Design and implementation of an offline face recognition locker

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Abstract: In order to promote the development of smart city and provide more intelligent and
safe services for people's life, an offline intelligent locker system based on face recognition is
designed. This paper describes the overall structure of the system, functional design of each
module, control logic and hardware design. The system is divided into user end and
administrator end. The main functions used are cabinet opening, face detection, eigenvalue
extraction, living detection, face comparison, communication protocol and information table
maintenance. The system uses the M1n module of Sipeed company as the core of the face
eigenvalue extraction module, the application layer module with Raspberry Pi as the core, and
the control module with STM32 Series MCU as the core, which makes it possible to realize the
low-cost face recognition system offline. After actual operation and debugging, the system
scheme has good reliability and stability.

1. Introduction
Since the 21st century, with the development of identification technology and Internet, many big cities
in China are moving towards the direction of intelligent development. Intelligent storage cabinet in
public places is one of the key construction projects of smart city. People's way to ensure the security
of public lockers is not limited to the traditional identification system based on IC / ID card, ID card
number, password, paper barcode / QR code. With the development of biometric recognition
technology, iris recognition, fingerprint recognition and face recognition are gradually applied. Its
unique identity can be identified by biometric technology.[1]

In this paper, an off-line intelligent storage cabinet based on face recognition is proposed. The
system is designed offline, which can effectively reduce the external influence. The modular design of
the system makes the optimization and upgrade of the system more flexible to adapt to different
application scenarios. Compared with fingerprint recognition unlocking, barcode unlocking, swiping
card recognition unlocking and key unlocking, it avoids the waste of materials and greatly improves
the convenience of people's storage.[2]

2. Face recognition
The resources of embedded development board are limited, and the algorithms that can be used have
certain limitations[3]. The computing power of many embedded development platforms can not meet
the actual application scenarios very well, so we consider using a third-party platform to develop face
recognition. This system plans to use M1n module for the development of face recognition. The M1n module takes the edge intelligent computing chip k210 (risc-v Architecture) as the core unit, which has powerful functions. The chip has 64 bit dual core processor, 8m on-chip SRAM, and various hardware acceleration units (KPU, FPU, FFT, etc.), and the total computing power can reach 1 tops. The module is cheap and equipped with complete data, and provides a trained face feature extraction model.

According to the actual scene analysis in this paper, the function of face recognition is user active recognition, that is, after the user prepares according to the prompt, the recognition is started by the user. In addition, the application scenario in this paper belongs to short-term storage, and the user's appearance will not change too much. Therefore, compared with other application scenarios, this paper only needs to correct the side face image handle. The process of face recognition is divided into two parts: face detection and face verification. Sipeed platform provides three models, which are face detection model, face five point key point detection model and face 192 vit eigenvalue model. When M1n starts, after loading the above three models, the serial port waits to receive the picture. In order to make the transmission speed fast enough, the image format is limited to JPG format, the resolution is 320 * 240, and the size is not more than 30K. When the baud rate of the serial port is 115200, the maximum transmission time does not exceed 2.2s, which meets the requirements of real-time. After receiving the image, M1n will load the image into the face detection model to locate the face and obtain the face coordinate position and the number of faces. In order to prevent multiple faces from being registered at one time during the registration of actual users, the image with the largest face area is taken and loaded into the face five point key point detection model. The left eye, right eye, nose, left mouth corner and right mouth corner of the face are located. The affine transformation matrix is obtained according to the obtained five point coordinates and the standard face coordinates, and then the original face image is transformed into a face image by affine transformation. The 192 vit eigenvalue of the face image is calculated by loading the front face image into the 192 vit eigenvalue model. Finally, it is sent to the upper layer through serial port for application.

In practical applications, live detection is another important part of face recognition. There are many methods of live detection, including action coordination, off-line near-infrared live detection, off-line 3D structured light live detection, etc. Body detection, off-line near-infrared living detection uses the principle of infrared imaging to realize the living body detection at night or under natural light conditions. The realization method is to add an optical infrared filter controller in front of the camera, and the live detection is mainly carried out on Raspberry Pi. The controller is composed of an infrared filter and a relay. The relay is switched on and off by the receiving level, and then the filter is added in front of the camera. After obtaining the normal picture of the picture, Raspberry Pi gives the control signal to add an infrared filter in front of the camera, and then obtains the image at this time, and carries out face detection. If the face is detected, the live detection passes, otherwise it fails. If the detection is passed, Raspberry Pi sends the images obtained before to M1n through serial port. Face detection method uses the classifier based on Haar features provided by opencv library, which can meet the requirements of fast speed and high precision. The effect of living detection is shown in the Figure 1. One is under normal conditions, and the other is when the living detection mode is turned on. You can see that the pictures on the phone can't pass the detection.

Figure 1. effect picture of living detection
3. Hardware design

The hardware design is divided into two parts, which are composed of main control board, lock control board and corresponding peripheral modules. The main control board is mainly responsible for receiving instructions from the upper Raspberry Pi and providing various interfaces to adapt to the subsequent upgrade. At the same time, the main control board integrates Raspberry Pi and M1n module to provide power for it. The main control board takes stm32f103zet6 as the core, which is the first 32-bit RISC processor based on AR - mv7-m architecture. It has many advantages, such as high efficiency of code execution and rich peripheral resources. It is mainly responsible for processing information and sending instructions. It communicates with Raspberry Pi through serial port to obtain user's operation instructions, and communicates with lock control board via sp3485 to send relevant instructions. In order to make the design and application of this paper more widely, the system still retains and integrates the traditional unlocking methods, such as IC card, fingerprint, two-dimensional code scanner and so on. The structure of the main control board is shown in Figure 2.

The main function of the lock control board is to open the corresponding electromagnetic lock according to the command. The communication mode of the lock control board adopts 485 communication. Due to the long transmission distance and high transmission stability of 485 communication, the problem of information error caused by too long transmission distance caused by too large cabinet is solved. Therefore, a 485 communication protocol between the main control board and the lock control board is formulated. The protocol structure consists of header and instruction Cabinet number, data and package tail. In order to facilitate the expansion of the lock cabinet, the lock control board takes stm32f103c8t6 as the core, and uses two sp3485 transceivers to communicate with the main control board and the electromagnetic lock drive module respectively. The control module is cascaded by three 74HC595, which outputs the data part in the instruction in parallel, so as to control 24 electromagnetic locks. In this paper, the 24 cabinets are regarded as a unit as a cabinet body, and multiple cabinets can be expanded in the form of adding lock control board. At the same time, the lock control board distinguishes different cabinets through hardware dialing, which is easier to operate than software differentiation. To meet the needs of different application scenarios, Three 74LS165 are used on the lock control board to output 24 feedback signals of electromagnetic locks in serial as the switch state of the lock. In addition, another three 74LS165 are used to output the signals of 24 infrared tubes in the cabinet as the internal state of the cabinet. At the same time, the structure of the lock control board is shown in Figure 3. The actual figure of main control board and lock control board is shown in Figure 4 & Figure 5.
4. Software design

The software design is mainly carried out on Raspberry Pi, and its system is based on Linux. It is a low-cost RISC microprocessors of the microcomputer. It has the type-C interface, micro USB interface, and 3.5mm audio output interface, etc[5]. The software part of this system mainly includes two parts: the bottom development and the application layer development. The bottom development is based on STM32. The main content of development is to establish communication protocol and hardware driver development. The protocol is divided into three parts: between the main control board and the lock control board, between the Raspberry Pi and the main control board, and between the Raspberry Pi and the M1n module. The communication contents between the main control board and the lock control board include: packet head, instruction, cabinet number, data and packet tail. Each content is one byte, and the data is three bytes. A total of 24 bits exactly correspond to 24 electromagnetic locks. Among them, the instructions include querying the lock status, querying the internal space status of the cabinet, opening all cabinet doors and opening the specified cabinet doors. The cabinet number corresponds to the hardware dial code to distinguish different cabinets. The communication content between Raspberry Pi and the main control board includes packet header, instruction, data and packet tail. Each content is one byte, and the data is five bytes. The lower three bytes of data bits correspond to 24 electromagnetic locks, and the higher two bytes correspond to different functions for different instructions. The instructions include: open the cabinet door, obtain cabinet status, read fingerprint, read IC card, read QR code, buzzer control, read function dial code, etc. The communication between Raspberry Pi and M1n module mainly adopts JSON format. The contents include instruction, status code, eigenvalue and information description. The instruction includes initialization of M1n and calculation of eigenvalue. The status code includes: successful face feature calculation, no face detection, multiple face detection, image format error, picture sending timeout, etc.
The application layer was developed on Raspberry Pi 3B +. Application layer development mainly includes user function development and administrator function development. The developed function interfaces are all packaged with QT. The development content includes the establishment of user information table, interface design, face feature value comparison. Raspberry Pi maintains the corresponding user information table for the cabinet. Each cabinet corresponds to a user information table. Each user information table contains 24 units, and each unit is composed of address and face eigenvalues. Address includes cabinet number and cabinet number. The interface design is divided into user interface and administrator interface. The function keys of the user interface are fetching and storing. The same point in the process of fetching and storing is to open the camera to obtain photos, cut and obtain face images, send pictures M1n module through serial port, acquire 192 vit eigenvalues, and send cabinet opening instructions. The difference is that the storage is to randomly generate the cabinet number that does not store face eigenvalues, and write the face eigenvalues into the corresponding cabinet number in the information table. The first step is to detect the living body, and then traverse the information table, then compare the Euclidean distance between the obtained face feature value and the face feature value stored in each cabinet number, and set the threshold value. The number with the maximum value greater than the cabinet threshold value is taken, and the corresponding face feature value corresponding to the number is cleared. The user function flow is shown in Figure 6.

The function keys of the administrator interface include opening specific or all cabinets, querying the cabinet status of all locked cabinets, system initialization and adding cabinets, etc. the information obtained will be fed back to the interface, These functions will be used to deal with special situations. When a cabinet needs to be added to increase storage space, the user information table of the system needs to be updated, that is, adding one page of information table corresponds to the new cabinet. To use the administrator function, you must log in the administrator account password at the login of the main interface. The main interface also includes two buttons to retrieve and store the file, which is convenient for users to use. The main interface is shown in Figure 7. From the user's perspective, the user can enter the function menu by simply clicking the retrieval or storage of the main interface, and click the detect button according to the prompt to open the cabinet. The function menu is shown in Figure 8.

![Figure 6. user flow chart]

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5. Summary

In the actual test, the accuracy and real-time performance of face recognition are tested. The accuracy rate refers to the proportion of the cabinet door opened when the user saves the pieces, and the real-time refers to the time consumed from the user clicking the detect key on the function interface to the cabinet door opening. And the performance of the initial operation and after a long time of running is tested. The number of test samples was 24, the sample size ranges from 6K to 24K. Table 1 records the initial operation of the cabinet and the situation after 12 hours of outage. The identification method of data part is (initial state data | data after 12 hours of intermittent operation), and the real-time data in the table is the average value. The test results are shown in Table 1. After analysis, the accuracy and real-time performance of the system basically meet the requirements, but the performance of the system has a certain degree of decline after a long time of operation, and the performance of the interface fluency has a certain stuck. It is expected that some memory may not be released during the program cycle operation. The reason why it takes more time to retrieve a piece than to save a part is that the process of live detection and eigenvalue comparison is more important.

The design and implementation of the face recognition locker system described in this paper is based on the actual application requirements, and comprehensively considers the system stability, running speed, accuracy and cost and other factors. In the actual use, the user operation is simple and fast, performance is relatively successful, but there is a certain lack of fluency, which is also an important aspect to be improved in the future.

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