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RESEARCH ARTICLE

Biometric authentication using fingerprint

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Abstract

Fingerprint identification is one of the most important approaches for identification. Fingerprint identification has been publicized because of its consistency and uniqueness over the period of time. Biometric identification process has gained popularity with the recent advancement of computing capability. The uniqueness of the fingerprint and the processing power has gained popularity in various walks of our life for the purpose of authentication and verification. This study describes a fingerprint identification system and its implementation to establish the identity of a person. The approach presented herein matches the fingerprint on two parameter minutia and furrows.

Keywords: Fingerprint recognition, minutia, binarization, matching score, segmentation.

Introduction

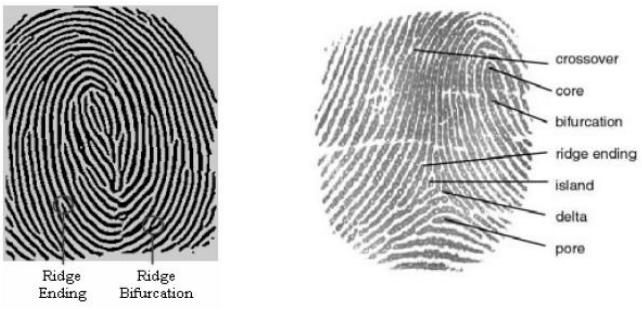
There are many classical ways to identify a person's authentication such as password, identity card, etc. but nowadays, the popular approach is Biometric which is used to authenticate a person. In this approach, we use different identification approaches such as face recognition, voice recognition, fingerprint recognition and retina recognition etc. So that, there is no need to carry an Identity card or to remember password. The most important thing is that it cannot be shared or misplaced. This approach can be used in the field of uniqueness, universality, acceptability, performance etc (Takita *et al.,* 2003). The technique used in biometric system has been broadly classified into two major areas namely behavioral and psychological biometric. Behavioral biometric has certain parameters such as signature, speech etc. but these parameters change with time and environment. Whereas the physiological characteristics such as palm print, face recognition, and fingerprint remain unchanged throughout the individual life span. This concept is focused around the study and implementation of a fingerprint recognition system.

Fingerprint is one of the most popular biometric methods used to verify and identify a person. Formally it is defined as "The pattern of ridges and furrows on an individual finger". Ridges are the lines in thumb and furrow is shallow trench of skin on an individual's finger. Furrow is also referred to as valley. The combination of ridges and furrows makes an individual's fingerprint. The combination of ridges and furrows that make the finger print of each person unique. The uniqueness of a fingerprint is exclusively determined by the local ridge characteristics and their relationships (Kuglin *et al*., 1975). The ridges and furrows present in the finger show good similarity in each small local windows, like parallelism and average width (Maltoni *et al*., 2003).

Fig. 1. Fingerprint image from an optical sensor.

The prominent local ridge is referred to as minutiae. This characteristic of the finger print image is used to compare an individual's finger image with the others stored finger images. Minutiae consist of ridge ending, ridge bifurcation, short ridge, or independent ridge, island, ridge enclosure, spur, crossover or bridge, delta and core. Ridge ending is the abrupt end of a ridge; a single ridge that divides into two ridges is ridge bifurcation, ridge that commences, travels a short distance and then ends is termed as short ridge, or independent ridge. Island is a single small ridge inside a short ridge, a single ridge that bifurcates and reunites shortly afterward to continue as a single ridge is called ridge enclosure. Spur is a bifurcation with a short ridge branching off a longer ridge whereas; crossover or bridge is a short ridge that runs between two parallel ridges. Y-shaped ridge meeting is known as a delta and core is a U-turn in the ridge pattern. A good quality fingerprint contains 25 to 80 minutiae depending on the sensor resolution and finger placement on the sensor. In some cases, it is difficult to extract prominent minutia, as the fingerprint impression is distorted due to various reasons like dry skin, injury, scars etc. This poor quality fingerprint image leads to false minutia. False minutia is the false positive result due to insufficient ink or due to cross connect of over-inking. A fingerprint image of an optical sensor is shown in figure 1.

Fig. 2. Main elements of a fingerprint image.



The main elements of a fingerprint image are seen in figure 2. Now with the help of fingerprint image we can recognize the image's identity. The fingerprint recognition is the process of comparing an unknown fingerprint and a known fingerprint to determine if the impression is from the same finger (Takita *et al*., 2003). The finger print recognition system can be divided into three sub-domains such as fingerprint enrollment, verification and fingerprint identification. The main goal of fingerprint verification is to verify the identity of a person. Verification is one to one matching process, while in, identification matching, a query fingerprint against a fingerprint database to establish the identity of an individual is used. Identification is one to many matching process. The principle of well defined representation of a fingerprint and matching remains the same. Fig. 3a and b shows the identification and verification.

Fig. 3a. Identification.

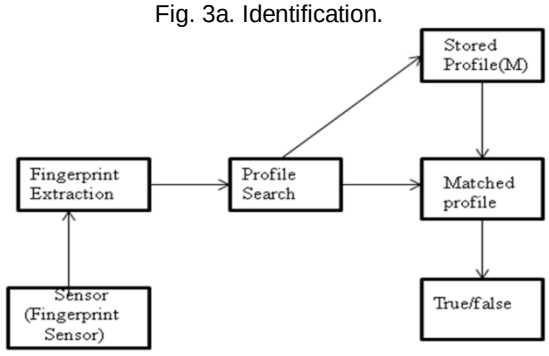
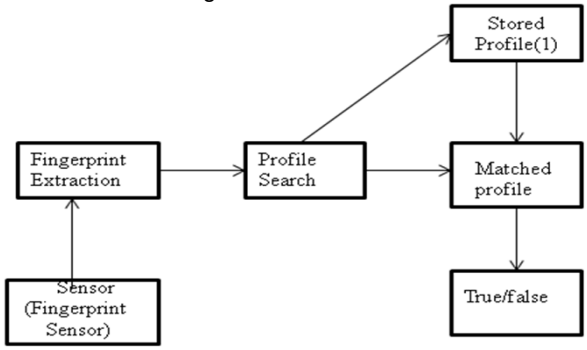


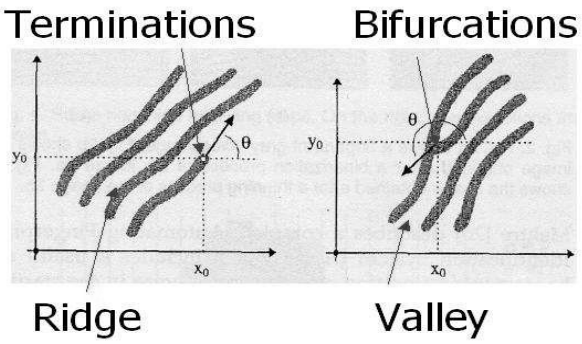
Fig. 3b. Verification.



Materials and methods

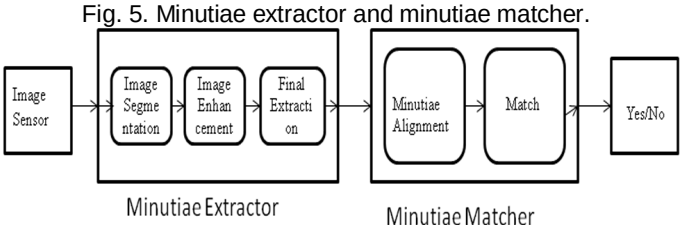
Implementation: There are three approaches to implement the fingerprint recognition system correlation base matching, minutiae base matching, and pattern based matching. In this study, we have implemented minutiae-based method. For implementing this, we concentrated only in two of the most important minutiae features Ridge ending and Ridge bifurcation as shown in figure 4.

Fig. 4. Minutia (valley is also referred as furrow; termination is also called ending and bifurcation is also known as branch).



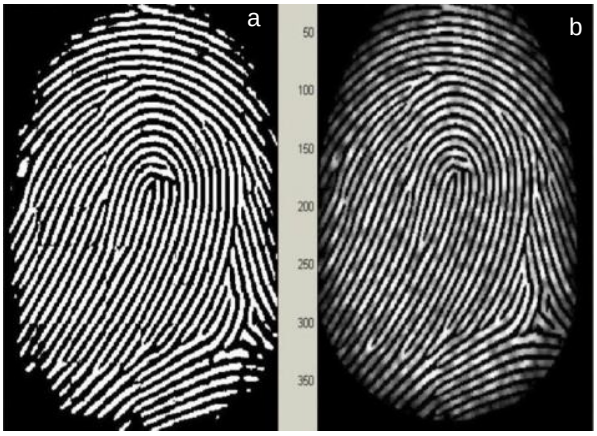
System architecture: Fingerprint recognition system mainly works on two stages minutiae extraction and minutiae matching (Fig. 5). In this approach, system takes two input fingerprints to be matched and it gives the percentage of matching between two images. As we can see in figure 5, the minutiae extractor can be further classified into three sub-modules such as image segmentation, image enhancement and final extraction. In figure 5, minutiae matcher can also be further classified into two sub-modules such as minutiae alignment and match. Image segmentation and image enhancement are further sub-divided in image binarization, histogram equalization and fast Fourier transformation (Jain *et al*., 1993). Further image enhancement uses the approach of Binarization so that image can be sharp.

Fig. 5. Minutiae extractor and minutiae matcher.



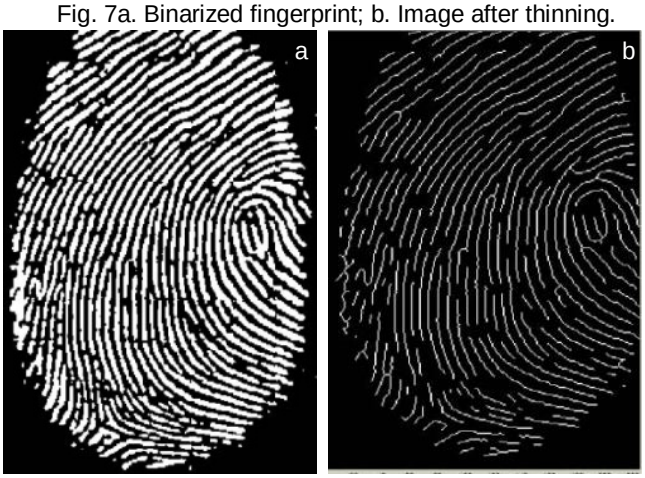
Binarization: System uses this technique to convert gray scale image into binary image by fixing the threshold value. The pixel values above and below the threshold are set to '1' and '0' respectively. We can see an original image and the image after binarization in figure 6a and b respectively. As we see with the help of binarization image get improved and now with the help of block filter we can increase the readability of ridges.

Fig. 6a. Image after binarization; b. Image before binarization.



Block filter: The image after binarization is sharp using block filter to reduce the thickness of all ridge lines to a single pixel both width to extract minutiae points effectively. It uses thinning that does not change the location and orientation of minutiae points compared to original fingerprint which ensures estimation of minutiae points. Thining preserves outermost pixels by placing white pixels at the boundary of the image; as a result first five and last five columns are assigned value of one. A binarized fingerprint and the image after thinning are shown in figure 7a and b.

Fig. 7a. Binarized fingerprint; b. Image after thinning.



Minutiae extraction: The minutiae location and the minutiae angles are derived after minutiae extraction. The terminations which lie at the outer boundaries are not considered as minutiae points. Crossing number is used to locate the minutiae points in fingerprint image. Crossing number is defined as half of the sum of differences between intensity values of two adjacent pixels. If crossing number is 1, 2 and 3 or greater than 3 then minutiae points are classified as termination, normal ridge and bifurcation respectively. We can see all these points in figure 8. Figure 9 shows the original image and the extracted minutiae points. Square shape shows the position of termination and diamond shape shows the position of bifurcation as in figure 9a and b.

Fig. 8. Crossing number and type of minutiae.

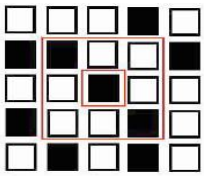
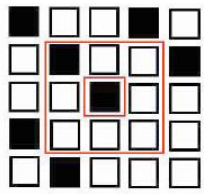
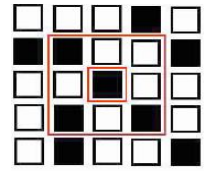
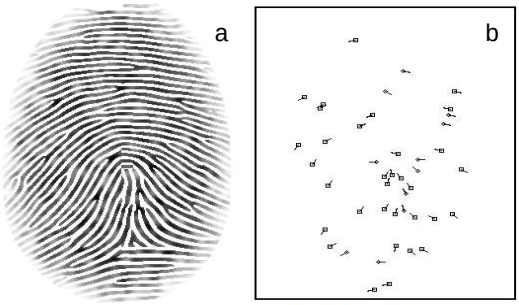
	Crossing number = 2. Normal ridge pixel.
	Crossing number = 1. Termination point.
	Crossing number = 3. Bifurcation point.

Fig. 9a. Gray scale fingerprint; b. Minutiae points.



Minutiae matching: In this process, the input image data is compared with already stored template database for exact matching. The extracted data from template and input image is stored in matrix format like this (Jain *et al*., 2000).

$$\begin{pmatrix} \text{No of minutiae point} \end{pmatrix} = \begin{pmatrix} \text{Row index of } k^{th}\text{'s minutiae point (r)} & \text{Column index of } k^{th}\text{'s minutiae point(c)} & \text{Orientation angle of each minutiae point} & \text{Type of minutiae} \end{pmatrix}$$

After this, for each minutia point of template data minutiae and input data minutiae was taken as reference point for their corresponding data sets. These data are used to convert into polar co-ordinates like this.

$$\begin{pmatrix} \rho_k^t \\ \varphi_k^t \\ \theta_k^t \end{pmatrix} = \begin{pmatrix} \sqrt{(r_k^t - r_o^t)^2 + (c_k^t - c_o^t)^2} \\ \tan^{-1}\left((r_k^t - r_o^t)/(c_k^t - c_o^t)\right) \\ \theta_k^t - \theta_o^t \end{pmatrix}$$

ρ_k^t = radial distance of k^{th} minutiae
φ_k^t = radial angle of k^{th} minutiae
θ_k^t = orientation angle of k^{th} minutiae
r_o^t = row index of reference points currently being considered
c_o^t= column index of reference points currently being considered
r_k^t = row index of k^{th} points currently being considered
c_k^t= column index of k^{th} points currently being considered

Similarly, input data matrix points are converted into polar coordinates using above mention equation by replacing k by m and t (template data) by i (input data) respectively.

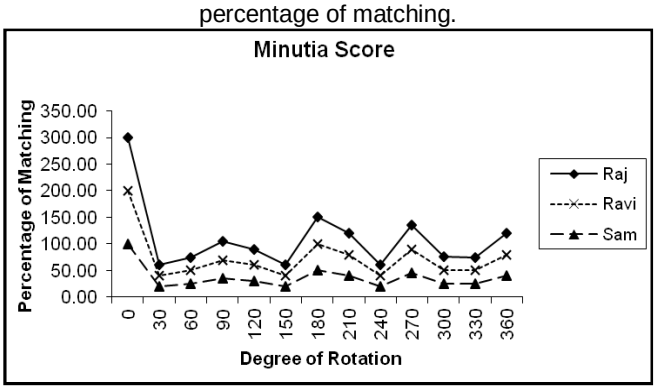
Results and discussion

Experiment was conducted on windows XP machine with 4 GB RAM and 3 GHz processor and Mat LAB version R2010b. For the experimental result, we choose three person's fingerprint images. After that, we calculate minutiae score percentage at different angle of rotation of fingerprint image (Hastings *et al*., 1992). This process is applied to all the test member fingerprint images. The angle of rotation and their respective score is shown in Table 1.

Table 1. The angle of rotation and corresponding minutiae. Experimental result and analysis.

Rotation angle/ image name	Minutiae score result		
	Sam.tif	Ravi.tif	Raj.tif
0	100.00	100.00	100.00
30	20.00	20.20	19.99
60	24.98	24.89	25.10
90	35.00	35.00	35.00
120	30.01	30.00	30.35
150	20.21	19.85	20.21
180	50.00	50.11	50.55
210	39.99	40.00	40.00
240	20.19	20.20	20.34
270	45.00	45.00	45.00
300	25.00	25.23	25.69
330	25.11	25.00	24.82
360	39.98	39.96	40.11

Fig. 10. Minutiae score, degree of rotation Vs percentage of matching.



A graph is plotted, as shown in figure 10. The minutiae percentage score Vs degree of rotation. From the graph, it can be seen that with the small variation in the degree of rotation of the fingerprint image, there is spurious change in minutiae percentage score. The minutiae score does not vary much with the change in the degree of rotation of fingerprint image of different person thus we can say that proposed system performs fairly well. This is due to the variation of pixel point from one image to another image angle of variation.

Conclusion

In this study, the given implementation was an effort to understand how fingerprint recognition is used as a form of biometric to recognize identities of human beings. It includes all the stages like (image enhancement, histogram equalization, FFT, image segmentation image binarization, block direction estimation ROI extraction, final minutiae extraction, minutiae alignment, minutiae match) from minutiae extraction from fingerprints to minutiae matching which generates a match values. There are many techniques which are used in the intermediate stages of processing. It has relatively low percentage of verification rate as compared to other forms of biometric identification indicates that the algorithm used is not very robust and is vulnerable to effects like scaling and elastic deformations. Various new techniques and algorithm have been found out which give better results. Also a major challenge in fingerprint recognition lies in the pre processing of the bad quality of fingerprint images which also add to the low percentage of verification.

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