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Design of Intelligent Sanitation Robot System Based on Raspberry pi and Deep Learning

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Abstract: An intelligent sanitation vehicle robot system based on deep learning algorithm is designed. The main control of the system is the raspberry pi development board, which collects the ground garbage pictures through the camera, uses the lightweight deep learning target detection algorithm YOLOV4-Tiny to detect the garbage pictures, uses the PID algorithm to control the robot arm to locate the garbage target, picks up the garbage and puts it into the corresponding garbage bin, thus realizing the collection and intelligent classification of the ground garbage. Train the deep learning model on the PC side, and then deploy the trained model into the embedded system.

Keywords: Raspberry pi; Deep learning; Object detection; Intelligent sanitation robot

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1. Introduction

At present, the city produces a large number of randomly discarded garbage every day. In order to ensure the cleanness of the urban environment, the country has deployed a large number of cleaning and sanitation workers on the urban roads, living quarters, scenic spots and other places to carry out manual cleaning, which requires a lot of human and material resources and other operating costs. When sanitation workers clean the environment, they have high labor intensity and low efficiency. Moreover, the sanitation workers' knowledge of garbage classification is relatively poor, and they can't do the correct classification, which is not conducive to the classification, transportation and treatment of garbage in the later stage.

An intelligent sanitation robot system integrating walking, sensing and executing mechanism is designed to replace the work of sanitation workers to pick up garbage to a certain extent, realize the intelligent classification of garbage and reduce the human cost of environmental cleaning.

2. Overall design of intelligent sanitation robot system

The raspberry pi development board is the main control of the system, realizing the coordinated operation of the whole system and the control of each module. The system uses the vehicle chassis as the carrier, and the DC motor is controlled by the deep learning automatic driving algorithm to realize the automatic driving of the robot. In the process of robot walking, the camera collects the ground image in real time. When the ground garbage is collected, the category and location of the garbage are obtained by the deep learning target detection algorithm. The raspberry pi controls the steering gear to drive the manipulator to pick up the garbage and put it into the corresponding garbage bin. The infrared sensor module is used to detect the full load status of the garbage bin in real time. When the garbage bin is full, the wifi module sends the full load information of the garbage bin to the cloud platform of the Internet of Things, and prompts the robot to wait for the relevant staff to transfer the garbage.

The core algorithm of the system includes garbage image target detection algorithm and robot automatic driving algorithm. Both algorithms are based on the deep learning model. First, on PC, GPU is used to train the deep learning model. During training, the dataset adopts the pictures collected by the camera in real time. Considering the shortage of the dataset, the pre-training model based on transfer learning is adopted.

3. System hardware design

The main control board of the system uses Raspberry Pi 4B, which provides 40 expandable GPIO interfaces, CSI and USB camera interfaces, and HDMI video output and audio output interfaces. The display screen adopts the official big screen of raspberry pi. The image acquisition module uses the official raspberry camera with CSI interface.

L298N double-H-bridge DC motor drive module is used for motor drive, and the four output ports (out1, out2, out3, out4) of the module are connected with the positive and negative poles of the DC motor respectively. The four input ports (IN1, IN2, IN3, IN4) are connected to the raspberry GPIO interfaces 11, 12, 13, and 15 respectively. The L298N module controls the rotation direction of the motor through the level signal of the four input ports.

The infrared sensor module uses the HW-201 infrared sensor. There are transmitting tubes and receiving tubes in front of the module. When the garbage compartment is full, the infrared rays emitted by the transmitting tubes will be blocked by garbage, so that the reflected infrared rays will be received. At this time, the output port is a low-level signal. When raspberry pi detects that the garbage can is full, it sends data to the cloud platform of the Internet of Things through the wifi module, which uses the ESP8266 series products developed by Anxinke. Set the working mode to STA mode through AT command, and the module can be used as a terminal to connect to the external network for communication.

The automatic obstacle avoidance module uses HC-SR04 ultrasonic ranging module. Connect the ultrasonic module TRIG and ECHO to GPIO29 and GPIO31 of raspberry pi respectively. TRIG is responsible for transmitting ultrasonic, ECHO is responsible for receiving ultrasonic, VCC is connected to raspberry pi 5V interface to realize power supply to the module, and GND is connected to raspberry pi GND interface. The time difference between transmission and reception is used to calculate the distance.

The mechanical arm uses a tabletop three-axis mechanical arm with a manipulator installed at the end for garbage grabbing. A total of 4 steering engines are required, of which 3 steering engines control the movement of the manipulator and 1 steering engine controls the opening and closing of the manipulator. The steering gear drive uses I2C to 16-channel PWM special steering gear drive board, and the drive chip uses PCA9685. The I2C interface pins SDA and SCL of the drive board are connected with the SDA1 and SCL1 (Pin3 and Pin5) of the raspberry pi.

4. Main algorithm

4.1 Garbage detection algorithm

The task of object detection is to find all interested objects in the image and determine their categories and positions. Target detection algorithms based on convolution neural network include One-stage and Two-stage. Common two stage target detection algorithms include R-CNN, SPP-Net, Fast R-CNN and R-FCN, and common one-stage target detection algorithms include OverFeat, YOLO, SSD and RetinaNet. Because the deep learning model is deployed at the mobile end, the system adopts the YOLOV4-tiny model structure.

YOLOV4-tiny structure is a simplified version of YOLOv4, belonging to the lightweight model, with parameters of only 6 million, equivalent to one tenth of the original, which greatly improves the detection speed. The overall network structure has 38 layers, using three residual units, the activation function uses LeakyReLU, the classification and regression of the target is changed to use two feature layers, and the feature pyramid (FPN) network is used when merging the effective feature layers. It also uses the CSPnet structure, and divides the channel of the feature extraction network into two parts, and takes the second part. 40.2% of AP50 and 371 FPS are obtained from COCO data set, which has a significant performance advantage over other versions of lightweight models.

Deep learning includes two stages: model training and model reasoning. The model training is completed on the PC. The trained model is deployed on the raspberry pi to perform the reasoning task. The deep learning framework uses Tensorflow.

4.2 Manipulator control algorithm

The PID control algorithm is used to accurately locate the garbage so that the robot arm can pick up the garbage and put it into the corresponding garbage bin according to the classification results. The basic principle is to collect the image in real time through the camera, input it into the target detection model to obtain the coordinate position of the garbage in the image, calculate the deviation value between the target center point and the image center point, and drive the manipulator to move through the PID algorithm debugging, so that the target center point coincides with the image center point, so that the manipulator can grasp.

4.3 Automatic driving algorithm

The first step to realize automatic driving is to let the system remember the map and know when to turn left, right or execute. The process of system memory map is the process of training model.

Use the remote control handle to control the robot vehicle to drive on the map. The camera collects and stores the pictures, and records the labels of each picture at the same time, that is, left turn, right turn, straight or acceleration operation. Therefore, this is a typical four-classification problem of images. In order to speed up the training, the transfer learning idea is adopted to download the pre-training model from the network and complete the training of the model on PC. Considering that the model will eventually be deployed to the mobile terminal, the lightweight deep learning model MobileNet-V3 is selected.

Deploy the trained model to the raspberry pi, and the robot system will send the real-time image into the model through the camera under the condition of unmanned control, so as to predict the next direction of the vehicle and realize the automatic driving of the robot.

5. Model optimization and deployment

Due to the limited computing power of raspberry, in order to enhance the real-time performance of the system, the model needs to be optimized and then deployed to the raspberry system. Common model reasoning deployment frameworks mainly include Intel's OpenVINO, Nvidia's TensorRT and Google's Mediapipe. TensorRt is a reasoning framework that can only be used on Nvidia Jetson platform. OpenVINO and Mediapipe can use ARM based embedded platforms, but Mediapipe only supports Tensorflow deep learning framework. In a comprehensive consideration, the system uses OpenVINO to optimize and deploy the model. First, convert the trained model (. pb format) to onnx model, then use OpenVINO to convert onnx model to IR model, and finally install OpenVINO on the raspberry pi and deploy the inference model.

6. Conclusions

Deep learning algorithm has a wide application prospect in intelligent robot system, but at present, the computing capacity and memory capacity of mobile terminal are still very limited, so there are still some defects in real-time. With the further improvement of mobile computing performance, more and more AI projects will be gradually implemented. This paper uses the raspberry pi control board to deploy the deep learning model to realize the automatic driving of the intelligent sanitation robot and the intelligent sorting and picking up of garbage, providing a feasible solution for the landing application of the artificial intelligence project.

References:

[1] Teng Kaiwen, Ding Kang, Wang Shuo. "Design and Implementation of Intelligent auto drive system Based on Raspberry Pi" [J]. Technology and Innovation, 2023 (2): 19-22

[2] Wang Xinlong et al. "Smart garbage sorting kiosk based on raspberry pi" [J]. Internet of Things Technology, 2022 (11): 83-86

[3] Lin Xianghui, Xie Benliang. "Real-time target detection based on TensorFlow Lite platform" [J]. Intelligent Computer and Application, 2021 (2): 80-83

[4] Zhu Yadongyang et al. "Research and implementation of real-time target detection system based on edge computing" [J]. Journal of Beijing Institute of Petroleum and Chemical Technology, 2022 (2): 40-45