FPGA-Based Finger Vein Recognition System for Personal Verification

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Abstract— In today's society with the rapid growth in the field of electronic information technology and its simultaneous deployment in every field, the personal verification is a critical key problem. Due to this fact, the biometric authentication has gaining popularity as it provides a high security and reliable approach for personal authentication. Finger vein biometric is advantageous over other types of biometric systems because it has low forgery rate, aliveness detection as well as stable over long period of time. The paper presents the implementation of image processing algorithm and Feature extraction process in MATLAB. And for final authentication the template matching is carried out on Field Programmable Gate Array (FPGA) for fast recognition. The system is prototyped on Papilio one 500k FPGA board which has Xilinx Spartan 3E chip inside. The performance of the proposed system is evaluated by the time required to verify one input finger vein sample and Precision.

Keywords— Biometric, finger vein recognition, feature extraction, FPGA, Papilio one, MATLAB, Precision

INTRODUCTION

The personal information can be protected in the form of biometrics. The traditional authentication systems like identity card or password can be easily stolen or acquired by unauthorized person [1]. All these traditional authentication systems are gradually replaced by biometric systems like fingerprints, iris recognition, palm print and veins. The biometric authentication system is chosen over conventional authentication system because of their distinctiveness and highly secured nature.

Out of these biometric systems, finger vein biometric is one of the emerging techniques. In this type of biometric system the vascular pattern under one's skin is utilized as a unique feature for authentication. Veins are hidden underneath the skin surface and are mostly invisible to human eye, they are not prone to external distortion and also the vein patterns are much harder to replicate as compared to other biometric traits. Vein patterns are unique for each individual and are stable over a long period of time. Because of its uniqueness, stability and high resistance to criminal attacks, vein pattern is more reliable biological feature for a secure biometric authentication system [5][2].

The Biometric system is often implemented in an untrusted environment that uses an insecure and non-reliable central server for the storage of the biometric templates [9]. This can be the source of biometric information leakage. The solution to this problems is given by recent development in vein authentication by hardware implementation of the system [12][7][11][18]. It provides secure information storage and tamper resistance, hence it provides the protection from physical and software attacks.The finger-vein biometric system for personal authentication is promising in security and convenience point of view. The comparison between different biometric systems is as shown in Table 1 [4], I=insufficient, N=normal, G=good.

Table 1 Comparison of Major Biometrics Method

Bio-metric	Anti-forgery	Accuracy	Speed	Enrolment rate	Resistance	cost
Finger print	I	N	N	I	I	G
Iris	N	G	N	N	I	I
Face	N	I	N	N	G	I
Voice	N	I	N	N	G	N
Vein	G	G	G	N	N	N

This paper presents preliminary requirement for the implementation of finger vein recognition system on FPGA. It includes image preprocessing and feature extraction processes on finger vein images in MATLAB which is required for developing Biometric recognition system on FPGA. According to best of our knowledge the implementation of the entire preprocessing module, feature extraction and matching on FPGA is very challenging and also it will be very time consuming process. The solution to this is proposed in this work by performing all preprocessing task and feature extraction in MATLAB and final template matching in FPGA. By doing this the speed of authentication is quite good. Also the system is cost effective.

RELATED WORK

A lot of work has been carried out in this field of biometric using finger veins for authentication and also for variety of applications on different platforms. In this section review of some prior work on finger vein biometric security system is discussed.

David Mulyono et al. in [2] introduced a preliminary process to enhance the image quality that worsen by the light effect and some noise produced by the web camera while acquisition, then vein pattern segmentation by adaptive thresholding and matched using improved template matching algorithm. The final result shows that by applying some appropriate process the vein image with not that much good quality can be used for personal identification as long as the veins are clear.

In [16] D. Wang et al. and M. Subramani et al. in [4] presented highly secured and reliable user identification mechanism using vein biometric technology for consumer electronics devices. Radon transforms and singular value decomposition method is used for feature extraction process and classification using a normalized distance measure.

N. Mahri et al. in [17] presented an algorithm for vein recognition with less complexity in the image preprocessing phase, where vein pattern extraction is not included in the authentication process. Phase only correlation is applied at the matching stage. In this technique, matching is by using phase component of 2D-DFT of an image. This technique is reliable, robust and doing less job in pattern extraction.

V. Ramya et al. in [8] introduced a novel design for personal authentication and for vehicle security using finger vein recognition system. Wavelet transform is used for feature point extraction using HAAR mother wavelet. The attracting feature of HAAR transform includes fast implementation and able to analyze the local features. The authors have presented hardware implementation of finger vein recognition system for vehicle security application, a vehicle set up consist of embedded main board module which has AT89C51 microcontroller and communication module consisting of LCD display, alarm and GSM. Purpose of this module is to alert the authorized vehicle user.

Zhi Liu et al. in [12] proposed a real-time embedded finger vein recognition system for authentication on mobile devices. The system is implemented on a DSP platform. The results proved that the system has low computational complexity and low power consumption, thus qualified for authentication on mobile devices.

M. Khalil-Hani et al. in [18] proposed an embedded system implementation of finger vein biometric on FPGA. The system is prototyped on Altera Stratix-II FPGA hardware board with Nios2-Linux operating system running at 100 MHz. In this authentication system, feature extraction is based on minutiae extracted from vein pattern images while biometric matching is based on modified Hausdorff distance technique. The system gives high performance and optimum accuracy by an embedded system implementation on FPGA.

From the prior literature it is observed that the hardware based approach is cost effective and gives high performance. Also such systems can be used for variety of applications.

OVERVIEW OF THE SYSTEM

The proposed system consists of three modules: Image acquisition module, human communication module (PC) and FPGA board. The figure 1 shows the functional block diagram of the proposed work. The image acquisition module is used to collect the finger vein images for processing. The human communication module (PC) is used to perform basic image processing algorithms like RGB to gray scaling, edge detection and also feature extraction process in MATLAB. This preprocessing is required to prepare finger vein images for further processing. This human communication module (PC) is used to display the recognition results and also to receive inputs from image acquisition module. After pre-processing and feature extraction processes, the template matching is done on FPGA for final authentication.

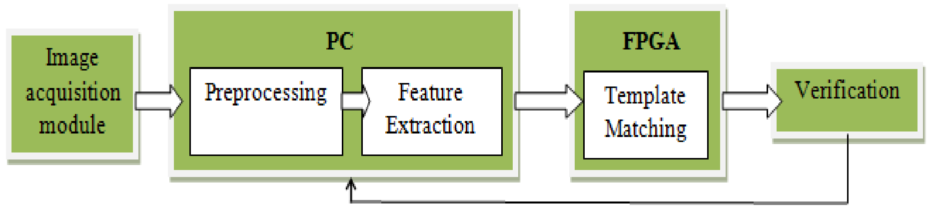

Figure 1 Functional block diagram of proposed work

The proposed finger vein recognition system consists of two stages: enrollment stage and verification stage[12]. The enrollment stage starts with pre-processing of the input finger vein images. For the verification stage after pre-processing and feature extraction process feature templates are generated. The input finger-vein image is matched with the corresponding template after its features are extracted and authentication is done for genuine or imposter user. Figure 2 shows the flowchart of the proposed system.

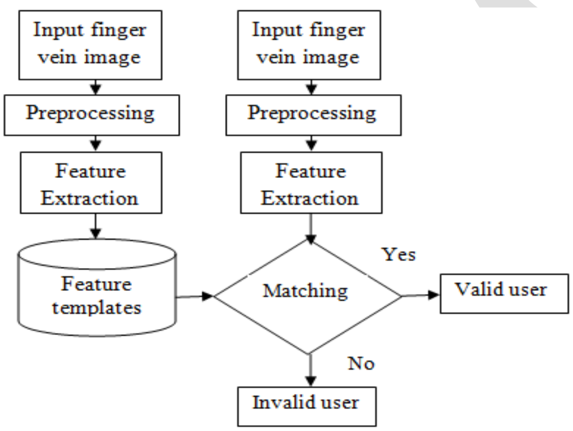

Figure 2 Flowchart of finger-vein authentication system

METHODOLOGY

In this section the step by step description for finger vein authentication is discussed, which includes image acquisition of finger vein image, different preprocessing techniques on vein image, feature extraction and matching process for final authentication.

A) Image acquisition

Image acquisition is of two types off-line and online. On-line images are the images which are taken in real time and off-line images means the images which are taken from already created database. The images in real time can be obtained by normal web camera or by designing a finger-vein imaging device based on light transmission for more distinct imaging.

In the proposed work the off-line finger vein images are used for human identification. Figure 3 shows some images from the used database.

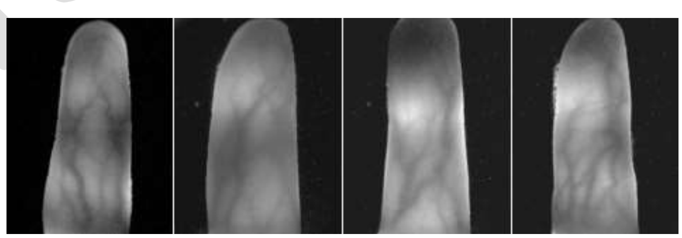

Figure 3 Database images

B) Pre-processing

In image-based biometric systems like finger vein system, a number of pre-processing tasks are required prior to enhance the image quality, some of these tasks are contrast, brightness, edge information, noise removal, sharpen image, etc., furthermore, to produce a better quality of image that will be used for later stage as an input image and assuring that more relevant information can be detected for authentication. A finger vein based authentication system mainly consists of following pre-processing stages and they are RGB to grayscale conversion, Gaussian blurring and edge detection.

In RGB to grayscale conversion color image is converted into grayscale. In the grayscale digital image the value of each pixel is a single sample means it carries only intensity information. Images of this sort are known as black-and-white, which are composed of shades of gray, varying from black at the weakest intensity to white at the strongest.

The formula for RGB to grayscale conversion is as stated below:

$$GRAY = 0.299*r + 0.587*g + 0.114*b \qquad (1)$$

The unwanted noise in the finger vein image is removed using Gaussian blur [4][8]. This blurring is also called smoothing. In this process blurring of an image is carried out by using Gaussian function typically to reduce image noise and image detail. As we are performing all the preprocessing operations in MATLAB, so this smoothing of an image is performed by calling *fspecial* function. This function has two argument *hsize* and *sigma*, where *hsize* specifies the number of rows or columns in the function means it gives size of the filter and *sigma* is a standard deviation of the Gaussian with units in pixels. The size of the *hsize* and *sigma* depends upon how much we want to smooth it. In the proposed work the size of these two arguments are taken as [5 5] and 2 respectively.

After this noise removal, the edges are detected by using canny operator in MATLAB. A canny operator with locally adaptive threshold is used to get the single pixel edge of the finger.

C) Feature Extraction

Feature extraction is most important step in this authentication process. It is a special form of dimensionality reduction. It is a transformation of input data into the set of features. In the proposed work for this feature extraction process the canny edge detection method is used for feature extraction process. Extraction of features such as edges and curves from an image is useful for final authentication. Edges are important features in an image, they represents significant local intensity changes.

An image is viewed as a function. For a given pixel values *i, j*; we have an intensity I (*i*,*j*). While extracting features there may be chance that operator will return non-zero values in regions where there is no edge. So, thresholding can be used which minimizes false positives and only pick local maxima. Final edges are determined by suppressing all edges that are not connected to a very strong edge. After this feature extraction process, the template database is generated which is used for final authentication in matching process. The canny edge detection algorithm used for this process runs in following steps as shown in figure 4 and figure 5 shows the result of extracted features from the finger vein image.

Figure 4 canny edge detection algorithm

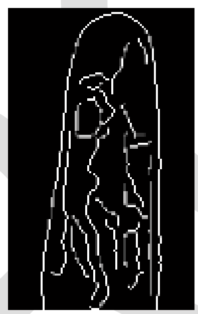

Figure 5 Feature extraction

D) Matching

After features are extracted from the vein image the matching stage measures the similarity or dissimilarity between the input finger vein image features and the previously enrolled ones in the database. Template matching is performed on FPGA, where input image and the image in the database which is generated after extracting features are compared. A standard threshold value is set for authentication purpose. During this template matching process, the error sum is generated. When this error sum is above the threshold value then the message will be displayed that the user is invalid; and if this error sum is less than threshold value then it is a valid user. In this way authentication takes place. Figure 5 shows the authentication of a valid user. Similarly, the result for invalid user will be generated with generation of error rate during template matching. This final authentication will be displayed on PC in MATLAB GUI.

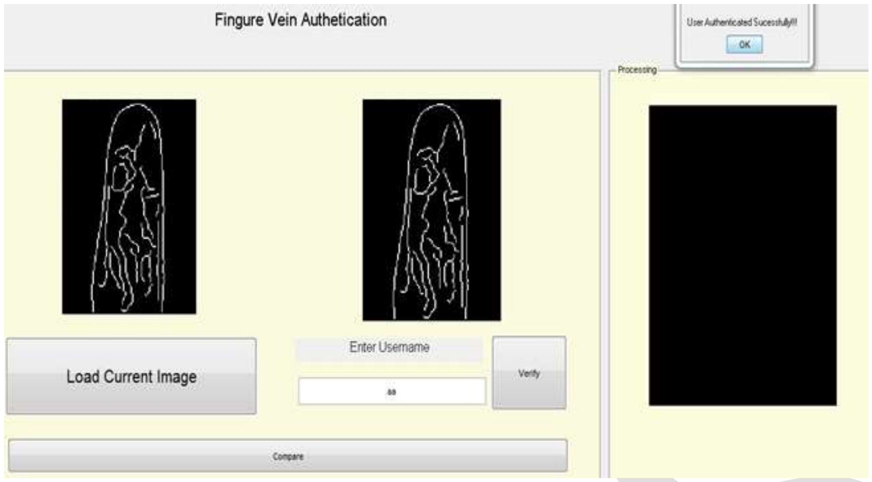

Figure 5 Authentication for valid user

RESULTS AND DISCUSSION

The performance metric used for the final authentication process is precision. Precision is a measure of exactness or quality. It is a probability that a randomly selected data is relevant. It is given by the equation as below

Precision= no. of correctly identified images/ total no. of correct images (2)

In the proposed work, total no of images taken are 20, out of which 16 users have enrolled in database. Out of these 16, 14 users are correctly identified and 2 are not may be because of some noise present in the image. For classification task, the terms True Positives (TP) and False Positives (FP) are the two outcomes which are considered.

Table 2 For classification task

	Identified	Not identified
Correct(relevant)	14 (TP)	2 (FP)

From the above table, the precision is calculated as shown below.

Precision= TP/ TP+FP= 14/ 14+2= 14/ 16= 0.875 (3)

From this analysis, it is observed that the precision of the template matching stage for the proposed system is calculated about 87.5% is. Also the platform used for template matching stage is papilio one 500k FPGA board which is very easy for implementing the logic for different algorithms according to the users interest and it is a very cost effective solution. Because of this the overall cost of the system is reduced.

CONCLUSION

In this paper, the hardware based approach for personal authentication is given based on finger vein patterns. The algorithms required for authentication are discussed in detail. These processes are required to prepare image for further processing and perform final authentication on FPGA. This authentication process uses predefined vein images from the database. This hardware system of finger vein authentication system on FPGA can be used for variety of application. The results for feature extraction and matching process are also discussed. From the analysis, it is observed that the recognition time means the time taken to match one sample of finger vein is about 41 seconds.

Also for performance evaluation of the proposed system, precision is one of the parameter considered. Precision is a probability that randomly selected input images are matched perfectly. For the proposed system the precision we get is about 87.5%.

The performance of the system can be improved by designing imaging device to acquire high quality finger vein images.

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