Journal of Computing and Electronic Information Management

ISSN: 2413-1660

Design of fingerprint recognition system based on STM32

Mengru Zeng, Jiayu Huang, Zhenzhen Chen, Gaokuan Wang, Baofeng Ji
College of Information Engineering, Henan University of Science and Technology, Luoyang 471000, China

Abstract: With the rapid development of science and technology, network information technology affects all aspects of our lives at all times, with advantages and disadvantages. Therefore, information security is becoming more and more important in modern life. Based on the fingerprint identification system of STM32, this paper designed and developed the application of the system on other modules. The main controller of the fingerprint identification system was the STM32F-103ZET6 chip (with ARM cortex-M3 as the core), and the fingerprint acquisition module is AS608 optical fingerprint module. Then, making the block diagram of the system design to complete the construction of the development environment and the design of the button circuit. Finally, the relevant software programs were compiled to realize the functions of fingerprint input, characteristic image conversion, fingerprint identification, fingerprint deletion and LCD screen display information to further realize the overall design of the fingerprint identification system.

Keywords: Fingerprint recognition system; STM32; Optical fingerprint collection module; LCD display.

1. Introduction

With the rapid development of science and technology, people's information security [1][2] in all aspects needs to be guaranteed, and people have begun to pay more attention to their own information security in their daily lives. As an important means of guaranteeing information security, biometric technology used the unique manifestations and behavior characteristics of organisms to identify and authenticate identity.

Based on the diversity of biological traits, biometrics can be studied from the aspects of face, palm print, gene, voice, fingerprint, iris, vein, etc., and form the corresponding recognition technology [3]. Among them, fingerprint recognition technology has a higher market share and lower cost. Fingerprints can be applied to many aspects of life through the fingerprint recognition module system, such as: smart access control systems, mobile phone fingerprint recognition unlocking and payment functions, company smart attendance systems, exam identification system. Compared with other biometric systems, the fingerprint recognition system has the following advantages: stable and reliable performance, more accurate effects, quick recognition speed, and low cost [4][5] of fingerprint acquisition modules.

Many identity information authentication devices and applications have emerged in the market, which can only be explored in high-precision products and computer equipment, but are difficult to reach in daily life. Therefore, once fingerprint identification technology is widely used in common facilities, it will arouse great interest of scholars and lay a foundation for the vigorous development of fingerprint identification technology. The fingerprint recognition module is used to further analyze and improve some devices on the market, which can improve some of its current problems in power consumption and performance.

Therefore, this paper aimed to modularize the fingerprint recognition technology. The proposed system took fingerprint recognition technology as the core, used the STM32 development board as the main controller, and utilized the AS608 module to support image acquisition. Finally, the processed information is displayed on the LCD screen to facilitate its application in intelligent systems, which improves its limitations and improves module performance.

The structure of this paper is as follows: The section II introduced the overall design of the system. The section III proposed fingerprint identification system and algorithm analysis. The section IV simulated and verified the proposed scheme and theoretical analysis. The section V mainly summarizes the content of this paper.

II The overall design of the system

This paper analyzed the current research status and market prospects of fingerprint identification technology and proposed a fingerprint identification system based on an embedded method and implemented through the STM32 development board. The design process of fingerprint identification system based on STM32 is shown in Figure 1. The following mainly introduces from two aspects.

Hardware parts

The main controller used in the system is STM32F103ZET6 with ARM cortex-M3 core, and the fingerprint collector is AS608 optical fingerprint module. The main controller and fingerprint collector module are connected through SPI interface to realize communication and information transmission.

The PC terminal transmits the relevant instructions to the main controller through the J-Link module, and displays the relevant operation requirements on the LCD screen. The fingerprint recognition module collects fingerprints, the main controller processes the results and feeds back the results to the PC and prompts information on the LCD screen.

Software parts

Fingerprint preprocessing algorithm: the fingerprint module first collects fingerprints, and then converts the collected fingerprint images into corresponding characteristic values through the corresponding fingerprint recognition algorithm. The preprocessing algorithm extracts the effective values from the characteristic values and stores them in the fingerprint acquisition module. In the memory, wait for the command from the main controller and call it out to perform the operation.

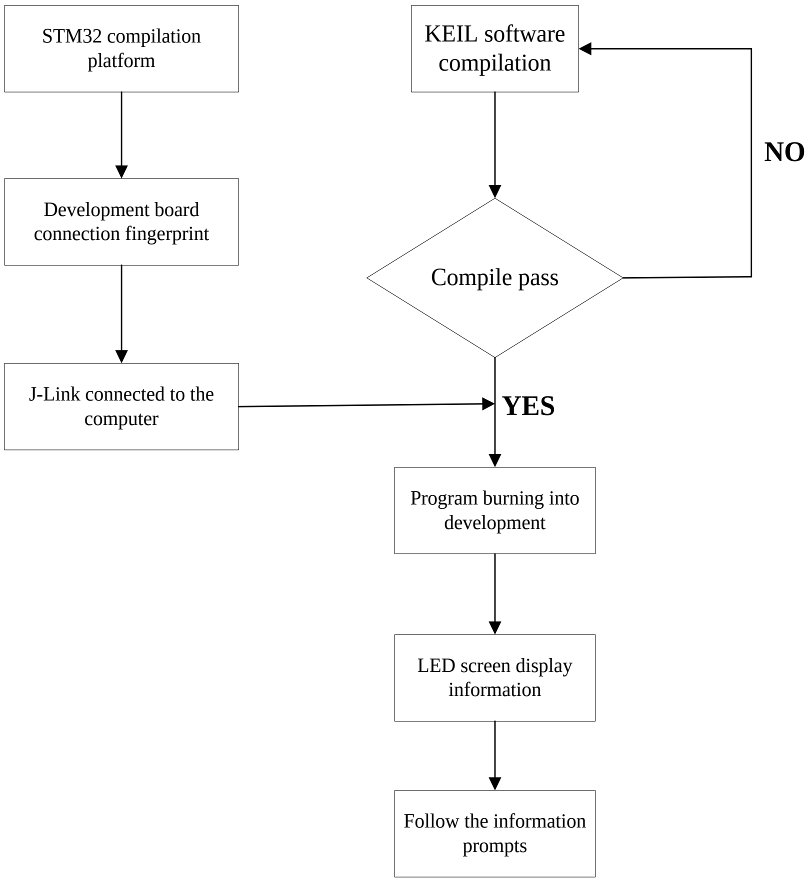

Fig.1 The overall design process of the system

After the program is compiled and ensured by Keil software, it is burned into the main controller via J-Link. The main controller mobilizes the coordinated work of the LCD screen, fingerprint acquisition module and keys to perform the entire operation process.

2. Fingerprint identification system and algorithm analysis

2.1 Process analysis of fingerprint recognition module

The fingerprint recognition module includes two processes: registration and comparison [6]. The specific process is shown in Figure 2. Registration means that the fingerprint is entered for the first time, and the quality of the fingerprint image is evaluated through the fingerprint collection window (if the fingerprint is not qualified, it will prompt to press the fingerprint again), and then the collected qualified images are preprocessed and feature data extracted, so that the fingerprints entered for the first time The information is stored in the memory. The comparison is to store the fingerprints collected the second time according to the method of the first registration (quality evaluation, preprocessing, feature data extraction), and then the system automatically calls the previous data for comparison and further shows whether the information matches or not.

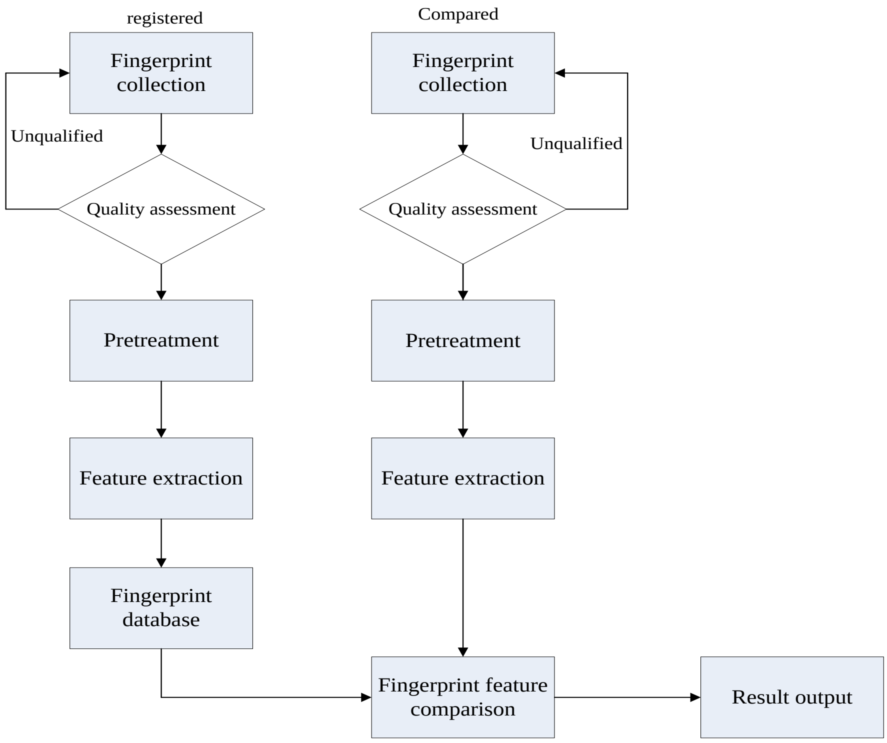

Fig.2 Fingerprint recognition module flow chart

2.2 Fingerprint collection

The fingerprint acquisition sensor is used to collect the characteristic points of the fingerprint image and usually each characteristic point is represented by a value between 0 and 255. Resolution refers to the number of dots in a certain range. dpi/in. is commonly used to indicate its unit and its range is between 250dpi~625dpi. The standard value is 500dpi, the characteristic value is between 0.5"×0.5" (12.7mm)-1.25" (31.75mm), and 1" (25.4mm) is the standard. Pitch refers to the interval between two characteristic points [7].

2.3 Fingerprint image preprocessing

In the process of fingerprint identification, it is very important to accurately and intelligently extract the characteristic data required by the system from the collected fingerprint images. The quality of the fingerprint image is related to the performance of the feature extraction algorithm, and the feature extraction algorithm has strict requirements for the fingerprint image. Therefore, the preprocessing aims to extract the characteristic data of fingerprint images quickly and effectively. The preprocessed fingerprint image is enhanced with its characteristic data, and then converted into characteristic values to facilitate the extraction of characteristic points. The fingerprint refinement process is shown in Figure 3.

2.3.1 Research and Implementation of Fingerprint Identification Algorithm

According to the different application fields of fingerprint recognition module, the suitability of the algorithm should be considered from two aspects:

Because the computer's calculation speed is faster, the calculation of the algorithm has no effect on the system when the algorithm is applied to the PC side. The accuracy of the algorithm can be put in the most important position.

When the algorithm is applied to other systems, its calculation rate is slow and the calculation of the algorithm will greatly reduce the performance of the system. Therefore, the efficiency and accuracy of the algorithm must be fully considered at this time to make the system reach the best state.

2.3.2 Calculation of fingerprint image field

(1) Fingerprint intensity field: refers to the amount of information intensity of a point in the fingerprint image. The brighter the point in the fingerprint image indicates the larger the intensity field at that point, and the darker the point indicates the smaller the intensity field at that point. Fingerprint intensity field is：

$$|Q(x,y)| = f(x,y) \tag{1}$$

Where, Q is the intensity field of a certain point in the fingerprint image, and $f(x,y)$ represents the gray value function. The formula indicates that the smaller the gray value, the darker the point; the larger the gray value, the brighter the point.

(2) Fingerprint gradient field: the quantity describing the degree of change of the fingerprint image ridges and spine. The fingerprint image is more tortuous when the gradient field is larger, and the fingerprint image is also smaller when the gradient field is smaller.

Suppose the fingerprint gray function is $f(x,y)$, and its gradient vector is $G = \left(\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}\right)$.

Where $\frac{\partial f}{\partial x}$ is the partial derivative of the gray function in the x direction, that is $A_x(x,y)$, $\frac{\partial f}{\partial y}$ is the partial derivative of the gray function in the y direction, that is $A_y(x,y)$, then:

$$A_x(x,y) = F(x+1,y) - F(x,y) \tag{2}$$

$$A_y(x,y) = F(x,y+1) - F(x,y) \tag{3}$$

The gradient value of the image at this point is:

$$|G(x,y)| = \left[A_x(x,y)^2 + A_y(x,y)^2\right]^{\frac{1}{2}} \approx |A_x(x,y)| + |A_y(x,y)| \quad (4)$$

Fingerprint direction field: It indicates the texture direction of the fingerprint image. The external manifestation of the fingerprint image is the position and direction. When fingerprints are collected, they will undergo translational changes in shape, direction, and position. Therefore, the calculation of the direction field plays a very important role in the fingerprint identification algorithm. The fingerprint image field can be calculated as follows:

In the first step, the fingerprint image is divided into areas of size A*A, and the partial derivative of the gray level function $f(x,y)$ is obtained through the Soble operator to obtain the partial derivative $A_x(x,y)$ along the x direction and the partial derivative $A_y(x,y)$ along the y direction.

The following is the Soble operator:

x direction is $\begin{pmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{pmatrix}$ and y direction is $\begin{pmatrix} 1 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{pmatrix}$.

Then according to the calculation formula of the direction field:

$$V_x(x,y) = \sum_{u-i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{u-j-\frac{w}{2}}^{j+\frac{w}{2}} 2A_x(x,y)A_y(x,y) \quad (5)$$

$$V_y(x,y) = \sum_{u-i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{u-j-\frac{w}{2}}^{j+\frac{w}{2}} \left(A_x^2(x,y) - A_y^2(x,y)\right) \quad (6)$$

Therefore, the image direction field is:

$$|Q(x,y)| = \frac{1}{2}\tan^{-1}\left(\frac{V_x(x,y)}{V_y(x,y)}\right) \quad (7)$$

The resulting direction field is 135 degrees different from the actual one, so the final result needs to be subtracted by 135 degrees [8].

Frequency field of fingerprint: It represents the number of ridges within a unit distance of a point perpendicular to the fingerprint texture line. Since the fingerprint image can be seen as composed of undulating texture ridges, a sine mathematical model can be established for it.

The calculation method of fingerprint frequency field is as follows:

Divide the fingerprint image into 16*16 non-overlapping sub-blocks equally;

Suppose the center point is the sub-block center point (i_0, j_0), and the fingerprint texture direction is the short axis to form a $1*w(32*16)$ rectangular area.

For each region, using the following formula to calculate the gray discrete signal $M(q)$ perpendicular to the center point of the fingerprint image sub-block direction $H_d(i_0, j_0)$.

Let u and v be the point (p,q) on a straight line parallel to the w direction in the rectangular area converted to the coordinate value of the image coordinate system, $A(u,v)$ is the gray value of the pixel point (u,v). The average value of the pixel gray values of each point on the straight line is used as the gray value of each point in the L direction of the rectangular window to form a discrete signal $M(q)$. And $M(q)$ roughly constitutes a two-dimensional sine wave. By calculating the average value L_0 of the peak distance L of the sine wave, the frequency $1/L_0$ of the sine wave is calculated, which is the ridge frequency F_0 of the fingerprint.

$$M(q) = \frac{1}{W}\sum_{P=0}^{W-1} A(u,v); q = 0,1,...L-1 \tag{8}$$

$$u = i_0 + \left(p - \frac{w}{2}\right)\cos H_A(i_0, j_0) + \left(q - \frac{L}{2}\right)\sin H_A(i_0, j_0) \tag{9}$$

$$v = j_0 + \left(p - \frac{w}{2}\right)\sin H_A(i_0, j_0) + \left(q - \frac{L}{2}\right)\cos H_A(i_0, j_0) \tag{10}$$

2.4 Fingerprint feature data extraction

Two commonly used methods of fingerprint image feature data extraction are fingerprint image feature data extraction based on binarization and feature data extraction algorithms directly based on grayscale images. The two extraction methods have their own advantages and disadvantages: the former is based on the refined fingerprint image, so the extraction speed is faster. But the extraction quality mainly depends on the accuracy and availability of the results of the previous steps. The latter There is more information to be processed, and the steps to be executed are correspondingly increased, so the extraction speed is slower, but the extraction quality is more accurate.

Feature data extraction method based on binarization: The algorithm first binarizes the pre-processed fingerprint image and the image enhanced by the feature data, and then extracts the feature value.

Feature data extraction method based on gray image: The algorithm directly starts from the gray image, analyzes the texture attributes of the fingerprint image, and then obtains its feature data [9].

2.5 Fingerprint comparison

An important function of this article is to be able to compare fingerprints, and then achieve the effect of matching fingerprints. The prerequisite for fingerprint matching is that both fingerprints are recorded accurately and the system can search and match. Store the fingerprint to be matched in the system memory, and then the system enters the fingerprint collection storage space to search, mainly matching detailed information, usually in point mode for comparison, rather than based on the pixel value or ridge value in the feature data [10] .

Fingerprint comparison mainly needs to solve the problems of the direction, rotation, and size of the two fingerprints. The point pattern matching algorithm is to physically transform the fingerprint image information recorded in the storage space. At this time, if the center point of the fingerprint image is found, the orientation and deformation of the fingerprint will be dealt with. However, it is not possible to find the center points of all fingerprints, and greater problems will occur when the fingerprint points are found wrong, so matching algorithms are needed to solve related problems. The algorithm has strong operability, high efficiency and accurate results.

3. Numerical Simulation

This section mainly simulates and analyzes the STM32 fingerprint recognition system mentioned in this article, which mainly includes the preprocessing stage and the final stage.

Pretreatment stage

Preprocessing is a crucial step in the fingerprint recognition module. After the fingerprint module algorithm is processed, the results of each step of the test are shown in the Figure 3.

Original fingerprint image Direction field calculation Equalization segmentation

smooth Enhance Binarization Refine

Fig.3 Pretreatment refinement process results

The final stage

After the KEIL software compiles the program and the single-chip computer for burning, the system complete the entire process of the fingerprint recognition system design based on STM32 through the peripheral modules: fingerprint recognition module AS608, LCD display and buzzer, etc.

Fingerprint recording process

According to the information on the screen, press your finger twice on the sensor and the system will automatically compare the fingerprint information twice. If the two times are the same, the fingerprint template will be automatically generated and the fingerprint ID will be entered at the same time to save it. Otherwise the fingerprint registration will fail. The fingerprint recording process is shown in Figure 4:

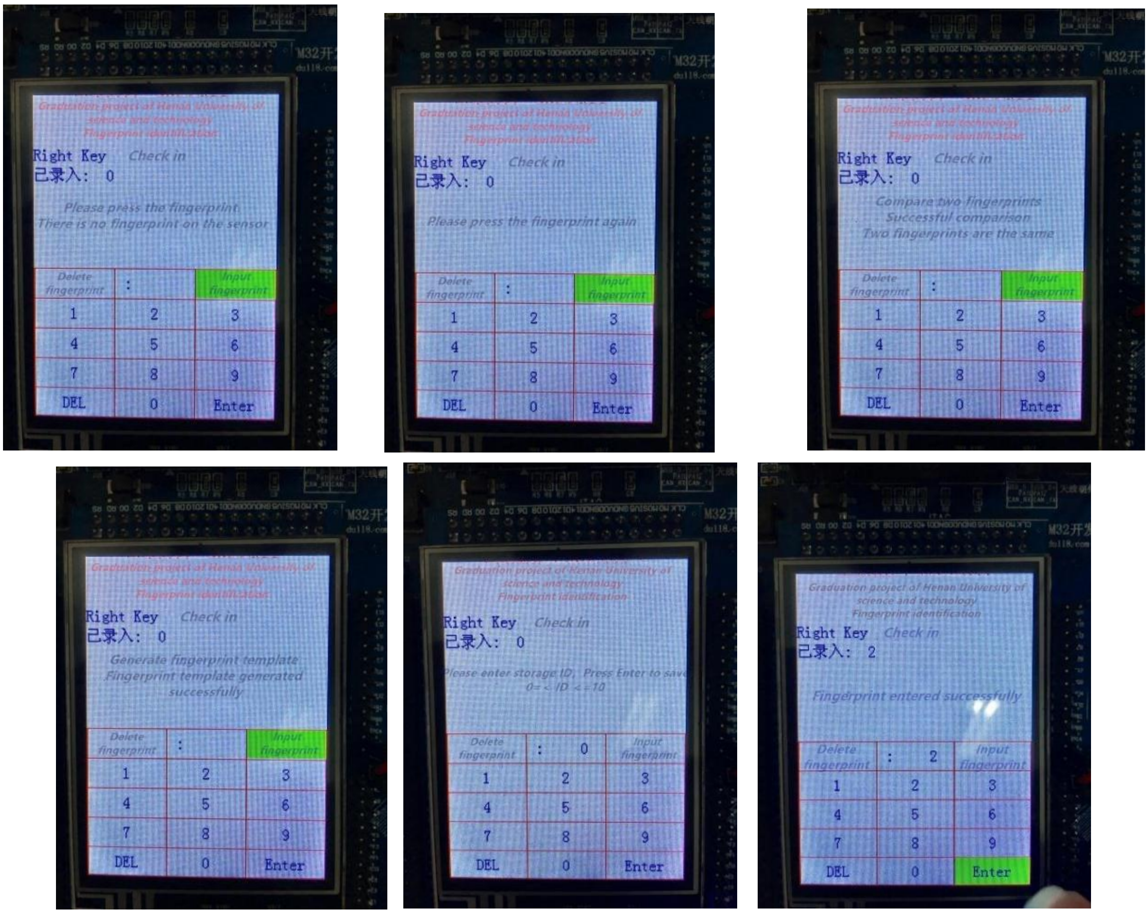

Fig.4 Fingerprint recording process

Delete fingerprint

Delete a single fingerprint: Click the delete fingerprint button on the screen, select the fingerprint number to be deleted and press ENTER to delete the fingerprint corresponding to the number.

Clear all fingerprints: Click the delete fingerprint button on the screen, and then select Clear fingerprints to delete all fingerprints that have been registered in the system. The fingerprint deletion process is shown in Figure 5:

Identify whether the fingerprint exists

If it exists, it shows that the fingerprint is successfully swiped and you have signed in; otherwise, it shows that no fingerprint is found. The fingerprint recognition process is shown in Figure 6.

d. Extensions:

Press the RIGHT KEY key on the development board to check the status of the sign-in. The name can be assigned to the number in the program in advance according to the purpose or use scene. The check-in result is shown in Figure 7.

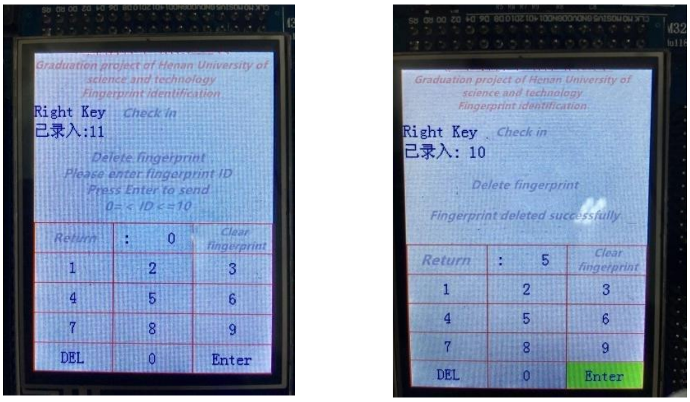

Fig.5 Process of deleting fingerprints

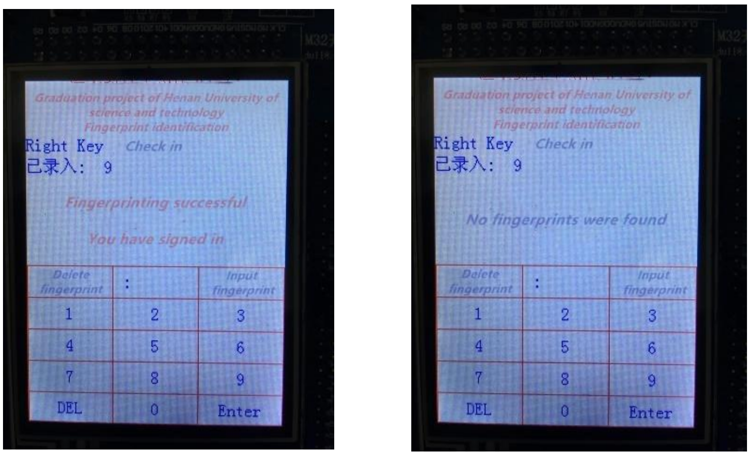

Fig. 6 Fingerprint identification process

Fig. 7 Fingerprint sign-in result

4. Conclusion

The fingerprint identification system based on STM32 mentioned in this paper can realize the main functions of fingerprint collection, fingerprint identification, fingerprint deletion and fingerprint emptying, and has developed the application function of member sign-in in the fingerprint identification function. This function can name the fingerprints of the group members, and then when the fingerprints are entered again, the system can identify the group members to which the fingerprints belong (this function is equivalent to signing in) to count the persons who have not signed in, and display their names and numbers. Due to the diversity of fingerprint collection modules and the limitation of fingerprint recognition algorithms, performance may not be optimized and efficiency needs to be improved.

References

[1] Sharma, Ruchi, and Kiran Davuluri. "Security Analysis for Machine Learning and Image Processing Related Information Systems." International Conference on Image Processing and Capsule Networks. Springer, Cham, 2020.

[2] Huang, Ping, et al. "Technology Architecture of Smart Grid Information Security Defense System." International Conference on Applications and Techniques in Cyber Security and Intelligence. Springer, Cham, 2020.

[3] Maltoni, Davide, et al. Handbook of fingerprint recognition. Springer Science & Business Media, 2009.

[4] Ji B, Chen Z, Chen S, et al. Joint optimization for ambient backscatter communication system with energy harvesting for IoT[J]. Mechanical Systems and Signal Processing, 2020, 135: 106412.

[5] Ji, Baofeng, et al. "SWIPT Enabled Intelligent Transportation Systems with Advanced Sensing Fusion." IEEE Sensors Journal (2020).

[6] Ali, Mouad MH, et al. "Overview of fingerprint recognition system." 2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT). IEEE, 2016.

[7] Abramovich, Gil, et al. "System and method for contactless multi-fingerprint collection." U.S. Patent No. 8,600,123. 3 Dec. 2013.

[8] Mazidi, Muhammed Ali, and Janice Gillispie Mazidi. The 8051 Microcontroller and Embedded Systems with Disk. Prentice Hall PTR, 1999.

[9] Rouzbahman, Masha, et al. "Data Mining Methods for Optimizing Feature Extraction and Model Selection." Proceedings of the 11th International Conference on Advances in Information Technology. 2020.

[10] Wayman, James L. "Fundamentals of biometric authentication technologies." International Journal of Image and Graphics 1.01 (2001): 93-113.