Detection of Virtual Core Point of a Fingerprint: A New Approach

Sarnali Basak, Md. Imdadul Islam, M. R. Amin

Abstract—In a fingerprint the profile of ridges are flowed by ridge orientation curves. The slope of each point of a ridge orientation curve varies with the radius of curvature of the line. The change in gradient will attain its maximum value when the curve changes its slope from positive to negative or vice versa which occurs on immediate left and right of maxima or minima point. Every ridge on a fingerprint will provide such point of maximum gradient and the mean value of those points is considered as the virtual core point. This paper presents a new model to determine the virtual core point based on changed in gradient of maxima and minima points, so that this core point is considered to be the reference point to select the region of interest (ROI) of a fingerprint for further processing. The results of the paper show that, the proposed method can provide the virtual core point from different types of fingerprint very efficiently and consequently simplifies the fingerprint recognition system.

Index Terms—Change in gradient, maxima and minima points, non-minutia and minutia based detection, ridge orientation, ROI.

I. INTRODUCTION

Biometric identification techniques are applied to identify an individual on the basis of an individual's characteristics (both physiological and behavioral). It is one of the most dependable and sensible approach to recognize an authorized person among several masquerades. The technology of biometric identification is applied in some specific regions to draw out furtive information such as face and eye structure, handwriting, signature, voice, hand and finger geometry, fingerprint as well as palm-print imaging [1].The process of identifying the human fingerprint where ridge skin layout is used is also known as dactyloscopy. Specifically, ridge and furrow patterns on the surface/tip of the finger including bifurcations, termination and valley have been applied in a comprehensive way to determine the uniqueness of fingerprint of human being. Bifurcations are identified by the branch of one ridge, termination is the endpoint of ridge and valley is the gap between two ridges. Therefore, according to the methodology of Henry Classification System [2], [3], there exist three main fingerprint textures: loop, whorl and arch. Generally, Automatic Fingerprint Identification Systems (AFIS) performs three basic steps to recognize fingerprint: pre-processing, region of interest (ROI) extraction and finally classification [4], [5].

Manuscript received on April 26, 2012.

Sarnali Basak, Department of Computer Science and Engineering, Jahangirnagar University, Dhaka, Bangladesh,
(e-mail: sarnali_basak@yahoo.com).

Md. Imdadul Islam, Department of Computer Science and Engineering, Jahangirnagar University, Dhaka, Bangladesh, (e-mail: imdad@juniv.edu).

M. R. Amin, Department of Electronics and Communications Engineering, East West University, Dhaka, Bangladesh, +880-1715296735, (e-mail: ramin@ewubd.edu).

Small and precise portions called minutiae represents those local ridge characteristics, which is also called singular points or singularities. This singular-point-based approach has minimized the tiresome job of manual classification and matching method. The success of singular point detection depends on the efficient method to localize the core point precisely as well as the accurate ROI extraction with less computational complexities. Several algorithms have been proposed to deal with the fingerprint recognition involving reference point identification. Zhang and Wang [6] propose multi-resolution direction field concept in which low resolution direction field (DF) is applied to select the ROI. Then high resolution DF applies over the localized area to search the core position. In [7], Mishra and Shandilya introduce the registration point and neighborhood averaging method where orientation mask is used to detect the fingerprint. In [8], Julasayvake and Choomchuay present direction field estimation of ridge in preprocessing and later merge the technique of detection of curvature and geometry of region respectively. Most recently, Khalil et al. [9] propose orientation reliability and perform Short Time Fourier Transform (STFT) in preprocessing steps. Fixed-length invariant moment feature is introduced by Yang and Park [10]. Most of the minutiae-based methods detect the singular points (i.e. core and delta) successfully for the competent and good quality of image, but the efficiency of algorithm degrades when the image quality is not satisfactory [6] or detecting false-candidate points [8], or cropping the ROI containing less information [11]. In general, error is decreased and the accuracy of chance to locate the core point is increased if the extracted region contains sufficient information. In this paper, we introduce the virtual core point detection algorithm using maxima and minima points of the ridge orientation curve. The paper is organized as follows: Sec. II deals with the detection technique of ridge orientation curves and algorithm in detection of virtual core point of a fingerprint, Sec. III shows the results taking four different types of fingerprint based on the analysis of section 2, and finally, Sec. IV concludes the entire analysis.

II. SYSTEM MODEL

In matching or identification of time varying signal or space varying signal like image, a reference point is essential. In this paper we use a new algorithm, using elliptic curvature of ridge [7] to detect the virtual core point of a gray scale fingerprint. Before applying the algorithm, we perform the 'gray-level normalization enhancement' of the image then compute the mean and variance at pixel-wise manner, as briefly described in [8].

*Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication*

To remove the noise introduced by the device and gray level background due to difference in finger pressure we need to normalize the fingerprint. Moreover, the normalization of images changes the mean and variance of images to specific values. The normalized image can be defined as follows [12], [13].

The normalized image can be defined as

$$N(x,y)=\begin{cases} m_0+\left\{\dfrac{v_0(\psi(x,y)-m_i)^2}{v_i}\right\}^{1/2} & ;\ \ if\psi(x,y)>m, \\ m_0-\left\{\dfrac{v_0(\psi(x,y)-m_i)^2}{v_i}\right\}^{1/2} & ;\ \ otherwise\ , \end{cases} \quad (1)$$

where, $N(x, y)$ is the normalized gray-level value at pixel (x, y), $\psi(x,y)$ is the gray-level value at pixel (x, y) of image ψ, m_i and v_i represent the estimated mean and variance respectively; m_0 and v_0 denote the desired mean and variance respectively. For $m\times n$ matrix of pixels, the mean and variance are represented respectively as

$$m(\psi)=\frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}\psi(x,y)\,, \quad (2)$$

and

$$v(\psi)=\frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1}\{\psi(x,y)-m(\psi)\}^2\,. \quad (3)$$

Let $\theta(x, y)$ represents the local ridge at pixel (x, y) as explained in [11] and calculated in non-overlapping block-wise manner. However, orientation field, based on least mean square (LMS) algorithm is briefly described below in relation to the research outlined in this paper [13]-[15]:

1) Separate and process the input image into non-overlapping blocks of size $w\times w$.

2) Find out the horizontal and vertical gradients $\varphi_x(x,y)$ and $\varphi_y(x,y)$ at each pixel (x,y) using gradient operator.

3) Estimate the ridge orientation with the following equations:

$$V_x(x,y)=\sum_{u=x-\frac{w}{2}}^{x+\frac{w}{2}}\ \sum_{v=y-\frac{w}{2}}^{y+\frac{w}{2}}2\varphi_x(u,v)\varphi_y(u,v)\,, \quad (4)$$

and

$$V_y(x,y)=\sum_{u=x-\frac{w}{2}}^{x+\frac{w}{2}}\ \sum_{v=y-\frac{w}{2}}^{y+\frac{w}{2}}\left\{\varphi_x{}^2(u,v)-\varphi_y{}^2(u,v)\right\}. \quad (5)$$

Consequently, the local ridge $\theta(x, y)$ is obtained from the following relation:

$$\theta(x,y)=\frac{1}{2}\tan^{-1}\left(\frac{V_x(x,y)}{V_y(x,y)}\right). \quad (6)$$

However, we know that the slope of a curve on the point of maxima is zero but the slope immediate left of the maxima is positive and that of on immediate right is negative. The situation is reverse for the case of minima, i. e., the slope immediate left of the maxima is negative and that of on immediate right is positive. The gradient of the immediate left and right points of the maxima are $m_1=(dy/dx)|_{(x_1,y_1)}$ and $m_2=(dy/dx)|_{(x_2,y_2)}$ respectively. The change in gradient $\Delta m=|m_1-m_2|$ is the maximum for the case of maxima or minima point of a ridge like Fig. 1, since polarity of the slope is different on left and right side of the maxima or minima point.

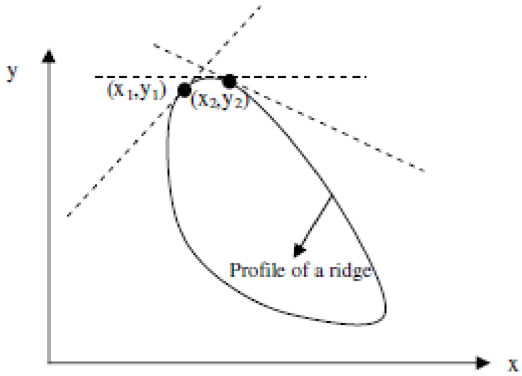

Fig. 1: Gradient of a ridge profile on immediate left and right of the maxima.

However, storing the ridge orientation mapping into an array and determining the maximum value $\Delta m=|m_1-m_2|$ of each row and their corresponding co-ordinate values, the virtual core point is therefore calculated.

The algorithm for virtual core point detection is summarized as follows:

1. Read the image.
2. Resize the image for uniform analysis.
3. Determine the ridge orientation curves of the image.
4. Store the ridge orientation image in an array $A(i, j)$; i =1, 2, 3, … size of the row(M) and j =1, 2, 3,… size of the column(N) of the image.
5. Select i-th row of the image $A(i\ ,:)$ and determine $R(i, q)$ = $abs(A(i,q)$-$A(i,q+1))$; where q =1, 2, 3, … N-1.
6. Determine the maximum value of $R\ (i,\ q)$, $z(i)$= $max(R(i,:))$.
7. Determine the co-ordinate (x_{max_i}, y_{max_i}) of the point of $z(i)$.
8. Repeat steps 5 to 7 for all rows to get (x_{max_i}, y_{max_i}); i = 1, 2, 3, … M.
9. Determine the following virtual core point

$$(\overline{X},\ \overline{Y})=\left(\frac{\sum_{i=1}^{M}X_{\max\_i}}{M},\frac{\sum_{i=1}^{M}Y_{\max\_i}}{M}\right)(7).$$

III. RESULTS

In this paper we consider four fingerprints of different persons with four different characteristics:

1) Fingerprint with single core point located at the middle of the image as in Fig. 2(a).
2) Fingerprint with two points as shown in Fig. 3(a).
3) Fingerprint with single core point located at the corner as shown in Fig. 4(a).
4) Fingerprint without core point as shown in Fig. 5(a).

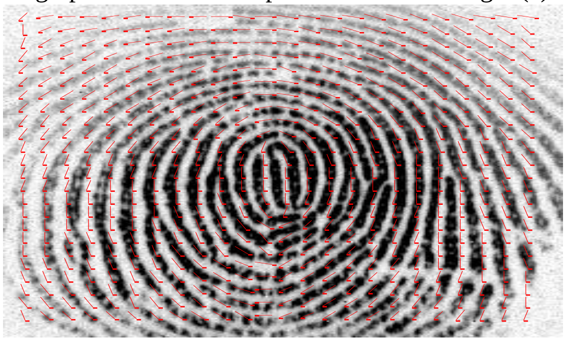

Fig. 2(a) Fingerprint of person-1 with single core at middle.

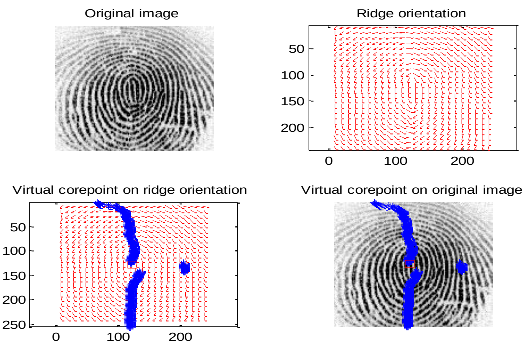

Fig. 2(b) Virtual core point of person-1.

Fig. 3(a) Fingerprint of person-2 with two cores.

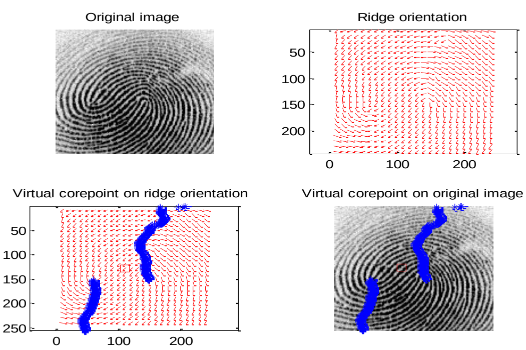

Fig. 3(b) Virtual core point of person-2.

Fig. 4(a) Fingerprint of person-3 with single core at one corner.

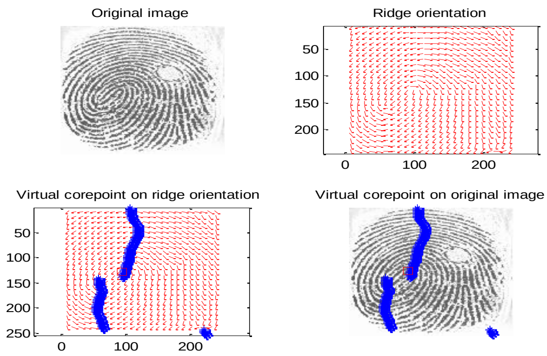

Fig. 4(b) Virtual core point of person-3.

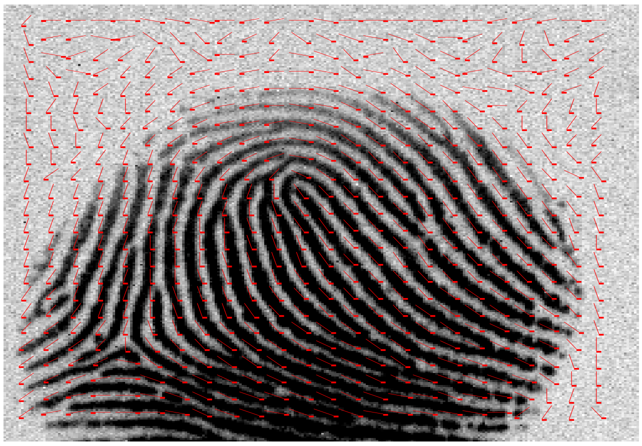

Fig. 5(a) Fingerprint of person-4 without core point.

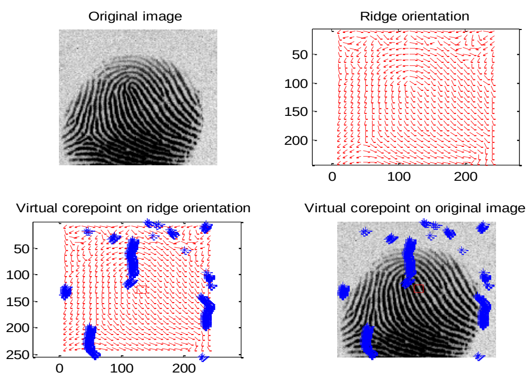

Fig. 5(b) Virtual core point of person-4.

Similar analysis is done for other three types of images. For the case of fingerprint of two core points, the virtual core point is found approximately on the middle point of the connecting line of two original core points as shown in Fig. 3(b). When the core point is located at one corner, the virtual core point shifts a little diagonally along opposite corner as visualized from Fig. 4(b). Finally, when the fingerprint does not have a core point, then $\left(\bar{X},\ \bar{Y}\right)$ indicates the point vicinity of the centroid of the image as shown in Fig. 5(b).

IV. CONCLUSION

The entire analysis of the paper is confined in detection of virtual core point of a fingerprint. The virtual core point of the paper is not the exact core point but it is considered as a reference point of a fingerprint in selection of ROI for image comparison. Taking the ROI of a finger print based on virtual core point will match closely with the images stored in database if the same procedure is applied on all the stored images. The work can be extended applying four different techniques on ROI for fingerprint identification. The techniques are: wavelet transform on the ROI, known as non-minutia based detection, invariant moment on ROI, the minutia of termination and bifurcation of the fingerprint and two dimensional cross-correlations on images.

REFERENCES

1. B. Tan, S. Schuckers, "New approach for liveness detection in fingerprint scanners based on valley noise analysis," *Journal of Electronic Imaging,* vol. 17(1), pp. 011009-1- 011009-9, Jan.-March 2008.
2. D. Batra, G. Singhal and S. Chaudhury, "Gabor filter based fingerprint classification using support vector machines," *IEEE India Annual Conference*, pp. 256-261, Dec. 2004.
3. E. R.Henry, *Classification and uses of finger prints,* London: George Rutledge & Sons, Ltd., pp. 17-18, 1900.
4. S. W. Lee and B. H. Nam, "Fingerprint recognition using wavelet transform and probabilistic neural network," *International Joint Conference on Neural Network*, vol. 5, pp. 3276 – 3279, 1999.
5. A. K. Jain, S. Prabhakar and L. Hong, "A multichannel approach to fingerprint classification," *IEEE Trans. PAMI*, vol. 21, no. 4, pp. 348-359, Apr. 1999.
6. W. Zhang and Y. Wang, "Singular point detection in fingerprint image," *Asian Conference on Computer Vision*, vol. 2, pp. 793-796, Jan. 2002.
7. A. Mishra and M. Shandilya, "Fingerprint core point detection using gradient field mask," *International Journal of Computer Applications*, vol. 2, no. 8, June 2010.
8. A. Julasayvake and S. Choomchuay, "An Algorithm For Fingerprint Core Point Detection," *International Symposium on Signal Processing and Its Applications*, pp. 1-4, Feb. 2007.
9. M.S. Khalil, D. Muhammad, M. K. Khan and K. Alghathbar., "Singular points detection using fingerprint orientation field reliability," *International Journal of Physical Sciences*, vol. 5(4), pp. 352-357, April 2010.
10. J. C. Yang and D. S. Park, "A fingerprint verification algorithm using tessellated invariant moment features", *Neurocomputing*, vol. 71, pp. 1939-1946, 2008.
11. Q. Zhao, D. Zhang, L. Zhang and N. Luo, "Adaptive fingerprint pore modeling and extraction", *Pattern Recognition*, vol. 43, pp. 2833-2844, 2010.
12. M. U. Munir and M. Y. Javed, "Fingerprint Matching using Gabor Filters," *National Conference on Emerging Technologies*, *Pakistan*, pp. 147-152, 2004.
13. C. T. Hsieh1, S.R. Shyu1 and K.M. Hung, 'An Effective Method for Fingerprint Classification," *Tamkang Journal of Science and Engineering*, vol. 12, No. 2, pp. 169-182,2009.
14. A. Jain, L. Hong, and R. Bolle, "On-line fingerprint verification," *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 19, pp. 302–314, Apr. 1997.
15. A.K. Jain, S. Prabhakar, L. Hong and S. Pankanti, "Filterbank-based fingerprint matching," *IEEE Transactions on Image Processing*, vol. 9, no. 5, pp. 846-859, 2000.

AUTHORS PROFILE

Sarnali Basak received her B.Sc. (Hons.) degree in Computer Science an Engineering from Jahangirnagar University, Savar Dhaka, Bangladesh in 2008. She is studying for her MS at the department of Computer Science and Engineering, Jahangirnagar University, Savar, Dhaka. She is working as a Lecturer in the Department of Computer Science and Engineering, Prime University, Dhaka-1216, Bangladesh. She has received NSICT fellowship for MS research in 2011 from Ministry of Science and Information & Communication Technology, Bangladesh. Her research interests include Image Processing, Pattern recognition, Artificial Intelligence, Neural Networks and Biometric.

Md. Imdadul Islam has completed his B.Sc. and M.Sc Engineering in Electrical and Electronic Engineering from Bangladesh University of Engineering and Technology, Dhaka, Bangladesh in 1993 and 1998 respectively and has completed his Ph.D degree from the Department of Computer Science and Engineering, Jahangirnagar University, Dhaka, Bangladesh in the field of network traffic engineering in 2010. He is now working as a Professor at the Department of Computer Science and Engineering, Jahangirnagar University, Savar, Dhaka, Bangladesh. Previously, he worked as an Assistant Engineer in Sheba Telecom (Pvt.) LTD (A joint venture company between Bangladesh and Malaysia, for Mobile cellular and WLL), from Sept.1994 to July 1996. Dr Islam has a very good field experience in installation of Radio Base Stations and Switching Centers for WLL. His research field is network traffic, wireless communications, wavelet transform, OFDMA, WCDMA, adaptive filter theory, ANFIS and array antenna systems. He has more than hundred research papers in national and international journals and conference proceedings.

M. R. Amin received his B.S. and M.S. degrees in Physics from Jahangirnagar University, Dhaka, Bangladesh in 1984 and 1986 respectively and his Ph.D. degree in Plasma Physics from the University of St. Andrews, U. K. in 1990. He is a Professor of Electronics and Communications Engineering at East West University, Dhaka, Bangladesh. He served as a Post-Doctoral Research Associate in Electrical Engineering at the University of Alberta, Canada, during 1991-1993. He was an Alexander von Humboldt Research Fellow at the Max-Planck Institute for Extraterrestrial Physics at Garching/Munich, Germany during 1997-1999. Dr. Amin was awarded the Commonwealth Postdoctoral Fellowship in 1997. Besides these, he has also received several awards for his research, including the Bangladesh Academy of Science Young Scientist Award for the year 1996 and the University Grants Commission Young Scientist Award for 1996. His current research fields are wireless communications and networks and also nonlinear plasma dynamics. He is a member of the IEEE.