Analysis of extracted fingerprint texture features

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Abstract

This paper describes an approach for electronic feature extraction from fingerprint images for identification purposes. Statistical analysis of the features extracted from the fingerprint provides the advantage of real-time analysis of the fingerprint information, providing a method to remove unwanted information prior to the matching stage required in electronic fingerprint verification. This method can also detect of noise within the fingerprint image and location of critical data in the fingerprint. In order to demonstrate the effectiveness of this work, experiments have been developed and conducted with the results and analysis provided at the end of this paper for discussion.

1. Introduction

Fingerprints are well known in society for their identification of individuals from criminal identification. The fingerprint has been chosen as the method of identification due its non-invasive nature to the individual. The properties of fingerprint formation are well known by forensic scientists and have been used for identification of criminals around the world [1]. The extensive use of fingerprint identification from criminal purposes proves the reliability of an identification system based upon the fingerprint. No two fingerprints have ever been found to have the same ridge detail sequence that is identical between any two individuals [2, 3].

Fingerprint identification is based on two fundamental properties: (1) fingerprint details are permanent, and (2) fingerprints of an individual are unique [4]. The individuality problem can be defined as the probability that any two individuals may have similar fingerprints within the target population. The individuality problem is defined as the probability that two individuals have sufficiently similar fingerprints.

Fingerprints are defined as 'sufficiently' similar by most human experts and automatic fingerprint identification systems if they originate from the same source. The amount of similarity between fingerprints for a match depends on the variations between multiple impressions of the same finger.

The structure of the fingerprint is made from a pattern of ridges and valleys. Fingerprints contain two main types of features; local features within a restricted region of the fingerprint, and global features that take an overall attribute of the entire fingerprint. Either of these two features can be used for identification of an individual as both features do not change over time.

A fingerprint can be viewed as an oriented texture and for sufficiently complex orientated textures such as fingerprints, invariant texture representations can be extracted [5]. Using this underlying structure within the fingerprint does not rely upon locating the core or delta points that is difficult to detect or not present in low quality images. A texture based representation of the fingerprint will be used combined with statistical analysis of the texture information to select the most appropriate texture features to use prior to the matching stage of electronic fingerprint identification.

The features that are extracted from the fingerprint are known as the individual's 'template'. This template is the signature of the fingerprint, taking only the key features and not the entire fingerprint. To create this template, the individual normally has to enrol onto the identification system by submitting the fingerprint to the system multiple times so that the features can be cross-referenced and check that no features have been missed between scans. Once enrolled this template can be used for verification in the future.

2. Texture Features

Texture features that are extracted can be categorised as; statistical, geometrical, structural, model-based and signal processing features [6]. In image analysis there are various methods available to extracting these texture features, and must be understood in selecting the optimal method for system being used.

The method uses structural features that involved partitioning the fingerprint image into sections and each individual section is normalised to a constant mean based upon the pixel intensity. This partitioning removes the need for a reference point to be extracted from the fingerprint image and provides a method that will enable feature information to be extracted directly from these individual sections. The partition size will be selected to reduce the requirements of the verification algorithm; more sections will require a more complex algorithm. From previous research, it has been found that a partition size of less than 20x20 pixels results in limited or loss of texture information [7].

The partitioning function is performed within the MATLAB environment and enables the section size to be selected by the user as depending on the verification algorithm the number of features available may need to be modified. A partition size of 60x60 pixels has been selected as it meets the requirements of [7] and also reduces the number of inputs to the verification algorithm to 36 features. The partition sections remain in gray scale (8-bit) format to retain the texture information prior to extracting the feature information.

The section size defined by the partitioning defines the number of features that can be extracted by this system. The sections of the fingerprint image contain 360 pixels with a range of 0-255 (gray scale). Using the pixel intensity value, the feature value calculated as the mean value of 360 individual pixels within the section. This provides a single feature value for each of the 36 sections that have been partitioned from the fingerprint image. As the image is not pre-processed all information is still available within the pixels intensity.

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Unlike traditional local feature extraction methods (i.e. minutiae extraction) from the fingerprint image, this thesis focused on using a texture feature extraction method. Five popular texture feature extraction methods were selected as candidates for use in this thesis; autocorrelation, edge frequency, primitive-length, law's method and co-occurrence matrices. Studies that were performed into these methods [8] determined that the co-occurrence matrices and Law's method perform better than other techniques.

3. Law's Method

Law's method is based on a series of pixel impulse response arrays obtained from combinations of 1-D vectors shown in Table 1 [7]. These five 1-D filters are capable of producing 25 possible features at each pixel location (using five different filters in both horizontal and vertical directions). The arrays are convolved with other arrays in a combinational manner to generate the masks generally labelled L5L5 for the mask resulting in the convolution of the two L5 arrays. The arrays are based upon the observations of Laws that found certain gradient operators such as Laplacian and Sobel operators accentuated the underlying microstructure of texture within an image.

Level L5 = [1 4 6 4 1]
Edge E5 = [-1 -2 0 2 1]
Spot S5 = [-1 0 2 0 -1]
Wave W5 = [-1 2 0 -2 1]
Ripple R5 = [1 -4 6 -4 1]

Table 1 – Five arrays identified by Laws [9]

Using Law's method enabled features to be extracted from the fingerprint image within the partitioned areas. The features were plot on a 3d graph to show how the feature values correspond to the matching fingerprint image. These values are scaled between 0 – 255 from the original gray scale image.

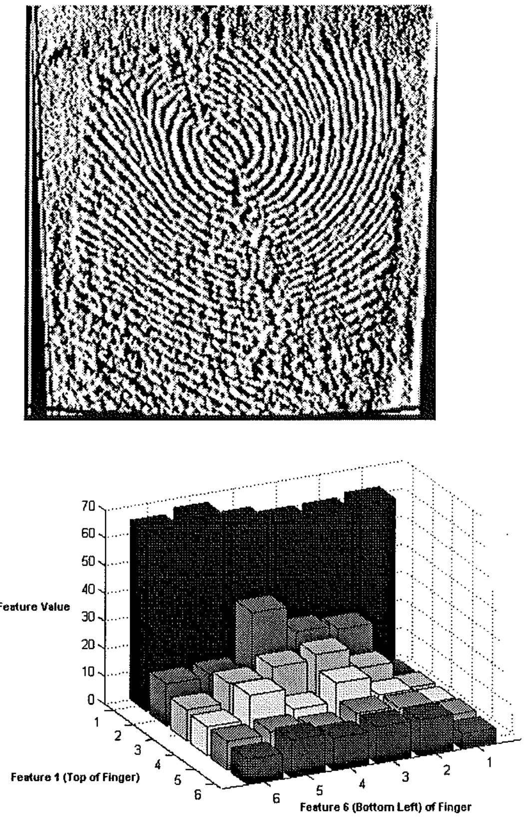

Figure 1 – Feature plot: values of features

These 36 individual feature values are used to represent the fingerprint image that has been captured using the electronic fingerprint sensor. Analysis methods will be used to determine if this is a reliable method of feature extraction and also to determine if irrelevant features that have no identifying information can be removed from the feature list.

Using the fingerprint image, texture features can be extracted by partitioning the fingerprint image into smaller sections. This method allows a feature value to be extracted based on the texture component of each partition. The feature values will be known as the texture features of the fingerprint. The number of features that are extracted from the fingerprint affects the size and complexity of the verification algorithm and must be taken into account when designing the partition size as well as the verification algorithm. The partition size selected is 60x60 pixels that result in 36 individual features that are extracted to represent a fingerprint.

4. Statistical Analysis

Texture feature information that has been extracted from a fingerprint image may not be relevant information that can be used to represent an individual. Unlike local feature information such as minutiae which are specific points of reference to a particular fingerprint, texture information could refer to noise within the fingerprint image. The purpose of analysing the fingerprint information is to determine a threshold that will enable irrelevant texture information to be removed from the feature set to provide a more robust representation of the individual.

Several analysis methods are available for analysing data, but for these particular experiments the amount of variance between features is to be analysed. Therefore two techniques are available which suit this application of data; Analysis of Variance (ANOVA) and Principle Component Analysis (PCA). Using these two techniques will allow cross-referencing between results to determine if statistical analysis provides a reliable and repeatable method to discard irrelevant feature information that has been extracted from a fingerprint.

Experiments will be used to determine the following from the fingerprint texture features; sufficient difference can be found between fingerprints in database, separation between features can be found and determining noise features within the fingerprint. ANOVA will be primarily used to find sufficient difference between the images in the database as it allows the analysis directly of variance within the sample (texture features). PCA will be used to analyse the difference between fingerprints, between features and for finding noise within the fingerprint.

5. Experimental Results

Using the extracted features analysis was performed to determine if the fingerprints within the database could be separated sufficiently proving that these fingerprints are indeed individual fingerprints. Using ANOVA this allowed the amount of variance between each of the 5 scans of the individual fingerprints within the database to be measured. The results of this experiment found that there was an average 80% similarity between successive scans of the same fingerprint across this small database (40 individuals; total 200 fingerprints). This was also cross-compared using PCA to locate the separation between a sub-set of these fingerprints within the database and the plot shown in Figure 2 depicts the individual fingerprint images.

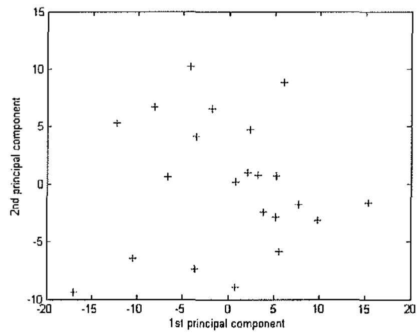

Figure 2 – PCA of Individual Fingerprints

This shows that the feature extraction method is able to differentiate between the individual fingerprints within the database. Further to this experiment PCA will be used to directly analyse the features to determine if any key points within the fingerprint itself can be extracted using this method.

An interesting observation that was found while analysing the texture features directly was what seemed to be a correlation between the noise in the original fingerprint image and the texture features themselves. Upon closer inspection it was noted (Figure 3) that the high value feature (greater than 50) were in fact the extreme noise that was present within the fingerprint image. The noise was located at the top of the image that was introduced by the fingerprint sensor. To determine if points within the fingerprint could be located within the image, PCA was used to separate out similar features.

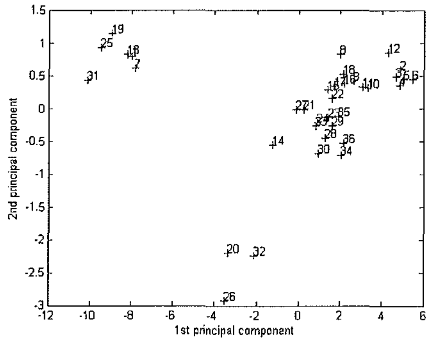

Figure 3 – PCA of Feature Information

The feature plot showed that the features corresponding to the noise within the fingerprint image (Features: 1, 7, 13, 19, 25 and 31) are clearly separated from the rest of the features within the fingerprint. This could be used as a method for extracting noise from a fingerprint image and to identify the fingerprint features that contain more specific information to identification of an individual; i.e. centred at the core of the fingerprint. Also, the core of the fingerprint is roughly located between features 20, 26 and 32 on the feature plot, enabling the algorithm to detect where the centre point of the fingerprint is located.

As PCA can be performed within the MATLAB environment, this property of finding noise within the fingerprint could be used to perform pre-processing of the fingerprint image prior to selecting the features that will identify the fingerprint. This process of removing noise from the texture features will improve the performance of the identification system as only the relevant features will be kept and unwanted features can be discarded.

Using the MATLAB interface is expected to be a valuable addition to a fingerprint identification system; being able to remove noise from a fingerprint image with a minimal amount of processing required. This may increase the security of a system due to irrelevant features being disregarding and focusing higher on the individuals fingerprint features.

6. Conclusion

Presented in this paper is the combination of extracting features from a fingerprint using textures with statistical analysis of these features to determine the most relevant information.

Future improvements can be made to this method to allow more precise location of the feature points within the fingerprint, by using a smaller partition size but this will add to the computational requirements. The concept for using texture feature extraction with statistical analysis is to reduce the processing requirements of an electronic fingerprint identification that may be able to utilise a lower cost and commercially available microcontroller.

Improvements can be made to the texture feature extraction method that can improve the features extracted from the fingerprint.

Analysis of the features outlined the need to extract more features that would enable the features extracted to be linked with specific locations of fingerprint. Features located around the core of the fingerprint generally contain more information and are clearer when captured using electronic fingerprint sensors. Additional methods may be used to improve the texture feature extraction such as using not only Laws method but also a secondary method to improve the reliability and security of the system.

Expanding upon the capability of the MATLAB development environment to directly export the developed algorithms to an embedded system using the inbuilt hardware-specific code generators. The use of this feature would allow a completed system to be evaluated then directly downloaded to the identification system without the need to write hardware specific instructions. This highly portable MATLAB code can then be used for a number of embedded identification products.

By providing a method to analyse fingerprint features within the identification system, performance may be increased but security will be increased by reducing the amount of irrelevant information that may be present within the original feature set that represents the individual on the fingerprint identification system.

This has provided a method of detecting and removing noise from a fingerprint image. Improving the feature set that represents an individual increases the reliability of the system by removing irrelevant feature information prior to the matching stage that is required within a fingerprint identification system.

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