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ENHANCED FILTERBANK ESTIMATION TO FINGERPRINT MATCHING

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ABSTRACT

Directional Gabor filter bank, a popular method for enhancing poor quality image is also used to capture global and local information available in the fingerprints. An improved region of interest has been experimented for feature vector compaction. Here, feature vectors are extracted from the directional representation of enhanced image. Matching is extremely fast as it computes only Euclidian difference between feature vectors to compute matching score. Feature vector requires less memory as compared to conventional minutiae based approach as it stores 64 intensity values only. This filter-bank approach has been tested on 880 images of DB1_a and DB1_b of FVC 2002. Here, Identification success rate accomplished 79.3%.

KEYWORDS: Filterbank, Fingerprint, Minutiae, Feature Vector, Gabor, Matching

INTRODUCTION

Fingerprints have been used as a means of personal identification for over a century. Traditionally, the driving force behind advancements in fingerprint technology has been law enforcement agencies and forensic scientists. Using fingerprints lifted at a crime scene to identify suspects can be a crucial step during a criminal investigation. Consequently, massive fingerprint databases have been collected by law enforcement agencies around the world. Fingerprint is the pattern of ridges and valleys on the surface of the finger [1]. Fingerprint matching is an essential technique for personal identification, the main reason for this is that every person is believed to have distinct fingerprints[2]. Presently, several organisations are using fingerprints not for only criminal investigation but also for many other civil and security applications. Fingerprints are one of the most popular biometrics techniques in both of verification and identification modes[3]. Matching of fingerprints depends mainly on features of fingerprint called minutiae. Most of the fingerprint matching techniques are based on traditional minutiae matching. But here filter bank based approach is adopted which is a new technology for fingerprint matching as compared to its minutiae, ridge and correlation based counterparts.

PROPOSED SYSTEM ARCHITECTURE

The steps of feature extraction from a fingerprint image are shown in Figure 1. Determination of the location of a reference point in the fingerprint image is the first step of feature extraction. To locate the reference point, core or delta detection equations[4] are used. Reference point of a fingerprint is determined as the point of maximum curvature of the concave ridges in the fingerprint image. Figure 2 shows the estimated reference point in a fingerprint image. The circle concentric on the reference point refers to the region of tolerance. Since fingerprints often suffer from deformation, therefore, a tolerance region is needed around the reference point location. The radius can be set as per deformation of the fingertip during image acquisition but a moderate value is needed here to ensure information loss as less as possible.

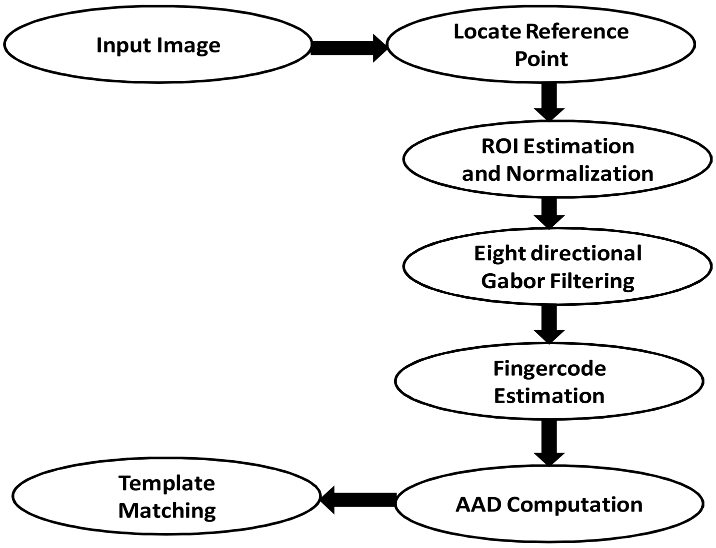

Figure 1: Proposed System Workflow

Figure 2 : Reference Point Detection

SYSTEM OVERVIEW AND METHODOLOGIES

To locate the position of region of interest, a square shape is assumed concentric on the reference point. The region is divided into 8 parts; centred on the reference point. Figure 3 depicts the estimated region of interest. A special thing to be noted, that the innermost circle shown in Figure 3 is not used for feature extraction. Actually the innermost circle is avoided to handle slight deformation of the reference point in the image. Here, the square region has been divided into eight regions. As shown in the Figure 3, each section correspondents to 45 degree of a total of 360 degree region. For any pixels F(x,y) in the image, it belongs to region of interest in section S_i if and only if

$$S_i = \{(x, y) : dist\{(x, y), R_{x,y}\} <= S_{\max} \tag{1}$$

Where, dist is the Euclidean distance, $R_{x,y}$ shows the reference point and S_{max} is the maximum distance of S_i's boundary point to $R_{x,y}$.

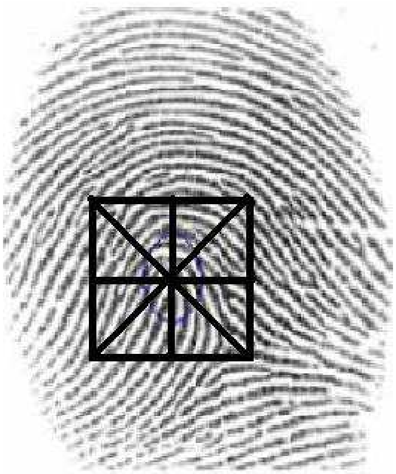

Figure 3 : Region of Interest

Since we have chosen to divide the square region into 8 parts, so $1 <= i <= 8$ and the angle, θ_i range for each section, i is defined as

$$P = \frac{2\pi}{d} \tag{2}$$

$$\theta_i = \{ P X I, P X (i+1) \} \tag{3}$$

Where, d is the number of sections and here it is 8. The region of interest is normalized using the equation as follows:

$$\begin{aligned} N_i(x,y) &= \{M_0 + \sqrt{\frac{V_0 X (I(x,y) - M_i)^2}{V_i}}, if\, I(x,y) > M \\ N_i(x,y) &= \{M_0 - \sqrt{\frac{V_0 X (I(x,y) - M_i)^2}{V_i}}, otherwise \end{aligned} \tag{4}$$

Where, I(x,y) denotes the gray value at pixel (x,y) , M_i and V_i are the estimated mean and variance of i'th sector, S_i , respectively. Normalized gray-level value at pixel(x,y) is denoted by N_i(x,y).

To extract the feature, we use the well known 8 directional Gabor filter bank. The configurations of parallel ridges and valleys with well defined frequency and orientation in a fingerprint image provide useful information to removing undesired noise. Base of the Gabor filtering is that sinusoidal-shaped waves of ridges and valleys vary slowly in a local constant orientation and a band-pass filter that is tuned to the corresponding frequency and orientation can efficiently remove the undesired noise and preserve the true ridge and valley structures. Gabor filters have both frequency-selective and orientation-selective properties and useful in both spatial and frequency domains. Gabor filtering in spatial domain is defined by the equation (5), (6) and (7) below.

$$G(x, y, f, \theta) = \exp\{-\frac{1}{2}[\frac{{x_1}^2}{\delta x^2} + \frac{{y_1}^2}{\delta y^2}]\} \tag{5}$$

$$x_1 = x \sin\theta - y \cos\theta \tag{6}$$

$$y_1 = x \cos\theta - y \sin\theta \tag{7}$$

This region of interest is filtered in eight different directions using a bank of Gabor filters (directions ranges from 0^0 to 180^0, 22.5^0 apart). Eight directions [0^0, 22.5^0, 45^0, 67.5^0, 90^0, 112.5^0, 135^0, 157.5^0] are required to completely capture the local ridge characteristics in a fingerprint while only four directions are enough to capture the global configuration in the fingerprint image[4]. To handle rotation partially, the original image is rotated by 90 degree and again the eight directional filter-bank is used the capture the local and global feature of the fingerprint image.

To extract feature (fingercode here), Average Absolute Deviation (AAD) is calculated from the mean (AAD) of gray values in individual sectors in filtered images. Feature vector or FingerCode is calculated as

$$V_{i\theta} = \frac{1}{N_i}\{\sum_{N_i} abs(F_{i\theta}(x,y) - P_{i\theta})\} \tag{8}$$

Where $F_{i\theta}$ is the θ direction filtered image for section, S_i, N_i is the number of pixels in S_i. So, now for a fingerprint image we have 4 feature vectors set where each vector consists of 8 AAD feature values as in equation (8) and each feature set is 90 degree apart from the next sequential feature set.

Fingerprint matching is based on the Euclidean distance between the corresponding FingerCode features. Feature of the input image is extracted and they are matched with registered template finger code just by calculating difference between them. Let, a feature vector consists of a value set (x1,x2,x3,…..,xn) and another consists of (y1,y2,y3,…..,yn). The matching score is given by.

$$\sqrt{(x1-y1)^2+(x2-y2)^2+(x3-y3)^2+............+(xn-yn)^2} \tag{9}$$

The final matching distance score is taken as the minimum of all matching scores among difference between input and template feature vectors. However, minimum score corresponds to the best alignment of the two fingerprints being matched.

RESULTS AND DISCUSSIONS

For our experiments, we have chosen two thresholds for a comparison study between precision and accuracy rate of the algorithm where threshold 1 < threshold 2. Effect of choosing threshold value can be observed from the precision and accuracy graph of Figure 4 and 5. Here test database consists of images of 15 persons, 8 images/person and fingerprint recognition system is trained with 2 images of 15 persons each.

From the Figure 5 and 6, we get best accuracy and precision rates 100 and 100, for the threshold1 and threshold 2, respectively. Worst cases of precision rates are 100 and 66.67, for the threshold1 and threshold 2, respectively. Worst case of accuracy rates are 37.5 and 37.5, for threshold 1 and 2 respectively. Here, precision rate is high due to threshold strictness as false acceptance decreases. But accuracy rate falls down due to the same reason of threshold as number of unknowns and false rejection increases with threshold strictness. For studying performance in a wider environment, we have trained the system with images of 100 persons, 2 images per person; system is trained with total 220 images and test database consists of 880 images of 110 persons (8 images per person). For 880 images, result is shown in table 1. We have chosen threshold value by observing the matching difference score between different images. We have chosen number of rotated image bands in the region of interest as 4 (90 degree apart from each other).

Table 1: Experimental Result on DB1_a and DB1_b of FVC 2002

Success Rate	Unknown	FR	FA
698(79.3%)	47(5.34%)	1(0.113%)	134(15.23%)

*Percentage on total images

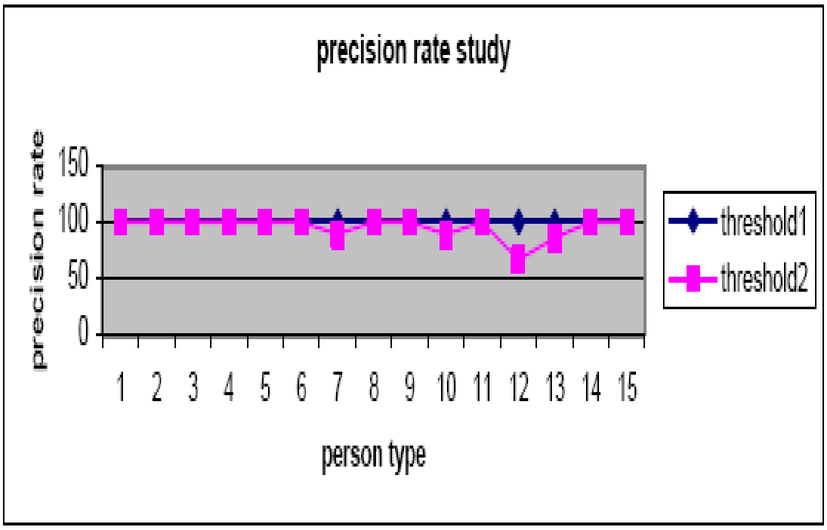

Figure 4 : Precision Rate Study

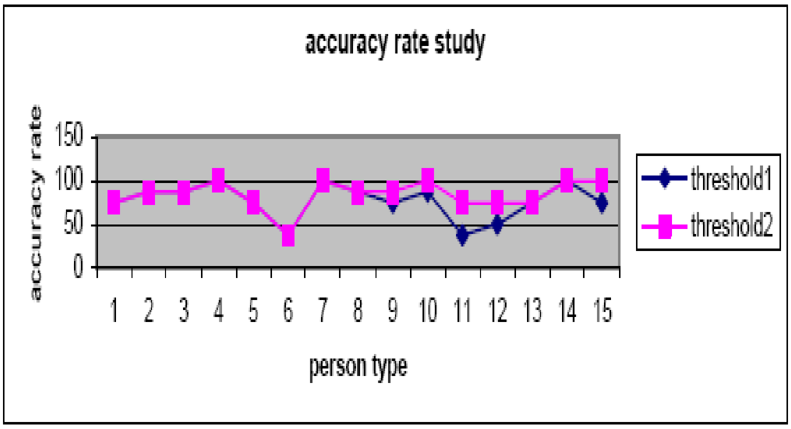

Figure 5: Accuracy Rate Study

The primary focus was to implement an automated fingerprint recognition software which is fast and memory efficient, a main requirement of small scale systems.. For FVC 2002 DB1_a and DB1_b database, image resolution is given as (388 X 374) but with the procedure proposed here, each image is stored only with 64 intensity values only. Thus it's memory efficiency is better as compared to Gabor filter bank based matching[4]. Among different methodologies of fingerprint matching, the correlation-based fingerprint verification method needs template matching which demands a rather high computational power, which makes the method less applicable for real time applications. But the proposed system does the faster template matching using Euclidean distance of intensity values only which can be implemented easily for small scale recognition system. Though the correlation method works well while image quality is low, but the proposed method works well for poor images too as 8 directional Gabor filter bank is used to capture local and global information available in the image.

Again, another approach, minutiae-based fingerprint verification systems first extract the minutiae from the fingerprint images. Then, the decision is based on the correspondence of the two sets of minutiae locations. Minutiae-based fingerprint verification systems use a large number of successive processing steps. In general, the steps it follows are, directional information estimation, adaptive filtering for noise reduction, thresholding to obtain a binary fingerprint map, morphological operations like thinning to obtain ridges that are only one pixel wide, minutiae extraction from the thinned image, application of heuristics to reduce the number of false minutiae and matching. Matching score computation is usually done by computing the positional distance between the alignments of template images. The main drawback of the minutiae-based approach is the error propagation from the minutiae extraction to the decision stage. In general, the extracted minutiae templates contain a number of false minutiae, while also some minutiae will be missed. This is especially the case when using bad-quality fingerprints. The heuristics do not catch all spurious minutiae, while they might reject some of the genuine minutiae. Moreover, in minutia based system, each feature vector for a fingerprint image consists of minimum 40 to 80 minutiae features where each minutiae requires directional and location information to be stored at it's minimum. In compare to this, our filter bank system proposes less steps, feature vectors from the proposed system are extremely small and matching is computing Euclidean distance only. The system can be easily implemented using less hardware requirements and low memory specification. Thus it can be a framework to the small scale systems easily.

Figure 6: (a)-(d) Fingerprint Images of a Person with Successful Reference Point Detection. (b) Fails to Detect

CONCLUSIONS

Due to compaction, information loss occurs here and that may result to increasing number of unknowns. That's why I have proposed it to use for medium and small scale systems, especially. If two fingerprints belong to same classes, possibility of false acceptance increases as reference point is chosen according to point of maximum curvature and only a fixed region is used for comparison. It also confirms that this method captures global information. So, it can be useful for indexing. If the image quality is very poor, location detection of reference point can't be determined accurately (Figure 6). This technology uses computationally expensive Gabor filter technique and 99% [4] of the total verification time is taken in order to accomplish the task of filtering image in eight direction. Future works will be dedicated to overcome the limitations as stated before. One of them is to focus on feature extraction based on orientation information from image data and to obtain features that are rotation independent and accurate detection of reference point in noisy images is also a special concern. Filter-bank approach is just a novice as compared to it's minutiae, ridge and correlation based counterparts but further research will be conducted to overcome limitations of this method.

REFERENCES

1. H. C. Lee & R.E. Gaensslen, Eds, (1991), "Advances in Fingerprint Technology", New York, Elsevier.
2. K. Jain, R.M. Bolle and S. Pankanti, Eds., (1999) "Biometrics: Personal Identification is a Networked Society", Norwell, MA:Kluwer.
3. K. A .Nagaty, (2001) "Fingerprints Classification Using Artificial Neural Networks: A Combined Structural and Statistical Approach", Neural Networks, vol.14, pp. 1293-1305.
4. Anil K. Jain, *Fellow*, *IEEE*, Salil Prabhakar, Lin Hong, and Sharath Pankanti, (2000),"Filterbank-Based Fingerprint Matching" ieee transactions on image processing, vol. 9, no. 5, May.
5. D. Maltoni, D. Maio, A. K. Jain, and S. Prabhakar, (2002), "Handbook of fingerprint recognition": Springer Verlag.
6. L. Hong, AK Jain, S Pankanti, and R Bolle, (1996),"Fingerprint Enhancement," Proc. IEEE Workshop on Applications of Computer Vision, Sanratosa, FL, pp. 202-207.
7. L. Hong, Y. Wan, and A. K. Jain, (1998) "Fingerprint image enhancement: algorithms and performance evaluation", IEEE Trans. Pattern Anal. Machine Intell., vol. 20, no. 8, pp. 777-789.
8. Jianwei Yang, Lifeng Liu, Tianzi Jiang *, Yong Fan,(2003), "A modified Gabor filter design method for fingerprint image enhancement ".
9. A.K. Jain and F. Farrokhnia, (1991), "Unsupervised Texture Segmentation Using Gabor Filters," Pattern Recognition, vol. 24, no. 12, pp. 1,167-1, 186.
10. L. Hong, AK Jain, S Pankanti, and R Bolle, (1996), "Fingerprint Enhancement," Proc. IEEE Workshop on Applications of Computer Vision, Sanratosa, FL, pp.202-207.
11. A.K. Jain, L. Hong, and R. Bolle, (1997), "On-line fingerprint verification", IEEE Trans. Pattern Anal. Machine Intell., vol. 19, no. 4, pp. 302-314.
12. L. Hong, Y. Wan, and A. K. Jain, (1998), "Fingerprint image enhancement: algorithms and performance evaluation", IEEE Trans. Pattern Anal. Machine Intell., vol. 20, no. 8,pp.777-789.
13. X. Jiang and W. Yau ,(2000) "Fingerprint minutiae matching based on the local and global structures", in Proc. 15th ICPR, Barcelona, Spain
14. D. Maio and D. Maltoni, (1997), "Direct gray-scale minutiae detection in fingerprints," IEEE Trans. Pattern Anal. Machine Intell., vol. 19 no. 1 , pp. 27-40.
15. D. .Maltoni, D. Maio, A. K. Jain, and S. Prabhakar, (2003), "Handbook of fingerprint recognition": Springer Verlag.
16. Feng Zhao, Xiaoou Tang:,(2002), "Duality-based Post-processing for Fingerprint Minutiae Extraction02, July 10-13.

17. Xiping Luo, Jie Tian and Yan Wu AILAB, Institute of Automation, The Chinese Academy of Sciences, Beijing, 10080, (2000) “A minutiae matching algorithm in fingerprint verification”.

18. Shih-hsu chang, fang-hsuan cheng ,wen-hsing hsu and guo-zua wu, (1996) “Fast algorithm for point pattern matching: invariant to translations, rotations and scale changes”Received 12 December 1995; received for publication 1 April.

19. D.Simon-Zorita, J. Ortega-Garcia, S. Cruz-Llanas and J. Gonzalez-Rodriguez, (2001), “Minutiae Extraction Scheme For Fingerprint Recognition System”.

20. Manvjeet Kaur, Mukhwinder Singh, Akshay Girdhar, and Parvinder S. Sandhu,(2008), “ Fingerprint Verification System using Minutiae Extraction Technique” Proceedings of World Academy of Science, Engineering and Technology Volume 36.

21. R. Cappelli, D. Maio, and D. Maltoni, (2001), "Modelling plastic distortion in fingerprint images", in Proc. ICAPR2001, Rio de Janeiro.

22. N.K. Ratha and R.M. Bolle, (1998), "Effect of controlled acquisition on fingerprint matching", in Proc. 14th ICPR, Brisbane, Australia.

23. Chitra Dorai, Nalini Ratha, and Ruud Bolle,(2000), "Detecting dynamic behavior in compressed fingerprint videos: Distortion", in Proc. CVPR2000, Hilton Head, SC.

24. Chul-hyun park, joon-jae lee, mark j. T. Smith, fellow, ieee, sang-il park, and kilhoum park, (2004), “Directional filter bank-based fingerprint Feature extraction and matching ”ieee transactions on circuits and systems for video technology, vol. 14, no. 1, January.

25. Lisa Gottesfeld Brown, (1992), “A survey of image registration techniques,” *ACM Computing Surveys*, vol. 24, no. 4, pp. 325–376.

26. Paul J. Besl and Neil D. Mckay, (1992), “A method for registration of 3-D shapes,” IEEE Transactions on PAMI, vol. 14, no. 2, pp. 239–256, February.

27. R. C. Gonzales and R. E. Woods, (2002), Digital Image Processing: Prentice Hall.

28. S. Greenberg M. Aladjem, and D. Kogan, (2002), “Fingerprint image enhanced using filtering techniques”, real-time imaging pp. 227-236.

29. B. G. Sherlock D. M. Monroand K. Millard, (1994),” fingerprint enhanced by directional fourier filtering”, IEEE Proc Visual Image Signal Processing pp.87-94.