Design of iris recognition system based on DSP and ZigBee

LI Jin-ming[1], MA Lin[1], ZHANG Shao-hua[2], CHENG Ya-li[1], CHENG Nai-peng[1]

(1. *School of Instrument and Electronics, North University of China, Taiyuan 030051, China*;
2. *Shanghai Aerospace Electronic Technology Institute, Shanghai 201109, China*)

Abstract: Due to complex computation and poor real-time performance of the traditional iris recognition system, iris feature is extracted by using amplitude and phase information of the mean image blocks based on Gabor filtering on image, and the k-nearest neighbor algorithm is combined to complete iris recognition function. The recognition reduces the recognition time and improves the recognition accuracy. At the same time, identification result is transmitted to the cloud server through ZigBee network to solve diffcult wiring problem. The experiment shows the system runs stably and has fast recognition speed. It has been applied to a security system.

Key words: iris recognition; digital signal processor (DSP); ZigBee; image block

CLD number: TP391.41 **Document code**: A

Article ID: 1674-8042(2018)02-0169-05 **doi**: 10.3969/j.issn.1674-8042.2018.02.011

0 Introduction

The iris is a fabric-like color ring between the pupil and sclera in the eye, and its advantage is more precise than other biometric features[1]. At present, there are three most common iris recognition algorithms, that are the iris texture phase coding algorithm proposed by Prof. Daugman[2], the algorithm of Wildes Gaussian filter to decompose iris images at different resolutions[3] and the iris recognition algorithm based on wavelet transform proposed by Boles[4]. Although the iris recognition system based on the three algorithms has a higher recognition rate, it has shortcomings such as a large computational complexity, a high degree of procedure and poor real-time performance.

At present, there are some problems about iris recognition equipment, such as low recognition rate, complicated wiring and inconvenient data reading. Combined with the powerful data processing capability of digital signal processor (DSP), an improved iris feature coding algorithm is designed, and the iris recognition system based on DSP and ZigBee is constructed by combining the advantages of ZigBee and low power. They can be obtained that the recognition time of the iris recognition system is 1.2 s, and the recognition accuracy rate is greater than 96%. The system has been successfully applied to a security system in a factory because of its small operation, fast processing speed, high accuracy, low power consumption and convenient wiring.

1 Overall design of system

The iris recognition system based on DSP and ZigBee is mainly composed of iris image acquisition, processing and display, data storage, human-computer interaction, ZigBee network and cloud server.

The structure of iris recognition system is shown in Fig. 1.

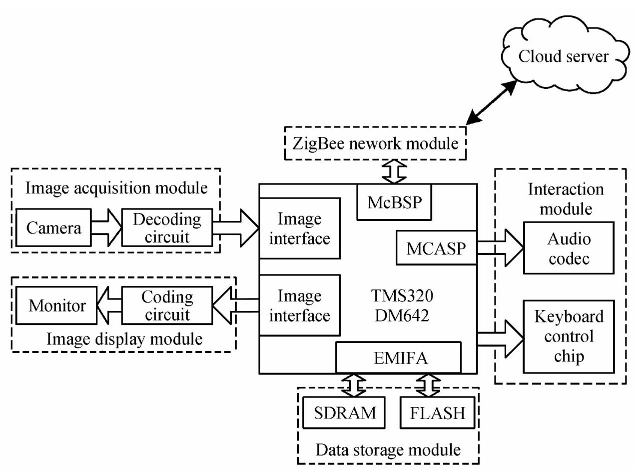

Fig. 1 General design structure of iris recognition system

Received date: 2017-12-11

Corresponding author: MA Lin (mllqff@qq.com)

The system uses the ZigBee network to send the processed results to the cloud server, thus generating an iris recognition record. The system utilizes the high efficiency of DSP local computation, the characteristics of low power consumption and stable transmission of ZigBee wireless network to make the iris recognition rate be high, and it is convenient for remote management.

2 Iris recognition algorithm and transplant

Iris recognition algorithm mainly includes three aspects of iris image preprocessing, iris feature extraction and coding, iris feature matching.

2.1 Iris image preprocessing

The iris image preprocessings are mainly composed of the accurate localization of inner and outer circles of iris image, the normalization of iris image and the enhancement of iris image by the algorithm.

Histogram statistics are applied to the collected iris images, and the appropriate threshold for the pupil segmentation recognition can be found according to the histogram characteristics. The canny operator is used to recognize the edge of the pupil, and then the least square method is used to fit the inner circle of the iris image. A wide range of calculus operator method is made to achieve the outer circle. The inner and outer circle localization process of iris image shown in Figs. 2 and 3 shows the effect of positioning.

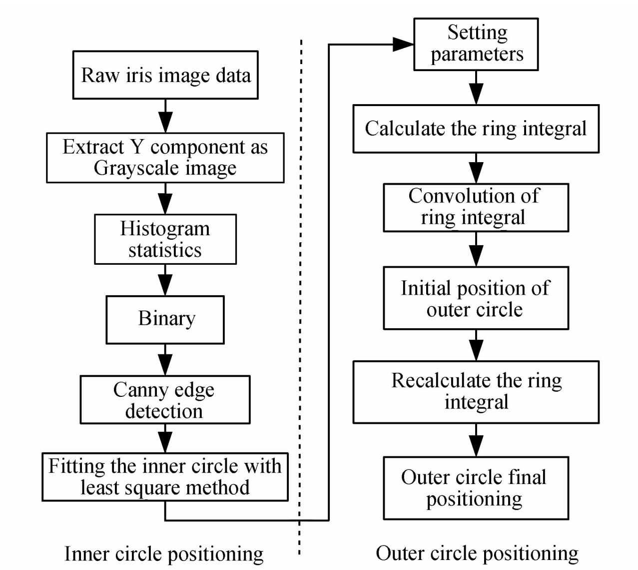

Fig. 2 Localization process of iris inner and outer circles

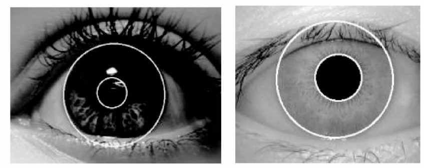

Fig. 3 Iris positioning effect

Based on the iris image processing, the results of inner and outer circle positioning are combined with the recognizable features of iris image to change its coordinates into polar coordinate system. The image is normalized to 512×64 pixel, and the image enhancement display is accomplished by histogram equalization method. The normalization and enhancement of iris image are shown in Fig. 4.

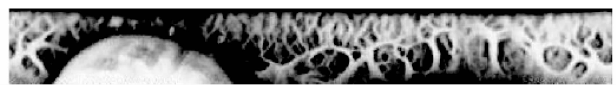

Fig. 4 Normalization and enhancement of iris image

2.2 Iris feature extraction and coding

In order to avoid the influence of the Gabor filter in different scales on extracting iris features[6], 24 filter groups (4 directions, 6 scales) are used to filter the previously normalized images, so that the feature information of the collected iris images can be obtained. The filtering results on different scales and directions are shown in Fig. 5.

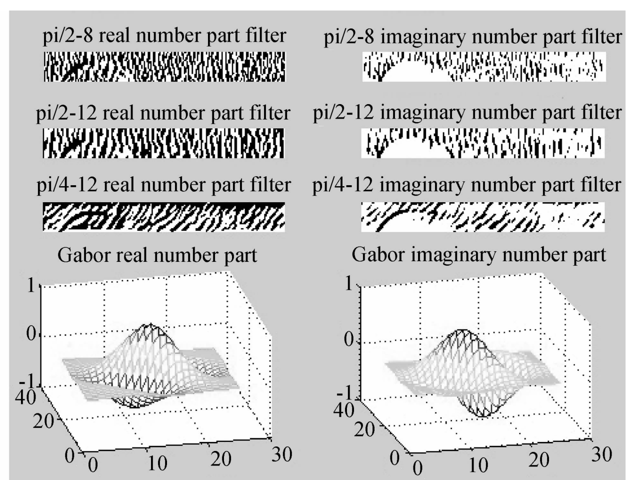

Fig. 5 Comparison of filtering results in different scales and directions

The phase information can effectively reflect the current texture of the phase information, but cannot reflect its energy, while the amplitude mean is able to effectively respond to the size of the texture energy, but can not characterize its phase information. Therefore, an improved iris coding method is proposed on the premise of reducing the information redundancy.

First of all, the filtered iris image is segmented into 32 image blocks, each one is 32×32 pixel, and each one is defined as B_j, $j=0,1,2,\cdots,31$. And then the amplitude mean $\mu_{B_i}^j$ of each image block is extracted to form the first part of the eigenvector. The second part is composed of the phase information of each image block. This method can not only preserve the global characteristics, but also highlight the energy efficiency effect of local features. The specific phase encoding method is expressed as

$$P = \begin{cases} (0,0) & \mu_r \geq 0, \mu_i \geq 0, \\ (0,1) & \mu_r \geq 0, \mu_i < 0, \\ (1,0) & \mu_r < 0, \mu_i \geq 0, \\ (1,1) & \mu_r < 0, \mu_i < 0, \end{cases} \quad (1)$$

where μ_r and μ_i are the real part and imaginary part of the image block B_i under the filter, respectively. The iris eigenvector $\boldsymbol{F}$ is expressed as

$$\boldsymbol{F} = [\mu_{B0}^0, \mu_{B1}^0, \cdots, \mu_{B31}^0, P_{B0}^0, P_{B1}^0, \cdots, P_{B31}^0, \mu_{B0}^1, \mu_{B1}^1, \cdots, \mu_{B31}^1, P_{B0}^1, P_{B1}^1, \cdots, P_{B31}^1, \cdots, \mu_{B0}^{31}, \mu_{B1}^{31}, \cdots, \mu_{B31}^{31}, P_{B0}^{31}, P_{B1}^{31}, \cdots, P_{B31}^{31}], \quad (2)$$

where $P_{B_i}^j$ indicates that image block B_i is encoded under the filter phase. The iris eigenvector coding process is shown in Fig. 6.

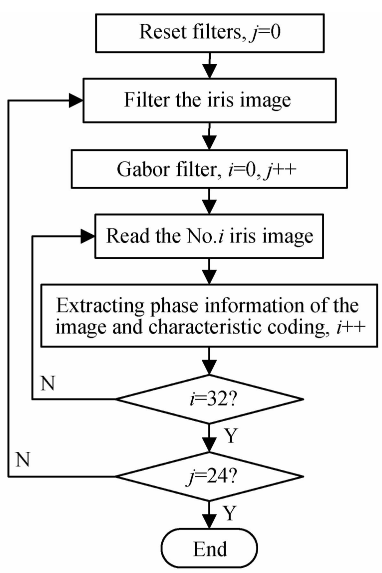

Fig. 6 Iris feature extraction process

In order to eliminate the dimension influence of two parts in eigenvector, the Euclidean distance and Hamming distance must be computed separately before and after the eigenvector, then the two distances are finally added as the final recognition distance.

2.3 Iris feature matching

After extracting eigenvector, the similarity of two iris eigenvectors is computed by the k-nearest neighbor algorithm (KNN)[7]. The iris recognition method based on k-nearest neighbor algorithm is to find the k-nearest neighbor of the sample in the library composed of N samples. The iris image to be identified is classified as k when and only the variance reciprocal weighted euclidean distance (WED) between the eigenvector of the iris image and the k-class eigenvector is minimized. The calculation of W_k is completed by

$$W_k = \sum_{i=1}^{N} \frac{(f_i - f_i^{(k)})^2}{(\delta_i^{(k)})^2}, \quad (3)$$

where f_i represents the i feature in the unknown sample; the $f_i^{(k)}$ and $\delta_i^{(k)}$ represent the mean and variance of the i characteristic of the category k iris image, respectively; and N in the formula represents the total number of features in the library.

2.4 Iris recognition algorithm transplantation

The software part of DSP system mainly includes the driving task and the applications of the two big classes[8]. In this system, the driving task controls and initializes the camera, SDRAM memory, keyboard chip ZLG7290 and speech codec chip TLV320AIC23 through the I2C protocol. The applications are made to design a multi-task iris recognition system code on TI's BIOS system. The system is designed to add idle tasks (TSK_idle), image acquisition and display tasks (TSK_cap_dis), image preprocessing tasks (TSK_preprocess), iris feature coding (TSK_feature code), iris matching tasks (TSK_ match), as well as the iris registration task (TSK_enroll). The priority of all tasks is set as 2, and the semaphores are used to complete the switch among different tasks. Multi-task based on DSP/BIOS system is shown in Fig. 7.

The TSK_cap_dis task is working for image acquisition and display, the main function of the task is to start and synchronize the camera, and the image data is moved to the image display buffer to be displayed for use. The TSK_preprocess task is to preprocess the iris image according to the designed preprocessing algorithm. In order to obtain the normalized iris image, the TSK_feature task is used to complete the iris feature extraction and coding, and obtains the iris moment which can be used for recognition based on the improved algorithm. The TSK_match task is made to realize two iris matching calculations based on the k-nearest neighbor algorithm.

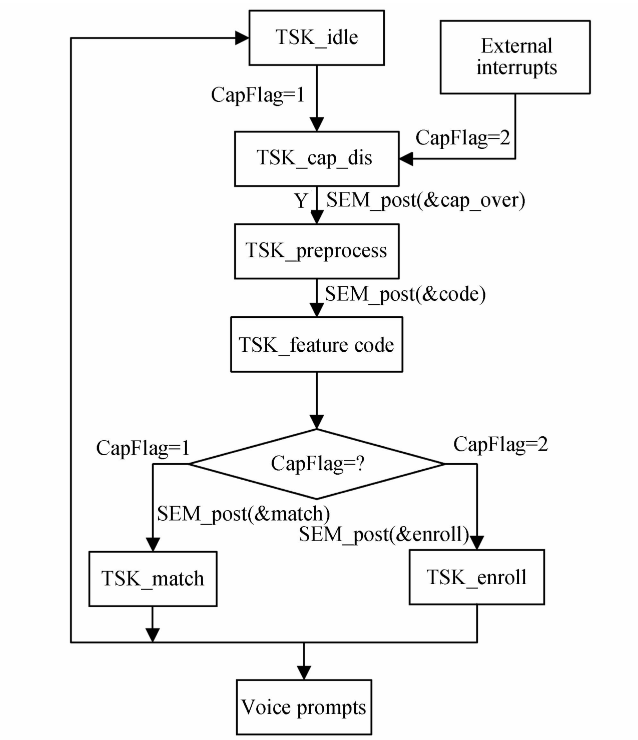

Fig. 7 Multi-task design of iris recognition system

In addition, because the system will involve the iris registration, it is necessary to set up an external hardware interrupt. Once the external interrupt captures the interrupt signal, the system will be immediately enter the interrupt to trigger the iris registration task, and the extracted iris feature data will be stored in the external expansion of iris feature library.

In the design of DSP embedded iris recognition system, 128 KB of the L2 can be used for storing bootloader code and Gabor template to improve the system and program's fast reading of common data. The 128 KB is used to store the cache, which can greatly improve the running rate and efficiency of the system. At the same time, the external extended SDRAM is divided into 8 blocks for storing temporary variables, system stacks, iris images and other information.

3 Designs of ZigBee network and cloud server

3.1 ZigBee network design

In order to facilitate wiring in complex environment, reduce the use of cables and increase the coverage of the network, a mesh network topology of the ZigBee network is used as a data transmission carrier. A number of iris recognition terminal modules can be installed in different locations. If the end device is far away from the coordinator, multiple ZigBee routers can be added to achieve wireless transmission of data between end device and the coordinator.

The data obtained from DSP can be sent out by using the MCBSP interface on the DM642. The system will transfer the data to the ZigBee wireless network, so that the data can be transmitted to the cloud accurately.

3.2 Cloud server design

Because the transmission speed of ZigBee module is not fast, and the design of transmission is only the corresponding identification code, so CH340T chip is used, and the ZigBee network coordinator is connected to the cloud server from USB interface. When the cloud server receives the iris identification code, the host computer calls cloud database, then identifiable individuals can be identified.

The server can send application programming interface (API) instruction to command the end device to enter a low-power sleep mode, thus system power consumption is reduced, so it's more environmental friendly and energy-saving.

4 Results

The iris recognition system processing period is only about 1.2 s in the processing iris image of 320×280 pixel of 8 bit, basically satisfying the real-time request.

We select 910 iris images, and values of k are 1, 2, 3, 4, respectively. Recognition rates are shown in Table 1.

Table 1 Recognition rate under different k values

k	Recognition rate (%)
1	79.5
2	85.3
3	96.8
4	89.7

The experiment shows that the system recognition rate can reach 96.8% when $k=3$. That is, the sample to be recognized is the reciprocal weighted euclidean distance (WED). Taking 3 neighbors of unknown sample, and identifying the majority of 3 neighbors, so that the samples identified can be grouped into the same class.

The accuracy rate of traditional iris recognition algorithm is about 90%, and the processing time is about 1.5 s or longer. The accuracy rate of algorithm proposed in this design can reach 96%, and the recognition time is shortened to 1.2 s. It is a big boost.

5 Conclusion

Combining with the advantages of DSP and ZigBee, the iris recognition system was designed. Based on Gabor filtering, the iris feature was extracted by using the amplitude mean and phase information of the block image, the iris recognition function was accomplished by the *k*-nearest neighbor algorithm, and the recognition result was transmitted to the cloud server through ZigBee network. This method can effectively solve the problems of complex structure, large computational complexity, poor real-time performance and wiring difficulty in iris recognition system. The test shows that the system runs stably, the response speed is fast, the recognition rate is high, and the layout is convenient. It can be widely used in the field of personal identification, such as security secrecy and electronic commerce.

References

[1] Chen Y R. Research on intelligent computing and biometric identification technology. Journal of Tianjin University of Science & Technology, 2015, 30(4): 78.

[2] Li H L, Guo L H, Wang X Z, et al. Iris recognition based on weighted Gabor filter. Journal of Jilin University (Engineering and Technology Edition), 2014, 44(1): 196-202.

[3] He Z H. Iris recognition based on generalized Gaussian distribution FDCT_Wrap and FSVM. Telecommunications Science, 2016, 32(7): 126-131.

[4] Fang Q, Yao P. Reliable iris recognition using 2D quadrature filters. Computer Science, 2015, 42(5): 281-285.

[5] He M S, Luo W S, Chen Q X et al. Research on anti-fatigue driving alarm system by iris recognition based on DSP. Journal of Safety Science and Technology, 2016, 12(1): 127-131.

[6] He F. Research on the iris recognition algorithms of multiple feature extraction and fusion based on Gabor filtering. Jilin: Jilin University, 2015.

[7] Zhang Z, Shao X X. A SIFT iris matching algorithm. Journal of Zhengzhou University (Natural Science Edition), 2017, 49(3): 14-19.

[8] Hu P, Wu Y B, Cao D H. Interest point extraction algorithm for robotic grasp and implementation on DSP. Instrument Technique and Sensor, 2015, (11): 85-88.

基于 DSP 和 ZigBee 的虹膜识别系统设计

李锦明[1]，马　林[1]，张少华[2]，成雅丽[1]，成乃朋[1]

(1. 中北大学 仪器与电子学院，山西 太原 030051；
2. 上海航天电子技术研究所，上海 201109)

摘　要： 针对传统虹膜识别系统计算复杂、实时性差等问题，在 Gabor 滤波图像的基础上，利用分块图像的幅值均值和相位信息来提取虹膜特征量，并结合 *k*-近邻算法来完成虹膜识别功能，缩短识别时间，提高识别准确度。同时，将识别结果通过 ZigBee 网络发送至云端服务器，解决了厂区内布线困难问题。实验表明，该识别系统运行稳定，识别速度快。该识别系统已被应用于某安防系统。

关键词： 虹膜识别；数字信号处理器；紫蜂协议；图像块

引用格式： LI Jin-ming, MA Lin, ZHANG Shao-hua, et al. Design of iris recognition system based on DSP and ZigBee. Journal of Measurement Science and Instrumentation, 2018, 9(2): 169-173. [doi: 10.3969/j.issn.1674-8042.2018.02.011]