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A Review of Fingerprint Compression Based on Sparse Representation

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Abstract—* Fingerprint analysis plays crucial role in crucial legal matters such as investigation of crime. But a fingerprint image consists of enormous amount of data. Therefore we have to reduce the amount of its data. To do this, we need some powerful image compression technique. There are many image compression techniques available. Fingerprint images are rarely of perfect quality. They may be degraded and corrupted due to variations in skin and impression conditions. Thus, image enhancement techniques are employed prior to minutiae extraction to obtain a more reliable estimation of minutiae locations. In this paper, we review various methods of fingerprint compression methods. Finally we discuss a fingerprint compression algorithm based on sparse representation. After the image enhancement, we are constructing a dictionary for predefined fingerprint image patches. For a given whole fingerprint, divide it into small blocks called patches. Use the method of sparse representation to obtain the coefficients then, quantize the coefficients and last, encode the coefficients. Three groups of fingerprint images are tested. The experiments demonstrate that our algorithm is efficient compared with several competing compression techniques The main feature used to match two fingerprint images are minutiae. Therefore, the difference of the minutiae between pre and post compression is considered.

***Index Terms*— Sparse Representation, Image Enhancement, JPEG 2000, Wavelet Scalar Quantization.**

I. INTRODUCTION

Fingerprints have been used for over a century and are the most widely used form of biometric identification. Fingerprint identification is commonly employed in forensic science to support criminal investigations, and in biometric systems such as civilian and commercial identification devices. Fingerprint identification methods are widely used by police agencies and customhouse to identify criminals or transit passengers since the late nineteenth century. ISO standardized the characteristics of the fingerprint files in 2004. However, with tens of thousands of persons being added into the repositories daily, the management of these data becomes a critical issue. Developing fine and delicate methods for fingerprint compression is necessary to both reduce the memory storage and identification time. Among many efforts, the compression technique is considered as one of the most effective solutions. The compression techniques make the database able to store more reference fingerprints, and also help to extract the effective features in improving the accuracy of fingerprint recognition. Because the fingerprint images are frequently sent between law agencies through internet, efficiently compressing the data before transmission is also desirable and necessary.

There are many image compression techniques available. JPEG, JPEG 2000, Wavelet Scalar Quantization (WSQ) are the existing image compression techniques. The JPEG, JPEG 2000 methods are for general image compression.

WSQ [9] is the commonly used fingerprint compression algorithm. Inspired by the WSQ algorithm, a few wavelet packet based fingerprint compression schemes have been developed. In addition to WSQ, there are other algorithms for fingerprint compression, such as Contourlet Transform.

The fingerprint images are rarely of perfect quality. They may be degraded and corrupted with elements of noise due to many factors including variations in skin and impression conditions. This degradation can result in a significant number of spurious minutiae being created and genuine minutiae being ignored. A critical step in studying the statistics of fingerprint minutiae is to reliably extract minutiae from fingerprint images. Thus, it is necessary to employ image enhancement techniques prior to minutiae extraction [16] to obtain a more reliable estimate of minutiae locations.

The primary aim of this project is to implement a techniques for fingerprint image enhancement and minutiae extraction. After the image enhancement construct a base matrix whose columns represent features of the fingerprint images, referring the matrix dictionary whose columns are called atoms, for a given whole fingerprint, divide it into small blocks called patches whose number of pixels are equal to the dimension of the atoms. Use the method of sparse representation to obtain the coefficients then, quantize the coefficients and encode the coefficients and other related information using lossless coding methods.

The compression performance of the algorithms are evaluated by using Peak Signal to Noise Ratio computation. The main feature used to match two fingerprint images are minutiae. Therefore, the difference of the minutiae between pre and post compression is considered.

The rest of the paper is organized as follows. In Section II, we present the current state of the art related to sparse, fingerprint compression and image enhancement. In Section III, we discuss about image enhancement. In section IV, we discuss the various methods of compression techniques. In Section V, we discuss the proposed work. Finally Section VI summarizes this paper with some concluding remarks.

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II. CURRENT STATE OF THE ART

Lili Liu et al [10] proposed an efficient verification system based on biometrics. In this system they have used Gabor filter based enhancement for minutiae extraction [12]. Ishpreet Singh et al [11] have used histogram equalization for fingerprint image enhancement, segmentation using morphological operations, minutia marking by specially considering the triple branch counting, branch into three terminations, an alignment based elastic matching algorithm minutia unification by decomposing has been developed for minutia matching were implemented.

One of the fingerprint enhancement techniques is the method employed by Hong et al [13], which is based on the convolution of the image with Gabor filters tuned to the local ridge orientation and ridge frequency. The main stages of this algorithm include normalisation, ridge orientation estimation, ridge frequency estimation and filtering.

An alternative approach to enhancing the features in a fingerprint image is the technique employed by Sherlock [14] called directional Fourier filtering. The previous approach was a spatial domain technique that involves spatial convolution of the image with filters, which can be computationally expensive. Alternatively, operating in the frequency domain allows one to efficiently convolve the fingerprint image with filters of full image size.

Anil Jain [15] have designed and implemented an identity authentication system which operates in two stages, minutiae extraction and minutiae matching. An alignment- based elastic matching algorithm is proposed for minutiae matching. Manvjeet Kaur et al [16] proposed fingerprint verification system using minutiae extraction technique. In this System they have introduced combined methods to build a minutia extractor and a minutia matcher. Segmentation with morphological operations used to improve thinning, false minutiae removal, minutia marking. For this system they have used histogram equalization.

F. A. Afsar et al [17] presented the minutiae based automatic fingerprint identification systems. The technique is based on the extraction of minutiae from the thinned, binarized and segmented version of a fingerprint image. The system uses fingerprint classification for indexing during Fingerprint matching which greatly enhances the performance of the matching algorithm.

One of the most widely cited fingerprint compression techniques is the method employed by Yu-Lin Wang et al [2]. In that paper, a DCT-based coder is developed for fingerprint compression by using the specific energy distributions of fingerprint patterns.

The field of sparse representation is relatively young. Early signs of its core ideas appeared in a pioneering work [3]. In that paper, the authors introduced the concept of dictionaries and put forward some of the core ideas which later became essential in the field such as a greedy pursuit technique. Thereafter, S. S. Chen et al introduced another pursuit technique which used l^1-norm for sparse [4]. It is surprising that the proper solution often could be obtained by solving a convex programming task. Since the two seminal works, researchers have contributed a great deal in the field, the activity in this field is spread over various disciplines. There are already many successful applications in various fields, such as face recognition, image denoising, object detection and super resolution image reconstruction.

III. IMAGE ENHANCEMENT

Fingerprint images are rarely of perfect quality. They may be degraded and corrupted due to variations in skin and impression conditions. Thus, image enhancement techniques are employed prior to minutiae extraction to obtain a more reliable estimation of minutiae locations. Enhancement [13] consists of the following stages.
i) Normalization ii) Segmentation iii) Orientation Estimation iv) Ridge Frequency Estimation v) Gabor Filtering vi) Binarisation

Normalization is used to standardize the intensity values in an image by adjusting the range of grey-level values so that it lies within a desired range of values. Normalization does not change the ridge structures in a fingerprint; it is performed to standardize the dynamic levels of variation in grey-level values, which facilitates the processing of subsequent image enhancement stages.

Segmentation is the process of separating the foreground regions in the image from the background regions. The foreground regions correspond to the clear fingerprint area containing the ridges and valleys, which is the area of interest. The background corresponds to the regions outside the borders of the fingerprint area, which do not contain any valid fingerprint information. When minutiae extraction algorithms are applied to the background regions of an image, it results in the extraction of noisy and false minutiae. Thus, segmentation is employed to discard these background regions, which facilitates the reliable extraction of minutiae.

In a fingerprint image, the background regions generally exhibit a very low grey-scale variance value, whereas the foreground regions have a very high variance. Hence, a method based on variance thresholding can be used to perform the segmentation. Firstly, the image is divided into blocks and the grey-scale variance is calculated for each block in the image. If the variance is less than the global threshold, then the block is assigned to be a background region, otherwise it is assigned to be part of the foreground.

The orientation field of a fingerprint image defines the local orientation of the ridges contained in the fingerprint as in Fig.1 [13]. The orientation estimation is a fundamental step in the enhancement process as the subsequent Gabor filtering stage relies on the local orientation in order to effectively enhance the fingerprint image. The least mean square estimation method is used to compute the orientation image.

In addition to the orientation image, another important parameter that is used in the construction of the Gabor filter is the local ridge frequency. The frequency image represents the

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local frequency of the ridges in a fingerprint. The first step in the frequency estimation stage is to divide the image into blocks. The next step is to project the grey-level values of all the pixels located inside each block along a direction orthogonal to the local ridge orientation. This projection forms an almost sinusoidal shape wave with the local minimum points corresponding to the ridges in the fingerprint.

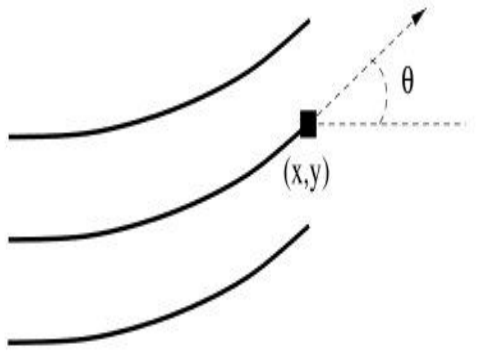

Fig.1 The orientation of a ridge pixel in a fingerprint

Once the ridge orientation and ridge frequency information has been determined, these parameters are used to construct the even symmetric Gabor filter. A two dimensional Gabor filter consists of a sinusoidal plane wave of a particular orientation and frequency, modulated by a Gaussian envelope. Gabor filters are employed because they have frequency-selective and orientation-selective properties. These properties allow the filter to be tuned to give maximal response to ridges at a specific orientation and frequency in the fingerprint image. Therefore, a properly tuned Gabor filter can be used to effectively preserve the ridge structures while reducing noise. The Gabor filter is applied to the fingerprint image by spatially convolving the image with the filter.

Most minutiae extraction algorithms operate on binary images where there are only two levels of interest: the black pixels that represent ridges, and the white pixels that represent valleys. Binarisation is the process that converts a grey- level image into a binary image. This improves the contrast between the ridges and valleys in a fingerprint image, and consequently facilitates the extraction of minutiae.

One useful property of the Gabor filter is that it has a DC component of zero, which means the resulting filtered image has a mean pixel value of zero. Hence, straightforward binarisation of the image can be performed using a global threshold of zero. The binarisation process involves examining the grey-level value of each pixel in the enhanced image, and if the value is greater than the global threshold, then the pixel value is set to a binary value one otherwise, it is set to zero. The outcome is a binary image containing two levels of information, the foreground ridges and the background valleys.

IV. METHODS OF IMAGE COMPRESSION

A. JPEG

JPEG is an image compression standard developed by the Joint Photographic Experts Group. It was formally accepted as an international standard in 1992. JPEG is a lossy image compression method. Transform coding method used in JPEG is DCT.

The JPEG encoder consists of the following main steps:
_ Transform RGB to YCbCr and subsample color.
_ Perform DCT on image blocks.
_ Apply Quantization.
_ Perform Zigzag ordering and run-length encoding.
_ Perform Entropy coding.

The JPEG compression scheme has many advantages such as simplicity, universality and availability. However, it has a bad performance at low bit-rates mainly because of the block based DCT scheme. For this reason, as early as 1995, the JPEG committee began to develop a new compression standard for still images, namely JPEG 2000.

B. JPEG 2000

In 1996, the JPEG committee began to investigate possibilities for a new still image compression standard to serve current and future applications.

In JPEG 2000, DCT of JPEG is replaced with DWT. JPEG 2000 is able to handle up to 256 channels of information, whereas the current JPEG standard is able to handle only three color channels. Such huge quantities of data are routinely produced in satellite imagery.

The main compression method used in JPEG 2000 is the Embedded Block Coding with Optimized Truncation algorithm (EBCOT), designed by Taubman. In addition to providing excellent compression efficiency, EBCOT produces a bit stream with a number of desirable features, including quality and resolution scalability and random access.

Consequently, JPEG 2000 is designed to address a variety of applications, such as the Internet, color facsimile, printing, scanning, digital photography, remote sensing, mobile applications, medical imagery, digital library, e-commerce, and so on.

C. WSQ Fingerprint Compression

The above algorithms are for general image compression. Targeted at fingerprint images, there are special compression algorithms. The most common is WSQ. It became the FBI standard for the compression of 500 dpi fingerprint images. The WSQ class of encoders involves a decomposition of the fingerprint image into a number of sub bands, each of which represents information in a particular frequency band. The sub band decomposition is achieved by a DWT of the fingerprint image. Each of the sub bands is then quantized using values from a quantization table. The quantized coefficients are then passed to a Huffman encoding procedure

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which compresses the data. Huffman table specifications must be provided to the encoder.

V. PROPOSED METHOD

In the previous section we discussed the methods of image compression. The Fig.2 shows the block diagram of proposed system. It consists of 5 blocks. Enhancement, Patches, Database, Testing and Evaluation.

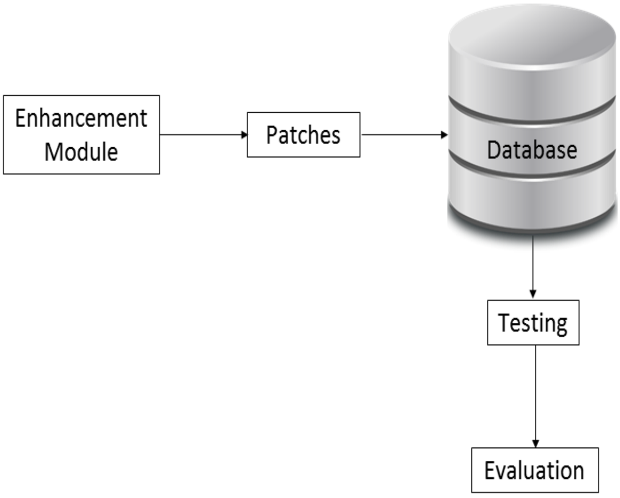

Fig.2: Basic block diagram

Fingerprint images are rarely of perfect quality. They may be degraded and corrupted due to variations in skin and Impression conditions. Thus, image enhancement techniques are employed prior to minutiae extraction to obtain a more reliable estimation of minutiae locations.

After image enhancement, whole fingerprint is divide it into small blocks called patches [1] as in Fig.3 whose number of pixels are equal to the dimension of the atoms. The columns of the matrix dictionary are known as atoms.

Database is constructed by using sparsity algorithms. Choose the whole fingerprint images, cut them into fixed size square patches. The first patch is added to the dictionary, which is initially empty. Then we check whether the next patch is sufficiently similar to all patches in the dictionary. If yes, the next patch is tested otherwise, the patch is added into the dictionary. The similarity measure between two patches is calculated by solving the optimization problem.

The Matching Pursuit algorithm is used because of its simplicity and efficiency is often used to approximately solve the optimization problem. Many variants of the algorithm are available, offering improvements either in accuracy or in complexity. Although the theoretical analysis of these algorithms is difficult, experiments show that they behave quite well when the number of non-zero entries is low.

The compression performance of the algorithms are evaluated by using Peak Signal to Noise Ratio computation. The main feature used to match two fingerprint images are minutiae. Therefore, the difference of the minutiae between pre and post compression is considered.

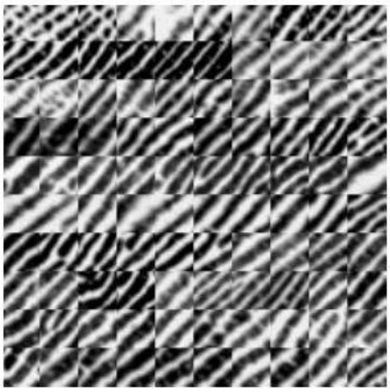

Fig.3: 100 patches with the orientation 45°

VI. CONCLUSION

A new fingerprint compression algorithm based on sparse representation is discussed. Obtaining an over complete dictionary from a set of fingerprint patches allows us to represent them as a sparse linear combination of dictionary atoms. Three groups of fingerprint images are tested. The experiments demonstrate that our algorithm is efficient compared with several competing compression techniques, especially at high compression ratios.

There are many intriguing questions that future work should consider. First, the features and the methods for constructing dictionaries should be thought over. Secondly, the optimization algorithms for solving the sparse representation need to be investigated. Thirdly, optimize the code to reduce complexity of our proposed method. Finally, other applications based on sparse representation for fingerprint images should be explored.

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