

Design of Palmprint Acquisition and Recognition Base on Embedded

Ping Xue, Tianyu Liu, Meiwei Hou and Wenchao Li

*Department of Automation, Harbin University of Science and Technology
417312507@qq.com*

Abstract

As a kind of biometric identification technology Palmprint identification has many characteristics such as large information quantity, high discriminatory power and strong anti-interference ability and so on. The palmprint acquisition and recognition system can be divided into four modules: palmprint image acquisition, preprocessing, feature extraction and feature matching. For completing the hardware design of Nios II processor, image acquisition and recognition module we adopt SOPC Builder, DSP Builder, IDE development tools and Verilog, C programming language. In this system we integrated the verifying algorithm, system design models and variety function interface in a FPGA chip. This method has many obvious advantages such as updatable algorithm, reconfigurable hardware and software and high operational reliability. Experimental results showed that the system meets the real-time authentication and reliable requirement of identification besides it has the reusable ability of system platform.

Keywords: *Palmprint; SOPC; DSP Builder; Nios II*

1. Introduction

Biological recognition technology is a new identification method. Palmprint has been a hotspot in the area of biological recognition, because as a biological feature palmprint contains large amount of information, its main characteristic is stable and low resolution and also it has many other advantages. Palmprint identification completes the identification through analyzing the palmprint with image processing and pattern recognition. In the palmprint identification technology, the most important part is the location and extraction of ROI [1].

The normal procedure is as follows. First, we separate the palm and background by doing binary processing to a digital palmprint image. Second, we do edge detection to the binary image to get the palm contour. Through the analysis of image contour we further hunt the feature points and the gap angle of the finger gaps, then we confirm the position of ROI by using these information. The traditional method [2, 3, 4] to extract the ROI is almost by using the palmprint capture sensor (CMOS or CCD image capture system) which is connected with the computer. This method needs computer to finish the whole work, so it takes abundant computer resources and the processing speed is limited by the performance of the computer. This method is high energy consumption, low price ratio and not portable. FPGA chip has already been widely used in areas of image acquisition and processing because of its many advantages such as powerful processing capability, high speed, flexible design and low energy consumption.

The development of rapid image edge extraction and relative processing hardware system are the two important research contents in the area of digital image processing. We use advanced hardware design concepts and convenient development environment to realize the development of hardware system of image processing and through this method we can

tremendously improve the development efficiency and system performance. So this paper studies a new method to extract the Palmprint edge quickly based on the DSP Builder development environment [5]. We do graphical design to the Sobel operator and then extract the ROI of the palmprint through the morphology algorithm. At last the whole process realizes on the FPGA and we get good results.

2. Image Preprocess

Image preprocess is the key and necessary step in pattern recognition, pretreatment effect will have a direct impact on the result of feature extraction and recognition. Pretreatment is mainly to enhance the collected image and extract its edge, at the same time, remove the noise, and improve image quality in order to be helpful for the feature extraction.

2.1. Image Color Transformation

The Palmprint identification is based on the algorithm of gray-scale image processing but the image captured by the image sensor used in this system is color image. So we need transform color image into 8-bit gray-scale image before further processing of palm information. The sensor used RGB format to encode. According to the definition, using the formula $\text{Gray} = 0.3R + 0.6G + 0.1B$ to complete the image color transformation. The gray-scale image is shown in Figure 2.



Figure 1. Initial Image

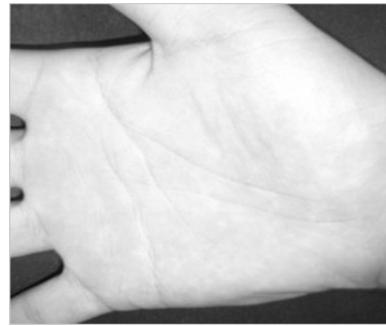


Figure 2. Gray Image

2.2. Palmprint Image Histogram Equalization

The essence of histogram equalization is that it can make the distribution of original image more uniform. So the histogram turns into a uniform intensity distribution by non-linear stretching which embodies the idea of a balanced. Through the conversion the contrast of the area occupied by the image is enhanced. If we want to get the best result of image output when the output amplitude of the digital image is limited, we must make its entropy maximum when the probability distribution of each pixel's amplitude is uniform. In this way we can reproduce the important details of Palmprint image.

$A(x, y)$ is the input image and its input image histogram is $H_a(r)$. The output image is $C(x, y)$ and its output image histogram is $H_c(r)$. If the gray transformation equation is a finite slope and non-decreasing continuously differentiable function $s = f(r)$. The relationship of them can be expressed as

$$s_k = H_c(r_k) = \sum_{j=0}^k H_{ar}(r_j) \quad (1)$$

In formula (1) $0 \leq r_k \leq 1$, $0 \leq s_k \leq 1$, $k = 0, 1, \dots, L-1$.



Figure 3. Histogram Equalization

2.3. Median Filter

The median filter is a nonlinear signal processing technology based on the sort statistical theory, it can effectively suppress the noise. The basic principle of the median filter is that the digital image or a point value in digital sequence is replaced with the median of each point value in the neighborhood of the digital image or a point value in digital sequence. With the method above the point value of pixels around are close to the true value, thereby eliminating the isolated noise point. The median filter is a nonlinear smoothing technique, it sets gray value of each pixels as the median of gray value of all the pixels within the neighborhood window of the corresponding point. Two-dimensional median filter output is:

$$g(x, y) = \text{med}\{f(x-k, y-l), (k, l \in W)\} \quad (2)$$

$f(x, y)$, $g(x, y)$ are the original image and the processed image, W is two-dimensional template which is typically 2×2 or 3×3 areas.

Realization Method:

1. The odd-numbered data is removed from the image of a sample window for sorting;
2. Replace the data which will be processed with the sorted median.

The main function of median filter is to change the relatively large difference of the surrounding pixel's gray value into the value of the peripheral pixel values which are possible close to eliminate the isolated noise point, so median filter can filter out the noise of the image and also the protect the edges of the image, thereby obtaining a more satisfactory recovery effect. It does not require the statistical properties of the image in the actual computation process, and it also brings a lot of convenience.

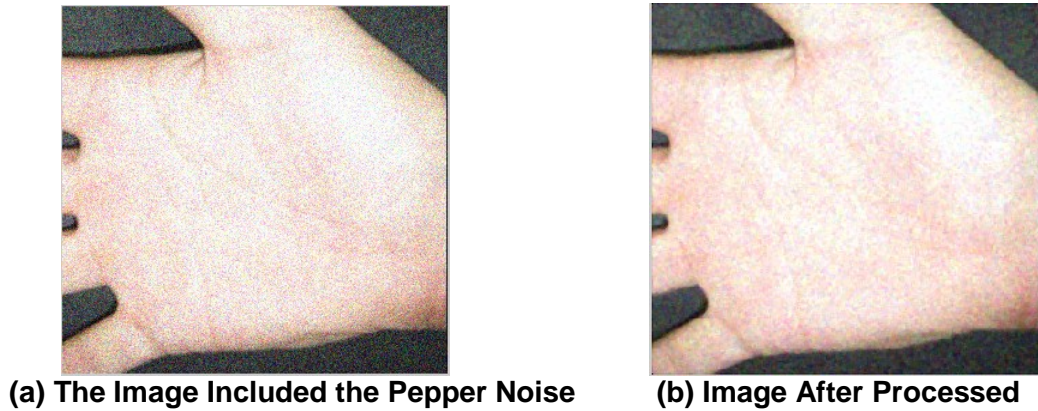


Figure 4. Median Filtering Effect Diagram

2.4. Image Binarization

One image includes target object, background and noise. If we want to extract the target object from the multivalued digital image, the most frequently-used method is image binarization. Binary image means an image which has two gray levels and it is the important subset of the digital image. The image binarization is that we set a global threshold T_n and separate the image data into two parts with T_n . One part is the pixel group whose value is greater than T_n and the other part is less than T_n . We set the pixel group whose value are greater than T_n as white and the one are less than T_n as black. The threshold corresponding new image can be expressed as (3)

$$g_{n0}(x, y) = \begin{cases} 255, & g_{ni}(x, y) \geq T_n \\ 0, & g_{ni}(x, y) < T_n \end{cases} \quad (3)$$

In (1), $g_{n0}(x, y)$ is the gray value before processing in (x, y) and $g_{ni}(x, y)$ is the gray value after processing in (x, y) . The image after processed is shown in Figure 5.

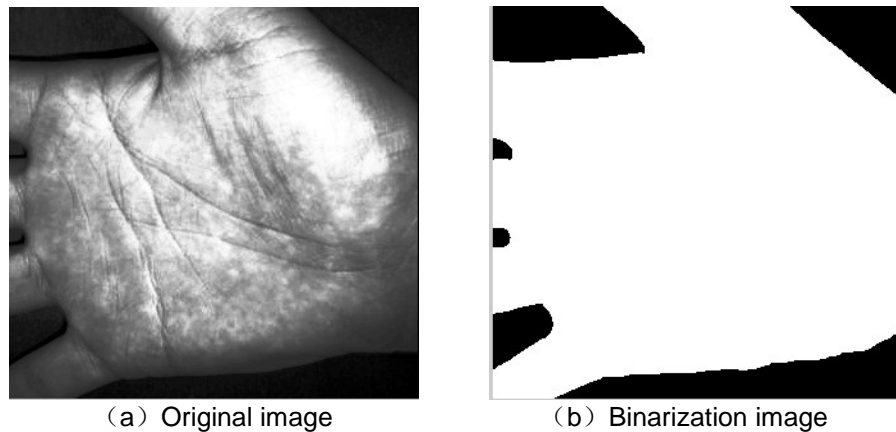


Figure 5. Binarization Result Image

3. Feature Extraction

Feature extraction is to extract the palmprint characteristic which has strong distinguish ability. Feature extraction is the most important part in palmprint identification, and the

quality of feature extraction is a key factor to the performance of palmprint recognition system. Feature extraction mainly includes palmprint edge detection, feature area localization and extraction.

3.1. EdgeDetection

Image edge is the area where the most apparent brightness change happens in the local area of image. The Gray-scale data of image edge changes very violently. Image detection and identification is based on the identification and extraction of image edge [7]. If we want to separate the target from the background we must extract the edge.

3.1.1. Improved Sobel Operator

The classic sobel algorithm is to carry on the neighborhood convolution to image with two direction templates. The most common direction template is direction templates on $\pm 45^\circ$. Algorithm block diagram of Sobel edge detection is shown in Figure 6.

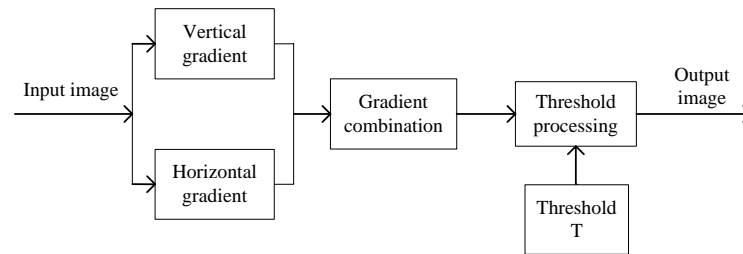


Figure 6. Program Flow Chart of Sobel

Sobel operator calculation is relatively simple and easy to implement. But the traditional method can only detect the horizontal and vertical edge. So the detection results of this algorithm will decline when dealing with the Palmprint image which has complex grain direction. We adopt the improved Sobel operator to improve the traditional algorithm for some shortcomings. Compared to the original algorithm, this new one increased 3 sets of templates which consist 4 sets of template from 8 directions. As shown in Figure 7.

-1	-2	-1	-2	-1	0	-1	0	1	0	1	2
0	0	0	-1	0	1	-2	0	2	-1	0	1
1	2	1	0	1	2	-1	0	1	-2	-1	0

1	2	1	2	1	0	1	0	-1	0	-1	-2
0	0	0	1	0	-1	2	0	-2	1	0	-1
-1	-2	-1	0	-1	-2	1	0	-1	2	1	0

Figure 7. Improved Sobel Pperator

3.1.2. Edge Detection with Sobel Operator

First, Calculate the palmprint image point by point with four direction templates [8], and it takes the maximum value for new gray value of the pixels. The direction indicated by the template corresponding to the maximum value is the edge direction of the pixel point.

Second, Given a threshold value TH, if the new gray value of the image pixels is equal to or greater than TH, it is determined that pixel is the edge point, or a non-edge point. At last, Tracing three continuous points to the edge point which is initially identified, and removing noise point, fixing the true edge point, so that it can detect a complete image edge. The result after the edge detection with Sobel operator is shown in Figure 8.

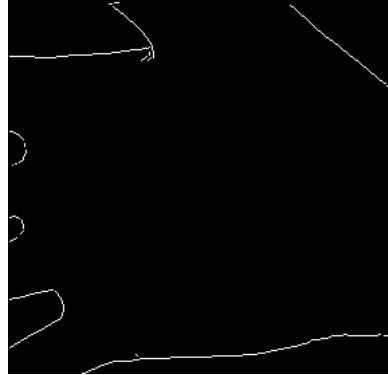


Figure 8. Sobel Operator Edge Detection

3.2. The Determination of Anchor Point

In mathematical morphology the most two basic morphological operations were erosion and dilation. Do contraction or refining operation to a binary image called erosion and do lengthening and thicken operation to a binary image called dilation. The process of morphological closing operation is that the image was expanded before eroded. This process can make the contour of target smooth and the slender gap and narrow discontinuous could be eliminated. A was set up as the origin image. B was the structure element A was defined by morphological closing operation of B as:

$$A \bullet B = (A \oplus B) \ominus B \quad (4)$$

In conclusion we chose appropriate structure element to operate the closing operation on the binary image. And we moved the origin point of structure element in parallel to cover the entire image area. We would get the image which had been operated. The image was shown in Figure 8. Compared to Figure 3 the closing operation filled up 4 depressions between each fingers. To get the anchor point the image should be done the minus operation with the original binary image.

The appropriate structure element was very important. The structure element was always represented by 0 matrix and 1 matrix. 1 matrix represented white and 0 matrix represented black. Of course the origin point must be clear [9]. Under normal conditions the shape of the part which we were going to fill up and the structure element should be similar. Through repeated experiments analysis we chose matrix S1 and matrix S2. They both had 2 rows' 1 and 2 lines' 1. Their size was 5×5. The element which was with * was the origin point. As shown in (5)

$$S1 = \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 \end{bmatrix} \quad S2 = \begin{bmatrix} 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} \quad (5)$$

In order to get two anchor point images we needed to do the minus operation between the image which had been done twice closing operation and the original binary image [6]. Then we did add operation between the two anchor point images. After that we could get the whole anchor point image of Palmprint. As shown in Figure 9.



Figure 9. Anchor Image

3.3. Build the Coordinate System

During the image acquisition we needed to rotate the palmprint image to the standard coordinate system by a certain angle to prevent palm position changes. We could confirm the position of anchor point with the find function in MATLAB. We set the connecting line of A and C as X-axis and set the vertical line of X which also went through B as Y-axis. We built the coordinate system on basis of the origin point which was the crossing point of X-axis and Y-axis. As shown in Figure 10 we extracted the ROI of palmprint through the coordinate system

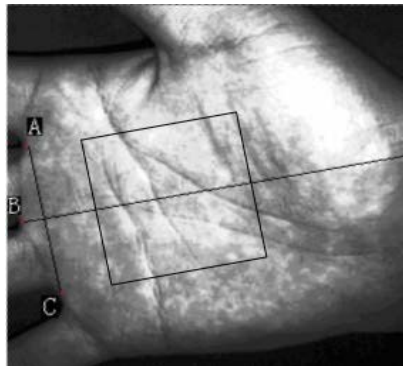


Figure 10. Build the Coordinate System of Palmprint

3.4. Image Rotation

In the process of palm image acquisition, although the palm placed roughly in the same direction, palm placement is not the same every time. In order to extract the same ROI from the same person we rotate the image to make the ordinate of anchor points same.

We adopt the linear interpolation method to rotate the image, the selected angle is α expression (6) as follows and the rotated image is shown in Figure 11.

$$\begin{aligned} X &= x \cdot \cos \alpha + y \cdot \sin \alpha \\ Y &= -x \cdot \sin \alpha + y \cdot \cos \alpha \end{aligned} \quad (6)$$

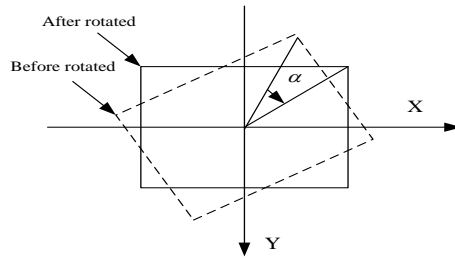


Figure 11. Rotate Image

4. Realize the Palmprint Acquisition Algorithm on FPGA

Altera DSP Builder is the connection between Simulink and Quartus II. In the seamless design process of DSP Builder, researchers firstly design algorithm in Matlab, then integrate the system in Simulink, finally make the output become the hardware design language (HDL) file in order to use it in Quartus II. For the designers who are lack of experiments in use of programmable logic design software, the design process is very convenient and intuitive. Owing to the limited space, we only introduce several main modules of DSP Builder design.

4.1. Histogram Processing Module

We build the histogram processing module with DSP Builder toolbox as shown in Figure 12. The Delay module represents one time unit delay [10]. Single-Port RAM module is the image data in some time and adds 1 to the address data and then buffers to the RAM. At last the output is the histogram of gray-scale Palmprint image.

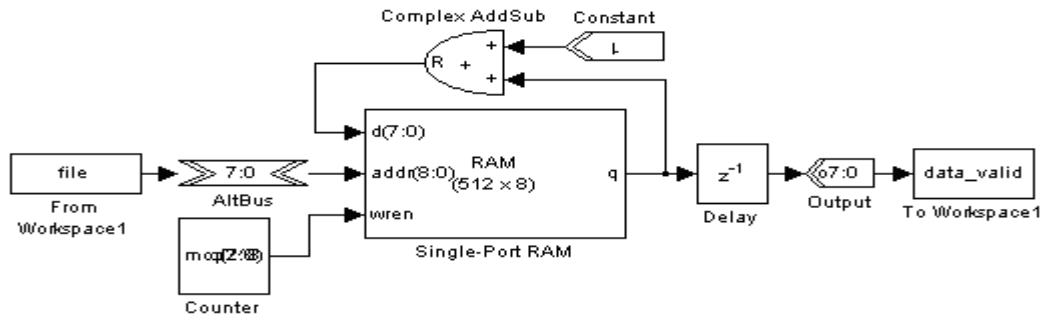


Figure 12. Histogram Processing Module

4.2. Median Filter Module

The key of parallel median filter is to realize two modules: 1) sliding window to realize tap module; 2) filter parallel comparison calculation module. The content below is that modeling in DSP Builder with 3×3 parallel filters.

4.2.1. 3×3 Window Module

Using FPGA to realize median filtering, in this paper uses the serial running water is changed into parallel line, by this way 3×3 sliding window tap is realized. As shown in Figure 13 delay module represents one time unit register. When all the delay time is satisfied, the next one clock cycle will output nine pixel positions in parallel. When real-time collected

image data flow into the input unceasingly, the 3×3 sliding window data will change constantly to realize all the pixel image real-time processing.

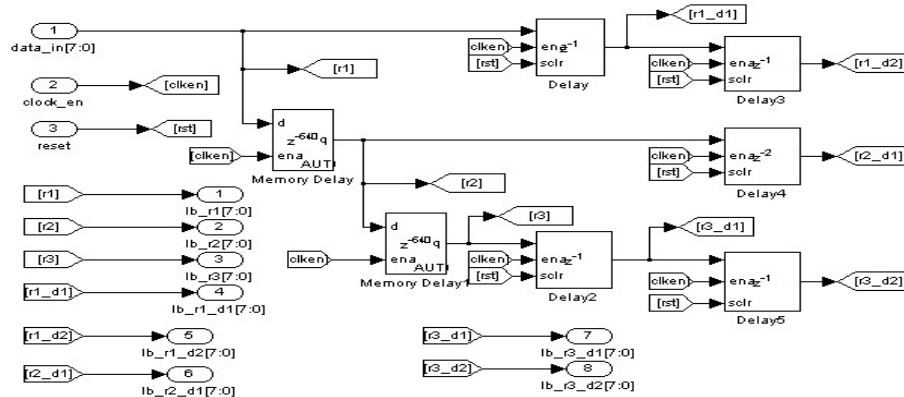


Figure 13. 3x3 Data Cache Window

4.2.2. Parallel Comparison Calculation Module

In order to reduce the difficulty of development and take full advantage of the modular design idea, only three modules are designed for the calculation of maximum value, median value and minimum value. The maximum and minimum module are called 4 times, seeking median module are called 5 times. So it is easy to identify the value in the 3×3 sliding window

Firstly compare the size of a and b by the comparator, secondly the larger number will be output through Multiplexer, thirdly the larger number and c will be compared, then the largest one among the three numbers will output through the selector, the methods to get the minimum and maximum value have same idea. And the comparison calculation structure of medium filtering is shown in Figure 14.

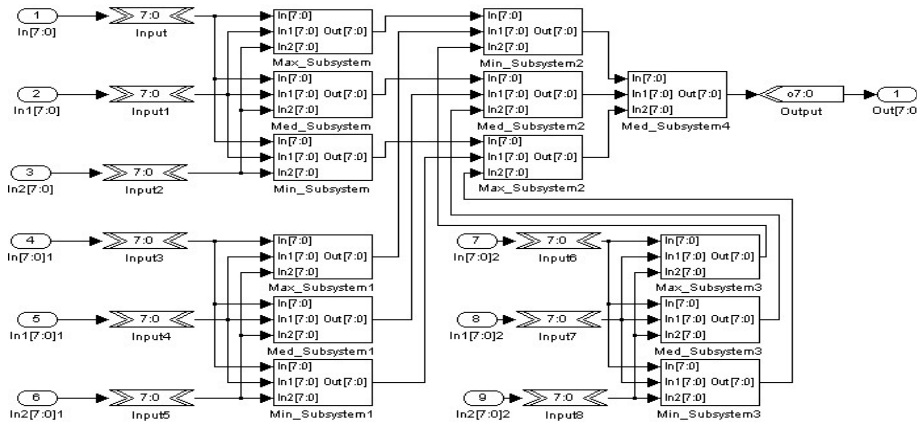


Figure 14. Calculated Median Block Diagram

4.3. Edge Detection Module

4.3.1. Gradient Calculation Module

We used 8 direction templates to calculate the edge of the image. We used the horizontal and vertical directions as the example to calculate the gradient. We adopted two pipeline

processing programs to improve the processing speed of the gradient calculation module. As shown in Figure 15 is the gradient calculation module in horizontal direction. In order to realize the gradient calculation of 6 relative pixels in horizontal direction 4 adders and 1 subtractor used in this module. In order to carry out a parallel gradient operator we added the vertical processing module same as the horizontal one. So we can get 8 pixels in a same cycle.

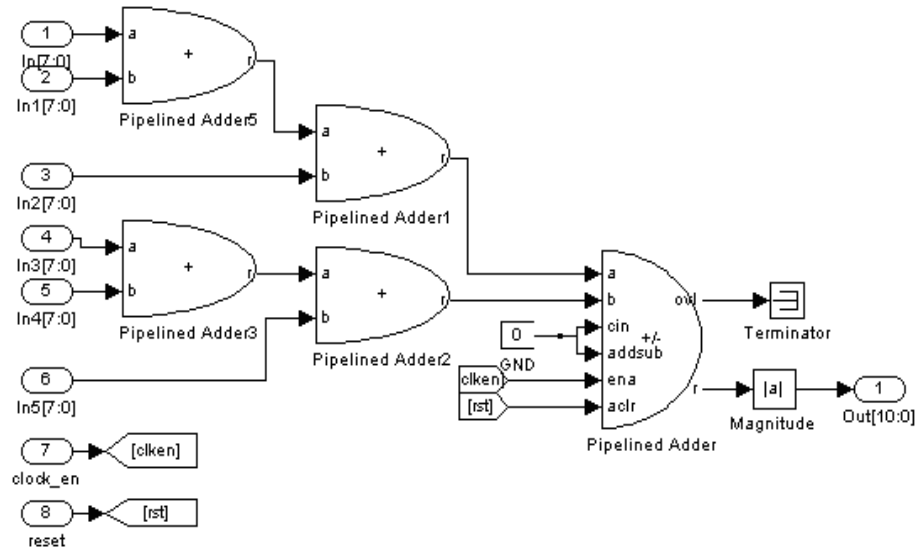


Figure 15. Gradient Calculation Module Chart

4.3.2. Gradient Calculation and Threshold Comparison Module

The gradient value is represented by the sum of absolute value. We compare the calculated gradient value with the pre-set threshold and then we can know if the pixel corresponds to the value is the pixel of image edge value. Figure 16 is the internal structure of the module. The judgment of gradient value in vertical direction and horizontal direction was realize in one adder and then carried on value comparison one time. If the value we got is bigger than the set threshold value the selector M will output a edge pixel whose value is 255(white) or the output will be the pixel value of the normal position.

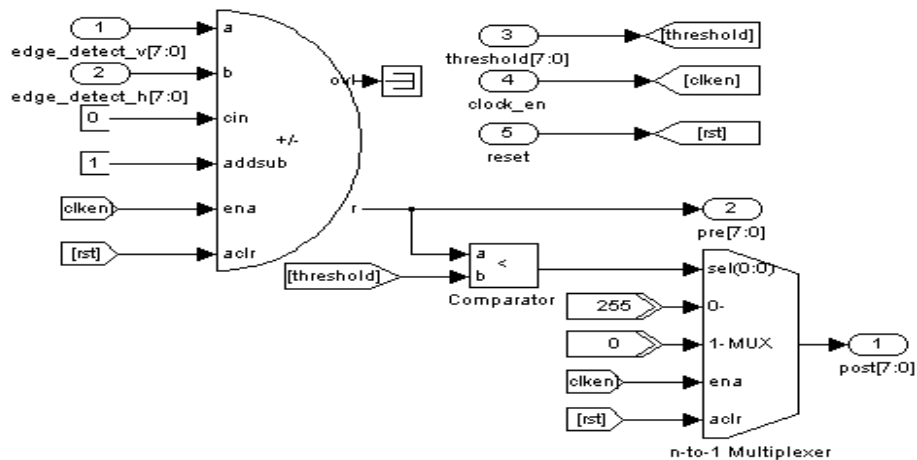


Figure 16. Gradient Calculation and Threshold Module Chart

5. Experiment and Result Analysis

The FPGA chip used in experiment is the EP2C35F672C6 chip produced by Altera. The palmprint image sensor is D5M. The software had been used included DSP Builder V9.1 and Matlab 2009a. In order to facilitate observation of the image, we sent the image data stored in the SDRAM to VGA to display it. The display result shows in Figure 16. Then in Matlab 7.8.0 we used DSP Builder toolbox to integrate the circuit design of Sobel edge detection algorithm and ROI area extraction algorithm. We used Signal Compiler to turn the circuit model into VHDL code and integrated the code into a complete image processing module and added the module into the text system. After compiling the program we downloaded the compiled result into the FPGA chip. Thus we realized the real time edge detection processing of image and the processing of ROI area extraction. We used 60 people as the training sample and each people had 10 images. There were 600 images in total. The size of each image was 640×480 and we confirmed a 128×128 region as the ROI of the image. Based on the method above we confirmed the position of anchor point, built the palmprint coordinate system and got the ROI of palmprint. The positioning results are shown in Table 1.

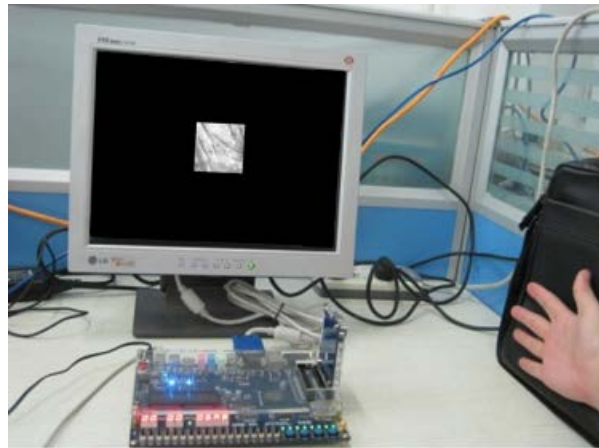


Figure 16. Feature Algorithm Test in FPGA

Table 1. Different Positioning Method of Matching

Method	Number of figure	Average time of position	Success rate
Traditional method	600	2.5s	97.6%
New method	600	2 s	98.2%

From the statistical results we could conclude that only small parts of palmprint were not located precisely. Through the analysis about the ROI of the palmprint which were extracted wrongly the main reason caused error was that the stretch of palm was not enough. In order to further improve the accuracy, we need to regulate the stretch posture of palm. Experiment result show that the algorithm of the ROI extraction above is simple, effective, applicable and has fast computing speed. Its extraction process is 0.5s faster than the one of computer so the algorithm is fast and practical.

6. Conclusion

The application of system resources reflects the advantages of system design based on FPGA chip. There are many innovations on the aspects of algorithm and system

reuse. The hardware language is used to finish the algorithm which occupied large system resource. In the design process of IP core about the image process we use the DSP Builder toolbox to simplify the difficulty of design. To sum up, we adopted the SOPC embedded technology and finished the system architecture and function design of software and hardware to realize the fast location and extraction of palmprint feature region which meets the expected results.

References

- [1] Z. Duo, "Base of Biometrics", Wuhan: Wuhan University Press, (2009), pp. 240-245.
- [2] A. K. Jain, A. Ross and S. Prabhakar, "An introduction to biometric recognition", IEEE Transaction on Circuits and Systems for Video Technology, vol. 14, no. 1, (2004), pp. 4-20.
- [3] D. Qingyun, Y. Yinglin and Z. David, "The orientation and segmentation technologies in palmprint-based identification systems", Journal of Guangdong University of Technology, vol. 19, no. 1, (2002), pp. 1-6.
- [4] F. Wang and H. Qin, "A FPGA based Driver Drowsiness Detecting System", Vehicular Electronics and Safety, IEEE International Conference on, (2005), pp. 358-363.
- [5] Altera Corporation. DSP Builder User Guide, (2007).
- [6] W. Xiangqian, Z. Dapeng and W. Kuanquan, "Plamprint Identification Technology", Beijing: Science Press, (2006).
- [7] S. L. Phung and A. Bouzerdoun, "A new imgae feature for fast detection of people in image", International Journal of Information and Systems Sciences, vol. 3, no. 3, (2007), pp. 383-391.
- [8] L. Wang, "Comparison for edge detection of colony image", Internetional Journal of Computer Science and Network Security, vol. 6, no. 9, (2006), pp. 211-215.
- [9] S. Bin, "Palmprint based on Gabor wavelet transform feature extraction algorithm", Jinan: Shangdong University, (2010), pp. 34-38.
- [10] W. Yanhua and Z. Jian, "Location method of palmprint image based on morphology", Journal of Liaoning Institute of Technology, vol. 29, no. 4, (2002), pp. 47-52.