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Machine vision garbage classification and recycling system based on deep learning

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Abstract

In recent years, the phenomenon of "garbage besieged cities" has been reported frequently in various places. The Chinese economy is in a stage of rapid development, the number of people is increasing, and the level of consumption is increasing. At the same time, it is also accompanied by a large amount of garbage. In view of the imperfect domestic garbage classification methods and the low utilization rate of garbage recycling, this project is committed to changing the functions of existing garbage bins and realizing garbage classification from the source. The intelligent IoT waste classification and treatment system uses information technology methods such as intelligent waste classification, collection, mobile communication, urban management, environmental protection, information interaction, etc., to functionalize, platform, and resourceize the trash can, so as to efficiently use urban land and space Resources to promote the construction of green and smart city infrastructure. This project innovatively uses the Stacking method of the machine learning integrated model for neural network training, which greatly improves the recognition accuracy of the garbage classification device; the software and hardware sides send and receive data through the cloud server through the MQTT protocol, so that the management user can perform the equipment anytime and anywhere Monitoring and use. The location information of the smart garbage device is used to clean up the trash cans in the corresponding street at fixed points, thereby saving manpower and capital investment, integrating effective resources, reflecting the concept of sustainable development, and creating a good environment for urban development and social services.

Keywords

Machine vision garbage classification, deep learning.

1. Introduction

China's economy is in a stage of rapid development, the number of people is increasing, and the level of consumption is increasing. At the same time, it is accompanied by a large amount of waste. In some areas with better waste management, most of the waste will be sanitary landfill, incineration, composting, etc. In addition, waste in more places is often simply piled up or buried, and contaminates soil and groundwater. The increase in urban waste poses a huge threat to the sustainability of cities, especially in developing countries. It has become one of the main sources of urban environmental pollution in China. Therefore, the classification of urban waste is of great significance to the sustainable development of cities. In essence, this is a social behavior that requires public participation. Shanghai is the first to implement waste classification legislation in China. [1] Starting from the status quo of garbage classification in my country, it emphasizes garbage classification from the aspects of law, quantity, economy, management, resources and successful experience of garbage classification in China, and provides enlightenment and guidance for garbage classification in other countries. [2] demonstrated a clean and sustainable CoD strategy for the safe disposal of municipal solid waste, revealing changes in the microbial community, which can provide a basis for efficient

bio-energy recycling of municipal solid waste. [3] Studies have shown that residents have limited knowledge and poor understanding of garbage recycling programs. However, they have a positive attitude towards garbage classification, and most residents just classify garbage into categories that can be sold, reused or exchanged for new garbage. The article [4] investigated the public participation in the classification of municipal waste in major cities in China. The results show that there is a deviation between the public's willingness to sort garbage and its behavior. This deviation mainly depends on background factors and the public's attitude and understanding of urban waste classification. [5] The study found that under the current status of garbage sorting in Shanghai, 51.8% of food waste can eventually be sorted. After garbage classification, the landfill load has been saved by 17.3% and 16.5% respectively. Appropriate classification methods and models, sustainable publicity and supervision of source classification behavior, and sufficient financial support will be the key factors for rural domestic waste classification and resource management [6]. These methods have great potential to promote solid waste classification in rural areas of China and other developing countries.

The current garbage classification method relies on manual classification in the garbage collection stage, and it is difficult to achieve satisfactory results under consistency, stability and sanitary conditions. [7] Adding a machine vision recognition module to the traditional smart trash can can effectively improve the efficiency of trash recognition. The intelligent garbage classification model constructed by the convolutional neural network can accurately identify the type of garbage with an average accuracy of 0.87. Garbage classification technology is not only an important foundation for the harmless treatment of garbage and resource recovery, but also an inevitable trend of social development. Zhichao Chen et.al researched, designed and developed a deep learning-based garbage classification system [8], and proposed a lightweight garbage classification model GCNet (garbage classification network). The average accuracy of GCNet on the self-built data set is 97.9%, the single inference time on the Raspberry Pi 4B is about 105ms, and the classification system only needs 0.88 seconds to complete the classification and collection of a single object. [9] proposed a model that uses MobileNet as the basic network, and the detection accuracy of this method can reach 93%. It has greatly promoted the automation of production and provided a reference for the intelligent waste sorting machine. [10] uses deep learning to solve the garbage classification problem and proposes a framework that combines saliency detection and image classification to improve generalization performance and robustness. The accuracy of the framework on the test set fused with complex background is improved by 0.50%-15.79%.

This design uses enhanced machine vision recognition and a new type of garbage disposal mechanism to achieve the integration of recognition and processing, which greatly improves the speed and accuracy of recognition. Put the trash into the fan-shaped tray to identify and pour it into four square sorting trash bins. The side is made of acrylic material, which is beautiful and elegant. In addition, the upper part is equipped with an LCD screen. The LCD screen can be used for garbage classification for a certain amount of publicity and play a supervisory role. It is also equipped with a full-load status monitoring system, which can upload real-time status to the cloud platform to achieve round-the-clock monitoring, so that sanitation workers can be assigned work organically, avoiding problems such as untimely garbage disposal and garbage overflow. The second chapter of this article introduces the overall design of the system, the third chapter is the hardware structure, the fourth chapter is the software structure, the fifth chapter is the system test, and the final is a summary.

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2. System Model

This system refers to common garbage classification standards and divides household garbage into four categories: recyclable garbage, hazardous garbage, kitchen waste, and other garbage. Through the design and continuous improvement of neural network recognition algorithms, the design of smart trash cans, the construction of cloud servers, and the writing of small The program realizes efficient garbage classification. System developers can obtain terminal data through small programs to optimize and update the system's identification model in time to improve the accuracy of garbage identification; area administrators can use the server to understand the overflow of each trash can in the area in real time, and release garbage according to residents Used to make dynamic adjustments, organically allocate sanitation workers to dispose of garbage, and improve work efficiency.

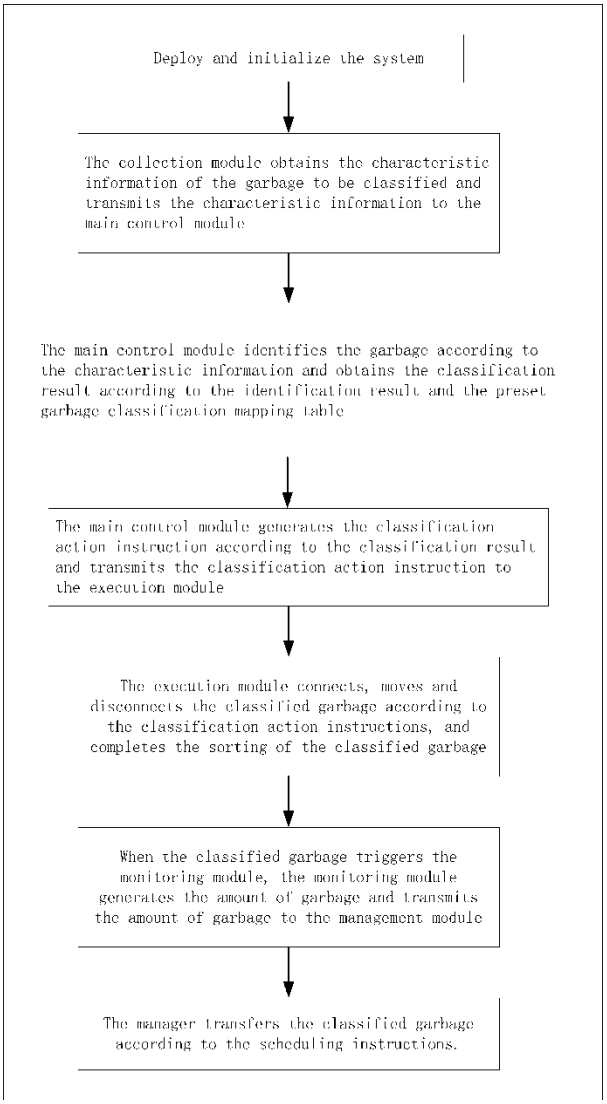

Fig.1 Workflow

The system includes: a collection module, used to obtain the characteristic information of the garbage to be classified; a main control module, used to identify the garbage to be classified according to the characteristic information to obtain the classification result; an execution module, used to sort the garbage to be classified according to the classification result The garbage to be classified is converted into classified garbage; the monitoring module is used to monitor the classified garbage to obtain the amount of garbage piles; the management module

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is used to generate scheduling instructions according to the amount of garbage piles. The system can automatically identify the garbage to be classified, and complete the classification of the garbage to be classified according to the recognition result, and then recycle the garbage according to the classification result, with higher accuracy and efficiency.

3. Hardware framework

Using STM32F407 single-chip microcomputer as the main control, OpenMV as the image processing module, combined with multiple sensors, realizes the core functions of garbage identification, garbage classification, visualization of classification results, and full load alarm. The hardware system block diagram is shown below.

3.1. Power supply

This product uses the Taineng cover plate to supply power, which basically solves the daily electricity needs. Sunlight irradiates semiconductor photodiodes to convert light energy into crystalline silicon solar cells to form electrical energy. Use single-chip microcomputer control, photoresistor, infrared sensor as switch judgment. The stored electric energy can basically meet the needs of daily equipment. This product can make full use of solar energy to achieve the environmental protection, green and friendly ecological concept.

3.2. Object recognition

The intelligent recognition of the system terminal uses OpenMV4 to collect garbage images, and the obtained photos are matched and compared with the sample atlas in the convolutional neural network, that is, to find the two according to the recognition methods such as contour recognition, feature recognition, color recognition, and material recognition. The common point between the two is judged its type, and the recognition result is returned to the main control MCU through the serial port. The microcontroller generates the corresponding PWM signal to drive the motor and the steering gear to perform corresponding actions. We have used a variety of intelligent algorithms and established a garbage recognition library. With the help of Edge Impulse cloud AI platform, we can improve the subsequent recognition algorithm and train the neural network model.

3.3. Classification mechanical structure

The mechanical part of the terminal 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 rolling of the incoming garbage, which helps to improve the sorting speed. When the image recognition is successful, the single-chip microcomputer will control the stepping motor to rotate the corresponding angle horizontally according to the programmed algorithm, and then the steering gear will control the stage to flip down and put it into the corresponding trash can.

3.4. Full alarm

In addition, the system terminal is also designed with a full load alarm function. After the single-chip control completes the disposal of garbage, the sensors in each small bucket will detect obstacles. The infrared emission tube continuously emits 38KHz infrared signals. 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. In this way, it is possible to prevent the overflowing garbage from polluting the environment.

3.5. Wireless communication

The Wi-Fi IoT module of this system uses the ESP8266 module, which has a 32-bit processor architecture, uses the 2.4GHz wireless standard and is equipped with a PCB on-board antenna, supports IPv4, TCP/UDP/HTTP/MQTT network protocols, and It can work in an environment of −40°C to +125°C, and can run Lua, Python, and JavaScript in addition to C language. The ecology is good, the compatibility is strong, and the most important thing is the low price. Support STA, AP, STA+AP three working modes. Usually use AP mode, that is, wireless access point mode, because it can reduce the cost of wireless networking. The ESP8266 module acts as a hotspot, enabling mobile phones or computers to directly communicate with the module, realizing wireless control of the local area network. When the stacking height exceeds the threshold, the bucket full information will be sent to the cloud server through the ESP8266 to warn that the garbage bags need to be replaced actively. The sanitation workers can efficiently collect the sorted garbage at regular points and points, so as to avoid excessive garbage accumulation and overflow.

3.6. Information exchange

An LCD color screen is installed above the sorted trash can, and the top of the screen displays the working status of the trash can, the quantity and type of garbage that has been put in, and the remaining capacity of the trash can. The promotional video is played in a loop at the bottom of the screen. On the one hand, it makes the trash can more scientific and technological, and better integrates into the actual application environment; on the other hand, it also popularizes the knowledge of the correct classification of garbage, which plays a role in popular science. Garbage classification is not a short-term problem, but a long process that "starts with classification and finally raises national environmental awareness and responsibility". Urban residents can watch garbage classification promotional videos when throwing garbage, so as to enhance the awareness of environmental protection responsibility of residents in the city

4. Software framework

4.1. Perception layer

We explored a method for convolutional neural networks to accurately identify various types of garbage on current low-end embedded devices: due to the limited performance of embedded devices, neural networks need to consume a lot of memory and resources for training. Therefore, we put the construction and training of the neural network on the PC, and with the help of the Edge Impulse cloud AI platform, we have well opened up the entire process from data collection, marking, NN model training, optimization to deployment; after reaching a certain level of recognition After the accuracy rate, the neural network training model is exported and transplanted to the embedded device; finally, the optimization test is performed on the single-chip microcomputer. The basic network models currently used are all deep convolutional neural networks, which is a multi-layer neural network, including input layer, convolution layer, pooling layer, fully connected layer, and output layer. Each layer is composed of multiple two-dimensional planes, and each plane is composed of multiple independent neurons. The local features of the image are extracted through different convolution models, and the local features are further combined into higher-level global features, thereby Complete the mapping of the image from part to the whole. Figure 13 shows a common convolutional network structure. However, increasing the depth of a single network model to improve accuracy often results in the difficulty of training convergence; the use of multi-model fusion methods can improve the accuracy of recognition and optimize the efficiency of recognition, so as to obtain higher-quality detection results. Model fusion is also called ensemble learning. The main idea is to first generate multiple primary learners through certain rules, then use the

primary learners to predict the test set, and use the output value as the input value for the next stage of training. The final The label is used as the output value to train the secondary learner, and the final result is more accurate. Fusion of multiple models can make up for the shortcomings of a single model, so as to achieve better classification results than training a single model. Common integration methods include voting, averaging, Boosting, Bagging, and Stacking. This system uses an integrated learning method based on Stacking.

The basic layer of Stacking usually includes different learning algorithms, so Stacking Ensemble is often heterogeneous. The basic layer used in our improved algorithm is Resnet50, Inception V3 network structure.

4.2. Network layer

The main board controls the Esp8266 module to connect to the network through WiFi, and the device uploads data to DevPubTopic through the TCP-based MQTT protocol and subscribes to the downstream command DevSubTopic to receive the downstream command. The choice of server takes into account the business logic given by each platform and the confidentiality of factory data, etc., choose the Alibaba Cloud ECS server. The upper computer adopts WeChat applet, which is simpler and faster than APP development, which saves users the trouble of downloading mobile phone programs. The user end subscribes to the device's upstream data DevPubTopic through the TCP-based MQTT protocol, obtains the device data and issues commands to DevSubTopic.

The process of using Alibaba Cloud ECS server to build a WeChat applet MQTT hardware server is as follows:

(1) Register an account, add products, and improve information;

(2) Add hardware equipment and complete information;

(3) Modify the product ID and device ID, modify the authentication information, and obtain the password and account number of the MQTT connection;

(4) Modify Esp8266WiFi name and password to connect to the network, and then connect to the cloud platform;

(5) Download the program and upload the data;

(6) Drag the controls, modify the properties, and make a visual interface;

(7) Save and release.

4.3. Application layer

The system front end of this project is based on the Serverless (serverless) architecture. The Serverless architecture allows users to focus on business logic without worrying about the operating environment, resources and quantity of the program. Through the cloud server, the interface services provided by many technology companies can be directly called, which greatly reduces the implementation cost. The front-end can be applied to community properties, community management departments and related government agencies. The system platform has functions such as content push, full load alarm, location service, and firmware upgrade of project terminals. The platform can facilitate urban residents and community residents to find intelligent sorting trash cans through positioning information, and reduce the possibility of randomly discarding trash because they can’t find trash cans. Sanitation workers can fix the corresponding time according to the platform's full load information and smart trash can positioning information. The street trash cans are cleaned up, thus reducing the manpower and capital investment in urban garbage classification, effectively saving our country’s resources, implementing the concept of sustainable development, and realizing recycling.

5. System test

After testing, our machine vision-enhanced garbage classification system can realize automatic garbage classification and information processing, which can facilitate urban residents and community residents to find smart classification garbage bins through positioning information, and reduce the risk of randomly discarding garbage because they cannot find the garbage bin. Possibly, sanitation workers can clean up trash cans in corresponding streets at fixed points based on platform full load information and smart trash can positioning information.

6. Conclusion

This article conceived and designed this waste sorting and processing system. The machine vision-enhanced intelligent IoT waste classification and processing system effectively uses the advantages of the big data era and is designed in accordance with the requirements of the era's ecological civilization. The work innovatively improves the ordinary garbage sorting device. At the technical level, it considers intelligent classification, garbage collection, information interaction and other aspects, carries out a functional and social design, and combines data, network, and cloud platforms in a reasonable and effective manner. Corresponding technologies such as mobile communications are a complex public facility that integrates multiple functions. To a certain extent, this product can bring convenience to people, reduce the trouble of sanitation workers, reduce pressure on the environment, and maximize the use of resources. Nowadays, the social requirements for garbage classification are high, and the product is universally applicable. There is a lot of room for promotion and application in various public places and cities in our country, and the market prospect is very broad.

Acknowledgements

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