects. One is to verify the correctness of the design of the target recognition unit, the core part of the target recognition unit is the target recognition algorithm; The second is the test experiment of the whole sorting system, which has been verified in the target recognition algorithm under the premise, the angle and position of the target are obtained to control the operation of the whole system. In the laboratory state environment, the background environment of target recognition is simulated, and all parts of the system cooperate to complete the operation of classification and target grabbing.

The technical performance requirements of the target recognition unit include image acquisition and detection speed and image detection accuracy. The main technical performance requirements are as follows. (1) The effective image acquisition frame rate of the image acquisition system is higher than 28 frames/s; (2) The effective recognition range of the image acquisition system exceeds 2m; (3) The acquisition and calculation time jitter of the image acquisition system is less than 10ms. During the test, when the intersection ratio of the actual position of the object and the detection result is greater than 0.5, it is judged that the object is successfully detected. The evaluation criteria used in the experiment are the false detection rate and the missed detection rate, which are defined as follows. false detection rate is equal to number of falsely detected targets divide number detected by target recognition multiply 100%; missed detection rate is equal to number of missed targets divide total the number of targets multiply 100%.

TABLE I. TARGET RECOGNITION ALGORITHM GALLERY RELATED TRAINING PARAMETER SETTINGS

Training set	6000Pcs(640×480)
Test set	1500Pcs(640×480)
Validation set	1500Pcs(640×480)
Training times	12864

The experimental results are shown in Table II. In the experimental environment, the prediction angle of the target is accurate, the false detection rate of the target is 5.33%, the missed detection rate is 8.67%, and the false picking rate is less than 10%. In terms of detection time, due to the long forward propagation time of the CNN network itself, the time is about 70ms, which basically meets the actual needs of the garbage sorting robot system project.

TABLE II. EXPERIMENTAL RESULTS

Target number	False detection rate	Number of missed inspections	False detection rate	Missed detection rate	Times
150Pcs	8Pcs	13Pcs	5.33%	8.67%	70ms

V. CONCLUSION

This paper presents a set of overall design scheme of intelligent garbage recycling robot system based on machine vision. The main features are as follows. (1) In the designated area, identify and pick up recyclable garbage; (2) Automatic traverse navigation, automatic identification and grabbing of garbage; (3) Through deep learning training, recyclable garbage can be identified accurately with the highest accuracy of 97.5%; (4) The target detection speed is fast. Through the improved algorithm, it is suitable for embedded devices to quickly detect and classify targets; (5) The cleaning methods are flexible and diverse. The solid garbage is grasped by the mechanical claw, and the garbage that fits the ground is grasped by the suction cup. Although there are all kinds of garbage sorting robots, most of them are task robots that can't move and navigate independently or can only patrol and sort according to specific routes. This scheme designs and implements the software and hardware of each part of the system, and finally verifies the accuracy of the embedded target recognition algorithm MobileNetv3-SSD through the actual operation of the system in the living environment, The feasibility of the system design is verified and a feasible solution is provided for the automatic garbage sorting in environmental protection industry.

ACKNOWLEDGMENT

This work was financially supported by the follow projects. The special innovation projects of ordinary universities in Guangdong Province. Project name: Research on intelligent garbage sorting robot based on vision recognition technology. Project number: 2019KTSCX252. Project of Guangdong University of science and technology. Project name: Research on sorting robot based on visual recognition technology; Project number: GKY-2019KYYB-7.

REFERENCES

[1] Cai Hanming, Zhao Zhenxing, Han Lu, et al. Multi-target detection algorithm based on SSD network model [J]. Mechanical and Electrical Engineering, 2017, 34(6): 685-688.

[2] Chen Xiaofei. Application analysis of machine vision technology in machine manufacturing automation [J]. China Equipment Engineering, 2017(1): 168-169.

[3] He Xiangyu. Research on machine vision recognition technology of plastic bottles for intelligent sorting and recycling[D]. Zhejiang University, 2017.

[4] Mur-Artal R, Montiel J M M, Tardós J D. ORB-SLAM: A Versatile and Accurate Monocular SLAMSystem[J]. IEEE Transactionson Robotics, 2017, 31(5):1147-1163.

[5] Liu W, Anguelov D, Erhan D, et al. SSD: Single Shot MultiBoxDetector[C] European Conference on Computer Vision. 2016.

[6] Yang Jucheng, Liu Na, Fang Shanshan, et al. Research review of face recognition methods based on deep learning [J]. Journal of Tianjin University of Science and Technology, 2016, 31(6): 1-10.

[7] Ji Dengchen Ji. Research on scattered multi-objective sorting system based on machine vision [J]. Industrial control computer, 2018 (12): 34-35.

[8] Wenshan Hui. Robot tactile recognition and adaptive grasping control based on CNN-LSTM[J]. Journal of Instrumentation, 2019(1): 211-218.

[9] Xuqing Wu. Design of Intelligent Sorting System for Parallel Robots[J]. Mechanical and Electrical Engineering. 2019 (2): 224-228.

[10] Yuqiang Zhou. Part recognition and sorting system based on convolutional neural network[J] Coal Mine Machinery. 2018 (6): 151-153.

[11] Design and implementation of ROS-compatible embedded real-time robot communication system [D]. Harbin Institute of Technology, 2018.

[12] Jiang M, Liang Y, Feng X, et al. Text classification based on deep belief network and softmax regression[J]. Neural Computing and Applications, 2018,29(1): 61-70.

[13] Levine S, Finn C, Darrell T, et al. End-to-end training of deep visuomotor policies[J]. The Journal of Machine Learning Research, 2016, 17(1): 1334-1373.

[14] Kong T, Yao A, Chen Y, et al. HyperNet: Towards Accurate Region Proposal Generation and Joint Object Detection[C]. IEEE Conference on Computer Vision and Pattern Recognition. IEEE Computer Society, 2016:845-853.

[15] Hariharan B, Arbeláez P, Girshick R, et al. Hypercolumns for object segmentation and fine-grained localization[C]. Proceedings of the IEEE conference on computer vision and pattern recognition. 2015: 447-456.

[16] Liu W, Anguelov D, Erhan D, et al. Ssd: Single shot multibox detector[C]. European conference on computer vision. Springer, Cham, 2016: 21-37.

[17] Cai, Y. L., He, Q., Duan, J., Gao, Z. Y. (2019). Full-order observer-based output regulation for linear heterogeneous multi-agent systems under switching topology. Journal of Artificial Intelligence and Systems, 1, 20–42.