Using Linear Symmetry Features as a Pre-processing Step for Fingerprint Images

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Abstract. This paper presents the idea to use linear symmetry properties as a feature based pre-processing step for fingerprint images. These features contain structural information of the local patterns. The linear symmetry can be computed by using separable spatial filtering and therefore has the potential to be a fast pre-processing step. Our results indicate that minutiae can be located as well as can be assigned a certain class type. The type of minutiae matching in combination with geometrical matching increases the matching efficiency as compared to the pure geometrical matching.

1 Introduction

In person identification systems using fingerprint images minutiae and their relative positions to each other are often used in the matching process. Minutiae are found in positions where the "simple pattern" in the fingerprint image is changed. In this position an identifiable signature, e.g. a ridge is suddenly broken, two ridges merge, etc. is seen. When the minutiae coordinates are extracted an alignment of the minutiae point-pattern to a reference is done (matching process). The entire matching process including processing of images may be inefficient due to false minutiae as well as missing correct minutiae. Also different minutiae point-patterns are of different sizes [1]. A review of finger-print identification studies is given in [1].

The aim of this work is to investigate if the local linear symmetry (LS) property can be used as a pre-processing step for fingerprint images in an attempt to increase the efficiency of the minutiae matching process. The pre-processing step should locate, and also assign a feature vector to each found minutiae point. Using a feature vector gives additional information compared to only have the locations of the minutiae. Also, representing a minutiae point by a feature vector it can be classified belonging to a specific type of minutiae. Knowing also the type of minutiae, the later matching process can be done more effectively.

It is desirable to find a representation of a fingerprint image that combines both local and global information [2]. In our representation the feature vector has the local

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information and the relative positions of the found minutiae points have the global information.

2 Linear Symmetry

A local neighborhood where the gray value only changes in one direction has linear symmetry, LS. A linear symmetry property defines also an orientation. Mathematically, linear symmetry orientation is the direction along which an infinitesimal translation leaves the pattern least variant, (ideally invariant). A fully equivalent formulation is that the linear symmetry orientation is the least inertia axis orientation of the Fourier transform energy of the pattern (ideally concentrated to a line, to which this symmetry originally refered to). The LS property can be extracted by using local spatial filtering [3] via separable gaussian filters and gaussian derivative filters. The LS property is obtained by applying averaging to the LS tensor which corresponds to a physical property, a vector field representing local orientations or the lack of local orientations, which does not change with the observer (coordinates). The LS vector field is three dimensional consisting of 3 real numbers when the images are 2-D (e.g. finger prints). In this case these 3 real numbers can be conveniently represented as one complex number, called $I_{20,}$ and one real number, called I_{11}. The complex number is obtained via $I_{20} = \langle Grad(f), Grad^*(f) \rangle$ where $Grad = D_x + i D_y$ is an operator, and the $\langle , \rangle$ is the usual scalar product, having a gaussian as a kernel. The real number is obtained via $I_{11} = \langle |Grad(f)|, |Grad^*(f)| \rangle$. The LS property can be generalized to comprise deformations of the local image, which allows to detect singular points such as spiral centers, [4]. In this case however, the definition of the Grad operator is changed to a gradient consisting of Lie derivatives, and the averaging kernel is replaced by a harmonic function multiplied by a gaussian.

2.1 Pre-processing

The output from the LS pre-processing step are two images I_{20} and I_{11}. I_{20} is displayed as a vector image (figure 1) where each pixel is represented by a vector. The length of the vector is a measure of the local “LS strength” and the argument is the estimated local orientation. I_{11} is a scalar image, it measures the “amount of local gray value change”. It can be shown that inequality $|I_{20}| \leq I_{11}$ holds, and that the upper bound of $|I_{20}|$ is attainable (equality holds) if and only if the pattern posseses LS property, an infinitesimal translation in a certain direction yields zero error.

2.2 Extraction and Labeling of Minutiae

Minutiae are found by the “lack of LS”. Here the lack of LS is computed as $1 - |I_{20}|/I_{11}$, which is never negative. This takes values in the interval [0, 1], where a high value indicates the lack of LS. Besides that, each minutiae is represented by a feature vector.

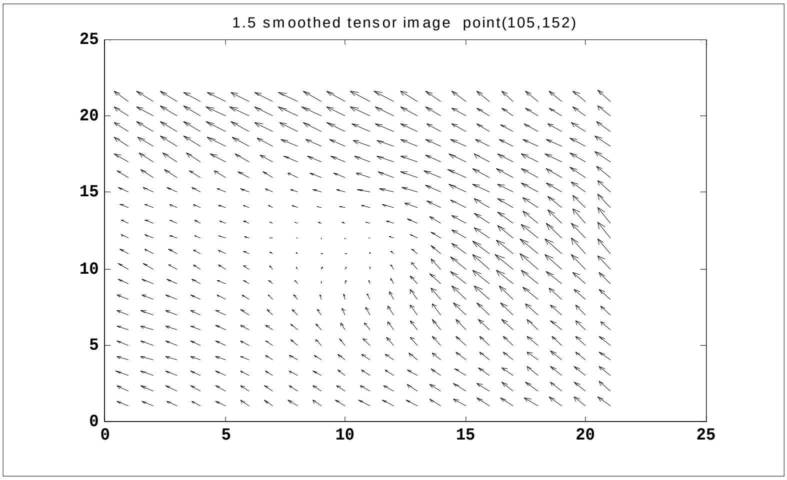

Fig. 1. The vector image I_{20}

As features the LS property in the *neighborhood* of the minutiae is used. To get a translation and rotation invariant numeric representation, the magnitude of the 1D Fourier transform of the extracted features is calculated. This will be described further below.

For use in a later matching process each minutiae is labeled as belonging to a specific class. Within each class there should be similar linear symmetry properties of the neighborhood of the minutiae. The classes are found by clustering, and the labeling of minutiae is done by finding the closest class (minimum distance to the cluster centers).

3 Experiments

The fingerprint images used are from the FVC2000 database, DB2 set A, and are captured by using a low cost capacitive sensor. The size of an image is 364 x 256 pixels and the resolution is 500 dpi.

In computing the I_{20} image the first partial derivatives of the 2D gaussian function are used. The size of the derivative filters are 1 x 11 with σ=1.8, and the smoothing filter, also gaussian, is 1 x 13, with σ=2.2. Figure 1 shows the vector image I_{20} in a neighborhood of a minutiae.

3.1 Extraction of Minutiae

First a low pass filtering of the fingerprint image is applied, and also to favor pixels in the center of the image the low pass filtered image is multiplied by a 2D gaussian.

From the “lack of LS image” the 15 strongest minutiae are extracted. When a minutiae is found, coordinates close to it are occluded in the search for new minutiae.

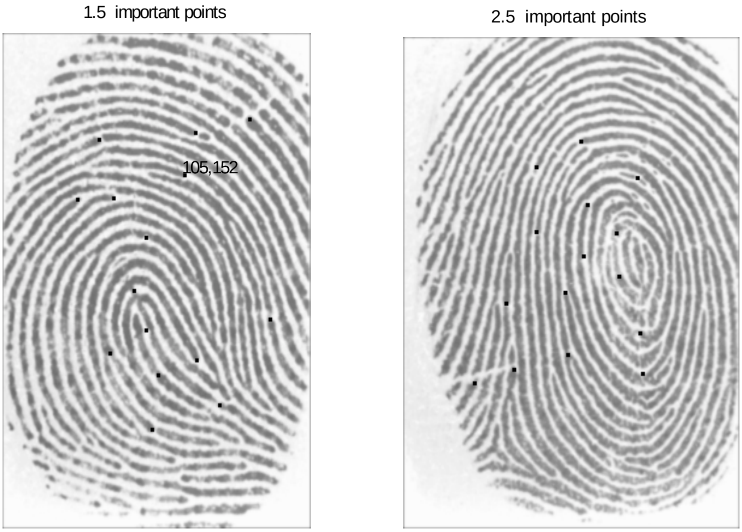

Fig. 2. Marked minutiae points

3.2 Feature Extraction

The LS property on a circle around each minutiae point are extracted. In particular, the vector image I_{20} is sampled in N=16 equally spaced number of points on a circle with a radius of 15 pixels.

To get a translation and rotation invariant representation of the linear symmetry property, and also to get a more compressed representation, the magnitude of the 1D Fourier transform of the 16 extracted points is calculated.

Also, only the lowest Fourier coefficients are used in the feature vector representing the neighborhood of the minutiae.

3.3 Labeling of Minutiae

For use in a later matching process each minutiae is labeled belonging to a specific class. Each specific class is represented by its feature vector (class-center). Minutiae within a class should have similar LS properties.

To find the specific classes and their class-centers, 100 images from different persons are used. From each of the 100 images 15 minutiae are extracted and their feature vectors are calculated. The first six Fourier coefficients are used as the feature vector representing the minutiae point.

The class-centers are calculated by a clustering technique. The “fuzzy c-means” clustering algorithm, [5] is utilized. Minutiae are labeled according to the shortest Euclidian distance to a class-center. The number of classes is 10.

Fig. 3. Labeled minutiae points, person 1

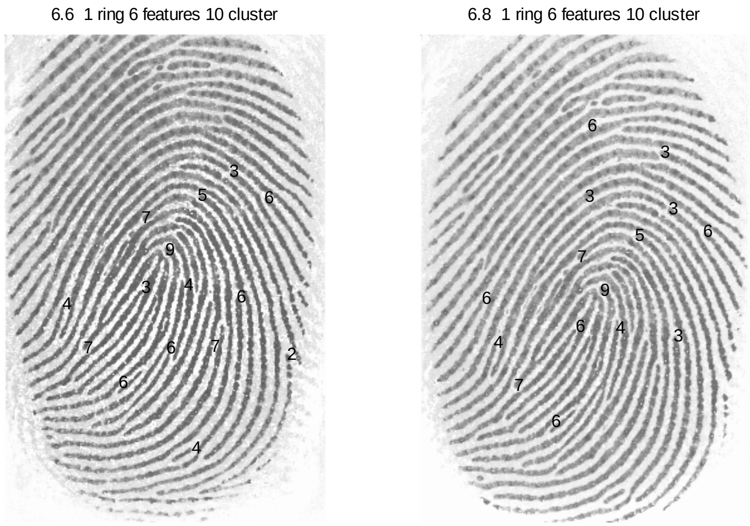

Fig. 4. Labeled minutiae points, person 6

Figure 3 shows fingerprint images from a person captured at different times. Figure 4 is the fingerprints from another person.

Most of the common minutiae are labeled with the same class-label (in figure 3: 7 of 9, in figure 4: 9 of 11), which indicates that the LS property has enough information to be used in a pre-processing step.

4 Conclusion

Our experiments indicate that the LS property has the necessary information for both extracting the minutiae points and also labeling each minutiae belonging to a specific type. More experiments have to be done on fingerprint images with differences in quality.

Acknowledgement

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