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Intelligent garbage sorting device based on machine vision neural network

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Abstract

The classification of domestic waste is of great significance to the construction of resource-conserving and environment-friendly society. A garbage intelligent classification device is designed, which takes STM32 chip as the main control and uses OpenMV4 camera to construct a garbage identification neural network for identification. The identification results are sent back to MCU through serial port, and then the motor is controlled to rotate to the corresponding Angle for garbage delivery through the obtained data. Infrared tube is used to judge the height of the garbage to realize the full load alarm. The product also has a display screen that shows the type and amount of garbage to be thrown, as well as a promotional video that can be played to raise people's awareness of garbage sorting. The intelligent garbage classification device can be applied to public places, families and other places to realize the identification of garbage types, and realize automatic classification into the bucket, complete the automatic garbage classification, instead of artificial classification, improve the accuracy of garbage classification.

Keywords

Garbage classification; Machine vision; The neural network.

1. Introduction

Nowadays, China's economy is in a stage of rapid development, the population is increasing, and the people's living and consumption levels are constantly improving. At the same time, it is also accompanied by a large amount of garbage. The issue of garbage sorting has also been put on the agenda. At present, our country mainly relies on manual garbage sorting. People need to judge by themselves what kind of garbage they are in, and then put them in the correct trash can. Manual classification has worked to a certain extent, but it is not a long-term solution. This requires a lot of time, manpower and material resources. In order to facilitate and save time, an intelligent garbage sorting device came into being. This will not only play a major role in the construction of a resource-saving and environment-friendly society, but also further improve the level of ecological civilization construction. And it brings great convenience to people's production and life.

2. The design of system hardware

For the entire design of the garbage intelligent classification device, starting from the hardware, it is mainly composed of an identification module, a garbage disposal mechanism, an infrared sensor module, a display module, and a GSM module, which respectively realize the functions of garbage identification, release, full load detection, display and alarm. The core of the smart trash can is based on the STM32F407 microcontroller as the main control to connect to other modules to achieve centralized control. The overall system frame diagram is shown in Figure 1.

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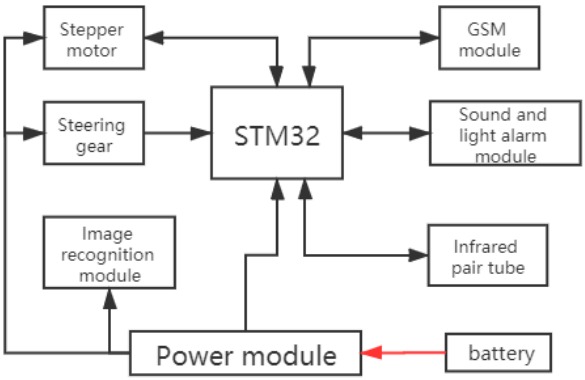

Figure 1 System frame diagram

2.1. Main module circuit introduction

2.1.1. Main control part

Adopt STM32F407 single-chip microcomputer as the main control, responsible for driving each module and carrying out serial communication with Open Mv. STM32F407 is a high-performance microcontroller. Its advantage is the integration of new DSP and FPU instructions. The high-speed performance of 168MHz makes digital signal controller applications and rapid product development reach a new level. Improve the execution speed and code efficiency of the control algorithm.

2.1.2. Garbage disposal agency

The mechanical part includes a fan-shaped garbage disposal platform and a garbage disposal device composed of a stepping motor and a steering gear. The fan-shaped design reduces the scrolling of the garbage thrown in, which helps to improve the recognition speed. After the recognition is successful, the single-chip microcomputer controls the horizontal rotation angle of the stepping motor, and then the steering gear controls the stage to flip down and put it into the trash can. The specific structure diagram is shown in Figure 2.

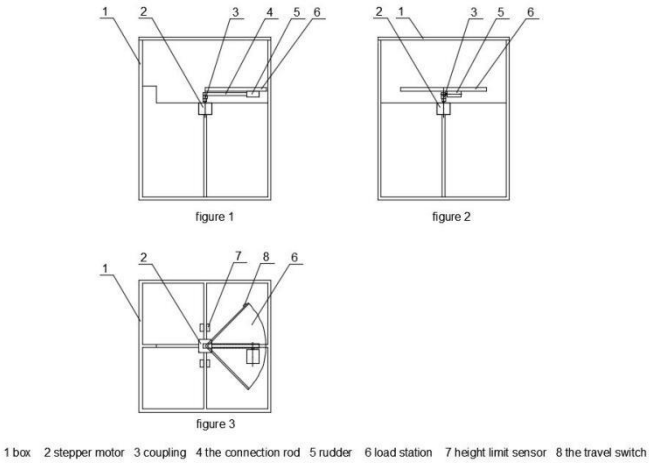

Figure 2 Internal structure diagram of garbage intelligent classification device

2.1.3. Identification Module

Use the programmable camera openMV4, the camera is small and low power consumption, the circuit board cost is low, suitable for machine vision applications, through the Micro Python language to identify garbage, Python's advanced data structure can easily handle complex output in the machine vision algorithm, return the recognition result and pass it to the master through the serial port. A variety of intelligent algorithms are used to establish a garbage identification database for subsequent identification upgrades.

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2.1.4. Infrared sensor module

The system is designed with a full load alarm function. The sensor in each small bucket will detect obstacles. When the stacking height exceeds the threshold, it will trigger a buzzer to alert and prompt to actively replace the garbage bag. The realization of this function depends on the infrared sensor module. The principle and structure of infrared induction ranging are relatively simple, with long ranging and low power consumption.

2.1.5. Display module

LCD color screen has the advantages of low cost, high resolution, high contrast, low power consumption, etc., so we choose LCD color screen. The bottom of the screen will play promotional videos in a loop, and the top of the screen will display the working status, including: full load status, working status of trash can, type, quantity and order of trash.

2.1.6. GSM module.

The GSM module of this system adopts the SIM800L series module, which can realize short message sending and receiving and GPRS data transmission. It has the advantages of small size, low power consumption, wide temperature range required for work, low price, and suitable for the use of the system of this design. Use AT commands to develop, easy to configure. Through this module, the emergency alarm function is realized, and the user is notified in the first time, reducing potential safety hazards.

2.2. Working principle

The intelligent garbage classification device uses the OpenMv4 plus camera to construct a garbage recognition neural network for identification, and realizes the intelligent discrimination, classification and storage of the four types of urban domestic garbage of "recyclable garbage, kitchen waste, hazardous garbage and other garbage". After the identification and classification, the smart trash can, through data processing and analysis, controls the steering gear on the device to rotate, and when it rotates to the angle of the corresponding small trash can, the garbage can be put in. When rubbish is put in, the type and amount of rubbish put in will be displayed on the screen. There are four infrared detection devices inside the product fixed at the height of 3/4 of the four small trash cans to detect the height of trash. When trash is detected beyond this position, the module light will change and a signal will be sent to the LCD screen. Shows which number of trash cans are in the state of being fully loaded, and can send SMS reminders to users via GSM.

3. Machine Vision Recognition

3.1. Machine Vision Module

The machine vision recognition module used in this intelligent waste sorting device is the OpenMv4 H7 Plus camera. The recognition module is based on the image processing module to obtain an image, match the image with the rubbish training set pre-input into the convolutional neural network, seek the common features between the two according to the contour recognition, colour recognition, material recognition and other recognition methods, and then identify the category of the rubbish placed according to the written image algorithm.

3.2. Algorithm introduction

The neural network used in OpenMv4 H7 Plus is a library of neural networks trained by TensorFlow. The general process of creating a neural network is to define the cost function, randomly initialize the weights, calculate the probabilities using the forward propagation algorithm, update the weights using the backward propagation algorithm, then repeat the random initialization of the weights and the forward propagation algorithm to calculate the probabilities, and optimize the network until the cost function converges. Deep neural

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networks are based on shallow neural networks mainly by adding hidden layers, the more hidden layers, the deeper the neural network.

Three parts of information are required to calculate the forward propagation results of a neural network. The first part is the input to the neural network, this input is the feature vector extracted from the entity, for example the part length x_1 and the part mass x_2 in the figure below. the second part is the connection structure of the neural network. The neural network consists of neurons (nodes), for example in the figure below the a_{11} node has two inputs which are the outputs of x_1 and x_2 respectively, and the output of a_{11} is in turn the input to the y node. The third part is the parameters of each neuron, e.g. in the figure below, W denotes the parameters of the neuron and the superscript indicates which layer, e.g. $W^{(1)}$ denotes the parameters of the first layer and $W^{(2)}$ denotes the parameters of the second layer. the subscript of W indicates the number of the connection point, e.g. $W_{1,2}^{(1)}$ denotes the weights of the edges connecting nodes x_1 and a_{12}. Given the input to the neural network, the structure of the neural network and the weights, the output of the neural network can be calculated by the forward propagation algorithm, as shown in Figure 3.

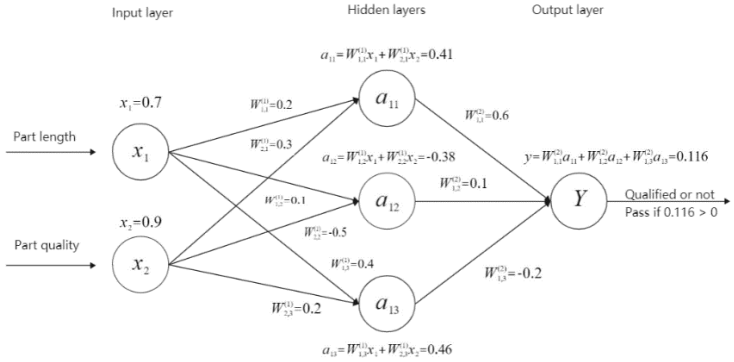

Figure 3. Computational neural network forward propagation algorithm

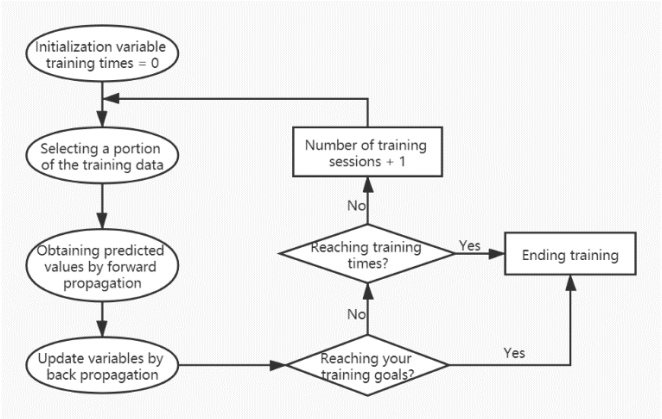

Figure 4. Computational neural network back propagation algorithm

Optimisation algorithms:TensorFlow supports seven different optimisation algorithms. All are in the tf.train package,the commonly used ones are tf.train.GradientDescentOptimizer、tf.train.AdamOptimizer and tf.train.MomentumOptimizer.

3.3. Neural network creation process

Training a neural network model for OpenMV online using Edge impulse is a four-step process: dataset acquisition, upload, training and deployment.

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3.3.1. Collection of data sets

The first data acquisition is carried out by the classification to be recognised, and approximately 100-200 images are acquired for each angle of the object to be recognised to ensure a diverse training learning. Approximately 4000 images are acquired for each classification.

3.3.2. Upload

Register on the Edge impulse website and create a 'refuse classification' project, then upload the collected rubbish datasets separately. The data will be automatically divided into a training set and a test set when uploaded, with a default ratio of "80% and 20%". 80% of the data set will be used for training and the remaining 20% for testing.

3.3.3. Training data set

First configure the processing module, set the default image aspect to "96 x 96" and select the image module to indicate that it is training to classify images, and finally set the learning model to "Transfer Learning (Images) The final model to be learned is "Transfer Learning (Images)". Next, select "Generate features" to initiate the process and pre-process the data into images, after which a 3D visualisation of the complete dataset is displayed. If the colours of each category of data are separated, the features are more clearly differentiated. A migration learning model is then performed and once the model is trained, the accuracy, confusion matrix and expected device performance can be seen. Once training is complete, the model is then tested using test data.

3.3.4. Running models on OpenMV

Once the training design, model training and model validation are complete, the model can be exported and three files are automatically generated: trained.tflite (the trained neural network model), labels.txt classification ei_image_classification.py which is the code to be run on top of OpenMV. Once the code is run, the image processing module can be used to identify the type of object.

4. Software programming

4.1. Serial communication function

First, the microcontroller detects that the serial port status bit is cleared, and enters the serial port to receive interrupt after a delay of 3 seconds.When USART_RX_STA&0x8000=0, that is, when the highest bit of the interrupt flag bit STA is 1, the interrupt is entered.First obtain the data length len of this transmission, and then nest the for loop to send the receiving buffer to the data register, and at the same time send it to the serial port. Use the sprintf function to convert the value into a string and call the LCD display function to display the transmitted single character. When it is judged that USART1->SR&0X40=0 (the seventh bit of the SR register is 1), the transmission is over, the receiving status flag is set to zero, and the column start address is set. The flowchart is shown in Figure 5.

4.2. Alarm procedure for full garbage load

After the single-chip microcomputer controls the steering gear and the motor to complete the garbage disposal, the state of the garbage in the garbage can is judged. The infrared transmitting tube continuously emits infrared signals of a certain frequency. When the detection direction encounters an obstacle, the infrared rays are reflected back and received by the receiving tube. After processing by the comparator circuit, the output indicator light will light up and the digital signal will be output at the same time. The single-chip microcomputer detects the level of the garbage to determine whether the garbage reaches the set warning value, and the detection distance can be adjusted through the potentiometer knob.

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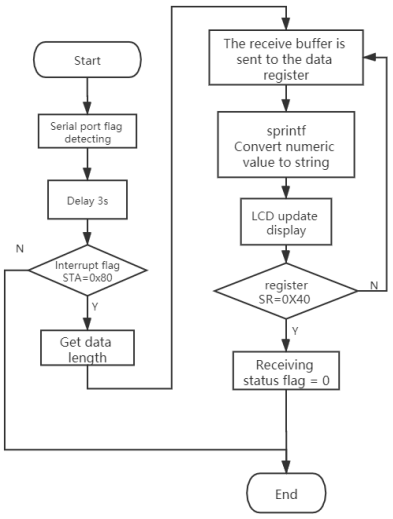

Figure 5 Serial communication flow chart

4.3. Remote communication alarm program

For the convenience of development, we use AT commands to control sim800. Only 5 lines of code are required to complete the configuration of the GSM module, wait for the full load status bit of the trash can to change, the buzzer sounds, call the send_GSM function, and send an alarm message to the user's mobile phone.

5. Physical test results and analysis

The test result is shown in Figure 6. The screen shows that the battery is detected, the identification is successful, and it is judged as hazardous garbage. The single-chip microcomputer controls the stepping motor to rotate horizontally, and then the steering gear controls the stage to flip down, and put the hazardous garbage into the trash can.

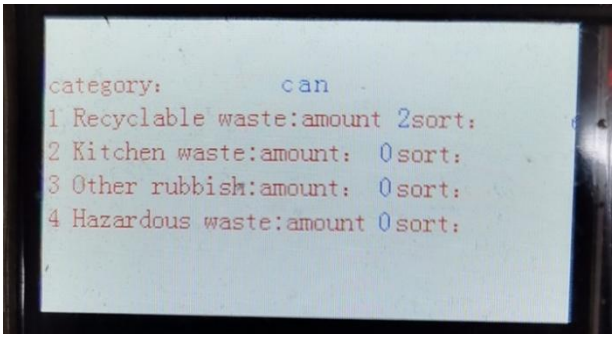

Figure 6. Test results

6. Conclusion

This article introduces an intelligent garbage classification device based on machine vision neural network. The system has the characteristics of simple operation, convenient use, automation and intelligence. It can realize the garbage classification in daily life. Its novelty is to simplify the garbage classification steps and add the function of garbage recognition neural network, which maximizes the problem of garbage classification.

Resources

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