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Brief paper

Fingerprint matching using multi-dimensional ANN

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A R T I C L E I N F O

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A B S T R A C T

Fingerprint matching is one of the most widely used biometric technique for personal identification. This identification is achieved in this work by using the concept that every fingerprint has a unique pattern of distribution of the minutiae points. In this paper, a new method of recognition of this pattern of distribution of the minutiae points of an enhanced image is considered by using a multi-dimensional artificial neural network (MDANN). The proposed technique has the distinct advantage of using the entire resized minutiae image as an input at once. It is capable of excellent pattern recognition properties as the distribution of the minutiae points are used directly for recognition. The proposed approach shows significant promise and potential for improvement, compared with the other conventional matching techniques with regard to time and efficiency of results.

1. Introduction

Biometrics is a technology that uniquely identifies a person based on his physiological or behavioral characteristics. Some of the biometrics which have excellent potential for identification are the fingerprint, iris, retinal scan (Jain et al., 1997). Fingerprint matching is one of the oldest and trusted biometric for identification (Lee and Gaensslen, 1991). The manual classifications of the fingerprints were time consuming and prone to errors, hence it was not possible to promote it on a commercial scale. The first scientific paper on fingerprint was given by English morphologist N. Grew in 1684, in which he had reported his study on the ridge, furrow and pore structures in the fingerprint. In 1823, Purkinje developed the first fingerprint classification scheme in which the fingerprints were classified into nine categories according to the ridge configuration (Lee and Gaensslen, 1991). Sir F. Galton after an extensive study of fingerprints introduced the minutiae features for the fingerprint classification in the year 1888. The minutiae points are the local discontinuities in the ridge flow pattern. The FBI invested a lot of effort since the early 1960s in the development of the AFIS (Federal Bureau of Investigation, 1984). Ever since the Automatic Fingerprint Identification System (AFIS) was developed in 1991, rapid progress has been made in improving the recognition rates. This development has greatly improved the scope of using fingerprint for identification purposes and in reducing the cost of hiring and training human experts for fingerprint matching. The current works in this field focus on mainly reducing the computation time for feature extraction and matching and improving the accuracy of the results. Today, with the crime rates increasing everyday there is an urgent need for a system which is safe and fast.

The general fingerprint recognition system comprises of two broad steps namely: (i) feature extraction and (ii) classification of the image using the features extracted. Some of the important feature extraction methods include: (i) filter based approach (ii) structure based approach (iii) statistical based approach which also comprises the method of extracting the minutiae points (Ern and Sulong, 2001). The methods of matching the fingerprint using the features extracted is carried out by using one of the many approaches namely: (i) syntactics, (ii) singularities based, (iii) structural, or (iv) neural network based (Ern and Sulong, 2001). Some of the recent work in the field of fingerprint matching includes the chain coded string matching technique (Paul et al., 2007), use of the combination of fast Fourier transform (FFT) and Gabor filters for the enhancement of the captured image (Aguilar et al., 2007) which have the potential of improving the speed and the performance of feature extraction and matching.

One of important methodology used in the fingerprint recognition system is the use of minutiae points for matching the fingerprints. Some of the popular minutiae matching techniques are: (i) using the Delaunay triangulation method (Bebis et al., 1999), (ii) using local structural similarity (Ratha

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et al., 2000), (iii) using neural networks or a combination of neural and fuzzy logic (Arantus et al., 2002; Hong and Hua, 2003). In this paper, we propose to use the MDANN in which the 2-D resized minutiae image is taken as an input directly and this method involves the training of the entire pattern at once as against the other earlier works of training, in which the whole image is either divided into a number of small images and then trained one by one or use the 1-D feature vector for training. This method is proposed as it uses the comprehensive data of the fingerprint and hence the chances of failure to recognize the authentic fingerprints are very remote.

The rest of the paper is organized as follows: Section 2 describes the image enhancement techniques along with the binarization and thinning techniques. Section 3 explains the minutiae extraction and its authentication method. Section 4 introduces the resizing algorithm briefly. Section 5 introduces the concept of MDANN and its algorithm. The results are presented in Section 5 and the concluding remarks are presented in Section 6.

2. Image enhancement

The quality of the fingerprint ridge structure is very important as they possess the necessary information for the extraction of minutiae points. Ideally the ridges and valleys should alternate with a clear demarcation and flow in a locally constant direction. Due to a number of factors, the obtained fingerprints may not have well defined ridge/valley structures and might contain a lot of disturbance in the image (Jain et al., 1997). So the fingerprint image is first enhanced before further processing and comprises of the following steps: (i) segmentation, (ii) normalization, (iii) orientation estimation, (iv) ridge frequency estimation, (v) Gabor filtering (vi) binarization, (vii) thinning (Jain et al., 1999).

2.1. Segmentation

Segmentation is the process of distinguishing the background region from the foreground regions. It is observed that the background regions have a low gray-scale variance value as compared to the foreground region. So a method based on variance thresholding is used for segmentation (Mehtre, 1993).

$$V(k) = \frac{1}{n^2}\sum_{i=0}^{n-1}\sum_{j=0}^{n-1}(I(i,\ j)-M(k))^2 \tag{1}$$

where $V(k)$ is the variance and $M(k)$ is the mean gray-level value of the block k. $I(i,j)$ is the pixel value at the pixel (i,j).

2.2. Normalization

Normalization is done in order to standardize the dynamic variation in the gray-level values.

$$N(i,\ j) = M_o + \sqrt{\frac{V_o(I(i,\ j)-M)^2}{V}} \quad \text{if } I(i,\ j) > M \tag{2}$$

$$M_o - \sqrt{\frac{V_o(I(i,\ j)-M)^2}{V}}\ otherwise \tag{3}$$

where '$N(i,j)$' is the normalized gray-level value and $I(i,j)$ is the gray-level value at pixel (i,j). 'M' and 'V 'are the estimated mean and variance of $I(i,j)$ respectively and 'M_o' and 'V_o' are the desired mean and variance values respectively.

2.3. Orientation estimation

The orientation field of a fingerprint defines the local orientation of the ridges and is necessary for the Gabor filtering stage to effectively enhance the image (Jain et al., 1997). The local orientation θ for the block centered at the pixel (i,j) is calculated by using the following equations.

$$O_x(i,\ j) = \sum_{u=i-W/2}^{i+W/2}\sum_{v=j-W/2}^{j+W/2} 2\partial_x(u,\ v)\partial_y(u,\ v) \tag{4}$$

$$O_y(i,\ j) = \sum_{u=i-W/2}^{i+W/2}\sum{}^{j+W/2}\partial_x^2(u,\ v)\partial_y^2(u,\ v) \tag{5}$$

$$\theta(i,\ j) = \frac{1}{2}\tan^{-1}\frac{O_x(i,\ j)}{O_Y(i,\ j)} \tag{6}$$

The orientation image is converted into a continuous vector field. 'ϕ_x', 'ϕ_y' being the x and y components of the vector field respectively. The Gaussian smoothing is then performed and the equations for the process are as under,

$$\phi_x(i,\ j) = \cos(2\theta(i,\ j)) \tag{7}$$

$$\phi_y(i,\ j) = \sin(2\theta(i,\ j)) \tag{8}$$

$$\phi_x'(i,\ j) = \sum_{u=-q/2}^{q/2}\sum_{v=-q/2}^{q/2} G(u,\ v)\phi_x(i-uw,\ j-vw) \tag{9}$$

$$\phi_y'(i,\ j) = \sum_{u=-q/2}^{q/2}\sum_{v=-q/2}^{q/2} G(u,\ v)\phi_y(i-uw,\ j-vw) \tag{10}$$

where 'G' is a Gaussian low pass filter of size q*q and the final smoothened orientation field 'O' at pixel (i,j) is given by

$$O(i,\ j) = \frac{1}{2}\tan^{-1}\frac{\phi\prime_x(i,\ j)}{\phi\prime_y(i,\ j)} \tag{11}$$

2.4. Ridge frequency estimation

Along with the orientation field, the ridge frequency is also required for the construction of Gabor filter. This represents the local frequency of the ridge in the fingerprint (Jain et al., 1997).

2.5. Gabor filtering

The orientation and the ridge frequency information is used to design the even-symmetric Gabor filter (Daugman, 1985). An even-symmetric Gabor filter is defined in the spatial domain as

$$G(x,\ y;\ \ \theta,\ f) = \exp\left\{-\frac{1}{2}\left[\frac{x_\theta^2}{\sigma_x^2}+\frac{y_\theta^2}{\sigma_y^2}\right]\right\}\cos(2\pi f x_\theta), \tag{12}$$

$$x_\theta = x\cos\theta + y\sin\theta \tag{13}$$

$$y_\theta = -x\sin\theta + y\cos\theta \tag{14}$$

where θ and f refer to the orientation and the frequency of the Gabor filter, while σ_x and σ_y refer to the standard deviation of the Gaussian envelope. The application of the Gabor filter to the image is performed as follows.

$$E(i,\ j) = \sum_{u=-M_X/2}^{M_X/2}\sum_{v=-M_y/2}^{M_y/2} G(u,\ v;\ \ O(i,\ j),\ F(i,\ j))N(i-u,\ j-v) \tag{15}$$

where E,O,F,N are the enhanced, orientation, ridge frequency and normalized fingerprint images respectively. M_x, M_y being the width and height of the Gabor filter mask. The range of frequency