Hardware Implementation of Palm Vein Biometric Modality for Access Control in Multilayered Security System

Sonal S. Athale⁠¹, Dhiraj Patil⁠², Pallavi Deshpande⁠³, Yogesh H. Dandawate⁠⁴*

⁠¹Student, Department of Electronics and Telecommunication, Vishwakarma Institute of Information Technology, Pune.sonal.athale91@gmail.com
⁠²Graduate in Electronics and Telecommunication, Vishwakarma Institute of Information Technology, Pune, 37dhirajpatil@gmail.com
⁠³Assistant Professor, Department of Electronics and Telecommunication, Vishwakarma Institute of Information Technology, Pune, deshpallavi2011@gmail.com
⁠⁴Professor, Department of Electronics and Telecommunication Engineering, Vishwakarma Institute of Information Technology, Pune. yogesh.dandawate@viit.ac.in; yhdandawate@gmail.com

Abstract

Among the biometric modalities palm veins are the most secure and difficult to duplicate. This palm vein verification system aims to recognize a person from its exclusive palm vein organization that cannot be forged easily since veins are situated in inner layers of skin. Embedded devices are gaining increased attention in biometrics due to reliability and cost efficient systems. An embedded palm vein recognition system is the need of today in institutes, industries, security places etc. The aim of this proposed work is to implement palm vein identification system on hardware unit so that it can be further build into a single standalone unit, where it can be used in final level security in multilayered security system without any possibility of hacking. The hardware platform used in the proposed work is Blackfin ADSP-561 processor and the algorithms used for matching of palm vein are performed using C language. The project focuses on storing images and implementing the matching algorithms on hardware platform itself such that PC or laptop is not needed for identification purpose. Principal component analysis (PCA) and template matching techniques are used as verification algorithms of palm veins. Finally, it can be concluded from the experimental results that this approach can verify an individual with an average accuracy of 92%.

© 2015 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of organizing committee of the Second International Symposium on Computer Vision and the Internet (VisionNet’15)

* Corresponding author.
E-mail address: yogesh.dandawate@viit.ac.in; yhdandawate@gmail.com
1. Introduction

The widely used authentication systems used to control access to security locations are passwords, Personal Identification Number (PIN) but those can be stolen or cracked. Thus biometrics has become strong alternative to the traditional verification methods. Biometrics is a way of automatic identification of an individual on the basis of behavioral or physiological traits of that person. Biometrics, such as fingerprint, hand geometry, iris, palm print, palm veins, voice, signature, are extensively used in security applications and each one has its pros and cons. Palm veins are situated in subcutaneous layer of skin which makes it impossible for intruders to copy. Also palm vein recognition system gives good accuracy, reliability and is cost efficient. Palm veins are used where multilayer security is required. In other words in areas such as banks, Automated Teller Machine (ATM) or where high level security is needed, palm vein authentication system will be more efficient than other biometric features. In market we get various fingerprint or iris recognition systems that are used at workplaces for log-in and log-out, at banks for security vaults etc. For multilayer security such palm vein authentication system is needed to be developed.

Even if systems based on computer are most admired in writing, embedded palm vein identification systems are in huge requirement since it is inexpensive, small in size. Yet it is very tough to implement an embedded palm vein authentication system with restricted CPU and memory resources. The embedded processors available in market have clock speed of couple of MHz, due to which running complicated algorithms like palm vein feature extraction and matching would get prolonged. Also it is difficult to get the software installed in every organization due to its expensive license. A common man cannot afford the licensed software just for sake of buying a palm-vein authentication system. To address this issue, we have used Blackfin dual core 500MHz ADSP 561processor to build stand-alone unit for palm vein authentication system. The software includes user interface and palm vein recognition algorithm running on DSP using visual dsp++ and C programming. After capturing palm vein images its ROI is extracted and palm vein recognition algorithm is run on ROI extracted images. Many techniques have been used for capturing palm vein images and identification of those images. In this paper we are proposing a low cost technique for effective ROI extraction and different methods like PCA and template matching for verification purpose. The novelty of this proposed paper lies in implementing the above mentioned verification algorithms on Blackfin processor which can be further made into a single stand-alone unit.

The rest of the paper is organized as follows: Section 2 describes the literature survey. The image acquisition approach is illustrated in section 3. The proposed approach is introduced in section 4. Section 5 describes the details regarding hardware and its related issues. The experimentation and results are projected in section 6 and section 7 concludes the paper.

2. Literature Survey

Extensive research has been conducted on many verification technologies using biometric features specifically hand over past decade. The work by L-q.Zhu, S-y.Zhang\(^8\) involves multimodal biometric authentication system in which knuckle print, finger geometry and palm print have been used as features for verification by adopting decision level AND rule fusion technique. It needed execution time of 1.393s. Lot of study has been done on finger knuckle print to bring this feature as good biometric. A. Kumar et al.\(^6\) proposed ant colony optimization technique for bimodal knuckle verification which utilizes fuzzy binary decision tree method. L. Zhang et al.\(^7\) introduced finger knuckle print recognition by score level fusion method by combining local features with Fourier transform coefficients that gave EER of 0.358%. L. Zhang et al.\(^9, 10\) presented in their work a new technique for finger knuckle print verification by adopting Gabor filter method for feature extraction. The identification rate given by this method is high compared to other existing finger back surface based methods. Although all these techniques justify finger knuckle print to be used as biometric feature for security purpose but usage of only feature will not serve the needs of high level security applications.
Wang et al. in their work described multimodal person identification system in which a single image was formed by combining palm veins and palm print. Features were extracted by Locality Preserving Projection (LPP) that is called as “Laplacian palm”. W-Y Han, J-Y Lee worked on implementing Gabor filter technique for palm vein verification system. The similarity of two Vein Codes i.e. bit string representation is calculated by hamming distance that gives speedy template matching. Dynamic fusion scheme was used to adapt to image quality. D. Zhang et al. developed an online verification method using palm vein and palm print modalities. Palm prints and palm vein images were acquired simultaneously and matched filters were used for feature extraction. Jifeng Dai and Jie Zhou in their work have used a novel scheme for palm print recognition in which creases on palm are located and smoothing is done to reduce noise.

Besides, some work has been done on embedded implementation of few biometrics like face, iris and fingerprint. T. D. Prasanthi et al. have proposed in their work a low cost design of face recognition using OpenCV library on ARM platform. Image processing part was performed using OpenCV and identification was done using ARM processor and GPS system. Similar work is done by L. Shen et al. but on palm print feature and using OMAP 3530 DSP processor along with ARM processor. They discussed an architecture where DSP processor is equipped with 600MHz ARM cortex processor. The hardware involves an image sensor that captures palm print image, OMAP 3530 and peripheral devices. ARM processor is used mainly to focus in areas like image capturing, controlling peripheral and user interface and running complicated algorithms on DSP. For feature extraction Gabor wavelet and Local Binary Patterns (LBP) is used that gives around 96% accuracy.

Based on the above mentioned work and by the results obtained from the previous work, we propose a new approach for verification of a person on basis of palm vein modality that can overcome the disadvantages of the previous work. We aim to build a stand-alone unit for palm vein identification system which will work independent of PC or laptop and which will be a low cost and reliable device.

3. Image Acquisition

3.1 Palm vein image capture setup

The palm veins cannot be seen clearly in ordinary light. Depending on amount of hemoglobin in blood visibility of veins in infrared light differs. Near-infrared (NIR) illumination is used due to its less sensitivity to temperature and humidity. Fig.1 shows the penetration of light in skin at different wavelengths.

G. Shah et al. employed penetration method for image capture by keeping hand between illumination source and camera. They developed an image capture system in which infrared filter was removed from iBall face to face c12.0 (1.3 Mega Pixel) web camera to sense only infrared light. However, illumination source has been made up of forty four high powered NIR LEDs SFH4550 arranged in a matrix pattern. Fig.2. depicts the LED arrangement and camera setup used for image capturing.

![Fig.1. Penetration of different wavelengths in skin (Source: Bashkatov et al.)](image-url)
3.2 ROI extraction, preprocessing

From hand images, Zhou and Kumar\(^2\) have proposed the extraction of ROI using webs. Afterwards, histogram equalization and adaptive histogram equalization is used for ROI preprocessing, further image is resized as per the requirement by using bicubic interpolation. For ROI extraction, thresholding is applied on binarised gray scale image so as to distinguish palm region from background. Webs are located by discarding redundant points in single web. The farthest two webs form a square and after rotating it we get ROI. Extracted ROIs are resized whereas histogram equalization is further used for enhancing image.

The idea, articulated in this paper, was meant to be implemented on hardware, but it was simulated in MATLAB. In our proposed work, we are using same hardware and preprocessing techniques for image acquisition and preprocessing. Fig. 3 and fig. 4 illustrate the ROI extracted image and enhanced image of palm veins.

![Fig3: (a) binarised image; (b) ROI and (c) extracted ROI](image)

![Fig4: Enhanced ROI](image)

Using hardware, preprocessing techniques and steps shown in above images, we have created our own database for palm images of 60 persons. The ROI extracted images of 60 persons have been used as training and testing database each. The captured images are 24 bit RGB having a resolution of 640 × 480 pixels. Camera is set approximately 3 inches apart from hand. The position of the hand is constrained while capturing images. For each individual, three images are captured of dorsal veins from left hand.
4. Methodology and Software Implementation

The features extracted are matched using different algorithms. Here we have used PCA algorithm and template matching methods for palm vein matching. When the ROI image is extracted it is needed to store those images in memory of the DSP processor. Thus for storing image file in memory we need to convert image file into text file and that text file is then filled in memory. After that PCA algorithm and template matching are performed for both training images and test images.

4.1 PCA algorithm steps:

- Read all ROI images and make a matrix (A) with columns equal to the total number of ROI’s read, by storing its pixel values in an array.
- Find eigen values and eigen vectors for training set database by Jacobi algorithm. Jacobi algorithm can be stated as follows:
  a. Initialize the v matrix that will contain eigenvectors to identity matrix
  b. Initialize b and d matrix to diagonal of a. This vector will accumulate terms of the form \( ta_{pq} \) as in equation:
  \[
  a_{pp} = a_{pp} - ta_{pq}
  \] (1)
  c. Take sum of diagonal elements
  \[
  S = \sum_{rs}|a_{rs}|^2
  \] (2)
  d. The diagonal elements give eigen values of original matrix A
  \[
  D = V^TAV
  \] (3)
  Where \( V = P1 P2 P3 \ldots \)

  Pi’s are successive Jacobi rotation matrices
- Sort eigen values and eigen vectors in decreasing order. Find highest eigen value and arrange corresponding eigen vector \( v(k) \) accordingly.
- Multiply \( v(k) \) with the original dataset i.e. A to obtain principal component P.
- Perform same steps for test image
- Find principal component value Q for test image.
- Find Euclidean distance between PCA value of test image and PCA value of training images.

\[
Eucd_{dist} = \sqrt{\sum_{i=1}^{n}(Q - P)^2}
\] (4)
- Image with minimum Euclidean distance represent verified image.

4.2 Template matching

In our proposed paper for template matching we have reshaped the ROIs to row vector. These vectors then form a matrix consisting of each row as single image. The ROI extracted from test image is also reshaped to row vector.

A difference vector is obtained by computing the difference between test ROI vector and each row of matrix. All the values in difference vector are added. The image corresponding to minimum sum is verified as matched image.

5. Hardware Implementation

Current work on biometric authentication systems is done using multiple processors and hardware units. To overcome this problem we have elected a platform for demonstration of our biometric recognition system with Dual core ADSP Blackfin BF561 (500MHz) processor, 328Kb on-chip memory, 128Mb SDRAM. This DSP platform supports RS232, RS422 and USB interface. It also has floating point arithmetic, which provides computational accuracy in algorithm. PC and DSP platform have been connected using USB interface. Now, processed palm vein
images’ dataset has been stored on SDRAM. The software development tool used for the interaction between PC and hardware is visualdsp++. Visualdsp++ supports C as one of the programming language and we developed our algorithm in C.

Processor has limited on chip memory. Dataset of images is stored on SDRAM. Fetching data from SDRAM and then executing the algorithm on that data becomes time consuming process. To overcome this problem, we didn’t process our algorithm on all the images every time. Instead of that, we stored processed data of images, and we kept update on only processed data of training images.

5.1 Hardware related issues:

While making a standalone palm vein recognition unit on this platform, we came across some issues. Due to the limited on chip memory, power consumption of the processor is more, as the amount of data is processed is additional. Also power dissipation in the processor is high. As power dissipation depends on the clock and supplied voltage, by reducing one of the factors, power dissipation can be reduced. But at the same time entire unit has to compromise with execution time and performance.

Cost of the development platform is near about $800. But adding features like more external memory, increasing clock frequency will increase total cost of the project. While making low cost standalone unit, increased cost is never desired.

6. Experimental Results

Experimentation was done using proposed development board and visualdsp++ software on PC with 4GB RAM, i5 machine. Palm vein images of 60 persons were used for training and testing of algorithm. The dataset consist of images taken at different times. As processor has limited on chip memory, fetching data from SDRAM and executing algorithm becomes more time consuming. While executing algorithm on new test images and recognizing similar match in stored data, the PCA method on current setup takes 6 seconds while template matching method takes nearly 7-9 seconds.

In pre-processing step, ROI is extracted from each image so that area of same size is used for feature matching. For experimentation purpose, database is divided into two sets: training and testing set. The verification results show that PCA algorithm yields 92% accuracy and template matching gives around 94% accuracy. However, accuracy can be further increased by improvising pre-processing so that exact ROI’s of two images will be matched. The proposed system can operate at false acceptance rate of 0.9% and a false rejection rate at 0.08%, thus making this system usable for real-time purpose.

7. Conclusion

The experimental setup used for palm image acquisition is cost effective and simple to develop. The experimental results show that the proposed system identified 60 palms with false acceptance rate at 0.9%. Our research work is mainly concerned with implementation of PCA algorithm for palm veins on DSP platform. The PCA algorithm and template matching enables correct identification of persons. All elements used in development are easily available in market. It costs much less than current available systems in market, which costs about $3000 to $4000.

This hardware unit provides low price and precise recognition system. While using this setup on large number of dataset, then execution speed must be increased. Since it increases the cost of the project, we need to use high efficiency image data compression techniques to reduce size of the data, but shouldn’t negotiation with accuracy of the data.

The main purpose of proposed work is to make hardware system which can be used commercially. Palm veins can be combined with more biometric modalities to provide more precise identification systems. Each modality can compensate for the others shortcoming so as to reduce the chances of false recognition and failure. This will advance the security and can be used for high level of security purpose. The future work includes developing the hardware setup and combining other modalities including palm vein so as to make it most efficient and reliable person identification system.
References

1. Shah, G., Shirke, S., Sawant, S., Dandawate, Y. H. (2015) 'Palm vein pattern-based biometric recognition system', *Int. J. Computer Applications in Technology*, Vol. 51, No. 2, pp.105-111
2. Zhou, Y. and Kumar, A. (2011) “Human identification using palmvein images”, *IEEE Transactions on, Information Forensics and Security*, Vol. 6, No. 4, pp.1259–1274
3. Zhang, D., Guo, Z., Lu, G., Zhang, L., Liu, Y., Zuo, W. (2011) ‘Online joint palmprint and palmvein verification’, *ELSEVIER-ScienceDirect*, Expert Systems with Applications, Vol.38, pp. 2621–2631
4. Wang, J.G., Yau, W.Y., Suwandy, A., Sung, E. (2008) ‘Person recognition by fusing palmprint and palmvein images based on “Laplacianpalm” representation’, *ELSEVIER-ScienceDirect*, Pattern Recognition, Vol. 41, pp.1514 – 1527
5. Han, W.Y., Lee, J.C. (2012) ‘Palm vein recognition using adaptive Gabor filter’, *ELSEVIER-ScienceDirect*, Expert Systems with Applications, Vol.39, pp.13225–13234
6. Kumar, A., Hanmandlu, M., Gupta, H. M. (2013) ‘Ant colony optimization based fuzzy binary decision tree for bimodal hand knuckle verification system’, *ELSEVIER-ScienceDirect*, Expert Systems with Applications Vol.40, pp. 439–449
7. Zhang, L., Zhang, L., Zhang, D., Guo, Z. (2012) ‘Phase congruency induced local features for finger-knuckle-print recognition’, *ELSEVIER-ScienceDirect*, Pattern Recognition, Vol.45, pp.2522–2531
8. Zhu, L.Q., Zhang, S.Y. (2010) ‘Multimodal biometric identification system based on finger geometry, knuckle print and palm print’, *ELSEVIER-ScienceDirect*, Pattern Recognition Letters, Vol.31, pp.1641–1649
9. Zhang, L., Zhang, L., Zhang, D., Zhu, H. (2011) ‘Ensemble of local and global information for finger–knuckle-print recognition’, *ELSEVIER-ScienceDirect*, Pattern Recognition, Vol.44, pp.1990–1998
10. Zhang, L., Zhang, L., Zhang, D., Zhu, H. (2010) ‘Online finger-knuckle print verification for personal authentication’, *ELSEVIER-ScienceDirect*, Pattern Recognition, Vol. 43, pp.2560–2571
11. Dai, J., Zhou, J. (2011) ‘Multifeature-Based High-Resolution Palmprint Recognition’, *IEEE TRANSACTIONS ON PATTERN ANALYSIS AND MACHINE INTELLIGENCE*, VOL. 33, NO. 5
12. Prasanthi, T.D., Rajasekhar, K., Janardhana rao, T.V., Satyanarayana, B.V.V. (2012) ‘Design Of ARM Based Face Recognition System using Open CV Library’, *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET) Volume 1, Issue 9*
13. Shen, L., Wu, S., Zheng, S., Ji, Z. (2012) ‘Embedded Palmprint Recognition System Using OMAP 3530’, *sensors*, Vol.12, pp.1482-1493
14. http://www.waveletgroup.com/DSPPORT-V-1.htm